

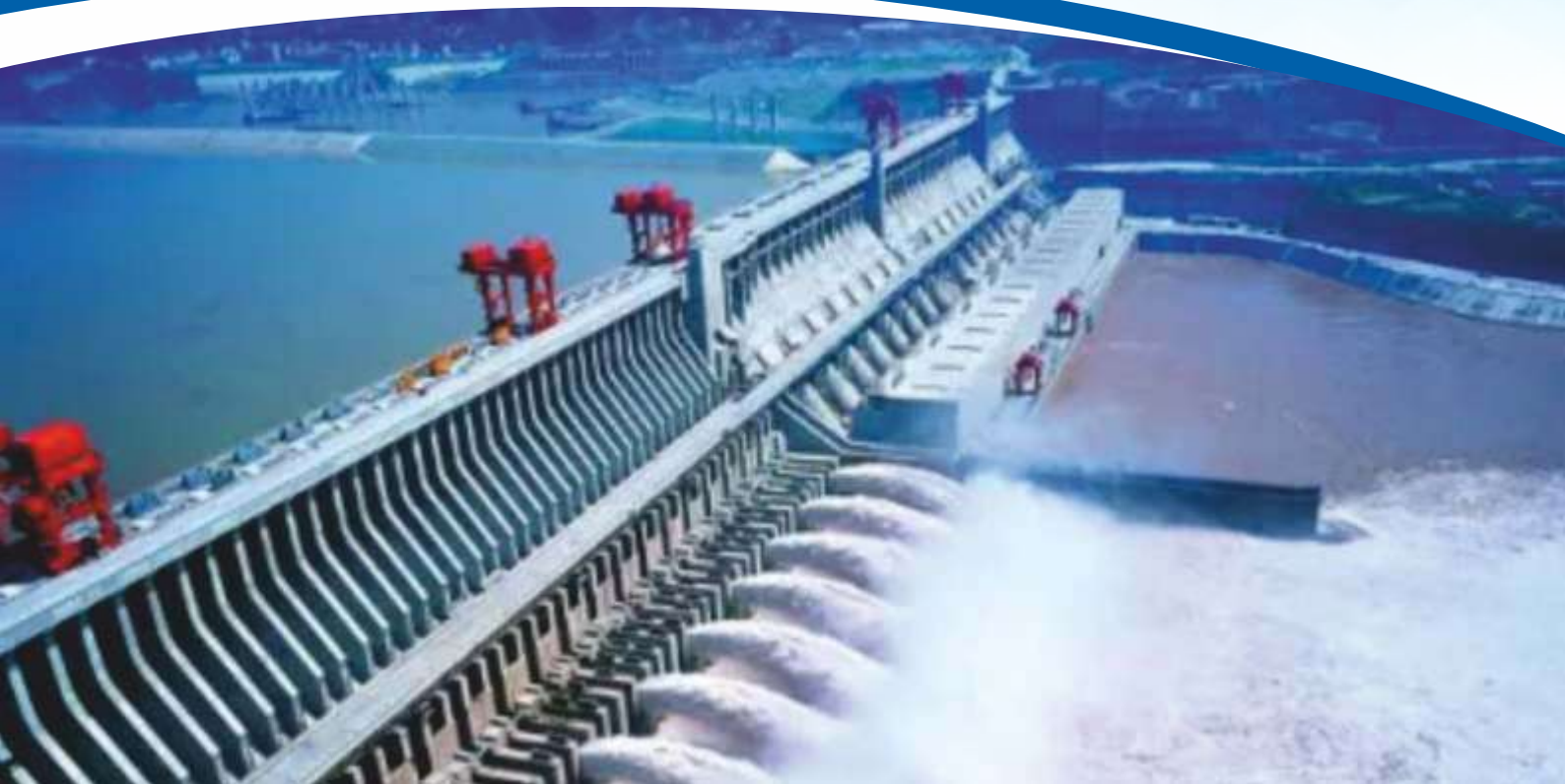
**Edited
Book**

Recent Advances in Basic Engineering & Science

- ▶ **Dr. Shailesh K. Mandavgade**
- ▶ **Dr. Sanjeev Gill**
- ▶ **Prof. Keval S. Neralwar**
- ▶ **Prof. Praful Nandankar**
- ▶ **Dr. Punit Kumar**
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Innovative Scientific Publication



*Edited E-Book
On*

Recent Advances in Basic Engineering & Science

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Plumes and Fibrin Spectroscopy Sensors Model: A Solution for Renal Dialysis

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Abstract – Renal failure is a disorder in which the kidneys gradually lose their ability to filter and clean the blood. Renal dialysis is a therapy option in which a machine performs the activities of the kidneys. This gadget contains ultrasonic and visual sensors to detect air bubbles, blood leaks, and clots. Unfortunately, the ultrasonic sensor can occasionally detect false positives, causing the operation to halt. These interruptions might impair the patient's blood circulation and result in blood clots. Moreover, abruptly resuming blood circulation might result in the formation of air bubbles, which can lead to air embolisms. Employing more effective sensors can decrease difficulties during renal dialysis and increase patient quality of life. The creation of an optical sensor prototype capable of detecting air bubbles and clots is presented in this work this sensor model can be used to enhance patient outcomes in the blood circuit of renal dialysis machines.

Keywords—Renal dialysis, spectroscopy Sensor, plume Sensor, fibrin sensor.

INTRODUCTION

People's life expectancy has grown as technology and science have advanced, yet industrialization and urbanization have resulted in an increase in chronic illnesses. Chronic illnesses have become more common in India, with Chronic Renal Failure being one of the most serious. Almost 100,000 individuals in India require Renal Replacement Therapy, and nearly all of them are on dialysis. This therapy alone is more expensive than the earnings. Unfortunately, just a few research in India are looking at how technology might be used to improve the quality of renal dialysis treatment. Chronic Renal Failure (CRF) is a dangerous illness that needs rapid medical attention to avoid complications that might result in death. Dialysis is frequently given to eliminate body metabolic byproducts from the blood. Many types of sensors, including three security alarms, are used in renal dialysis equipment. To begin the Renal -dialysis session, the ultrasonic sensor identifies air bubbles in the circuit, while two optical sensors detect blood leakages and the presence of blood. The quick and precise identification of these occurrences is critical for the treatment's success and the patient's safety. Early detection and treatment of CRF are critical for avoiding problems, and dialysis is one of the most often utilized therapies. as a result, the development and deployment of new and more efficient sensors, such as.

According to nurse services, the ultrasonic sensor frequently identifies erroneous positive findings. Pollution accumulated across the extracorporeal circulation circuit is mostly to blame. These contaminants might be caused by the talc in the procedure sleeves. When the sensor detects a false positive, the system stops the external blood circulation. Clots might occur as a result of this stoppage. Moreover, the rapid resumption of blood external circulation might result in the formation of air bubbles that are not detected by the ultrasonic sensor, resulting in an air embolism. Clots and bubbles can cause a variety of injuries in patients and must be recognized. The creation of an optical sensor prototype to detect air bubbles and blood clots is described in this article. Renal equipment, additional security may be provided on Renaldialysis, and as a result.

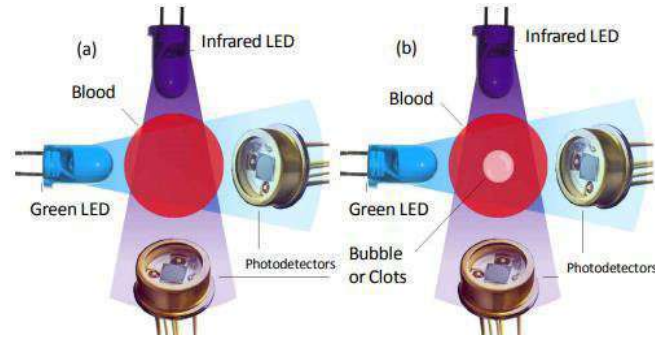


Figure 1-.Layout of the LEDs and Photo-detectors.

Spectroscopy Sensor model

The initial iteration of the bubbling and coagulation optical sensor prototype consisted of two right angles photo-detectors aligned with two LEDs with wavelengths oriented in the blue and infrared range. The blood channel is encircled by LEDs and photo-detectors. The light emitted by the LEDs is transmitted or scattered by the blood to the photo-detectors. The first illustration shows the component arrangement.

The presence of bubbles and clots alters blood transmission. The existence of tiny bubbles also results in a high Optical scattering caused by a large variation in refractive index between blood and air. Blue and near-infrared LEDs were employed in the original sensor design. Yet, the relatively poor transmittance of blood on blue light practically cancels out the received signal. The blue LED is replaced with a green LED in the implementation used in this work.

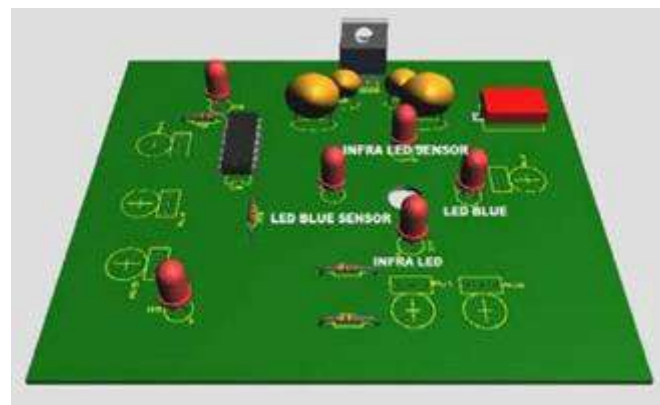


Figure 2.Print circuit board model of the sensor

A printed circuit board was created to house LEDs and photo-detectors, assisting in the proper arrangement of these components and the blood circuit. **Figure 2** shows a 3D view of the board. The electrical circuit may change the brightness of the LED light as well as the sensitivity of the photo-detectors Red wine was used to imitate blood in the tests. That is feasible because red wine has optical properties that are remarkably comparable to blood in the visible and near infrared spectrums [6]. 3 ml and 10 ml syringes were used to introduce air bubbles into the external vein circuit carrying wine. Tiny syringe touches release tiny bubbles into the circuit. Crushed grape peel bits were utilized to simulate clots because their physical and visual optical properties are comparable to those of blood and clots. The simple experimental equipment is depicted in **Figure 3**.



Figure3: Material used in the experimental apparatus and The circuit under test

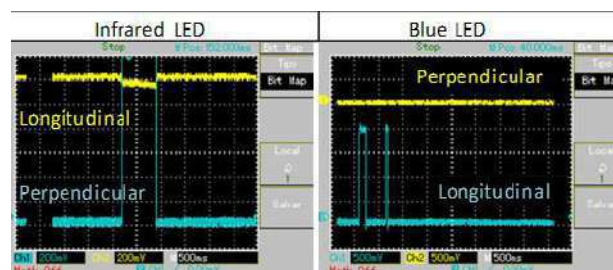


Figure4: Bubble detection signals

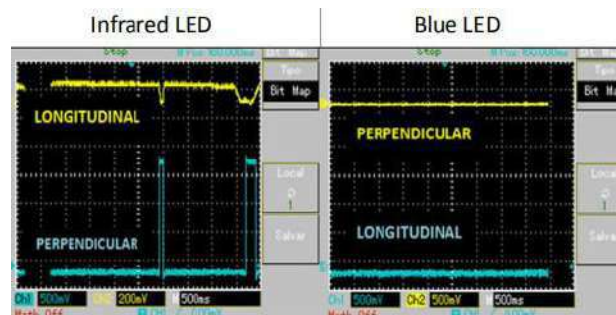


Figure5: Clot detection signals

EXPERIMENTALRESULTS

First, various experiments were carried out in order to calibrate the sensor, with the photo-detector signal for the infrared LED being placed around 1 V. This enables for the detection of both bubbles and clots, as well as the increase and decrease of transmittance levels. Air bubbles were then added into the system. The initial experiments were carried out by individually activating the Lights. **Figure 4** depicts the photo-detectors' signals after bubbles were pushed to flow through the sensor system. The existence of bubbles encourages light scattering, which is detected by the perpendicular photo-detector. The reflection at the wine-air-wine interaction limits the amount of light transmitted.

When clots are present in the circuit, the system behaves in certain ways similarly to bubbles. As seen in **Figure 5**, there was can be easily recognized and may lead to incorrect signal interpretations.

There were no significant changes in the signals owing to the presence of clots when just the blue LED was engaged. Pictures 4 and 5 show that clots and bubbles may be distinguished. The blue LED may be utilized to tell the difference between



bubbles and clots. The usage of a Green LED increases signal quality and allows for the use of a single LED. The signals acquired with the green LED with bubbles and clots in **Figure 6** show that they may be distinguished.

The passage of bubbles was captured on video using a high definition video camera. The diameters of the bubbles may be calculated by comparing the photographs and the electrical detected signal. **Figure 7** shows the identification of bubbles as tiny as 0.1 cm.

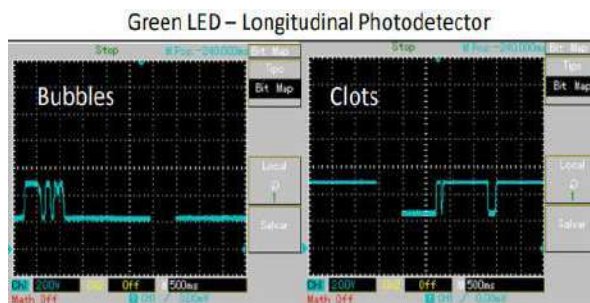


Figure6: Clots and bubbles detection signals with green LEDs.

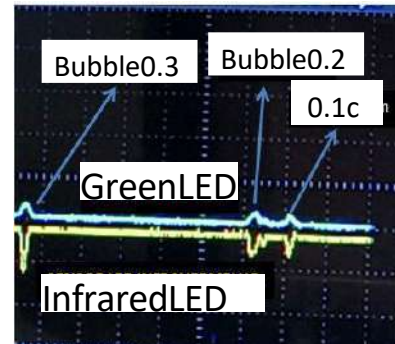


Figure7: Bubbles signal with their approximated sizes.

CONCLUSION

Early results from this study's optical sensor confirmed its feasibility and efficacy in detecting

In an extracorporeal blood circuit, there are bubbles and clots. The objective of this prototype is to reduce the amount of renal dialysis-related problems, morbidity, and death, and thus enhance the quality of life for patients with renal impairment.

Laboratory tests have demonstrated the sensor's capability to identify bubbles and clots particularly in the circulation. Contrary to what actually occurs in practice today, the dosage of an anticoagulant may be managed with greater precision if clots are detected in the blood circuit.

In addition, the use of the sensor created in this study may produce a reduction in the frequency of occurrences during renal dialysis by the fact that the sensor is less sensitive to talc. A straightforward procedure of self-calibrating signals to baseline levels measured by photo-detectors in the presence of blood can be used to get this talc partial immunity..

The circuit created in research utilizing human blood as a sample should be tested in further study

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For The Investigation of Biological Fluids, A Drop Sample Spectra-Photometric Method Is Being Used

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Abstract – - The method of assessing liquid biological media based on photometry of chemical deposition samples is described in the article. The potential of employing drops as test specimens is theoretically supported. The explanation procedures for how processes in droplet samples affect their electro - optic attributes are given. This article additionally addresses the creation of an easy-to-use testing method for performing studies and offers the findings of the technique's approval for measuring the dynamic behavior of erythrocyte sedimentation and the process of fibro clot formation during several coagulation tests.

Keywords- — clotting cascade, hem-agglutination, erythrocyte sedimentation percentage, fibrous clot, and biomedical use of different wavelengths

INTRODUCTION

Diagnostic tests in laboratory and clinical practice require a multi-stage sample preparation process that can introduce errors during analysis. This is because the majority of medical analyzers rely on evaluating the optical properties of the final product, which is obtained through the transformation of the original sample. When working with small sample volumes, it becomes necessary to optimize the optical measuring techniques themselves to increase their sensitivity to the analyzed processes. One promising approach to address this issue is the development of "open" cuvettes that rely on the surface tension of the liquid and interfacial interactions with the substrate to define the volume and shape of the study area. This allows for studies to be conducted with small sample drops, reducing sample volumes to just a few micro-liters or even hundreds of nano-liters. Furthermore, drop techniques offer the possibility of exploring the energy characteristics of the sample that change during chemical and physicochemical transformations of substances.

While studies have shown the potential of using drop techniques for chemical and physical analyses, their application in medical laboratory research is limited by the lack of simple instruments and appropriate techniques developed for specific types of medical analyses. Despite this, ongoing research aims to overcome these limitations and improve the use of drop techniques for clinical laboratory tests.[1]Therefore, the article discusses the challenges associated with sample preparation and the potential benefits of using drop techniques in clinical laboratory testing, highlighting the need for further research and development to optimize these techniques for medical use.

Fluid Specimens Spectra photometric Methods

About majority of the research that was done to examine fluids utilizing droplets was focused on examining the morphological properties of the droplets. This would be accomplished using methods for image and video verification of the droplets' lateral projection with further computing. Yet, in this situation it is uncommon to evaluate the file's absorption spectra. Moreover, dangling droplets are frequently the research subjects in these kinds of instruments that employ spectroscopic techniques and are dependent on the examination of specimen radiation properties. A fiber fluid spectrometer created by McMillan N.D. and his team of researchers is a spectacular specimen [2]. It operates on the following principles.



The fiber laser's tip forms dangling drops. A specific portion of the dropped contact is exposed to specific wavelengths throughout an optical system, and when the fiber's inner layer has undergone refract, that light emission enters a subsequent fiber. Throughout the development, growth, and separation of drops from the base, spectra-photometric studies are conducted. The interfacial tension, fluidity, and optical properties of the examined fluid are all related to the photo-detector's signal. A presented analysis tool does, though, have several key characteristics that often restrict its application. It mainly has to do with Since this necessitates exact controllability inside the system, the technological execution of these instruments is challenging. Moreover, the specimen needs to be big enough to fill the device's whole micro fluidic mechanism. It must be observed that these analyses cannot be used to examine a thick media, such as cellular fluids. In this article, we propose a spectrophotometric technique in which the specimen under investigation is put on a translucent sample holder as a sessile drop with a predetermined size, between such a concentrically placed optical emission transmitter and receiver (**Fig.1**). A drop deposited on a repellent clear cuvette is built in such a way that it doesn't disperse and maintains its form.

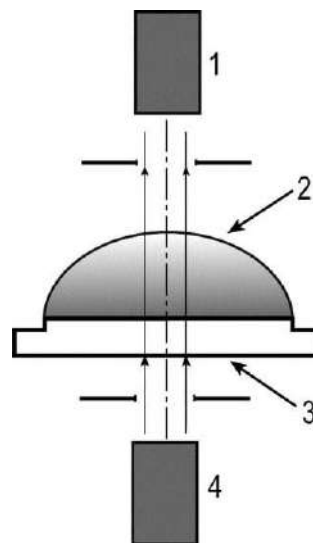


Figure 1: The diagram of the spectra photometric fluid sampling procedure: 1 Infrared detector, 2 fluid specimens, 3 a clear wet micropipette are listed in that order. 4 - Radiological emitter

Fig2 shows a component schematic of the arrangement for doing investigation.

Several prerequisite for development are included in the researcher reports. Using solar fluxes to analyze it, the basic information regarding permeability changes and fall optics is discovered. Using the setup with the specimen (4), emitter (2), and radiated reception (3), the principal measurements transducer's picture is included (1). In this lens, the relative humidity and temperature are kept constant. The radiation source was an NIR LED with a thin continuous beam of light that had a 2 mm diameter. A photoelectric with wavelength-matched spectral sensibility served as the radiation's recipient.

The continuous power supply (9) that supplies the photon beam supplies the necessary power output parameters for the probing beam.

Light enters the cuvette that holds the specimen and then exits through the sensor. An operational amplifier then pre-amplifies the electrical impulses from the photodiodes (11). The term "photoconductive converters" will now be used to refer to the combination of the photodiodes and the accelerator (PEC). The signals from the amplifier is sent to the Utilizing an interaction equipment to access the computer (12). An interconnection device called NI USB 6009 was employed.

The thermoregulation block (10) is used to keep the measurement container at a certain temperatures. It regulates the thermal entity's voltage (figure 6)

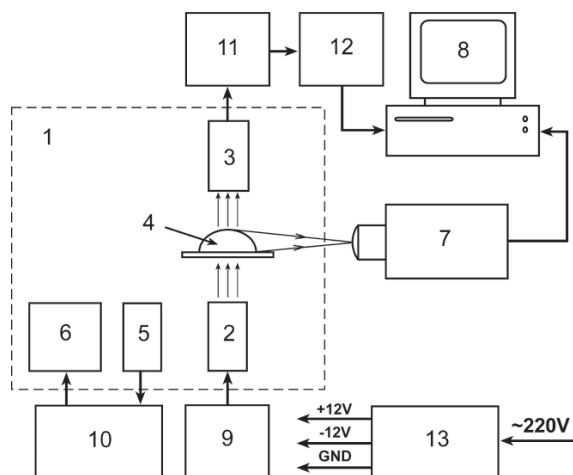


Fig. 2. Test rig schematic representation: the principal sensing instrument, the radiological origin, 3 - a photon catcher, 4 - specimen of a liquid Temperature sensor no. 5, 6 - the thermostat 7: a camcorder, 8: a computer, Current controlled source (9), temperature (10), amplifier (11) storage medium (12), and power supply (13)

The configuration enables synchronous logging of the drops horizontal projection's form and measurement of the protein's microstructural properties. It offers the chance to relate the patterns of changing current and drop form to the nature of the processes occurring.

The gadget includes a digitized video camera because of this (7). Its lens is mounted on the side wall of the primary measuring transducer's camera and is directed at the droplet sample. A DiGiVi CM-CH2-W5 CCD camera was employed. In the RF patent [3], a more thorough characterization of the experimental setting is provided.

According to this study plan, the optic characteristics of the environment and drop pattern, which rely on the specimen and attenuation coefficient, affect the amount of light that hits the photo-detector. Activities of redistribute of nutrient medium in the dimension of the drop sample underneath the impact of gravity, surrounding conditions, and microflows happening in the drop are significant variables impacting the form and optical characteristics of the drops [4]. Also, during the investigation of fluid samples, the concentrating phenomena of light by drop has a significant impact on how refractive characteristics change.

As a result, this technique enables consideration of a variety of drops structural qualities that are related to the makeup and characteristics of the material under study. As a result, in this instance, the research becomes more sensitive and enlightening without any tech problems with the optically measurement tool.

Result of the Use of the Fluid Test specimens Spectrophotometric Methods

We have performed research works on the use of the spectrophotometric analysis of drops technique for assessing the mechanisms of erythrocyte aggregating and sediment, granulocyte - macrophage colony, and the development of a fibrin during coagulation experiments.

The examination of erythrocyte sedimentation.

One of the most used blood tests is an analysis of the erythrocyte sedimentation rate (ESR). Both Russian and international medical practises make use of it. Reducing the number of sample needed for the research is one of the primary challenges in test optimization. Hence, the Panchenkov micro method used now in Russia requires up to 500 l of blood, but the Westergren technique used today outside only requires up to 2 ml. As a conclusion, even if completing this study is rather simple, ESR inquiry procedures need to be optimized and

In the fluid specimen, it is feasible to assign a variety of procedures that are particular to erythrocyte sedimentation. One distinctive characteristic of the membrane filtration in the droplets is the occurrence of redistribute of cells coated in the centre axial area of the drop across the depth of the shell layer. As a result, there are fewer cell in the axial region, which enhances the transparency of the drop area [5]. Moreover, a serum effluent layer that serves as a concentrating lens forms



above the layer of settling cells [6]. We have demonstrated that the thickness of the settled layer of cells is approximately linearly proportional to the change in luminance penetrated through the drops during the sediment of red blood cells [5], and this relationship may be utilised to analyse this process [7]. The technique of drops spectrophotometric analysis has substantial benefits, as demonstrated by earlier quantitative investigations on alterations in the surface morphology of the same clinical specimens when they are put in a lateral, flat cuvette and turned into sessile drops [5]. This is principally caused by the fact that drop specimens exhibit a rate of curve rise that is markedly higher than that of a flattened cuvette at equivalent ESR levels. Moreover, a disparity here between curves for specimens with both a high and a low ESR is more pronounced for drop specimens.

This suggests that, as comparing to spectra-photometric analysis on a flat cuvette, the technique of drops spectra-photometric analysis is more sensitive to the activities taking place in the sample. All of these characteristics demonstrate how our strategy improves the test's analytical usefulness.

The assessment of hem agglutination's response.

The haemolytic response was also assessed using the drop specimen spectrophotometric technique. The adherence and precipitate of erythrocytes with antibody and antigen molecules attached to them is known as hemagglutination. Several dangerous infections, including syphilis, viral hepatitis B, tick-borne encephalitis, etc., are diagnosed in the laboratory using this response. However alternative immuno diagnostic techniques are gradually replacing the hemagglutination response. It is mostly linked to the shortcomings of outcomes evaluation techniques [8]. Nevertheless, this drawback is removed by the drop specimens spectrophotometric technique. In experiments, we employed the hemagglutination reaction to establish blood group using the AB0-system. Blood from III group III and test method serum were utilised (II group). In the typical scenario, serum containing certain antibodies was added to blood to create droplet samples, which were then created immediately on the optoelectronic cuvette. An hour and a half of spectrophotometric analysis was completed. As a result, we discovered throughout the course of our studies that the intensity of the change in the optical characteristics of the drops specimen increased with the serologic titre. As a result, in this instance, a clinical features is the dynamic of variations in the surface morphology of the drop samples during the formation of binding to specific complexes. This claim is supported by research comparing the optical characteristics of blood samples added to binding to specific skincare products with antibody titers of 1:32 and 1:2048 in drops form to the same clinical specimens added to a flat cuvette (Fig.3).

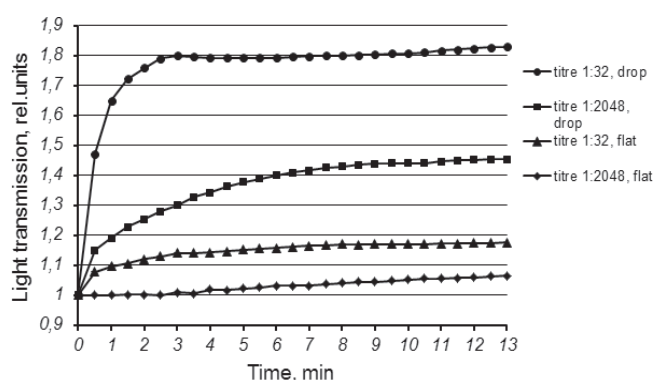


Figure 3 shows empirical curves showing the characteristics of changing illumination during the activity of enzyme-linked immune sorbent assay in a fluid specimen (drop) and plain cuvette (flat).

Consequently, compared to the traditional photographic enrollment in the flat cuvette, the technique of drops test specimens spectrophotometric analysis is more sensitive to the activities of antibody and antigen engagement during the coagulase experiment.



Analyzing the blood clotting mechanism.

The measurement of the development of a plasminogen during thrombosis assays was also done using the droplet specimen spectrophotometric method. Nowadays, optical-mechanical scanners are often used to do these types of evaluations. They estimate the genre's fluidity or dispersion to determine the timing of thrombus formation. We measured activated partial thromboplastin time throughout empirical experiments. We employed a collection of chemicals called "Techplast-test" for this ("Technology-Standard", Barnaul, Russia). Techplastin and plasma proteins were produced as reagents for analysis in accordance with the steps outlined in the set of materials' guidelines. These chemicals were then combined on the optoelectronic cuvette that was creating the droplet sample, and photometry was started right away. It should be emphasised that during spectrophotometric analysis, the sensor was positioned in the optical center of the drop specimen. The optoelectronic curve that was captured in this instance (Fig. 4) is rather intricate. The physical events that take place in the slide can be used to describe its form [9].

Thrombin fiber creation starts as soon as the chemicals are mixed, and it continues throughout the entirety of the droplet quantity. The channel becomes generally clouded as a consequence of this procedure, which reduces the photonic signal's strength. The clot is then formed by the fibrinogen strings and is mostly concentrated in the drop's core. When the drop's edges are freed from the strings, they get illuminated and start to concentrate the radiant energy more and more, raising the photo-detector's signal amplitude.

Researchers performed research photometric analyses on biological fluids with various clot times. On the coagulometer APG4-02-P, the time at which a fibrin clot forms has been specified for each serum sample. It was discovered that the clotting time values, as determined by the coagulometer, match the location of the photonic bottoms on the experiment curves (Fig.4). As a result, the temporal position of the minimum as well as the rate of fall and rise of the curve of light transmission may be employed as indicators of the blood clotting time.

Hence, experimental investigations have demonstrated the potential for employing this approach to learn more about the dynamics of the coagulation process in addition to determining the timing of clot formation.

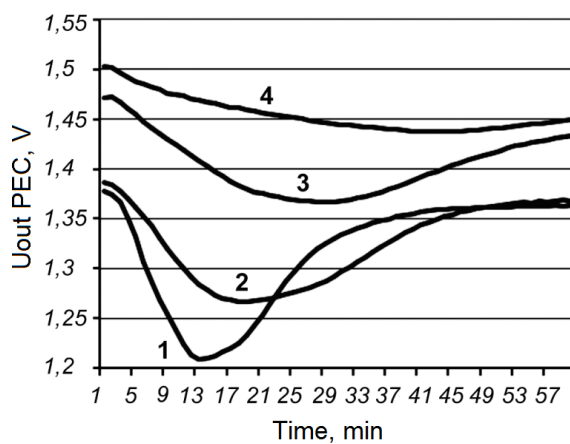


Figure 4 shows luminescence curves for blood serum with varying clot creation times.

According to the coagulometer APG4-02-P, the thrombosis times for samples 1, 2, 3, and 4 are, respectively, 13–15s, 18–20s, 26–30s, and 41–50s.

CONCLUSION

The acquired empirical results demonstrate the potential for a broad use of the drop specimens spectrophotometric approach in the medical scientific experiments in medicine. In fact, a lot of biological tests depend on the physico-chemical interplay



of the format's constituents (agglutination, aggregation, adsorption, etc.). Dispersion changes as a result of these interactions, which significantly alter the medium's optical and energetic characteristics.

It should be realised, nonetheless, that any practical use of this approach needs more investigation. The characteristics of the optical system (wavelength, beam diameter, receiver position), the parameters of the sample, the methodology, etc., must be chosen for each instance (ESR determination, assessment of the hemagglutination response, carrying out of clotting tests, etc

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Investigation of Blood clot Peril and Thrombus formation Diagnosis by Plasma Electro Resistivity Testing

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Abstract – - Ventricular assistance devices (VADs) used for advanced coronary artery disease lack a method for legitimate tracking of thrombin activity. Nerve impulses can fluctuate with fluctuations in thrombin and blood cell density, making them potentially useful for early detection of pro coagulant behavior. In order to track temporal changes in electrical resistivity of bovine plasma during chromogenic and quasi settings, the study evaluated an instrumentation system employing electrical resistance scanning with an eight-electrode probe. In non-chromogenic circumstances, identical resistance and steadily over time declining standard resistance were seen, however under thrombotic situations, quasi distributions and variable average resistivity have been seen.

INTRODUCTION

Severe patients with coronary artery disease now enjoy a greater standard of living because to implantable ventricular assistance devices (VADs), which enable them to depart healthcare facilities and go home. Plasma seems to congeal more often than usual whenever it gets into touch with synthetic turf, which raises the probability of clotting. The danger of clotting still exists even if implantable cardiac pump designers have decreased compatibility problems owing to design. Patients using LVADs must take heparin medicine, however regular usage might exacerbate hemorrhage following injuries. The right dosages of blood thinners must be given in order to reduce this risk. Consequently, a legitimate blood coagulation management and monitoring system is required to identify early indications of thrombus formation and improve the treatment of anticoagulants, thereby lowering problems related to anticoagulants.

Significant risk assessment of clotting is required for anticoagulants. Almost majority of the sterility testing used today to assess the likelihood of thrombin are standalone assays. To readily conduct such checks on a frequent basis is not viable, either scientifically or financially. Prior research has suggested optic development part for pre thrombus corpus, but these measures are unable to pick up variations in blood crude protein that lead to thrombosis. Realization is further made challenging by synopsis layers that obstruct light exposure, and the utilization of optical components and charging infrastructure boosts the dimensions of implanted VADs. Technological techniques have the possibility of being an excellent substitute since they can monitor variations in protein level and enable early clot identification. The electrical characteristics of plasma have been effectively utilized in various clinical uses and can disclose significant clinical qualities linked to the incidence of clotting, hence the investigators examined changes in electrical resistivity of plasma during thrombogenic and non-thrombogenic situations.



THERAPEUTIC ILLUSTRATION

The electrical characteristics of the liquid and red blood cells serve as a general definition of the blood's electrical characteristics (RBCs). Cell membranes functions as a capacitor, whereas plasma may be thought of as a resistive component. Similar to that, the RBC's intracellular area functions as a resistive component.

As seen in figure 1 , these components can be seen as elements of an electrical circuit. The equiv impedance of the plasma can be expressed as equation central to the creation on Maxwell- Fricke formulation of electrical characteristics of the suspension of elliptical particulate under an extremely lower frequencies alternating electric fields (1 MHz), in which dielectric strength of the tissue is very low .

$$\rho_b = \frac{\rho_p(1 + KV_{con})}{1 - V_{con}}$$

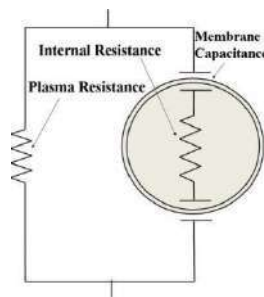


Figure1. Fluid Visualization in Electric Form

In the equation, ρ_b and ρ_p represent the resistivity of the whole blood and plasma respectively. Red blood cell density is denoted by V_{con} , and the parameter K relies on the arrangement and form of RBCs.

Because of a shift in the level of clotting components, a change in serum impedance is anticipated during clotting. For instance, a prior research [21] revealed a significant link between fibronectin, a key clotting agent, and the electrical properties of plasma. To evaluate the risk and identify the thrombotic procedure at a premature time, it is crucial to understand how impedance changes as thrombin alter. Similar to this, thrombin processes alter blood cell arrangement, which in turn alters weight percentage (V_{con} in the equation above) at a specific place.

As a result, spatiotemporal imaging of the blood's changing resistivity can show the likelihood and stage of blood coagulation process. The goal of this research is to track the spatial variation in blood's electrical resistance under blood coagulation conditions. Electrical resistance tracing technology (ERT) is used to visualise these changes [22], [23]. Using measurements performed at the channel/boundary, container's an ERT approach creates a cross-sectional picture illustrating the dispersion of electrical resistivity of the contents within.

EXPERIMENTS AND RESULTS

Experimental Setup

The apparatus used for the studies is illustrated in Figure 2. The container for the blood was an acrylic cylinder made of poly (vinyl alcohol; height: 80 mm; inner diameter: 30 mm). In the cylinder for computed tomography analysis, there are two separate planes, each with 8 stainless electrodes (SUS304; Diameter: 2mm; Length: 10mm). The lowest of the two planes, which was 5 mm from the cylinder's bottom, was chosen as the measuring plane. To give the electrodes in the measuring plane a consistent reference, another plane that was grounded was positioned 10 mm above it. Alternating current is applied to the electrodes by a composite splitter and data collection device (ITS P2000, Industrial Tomography



Systems ltd, UK), which then measures the voltages that occur.

These voltage values were inputted into the computer, where the back-propagation technique for computed tomography restructuring was used to get the cross-sectional impedance dispersion [22], [23]. The apparatus was built up so that, in each case, two of the electrodes (poles 1-2) were used to inject the current and two of leftover anode and cathode were used to determine the voltage that resulted from that injection (electrodes 3- 4). After that, the voltages between the remaining electrode pairs (4-5, 5-6, 6-7, and 7-8) were measured while maintaining the current injection pair.

The voltage between the remaining five adjacent cathode pairs then was observed after switching the current injection pair to pairs 2-3. The quantity of voltage measurement pairs steadily decreased when the current injection pair was modified further due to the reversal of the current and voltage cathode pairs would reflect the same electrical resistance. With an 8-electrode setup, there were therefore 20 independent voltage readings. A resistivity tomogram was created using this single complete quantification set to estimate the resistivity dissemination of one instance.

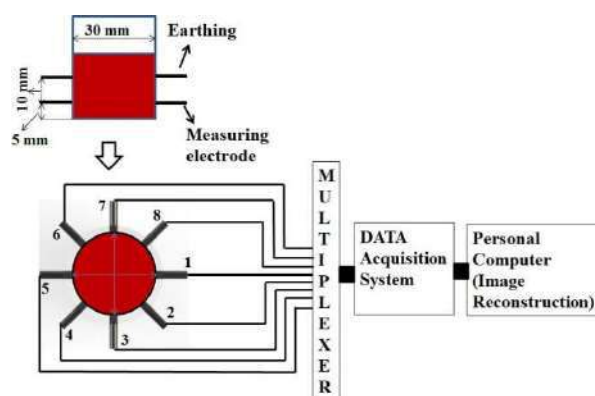
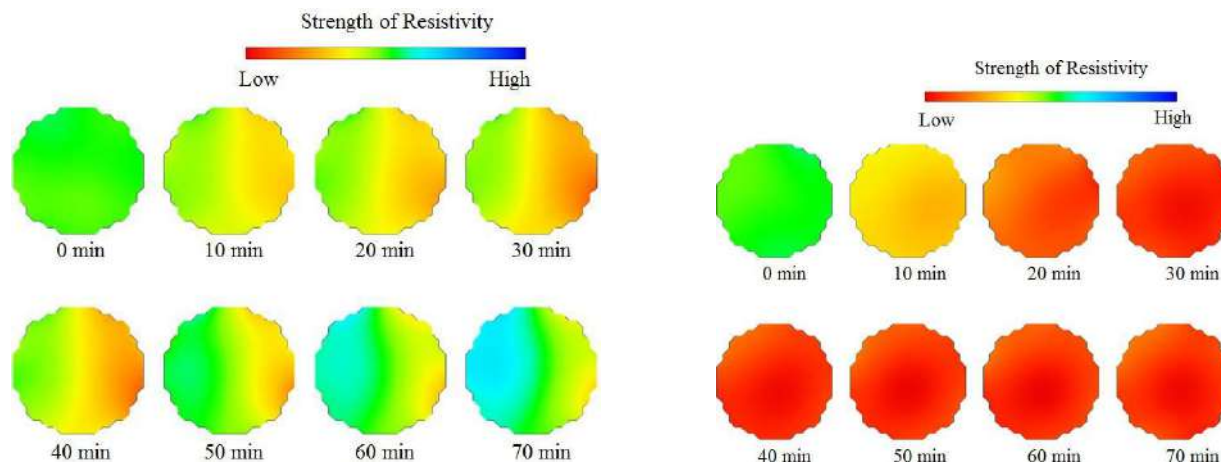


Fig. 2. Experimental Setup

Experimental Conditions

One research study used 15ml of cattle blood that had been medicated with sodium citrate solution as an anticoagulant (Shibaura Zouki KK, Tokyo, Japan). 3.75ml of calcium chloride solution (0.02M CaCl₂, Sysmex Company) was administered to induce thrombosis prior to the measurements. In a different series of tests, nothing was added to the citrated plasma to prevent any pro-coagulant activity. In each example, the voltage was measured with a 15 mA injection current at a rate of 9600 Hz. A set of voltage measurements needed to assemble one computed tomography picture of the cross-section took 167 millisecond, or 8.33 milliseconds for each pair of measurements needed. The trials were carried out in a room-temperature setting. As the major goal was to track the difference in impedance change between thrombogenic and quasi situations, no specific steps were made to regulate the temperature.



In thrombogenic and quasi conditions,. Computed tomography resection outcomes figure 3



Results and Discussions

Once the studies were finished, the first patient had considerable clotting, as was predicted. No thrombus was demonstrated in the second case denoting that epoxy canister and electrode materials didn't become a contributor to patton under given fibrinolytic treatment. The cross-sectional roughly comparable impedance under thrombogenic and quasi conditions is represented by the tomographic images in figure 3. The colour progression from red (low resistivity) to blue (low resistance) indicates the strength of the relative resistivity (high resistivity). Figure 4 displays the resistivity change over time in each half of the measuring region.

The roughly equivalent resistivity in the left half of the cross-section is greater than the relative amplitude in the right half of the cross-section under procoagulant conditions, as shown in Figures 3 and 4. The mean resistivity's trend of fluctuation also differs. At first, the left side's resistivity gradually starts to decrease. It then rises a little before tenderly descending once more. Around 30 minutes later, the resistance starts to rise tediously. Right-half of the way.

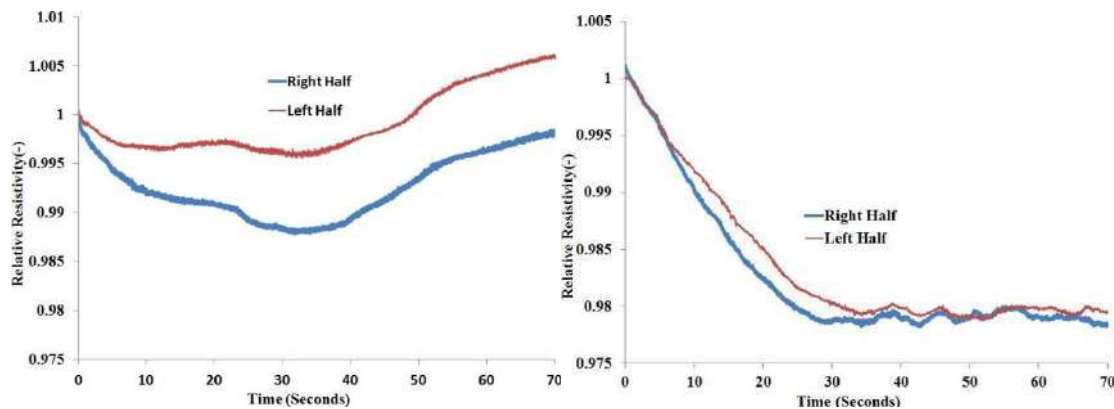


Figure -4-In thrombogenic and quasi conditions Time-dependent variation of cross-sectional mean impedance

Initially decreasing steadily over time for around 30 minutes, the impedance then increases steadily over time. In contrast, as seen in figures 3 and 4, the impedance across the cross-section is symmetrical in non-thrombogenic conditions. In this instance, the resistivity dropped steadily over time in either side of the jar before becoming level.

While the trials were carried out under stable loading, erythrocyte sedimentation can be partially blamed for the difference in impedance under quasi conditions. RBCs' result in an enhanced in the measuring plane and, to some extent, their direction, are both affected by the sedimentation of erythrocytes. These elements significantly alter the resistivity as expressed in equation 1 as a result. Temperature is another element that might alter the impedance. When the trials were carried out in similar laboratory environment and blood, we didn't regulate the temperature because our goal was to compare the differences between thrombogenic and non-thrombogenic conditions. As the assessments were done using blood taken from the same specimens, the clonogenic effect is likewise regarded as being identical.

As comparison to non-thrombogenic condition, the right half section's behaviour in thrombogenic condition is largely normal during the first 30 minutes. On the other hand, the left side of the alteration is noticeable and may be as a result of engaging in thrombogenic process. The variation in crude protein and red blood cell distribution indicated in above can be linked to the alteration in impedance under prothrombotic conditions.

This transitory increase and decrease of the impedance in the left half of the cross-section is unusual and appears to represent the first step of the development of a clot, even if it is impossible to pinpoint the exact cause. Similar to that, the subsequent monotonic climb might be the consequence of thromboembolism progressively concentrate blood cells. The tomograms in figure 3 indicate that the area of greater resistivity is moving from left to right, increasing the resistance in the right hand side section. As the recent investigation design makes it impossible to understand the



contributions of protein concentration and blood cell dispersal in each incident of change, the precise causes of the changes stated above remain unknown. Nevertheless, the uniformity and pattern of variation in the impedance across the cross-section in the measuring plane represent the primary distinction between thrombogenic and non-thrombogenic conditions. This discrepancy may be replicated, too. The knowledge of the thrombogenic risk, which is ordinarily challenging to quantify in absolute quantitative terms, is made easier by such a glaring discrepancy in the temporal arena. The assessment under the stationary condition is the research's evident restriction. A comprehensive examination that takes into account the liquid characteristics of moving plasma is required. Similarly, carrying out the computed tomography studies at various ac frequency is one of the potential expansions of this study. In this situation, it is possible to use the RBCs' capacitive performance and reactance to understand their intensity in the targeted area, which may provide insight into the roles played by the varying factors (blood peptides and blood cells) in each instance of spatial and temporal resistivity change.

CONCLUSION

Using impedance tomography, the prothrombotic activity in plasma was seen. In contrast to the homogenous distribution of resistivity in the quasi condition, the thrombotic condition was characterised by a non-uniform and fluctuating spatio-temporal distribution of the resistance over the measurement cross-section. The findings are the first step in the construction of the instrumentation system where variations in spatio-temporal domain might disclose the danger or presence of thrombogenic impact, even if the comprehensive mathematical logic behind certain variations still needs additional research.

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Living Beings Full Plasma Connectivity Prototype in A Micro Channels Dielectric Sensor

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Abstract – The process of monitoring changes in the dielectric characteristics of plasma during clotting is known as insulating coagulometry. RBC density rises and electron mobility of the blood falls when blood cools and solidifies. This results in changes to the blood's dielectric characteristics, which may be recognized and examined utilizing DS methods. Dielectric coagulometry can tell when the coagulation process starts, progresses, and ends by keeping track of these changes in area under the curve.

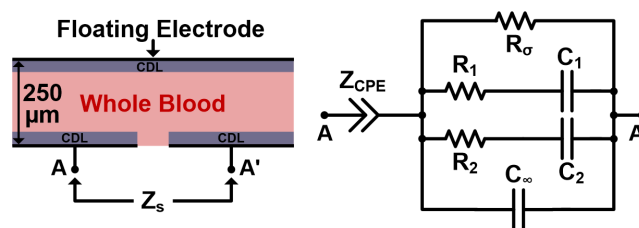
Keywords- — clotting cascade, hem-agglutination, erythrocyte sedimentation percentage, fibrous clot, and Dielectric coagulometry

INTRODUCTION

Dielectric spectrum (DS) is a method for obtaining molecular as well as cell characteristics from biological substances, such as whole human blood. At the point-of-care (POC), DS may be used to assess the blood - clotting state, but because it affects the blood's dielectric characteristics, the hematocrit (Hct) number must be examined. Due to the capacitive double-layer (CDL) effect, thorough DS analysis on a single blood drop in a fluid dielectric biosensor is difficult. This paper proposes a method to compensate CDL effects and extract critical circuit characteristics together with a circuit model of human whole blood in a micro fluidic dielectric sensor. DS observations of genuine human plasma with different Hct levels are used to verify the method, which demonstrates important correlation with electrical modeling. The constraints of miniaturizing DS devices for POC applications may be overcome by the work presented here, enabling quick and precise evaluation of clotting cascade state in a wider spectrum of healthcare contexts.

Prototype Simulation

The suggested serum circuitry model is shown in Fig. 1 in a micro channel dielectric sensor with a drifting electrodes and a 3D parallel-plate capacitive sensing topology.



Human plasma is depicted and a schematic diagram for a micro-channel dielectric sensor is shown in Figure 1.



The sensor impedance is $Z_S = Z_{CPE} + (j\omega\epsilon_r C_0)^{-1}$, where Z_{CPE} is the impedance of a constant-phase element (CPE) that models the CDL and rule over frequencies below 500 kHz. C_0 is the sensing area's nominal air-gap capacitance, and r is the plasma sample's complicated relative dielectric permittivity. The interfacial polarization between the hanging RBCs and the ambient conducting fluid (plasma) gives birth to the frequency-dependent structure of r , which has a distinctive dispersion zone that normally ranges from 100 kHz to 100 MHz. The sum of two Debye relaxations and a conductivity component, was empirically proven to be a permittivity model for this scattering area and is stated as follows: and attenuation coefficient, affect the amount of light that hits the photo-detector. Activities of redistribute of nutrient medium in the dimension of the drop sample underneath the impact of gravity, surrounding conditions, and microflows happening in the drop are significant variables impacting the form and optical characteristics of the drops [4]. Also, during the investigation of fluid samples, the concentrating phenomena of light by drop has a significant impact on how refractive characteristics change.

As a result, this technique enables consideration of a variety of drops structural qualities that are related to the makeup and characteristics of the material under study. As a result, in this instance, the research becomes more sensitive and enlightening *without any tech problems with the optically measurement tool*.

A permittivity model for this dispersion region was empirically determined as the sum of two Debye relaxations and a conductivity term, given as

$$\epsilon_r = \epsilon_\infty + \frac{\Delta\epsilon_1}{1 + j\omega\tau_1} + \frac{\Delta\epsilon_2}{1 + j\omega\tau_2} + \frac{\sigma}{\omega\epsilon_0}$$

Where $\Delta\epsilon_{1,2}$ and $\tau_{1,2}$ are the strengths and time constants of the two Debye relaxations, respectively, and ϵ_∞ is the final permittivity due to that of water molecules, which is the dominant term for frequencies $> \sim 100$ MHz. As shown in Fig. 1, whole blood in a parallel-plate capacitive sensor can thus be modeled as two RC branches (R_1, C_1, R_2, C_2) to model the RBC interfacial polarization, a fixed capacitor (C_∞) to model the water permittivity, and resistor R_σ to model the dc resistance

Assessment of Sensors and Recovery of Parameters

Following standard practices, real whole blood was extracted from a donor cell [2]. A capillary was used to merge the fluid and various RBC volumes percentage after centrifuging the blood sample to produce swabs with Hct values of 0.2, 0.4, and 0.6. The micro-vascular biosensor was then filled with 10 μ l of each specimen, and r was then determined using an equipment called (Agilent 4294A) over a frequency range of 10 kHz to 100 MHz (see supplementary Fig. S1).

To account for CDL impacts and retrieve the circuitry characteristics shown in Fig. 1 from the observed sensor data, a two-step method was created. The obtained schematic for the 3 serum sample is shown in SPICE simulations together with the observed actual component of r in Fig. 2. For Hct values of 0.2, 0.4, and 0.6, respectively, the findings demonstrated excellent agreement between observed and SPICE-simulated curves, with corresponding rms errors of 2.3%, 2.9%, and 4.6% throughout the whole frequency spectrum of 10 kHz–100 MHz.

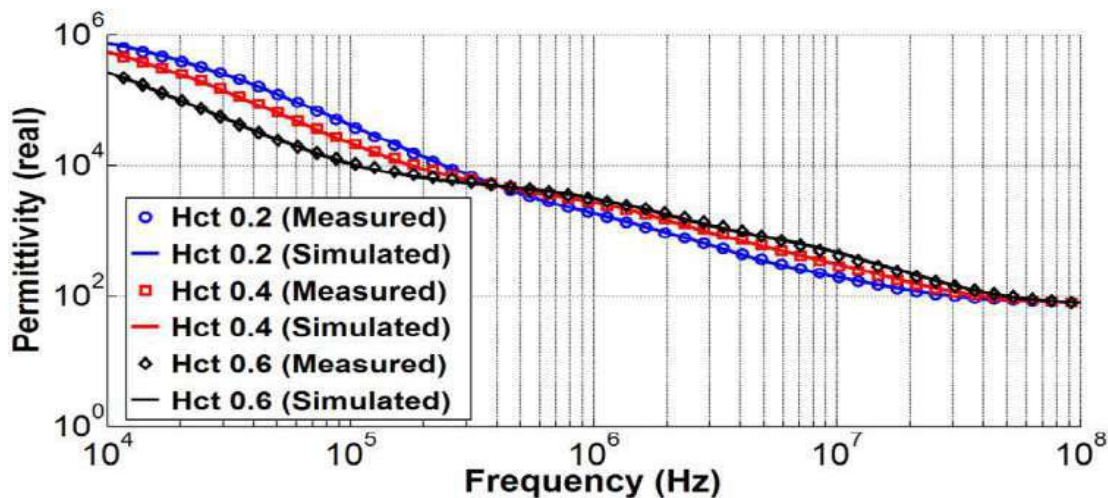


Figure 2 shows the real component of the ϵ_r vs in relation to frequency for human whole blood at various hematocrit levels. Marks denote data collected using a micro-vascular dielectric sensor, and black lines represent schematic models of the attributes that were obtained.

Conclusion

We have demonstrated an outstanding agreement between circuit computations and sensing field measurements by presenting a circuitry model that simulates whole plasma in a capillary dielectric sensor. For POC diagnostic purposes, this method is effective for monitoring medically significant blood parameter

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Pzt Semiconductor Crystal Probe Measurement of Clotting Rate in Whole Plasma Contains Astringent

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Abstract – - Earlier, plasma clotting was seen using a piezoelectric ceramic crystal (PQC) technique with enough sensitivities to a little change in viscous. Here, the PQC system was used to evaluate the triggered partial thromboplastin time (aPTT), clumping time (CT), and platelet poor plasma (PPP), including whole bleed (WB), and the findings indicated a fair agreement with the aPTT data determined by optical coagulo-meter (OC). As a consequence, it was possible to acquire in PQC and OC systems a satisfactory linear correlation for heparin level from 0 to 1 unit/ml injected in both samples. All rights reserved. 2000 Elsevier Science S.A.

Keywords- — Partial thromboplastic with activation time; Piezoceramic semiconducting sensor; Aspirin;

INTRODUCTION

Piezoelectric ceramic crystal (PQC) sensors have attracted a lot of interest in a variety of industries, including the food processing industry, pharmaceuticals, and diagnostics. The PQC sensor was also used in hematological investigations to measure the plasma percentage (w1x), the interaction of the thrombotic components VIII and IX (w2x), the study of homeostasis (w3x), and the erythrocyte aggregation (w4x). We recently reported on its use for calculating the arterial prothromboplastin time (PT) and the whole blood recalculation time (w5x), respectively. It is crucial to keep an eye on the blood's level of the mucopolysaccharide heparin both during surgery and thereafter. Figure 1 depicts the clotting mechanism of heparin. The partially thromboplastic activation time (aPTT) and the clotting time (CT) are two of them. are often performed in clinical laboratories to gauge how much anticoagulation has been administered. In this study, we employed the PQC biosensor to track how different thrombin levels affected and samples of entire plasma, and assessed using an optical coagulo-meter (OC) the PQC result and the a PTT findings.

Innovative equipment and equipment

The PQC sensor from Taiwan, ROC., Tai Tin, employed in this study has an AT-cut design with a fundamental resonance frequency of 10 MHz. The crystal is made of a 8 mm diameter quartz wafer that has two 4.5-mm-diameter gold sensors connected to it. To determine the density and stiffness of specimens, a resonance oscillate circuit PQC setup with a wideband Amplifier circuit w5x was used. The aPTT result of the PPP specimen was contrasted with the CT findings as determined by the PQC sensor using the OC, a STAGO-ST4 system from Diagnostcia Stago, France. Anticoagulation, CaCl₂, and the aPTT reagents were purchased from Sigma and Forensics Stago, respectively. PPP was obtained by centrifuging serum that had been sodium citrate-anticoagulated for 10 minutes at 2500 rpm from healthy males. The Millipore system provided the filtered water.



Procedure

Laser coagulometry

An alternate magnetic field was used to agitate a metal thin layer during the optic investigation in a chemical sample cell. the biological fluids PPP samples with different Atropine levels were included in the reaction cuvette, and an equal volume of the aPTT diluted sample was then blended. Once a portion of a 25 mM Calcium chloride was applied to the cuvette, the timer began to run. Due to liquid clotting, the metal bead's vibrations halted, allowing the examined plasma's aPTT data to be acquired.

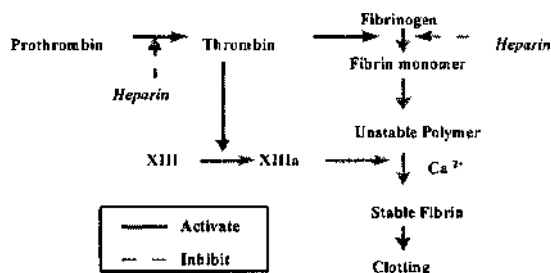


Figure 1 illustrates how the common route of the plasma coagulant is hindered by clotting factors and protein present in the plasma.

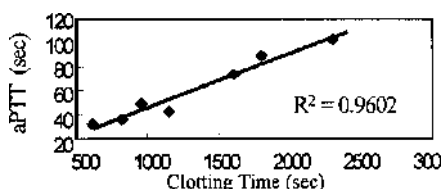


Figure 3 shows correlations between all coagulating time and fluid aPTT that were established using the PQC biosensor and value category coagulometry, accordingly. The proportion of thrombin is changed from 0 to 1 unit/ml.

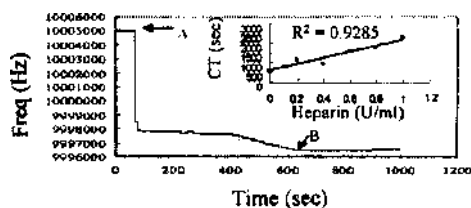
PQC test for clotting

Nine parts of brand-new jugular vein were carefully combined with one part of 3.8% sodium citrate. The same amount of 25 mM CaCl₂ solution was then added one at a time to 20 µl of whole blood, or 20 water to infiltrate of PPP specimen generated with varying concentrations of heparin. The longer CT was seen after additional heparin was added. The liquid was blended for 30 seconds before being dripped onto the PQC sensor's surface. Using a sample period of 0.5 s and a gate time of 1000 s, oscillator spectrum measurements were conducted.

Result and analysis

When compared to a visual coagulo-meter

Consequently, compared to the traditional photographic enrollment in the flat cuvette, the technique of drops test specimens spectrophotometric analysis is more sensitive to the activities of antibody and antigen engagement during the coagulase experiment.



The inset diagram in Fig. 2 shows a calibration curve in CT and heparin concentration of whole blood. As a result, the



due to the load capacity, which came along with the sample's mass and the effects of the sample's viscosity and density on the quartz crystal's interfacial layer. Following then, the frequency initially remained constant, but it eventually decreased to a relatively low value, leading researchers to infer that the addition of the calcium ion Ca^{2+} to the coagulation process was what caused the frequency response to occur in order to create fibrin formation. We discovered that the heparin content of whole blood samples had a significant impact on the CT findings based on the PQC sensor, judging from the declining duration detected from A to B and added with mixing time as the CT value.

CONCLUSION

Figure 2 shows the oscillating frequency response to the reaction of whole blood coagulation with zero units per milliliter of sample heparin. The sample drop point on the sensor is shown by arrow A, and the coagulation termination point is indicated by arrow B. A curve between whole clotting factor time and thrombin level is displayed in the inset. We came to the conclusion that the PQC sensor, which was directly utilised on PPP or whole blood having different doses of heparin, could also be employed as a reliable instrument for blood-clotting monitoring by assessing the frequency change. The aPTT findings for PPP specimens by OC for heparin concentration from 0 to 1 unit/ml introduced demonstrated a good agreement with the CT results for the PPP and whole blood sample based on the PQC sensor. We take into account other anticoagulants' effects, which might also be established using the PQC sensor.

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Study on Wireless Power Transfer System Characteristics Using U-Type Coupling Mechanism

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Abstract – A wireless power transfer system based on a U-shaped core coupling mechanism with a primary coil is developed in order to address the power supply issue of high-speed rotating equipment. First, the wireless power transfer system using the U-type coupling mechanism's transfer model is constructed. Theoretical calculations are used to derive the expressions of transfer power and efficiency, and an analysis of the variables influencing the system's transfer characteristics is done. When the relative location of the main and secondary coils is altered through simulation analysis, the system's magnetic field distribution and coupling characteristics also change. In order to conduct experimental verification, a platform is developed. When the secondary coil and U-core are separated by 15 mm and 30 mm, respectively, the system can provide 1.72 w of output power with 51.19% transfer efficiency, according to the results. The primary coil and secondary coil's power and transmission effectiveness under various misalignments are evaluated and compared. It has been demonstrated that the rotating equipment monitoring system's steady power supply can be successfully realized by a wireless power transfer system based on a U-type coupling mechanism.

Keywords—Wireless power transfer, microwave power transmission.

INTRODUCTION

With the advancement of its research, wireless power transfer (WPT) technology has become extensively adopted in a variety of working environments and application domains. Dynamic WPT technology, in particular, offers wireless power for machinery that uses relative motion, successfully addressing friction loss, contact arc, and difficult installation issues. WPT technology is a practical and efficient power supply system that enables the stable, long-term operation of related moving equipment [1-3]. The dynamic wireless charging of electric automobiles and rail trains as well as the wireless power supply of rotating equipment are the two most often utilised applications for the dynamic wireless power supply of relative moving equipment. For the wireless power supply of trams, the Korea Academy of Science and Technology proposed an I-type structural bipolar core track and an S-type bipolar core track in 2015.

I-core track provides the benefits of a small width, a big air gap, more power output, and cheap manufacture. The greatest efficiency of the U-core track, which is smaller than the I-type track and has a power of 9.5 kW, is 91% [4, 5]. Through the development of an experimental platform, Seoul University in South Korea suggested a WPT system in 2016 that transferred 300 kW of electricity with a 96% efficiency under a 7 cm air gap [6]. A wireless inductive power supply system for rotating machinery was suggested by the German Fraunhofer Institute of Integrated Systems and Device Technology in 2016. Three components make up the system: a bearing, a rotating shaft, a rotary transformer, and sensor load that is mounted to the shaft. It is compact and simple to install. It can transmit 20 W of wireless power with an efficiency of 89.7% [7]. An asymmetric coupling wireless power supply system with a single rectangular coil at the transmitter and a multisquare coil at the receiving end was suggested by Tianjin University of Technology in 2017. When the transfer distance was 5 cm, a 10:1 reduced experimental model was built, and it was confirmed that the system's transfer efficiency could reach 91.4% and its maximum load power was 139 W [8]. A wireless power supply system for rotating machinery was put out by Harbin Institute of Technology in 2018; it makes use of a skeletal magnetic core and a solenoid nested coupling mechanism.



With 87.1% transmission efficiency over the experimental system and a 1 cm distance, 3 kW power level wireless power transfer is accomplished [9]. The Chinese Academy of Sciences' Institute of Electrical Engineering created an omnidirectional three-dimensional receiving resonator in 2019 in anticipation of the load end's angle deflection and offset due to a unique environment. It is capable of achieving high-power, multiattitude, and all-angle wireless power transfer. The simulation experiment shows that the developed three-dimensional resonance device has some antioffset ability since the load power attenuation is less than 25% when the system offset distance is within the radius [10]. An inductive WPT system based on an active boost bridge inverter for wireless charging of electric vehicles was suggested by Auckland University of New Zealand in 2020. The system can track the optimum efficiency under a variety of operating situations and requires less switching equipment than the conventional full-bridge system. It also decreases switching loss. The 3.5 kW trial prototype created proves the suggested system's viability [11]. The University of Science and Technology Beijing created a high-frequency induction power supply system in 2020 to address the issue of wireless power supply for equipment on rotating shafts. The primary coil is constructed of an aluminium ring, while the secondary coil is built of PCB. *e system has been deployed steadily in the field with satisfactory operating effect [12, 13], and eddy current loss produced by the central driving shaft of the coil was researched and analysed. The University of Malaya created a 1 kW WPT system in 2018 that has a 90.5% transmission efficiency rating and can still guarantee 72% transmission efficiency even with 40% misalignments [14]. An innovative three-coil WPT system with an S-S-LCLCC compensating structure was proposed by the University of Malaya in 2021. The power transmission efficiency of the developed system is 10% greater than that of the conventional WPT system when the system's load resistance is 222 [15]. Table 1 lists and compares the key experimental parameters that contributed to the findings of the aforementioned research.

This research suggests a WPT system based on a U-core coupling mechanism in the main side to address the issue of wireless power delivery for rotating machinery. The primary side U-shaped connection mechanism may minimise the size of the primary side coil construction and make installation in a small area easier than the conventional space planar coil and spiral coil. The power transmission channel's coupling coefficient and magnetic field distribution can both be improved by a U-shaped core construction.. The expressions for system transmission efficiency and power are derived from the circuit topology of the U-type coupling mechanism WPT system, the system simulation model is established, the system's spatial magnetic field distribution is examined, and the system's viability is confirmed by establishing an experimental platform.

2. WPT System Analysis of U-Type Coupling Mechanism

In order to transmit power in a WPT system, the main and secondary coils must have mutual inductance and coupling coefficient. These parameters are connected to the relative location and spacing between the primary side and the secondary side. Designing a suitable coupling mechanism that satisfies the demands of mutual inductance and coupling coefficient is required to increase efficiency and output power transmission. Figure 1 depicts the structural diagram of the WPT system based on the U-core coupling structure, where the secondary side coil is mounted on the rotating axis and spins with the shaft while the primary coil is looped around the U-shaped magnetic core and remains stationary, while the secondary side coil is fixed on the rotating axis and rotates with the shaft.

U-type coupling system Series-series (SsS) reactive power compensation circuit topology is used in the WPT system. S-S topology structures provide easy parameter design and straightforward circuit structures. Additionally, the system may produce constant current and its output characteristics are independent of the primary and secondary coils' inductance levels [16, 17]. Figure 2 depicts the system's circuit architecture. After being rectified, the input AC voltage is sent to the inverter where it is converted to high-frequency AC voltage that powers the primary coil. Through induction, the secondary coil produces high-frequency AC voltage and sends it to the load side through the rectifier circuit. In Figure 2, US stands for the source of AC voltage, S1, S2, S3, and S4 for the switch tubes in the inverter circuit, C1 and C2 for the resonance compensation capacitance of the primary side and secondary side, respectively, L1 and L2 for the coil selfinductance of the primary side and secondary side, respectively, M for the mutual inductance of the primary side and secondary side coil, and RL for the equivalent resistance value of the load.

In order to calculate the transfer efficiency and power of the system, let $R_1 = R_S + R_{TX}$, $X_1 = L_1 + 1/\omega C_1$, $R_2 = R_L + R_{RX}$, and $X_2 = L_2 + 1/\omega C_2$, where R_S is the internal resistance of the voltage source, R_{TX} and R_{RX} are the equivalent resistance of the primary side and the secondary side, respectively, and ω is the working angular frequency of the system



$$\begin{cases} Z_1 = R_1 + jX_1, \\ Z_2 = R_2 + jX_2. \end{cases} \quad (1)$$

The primary and secondary circuits' reflection impedance can be represented as follows:

$$\begin{cases} Z_1' = \frac{(\omega M)^2}{Z_2} = \frac{(\omega M)^2}{R_2 + jX_2} = R_1' + jX_1', \\ Z_2' = \frac{(\omega M)^2}{Z_1} = \frac{(\omega M)^2}{R_1 + jX_1} = R_2' + jX_2'. \end{cases} \quad (2)$$

Among them Journal of Electrical and Computer Engineering

TABLE 1: System parameters.

Institution	Gap	P (kW)	η (%)
Korea Institute of Science and Technology	20 cm	9.5	91
Korea Institute of Science and Technology	7 cm	300	96
Fraunhofer Institute of Integrated Systems and Device Technology	3 mm	20	89.7
Tianjin Polytechnic University	5 cm	139	91.4
Harbin Institute of Technology	1 cm	3	87.1
Institute of Electrical Engineering, Chinese Academy of Sciences	16 cm	80	88
University of Auckland	15 cm	2.2	95.4
University of Malaya	150 mm	1	90.5
University of Malaya	—	420	91.2



Figure 1: Schematic diagram of U-type coupling structure WPT system.

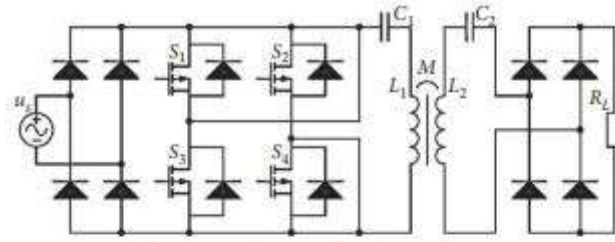


FIGURE 2: System circuit topology.

$$\begin{cases} R_1' = \frac{(\omega M)^2}{R_2^2 + X_2^2} R_2, \\ X_1' = \frac{(\omega M)^2}{R_2^2 + X_2^2} X_2, \\ R_2' = \frac{(\omega M)^2}{R_1^2 + X_1^2} R_1, \\ X_2' = \frac{(\omega M)^2}{R_1^2 + X_1^2} X_1. \end{cases} \quad (3)$$

The total impedance of the primary and secondary circuits may be calculated using formula (1) and equation (3) as follows:

$$\begin{cases} Z_{Tx} = Z_1 + Z_1', \\ Z_{Rx} = Z_2 + Z_2'. \end{cases} \quad (4)$$

According to KVL and KCL, the primary and secondary loop current expressions are as follows:

$$\begin{cases} I_1 = \frac{1}{Z_{Tx} + ((\omega M)^2 / Z_{Rx})} U_s, \\ I_2 = -\frac{j\omega M}{Z_{Tx} Z_{Rx} + (\omega M)^2} U_s. \end{cases} \quad (5)$$

The system's output power and transfer efficiency may be found as follows:

$$\begin{cases} P_{out} = \frac{U_s^2 R_L}{[(Z_1 Z_2 / \omega M) + ((\omega M)^3 / Z_1 Z_2) + 3(\omega M)]^2}, \\ \eta = \frac{U_s R_L}{(Z_1 Z_2^2 / (\omega M)^2) + ((\omega M)^4 / Z_1^2 Z_2) + (4(\omega M)^2 / Z_1) + 4Z_2}. \end{cases} \quad (6)$$

Equation (6) demonstrates that, once the system parameters have been established, the resonance frequency and mutual inductance of the system—which is closely correlated with the distance between the primary and secondary coils—are the main variables affecting the output power and transfer efficiency of the system. So, by examining changes in the relative distance between the main coil and secondary coil, it is possible to determine the changing trend of transfer efficiency and power.

3. Electromagnetic parameters of the U-type coupling mechanism WPT system simulation and analysis

Understanding the distribution of the magnetic induction intensity of the system is important in order to investigate the



impact of the system's relative location on the mutual inductance and coupling coefficient. Modeling and analysis made use of the variables in Table 2.

TABLE 2: System parameters.

Parameter	Value
Core opening width (mm)	60
Core opening height (mm)	60
Cross-sectional area of magnetic core (mm ²)	600
Primary coil diameter (mm)	2
Primary coil turns (turn)	30
Cross-sectional area of secondary coil (mm ²)	0.25
Secondary coil turns (turn)	9
Inner diameter of secondary coil (mm)	100

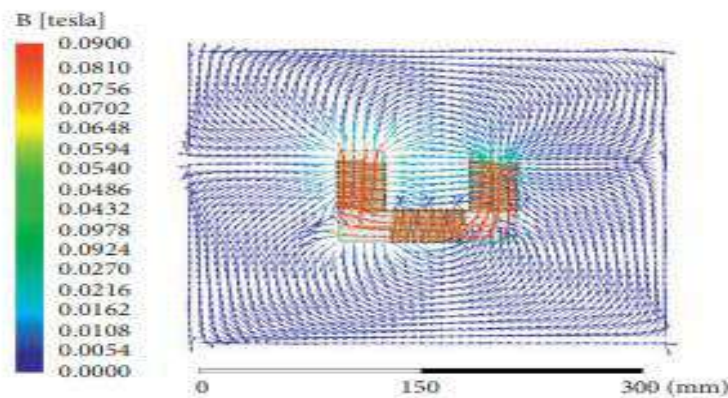


FIGURE 3: Distribution of magnetic induction intensity of the primary U-shaped core coil.

Figure 3 shows that the magnetic field is symmetrically distributed around the primary side coil based on the U-core. The maximum magnetic induction intensity inside the core can reach 390 mT, the magnetic induction intensity at the core's opening is primarily around 10 mT, and the maximum magnetic induction intensity at the opening can reach 100 mT. Eventually, a closed magnetic field loop is formed as the magnetic induction intensity at the opening decreases and the magnetic induction intensity inside the core increases.

The variation law of the mutual inductance and coupling coefficient is investigated by varying the transverse distance d and the longitudinal distance h between the primary coil and the secondary coil, as shown in Figure 4, when examining the impact of the relative position of the coils on the mutual inductance and coupling coefficient of the system. $D = 15$ mm and $h = 15$ mm are chosen as the minimum reference spacings in order to prevent interference between the main and secondary coils brought on by high-speed rotation. The values listed in Table 2 are utilised for modelling analysis and physical fabrication.

The electromagnetic parameters of the coupling mechanism are measured using the RLC bridge metre and Maxwell electromagnetic simulation with the starting standard spacing set at $d = 30$ mm and $h = 30$ mm, as shown in Table 3. The statistics in Table 3 show that the largest error is just 3.03% and that there is essentially no difference between the simulated results and the actual measured values. The coil's self-inductance and mutual inductance barely differ when the operating frequency of the system is raised from 100 kHz to 300 kHz. The system operating frequency for analysis and study in the following analysis can thus be $f = 200$ kHz. D and h are set, respectively, at the system's operating frequency of 200 kHz. With respect to the simulation computation, when the distances d and h change, Figure 5 depicts the changing trend in the mutual inductance between the coils. Figure 5 shows that the change in mutual inductance M is not immediately apparent when the secondary side coil advances to the right. The mutual inductance rises by 0.2 H and 1.21% as the coil advances 15



mm to the right. The mutual inductance changes notably when the secondary coil descends.

The mutual inductance rises by 4.28 H and 25.90% when the coil advances 15 mm. So, by adjusting the secondary coil up and down to increase the system's mutual inductance to its maximum level, the efficiency and output power of the system may be increased to their maximum levels. The results of the research above indicate that the change in d has no impact on mutual inductance. When the minimal reference distance in the vertical direction is met, the system may achieve the maximum mutual inductance $M = 20.81$ H at $h = 15$ mm while maintaining a considerable gap between the primary and secondary coils in the horizontal direction at $d = 30$ mm. As a result, $d = 30$ mm and $h = 15$ mm are chosen as the system's maximum mutual inductance positions. Now, Figure 6 displays the system's magnetic induction strength distribution. Figure 6 demonstrates that the magnetic induction strength surrounding the primary coil is greatest close to the U-shaped core's entrance, where it is around 10 mT.

4. Simulated and experimental studies

Based on the findings of the previous research, this article chooses $d = 30$ mm and $h = 15$ mm as the primary side and secondary side's respective positions, and then creates a model using the Maxwell and Simplorer software using the structural parameters listed in Table 1 for joint simulation analysis. In Figure 7, the joint simulation model is displayed.

Table 4 displays the precise system circuit parameters from the simulation model. Figure 8 displays the system's input voltage, current, output voltage, and current waveforms.

The input voltage and current waveforms for the system simulation are displayed in Figure 8(a). Voltage and current are essentially in phase, as can be shown. The current stabilizes after a number of cycles, and the peak value may be maintained at 560 mA. Thus, 4.20 W may be calculated as the input power. The output voltage and current waveforms of the system are depicted in Figure 8(b) prior to rectification.. It is evident that the waveforms of the output voltage and current are out of phase with those of the input voltage and current. The voltage and current stabilise after a number of cycles.

Peak voltage and current levels are stabilised at 10.4 V and 530 mA, respectively, and 2.76 W is the output power. In summary, the system's simulation output efficiency is 65.71%.

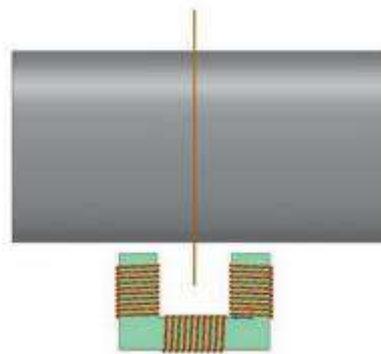


Figure 4: Schematic diagram of relative position between the secondary coil and primary coil

TABLE 3: Simulation and measured electromagnetic parameters of coupling mechanism under initial standard spacing.

Parameter		Simulation value/ μ H	Experimental values/ μ H	Error value (%)
L_1	$f = 100$ kHz	122.91	120.79	1.72
	$f = 200$ kHz	122.81	120.52	1.86
	$f = 300$ kHz	122.78	120.64	1.75
L_2	$f = 100$ kHz	45.15	44.35	1.77
	$f = 200$ kHz	45.14	44.32	1.82
	$f = 300$ kHz	45.14	44.28	1.91
M	$f = 100$ kHz	16.54	16.12	2.54
	$f = 200$ kHz	16.53	16.06	2.84
	$f = 300$ kHz	16.52	16.01	3.03

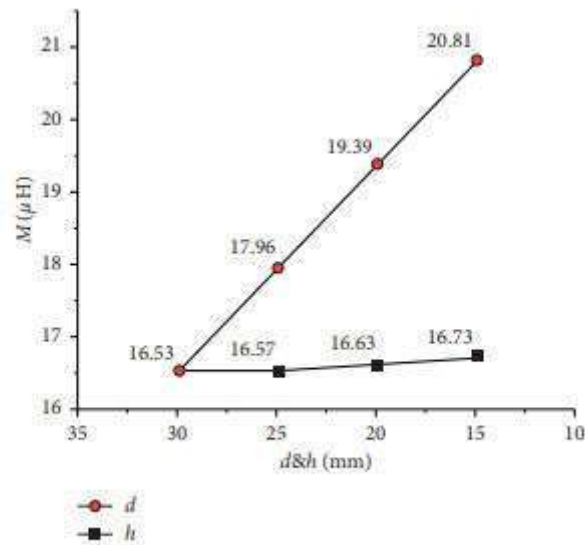


FIGURE 5: Variation trend of coil mutual inductance.

An experimental platform for the U-shaped coupling mechanism radio power transmission system is constructed in accordance with the results of the aforementioned simulation, as shown in Figure 9. The size parameters of the system coupling mechanism are shown in Table 1, and the parameters of the system circuit components are shown in Table 4. In the experiment, the system's inductance, capacitance, impedance, and other characteristics are measured using the VC4092D digital bridge metre, the UTP3705 S DC power supply, the UTD2112CEX oscilloscope, and the UTP3705 S.

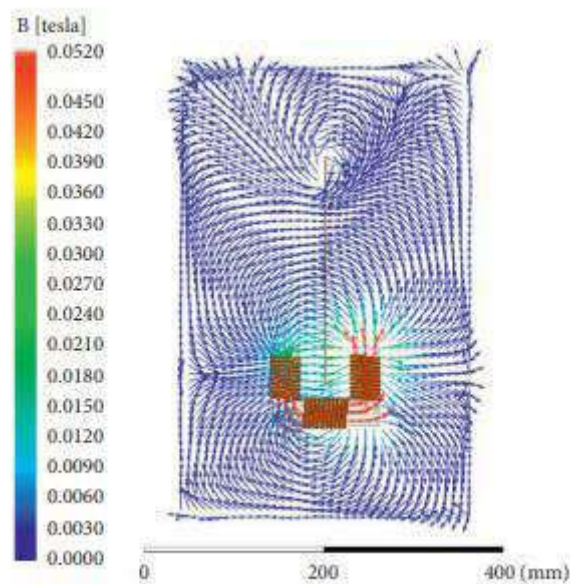


FIGURE 6: Distribution of magnetic induction intensity.

Table 3 displays the primary and secondary coils' mutual and self-inductance values as determined by the VC4092D digital bridge metre. Figure 10 illustrates oscilloscope measurements of the primary side input voltage waveform and secondary side output voltage waveform. The primary side input voltage waveform is around 12.2 V, while the secondary side output voltage waveform's amplitude is approximately 6.14 V.

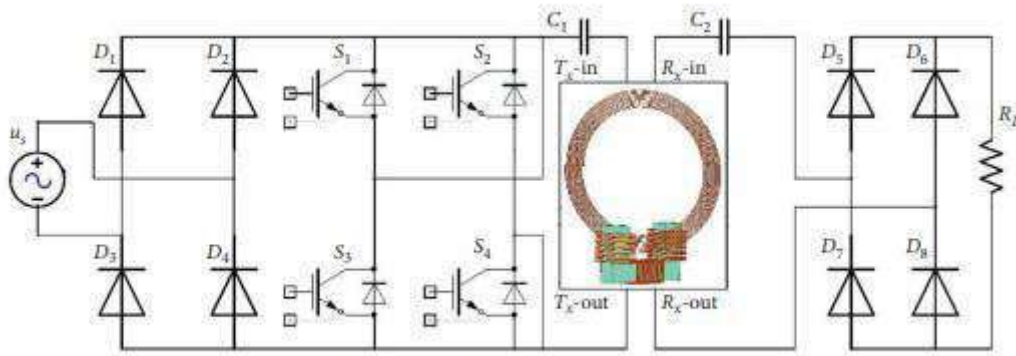


FIGURE 7: Joint simulation model.

TABLE 4: System circuit parameters.

Parameter	Value
f (kHz)	200
L_1 (μ h)	120.52
R_{Tx} (m Ω)	328.74
C_1 (nF)	5.25
L_2 (μ h)	44.32
R_{Rx} (m Ω)	511.12
C_2 (nF)	14.29
R_L (Ω)	100
Input AC voltage peak (V)	15

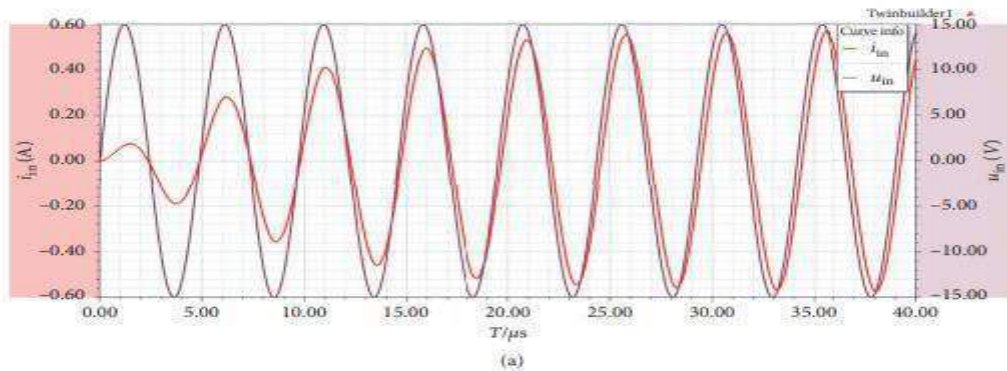


FIGURE 8: Continued.

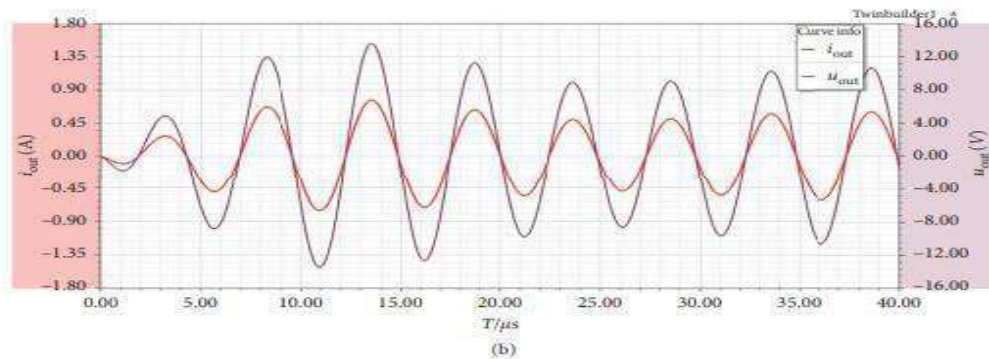


FIGURE 8: Waveform of simulation voltage and current. (a) Input voltage and current waveform. (b) Output voltage and current waveform.

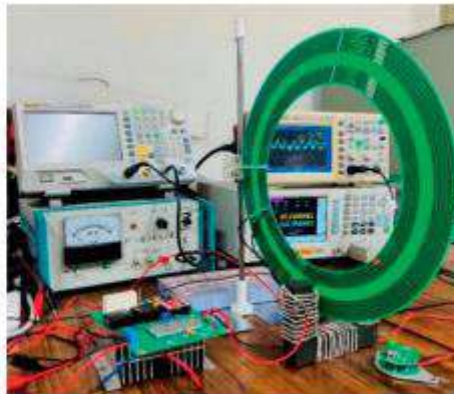


FIGURE 9: Experimental platform of the U-type coupling mechanism wireless power transfer system.

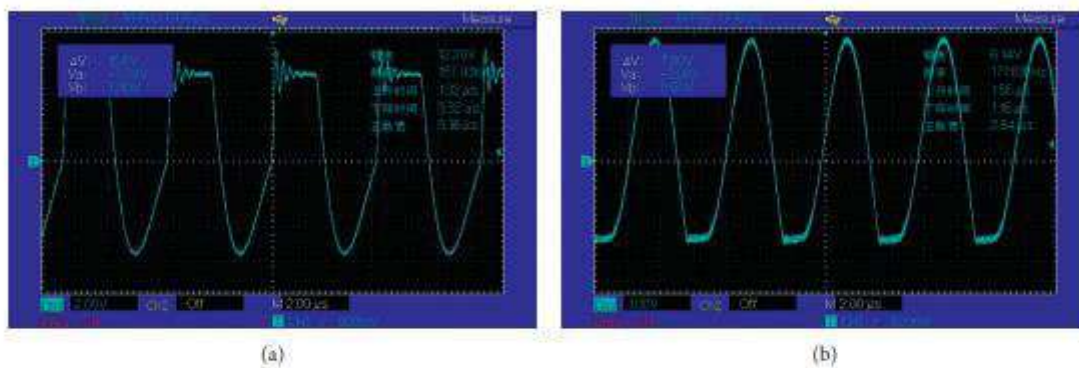


FIGURE 10: Experimental voltage waveform. (a) Primary side input voltage waveform. (b) Secondary side output voltage waveform.

By measuring the input power of the DC power supply at the main side and the power used by the load at the secondary side, it is possible to determine the input and output power of the system. The system's input power is the input power of the primary side circuit's inverter circuit, and the system's output power is the power input to the load following secondary side rectification. 3.36 W and 1.72 W, respectively, are the system's input and output powers. The system's transfer efficiency is 51.19%. The difference in transfer efficiency between simulation and experiment is 14.52% when compared to the outcomes of the two. Because the power loss resulting from the inverter and rectifier is included in the transfer efficiency determined by experiment but is not included in the transfer efficiency of the simulation component, the transfer efficiency of experimental findings is lower than that of simulation analysis.

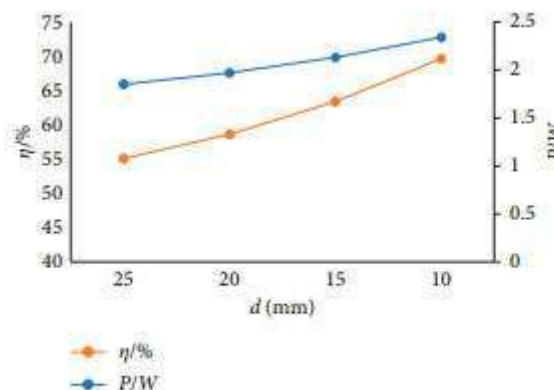


FIGURE 11: Comparison of experimental results.

The comparative findings are depicted in the figure when the system's primary and secondary coils are separated by $d = 25$ mm, $d = 20$ mm, $d = 15$ mm, and $d = 10$ mm.

Figure 11 illustrates how the system's transmission efficiency and transmission power vary when the primary coil and



secondary coil's relative positions are altered. As the transmission power and efficiency steadily rise as the distance d decreases, the chance of a collision between the primary and secondary coil also grows as the distance does.

This means that the primary coil and secondary coil are best positioned relative to one another at a distance of 30 mm, which is still the case.

The U-type coupling mechanism wireless power transfer system can successfully realise the wireless transfer of electric energy, which provides a good solution for wireless power supply of high-speed rotating shaft equipment. However, there are some differences between the experimental and simulation results, which must be taken into account through simulation analysis and experimental verification.

5. Conclusion

A WPT system based on a U-type magnetic core coupling mechanism is suggested in this research. The following results are reached after doing a preliminary theoretical study, simulation analysis, and experimental verification: (1) The mutual inductance and coupling coefficient of the system are influenced by the proximity of the primary U-core coupling mechanism to the secondary coil, which has an impact on the transfer efficiency and output power of the system; (2) electromagnetic simulation demonstrates that the system's magnetic field is primarily distributed close to the U-shaped core's opening; (3) experimental results demonstrate that the system's transfer efficiency can reach 51.19% and its output power can reach 1.72 W, demonstrating the viability of the U-shaped magnetic core coupling structure for wireless power transfer. There is still potential for refinement and optimisation, but the conclusion of this work provides the theoretical foundation and actual application of the U-core coupling mechanism wireless power transmission. The focus of additional study in the follow-up work will be on how to increase the transfer efficiency and output power of the system.

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The Challenges Associated with Wireless Power Transmission Technology Research

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Abstract—In recent years, Wireless Power Transfer (WPT) has become quite popular due to its many benefits, including high transmission efficiency and long transmission distance. This study begins by outlining the development of transmission technology applications both domestically and internationally. The essential issues with wireless power transmission technology are presented in this study from four angles, along with the advancement of the current technology. Finally, the report highlights and presents the most pressing and challenging issues right now.

Keywords—Wireless power transfer, microwave power transmission.

INTRODUCTION

Traditional cable power transmission has issues with wear, ageing, producing electric sparks, and other things. In the meantime, the safety and dependability of the cable's use are significantly reduced in particular special circumstances, such as steep mountains and the seabed [1]. Hence, as technology has advanced, individuals have begun to focus on wireless power transfer. Because it has benefits including a low rate of wear, excellent reliability and safety, easy and flexible use, lovely appearance, and more. The wireless power transfer technology currently has a variety of methods, including electromagnetic, resonant, electromagnetic radiation, and so forth [2]. This essay analyses the development of WPT application in recent years. This paper discusses in detail the transmission mechanism and modelling of resonant WPT technology before posing several significant issues.

APPLICATION OF WIRELESS POWER TRANSMISSION TECHNOLOGY

Nicola Tesla developed the radio energy transfer technology in the nineteenth century [3]. Wireless power transmission technology has made significant progress after years of development. Using the S/P capacitance compensation technique, Donaldson's research from 1983 demonstrates that the optimal electromagnetic coupling coefficient of the transmitter and receiver can be attained, and the transmission efficiency can exceed 50% [4]. Professor Joun then advanced the S/S capacitor correction method in 1996 [5]. The hybrid wireless charging compensation methods include P/P, P/S, S/P-S/SP, and others. Resonant WPT principle was introduced to science by Professor Soljacic Marin and his research team in 2007, and it quickly gained popularity [6-7]. MIT successfully ignited a 60W light bulb 2 metres distant, and their charging transmission efficiency was over 40%. Also, they discovered that the charging efficiency rises very quickly when the distance is reduced. The efficiency is greater than 85% at a distance of 125 cm. The efficiency increased to a more astounding 95% when the distance was 75 cm.

In 2009, KAIST tested an SUV vehicle, and the results showed that the output power was 15kW and the efficiency was 71% [8]. In 2009, Witricity was able to reach a 6.4MHz base, a transmission distance of 60cm, and a 95% efficiency [9].

Over 90% of the 3.3kW radio's total transmission efficiency was attained by Witricity in 2011 [10]. With a transmission distance of 630 cm, a resonance frequency of 13.56 MHz, and a maximum charge efficiency of 85%, Professor Hori of the University of Tokyo in Japan achieved high efficiency power transmission in 2012 [11]. The following 200 kHz automobile wireless charging, with a transmission power of 2 to 6 kW and a transmission efficiency of up to 94%, was accomplished in



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2013 by Professor Mi of Michigan State University and his team [12]. Professor Park C. and his colleagues developed a wireless power transmission system using a "bipolar magnetic core coil" from 2012 to 2015, and they are now working to increase the transmission distance [13].

China's study was done late, yet the pace of advancement is quite quick. Professor Sun Yue's team started working on related research into the frequency stability of contactless power transmission in 2005, and he also advanced the technology for controlling voltage output in relation to CPT systems [14]. The properties of the power, efficiency, and frequency of the near field magnetic resonance WPT were then examined in 2011 by Liu Sucheng of Chongqing University [15]. A summary of the advancements in wireless power transmission technology was provided by Professor Chen Qianhong [16]. Professor Zhang Bo also described the three primary methods in which the magnetic resonance WPT works and examined the possible limit parameters, noting that the transmission efficiency of the WPT does not always reach 100% [17]. The research team at Xi'an University of Technology unveiled four different types of hybrid wireless charging topology technology in 2016, concentrating on the examination of the compensating technique of S/P-S/SP. [18]. Professor Huang Xueliang conducted research on the evolution of magnetic resonance series and models, receiving devices, and other topics [19]. Many conferences are also crucial for advancing the advancement of radio transmission technology. For instance, the Chinese Conference on Decision and Control (CCDC), the Chinese New Energy Vehicle Charging and Drive Technology Conference (GVCD), the WPC conference of the Silk Road International Wireless Charging Union, and other events organised by IEEE.

SEVERAL PRIMARY PROBLEMS WITH WPT TECHNOLOGY

Although WPT technology offers clear benefits over conventional technology, there are still several problems preventing it from developing fully, necessitating more study.

Quantitative Connections in Many Areas

WPT technology research has continuously concentrated on the factories' frequency, power, efficiency, and transmission distance. The study demonstrates a favourable correlation between the inductive WPT technology's transmission efficiency and transmission distance. Resonant WPT technology has the greatest transmission efficiency at the same resonant frequency. Nevertheless, efficiency rapidly declines over a particular frequency range, and there aren't many mathematical relationships between these factors. Thus, understanding the quantitative link between these parameters will be of extreme practical importance.

The Electric Transmission Direction About Resonant WPT

The research team at MIT presented resonant WPT technology but also demonstrated in principle that power transmission is not direction-dependent. Many research have been conducted in recent years to investigate the under-coaxial parallel condition, which is based on the coupled, critical coupling, and over-coupled square. According to experimental findings, in the circumstance of excessive coupling, there is no direction in a specific range. There are several directions under the circumstances of critical coupling and under coupling. The direction of system energy transmission has a significant influence on transmission distance, transmission efficiency, and other factors. This topic is still being researched, and the industry has not yet agreed upon a set of study findings.

Spatial Power Density Variation and WPT Transmission Mechanism

Many nations have analysed the WPT technology using the Circuit Theory, Coupled Mode Theory, and Two Port Network Theory, according to the literature. The Coupling Mode Theory is primarily utilised to investigate various fundamental aspects of resonant WPT, including the system's transmission effectiveness, its parameters, and so on. The study of the spatial power density change over time, the law of spatial energy transfer, and its mechanism, however, is not as extensive as that of the WPT transmission mechanism. In order to accomplish efficient spatial limitations, this study will assist to understand how electromagnetic energy is transmitted spatially. This will enable future efforts to increase the transmission distance, the coil size, and other factors to improve the efficiency of the transmission.

High Frequency Electromagnetic Leakage's Effects on Biological Safety

The WPT method of energy transfer involves linking high frequency electromagnetic space. According to study, internal and



external variables prevent the efficiency of electricity transmission from reaching 100%. One part of the lost electric energy is converted into heat energy and lost in space electromagnetic transmission. According to the study, animals' heart, blood vessel, and blood illnesses would develop over time in an environment with radio frequency exposure because the plant body will create genetic variation and other phenomena. There are currently only two international standards for electromagnetic radiation: ICNIRT and IEEE.

The majority of nations using the ICNIRT standard include Australia, Europe, and others. The principal users of the IEEE standard include Japan, the United States, Canada, and other nations. China has also introduced a number of standards, the most popular of which is GB 8702-88. The effects of the power system size and distance from the coil on the human body were studied using the reference [20] model for adults and children in the body to tolerate four SAR radiation magnetic coil system. The WPT technology will direct electromagnetic leakage that is too great and has lasting consequences on the biological safety of the surrounding system.

Nevertheless, the majority of domestic and international research on electromagnetic radiation is based on model simulation analysis and quantitative qualitative test, which has certain restrictions. It is necessary to conduct a thorough analysis of the system power, frequency, environment, and radiation duration of various grades in order to produce a more complete magnetic radiation effect. According to the aforementioned factors, it is not difficult to conclude that in order to achieve efficient power transmission, factors such as the power supply, the circuit, as well as the power frequency, transmission distance, and size distribution of electromagnetic space must be taken into account. Additionally, the power density and the direction of magnetic leakage about the beam during electromagnetic transmission will also have a big impact. The biological safety of the environment can also be impacted by magnetic leakage, but using cutting-edge materials can also increase transmission efficiency and achieve the direction-constrained electromagnetic environment protection function. As a result, in order to accomplish future progress, emphasis must be given to all elements of WPT technology.

CONCLUSION

This study primarily introduces the state of domestic and international research and highlights several significant fundamental issues. Without a doubt, research into wireless power transmission technology has made great strides, but there are still many issues to be resolved, including a low energy conversion rate, a fragmented charging standard, issues with biological safety, a discrepancy between cost and market demand for wireless charging, and more. The radio transmission technology will be used more effectively and subsequently developed with more in-depth study.

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Wireless Power Transfer: Concepts, Applications, Difficulties and Mitigation Strategies

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Abstract –The wireless power transfer (WPT) system's most recent developments are reviewed in this study. The classification of wireless power transmission, its use, trend, and influence on society are all covered in this essay, along with its benefits and drawbacks. Also, it provides a comparative study of prior research in the area of wireless power transfer, highlighting the limitations of different topologies, communication, and optimization techniques used to boost overall performance efficiency and offering suggestions for future research.

Keywords—wireless power transfer, application, advantages, disadvantages topologies, communication, optimization, efficiency

INTRODUCTION

Electricity has been transferred for a very long time mostly via traditional wire systems. The issue with conventional cable (wire) power transmission is that it ages, wears out, and generates electric sparks. Due to the negative effects on the safety and dependability of its use, it is challenging to utilise the cable to transmit in some terrains, such as high mountains and sea beds [1]. Wireless Power Transfer (WPT) has the potential to totally transform the way electricity is transmitted, leading to a paradigm change. WPT is a significant method for moving large amounts of electrical energy over long distances across a vacuum or environment without using conventional wires or any other material [2].

From being only theoretical ideas to being a regular function on manufactured goods, particularly mobile phones and portable smart gadgets, wireless charging has advanced [3]. Modern high-end smartphones were produced in 2014 by industry leaders in mobile, such Huawei and Samsung. These gadgets included wireless charging capabilities. Several businesses, including Qualcomm, Evatran, WiTricity, and others, have already created solutions that can transmit power via an acceptable efficiency gap of 15 to 30 cm. A broad overview of the wireless power transfer technique is provided in this work.

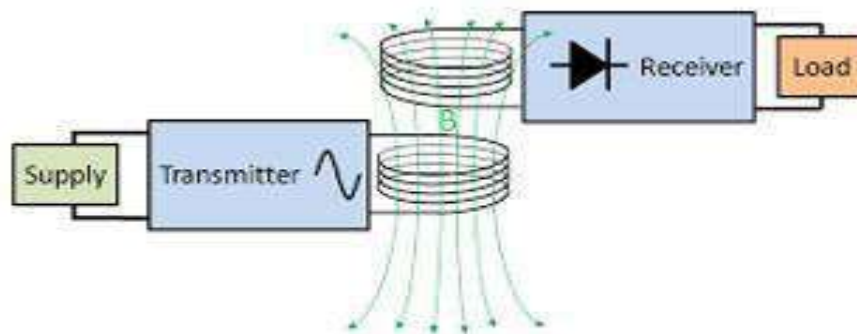


Figure 1: Wireless Power Transfer



THEORETICAL BACKGROUND

WPT systems may be categorized into two groups, namely, far-field and near-field WPT systems, in accordance with the energy transfer mechanism [1].

Far-Field Wireless Power Transfer

Far-field wireless power transfer, also known as electromagnetic radiation WPT [1], uses radio frequency transmissions and other electromagnetic waves as a medium to transmit energy in the form of radiation [3]. This is then transmitted by the radiative electric field of an electromagnetic wave [3]. Laser power transfer, solar power transfer, and microwave power transfer are all examples of far-field WPT [2].

Microwave Power Transfer (MPT)

Based on electromagnetic radiation, microwave power transfer (MPT) transfers power in empty space by making use of the far-field radiation effect of the electromagnetic field. [4]. When initialized at the base stations and transmitted to the mobile devices and receiving station, this method ensures a high power transmission level. The line of sight must pass through two places for this to work. The system uses magnetrons to increase the power of items retrieved from the base station when used with geosynchronous transmission and receiving satellites. MPT is efficient in the area of energy conversion, however difficulties are encountered when attempting to concentrate the beam across a constrained space [5]. Electrical energy is first transformed into microwaves by the retina, which are then used to transmit power. Alternating Current (AC) is not transformed directly into the necessary microwave energy while utilizing this method. To convert to microwave using a magnetron, Direct Current (DC) must first be converted. The antenna effectively converts the microwaves from the transmitted waves to DC power and back to AC afterward. [5]

Transfer of Laser Power (LPT)

Power is transmitted via laser power transfer (LPT) at visible or near-infrared frequencies. To efficiently distribute electricity across great distances, it employs laser light that is highly focused and pointed towards the energy receiver. Specialized photovoltaic cells are used by the laser powering receiver to transform the received laser light into energy [6].

LPT offers the benefit of concentrated energy. However, laser radiation has the potential to be dangerous and needs a Line of Sight (LOS) link in addition to precise aiming at the receiver, both of which can be difficult to obtain in actual use [7]. Additionally, a broad range of gadgets and intricate tracking systems are needed. Laser beaming is more susceptible to atmospheric absorption and dispersion by clouds, fog, and rain than microwave WPT, which significantly limits its practical applicability [8]. Strong laser beams pose major health risks to people, and it is expensive to really implement this approach [9].

Solar Powered Satellite (SPS)

It uses satellites with enormous solar arrays that are placed in Geosynchronous Earth Orbit and is the largest application of WPT. When power is generated and transmitted to the ground as microwaves, these satellites are crucial [10].

Near-Field Wireless Power Transfer (NFWPT)

Close field In order to transmit energy, WPT, sometimes referred to as non-radiative wireless charging, relies on the coupling of the magnetic field between two coils at a distance equal to their coil-diameter [11]. The power transfer over a distance is primarily constrained because the magnetic field of an electromagnetic wave attenuates considerably more quickly than the electric field. Non-radiative wireless charging has been incorporated into the design of common household goods, from simple devices like toothbrushes to more complex ones like electric vehicles, due to its safety benefits. Inductive Power Transfer (IPT) and Capacitive Power Transfer are two categories for the Near field WPT. (CPT). Inductive Coupled Wireless Power Transfer (ICWPT) and Magnetically Coupled Resonance Wireless Power Transfer (MCR WPT) are additional classifications for inductive power transfer [1]. The aforementioned techniques all successfully accomplish the wireless power transmission required for charging, despite their differences in transferred



distance, effectiveness, frequency, transferred power, and resonator dimensions. Their methods differed in the following ways [12]

Wireless Inductive Coupled Power Transfer

The most popular technique for wirelessly recharging low powered gadgets to date is the inductive coupled WPT [13]. It is used to transmit power from one coil to another and has been utilized to power RFID tags, implants, sensors, wireless charging, and the automobile manufacturing sector [4]. When employed within a few millimeters to a few centimeters (20 cm) of the intended load, inductive coupling's operating frequency is in the kilohertz range [4]. Its power ranges between watt and kilowatt depending on transmission efficiency [4]. Easy implementation and practical operation are two benefits of the inductive coupling WPT system [14]. It is non-radiative and regarded as safe for people [2, 4] because of its low transmission frequency. It has a high transfer efficiency of up to 95% at short distances [2], prevents sparks and other hazards in circumstances like coal mining, and because the coupling is magnetic, there is never a risk of electrocution or short circuit under any power range condition [12]. However, a drawback of conventional inductive charging is that it only functions well over very short communication distances; as the distance increases, the performance degrades.

Wireless Power Transfer through Magnetically Coupled Resonance (MCR WPT)

The fundamentals of inductive coupled wireless power transmission and magnetically coupled resonance wireless power transfer (MCR-WPT) are similar. Power is also transmitted from a source to a load through it [15]. The magnetic resonant coils used by this magnetically connected resonant, however, function at the same resonance frequency [4]. It is feasible to achieve up to 50% efficiency for power transmission over greater distances by employing magnetically linked resonant over conventional inductive coupling, without altering coil size and power consumption [16]. Because it may be used to all facets of human life, including consumer and medical devices, smart homes, and electric vehicles, MCR-WPT technology has garnered a great deal of interest from both academics and business.

A few hundred kHz to a few tens of MHz are used as the operating frequency. As opposed to inductively coupled wireless power transfer, magnetically coupled resonance wireless power transfer has higher transfer power and efficiency and is currently thought to be one of the most effective methods for mid-range WPT applications [17]. MCR WPT benefits include long-distance within several meters, immunity to environmental conditions like weather [2], and the lack of a need for line of sight (LOS) when charging devices. When compared to the microwave and laser WPT, the coupled magnetic resonant system's non-radiative nature poses no environmental risk. However, because to the axial mismatch between the receiver and transmitter coils, lower efficiency with greater distance, and complex implementation, MCR WPT sees a loss in efficiency [2].

Capacitive Power Transfer (CPT)

Energy is transferred between electrodes, such as metal plates, during capacitive power transfer (CPT). Receiving and transmitting electrodes combine to create a charged holding capacitor. Through electrostatic induction, the transmitter generates an alternating voltage on the transmitting plate, which the oscillating electric field uses to produce an alternating potential on the receiving plate. This causes an alternating current flow in the load circuit. [18]. although magnetically coupled resonant and inductive coupling are more expensive than capacitive power transmission, CPT still necessitates close contact between the two metal surfaces. Consequently, range requirements severely restrict it [4]. Due to the relative field strength of electric fields being substantially higher than that of magnetic fields, which puts both people and electronic devices at risk [4, 5], this is the main disadvantage of capacitive WPT systems. Additionally, the device's available area affects the coupling capacitance that can be achieved. However, while taking into account normal-sized portable electronic gadgets, it is challenging to provide sufficient power density needed for charging [11].

WIRELESS POWER TRANSFER DEVELOPMENT TRENDS AND IMPACT ON SOCIETY

Rezece by the Alliance for Wireless Power (A4WP)

The Alliance for Wireless Power created the magnetic resonance wireless power transfer standard called Rezece. (A4WP). Up to eight receiver devices can receive power from a single transmitter over medium distances. Through the use of Bluetooth, communication between transmitters and receivers is carried out "out-of-band." Early in 2012,



the A4WP was established to create a widespread WPT ecosystem. The members of PMA come from every known sector of the telecommunications industry, including Broadcom, Panasonic, Microsoft Corporation, LG Electronics, Samsung, Logitech, WiTricity, Qualcomm, Incorporated, Gill Electronics, Hewlett Packard, Integrated Device Technology, Inc., Intel, and others [25].

Qi Technology

The Qi (pronounced "Chee") wireless charging standard was initially introduced in 2008 [19]. The Qi Wireless Power Transfer standard utilizes the magnetic induction concept. This technology supports a maximum charging distance of a few centimeters and employs tiny inductors to transmit electricity over higher frequencies.

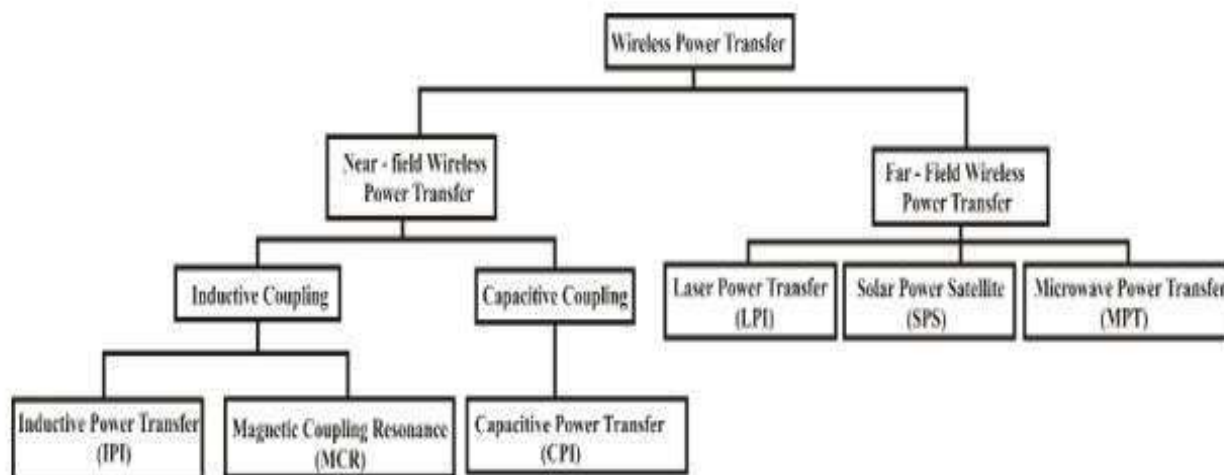


Figure 2: Classification of Wireless Power Transfer

Because of this, it is necessary to dock portable equipment precisely in order to prevent a lack of a strong magnetic field [5]. It is capable of supplying the load with 5W to 10W of electric current. In order to establish the power transmission, digital communications are used. Simply placing the device over the charging pad initiates the power transfer [20]. Qi components can use several resonator arrays to produce a greater charging area due to its charging area restriction. However, turning on individual coils still doesn't solve the issue and really consumes a lot of energy. Users must therefore properly align their gadgets with the magnetic fields in order to maintain a solid connection [5]. Because of the conductive material it is constructed of and the operating frequency, the wireless charger at present can become warm when charging and heats the back of the device. The Qi uses a constrained communication protocol to reduce the power used by several coils. With this, the receiving device can communicate to the charger how much power and when it is fully charged. The charger can also change its power output to accommodate any receiving devices and can go back into standby mode when a full charge is reached or if no device is connected [5].

Samsung, LG, Philips, Toyota, Microsoft, and Sony are among the companies who use this standard for charging their products [21]. The Alliance for Wireless Power (A4WP) Technology is less effective than the Qi, a Tightly-Coupled [TC] WPT technology. There are some restrictions with Qi, including the need for positional alignment, metal heating, and single device charging [22].

Power Matters Alliance (PMA) Technology

The Power Matters Alliance (PMA) is a newer piece of technology [5]. It is a nonprofit organisation that creates standards for inductive and resonant power transfer. In order to technically harmonise and improve numerous inductive WPT standards, market WPT within the automotive sector and well-liked public infrastructure places, and more, PMA was established in 2012. [23]. The batteries of mobile devices are charged using tightly linked coils. PMA can transmit 5–10W of power. Every recognised segment of the mobile device industry, which makes up the core value chain, is represented among PMA's members [24]. Duracell, Powermat, LG, Innatek, Panasonic, Samsung Electronics, Toshiba, Sony, Energous Corporation, Freescale Semiconductor Inc, Integrated Device Technology (IDT), and Microsoft Corporation are some of the most notable PMA members [23].

WIRELESS POWER APPLICATION



Consumer electronics (smartphones, PCs, music players, tablets, etc.) have all made use of WPT[30]. WPT technologies can be employed to charge TVs in addition to cellphones, cameras, and watches [21]. In order to diagnose and treat disorders in the human body, medical implant applications are also employed in medicine [2]. The wireless sensor network (WSN), unmanned aerial vehicles (UAV), Internet of Things (IoT), electric vehicles, and charging systems for autonomous underwater vehicles are other areas where WPT is used. The following subsections provide a summary of the benefits and drawbacks of wireless power transmission technologies:

Advantages of Wireless Power Transfer

- Since a cable connection is not required, it is convenient. [26].
- It is economical.
- It is useful as a multiple device charger by enabling dependable power transfer in demanding circumstances like moving settings and damp, unclean conditions, wireless power transfer improves product durability [27].
- Another benefit of wireless power transfer is the ease of product design. Power ports and other common elements can be fully sealed up to create a waterproof device. [28]

Disadvantages of Wireless Power Transfer

- Despite their increasing popularity, wireless chargers are still substantially more expensive to construct than a traditional wall socket charger [26].
- It may sound very simple to use a wireless charger, but it is not. You must place a device on the charger correctly for wireless charging to work. Some chargers even include sections with markings that show you where to place the phone.
- Even while this is evolving due to improvements in design, it is still far from seamless [26].
- The practical use of laser and microwave WPT is similarly impacted by fog and rain [27].
- Microwave interference occurs when other communication systems are present, which is a drawback [27]

COMPARATIVE ANALYSIS OF EXISTING WORK

In [1], modelling and experiments were used to create a 3D structured WPT that can transfer power wirelessly in a robotic application at a frequency of 500 kHz. The proposed winding method used a joint composed of two spherical components. The joint is composed of a spinning spherical structure mounted on a large sphere at an angle of 0° to 85° . On a spherical framework, the transmitter coil (Tx), with a radius of 3.85 cm, was wound (with a slot). The little spherical can rotate up to 45 degrees on the mechanical stud. A tiny sphere construction was wound with the receiver coils (Rx) having a radius of 2.85 cm, producing a displacement angle in degrees. Measurements between the vertical axis of the joint structures were taken to determine the value of. The results revealed that the hemispherical winding generated an efficiency of up to 96% at $= 0^\circ$ at a load (RL) of 20. At 85 degrees, the efficiency dropped to under 10%. In contrast, the optimised WPT had an efficiency of 95.75% and 96% at $= 0^\circ$ and 85° , respectively, under the same load conditions. The magnetic field density is focused around the coils when utilising the suggested method, which could be dangerous if used close to the human body. The optimisation technique utilised to determine the ideal dimensions for the core, coils, and detecting circuit components was also left unmentioned by the authors.

The ideas presented in [37] are expanded upon by a professor of Nuclear & Quantum Engineering at KAIST and his team. Prof. Park's team showed a significant improvement in the wireless transmission of electricity. With efficiencies of 29%, 16%, and 8%, respectively, the authors created the "Dipole Coil Resonant System (DCRS)" with a ferrite core wound in the middle allowing an increased range of inductive power transfer to distances of 3, 4 and 5 metres between transmitter and receiver coils. Based on the 20 kHz oscillating frequency in the transmitting coil, this team transmitted energy. This system's measurements for length, width, and height are 3 meters, 10 centimeters, and 20 centimeters, respectively, with a low Q factor of 100. Several tests were run on this system, and the results showed that it could generate a maximum power of 1403W at a distance of 3 meters, 471W at 4 meters, and 209W at 5 metres when operating at a frequency of 20 kHz. For distances of 3 meters, 4 meters, and 5 meters, respectively, 100 W of electric power transfer produced an overall system power of 36.9%, 18.7%, and 9.2%. The Dipole Coil Resonant System has a maximum power output of 209v at 20 kHz and can charge up to 40 cellphones at once. It was noted, nonetheless, that the coupling was not taken into account for neighbouring and nonadjacent situations [38]. Second, it is challenging to include receiver coils into portable consumer products due to their complicated structure and size. The authors of [39]



conducted research on the relay effect for wireless power transfer using magnetic resonant coupling to increase the energy transfer distance. Software from Computer Simulation Technology (CST) called Microwave Studio was used for modelling and numerical analysis.. According to the authors, a conventional wireless power transfer system can only transmit energy with a 4.6% power efficiency at a distance of 1 metre due to its low performance in this area. In order to address this weakness, a relay coil with a 24 cm diameter and a 41.586 MHz working frequency was placed between the transmitter and receiving coils. This increased the system's power transmission distance. The system's power efficiency increased by up to 50% when the relay coil was installed in comparison to the system without one.

In [41], the authors presented analytical and experimental investigations of omnidirectional wireless power transfer using a cubic transmitter, in this paper, the authors proposed the use of cubic transmitter coil to achieve omnidirectional power transfer. Through study and execution, the effectiveness of the suggested omnidirectional WPT accounting for varied distances between the transmitter and receiver as well as the transmitter structure was assessed. The outcome indicates that at an operating frequency of 13.56 MHz and an ideal spacing of 30 cm, the cubic transmitter was able to achieve an omnidirectional power transmission capability of 60% efficiency.. The transmitter and reception coils' loop dimensions, which were set to 20 cm, were too huge to fit inside consumer electronics, and thus cannot be considered portable since they would take up room in the workspace. Additionally, there was no mention of any optimisation procedures utilised to determine the pick-up coil and detection circuit components' ideal size. The significant correlation between the number of excitation and pick-up coil turns, as well as the excitation and detection circuits, may eventually result in a mismatch between the transmitter and receiver characteristics. Based on a unique reactance steering network (RSN), Dual-Band Multi-Receiver Wireless Power Transfer Architecture, Topology, and Control were reported in [42]. The RSN can perfectly correct for any load reactance by dynamically guiding the power between two inverter branches. One WPT system with dual-frequency operation has an integrated transmitter and receiver. The author created a dual-band transmitter using RSN technology that can independently modify the power sent at two frequencies. The RSN architecture reuses the components and creates mutual benefits at two frequencies to increase performance rather than combining two independent single frequency transmitters.. The authors created a dual-band receiver that can switch between operating at 100 kHz and 13.56 MHz on the receiver side. With significant coil misalignment, multiple dual-band receivers may receive up to 30W of power from the prototyped RSN transmitter with 74.8% efficiency at 13.56 MHz and 82.5% efficiency at 100 kHz. The distance (2.8 cm) that was accomplished in this study is insufficient, a large coil misalignment of 5 cm was observed, and the transmitting and receiving coils' intended diameters of 10 cm and 20 cm, respectively, were employed, increasing the device's size and making it impractical for commercial usage. The design parameters were chosen at random, thus the power obtained might not be entirely optimal.

The optimisation design and analysis of the wireless power transfer system with a converter circuit running at 13.56MHz were provided by the authors in [43]. It was examined using a differential evolution (DE) technique. The receiver and transmitter coils' starting parameters, which were found to be 10mm and 64mm in diameter, were used to optimise the WPT system. The outcome shown that when the frequency was 13.56MHz with an output voltage of 5V, the power transfer efficiency reached its maximum value of 30%..

In [44], the authors concentrated on applying a Differential Evolution (DE) algorithm and an established mathematical model to optimise the output power and transmission efficiency of a magnetically coupled resonance (MCR) wireless power transfer system. In order to maximise the output power and transmission efficiency of the two-coil system and four-coil MCR WPT, ideal parameters, such as the distances between the coils, the resonance frequency, and the resistance of the load, are found in this study using a differential evolution method. For a given resonance frequency of 1MHz, the output power and transmission efficiency results for two coils with a coil radius of 0.1m at an optimised transmission distance of 0.2m were shown to be 0.46W and the results for four coils at 0.3m distance were found to be 10W, respectively. The output power and transmission efficiency of the MCR WPT system with defined coil structure were enhanced by comparing and analysing simulation data. Although the differential evolution optimisation approach utilised in this research work was straightforward to develop, the model needs a lot more time to simulate, and the likelihood of finding the closest optimal point is relatively low. The most prevalent occurrence in DE is premature convergence. In [45], the authors suggested using a novel Particle Swarm Optimization (PSO) technique to solve the issue of a magnetically-coupled resonant wireless power transfer (MCR- WPT) system's poor transfer efficiency. This work includes included analytical computation, numerical modeling, and experimentation. Finally, the theoretical theory was empirically tested. The optimal frequency search in the MCR-WPT systems with or without frequency splitting was simulated. The outcome demonstrates that the peak voltage across the load reduces suddenly from 12 V to 4.2 V when the transfer distance falls from 14 cm to 8 cm at a resonant frequency of 8MHz and a coil radius of 15 cm. When the



transfer distance varies, the voltage in the MCR-WPT system utilising the suggested PSO algorithm stays higher. To accomplish the better search route in deciding, the suggested PSO algorithms have the disadvantage of keeping a lot of sophisticated algorithmic control parameters. They also have the disadvantage of premature convergence and dropping into regional optimum. The Simulated Annealing (SA) optimisation approach was used by the authors of [46] to optimise a wireless power transmission system and identify the parameters of the parasitic wires. By carefully changing the position, size, and shape of the parasitic wires, the authors used Simulated Annealing (SA) optimisation technique to estimate the parameters of the parasitic wires in order to maximise the efficiency of wireless power transfer. In comparison to the present design of the wireless power transfer system, the result obtained indicates an improvement in the overall efficiency of the system of 30% at 1GHz frequency, parasitic wire radius of 0.02, and distance of 0.42. Despite SA's ability to avoid becoming stuck in local minima, the SA approach used in the design cannot demonstrate if it has reached the best solution. This can only be accomplished using another approach (such as branch and bound), which similarly needs infinite time because there is no way for limiting the number of iterations. The research necessary to take into consideration many limitations makes it challenging to precisely adjust the algorithm's settings.

In order to increase transmission distance and also to establish a steady power transmission of a wireless transfer system, the authors in [48] explored a 3-coil MCR WPT system based on the equivalent circuit and fundamental harmonic analysis (FHA) approach. The outcome demonstrates that at a frequency of 200 kHz and a coil radius of 11 cm, a consistent output power of roughly 70 W can be attained by positioning the repeater coil at the centre of the transmitting and receiving coils. Nevertheless, adding more coil makes the system more complicated and suggests that more turning labour would be required to align all the parameters, making it challenging to maintain optimal performance in a challenging environment for the actual applications [49].

To enhance and maximise the transfer efficiency of a 4-coil resonant linked (each loop's diameter is 20 cm) WPT system running at a 12Hz operating frequency, the authors in [50] presented an impedance matching strategy based on coupling tuning using the Advanced Design System (ADS) simulator. The loaded quality factors and coupling coefficients were used to determine the system's maximum efficiency. Through simulation, the impact of coil distance change was investigated, and the findings indicated enhanced system performance. However, the impedance matching circuit includes several passive parts, such inductors, capacitors, and switches, which take up a lot of space and raise system loss.

CONCLUSION

Based on the research discussed in this paper, the chosen researchers have created and tested a variety of compensation approaches for diverse applications to enhance the performance of the wireless power transfer system. Despite the extensive research in the field of wireless power transfer, WPT has not yet reached its full potential in terms of transfer power and distance, frequency, and coil dimensions because the currently designed transmitter and receiver coils are too large to be integrated into consumer devices. Additionally, the coils cannot be considered portable because they would take up space in the working area. As a result, there is a need for more study in this area since wireless power transmission is suitable for a wide range of interesting applications.



Table 1. Comparative analysis of existing work based on optimization and topology used

Ref no	Year	Optimization/simulation method used	Topology method used	Frequency	Coil diameter	Vout/Output power	Distance	Efficiency %
1	2018	ANSYS electronics	Series-series	500(kHz)	Tx coil =7.7cm Rx coil =5.7cm	5v		96
37	2014	Numerically modeled		20(kHz)		1,403W, 471W, 209W	3m 4m 5m	29 16 8
39	2016	Computer Simulation Technology (CST) Microwave Studio simulation software	relay resonator coil	41.587(MHz) 29.982(MHz)	24cm 28cm		1m	71 89
41	2018	Mathematical analysis		13.56(MHz)			30cm	60
42	2019		reactance steering network (RSN)	100 (kHz) 13.56 (MHz)	10cm 20cm	15W 10W	2.8cm	80 70
43	2017	differential evolution (DE) algorithm		13.56(MHz)	Tx=64mm Rx=10mm	5V		30
44	2018	mathematical model and Differential Evolution (DE) algorithm		1(MHz)	0.2m	0.46W 0.10W	0.2m 0.3m	0.93 0.67
45	2018	Particle Swarm Optimization (PSO) algorithm		8(MHz)	30cm	4.2 V	14cm	85
46	2016	Simulated Annealing (SA)		1(GHz)	0.04 λ		0.42λ	30
48	2017	fundamental harmonic analysis (FHA)		200(kHz)	22cm	70W		
50	2016	Advanced Design System (ADS) simulator		12Hz	20cm			

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Power System Security Assessment M L Approaches

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Abstract

This paper describes ongoing research and development of machine learning and other complementary automatic learning techniques in a framework adapted to the specific needs of power system security assessment. In the proposed approach, random sampling techniques are considered to screen all relevant power system operating situations, while existing numerical simulation tools are exploited to derive detailed security information. The heart of the framework is provided by machine learning methods used to extract and synthesize security knowledge reformulated in a suitable way for decision making. This consists of transforming the data base of case by case numerical simulations into a power system security knowledge base. The main expected fallouts with respect to existing security assessment methods are computational efficiency, better physical insight into non-linear problems, and management of uncertainties. The paper discusses also the complementary roles of various automatic learning methods in this framework, such as decision tree induction, multilayer perceptron's and nearest neighbor classifiers. Illustrations are taken from two different real large scale power system security problems: transient stability assessment of the Hydro-Québec system and voltage security assessment of the system of Electricité de France.

Keywords: Electric power systems; security assessment; decision tree induction; neural net- works; nearest neighbor.

1 Introduction

Security assessment is a major topic in planning and operation of electric power systems. It consists of evaluating the ability of the power system to face various contingencies and of proposing appropriate remedial actions able to counter its main weaknesses, whenever deemed necessary. Contingencies may be external or internal events (e.g. faults subsequent to lightning vs operator initiated switching sequences) and may consist of small/slow or large/fast disturbances (e.g. random behavior of the demand pattern vs generator or line tripping).

The effect of a contingency on a power system in a given state is usually assessed by numerical (e.g. time-domain) simulation of the corresponding scenario. However, the nonlinear nature of the physical phenomena and the growing complexity of real-life power systems make security assessment a difficult task. For example, the everyday monitoring of a power system calls for fast analysis, sensitivity analysis (which are the salient parameters driving the phenomena, and to which extent?), suggestions to control. On the other hand, increasing economic and environmental pressure make the conflicting aspects of security and economy even more challenging. Overall, the need for methods different from the standard time domain simulation is increasingly felt.

This paper describes ongoing research and development of such methods, using machine learning (and other automatic learning) techniques in a framework adapted to the specific needs of power system security assessment. In the proposed approach, schematically sketched in Fig. 1, random sampling techniques are considered to screen all relevant situations in a given context, while existing numerical simulation tools are exploited - if necessary in parallel - to derive detailed

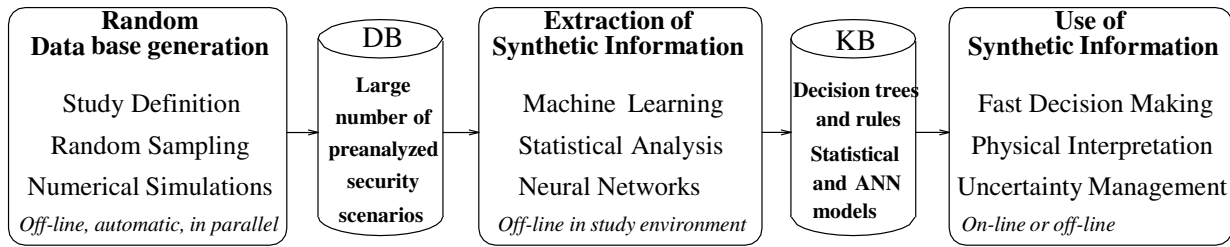


Figure 1: Machine learning framework for security assessment

Security information. The heart of the framework is provided by machine learning methods used to extract and synthesize relevant information and to reformulate it in a suitable way for decision making. This consists of transforming the data base (DB) of case by case numerical simulations into a power system security *knowledge base* (KB). As illustrated in Fig. 1, a large variety of automatic learning methods may be used here in a toolbox fashion, according to the type of information they may exploit and/or produce. The final step consists of using the extracted synthetic information (decision trees, rules, statistical or neural network approximations) either in real-time, for fast and effective decision making, or in the off-line study environment, so as to gain new physical insight and to derive better system and/or operation planning strategies.

How will this automatic learning based framework complement classical system theory oriented methods (relying on analytical power system models, such as numerical simulation) for security assessment? In practice, there are three dimensions along which we expect important fallouts.

First of all *computational efficiency*

By using synthetic information extracted by automatic learning, instead of analytical methods, much higher speed may be reached for real-time decision making. Further, in terms of data requirements, whereas analytical methods require a full description of the system model, the approximate models constructed via automatic learning may be tailored in order to exploit only the significant input parameters. Computational efficiency was actually the motivation of Dy Liacco, when he first envisioned in the late sixties the use of automatic learning (at that time, statistical pattern recognition) for real-time security assessment [1]. Even today, and in spite of the very significant increase in computing powers in the last twenty-five years, this remains a strong motivation.

But the synthetic information extracted by automatic learning methods, may itself be complementary to and generally more powerful than that provided in a case by case fashion by existing analytical methods. In particular, much more attention is paid nowadays to *interpretability* and management of *uncertainties*, the two other important fallouts expected from automatic learning methods.

As concerns *interpretability*, the use of automatic learning to provide physical insight into the nonlinear system behavior was first proposed by Pao et al in the mid-eighties [2]. In the meanwhile, it has been demonstrated that machine learning is indeed an efficient and effective way to generate reliable and interpretable security rules from very large bodies of simulated examples [3, 4], even for as complex systems as are real large-scale power systems. The extracted rules are found to express explicitly problem specific properties, similarly to human expertise, and hence may be easily appraised, criticized and eventually adopted by engineers in charge of security studies. This means that the above framework should also be viewed as an approach to the maintenance and enhancement of utility expertise. The flexibility of the machine learning framework allows one to tailor the resulting information to analysis, sensitivity analysis and control applications.

As concerns management of *uncertainties*, the need to devise a rational way to take decisions whenever there are major uncertainties about the power system state becomes more and more apparent. Today, for example, it is well known that operators are often sorely missing guidance in the context of unusual system states reached after major disturbances, where reliable real-time information is generally lacking. Tomorrow, technological and economic



changes will probably lead to a higher and physically more irrational distribution of decision making and thus to more uncertainties in routine operation and planning activities. Indeed, on the one hand, new devices (e.g. flexible alternating current transmission systems (FACTS)) may cause stronger interactions among remote components of very large interconnections. On the other hand, increased competition among economic actors may further reduce their willingness to share information on their respective subsystems, in spite of the stronger physical interactions. Under such circumstances, approaches able to manage uncertainties, such as the above framework based on automatic learning, will be urgently needed.

Nonetheless and despite repetitive attempts, there are still no large-scale industrial applications of the machine learning framework to power system security assessment. This is mainly due to the fact that until recently, the existing automatic learning methods were not powerful enough while the amount of possible security studies was limited by available simulation hardware and software.

Today, however, all the required conditions are met. Present day computer networks together with fast simulation tools allow the generation of large amounts of detailed studies. At the same time much progress has recently been achieved in automatic learning methods and their application to large-scale power systems was shown to be feasible. Hence, automatic information synthesis tools to assist engineers to compare and interpret the numerous elementary results, and extract and appraise useful synthetic information are at the same time strongly needed and technically feasible.

Therefore, while we expect additional progress in learning methods and application methodologies, we foresee that some important electric power companies e.g. in North America or Europe will soon start using this approach more or less routinely for security studies.

2 Aspects of power system security problems

In this section we provide a guided tour of power system security for the unfamiliar reader. We will first analyze the different types of physical problems, then consider the practical application environments where security is treated, and finally mention briefly the main classes of existing analytical tools for security assessment. In our discussion, we will focus on security problems involving *large* disturbances corresponding to nonlinear system behavior. Although such disturbances are generally very unlikely to happen, their potential consequences can be extremely important and may lead to complete system blackouts, freezing the economic activity of a whole country for many hours.

Classification of operating states

The different operating modes of a power system were defined by Dy Liacco [1]. Figure 2 shows a more detailed description of the “Dy Liacco state diagram”.

Preventive security assessment is concerned with the question whether a system in its normal state is able to withstand every plausible disturbance, and if not, preventive control would consist of moving this system state into a secure operating region. Since predicting future disturbances is difficult, preventive security assessment will essentially aim at balancing the reduction of the *probability* of losing integrity with the economic cost of operation.

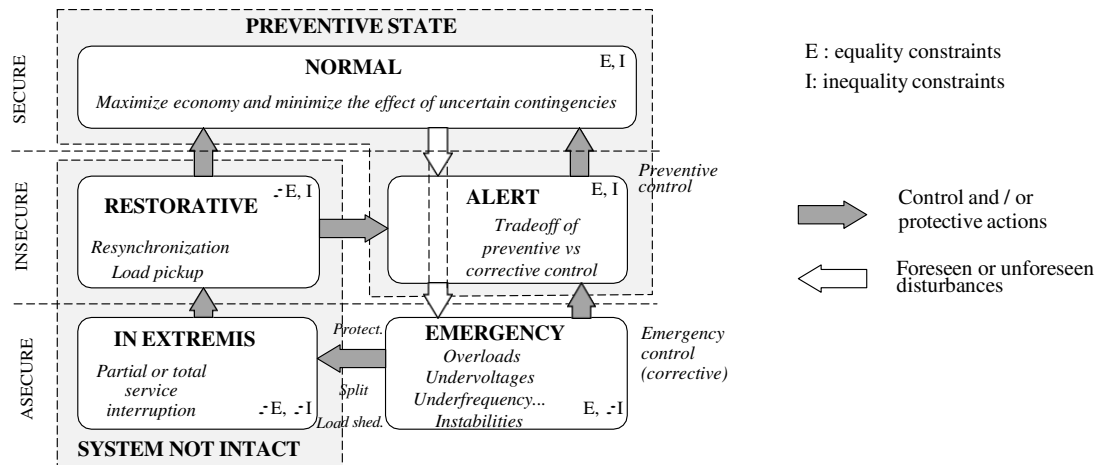


Figure 2: Operating states and transitions. Adapted from [5]

Emergency state detection aims at assessing whether the system is in the process of losing integrity, following an actual disturbance inception. This is a more deterministic evolution, where response time is critical while economic considerations become temporarily secondary. Emergency control aims at taking fast last resort actions, to avoid partial or complete service interruption.

When both preventive and emergency controls have failed to bring system parameters back within their inequality constraints, automatic local protective devices will act so as to preserve power system components operating under unacceptable conditions from undergoing irrevocable damages. This leads to further disturbances, which may result in system splitting and partial or complete blackouts.

Consequently, the system enters the restorative mode, where the task of the operator is to minimize the amount of undelivered energy by resynchronizing lost generation as soon as possible and picking up the disconnected load, in order of priority.

We will confine ourselves to preventive and emergency aspects.

Physical classification of security problems

Various security problems are distinguished according to the time scales of the dynamics, the characteristic symptoms (low voltage, large angular deviations: : :), and the control means (reactive power, switching: : :) to alleviate problems.

Transient stability. Transient stability concerns the ability of the generators of a power system to recover synchronous operation following the electromechanical oscillations caused by a *large* disturbance. In this context, the dynamic performance is a matter of seconds and is mainly affected by switching operations and fast power controls (e.g. fast valving, high voltage direct current converters, FACTS) and voltage support by the automatic voltage regulators of synchronous generators and static var compensators (SVCs). To determine the *degree* of stability we may evaluate the critical clearing time of a fault, which is the maximum time duration it may take to clear the fault without the system losing its ability to maintain synchronism.

Voltage security. The fastest voltage instabilities are characterized by sudden voltage collapse phenomena which may develop at the same or even higher speeds than loss of synchronism. More classical is the *mid-term* voltage instability, which corresponds to a typical time frame of one to



Table 1: Security assessment environments. Adapted from [6]

Environment	Time scales	Typical problems	Operator	Expert
System planning	1 - 10 years	Generation Transmission Protection	No	Yes
Operation planning	1 week - 1 year	Maintenance Unit commitment Protection settings	No	Yes
On-line operation	1 hour - 1 day	Preventive mode Security assessment	Yes	Partly
Real-time monitoring	sec. - min. - hour	Emergency control Protective actions	No	No
Training	months - days	Improve operator skill	Yes	No

Here we distinguish between *real-time*, which considers dynamic situations following a disturbance inception, from merely *on-line* which considers static pre-disturbance situation except for static security corrective control five minutes. In this case voltage collapse is mainly driven by automatic transformer on-load tap changers trying to restore voltage nearby the loads. There is a third, even slower time frame, corresponding to the so-called *long-term* voltage instability, which involves the gradual buildup in load demand. This interacts with classical static security and is well within the scope of operator intervention.

Although a voltage collapse may result in a wide spread degradation of the voltage profile and subsequent loss of synchronism, it is normally initiated by a *local* deficiency in reactive power reserves and/or a reduced reactive power transmission capability into a given load area. The distance to voltage insecurity may be evaluated by a load power margin which is the maximum additional amount of power which may be transferred safely from the generation to a given load area.

Static security

It concerns essentially thermal overload problems of generation transmission system components, where phenomena span over significantly longer periods of time. For example, line overloads may be tolerated during 30 to 60 minutes under favorable weather conditions.

Practical application domains

Table 1 shows the practical study contexts or environments which may be distinguished in security assessment applications. The first column identifies the study context; the second specifies how long in advance (with respect to real-time) studies may be carried out; the third column indicates the type of subproblems that are generally considered in a given environment; the last two columns indicate respectively if an operator is involved in the decision making procedure and if an expert in the field of power system security is available.

In the first three contexts one currently relies mostly on the intervention of human experts exploiting the numerical simulation tools. In real-time monitoring and emergency control, the reduced time available calls for more automatic procedures.

System planning. Multitudinous system configurations must be screened for several load patterns, and for each one a large number of contingencies. An order of magnitude of 100,000 different scenarios per study would be realistic for a medium sized system. While enough time may be available to carry out so many security simulations, there is still room for improved data analysis methods to exploit their results more effectively for the identification of structural



system weaknesses and to provide guidelines to improve reliability.

Operation planning. As suggested in Table 1, operation planning concerns a broad range of problems, including maintenance scheduling (one year to one month ahead), design of operating strategies for usual and abnormal situations, and setting of protection delays and thresholds. The number of combinations of situations which must be considered for maintenance scheduling is also generally very large, and automatic learning approaches would equally be useful to make better use of the available information and to exploit the system more economically.

Similarly, for the closer to real-time determination of operating security criteria, machine learning is particularly well adapted. It would allow engineers to screen more systematically representative samples of situations, in order to identify critical operating parameters and determine their security limit tables needed for on-line operation. This would actually consist of automating and enhancing such manual approaches presently in use at many utilities.

On-line operation. In the context of this framework, it would consist of exploiting on-line the security knowledge bases set up off-line, e.g. in operation planning. Appropriate strategies are required in order to update this information when major changes happen in the system. For example, several weeks ahead routine security criteria could be designed for a forecast range of topologies, load levels and generation schedules, while, closer to real-time, maybe a day or some hours ahead, these criteria might then be refreshed to handle previously unexpected situations. In order to be compatible with the way operators usually appraise their system, it is particularly important for the synthetic information extracted by automatic learning to be as simple as possible to interpret.

Real-time monitoring. Here, the purpose is to design criteria to trigger more or less automatically emergency control actions, so as to prevent a disturbed system state to evolve towards blackout. An important aspect is the use of appropriate models¹ to reflect the *disturbed* power system behavior, when designing the security criteria. Furthermore, the use of readily available system *measurements* as inputs to the derived emergency control rules is often an operational constraint in addition to minimal data requirements and ultra high speed.

Training. During operator training, the security criteria derived in either of the preceding contexts might be usefully exploited as guidelines, provided that they are presented in an intelligible way. In addition, these models might be used internally in a training simulator software,.

Analytical tools

A rather large set of numerical methods are available for security assessment in the different timeframes mentioned. We call them *analytical* tools since they exploit analytical power system models in contrast to the *synthetic* ones extracted by automatic learning techniques. Some of them are based on general purpose power system dynamic simulation packages and have a very broad scope. Others are based on simplified models or approaches representing only those features which are relevant for the particular study. The latter methods may be significantly more efficient, although at the expense of being restricted to some particular physical phenomena and/or some particular (types of) power systems. We briefly discuss them since they provide the raw input data exploited by the automatic learning methods in order to synthesize the high level security information.

Transient stability

There are two main classes of analytical tools for transient stability assessment : time-domain (or step-by-step) simulation approach and direct methods, based on the second Lyapunov method.

Time-domain simulation. The general power system dynamic model is composed of mixed algebraic and differential equations strongly nonlinear, involving typically a few thousand discrete or continuous time state variables. To assess transient stability, the time-domain approach consists of simulating the during and post-fault behavior of the system for a given disturbance, and observing its electromechanical angular and voltage swings during a few seconds. Practical criteria vary from one utility to another, but an unacceptable performance would generally imply too large or undamped angular deviations (e.g. pole slips) or excessively large variations of voltage or frequency. To obtain stability margins, repetitive simulations must be carried out for various pre-fault operating states or for various



assumptions concerning the delays of protection devices. While this approach is still considered as very CPU intensive, we observe that within the last three years the time required for a typical power system simulation with high order models has shrunk from one hour to some minutes.

Direct Lyapunov type methods. They aim at identifying when the system leaves its stability domain without further integration of the system trajectory. By avoiding the simulation of the post-fault trajectory, they reduce the simulated time period to a fraction of a second instead of theseveral seconds of time-domain methods. Some of them are thus able to provide a rich stability assessment (margins, sensitivities, mode of instability) within a fraction of the time required for asingle time-domain simulation. A major drawback is their difficulty to exploit accurately models of generators and control loops as well as nonlinear or dynamic loads. However, since the first multimachine direct methods developed in the late sixties much progress has been achieved in incorporating more realistic models.

Voltage stability and security

Tools for voltage security assessment range from static load-flow calculations to full short- term / mid-term time domain simulations. It is worth mentioning that due to the rather recent emergence of voltage security problems, modeling practices have not yet reached maturity comparable to those used in transient stability studies. In particular, one intrinsic difficulty of analyzing voltage collapse phenomena is the very strong dependence on load behavior, for which good models are generally missing.

Short-term / mid-term dynamic simulations. Since voltage collapse phenomena may involve time constants ranging from a fraction of a second to a few minutes, a variable step-size numerical integration method with stiff system simulation capability is preferable for the sake of efficiency and accuracy, in contrast to transient stability where fixed step-size methods have been widely used.

Simplified simulations. Since many voltage security problems are essentially driven by automatic on-load tap changer mechanisms, it is possible to neglect sometimes the faster interactions among load and generation dynamics. The differential equations corresponding to the faster phenomena are then replaced by equilibrium equations and only the slower dynamics are modeled. With the intrinsic limitation of neglecting problems caused by the fast dynamics, this kind of approach allows drastic reduction in computing times.

Post-contingency load-flow. A further simplification consists of neglecting totally the dynamics, and using only purely static post-contingency load-flow calculations. Typically, this allows one to compute maximal loading limits, based on successive computations or even on direct optimization.

3 Aspects of automatic learning

In this section we introduce classes of potentially useful automatic learning methods for the synthesis of security assessment information. We first give a definition of the generic *supervised* learning problem and introduce three important classes of algorithms for this problem, and finish with some comments on the use of *unsupervised* learning methods.

Supervised learning problem

The generic problem of supervised learning from examples can be formulated as follows :

Given a learning set of examples of associated input/output pairs, derive a general model for the underlying input/output relationship, which may be used to explain the observed pairs and/or predict output values for any new unseen input.



In the context of security assessment, an example corresponds to a given operating situation. The input attributes would be (hopefully) relevant parameters describing its electrical state and topology and the output could be information concerning its security, in the form of either a discrete classification (e.g. secure / marginal / insecure) or a numerical value derived from security margins.

In general, the solution of this overall learning problem is decomposed into several subtasks.

Representation consists of (i) choosing appropriate input attributes to represent the power system state, (ii) defining the output security information, and (iii) choosing a class of models suitable to represent input/output relations.

The *representation problem* is left to the engineer. A compromise has to be found between the use of very elementary standard operating parameters and more or less sophisticated compound features. Below we discuss how unsupervised learning techniques may help to choose appropriate input attributes.

Feature selection aims at reducing the dimensionality of the input space by dismissing attributes which do not carry useful information to predict the considered security information. This allows one to exploit the more or less local nature of many security problems.

Model selection (or learning per se) will typically identify in the predefined class of models the one which best fits the learning states. This generally requires choice of model structure and parameters, using an appropriate search technique.

The distinction between *feature selection* and *model selection* is somewhat arbitrary, and some of the methods actually solve these two problems simultaneously rather than successively.

Interpretation and validation are very important in order to understand the physical meaning of the synthesized model and to determine its range of validity. It consists of testing the model on a set of unseen test examples and comparing its information with prior expertise about the security problem.

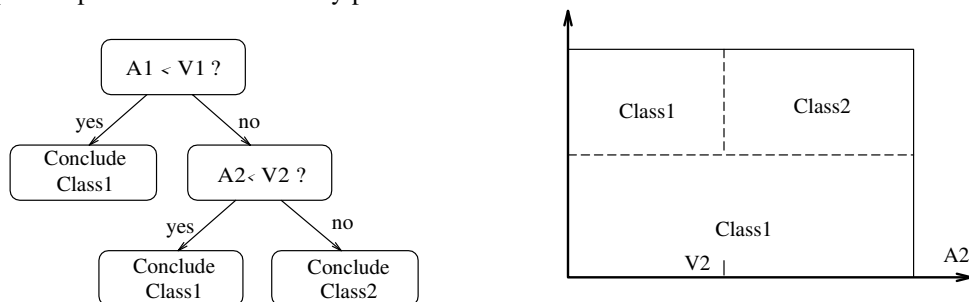


Figure 3: Hypothetical decision tree and its corresponding input space decomposition

From the interpretation and validation point of view, some supervised learning methods provide rather black-box information, difficult to interpret, while some others provide explicit and very transparent models, easy to compare with prior knowledge.

Model use consists of applying the model to predict security of new situations on the basis of the values assumed by the input parameters, and if necessary to “invert” the model in order to provide information on how to modify input parameters so as to achieve a security enhancement goal.

As far as the *use* of the model for fast decision making is concerned, we notice that there are speed variations of several orders of magnitude between various techniques, but most of the methods are sufficiently fast in the context of control center oriented power system security analysis

Supervised learning methods [7]

In what follows, we consider only non-parametric automatic learning methods. Parametric methods may be useful in



some particular circumstances, but are not powerful enough to treat the wide variety of practical security problems. We will discuss three classes of methods providing three *complementary* types of information. Although we have selected them from three different paradigms (machine learning, neural nets, pattern recognition) we insist on the type of information provided rather than on the paradigm itself.

Symbolic knowledge via machine learning

Machine learning is the subfield of artificial intelligence concerned with the design of automatic procedures able to learn from examples. *Concept learning from examples* denotes the process of deriving a logical description of the necessary and sufficient conditions corresponding to a class of objects, i.e. a *rule* in some given representation language. A major concern is to find out adequate compromises between rule *complexity* and data fit, so as to avoid over-fitting and to privilege interpretability.

Top down induction of decision trees (TDIDT) is one of the most successful classes of such methods which was popularized by Quinlan [8]. Figure 3 shows a hypothetical binary decision tree (DT) :to infer the output information corresponding to given input attribute values, one traverses the tree, starting at the top-node, and applying sequentially the dichotomous tests encountered to select the appropriate successor. When a terminal node is reached, the output information stored there is retrieved.

As suggested by the acronym, TDIDT approaches the decision tree learning in a divide and conquer fashion, whereby a decision tree is progressively built up, starting with the top-node and ending up with the terminal nodes. At each step, a tip-node of the growing tree is considered and the algorithm decides whether it will be a terminal node or should be further developed. To develop a node, an appropriate attribute is first identified, together with a dichotomy on its values. The subset of its learning examples corresponding to the node is then split according to this dichotomy into two subsets corresponding to the successors of the current node. The terminal nodes are “decorated” with appropriate information on the output values derived from their learning examples, e.g. the majority class label or probabilities, or expected value and standard deviation of numerical output information.

The right part of Fig. 3 shows how the decision tree in its left decomposes its input space into *non-overlapping* subregions. The number of such regions should ideally be as small as possible and at the same time the states contained by each region should belong to a same class. Thus, to build good decision trees, an algorithm must rely on appropriate *optimal splitting* and *stop splitting* rules. Optimal splitting has to do with selecting a dichotomy at a test node so as to provide a maximum amount of information on the output value (i.e. separate states of different classes) whereas stop splitting has to identify situations where further splitting would either be useless or lead to performance degradation, due to over-fitting.

Decision trees have been quite extensively studied in the context of various security assessment problems [6]. A main asset lies in the explicit and logical representation of the induced classification rules and the resulting unique explanatory capability. In particular, the method provides systematic correlation analyses among different attributes and identifies the most discriminating attributes at each tree node. From the computational viewpoint it is efficient at the learning stage as well as at the prediction stage.

There are two generalizations of decision trees of interest in the context of security assessment. First, *regression* trees which infer information about a numerical output variable; they are illustrated below. Second, *fuzzy* trees which use fuzzy logic instead of standard logic to represent output information in a smooth fashion. Both approaches allow us to infer information about security margins, similarly to the techniques discussed below. Fuzzy trees have not yet reached the maturity of crisp classification or regression trees, but they seem particularly well suited to our types of problems. Indeed, they appear to be more robust with respect to noise than classical machine learning methods and are able to combine smooth input/output approximation capabilities of neural networks with interpretability features of symbolic machine learning [9].



Smooth nonlinear approximations via artificial neural networks

The field of artificial neural networks has grown since the early work on perceptrons to an important and productive research field. We restrict ourselves to multilayer perceptrons; for further information, a widely recommended theoretical introduction to neural networks is given in [10].

The single-layer perceptron, is basically a simple linear threshold unit together with an error correcting learning algorithm. It is able to represent a linear boundary in its input space. Its limited representation capabilities have motivated the consideration of more complex models composed of multiple interconnected layers of perceptrons, MLPs for short. Figure 4 illustrates the classical feed-forward MLP. The first or *input* layer corresponds to the attribute values, and the last or *output* layer to the desired security classification or margin information. Intermediate layers enable the network to approximate arbitrarily complex input/output mappings, provided that its topology and its weights are chosen appropriately.

The discovery of the back-propagation algorithm has been central to the success of MLPs. It allows one to compute efficiently and locally the gradient of the output error of the network with respect to its weights and thresholds. It may be exploited iteratively in order to adjust the weights so as to reduce the total mean square output error for learning examples. In recent years, much progress has been made in improving efficiency of optimization techniques for the learning procedures of MLPs, but the MLPs are still very slow at the learning stage, which may prevent extensive experimentations for data base sizes typical of security assessment of realistic power systems.

Similarly to decision trees, an interesting property of MLPs is their ability to achieve feature extraction and learning in a single step : the weights connecting the input layer with the first hidden layer may be interpreted as projecting the input vector in some particular directions, realizing a linear transformation of the input space, which is used in subsequent layers to approximate outputs. However, one of the difficulties with MLPs comes from the very high number of weights and thresholds related in a nonlinear fashion, which makes it almost impossible to give any insight into the relationship learned. All in all, one can say that MLPs offer a flexible, easy to apply, but essentially black-box type of approach to function approximation.

It should be observed that a bunch of similar methods exist nowadays, such as radial basis functions and projection pursuit regression techniques. They offer the possibility of translating the case by case information provided in the learning sets into an approximate but closed form numerical model. The latter one may be used for fast assessment of unseen situations and direct computation of sensitivities.

Memory based reasoning via statistical pattern recognition [11]

The previous two approaches essentially compress detailed information about individual simulation results into general, more or less global security characterizations.

Additional information may however be provided in a case by case fashion, by matching an unseen (e.g. real-time) situation with similar situations found in the data base. This may be achieved by defining generalized distances so as to evaluate similarities among power system a

4 Application of automatic learning to power system security

Below we will first describe a hypothetical application of the automatic learning based framework to a hypothetical security problem. Then we will provide a short overview of some real-life applications to large-scale security problems.

A hypothetical illustration of the framework

A security problem

Let us imagine that our hypothetical power system is voltage security limited in some reactive power weak area, and let us suppose this security problem was discovered in a preliminary screening security study, where also the possibly



constraining disturbances were identified.

Then, a practical problem would be the characterization of security regions with respect to these disturbances, so as to provide operators with preventive security assessment criteria and effective preventive control means to alleviate potential insecurities, such as optimal rescheduling of available reactive power resources.

Another, different problem would be the design of emergency state indicators to be applied in case of a disturbance, ideally highly anticipative and reliable at the same time while providing information on appropriate emergency control means, such as on-load tap changer blocking and load shedding.

How could we generate a data base ?

In order to provide a representative sample of voltage security scenarios for the above problems, we would first ask for the advice of planning and operation planning engineers and operators of that system, so as to gather information about known system weaknesses and operating practices.

From this information, data base building software would then be designed in order to generate randomized samples representative of normal operating conditions, including also a sufficient number of unusual situations, deemed relevant for security characterization. In particular, with respect to real-life operating statistics, this sample would typically be biased towards the insecure regions of the state space.

According to that sampling procedure, an initial data base would be generated, typically comprising several thousand states and the security of each state would be pre-analyzed with respect to the studied disturbances. For example, post-contingency load power margins could be computed for real large-scale power system models on existing computer networks within some hours of response time, by using an efficient simulation software and exploiting trivial parallelism. In addition to this information, appropriate preventive or emergency control information could be pre-determined for the insecure states and secure economic generation dispatch for the secure ones.

Further, a certain number of attributes would be computed, which would be proposed as input variables to formulate security criteria. In the preventive mode security assessment problem, these attributes would typically be *contingency-independent* pre-fault operating parameters, such as voltages, reactive power generation and compensation reserves, power flows, topology indicators. For the emergency state detection problem, we would rather use raw system measurements (e.g. voltage magnitudes, power flows, transformer ratios, breaker status) of the intermediate *just after disturbance* state. In contrast to the preventive mode attributes, the emergency state attributes would depend on the disturbance and on the short-term system modeling, in addition to the pre-fault operating state.

When designing the data base generation software, care must be taken so as to appropriately take into account various kind of uncertainties. For example, random noise terms should be added to the attribute values so as to model measurement or state estimation errors and delays. Further, static and dynamic power system model parameters are often uncertain (load distribution and sensitivity to voltage, external systems, parameter variations with temperature : :) and should thus be accordingly randomized.

Unsupervised learning for data pre-processing

In practical security problems, many different attributes often turn out to provide equivalent information, due to the very strong physical correlations among geographically close components of a power system. Thus, clustering methods may be used to define a small set of representative attributes from a larger number of elementary variables.

To fix ideas, let us consider the case of voltage magnitudes. Correlation coefficients among any pair of bus voltages may be easily computed on the basis of the data base statistical sample. They may then be used as similarity measures by a clustering algorithm searching for a reduced number of voltage “coherent” regions. For each region an equivalent (e.g. mean) voltage would be used as an attribute instead of individual bus voltages, and the computational burden of the subsequent supervised learning of security criteria would be reduced, while robustness and interpretability would be improved. For example, two-dimensional Kohonen feature maps may be exploited in order to visualize the



relationships among voltage regions and compare them easily with the geographic location of busbars in the power system.

In addition to the above “feature extraction” application, clustering techniques have also been proposed in a more conventional way, to identify groups of similar power system operating states. One possible purpose is to partition a very large data base into smaller subsets for which the security assessment problem could be easier to solve. Another interesting application would be to “condense” the full data base into a reduced number of representative prototypes, thereby decreasing the number of required security simulations and shortening the associated computation delays.

Supervised learning of security criteria

Given a data base composed of examples, for which security margins have been determined for several contingencies and a number of candidate attributes have been computed, supervised learning would proceed so as to derive appropriate security criteria. First of all however, the data base would be partitioned into disjoint learning and test samples. The learning sample will be used to build the synthetic security criteria, whereas the test set will be used to assess their reliability by comparing the security information predicted by them and the “real” one determined by simulation. In addition to the unseen test states generated automatically together with the learning states, a test sample representative of *actual* operating statistics should be collected from historical on-line records.

What can decision trees do ? We need first to define security classes by appropriate thresholds on the security margin. Then, the decision tree building includes (i) the automatic identification of the subset of attributes among the candidate ones relevant for the prediction of the security class (say ten to twenty among one or two hundred), and (ii) the definition of appropriate threshold values for these attributes so as to provide an approximate model of the voltage security region of the studied area of the power system. In addition to a global DT covering all disturbances simultaneously, single-contingency DTs may also be constructed to provide more specific information and additional insight. Further, various DTs may be constructed for various security margin threshold values, so as to discriminate between marginally secure and very secure situations. Depending upon whether normal pre-disturbance or just after disturbance attribute values are used, the DTs can be used either in a preventive or in an emergency wise approach.

If there are too many non-detections of insecure states, the threshold value used to define the secure class in terms of the security margin may be increased before rebuilding a tree. If there are too many false alarms, additional candidate attributes or learning states should be used.

What can neural networks add ? In addition to the simplified view on security, provided by the DTs in terms of a discrete model relating a small number of security classes and thresholds on attribute values, one is generally interested in providing a continuous security margin, at least in the neighborhood of the threshold values used to define security classes.

As we have mentioned, one of the strong points of the MLP is its nonlinear modeling capability. On the other hand, the decision tree identifies the attributes in strong correlation with the security class. Thus, in a hybrid approach we may use the latter attributes as input variables to a MLP model, while using a normalized security margin as output information.

In practice it may be necessary to proceed by trial and error to determine an appropriate number of hidden neurons and topology for the MLP structure. Once its structure and weights have been adapted on the basis of the learning states, the MLP provides a closed-form and differentiable security approximate, which may be used for fast margin prediction for any seen or unseen state and as well to compute margin sensitivities to attribute values.

Practical experiments reported below with various security problems have shown that this leads to richer and more reliable security assessment information.

What do distance based methods offer? With the previous two approaches, we have essentially compressed detailed information about individual simulation results into general, more or less global security characterizations. This allows us to provide the required physical understanding, thanks to the data analysis component of decision trees and attribute clustering techniques. In addition, the derived models may be used efficiently for on-line security analysis.



In this latter context, further information may be obtained via memory based reasoning exploiting appropriate distances to find the most similar pre-analyzed situations to the real-time state. Once identified, these may be used in multitudinous ways. For example, their distance to the current state would provide a measure of confidence of the security information provided by any model derived from the data base (DT and/or MLP). If the latter were too large, it would then be concluded that for the current state no reliable security information may be derived from the data base. If the nearest neighbors were on the contrary sufficiently close to the current state, then various kinds of detailed and specific security information may be extrapolated from these states to the current situation and shown to the operator, including detailed contingency analysis and preventive and/or emergency controls.

Overview of some real-life applications

Below we provide more specific information about feasibility studies of the automatic learning approach, made for some real practical power system security problems.

Transient stability

A first large-scale feasibility study was initiated in early 1990, for preventive transient stability assessment of an important generation plant within the large-scale EHV system of Electricite´ de France (EDF) [13].

A more recent study was carried out on the Hydro-Québec system which is illustrated in Fig. 5. Its normal operating condition is considered secure if it withstands any permanent single-phase to ground fault, followed by line tripping, fast re-closure and subsequent permanent tripping. It is notable that this system is mainly constrained by its transient stability limits, due to the very large power flows and long transmission distances.

More specifically, in our investigations we have considered only faults occurring within the James' Bay transmission corridor in the Western part of the system. With respect to such faults, the stability is mainly influenced by the power flows and topology within the same corridor. A set of transient stability limits have previously been developed, in a manual approach, where operation planning engineers have determined off-line, on the basis of carefully chosen simulation scenarios, a set of approximate limit tables relating the system topology and power flows to a Stable/Unstable classification. These limit tables have been implemented on the real-time computer of Hydro- Québec, via an ad hoc data base tool called LIMSEL, presently in use for operation. The purpose of our investigation was to evaluate the capability of the automatic learning approach to provide a more systematic and potentially more efficient methodology to derive these operating guidelines.

A data base, composed of 12,500 normal operating states was generated via random sampling and chained load flow computations; it comprises more than 300 different combinations of up to 6 line outages, and about 700 different combinations of reactive voltage support equipment in operation, and a wide variety of power flow distributions. The dashed lines in Fig. 5 show the variable topology part of the 735kV system. For each state, the corresponding classification Stable/Unstable was obtained from LIMSEL, running on the backup on-line computer, resulting in 3,939 stable states and 8,561 unstable ones, among which 393 are marginally and 8,168 fairly unstable.

To describe the operating states, and in order to characterize their stability, the following types of

Clustering and unsupervised learning

In contrast to supervised learning, where the objective is clearly defined in terms of modeling the underlying correlations between some input variables and some particular output variables, unsupervised learning methods are not oriented towards a particular prediction task. Rather, they try to identify existing underlying relationships among a set of objects characterized by a set of variables or among a set of variables used to characterize a set of objects.

Thus, one of the purposes of clustering is to identify homogeneous groups of similar objects, in order to represent a large set of objects by a small number of representative *prototypes*. Graphical, two-dimensional scatter plots may be used as a tool in order to analyze the data and identify clusters. Another application of the same techniques is to identify similarities (and redundancies) among the different attributes used to characterize objects. In the context of power



system security both applications may be useful as complementary data analysis and preprocessing tools.

Unsupervised learning algorithms have been proposed under the three umbrellas given above to classify classification methods, termed *cluster analysis* in the statistics literature, *conceptual clustering* in the machine learning community, and *self-organizing maps or vector quantization* in the neural net community [12].

Indicate attributes were computed: active power flows through important lines and cut-sets in the James' Bay corridor; total active power generated in the 4 La Grande (LG) power plants and various combinations; number of SVCs in operation within the six substations in the James' Bay corridor; logical indicators (in/out) for important lines. This set, composed of 67 candidate attributes was determined with the help of an expert in charge of transient stability studies at Hydro-Québec. From previous studies it was already known that the total power flow through the corridor would be an important attribute, together with the topological information and the total number of SVCs.

The tree partially represented in the right hand part of Fig. 5 was built on the basis of the first 10,000 states² of the data base and 87 candidate attributes, including in addition to the above 67 ones four linear combination attributes and some other combined ones. Fig. 5 shows its most important parts nearby the top-node. The notation used for a typical node is also represented at the top left hand side of the tree: each node is represented by a box, the upper part of which corresponds to the proportions of stable and unstable *learning* states relative to this node. Test nodes are identified by the label "Ti" or "STi", the latter corresponding to subtrees which have not been drawn on the picture. Terminal nodes are identified by a label "Li" for leafs and "Di" for deadends. A leaf is a terminal node with a sufficiently class pure learning subset (in the algorithm used this is expressed in terms of an *entropy* measure) whereas a deadend is a node which corresponds to a subtree pruned to avoid over-fitting. In addition to the label indicating the type of a node, the number of learning states of the node is indicated next to it. above which a state is unconditionally declared unstable for at least one line-fault in the corridor.

To evaluate its generalization capability, the tree was tested on the basis of an independent test set comprising the 2,500 states of the data base not used for its building, yielding an overall error rate of 4.3% (the proportion of erroneous classifications of test states of each subtree are depicted in the lower part of each node-box in Fig. 5). Out of the 1,622 fairly unstable states, only 30 are classified as stable yielding 1.85% "dangerous" errors. On the other hand, 23 marginally unstable states are classified stable, leading to small non-detection errors. There are also 52 false alarms, i.e. stable test states classified unstable by the tree.

To improve accuracy, the same data base was further exploited by building a multilayer perceptron (with a single hidden layer of 20 neurons) on the basis of the same 10,000 learning states, leading to a reduced test set error rate of 2.4%.

In terms of computational requirements we mention the following CPU times determined on a SUN Sparc10 workstation : about 1 week for the data base generation, 1 hour for the decision tree building and 1 second for testing; and 60 hours for the learning of the MLP weights and 10 seconds for testing.

Further investigations were made, concerning the data base decomposition into various topology classes for which simpler and more interpretable trees were obtained. These and other recent research results, e.g. concerning a nearest neighbor technique optimized using genetic algorithms, are described in [14].

Voltage security

A second rather extensive feasibility study was carried out for voltage security, on a test problem concerning the Brittany region of the EDF system. Both preventive security assessment and emergency state detection were considered [4, 15]. Figure 6 depicts in its left part the one-line diagram of the related part of the EDF system. Its subregions correspond to voltage coherent load areas, determined with respect to behavior of HV voltage magnitudes just after the loss of a generator in Plant No. 1. These regions were automatically determined in a preliminary study by non-supervised learning using a Kohonen feature map [16].

The independent variables used during the random sampling of the pre-disturbance states concerned the following: topology (single or double line or transformer outages); regional load level, unit commitment and generation dispatch;



reactive support by synchronous condensers and gas turbines. To account for uncertainties the following quantities were also randomized : secondary voltage control set-points; individual HV load distribution and power factors; MV shunt compensation; voltage sensitivities of the active and reactive load powers.

A total of 13,513 random variants were drawn to yield 5000 pre-disturbance states. (The remaining 8,513 variants led to power flow computation divergence or non-convergence.) For each state about 200 attributes were computed, corresponding to key variables such as topological indicators, important EHV power flows, 400kV voltages, numbers of units in operation in power plants, total load demand, reactive shunt compensation reserves in the study region, and reactive generation

All in all 26 different contingencies were considered in this broad study, corresponding to synchronous condenser, generator or line tripping and busbar faults. The electrical static and dynamic models, the voltage security criterion and the load power margin computation procedure used are described in [15]. The severity of a disturbance was determined by the difference between pre- and post-disturbance load power margins in the Brittany region. Thus, in addition to the pre-disturbance margin, the corresponding 26 post-disturbance margins were computed for each operating state, yielding a total number of 135,000 load power margin computations. Overall, the data base generation required about one month of CPU time on a SUN Sparc10 workstation.

Several tens of multilayer perceptron's and even more decision and/or regression trees were built, for different disturbances and both preventive security assessment and emergency state detection. In addition, various nearest neighbor classifiers were also tried out. For illustration, we will comment briefly on the regression tree depicted in the right part of Fig. 6, built to estimate the severity of the loss of Circuit No. 1 of an important 400kV line (see the one-line diagram in Fig. 6). Each node of the tree is represented by a box containing a graphical representation of the distribution of values of the contingency severity in the learning set at this node, together with its sample mean value and standard deviation, and the number of its learning states: at the top-node, $N = 2775$ corresponds to the total number of learning states used to build the tree.

Once the tree has been constructed, it may be used to estimate the contingency severity of an unknown state: to this end, we direct the state from the top-node to the appropriate successor according to its reactive reserve and further to a terminal node according to the status of Circuit 2. There, the severity is estimated by the mean severity of the corresponding learning states.

This very simple tree provides actually a very accurate estimate of the severity of the disturbance. Admittedly, it might be further improved by further developing some of its terminal nodes using other attributes carrying complementary information. Applying it to a representative independent test sample, the difference between this estimate and the "actual" pre-computed severity yields an overall mean error of -0.5MW and standard deviation of 43.6MW, which is indeed almost negligible if compared to the overall load level of the study region which varies between 5,000MW and 7,700MW.

Conclusions

In this paper we have attempted to survey state of the art and future potentials of *machine learning approaches for power system security assessment*.

We have described the high diversity of power system security problems so as to justify the combined use of machine learning and other statistical and neural network based automatic learning methods, in a tool box fashion. To provide insight into the possible complementary uses of these various methods, we have put the emphasis on illustrations and discussions, rather than on theoretical presentations. To render credible machine learning approaches to power system security, we have reported a small subset of results obtained with two different real-life problems.

One of the messages we would like to convey is that to make automatic learning methods really successful it is important to include the human expert in the process of deriving security information. For example, to guide the security studies it is necessary to exploit his prior expertise and then to allow him to criticize, assimilate and accept the new



information. The results must therefore be provided in a form compatible with his own way of thinking. In the general class of automatic learning approaches, machine learning is presently the only one able to meet this requirement; it is therefore a key element of the tool box.

Clearly, machine learning as well as other learning methods can produce interesting security information only when they exploit representative data bases. To obtain them, the initial investment is quite important for each new security problem, but the subsequent data base generations take full advantage of the previous ones. To further enhance the approach, powerful parallel simulation environments could be developed to enable a transparent allocation of simulations on virtual machines composed of the large numbers of elementary workstations available through local or wide area networks, and not fully exploited today.

After eight years of research, we deem that automatic learning methods are indeed able to provide interesting security information for various physical problems and practical contexts. Actually, in their philosophy they are quite similar to existing practices in power system security studies, where limits are derived from simulations, though in a manual fashion. But automatic learning approaches are more systematic, easier to handle and master, in short more reliable and powerful.

These possibilities open up new perspectives to power system engineers to respond to the challenge of planning and operating future power systems with an acceptable level of security, in spite of growing complexity and level of uncertainties (e.g. due to the de-regulation of transmission systems and faster technological changes) and increasing economic and environmental pressures.

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Fundamentals of Systems Ergonomics/Human Factors

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I – INTRODUCTION

Systems Ergonomics/Human Factors is a field that encompasses a wide range of disciplines, including psychology, engineering, industrial design, and occupational health and safety. It is concerned with designing systems and products that are compatible with the capabilities and limitations of humans, with the goal of optimizing performance, safety, and well-being. The fundamentals of systems ergonomics/human factors involve understanding the various factors that influence human performance and well-being, such as cognitive and physical abilities, perception, attention, and motivation. By taking these factors into consideration, designers and engineers can create systems and products that are intuitive, easy to use, and minimize the risk of errors and accidents. This research paper will provide an overview of the key concepts and principles of systems ergonomics/human factors, including user-centered design, task analysis, human-computer interaction, workload management, error management, human reliability, and environmental design. It will also explore the history and development of the field and its importance in various industries, such as healthcare, aviation, and manufacturing. Ultimately, this paper aims to highlight the essential role that systems ergonomics/human factors play in the design and development of safe and effective systems and products and to provide a foundation for further exploration and research in this field.

II - OVERVIEW OF SYSTEMS ERGONOMICS/HUMAN FACTORS

Definition of Systems Ergonomics/Human Factors: Systems Ergonomics/Human Factors is an interdisciplinary field that aims to optimize the relationship between humans and their environment, including workspaces, equipment, and technology. It involves the study of human abilities and limitations and the design, development, and evaluation of systems and products that are compatible with human capabilities and limitations.

History and Development of the Field: The origins of Systems Ergonomics/Human Factors can be traced back to World War II, when military psychologists and engineers collaborated to improve the safety and efficiency of military systems. After the war, this collaboration continued in the aviation and automotive industries, and the field of ergonomics was born.

Over time, the field evolved to include a broader range of disciplines and applications, including healthcare, technology, and product design. Today, Systems Ergonomics/Human Factors is a critical aspect of many industries, as the safety and well-being of workers and consumers depend on the careful consideration of human factors in the design and development of systems and products.

Key Concepts and Principles: Systems Ergonomics/Human Factors is based on several key concepts and principles, including:

- **User-Centered Design:** This involves designing systems and products that are intuitive, easy to use, and meet the needs and preferences of users.
- **Task Analysis:** This involves analyzing the tasks that users perform and identifying the cognitive and physical demands of those tasks, to ensure that systems and products are compatible with human capabilities and limitations.
- **Human-Computer Interaction (HCI):** This involves designing user interfaces that are efficient, effective, and user-friendly, to minimize errors and enhance productivity.
- **Workload Management:** This involves managing the demands placed on users to ensure that they can perform their tasks safely and effectively, without becoming overwhelmed or fatigued.
- **Error Management:** This involves designing systems and products that minimize the risk of errors and accidents, and developing strategies to prevent and mitigate errors when they do occur.



- **Human Reliability:** This involves optimizing human performance and reducing errors by improving training, communication, and decision-making.
- **Environmental Design:** This involves designing workspaces and equipment that are comfortable, safe, and promote well-being.

These concepts and principles are essential to the design and development of safe and effective systems and products and are the foundation of Systems Ergonomics/Human Factors.

III- USER-CENTERED DESIGN

User-Centered Design is an approach to design that places the needs, preferences, and abilities of users at the centre of the design process. The goal of user-centered design is to create products and systems that are intuitive, easy to use, and meet the needs of users, ultimately leading to increased satisfaction, productivity, and safety.

Importance of User-Centered Design: User-Centered Design is essential because it recognizes that the end-users are the ultimate judges of a product's success or failure. By involving users in the design process, designers can gain insights into how users interact with products and systems and can design with these insights in mind. This approach helps to create products and systems that are more efficient, effective, and user-friendly, resulting in increased productivity, safety, and satisfaction.

Methods for Involving Users in the Design Process:

There are several methods for involving users in the design process, including:

User Research: This involves conducting research with users to understand their needs, preferences, and behaviors.

Surveys and Interviews: These methods involve gathering feedback from users about their experiences with existing products and systems, as well as their needs and preferences for future products and systems.

Usability Testing: This involves testing prototypes or early versions of products with users to identify usability issues and gather feedback for improvement.

Participatory Design: This involves involving users in the design process, allowing them to provide input and feedback throughout the design process.

Examples of Successful User-Centered Design:

One example of successful user-centered design is the iPhone, which was designed with a focus on simplicity, ease of use, and intuitive interfaces. Apple conducted extensive user research and usability testing to identify user needs and preferences and incorporated this feedback into the design of the iPhone.

IV. Task Analysis in systems ergonomics/human factors:

Definition and Importance of Task Analysis: Task analysis is the process of identifying and breaking down tasks performed by individuals or groups to understand how they interact with the system or environment. It involves examining how people perform tasks, identifying the specific actions involved, and the cognitive processes required to complete the task. This information is then used to design systems, tools, and processes that optimize human performance and reduce the risk of errors or accidents. Task analysis is a critical tool in systems ergonomics/human factors because it provides a systematic approach to identifying and understanding the requirements and limitations of human performance.

Methods for Conducting Task Analysis: There are various methods for conducting task analysis, including:

1. **Observation:** Observing people performing tasks in real-world settings and documenting the actions and cognitive processes involved.
2. **Interviews:** Conduct structured or unstructured interviews with subject matter experts or individuals who perform the tasks to understand their thought processes and decision-making.
3. **Questionnaires:** Administer questionnaires to gather data on the frequency and duration of specific tasks, as well as the difficulty and importance of each task.
4. **Cognitive task analysis:** A set of methods designed to capture the cognitive processes involved in completing a task. It involves techniques such as verbal protocol analysis, critical decision method, and knowledge audit.

Examples of Task Analysis in Different Industries: Task analysis is used in various industries, including:

1. **Healthcare:** Task analysis is used in healthcare to optimize patient safety and clinical workflows. For example, task analysis has been used to develop electronic health records systems that are user-friendly and support efficient clinical decision-making.



2. **Manufacturing:** Task analysis is used in manufacturing to improve production processes, reduce errors, and improve safety. For example, task analysis has been used to design assembly line workstations that optimize worker performance and minimize injury risk.
3. **Aviation:** Task analysis is used in aviation to optimize cockpit design, pilot training, and air traffic control procedures. For example, task analysis has been used to design cockpit displays that support pilot situational awareness and decision-making.
4. **Military:** Task analysis is used in the military to optimize mission planning and execution, as well as equipment design. For example, task analysis has been used to design soldier gear that optimizes performance and reduces injury risk.

V-HUMAN-COMPUTER INTERACTION (HCI)

Definition and Importance of HCI: Human-Computer Interaction (HCI) is the study of how people interact with computer systems and how computer systems can be designed to be more user-friendly and effective. It is a multidisciplinary field that draws upon knowledge and techniques from psychology, computer science, design, and other fields to improve the design and usability of computer systems.

The importance of HCI lies in the fact that it directly impacts the user experience, which in turn affects the adoption and success of the system. A system that is poorly designed and difficult to use can lead to frustration, errors, and decreased productivity, while a well-designed system can increase efficiency, productivity, and user satisfaction.

Principles of Effective User Interface Design: Effective user interface design is essential for creating user-friendly and intuitive computer systems. Some key principles of effective UI design are:

1. **Visibility:** The system should provide users with clear and visible cues about its functionality and how to use it. Users should be able to easily see and understand the different elements of the interface.
2. **Consistency:** The system should be consistent in its layout, design, and behavior. This consistency makes it easier for users to understand and predict how the system will respond.
3. **Feedback:** The system should provide feedback to users about their actions and the status of the system. This feedback helps users to understand what is happening and to make informed decisions.
4. **Flexibility:** The system should be flexible enough to accommodate different users, tasks, and contexts. It should provide different options and settings to allow users to customize their experience.
5. **Simplicity:** The system should be simple and easy to use. It should not overwhelm users with unnecessary complexity or clutter.

VI- WORKLOAD MANAGEMENT

Definition and Importance of Workload Management:

Workload management is the process of monitoring and regulating the amount and complexity of tasks assigned to a worker, with the goal of maintaining a balance between their available resources and the demands of the job. The aim of workload management is to prevent individuals from experiencing excessive physical, cognitive, or emotional demands, which can lead to stress, fatigue, errors, accidents, and reduced performance. Workload management is a critical aspect of systems ergonomics/human factors, as it aims to optimize the match between human abilities and job demands, thereby enhancing worker well-being, safety, and productivity.

Factors that Influence Workload:

The workload is influenced by a wide range of factors, including:

1. **Task Characteristics:** The complexity, novelty, duration, and frequency of tasks can affect workload. Tasks that require high levels of attention, memory, decision-making, or physical effort can increase workload.
2. **Environmental Factors:** The physical and social environment in which the work is performed can influence workload. Noise, lighting, temperature, and other factors can affect worker comfort and performance.
3. **Individual Factors:** The worker's age, health, skill level, motivation, and personality can affect workload. Different individuals may perceive and respond to the same workload differently.
4. **Organizational Factors:** The culture, policies, and resources of the organization can affect workload. Poor communication, lack of support, and inadequate training can increase workload.



Strategies for Managing Workload in Different Work Environments:

1. **Industrial Environments:** In industrial settings, workload management can be achieved by optimizing task design, reducing physical demands through automation, providing rest breaks, rotating job tasks, and training workers to use equipment and techniques that reduce physical strain.
2. **Healthcare Environments:** In healthcare settings, workload management can be achieved by reducing administrative tasks, implementing electronic health records, optimizing patient flow, providing social support, and offering resources for stress management and self-care.
3. **Office Environments:** In office settings, workload management can be achieved by providing ergonomic workstations, reducing interruptions, setting realistic deadlines, delegating tasks, and offering opportunities for skill development and career growth.
4. **Transportation Environments:** In transportation settings, workload management can be achieved by optimizing routes, scheduling rest breaks, implementing automation, providing social support, and monitoring driver fatigue and alertness.

Overall, effective workload management is crucial for maintaining worker well-being and performance and can be achieved by understanding the factors that influence workload and implementing appropriate strategies to manage workload in different work environments.

VII- RROR MANAGEMENT

Definition and Importance of Error Management:

Error management refers to the processes and strategies used to prevent, detect, and mitigate errors in systems and products. The goal of error management is to minimize the frequency and impact of errors on human performance, safety, and productivity. Effective error management is critical for systems ergonomics/human factors, as it can reduce the risk of accidents, improve system reliability, and enhance user satisfaction.

Types of Errors and Their Causes:

There are several types of errors that can occur in systems and products, including:

1. **Slip errors:** These errors occur when an intended action is mistakenly replaced by an unintended action due to attentional lapses, distraction, or automation bias.
2. **Mistake errors:** These errors occur when an incorrect decision is made due to inadequate or incorrect information, knowledge, or experience.
3. **Skill-based errors:** These errors occur when an action is incorrectly performed due to inadequate or incorrect motor skills, perception, or memory.

The causes of errors can be attributed to various factors, including:

1. **Individual factors:** These include factors such as fatigue, stress, lack of knowledge or experience, or cognitive overload.
2. **Organizational factors:** These include factors such as poor communication, inadequate training or supervision, or inadequate resources.
3. **Environmental factors:** These include factors such as poor lighting, noise, or distractions.

Strategies for Preventing and Mitigating Errors in Systems and Products:

1. **Design for Error:** This involves designing systems and products with the aim of reducing the likelihood of errors occurring. Examples include designing user interfaces that are easy to use, providing clear instructions, and minimizing cognitive load.
2. **Error Detection and Correction:** This involves implementing systems and processes that can detect errors and provide feedback to users to correct them. Examples include using error messages or alarms, providing visual cues, or providing user training.
3. **Risk Assessment and Management:** This involves identifying potential sources of errors and assessing the likelihood and impact of their occurrence. Examples include performing hazard analysis, conducting safety audits, and implementing risk mitigation strategies.
4. **Human Factors Training:** This involves providing training to users on human factors principles, such as situational awareness, communication, and decision-making skills. This can improve user performance and reduce the likelihood of errors occurring.



Overall, effective error management is critical for improving the safety, reliability, and usability of systems and products. It involves a combination of strategies aimed at preventing, detecting, and mitigating errors, as well as promoting a safety culture that values error reporting and learning.

VIII - HUMAN RELIABILITY

Definition and Importance of Human Reliability:

Human reliability refers to the ability of individuals to perform tasks effectively and consistently without making errors. In systems ergonomics/human factors, human reliability is an important concept that refers to the extent to which human performance contributes to system safety, reliability, and productivity. Human reliability is critical for industries such as aviation, healthcare, and nuclear power, where errors can have severe consequences.

Factors that Influence Human Reliability:

Human reliability is influenced by a variety of factors, including:

1. **Individual Factors:** These include factors such as age, health, fatigue, stress, motivation, personality, and training.
2. **Task Factors:** These include factors such as task complexity, task demands, task duration, and task frequency.
3. **Environmental Factors:** These include factors such as lighting, noise, temperature, humidity, and distractions.
4. **Organizational Factors:** These include factors such as culture, communication, supervision, workload, and resources.

Strategies for Optimizing Human Performance and Reducing Errors:

There are several strategies that can be used to optimize human performance and reduce errors in systems and products, including:

1. **Design for Human Factors:** This involves designing systems and products with human factors principles in mind, such as user-centered design, easy-to-use interfaces, and reducing cognitive load.
2. **Training and Education:** This involves providing adequate training and education to individuals to improve their skills, knowledge, and awareness of human factors principles.
3. **Task Allocation and Scheduling:** This involves allocating tasks and scheduling work in a way that considers the individual's capabilities, workload, and resources.
4. **Performance Feedback and Monitoring:** This involves providing performance feedback and monitoring to individuals to improve their awareness of their performance, identify errors, and provide opportunities for improvement.
5. **Safety Culture:** This involves creating a safety culture that values error reporting and learning, encourages communication, and promotes a positive work environment.
6. **Automation and Technology:** This involves implementing automation and technology to reduce the risk of errors, such as using warning systems, checklists, and automation tools.

Overall, optimizing human performance and reducing errors are critical for improving the safety, reliability, and productivity of systems and products. By considering human factors principles and implementing appropriate strategies, it is possible to enhance human reliability and reduce the risk of errors.

IX- ENVIRONMENTAL DESIGN

Definition and Importance of Environmental Design:

Environmental design in systems ergonomics/human factors refers to the process of designing physical environments, such as buildings, workspaces, and public spaces, with the aim of promoting human performance, well-being, and satisfaction. Environmental design takes into account human factors principles, such as ergonomics, anthropometry, and aesthetics, to create environments that are safe, comfortable, and efficient.

Factors that Influence Environmental Design:

Environmental design is influenced by several factors, including:

1. **Human Factors:** This includes factors such as human anatomy, physiology, and psychology, as well as considerations of human performance, comfort, and safety.



2. Environmental Factors: This includes factors such as lighting, temperature, humidity, noise, and air quality.
3. Architectural Factors: This includes factors such as building layout, materials, and construction techniques.
4. Cultural Factors: This includes factors such as social norms, values, and aesthetics.

Strategies for Optimizing the Physical Environment for Human Performance and Well-being:

There are several strategies that can be used to optimize the physical environment for human performance and well-being, including:

1. Lighting: Providing adequate lighting that is appropriate for the task at hand can improve visibility, reduce eye strain, and enhance mood.
2. Temperature and Humidity: Maintaining appropriate temperature and humidity levels can improve comfort, reduce fatigue, and enhance productivity.
3. Noise Control: Reducing noise levels through sound insulation, sound absorption, and strategic layout can reduce stress, improve concentration, and enhance communication.
4. Air Quality: Maintaining appropriate air quality through ventilation, air purification, and reducing sources of indoor pollutants can improve health, reduce absenteeism, and enhance productivity.
5. Ergonomics: Designing workstations, furniture, and equipment that are ergonomic can reduce the risk of musculoskeletal disorders, enhance comfort, and improve productivity.
6. Aesthetics: Creating visually appealing and stimulating environments that reflect cultural values can enhance mood, reduce stress, and improve well-being.

Overall, environmental design plays a crucial role in promoting human performance, well-being, and satisfaction. By considering human factors principles and implementing appropriate strategies, it is possible to create physical environments that are safe, comfortable, and efficient.

X-CONCLUSION

Summary of Key Concepts and Principles:

Systems ergonomics/human factors is a multidisciplinary field that involves the study of human performance and behavior in relation to systems and products. The key concepts and principles include:

1. Human Factors: Understanding human anatomy, physiology, psychology, and behavior, and their interaction with systems and products.
2. System Design: Designing systems and products that are safe, efficient, and easy to use, and that take into account human factors principles.
3. Error Management: Identifying and mitigating errors in systems and products to enhance safety and reliability.
4. Human Reliability: Optimizing human performance and reducing errors through appropriate training, task allocation, feedback, and safety culture.
5. Environmental Design: Designing physical environments that promote human performance, well-being, and satisfaction.

Implications for Future Research and Practice:

The field of systems ergonomics/human factors has significant implications for future research and practice. Some of these implications include:

1. The need for further research to better understand the interaction between humans and technology, and to develop new methods and tools for designing and evaluating systems and products.
2. The need for increased attention to the social and organizational factors that influence human performance and behavior, such as culture, communication, and teamwork.
3. The need for greater collaboration between researchers, designers, engineers, and end-users to ensure that systems and products are designed with human factors principles in mind.
4. The need for increased awareness and training among practitioners and decision-makers in industries that rely heavily on human performance, such as aviation, healthcare, and nuclear power.

Final Thoughts and Recommendations:

In conclusion, systems ergonomics/human factors are a critical field that has significant implications for the safety, reliability, and productivity of systems and products. By considering human factors principles and implementing



appropriate strategies, it is possible to enhance human performance, reduce errors, and promote well-being. Some final thoughts and recommendations include:

1. Encouraging greater collaboration between practitioners, researchers, and end-users to ensure that systems and products are designed with human factors principles in mind.
2. Promoting the development and use of new methods and tools for designing and evaluating systems and products that take into account human factors principles.
3. Increasing awareness and training among practitioners and decision-makers in industries that rely heavily on human performance, such as aviation, healthcare, and nuclear power.
4. Encouraging the adoption of a safety culture that values error reporting and learning, encourages communication, and promotes a positive work environment.

Overall, the field of systems ergonomics/human factors has the potential to make significant contributions to the safety, reliability, and productivity of systems and products. By continuing to advance research and practice in this field, we can create systems and products that are better designed to meet the needs and capabilities of human users.

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A Review: Microwave Sintering Of Advanced Composite Material

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Abstract -Microwave sintering of green compacts during the powder metallurgy process is quickly becoming recognized as a cutting-edge technique with numerous benefits over traditional sintering. This review article gives a mathematical equation that summarizes the dynamics of stable neck-growth and the theory of neck creation and growth related to diffusion mechanisms during sintering for pure metal powder. To understand the possible benefits of microwave sintering over traditional sintering for superior mechanical properties in the components generated by powder metallurgy method, the effect of microwave sintering on various pure metal powders has been described.

1- INTRODUCTION

Microwaves have been used to process a wide range of materials, including ceramics, polymers, and composites, beginning with the heating of food. Although it is now utilized for sintering, joining, and coating/cladding of metallic materials, the application of microwaves for metallic material processing is a tough area of research due to the reflection of electromagnetic waves by most metals under normal conditions. Roy et al. (1999); Chillar et al. (2008); Mondal et al. (2009) and Rodiger et al. (1998) published some limited research in the domain of processing metallic materials in the form of sintering under specific conditions. Furthermore, brazing of specific metals under particular circumstances was documented [Brametz et al., 2000; Budinger, 2008]. There have been reports of the joining of bulk metallic materials in various forms in a home microwave system [Siores et al., 1995; Sharma et al., 2009]. Nonetheless, it has been documented that metallic and nonmetallic powders can be coated or clothed on metallic substrates [Sharma et al., 2010]. The processing of metal powders for a variety of products and applications has led to the development of finer microstructures and near theoretical densities, which calls for new and improved methods, high-integrity materials, and cutting-edge technology. Hence, microwave processing can satisfy these needs by giving powder metal products improved microstructures and characteristics [Agrawal, 2006]. In the earliest studies of microwave interaction with metallic particles, the heating rates of during the densification mechanisms of microwave sintering in case of ceramic powders [Rahaman, 2003]. It is reported that copper steel (MPIF FC-0208 composition) and nickel steel powder (FN-0208) sintered by microwave technique have exhibited higher sintered density, better hardness and flexural strength than the conventionally sintered samples [Anklekar et al., 2005]. It has been found in literature that microwaves may be effectively used in sintering of pure metals than conventional sintering. This paper summarizes the theoretical and mathematical aspect of neck growth mechanism of microwave sintering of pure metals. The behavior of aluminum, tungsten and copper powders has been discussed when exposed to microwave.

II- MECHANISM OF MICROWAVE SINTERING OF PURE METAL POWDER



The synchrotron radiation X-ray computed tomography technique was introduced for the in-situ investigation of microstructure evolution of aluminum powder and kinetics mechanisms of microwave sintering was carried out and compared with conventional sintering. The investigations of sintering neck growth kinetic mechanisms clearly indicate that in the early stage, the surface diffusion for the conventional sintering and the grain-boundary with volume diffusion for the microwave sintering was dominant. In the next stage, oxidation on grains surface reduce or nearly stop the neck growth in the conventional sintering but the microwave sintering was influenced slightly because of the non-thermal effects such as the micro-focusing, interfacial polarization etc. The sintering with microwave has two types of effects: one similar to conventional and other different from it. In the similar effect, the sintering necks form and grow. In the different effect, after a short sintering time the contact breaks off because of the tensile and pressure force from other particles and the large initial differences in surface curvature of particles removed, so the rough surface becomes smooth in a short time [Kuczynski, 1949]. The two sphere model was developed for the powder system which consists of two equalized spheres with two slightly different geometries according to different possible particle situations, depending on whether the mechanisms are densifying or non-densifying [Demirskyi et al., 2010]. This model for the densifying mechanisms interprets the spheres (i.e. shrinkage) as well as neck growth. The neck formed between particles (of radius a) is assumed to be circular with a radius of x . The assumption for end of transition of particles is that the radius of the neck between the particles must reach a value of 0.4–0.5 of the particle radius [Rahaman, 2003]. However, the basic assumption in the models of a single dominant mass transport mechanism is not valid for most powder systems.

III- APPLICATION OF MICROWAVE FOR SINTERING OF METAL POWDERS

The sintering of pure metal powder by microwave was reported in literature [Demirskyi et al., 2010; Prabhu et al., 2009; Mondal et al., 2009; and Ghosh et al., 2011]. The pure metal powders were sintered in different situations and effects of parameters on mechanical properties were reported.

3.1 Tungsten Powder

The study of microwave sintering of pure tungsten powder of as-received grade and tungsten powder activated by high-energy milling (HEM) was carried out for sinterability comparison and analysis for process optimization when both the powder compacts are sintered under identical conditions [Prabhu et al., 2009]. Densification in sintered compact made of as received powder is around 85% and activated powder around 93% of theoretical density (19.3 g/cm³ for tungsten). High-energy milling has reduced the particle size, increased surface area and thereby a higher energy state of the powder due to significant strain of the particles from high impact forces during milling which facilitates atomic mobility during the sintering process resulting in rapid densification. The unetched microwave sintered (at 2073 K with 1 hour soaking) samples reveal that the porosity is higher in as-received powder as compared to activated powder. In etched condition, the sintered sample (with 93% density, at 2073 K with 1 hour soaking, Etched with 60% H₂O₂ solution) of activated tungsten reveals considerable sintering with the presence of grain boundaries.

3.2 Copper Powder

The investigation of the neck growth kinetics during microwave sintering of freepacked copper powder was carried out by application of the classical sphere-to-sphere approach which shows similarities between microwave and conventional sintering processes for long soaking times [Demirskyi et al., 2010]. Surface diffusion was the predominant diffusion mechanism during microwave sintering at other cases for low temperatures. At higher sintering temperatures, volume diffusion is the main sintering mechanism. The study of thermal profile of copper metal powder was done when the material is exposed to 2.45 GHz microwave radiation in a multimode microwave furnace [Mondal et al., 2009]. The temperature variation with time of exposure of the copper powder compacts when sintered in multimode microwave furnace depends upon the particle size and initial porosity for a specific particle size of Cu powder while keeping the power setting and total exposure time constant. As particle size increases the heating rate decreases and after certain time heating rate becomes constant at a particular power setting.

3.3 Aluminum Powder



By examining the sintered powder, the microwave sintering of aluminium was investigated. After 45 minutes of microwave exposure to commercial aluminium powder. The analysis of the microwave-treated aluminium powder proved that Al—Al₂O₃ had formed. After 45 minutes of heating the Al powder in a microwave, a temperature of 1000–10°C was recorded. Al phase was only found in the untreated Al powder, whereas Al and -Al₂O₃ phases were found in the Al powder that had undergone microwave treatment. Al—Al₂O₃ is produced as a result of the oxidation of Al particles, which absorb microwave energy and heat the surrounding atmosphere. So, it is reasonable to suppose that the heating of the finely divided Al metal powder was caused by some sort of energy loss mechanisms.

IV- CONCLUSIONS

Application of microwaves for sintering of the pure metal powder in powder metallurgy process has been emerged as a potential process. The microwave sintering has significant advantages over conventional sintering because of different diffusion mechanism involved in it. The following facts of microwave sintering can be summarized as:

1. The diffusion mechanisms in conventional and microwave sintering are quite different because of non thermal effects of microwave.
2. The smoother surface of powder compact is developed in short time by microwave sintering than conventional sintering.
3. The log (x/a) and log (t) have a linear relationship with a slope equals to 1/n where values of n different for conventional and microwave sintering which interprets existence of the different diffusion mechanisms.
4. The mechanical properties of microwave sintered compacted metal powder can be improved by pre working on metal powder as in the case of tungsten powder.
5. During microwave sintering, at lower temperatures surface diffusion and at higher temperatures volume diffusion are dominant diffusion mechanisms as in the case of pure copper powder.
6. Thermal profile during microwave sintering in multimode microwave furnace depends upon particle size and porosity present in compacted powder metal.
7. The effect of oxidation on sintering of metal powder by microwave is less effective phenomenon in comparison to conventional sintering

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A Review on Evaluation of the Effectiveness of Teaching and Learning of Thermodynamics

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Abstract

Thermodynamics is a subject that deals with energy and is one of the most advanced tools for understanding our physical universe. As can be seen from the literature, engineering students around the world have difficulty learning thermodynamics. There are various studies that report efforts to overcome the deficiencies and suggestions for teaching approaches to improve student learning, such as blended learning approach, active learning techniques, computer-assisted instruction, virtual laboratory - a web-based learning tool for students on the thermodynamic concept related to multistage compressors and turbines, TESTTM software in design projects and laboratory, etc. In this paper, the different approaches to help students learn thermodynamics are investigated and analysed. The criteria for the analysis are the characteristics of the learning system, the effectiveness based on student performance, the skills developed with the learning system, and student feedback.

1. Introduction

Thermodynamics is related to the physical universe and plays an importance role in our lives. It is a fundamental course and has been an essential part of the global engineering curricula [1-2]. Engineers use thermodynamics principles in their study and design of a wide variety of energy systems, such as jet engines and rockets, refrigeration systems, air conditioning systems, chemical processes, automobiles, and power plants. Engineering students facing difficulties in learning thermodynamics occur globally as stated by many researchers. In order to enhance the teaching and learning of thermodynamics, the approach to teaching thermodynamics has progressed from the traditional method to a more sophisticated method such as using computer technology and multimedia. Learning is a process of acquiring and synthesizing ideas and concepts. The process not only involves obtaining information but also full participation by the learner (student-centered learning) [17]. According to Moron-Garcia [18], the use of web or internet based technology can facilitate the creation of student-centered learning environment. Student-centered learning and learning environments designed with reference to constructivist theories of learning will produce in students the critical and cognitive skills that higher education aims to develop [18, 19]. This paper outlines the problems faced by students learning thermodynamics as well as reviews and analyses the different approaches in supporting students to learn and understand thermodynamics. The criteria for analysis are the characteristics of the methods of enhancement used; their effectiveness based on students' performance, the skill developed using the methods, and comments by students.

2. Problems Faced by Students Learning Thermodynamics

Many students have difficulties in learning thermodynamics for decades and quite a number of researchers have written on the issues. A quote by Arnold Somerfield [3] on the learning of thermodynamics:



“Thermodynamics is a funny subject. The first time you go through it, you don’t understand it at all. The second time you go through it, you think you understand it, except for one or two small points. The third time you go through it, you know you don’t understand it, but by the time you are so used to it, it doesn’t bother you anymore.”

The quote shows that thermodynamics is difficult to understand, even after going through the subject several times. This view is supported by Hassan and Mat [1] and Patron [4] that even after instruction; students retain significant misconception about thermodynamics principles. According to Patron [4], Junglas [5], Anderson et al [6], Meltzer [7], Cotignola et al [8], many students face difficulties in understanding basic concepts in thermodynamics. They have misunderstanding or misconceptions about terms such as work, heat, internal energy, enthalpy, entropy, first law of thermodynamics and their use for concrete applications. In teaching practices, Liu [9] found that most students were confused about how to properly determine the state of pure substances. Abu-Mulaweh [2], Patron [4], and Junglas [5] stated that there was a perception among engineering college students that thermodynamic is an impossibly difficult and most hated subject. This was reflected in poor final examination results of the students. The finding is supported by Bullen and Russell [10] that students at many UK universities tend to underperform in subjects such as thermodynamics. Baher [11] stated that both the learning and the teaching of thermodynamics were no easy tasks.

Students also face obstacles in mapping abstract, theoretical understanding of thermodynamic principles on to plant operation [12]. Kelly [12], found that visiting the real power plant did not help the students’ understanding because the huge size of the plant makes it hard to conceptualize how the different cycles and components work together, and also by design some components of the plant were difficult to view. According to Huang and Gramoll [13], and Cox et al [14], topics in thermodynamics are abstract and difficult to visualize. Furthermore, with traditional teacher-centered educational approach engineering students sometimes learn theories that they cannot transfer to real situations, or have experiences that they cannot explain with the knowledge they have already obtained. Forbus et al [15] stressed that students lack intuition and treat thermodynamics problems as abstractions divorced from practical application. Students also face difficulties in retention of knowledge when traditional teaching method is used [1, 6, 13, 16]. According to Chaturvedi et al [16], students’ learning through traditional approach is not effective in the twenty-first century. Students also have trouble in solving thermodynamic problems. Studies by Liu [9] indicated that some students cannot properly build an image of the problem and do not know how to start, therefore they struggle everywhere in solving the problem. Such common pitfalls associated with problem solving can result in difficulties as problems become more complicated.

3. Methods of Enhancement the Teaching and Learning of Thermodynamics

Due to the many problems face by students learning thermodynamics, various methods for enhancing the teaching and learning thermodynamics have been designed and developed. From 1993 to 2009 there are numerous published papers on the methods on enhancing the teaching and learning of thermodynamics. See Table 1. The list is in descending order of the year the articles were published. Besides, some thermodynamics text books such as written by Cengel and Boles [20] and Moran and Shapiro [21] had include CD-ROMs consisting of materials on the subject matter. Publishers such as McGraw-Hill also provide a courseware on thermodynamics that are accessible online.

Table 1. Methods of enhancement the teaching and learning of thermodynamics

Researchers	Methods of Enhancement
Liu	Instructional courseware in thermodynamics education. (2009)
Bullen & Russell	A blended learning approach. (2007)
Chaturvedi et al	Virtual assembly- a web-based student learning tool related to multi-staging in compressors and turbines (2007)
Junglas	Simulation programs to perform virtual experiments (2006)



Hassan & Mat	Active learning environment (2005)
Abu-Mulaweh	Portable experimental apparatus (2004)
Huang & Gramoll	Multimedia Engineering Thermodynamics (2004)
Cox et al	Teaching with physlets (2003)
Ngo & Lai	An online thermodynamic courseware (2003)
Kelly	Virtual power plant website (2002)
Anderson et al	Computer-based active learning materials (2002)
Kumpathy	TESTTM software (2002)
Baher et al	Virtual lab- cyclepad (1999)

None of the developers of the methods listed in Table 1 stated that their methods were supported by learning theory. However, Huang and Gramoll [13] claimed using the same structure as Multimedia Engineering Statics which was supported by a learning theory when they developed Multimedia Engineering Thermodynamics. An antidote for learning is to engage learners in active, constructive, intentional, complex, cooperative and reflective learning activities [22]. These characteristics are the goals of constructivist learning environments (CLEs). In the constructivist learning environments, learners engage in exploration, articulation and reflection; while instructors provide instructional support in modeling, coaching and scaffolding [19, 22]. Jonassen [19] stated that the essential components in CLEs include problem, question or project as the focus of the environment; related cases; information resources; and cognitive tools. Cognitive tools are computer tools that help visualize (represent), organize, automate, and enhance thinking skills. The focus on problem, question or project constitutes a learning goal driving the learning process. Three major components need to be included in the design of the problem: the problem context, the problem representation or simulation, and the problem manipulation space [19]. The representation of the problem should be interesting, appealing and engaging.

Problem manipulation space provides meaningful learning in which learners are provided with opportunities to manipulate objects and interact with the environment. The related cases support learning by scaffolding student memory; providing different perspective, themes and interpretations; and enhancing student cognitive flexibility. Out of the 15 methods listed in Table 1, only 2 methods do not use computer or multimedia. The methods are active learning environment [1] and portable experimental apparatus [2]. Although the remainder use computer technology and multimedia in their systems, each are different in their approach and design. However, all methods have a common goal of enhancing the teaching and learning of thermodynamics. A few methods give complete thermodynamics content such as in online courseware for use such as in lectures, as self-paced study, as reference material or as supporting exercises/exploration in classrooms. Others provide virtual laboratory experiences with different apparatus such as the power plant or thermodynamic cycles or multi-staging in compressors and turbines for the student to perform alone or in a group. Irrespective of the methods is web-based or CD-ROM, the multimedia used promotes interactivity and visualization.

4. Analysis of the Different Methods of Enhancement

The criteria for analysis are the characteristics of the methods of enhancement the teaching and learning of thermodynamics and their effectiveness based on students' performance, the skill developed using the methods, and comments by students.

4.1. Characteristics of the methods of enhancement the teaching and learning of thermodynamics

All the methods listed except two, used computer technology for the enhancement of the teaching and learning of thermodynamics. This is in line with current students' learning styles that are more interactive and visual. A study by Fowler et al [17] stated that 79% of engineering students are visual and 55% of them learn best actively. The advance in



computer technology and multimedia can cater for this interactivity and visualization. However, each method of enhancement has its own characteristics as outlined below.

4.1.1. Without using computer technology

The methods without using computer technology are active learning environment [1] and portable experimental apparatus [2]. In the active learning environment, a lecture was conducted for the first part of the period detailing the theories involved and solved problems as illustration. During the second half of the period, volunteers would come up to the white board to solve problems followed with discussions on alternative approaches. Whilst in the portable experimental apparatus, a single stage vapour compression refrigeration system is used to demonstrate the concepts of thermodynamics such as the first law and second law. The objective was to help students understand the basic thermodynamic processes by using real-life applications.

4.1.2. With computer technology

Junglas [5] uses an interactive simulation program based on classical approach to perform virtual experiments with the purpose of providing insights into abstract concepts that can lead to better mental models as well as to engage students in active learning. There were 6 programs that deal with ideal gas laws and gas cycles only.

Anderson et al [6] on the other hand developed active learning module on CD-ROM. The module includes interactive exercises, immediate feedback, graphical modelling, physical world simulation, and exploration. Interaction and exercises include narrative voice-overs and animations; interactive questions; short-response interactions; coaching interactions; and experimental simulations. Many of the screens contain cursor-over-pop-ups to display additional graphics or information about the topic. The module seems to be developed with the support of the constructivist learning theory and covers all the topics in introductory thermodynamics.

Instructional courseware in thermodynamics education [9] was developed for solving 3 types of fundamental thermodynamics problems: determining gas status after specified processes; evaluating pure substance thermodynamic properties at given states; and analyzing power, refrigeration, and heat pump cycles. The courseware is very instructive and user friendly for data and information input. The presented program only provides basic governing equations for the cycles from the perspective of conservation of energy principle. Thus, it does not cover all the topics in introductory thermodynamics. Bullen and Russell [10] use a blended learning approach to teach thermodynamics to first year engineering students. The approach consists of lecture, tutorial, laboratory and supplemented by the use of a managed learning environment (MLE) and utilizing other opportunity of increasing cooperation and contact between students and students, and students and staff. This includes weekly assessed tutorials that are computer-aided to give rapid feedback to students, peer assessment of laboratory reports and just in-time teaching. It provides tools to enhance teaching and learning by delivering course materials and facilitating online communication, group work, and active learning. The blended learning approach seems to support the constructivist learning theory. Others had used cyclepad [11, 15, 27], an articulate virtual laboratory (AVL) that is user oriented and tends to be a self learning tool. Students can build, design and analyze thermodynamics cycles and receive coaching help. The software programs make conceptual tasks more accessible to students and provide explanation to the “how” and “why” of the science behind their design. The software serves as a monitoring aid during the problem solving process and free students from the burden of tedious numerical and algebraic manipulations. It also shows students the formulas underlying all the values which it calculates.

A virtual power plant website [12] was developed to help undergraduate mechanical engineering students understand thermodynamics principles through their exploration and manipulation of plant operations in a virtual learning environment. With this knowledge, students have the opportunity to solve practical problems by designing, analyzing, and manipulating the operations of a power plant. The 2 simulation packages used are realistic and provide motivation to the learners, provide student-centred activities, give reflection and collaborative construction of knowledge.

Huang and Gramoll [13] developed an interactive multimedia online e-Book to enhance the learning experience of students studying basic concepts in engineering thermodynamics. The e-Book is case-based and comprises of 42 real-world case problems with each case is presented in 4 parts: introduction, theory, case solution, and simulation. The fourth part provides an opportunity for students to experience a simulation by modifying parameters of the case problem and invoke students thinking. Movies, diagrams, graphics, animations, sounds and tables play an important role in the



e-Book to help visualize and simplify abstract thermodynamics concepts such as enthalpy or entropy. The e-Book covers the same material addressed in a typical undergraduate engineering thermodynamic text book. Cox et al [14] also used interactive simulation software, a Physlet-based curricular material designed to help students learn concepts of thermodynamics with a particular focus on the use of kinetic theory models. Physlet exercises have simple animation allowing students to focus on the desired concepts. These exercises help students visualize ideal gas particles dynamics and engine cycles, and develop a conceptual framework for problem solving. The software helps students study thermodynamics by providing them with dynamic connections between graphs and thermodynamic processes, by modeling real-world applications, and changing the parameters of different systems. Chaturvedi [16] developed an alternative web-based interactive learning tool for thermodynamics concepts related to multi-staging in compressors and turbines only and thus does not cover all topics in thermodynamics.

The system uses simulation and visualization software. The authors contended that students learning can be enhanced by creating visual images of complex thermodynamic devices and allowing students to relate these images to thermodynamic processes on temperature-entropy diagrams. The pedagogy used is “learning by doing in virtual environment”. Using computer generated results and relevant equations, students calculate manually the final overall cycle efficiency. This keeps the students active in their interaction with the module.

Besides [9], Ngo and Lai [23] also developed an online thermodynamics courseware that presents the materials in a dynamic and interactive fashion. The course module contains detailed notes presented in a visually appealing manner with the use of interactive simulations, animations, and examples to reinforce concepts in the classroom. The courseware includes workshops to help students become familiar with the use of thermodynamics tables. Meanwhile Kumpaty [24] in his works, use software called expert system for thermodynamics (TESTTM) for enhancing students’ learning thermodynamics fundamentals. The TEST

TM is interactive and is used in assignments, design projects and laboratory. Likewise, Weston [25] also developed software of visual and interactive models of thermodynamic cycles. The applications produced include air cycles, Rankine cycles, Brayton cycles, and vapor compression refrigeration cycles. Questionnaires for students, instructors or general users were developed via HTML for electronic feedback by users. To remedy students’ lack of ability to integrate thermodynamic concepts to the more complex phenomena and to increase the emphasis on understanding, Lewis et al [26] used the computer as Lab Partner (CLP) curriculum. It consists of an 11- week microcomputer-based study of thermodynamics properties and variables and includes simulations of problems encountered in students’ daily lives. Students integrated experiments using real time data collection with simulated experiments and later made prediction and reflection.

4.2. Effectiveness of the learning systems

Most of the researchers claimed that they obtained positive results when applying their methods of enhancement. The effectiveness of the learning systems is divided into students’ performance, skills developed, and comments by the students.

4.2.1. Students’ performance

Of the 15 methods of teaching and learning enhancement as listed in Table 1, 6 did not mention students’ performance using their methods. They are courseware in thermodynamics education [9], multimedia engineering thermodynamics [13], physlets [14], virtual power plant [12], thermodynamics cycle using HTML and JavaScript [25], and portable experimental apparatus [2]. They described mainly the development and the operation of the methods as well as their advantages. The remainder of them stated improved students’ performance.

According to Bullen and Russell [10], the adoption of the blended learning approach has resulted in an improved students’ performance as measured by their final examination results. From 2000 – 2004, the percentage of students achieving the minimum examination pass mark has improved from 49% to 77%. For the web-based student learning tool related to multi-staging in compressors and turbines [16], there was a 14% improvement in the average score of a quiz administered for the group using the module over the group without the exposure to the module. According to Junglas [5] students using simulation programs to perform virtual experiments, take a more active part in the lecture, mainly due to the hands-on approach that complements the theoretical section. As a consequence the average score of the final examination has increased. The application of active learning environment even without the computer-based instruction [1] resulted in no failure in the final examination of this group of students compared to the group taught using conventional method of teaching that have 4% failures. The number of students obtaining grade A’s was higher in the



active learning class. For the application of active learning technique to computer-based instruction for introductory thermodynamics course [6], the test performance has been positive. For the online thermodynamic courseware [20], students also have a better understanding of the subject as shown by scoring better in their examination. Lewis et al [26] carried a thorough assessment on students' performance. The post-test showed that the students displayed understanding of general, real-world questions and did very well at explaining naturally occurring phenomena. Students displayed more integrated understanding than any previous semesters. There was a greater improvement in students' ability to provide explanations (63.9% pre-test to 83.1% post-test). Students also showed statistically significant improvement from pre-test to post-test on conductors and insulators. Most methods claimed that students understand better basic thermodynamics laws and principles, and able to enhance the learning experience of students.

4.2.2. Skills developed

The methods for enhancing teaching and learning thermodynamics provide students skills such as problem solving, designing, team working and so on, depending on the methods of enhancement used. Table 2 summarizes the skills developed using the various methods.

Table 2. Skills developed by students

Methods of teaching and learning thermodynamics	Skill developed
Blended learning	Problem solving
Cyclepad	Problem solving
Virtual assembly in compressors/turbine	Problem solving
Cyclepad	Designing
Virtual assembly in compressors/turbin	Designing
Active learning environment	Interactivity
Simulation program for virtual expts.	Interactivity
Computer-based active learning	Interactivity
Courseware in thermodynamics education	Interactivity
Blended learning	Interactivity
Cyclepad	Interactivity
Virtual power plant website	Interactivity
Multimedia engineering thermodynamics	Interactivity
Virtual assembly in compressors/turbin	Interactivity
Online thermodynamics courseware	Interactivity
TEST TM software	Interactivity
Interactive thermodynamic cycles	Interactivity
Computer simulation of experiments	Interactivity
Virtual power plant website	Team working
TEST TM software	Team working
Computer simulation of experiments	Team working



Online thermodynamics	Thermodynamics property
Coursewre	Tables

Problem solving skill is developed using instructional courseware in thermodynamics education [9], blended learning [10], cyclepad [11, 15, 27], virtual assembly [16], and online thermodynamics courseware [23]. Cyclepad made students more systematic when approaching a problem, helped students in tracking their errors and thinking about their modelling assumptions. Students are able to calculate the final overall efficiency of the cycle manually by using virtual assembly. Cyclepad [11, 15, 27] and virtual assembly [16] developed designing skill in students. Cyclepad helped students in visualizing, simulating, analyzing and designing cycles. Students were able to complete complex designs that exceeded their knowledge. Virtual assembly enabled students to assemble a multistage compressor and turbine. Methods that employ interactivity in the systems developed interactivity skill in students [1, 5, 6, 9-13, 15, 16, 23-26]. On the other hand, methods that required working in groups developed team working skill in students. Students developed skill in obtaining the properties of thermodynamics tables using the interactive workshops of thermodynamic courseware [23] and from the software of instructional courseware in thermodynamics education [9] and interactive thermodynamic cycles [22].

Computer simulation of experiments [23] developed students' ability to reflect, to apply scientific ideas to complex ambiguous situations, to compare the result of laboratory investigations to every day observations, and to predict prediction curves based on real time experiments. Students developed a deep approach to learning when using the blended learning method compared to students who barely used the system. Portable experimental apparatus and teaching with Physlets did not mention any skill developed by students.

4.2.3. Students comments

Many students gave comments on the methods they used on enhancing their learning of thermodynamics. Almost all gave favorable remarks as shown in Table 3.

Table 3. Comments by students

<i>Methods of teaching and learning thermodynamics</i>	<i>Comments by students</i>
Active learning environment	Positive on interaction and assessment
Computer-based active learning	Positive on materials Comprehensibility
Blended learning	Positive on the discussion forum
Cyclepad	positive on excitement of learning, easiness using the software, understanding of cycles, and time consumption Negative on working with computers
Physlets	Positive on interactivity, visualizing and understanding concepts
Online thermodynamics courseware TESTTM	Positive response from Students for reviewing notes & assignments' solutions
Interactive thermodynamic cycles (HTML)	Interactive thermodynamic cycles (HTML) Positive on as learning tool, delivery of thermodynamics fundamentals, examination preparation Negative on substitution for actual hands-on experience



Computer simulation of expts.	Computer simulation of expts. Positive on learning experience, enjoyment, excitement, and team-working
Portable experimental apparatus	No comments
Virtual power plant website	No comments

On active learning environment [1], students gave good to excellent remarks on interaction between lecturers and students, and on assessment. On computer-based active learning [6], 84% of the students commented that the materials presented were comprehensible. Two third of students interviewed commented that the discussion forum in blended learning [10] were useful. A number of the students interviewed identified the provision of more worked examples as the way to improve the module used in blended learning. Students commented on cyclepad [11, 15, 27] as ‘fun and exciting’, ‘the software is easy to learn’, and ‘they learn more because they do more’. Some students felt that by constructing and analyzing a complete cycle they had a better understanding of the cycle. Students also mentioned that cyclepad helped them see the relationship between parameters, gave them more accurate answers, and less time spent on calculations. Although most students felt cyclepad helped them to understand thermodynamics system better, however, a few students gave negative responses such as ‘frustrating to work with computers and computers were too slow’. Students comments on the interactivity and feedback from Physlets [14] as follows: ‘Wow – this is the coolest thing that I’ve ever seen’. Over 70% of students surveyed either agreed or strongly agreed with the statement that ‘the exercise helped me visualize and understand concepts presented’. Students also claimed that they can differentiate the different thermodynamic processes.

Online thermodynamics courseware [23] received overwhelming response from students. Students found it helpful to review notes from any missed classes and obtain solutions for homework assignments. Students also commented that the table wizard was very useful in obtaining thermodynamic properties.

Students’ feedback on TESTTM software [24] has been very affirming. Some comments are as follows: ‘I wish I had known about this software exists a year earlier’, ‘I will use the software in my workplace after I graduate’, ‘TEST TM has made my learning easier and I will continue to use it in my engineering practice’, ‘thanks for introducing me to such fantastic tool to solve thermodynamics problems’, and ‘the software guides your thinking on how to attack thermodynamics problems correctly and efficiently’. None of the 120 students introduced to TESTTM have said they disliked its use. Students comments on thermodynamics cycle using HTML and JavaScript[21] include: ‘I am very impressed’, ‘very helpful especially for students learning the material for the first time’, ‘increase my appreciation of computer programming’, ‘very interesting and could see its use in preparing for examination’, ‘informative, an excellent learning tool’, ‘an asset for examples to the situations we had in class’, and ‘had merit in enhancing the delivery of thermodynamics fundamentals’. However, a majority of students stated that such tools could not be a substitute for actual “hands-on” experience.

According to Lewis et al [26], students were remarkably positive about the use of the Notebook. On questionnaire given to students, 84% of students stated they liked using the notebook from ‘medium’ to ‘a lot’. Students made comments such as ‘excellent’, ‘great, a wonderful idea’, ‘it was fun and also a learning experience’, ‘a new kind of learning and I enjoyed it’, ‘fun, we learned a lot, but still had a good time’, ‘we liked the way the computer did the actual experiment based on real time experiment’, ‘easy to use, we liked predicting the result, making graphs, and finding out if we were right or not’, and ‘we liked the teamwork’. However, there were students who gave comment that they were bored with the program, although they had fun sometimes. Methods that did not gave students comment were portable experimental apparatus, simulation programs to perform virtual experiments, instructional courseware in thermodynamics education, a virtual power plant website, multimedia engineering thermodynamics, and virtual assembly – a web-based student learning tool related to multi-staging in compressors and turbines [2, 5, 9, 12, 13, 16].



5. Conclusion

Many engineering students worldwide have difficulty learning basic/introductory thermodynamics. This has led to much research on the development and implementation of various methods to improve the learning of thermodynamics for students. Most of the methods developed use computer technology and multimedia to provide interactivity and visualization. The methods have improved student performance and enhanced their skills. Student feedback and comments have been positive and encouraging.

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The Application of Ergonomics in Rural Development: A Review

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Abstract: - The importance of ergonomics issues in rural development is highlighted in this paper. Some examples are given of the contribution that ergonomics has already made to industrially developing countries, cases which are mainly concentrated in the industrial sector. Key areas for future ergonomics research are identified, focusing on the needs of communities living and working in the agricultural sector where most of the population in the industrially developing world is located.

Keywords: Agriculture; Workplace design; Equipment design; Safety; Work organisation

1. Introduction

In industrially developing countries (IDCs), the majority of the population is engaged in farming activities, some in small-scale enterprises and relatively few in factory or industrial work. Much of the power required for farming activities, such as ploughing, harvesting, weeding and sowing, is derived from human energy, some from animal power and little from engine power. Most of these farming activities can cause fatigue and work-related illnesses, which in turn reduce production capacity. The multi-disciplinary nature of ergonomics can play a unique role in the protection of people's health and in the prevention of work-related health hazards. Ergonomics can do this by integrating concepts from the social sciences with technological advances to enhance productive capacity and improve people's health. This paper illustrates the importance of ergonomics to rural development and demonstrates how *appropriate* attention to ergonomics has brought, and can still bring, benefits.

2. Ergonomics and rural development

Rural development has a number of definitions but it generally refers to the process of change in rural societies or communities. It has generally been held that rural development is driven by three main elements, *economic*, *social* and *human*, which interact together to bring about change. It is proposed here that *technological factors*, to improve the performance of rural production systems, should also be considered a major contribution to the process of development. All four elements need to be considered separately but, more importantly, also at the interactive level in order to promote development. The interaction between social and economic factors is well documented * hence the science of socio-economics. However, the sign "cancel of interactions between the other elements, particularly the human} technical relationship, has been obscured or overlooked (Jafry and O'Neill, 1994). This is clearly evident from the many cases of failed technology transfer (Sutton, 1989) where the technology was inappropriate for the intended users. Sutton (1989) commented that development is about people as much as technology and that technology is for *people* to use * it serves little purpose on its own. The relative amounts of attention given to the various interactions between the elements is illustrated in Fig. 1.



Whilst there are some similarities between rural and industrial development and the related ergonomics needs, improvements in working conditions and the quality of life arising from *ergonomics* applications are likely to have a greater impact and bring about wider benefits, in the rural sector. Dy (1979) commented that rural work has a stronger influence on life than factory work because factory work is done away from the home, as a distinct activity, and is more clearly separated from leisure and family life. The rural sector requires a different approach from the industrial sector, in terms of development, because technological change is more alien, sociological and anthropological factors are relatively more important, and more assistance is required in terms of the transfer of knowledge and training in technical skills.

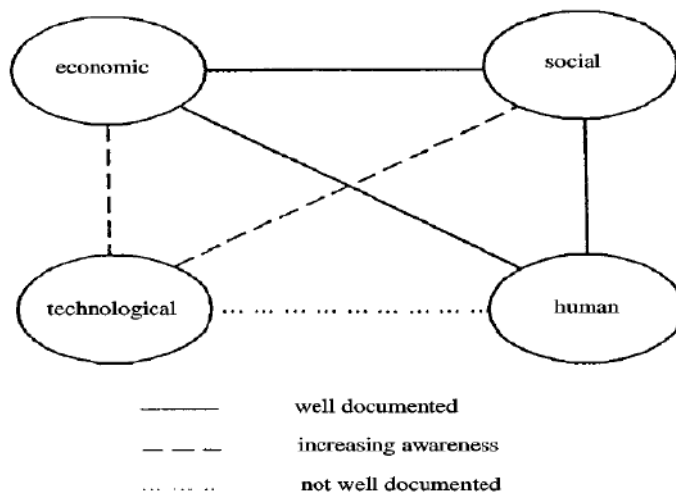


Fig. 1. Interacting elements in rural development (from Jafry and O'Neill, 1994).

3. Ergonomics achievements in developing countries

Ergonomics and its applications attempt to harmonise work and the working environment to raise productivity and work efficiency and promote individual well-being through optimising the effort of the worker or user. Much of the ergonomics research in developing countries, to improve productivity has been focused in the industrial sector; little work of an ergonomics nature has been done in small-scale or subsistence agriculture. It is a neglected area, but one that has considerable potential for improving and sustaining the quality of life. Some examples of the contribution that ergonomics has made in developing countries, but mainly in the industrial sector, are given below.

3.1. Work organisation and workplace design

Increased productivity can be achieved through improvements to the organisation of work, workplace layouts and work schedules. To create a good working environment, it is necessary to control all the factors that influence human performance and efficiency. For example, in the food processing environment in the East Java, women were able to increase their output of shelling coffee beans from 20 kg/day to 25 kg/day by moving from a squatting position on the floor to using an ergonomically designed table and chair (Priatna, 1985). Yusuf (1985) measured the body sizes of 67 female workers in an Asian biscuit factory in order to fit workbenches to the workers. The ergonomic workbenches allowed for better movement of the legs and forearms in packing operations, which led to a 9.8% increase in productivity. These studies indicate that by implementing ergonomics the benefits of productivity gains are likely.

3.2. Tool and equipment design



In the industrialised world, the composition of the workforce is changing, with a decline in the number of agricultural workers. However, in developing countries, as the population grows the demand for food increases (Quisumbing et al., 1995). Farms and farming systems have to adapt and become more efficient to meet the ever-increasing demand for food. Providing farmers with suitable means of production such as adequate tools and implements is one way of easing the burden associated with food production. Ergonomic changes in the design of tools and implements can be shown to be effective both in terms of increased productivity and, indirectly, in terms of decreased operating costs. Some tools are well adapted to people's needs but often one tool is used for nearly all "eld operations. For example, a farmer may use a hoe for seed-bed preparation, planting, weeding and harvesting (Ngunjiri, 1986; Bassi, 1992). The use of only one design or type of tool has its drawbacks in that it is tedious and the rate of work is slow (Ngunjiri, 1986). Generally, hand tools and implements are powered and controlled by people, thus they should be designed keeping human capabilities and limitations in mind. Studies have shown that if the designs of hand tools are improved they require less energy to use and can lead to better working efficiency (Gite, 1991, Manuaba, 1979, Nwaba and Kaul, 1986, Sen, 1984). Bassi (1992) introduced improvements to the design of the hand hoe which is one of the most commonly used agricultural tools in Nigeria. The traditional hoe had short handle lengths which varied from 475 mm to 745 mm with the hoe angles varying from 45^o to 82^o. This meant that the user had to work in a bent posture. The hand hoe was redesigned according to the anthropometric characteristics of the Nigerian user group. The new handle length was determined to be 770 mm with a hoe angle of 75^o. A handle length of 110 mm and a hoe angle of 90^o were determined as best for digging. The new design has many benefits including improved posture in usage and reduced energy demands.

3.3. Accidents and injury

With rapid industrialisation and mechanisation in developing countries, occupational health problems are becoming more prominent (El-Batawi, 1981). As more technology or technological packages are imported, developing countries face an increasing array of problems such as the ability to repair, maintain or even operate the machinery/equipment, unsafe working conditions, unguarded machinery and injurious working postures (Cilindro, 1985). Holmer et al. (1985) reported that industrialisation in Thailand has brought with it considerable problems of occupational health and safety and they attributed this to the imposition of modern technology without proper consideration of human and social requirements in the working population. For example, mechanising ploughing and harrowing in Western Nigeria using a small engine powered pedestrian-controlled cultivator (two-wheeled tractor) failed because the human factors elements were not taken into account (Dibbitts et al., 1978). The heart rate and energy expenditure of the operators indicated that in most operations the physiological strain exceeded the tolerance limits for continuous work. Other factors that increased the strain on the worker included muddy and rough soil conditions. Also, there were no gears to control the working speed and inadequate clutch control for steering. The authors concluded that one tractor needs to be operated by two men, working and resting in turn. The other potential solution is to develop a four-wheeled ride-on tractor to reduce the physical workload.

3.4. Safety

Due to the growth in mechanisation which frequently accompanies agricultural development (for example, machines for seeding, spraying and threshing), safety issues are becoming more important. Safety, or the lack of it, has been attributed to the lack of ergonomics input, particularly during equipment design and development. Kogi (1985) associated the use of primitive tools and techniques and poor unregulated working conditions with factors undermining workplace safety. Ahmed (1979) reported that the implementation of ergonomics in the Philippine forestry industry led to better postures being adopted, fewer arduous tasks, fewer safety hazards and reduced working hours when compared to traditional methods. Training in correct ergonomic working techniques has also improved safety consciousness in forestry workers in Tanzania (Abeli, 1979). Many forestry workers, mainly loggers, are illiterate and unskilled. They have little knowledge of the hazards and precautions necessary to prevent accidents and injuries when using chainsaws. The forest workers were trained in their own language-using symbols that were culturally recognised and understood-on correct ergonomic working techniques, basic tool maintenance and efficient handling of tools. The better trained workers were



able to use their tools properly, thereby making work less strenuous, and there was increased awareness on the causes of accidents and the risks involved in various work operations (Abeli, 1979).

4. Future needs of ergonomics

Ergonomics has already made some contribution to development in IDCs, but it has been unstructured and patchy. Many studies reported in the literature relate to ergonomics in the industrial sector of developing countries. However, given that the majority of the population in developing countries live and work in the agricultural sector, more attention needs to be directed to agriculture. Some areas for future research in developing country agriculture are suggested below.

4.1. Technology transfer

As technology advances, there will be increasing demands from developing countries to have access to it. In order to realise the potential benefits of advancing technology, it is vital that the transfer of technology from one country to another is effected with caution and that the 'people' factor is considered in all stages of transfer. If adaptation to new technologies is incomplete then the advantages of technology are lost and problems such as accidents, occupational disorders and low productivity prevail. Compatibility of imported technology with the characteristics of the users (Sen, 1984; Shahnavaz, 1989; Wisner, 1989) and the general effect on the community (Sen, 1984) must be considered if technology is to be transferred successfully. Manuaba (1979) warned of the possible detrimental effects of applying new technologies in developing countries without a thorough ergonomics evaluation. One example is the case of transferring toxic agrochemicals to developing countries without giving due consideration to the farmers' knowledge of their safe use (Jafry and O'Neill, 1994). Agricultural workers are at risk of pesticide poisoning because of their close involvement with concentrated forms of toxic substances.

Exposure may be due to pesticide application (mixing, loading into sprayers and spraying) or other tasks such as tending crops soon after they have been sprayed (Rainbird and O'Neill, 1995). However, adult education levels in developing countries are lower than those of developed countries and this may influence the ability to process safety information (Abeysekera, 1990). If users cannot understand the language and symbols in which instructions and manuals are written, errors and accidents will occur (Meshkati, 1989). In order to reduce accidents and errors occurring, future research needs to address the design and development of instructions and operating manuals for imported technology, using icons, symbols and language that are culturally recognised and socially sensitive.

4.2. The needs of women

Women spend long hours in the field, often many more than men (Rahman, 1993) and are the main labour suppliers in collecting water and fuel-wood (Bryceson and Howe, 1993), fodder collection, watering and milking of livestock and domestic activities including child care (Mies, 1986). Women's contributions and responsibilities in agriculture can have serious consequences including health problems, for example, backache, chest pains and miscarriage. In view of this, it may be argued that the impact of work on family life is greater for women than for men (Chavalitsakulchai and Shahnavaz, 1990) and that women are burdened with the greater share of the toil and hardship underlying rural development. Ergonomics can address the problems of drudgery and hardship faced by women, for example by analysing women's transport strategies to provide simple solutions (Page, 1996). Rahman (1993) stated that many agricultural projects are often aimed at men with the assumption that they will somehow automatically benefit women. In light of this, greater efforts must be made to target women and more equipment must be developed explicitly for female use, since it is they who do the majority of farm work. Ensure that the needs of women are taken into account in the design or transfer of equipment in the future requires good knowledge of the anthropometric and physical characteristics of women; participation of women at the design stage; involvement of women in training programmes; and access to credit or saving schemes to enable women to purchase any equipment.



An example of a project where the needs of women are being taken into account is the KRIBHCO Indo-UK East India Rain-fed Farming Project (funded by the UK Department for International Development, DFID). In the eastern state of West Bengal, the threshing of paddy is normally done manually and usually by women (Fig. 2). It is a long and laborious activity taking a whole day to process 100 kg of paddy. With the help of a savings and credit scheme provided by the project, a group of landless women were provided with a paddy thresher to help promote commerce and generate income. The women hire out the thresher to landowners, from which they get income. They are also able to continue with their work as daily labourers. As a result, their daily income has doubled. The landowners also benefit. They are able to thresh 400}500 kg of paddy in a day, releasing time and energy for other activities (Fig. 3) (Jafry, 1998).

4.3. Musculoskeletal injuries

Poor working conditions and the absence of an effective work injury prevention programme in IDCs have resulted in a very high rate of musculoskeletal disorders (Holmer et al., 1985; Iskandar, 1985; Bai-Hua, 1985; Shahnnavaz, 1987). Common disorders are backache and neck-ache attributable to heavy lifting, poor working posture, poor machine design and poor organisation of work (Shahnnavaz, 1987). Although reports of musculoskeletal injuries have predominated in the industrial.



Fig. 2. Manual threshing by women in West Bengal (from Jafry, 1998).

The sector of developing countries, it does not mean that these problems do not also occur in the agricultural sector. Agricultural work involves all the risk factors which lead to these injuries, including heavy lifting, carrying of water and fuel wood and unsuitable working postures. It is a neglected area of research and one that warrants considerable attention. Ergonomics intervention can reduce the risk of musculo-skeletal injury by providing information on musculoskeletal problems, how to prevent them from occurring, how to improve the working environment and how to organise work (Shahnnavaz et al., 1991). The EU (European Union) has recognised that musculoskeletal injury sustained from work can be potentially disabling and translates to a loss of income, absenteeism from work and disruption to family and home life. To ensure that the risk of injury to all employees is eliminated, or at least reduced, the Management of Health and Safety at Work Regulations (1992) came into force across the EC on January 1st, 1993 (Health and Safety Executive, 1992). Based on this, there is every reason to suppose that workers in developing countries are at risk but, more importantly, it must be appreciated that in the agricultural sector farmers and their families are also at risk and that their needs must be given similar attention (Gite and Singh, 1997).



One way to tackle this is to provide primary health care training in remote and rural areas where workers generally live far from any form of health service. In Botswana, health aiders are being trained to operate in remote areas. The health aiders are made up of men and women who live on farms and are selected by the communities with the help of the District Health Team (Selema, 1989). The aiders are taught simple methods of recognition, prevention and emergency treatment of the most prevalent health problems, for example, tuberculosis, health and safety of agricultural workers, safe use of pesticides and "first aid (Selema, 1989).



Fig. 3. Threshing using the paddy pedal Thresher (from Jafry, 1998).

5. Concluding remarks

This paper has shown the relevance and application of ergonomics to a number of important issues in rural development. Furthermore, it has shown how neglect of human-technical interactions might also inhibit development. In order to achieve sustainable development, ergonomics issues must be fully addressed alongside social and economic issues. Ergonomics has already achieved some successes in the industrial sectors in developing countries, for example, through improved factory environments, improved work organisation and improved work efficiency. The agricultural and forestry sectors in Europe and North America have also benefitted from ergonomics, through the standardisation of agricultural equipment, machine design and health and safety legislation (safe workplace design and safety guidelines). These have reduced the incidence of accidents and injuries occurring among farm workers. This, in turn, has reduced labour turnover, and absenteeism, improved work practices and increased productivity (Chisholm et al., 1992). With this sort of achievement record, there should be considerable scope for applying ergonomics to goods effect in the agricultural sector of developing countries.

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A Profound Learning-Based Object Identification Technique for UAVs

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Abstract: *To resolve the issues of existing profound learning-based complaint discovery techniques, which are computationally serious, take up a ton of memory to run and can't be sent on UAV gadgets, a simulated intelligence based shrewd recognition and recognizable proof strategy for UAV airborne is proposed. In light of the YOLOv3 object identification model and improved, the model size and number of boundaries are diminished without essentially forfeiting discovery precision. First and foremost, a PDW module is proposed in light of a depth-wise detachable convolution and lingering organization. An article location model for UAV airborne hardware with shallower network layers and less channels is planned. Proposed strategy at last assesses on MS-COCO and Vis Drone dataset. The exploratory outcomes show that the strategy has a more modest model size, less boundaries and quicker running times than the YOLOv3 organization, while keeping up with great precision, which is fundamentally better compared to YOLOv3-minuscule, and is likewise more ongoing and exact than current objective acknowledgment identification techniques.*

I- INTRODUCTION

Since the 2100 years, shrewd gadgets with functional PC vision have an extensive variety of use space and improvement possibilities. For instance, vehicle-mounted canny traffic recorder, shrewd extraction robot, smart UAV, and so on. Among them, as a delegate of cutting edge keen hardware, wise UAV has been growing its application market. It is the on-board camera and implanted programming framework on the UAV that are invested with PC vision capacities. The principal capabilities are to distinguish the kinds of articles in the scene, find the places of these items, decide the specific limits of each article, and so forth. These scene parsing capabilities relate to three essential examination assignments in the field of PC vision, to be specific picture characterization, location and acknowledgment, and semantic division. Among them, location and acknowledgment are the most essential utilitarian module, so object recognition has forever been an exploration area of interest in the field of vision [1,2]. Because of the variety of the open arrangement climate, it is challenging to examine the scene toward the front hardware of the UAV, which carries numerous troubles to the airborne objective discovery and acknowledgment calculation. The principal troubles are as follows:(1) How to manage different changes of visual appearance in aeronautical location, like light, Point, and deformation;(2) How to effectively send the objective identification and acknowledgment framework on the UAV gadget with restricted figuring power and memory.(3) How to adjust the recognition precision and constant prerequisites. Object identification and acknowledgment strategies in view of AI and hand-planned highlights are inclined to flop notwithstanding these changes. As of now, the item location and acknowledgment technique in light of profound learning is by all accounts an effective method for settling this difficulty. Driven by the advances in registering force of illustrations cards and the far and wide utilization of huge scope marked informational indexes (e.g., ImageNet and MS-COCO), object discovery and acknowledgment strategies in view of profound learning have turned into the examination focal point of an ever increasing number of specialists because of their great benefits of versatility and start to finish. As of now, there are two sorts of systems for object discovery calculations in light of profound learning: two-stage location and acknowledgment structures [3-9] and start to finish one-stage systems like Just go for it series [10-15]. Nonetheless, these objective location and acknowledgment techniques have enormous computational above and high-power utilization, which are not reasonable for smart discovery and acknowledgment of UAV airborne front-end. Hence, how to



diminish drifting point tasks (Failures), teachable boundaries, and keep up with the discovery precision of article identification and acknowledgment strategies without essentially forfeiting recognition exactness is an earnest issue to be settled. As of now, there are numerous approaches to "Thin" the item discovery model, for example, Consequences be damned minuscule, Thin Just go for it, portable SSD, and so on [16]. Thusly, this paper essentially fosters a calculation appropriate for canny discovery and acknowledgment of UAV airborne front-end as per the ongoing lightweight objective location and acknowledgment structure. Its primary commitments are as follows:(1) A lightweight organization unit: PDW engineering is proposed;(2) A shrewd objective recognition network reasonable for UAV airborne front-end is designed.(3) A model structure of savvy target discovery for automated ethereal vehicle (UAV) is proposed The leftover parts of this paper are organized as follows: Segment II presents related work, Segment III subtleties the calculation reasonable for smart location and ID of UAV airborne front-end, Segment IV is the similar investigation part, and Area V finishes up.

II- RELATED RESEARCH

2.1 Two stage The two-stage object identification technique is otherwise called the item discovery strategy in light of locale search, which matches the consideration component of the human mind, and first sweeps the entire picture all in all. Then, at that point, we track down the locale of interest (return for capital invested) in the picture. In this strategy, CNN is embedded into the sliding window technique, and the highest component map is straightforwardly anticipated by the situation to get the outcomes. The RCNN series ought to be illustrative of current two-stage object recognition strategies. Girshick et al. [3] proposed R-CNN brain organization and accomplished 53.3% Normal Accuracy (Guide) on the PASCAL VOC 2012[4] open dataset. He et al. [5] proposed another CNN design named SPP-net from spatial Pyramid Coordinating (SPM) in principle. He et al. proposed Quick R-CNN[6] in light of SPP-net, which basically further developed the organization pooling layer. Based on Quick R-CNN, He et al. proposed progressively Quicker R-CNN[7] and Veil R-CNN[8] calculations. Among them, Quicker R-CNN originally proposed the utilization of Locale proposition network for extraction. Contrasted and R-CNN, the SS(Selective Search) strategy [9] is utilized to create discovery boxes, which works on the speed of competitor box age. Albeit the two-stage technique has high exactness, it likewise requires high processing force of the sent hardware, which is challenging to be applied to the savvy location and acknowledgment of the airborne front-finish of UAV.

2.2 One stage The Just go for it series calculation [10-13] is mostly a general item location model proposed by Joseph et al., which regards the discovery issue as a relapse issue, further develops the identification speed, and acknowledges input pictures of various sizes. Consequences be damned, then again, battles with little articles. To tackle this issue, Liu et al. [14] proposed an item identification technique named SSD. It is enlivened by the Anchor system embraced in Multi-Box. (Likewise allude to the Anchor utilized in the up-and-comer area suggestion organization). Given a particular component map, there is no proper framework like the one embraced in Just go for it. SSD utilizes a bunch of default secures [15] and utilizes different perspective proportions and scales to decide the district. To manage objects of various sizes, the SSD network consolidates the result of numerous element maps with various goal sizes. Just go for it and SSD series are exemplary one-stage object location and acknowledgment structures [16]. In spite of the fact that it has a little model size, it can't be straightforwardly sent on the UAV, so we really want to utilize the model lightweight strategy to improve the one-stage object identification structure.

2.3 Model lightweight Xu et al. [17] further superior in view of Origin V3 in 2017, and proposed the profundity distinct convolution. Around the same time, the idea of profundity distinct convolution was likewise presented in Portable net, which is a strategy to scale down the organization model. The substance is to deteriorate the standard convolution into two stages. The profundity wise distinct convolution process is as per the following. We utilize the accompanying equation to work out and analyze the drifting point calculation of standard convolution and profundity wise divisible convolution. The standard convolution is processed as adheres to:

$$K_h \times K_w \times C_{in} \times C_{out} \times W \times H \dots\dots\dots (1)$$

The depthwise separable convolution is computed as follows

$$K_h \times K_w \times C_{in} \times W \times H + C_{in} \times C_{out} \times W \times H \dots\dots\dots (2)$$



The ratio of floating-point operations of depthwise separable convolution to standard convolution is:

$$\frac{K_h \times K_w \times C_{in} \times W \times H + C_{in} \times C_{out} \times W \times H}{K_h \times K_w \times C_{in} \times C_{out} \times W \times H} = \frac{1}{C_{out}} + \frac{1}{K_{h,w}^2} \dots\dots\dots(3)$$

According to Equation (3), when the size of the convolution kernel is 3×3, the FLOPs that can be depthwise separated are about 1/9 of the standard convolution. In depthwise separable convolution, it is mainly divided into two steps. First, different convolution kernels are used to convolute different depth channels, and then the standard convolution is decomposed into individual channels. These two processes combined are like the convolutions of standard convolutions, but the model has significantly less computation and model parameters. Therefore, this paper uses the improved depthwise separable convolution when constructing the lightweight and efficient backbone network.

III- OBJECT DETECTION METHOD OF UAVs

As of now, because of the advancement of elite execution processing designs cards and enormous informational collection comment, increasingly more high-accuracy object recognition models have arisen, yet the computation sum and memory inhabitation of the model have additionally expanded, and they can't be applied to the airborne front-finish of UAV. To this end, this paper plans another man-made brainpower put together brain network model based with respect to Just go for it v3-minuscule, which has lower calculation and better execution. In this paper, expanding the profundity of the organization layer empowers YOLOv3-small to extricate more extravagant convolution highlights. Nonetheless, taking into account that raising the profundity of the organization will cause enormous memory control of the organization and longer location time, it isn't reasonable for the ongoing exhibition expected by the airborne front-finish of the UAV. Subsequently, in this paper, we utilize the improved depth wise detachable convolution and lingering module to shape the spine organization. FIG. 1 shows the organization design outline of the savvy identification strategy for the UAV airborne front-end. As displayed in Figure 1, the savvy discovery network structure of UAV in the front-end incorporates two sections: spine organization and identification organization. In accordance with the objective of organization lightweight and improving component extraction capacity, we updated the essential unit of the spine organization, which is called PDW structure. The spine network comprises of one standard convolution and nine PDW structures. Through this design, multi-facet include reuse and combination can be understood, and how much computation presented by the new construction can be decreased. To distinguish objects at various distances, the forecast network comprises of two branches, comparing to yields at two scales. The accompanying article will present the contrast between PDW structure, standard convolution and depth wise distinct convolution. Fig 1

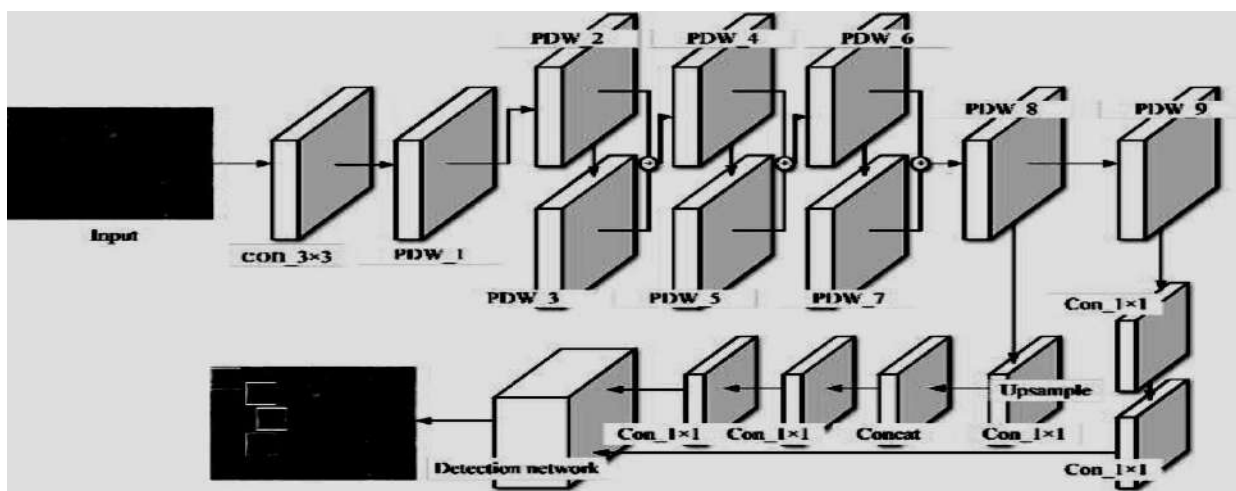


Figure 1-Proposed method model architecture



3.1 PDW structure The standard convolution is shown in FIG. 2 (a). The addition of BN layer and ReLU in the standard convolution is mainly to speed up the convergence of the model. The BN (Batch normalization) layer is usually placed between the standard convolutional component and the ReLU. The depth wise separable convolution is shown in Figure 2 (b). The improvement over Figure 2 (a) mainly lies in the use of DW convolution and PW convolution. The effect of this structure is like the standard convolution but with much lower computation.

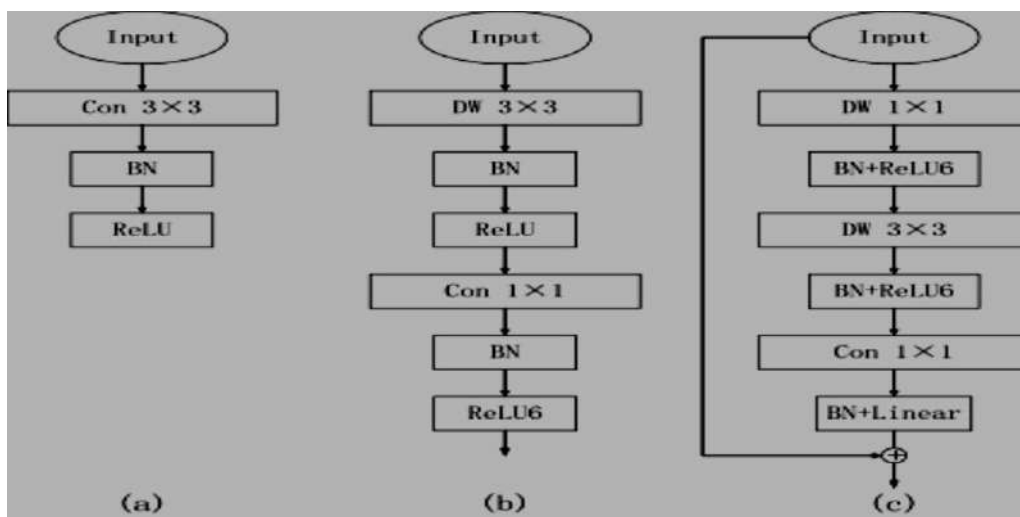


Figure 2: (a) Ordinary convolution; (b) Deep separable convolution (c) PDW structures

To the residual structure. Upgrade the proliferation of slopes. The superior construction can remove high layered include space. Simultaneously, this paper adds a BN layer after every convolution activity to accelerate the intermingling of the model. The result of the first and second steps utilizes the nonlinear actuation capability ReLU6 to make the model more vigorous in low-accuracy computations. In the third step, the result of the convolution activity doesn't utilize an enactment capability, however a direct straight result to diminish the deficiency of data. We utilize the PDW structure rather than the standard convolution of the first organization, which extraordinarily diminishes how much calculation. By expanding the quantity of channels and organization layers, we can work on the exactness of the model and make it simple to relocate to installed gadgets, cell phones, or UAVs.

3.2 Backbone network In Figure 1, n in convolution PDW_ n addresses the times the PDW structure is presently utilized. The spine network initially performs standard convolution on the information picture utilizing a 3x3 convolution bit to get convolution 1, extricate highlights, and overhaul the aspect. To improve the organization include data, we utilize the possibility of leftover, add convolutional PDW_2 and convolution_PDW_3 (where convolutional highlight maps are added, yet the quantity of channels is unaltered), and afterward keep on utilizing the PDW design to produce convolution_PDW_4. Once more, Conv_PDw_6 and conv_pdw_8 are acquired. Accordingly, the spine network has utilized the PDW structure multiple times. Then, we supplant convolution and Max pooling with convolution with a stage size of 22. This permits us to keep the quantity of boundaries unaltered and overlook the calculation associated with Max pooling, which is 1/4 of the first organization.

3.3 Detection Network The expectation network comprises of two branches comparing to two sizes of result. The main branch yields a $13 \times 13 \times 18$ convolutional include map. When the convolutional highlight guide of the spine arrives at Conv_PDW_8, the subsequent branch is created in equal. The subsequent branch is combined with the $26 \times 26 \times 64$ result of the primary branch, bringing about a last result of $26 \times 26 \times 18$. We utilized the k-implies bunching strategy to work out six anchors for the current dataset: (50x66), (74x99), (91x125), (113x154), (140x190), and (220x284). K-implies utilizes the Euclidean distance. In the spine network yield, the initial three anchors are utilized for 13×13 convolutional highlight maps, and the last three anchors are utilized for 26×26 convolutional highlight maps. For 13×13 and 26×26 results, every boundary incorporates x, y, w, h, certainty, and likelihood.



4.1 EXPERIMENTAL SETTING We used many environments and tools for image recognition and detection in the experiment, as shown in below Table:

S. No.	Projects	Details
1	Operating System	Linux Ubuntu 18.04
2	Computing architecture	CORE i7-9750h + NVIDIA GTX 1080 T _i
3	Framework	Pytorch
4	Image Processing Framework	Python 3.7 , Open CV 3.0

4.2 Datasets Microsoft Common Objects in Context (MS-COCO)

Dataset:MS-COCO dataset is an image classification, image detection, and image segmentation dataset built by Microsoft team. The dataset has the following characteristics: (1) Object independence (2) Context recognition (3) multiple objects per image (4) Over 300,000 images (5) over 2 million instances (6) 80 object categories.

VisDrone dataset: The VisDrone dataset was collected by the AISKYEYE team at the Machine Learning and Data Mining Laboratory of Tianjin University. The benchmark dataset consists of 400 video clips consisting of 265,228 frames and 10,209 still images.

4.3 Experimental results of UAVS To guarantee the practicability of our calculation, YOLOv3-minuscule is chosen as the examination calculation in this paper on the UAVs informational index, and YOLOv3-small article discovery calculation is applied to UAV front-end location and acknowledgment to contrast and the calculation proposed in this paper. In this examination, we set that just when the IOU between the identified objective and the genuine named target is more prominent than 70%, the discovery and acknowledgment task is finished, in any case it is as yet treated as disappointment, and afterward the review rate and precision rate are determined to acquire the exact F-measure. The experimental results are shown in Figure 3:

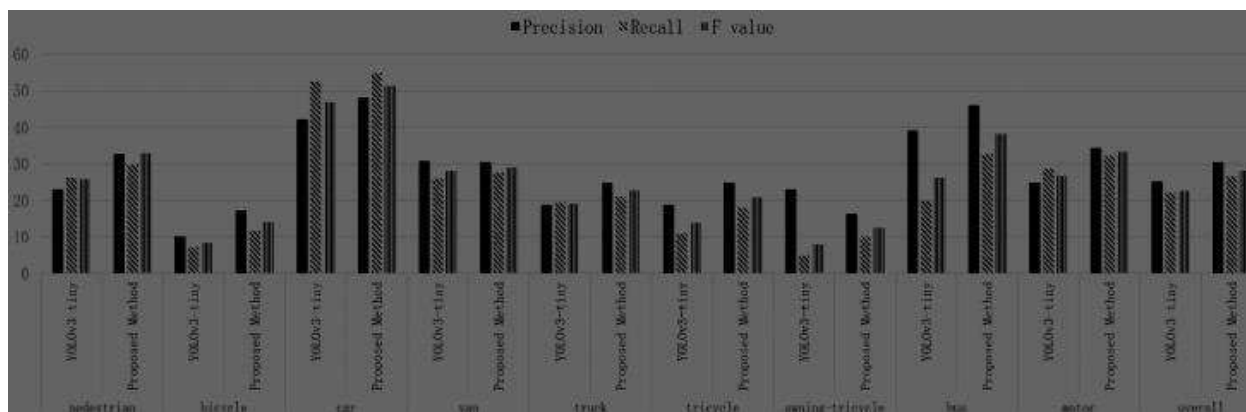


Figure 3: Performance of the YOLOv3-tiny algorithm and proposed method detection result

Compared with the YOLOv3-tiny method, the proposed method has improved the precision recall rate and F value under various categories. From the comprehensive results, the F value of the proposed method is 5.6 percentage points higher than that of the YOLOv3-tiny algorithm. In general, the proposed method has higher accuracy than the original YOLOv3-tiny method, and has higher accuracy in recognition and detection of this data set.

V- CONCLUSION

Because of the enormous measure of computation, model boundaries and memory utilization of the ongoing objective location technique in light of profound learning, it can't be effectively conveyed to the UAV for target discovery assignments. To tackle this issue, this paper accepts YOLOv3 as the base calculation and further develops it, and



proposes a UAV discovery technique in light of man-made consciousness. In this paper, the principal commitments are as follows:1) A PDW structure is proposed to lessen the issue of enormous measure of information and high estimation of conventional convolution structure;2) A superior organization structure in view of YOLOv3 target acknowledgment and recognition network is given.3) The proposed strategy is checked on various informational indexes and contrasted and the current techniques. It tends to be acquired that the proposed technique has higher ongoing execution and exactness than the ongoing objective acknowledgment and identification strategies.

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An Electric Vehicles (EV): A Review

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Abstract: *Electric vehicles (EV), as a new way to reduce the pollution and greenhouse effect, have been researched extensively. With research in the areas of power electronics, electric storage and support, the plug-in hybrid electric vehicle (PHEV) provides long driving range and fuel saving compared to the IC engine vehicle (ICEV). Operating with optimized control strategies or utilizing the concept of the energy management system (EMS), the efficiency of the hybrid electric vehicle could be improved.*

In this review paper, the operating process of the various types of EVs will be understood. Battery technology and super-capacitor technology will also be discussed as a possibility to increase the energy efficiency of PHEV.

Keywords: *EV, PHEV, IC Engine, Battery*

1 Introduction

The issues of greenhouse effect have been rigorously discussed by many countries since the early 21st century. A large number of reports have revealed the negative impact of environment dominantly driven by human work. With the worldwide increasing civilization and industrialization, a large number of fossil fuel or conventional fuels burnings in industries have led to the acute problem of climate. Simultaneously, the waste emissions from automotive vehicles as smoke cannot be neglected. IC Engine vehicle emissions, which mainly include CO₂, CO, NO_x, S and particulate matters (PM-10 and PM-2.5), have been considered as the large contributors to the effect of greenhouse gases or climate effect, also leading to the increase in different forms of serious illness and other serious diseases.

Now days, rapidly growing transportation sector consumes about 51% of oil resources. Following the oil consumption and crude oil sources, As per the direction of oil companies, oil resources are predicted to be depleted by 2040. Therefore, replacing the conventional energy resources with renewable energy sources and use of these energy-saving technologies seems to be needed. Electric Vehicles (EVs) as a great solution for solve the traffic-related environmental problems have been investigated and studied extensively compared to ICEV, the attractive features of EVs mainly are the power source and drive system.

1.1 Classifications of electric vehicle

Electric Vehicle could be classified into 3 different types: complete electrical vehicle/Pure electrical vehicle (CEV/PEV), hybrid type electrical vehicle (HEV) and fuel cell electrical vehicle (FCEV) Table 1 describe a brief classification of different EVs. The complete electrical vehicle is purely driven by electricity from the power storage unit, while the propulsion of PEV/CEV is totally provided by an electric motor. The driving system of HEV combines the electric motor and the IC engine, while the power sources involve both electricity and gasoline or diesel. FCEV is driven by an electric motor and could be directly or indirectly powered using hydrogen, methanol, ethanol or gasoline.

Table 1 Comparison of different electrical vehicles

Types	CEV/PEV	HEV	FCEV
Drive Section	Electric Machine	Electrical machine, internal combustion engine (ICE)	Electric machine
Energy Resources	Battery, Ultra-capacitor	Battery, ultra-capacitor, ICE unit	Fuel cell
Energy Supplements	Electricity and power system	Electricity and power system, gasoline station	Hydrogenate



In PEV, loosely named as battery operated electric vehicle (BEV), energy storage capacity is fully depends on the battery technology. No discharge emission of PEV should be significant advantage/benefits because the electrical energy is completely supplied from the vehicle-mounted batteries. On the other hand, the disadvantages on the present status of the chemical battery technology of PEV make it disgusting than ICEV under the same economic and driving requirements. Batteries having high power densities but low energy densities result in more charging time – even with fast charging technologies, one hour to several hours for full charging is necessary because of trickling charges in last 5%. Thus, main challenges of the PEV are limited driving range, high charging time, high initial cost and lack of charging infrastructures. As far as practical consideration, the size and location of the battery inside the PEV should also be standardized.

FCEVs are attractive because of zero emissions on roadside. Considering the overall emissions into account, which incorporates the emission from industries and on-road vehicles, the FCEV seems still competitive. Fuel cell (FC) is the main power supplier and the advance technology for FCEV is an electro-chemical device that produces DC energy from a chemical chain reaction. There are five major components in FC: an anode, an anode layer, electrolyte, cathode and a cathode catalyst layer. It is suitable parallel/series connection of FC sources; the total amount of power can be generating to drive the car. As far as car reaches, it is identical to ICEV, thus applying in a wide range of application of FCs from small scale plants of the order of 220 W to power plants of the order of 500 kW. However, the initial cost is very high and shortages of refueling stations are still regarded as more challenges for the success of FCEV. Also, the supply of electricity continues of FCs is not more reliable than conventional battery which is used in EVs.

The major benefits of BEV and FCEV are the ‘zero emission’ and hence reduced green house effect/ air pollution. However, the ‘zero emission’ of BEV and FCEV is not exactly in view of the emissions during the whole processing. Then, “what are the main contributor of pollution and how?” it is mainly discussed. For example, the contributors of pollution involve chemical contamination of chemically chain reaction, when producing the fuel cell and the battery, the less emissions during the vehicle manufacture and the major pollution from scrap battery process, etc.

The HEV considering the combines effect of properties of ICEV and BEV. Vehicle driving power sources of HEV considering both gasoline/diesel and electricity; the propulsion accelerate the engine and electric motor. According to different refueling or recharging measures, HEVs may be described as either conventional HEVs or grid-able HEVs. Based on levels of the combination, the conventional HEV may be advance developed to 3 types: micro, mild and full HEV. The grid-able HEV should be either plug-in hybrid electric vehicle (PHEV) or may be extended range of electric vehicle (REV). Figure 1 shows different classifications of EVs based on the energy source and propulsion device.

Figure 1 Classification of EVs

Energy Source	Vehicle Type	Propulsion
Electricity	ICEV	Electric Motor
	Micro HEV	
	Mild HEV	
	Full HEV	
	PHEV	
	REV	
	PEV	
Hydrogen	FCEV	

As both energy sources (i.e. electricity and petrol) propel the HEV, the driving range of HEV is more then compare to that of ICEV. The economics of HEV seems to take more benefits than PEV due to the current status of present battery technology. However, the need for the engine and gasoline is not removed in HEV – so there is no zero emission in HEV. The combine effect of electric generator and engine increases the designing of the manufacturing process and the initial product cost. So that, the new challenges for HEV are focusing on concentrate on these two propulsion devices to achieve maximum efficiency while reducing the design complexity at the same time. Going to the overall development of



Electric Vehicles and considered both factors economy and the technology, HEV has the most viable to develop and dominate the next few years.

Taking the both energy sources into account, Electric Vehicles are fully or partially energized from the batteries, which themselves charged directly or indirectly from either a power source and/or electro-chemical reactions. Therefore, the various types of renewable energy sources (like Solar, Wind, Noise, etc.) should be used to improve the overall emission of EVs. Figure 2 described the energy diversification based on different feeding measures for the EV.

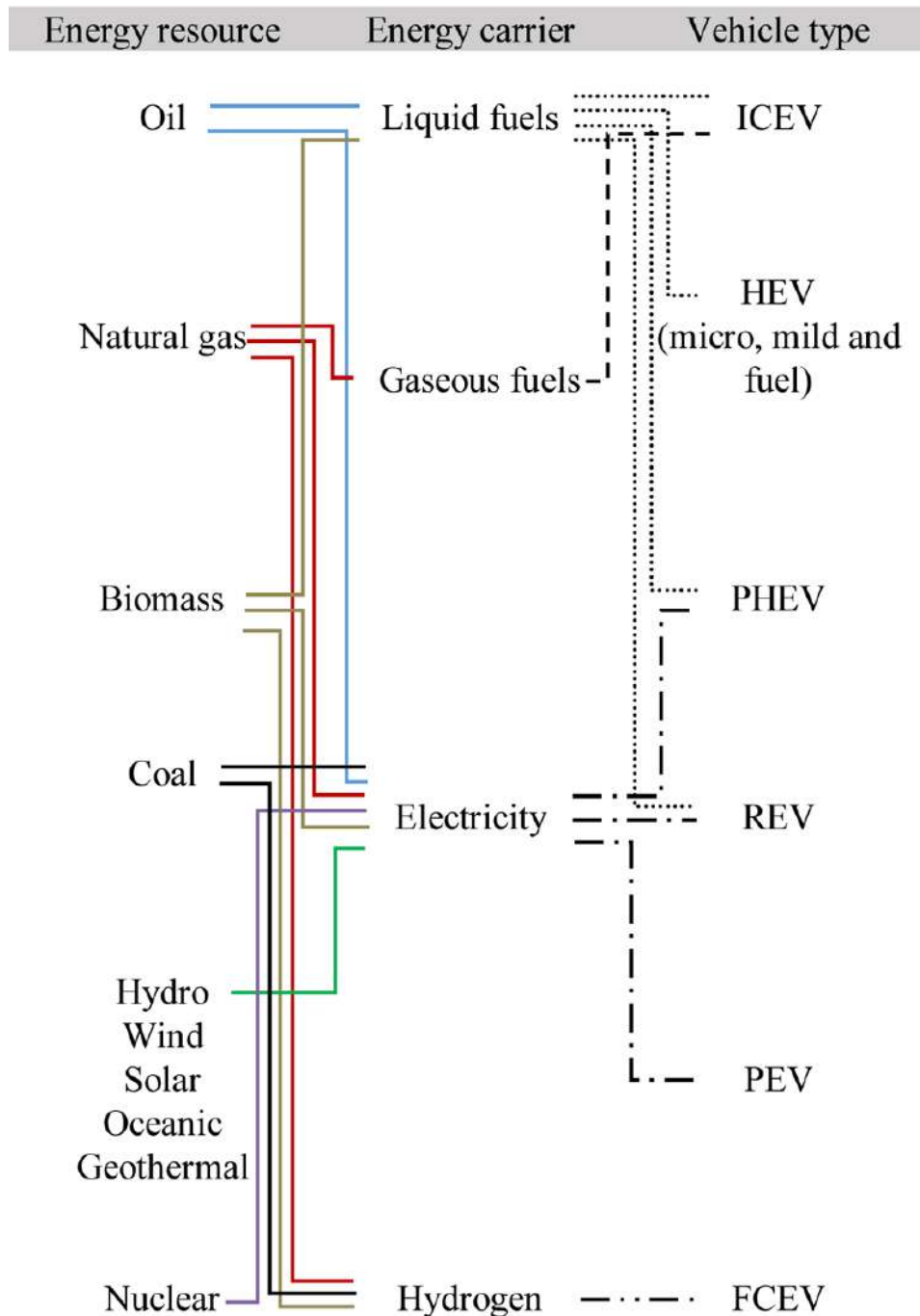


Figure 2 Energy diversification of EVs (see online version for colours)

2 Technologies of hybrid electric vehicle

2.1 Conventional HEV



2.1.1 Micro and mild HEV

Based to the proportion of the final power from the electric motor, HEV divided into micro, mild and full HEV modes. On comparison with ICEV, the micro-HEV starts the engine from starting motor with a belt-alternator start generator (BSG). The BSG may be neglects the idling of the motor and simultaneously low the consumption of petrol. The micro-HEV could not be classified as a hybrid electric vehicle because the electric motor does not produce a continuous power. In mild HEV, the conventional starting motor (engine) is replaced by integrated starter-generator (ISG) that is situated between the engine and the transmission. As compare, the size of the engine is small since ISG assists the engine to accelerate the vehicle. One of the noble examples of mild HEV is Buick Lacrosse, developed in 2006. The working principle of mild HEV is summarized as follows: when the vehicle is starts, electric generator comes active whenever the petrol engine is off. Subsequently, all the working equipment will work on the electric motor. As the brake pedal is released and the vehicle is speed up, the petrol engine start and continuously gives the entire propulsion on fast speeds. These processes bring out in a significant feature: the engine should be closed down once the vehicle slow down, which is known as an idle stop-start feature. The battery is principally re-energized when the vehicle is either decelerating as well as slowing down. The design of ISG requires both engine and electric motor to work cooperatively when fast acceleration is required. Honda CR-Z is one of the most regular delegates for mild HEV.

2.1.2 Full and dual-mode HEV

For full HEV, the major technology is the electric variable transmission (EVT) which is moreover operated as a power splitter. Power splitting givend by EVT gives access to electric launch which refers to the underlying acceleration under electric power only. It keeps up almost all of the benefits of different types of regular HEVs such as idle stop-start, regenerative braking, smaller-size engine and electric launch. Toyota Prius embraced the full HEV mode in large scale manufacturing in 1997 and further improved by adding a planetary gear to help the power splitting. After an effective design and adoption of hybrid power system existing in the vehicle market, an extraordinary number of engine organizations are committing to form it into more fuel-monetary and climate cordial status. Lexus LS600HI worked on the full hybrid mode and has accomplished 'real zero emission starting'.

To additional location the issue of fuel utilization during start, stop and restart in an urban region, dual-mode in view of full hybrid electric vehicle system is introduced to improve the overall efficiency. 'Dual-mode' implies that the hybrid system and electric motor collaborate effectively to accomplish a premium performance under the conditions of quick acceleration and full speed. The new generation motor of Lexus ct200h and BMW x6 are extra ordinary models to recognised and accepted by the public. It is important to make reference that dual-mode has contributed not exclusively to conventional HEV technologies but also to some module HEV technologies. Conventional HEV advancements have been investigated widely and have vastly improved. When conventional HEV system created from micro and mild modes into the full mode, the working characteristics of the vehicles have changed. The micro and mild conventional HEVs give need to gas/diesel machine while electric generator or battery goes about as auxiliary device. In contrast, the full or dual-mode HEV uses electricity as the principal energy to propel the vehicle. Right now, HEV has taken a dominating position. Although conventional HEV can be improved in dual-mode or full HEV to build the driving range and efficiency, the drawbacks of burning gasoline/diesel, heavy battery pack and high starting expense can't be ignored.

Moreover, the complexity of the manufacturing process could be another challenge. In this manner, traditional HEV is yet inappropriate when taking into consideration issues, for example transmission loss, gear noise and lubrication. In any case, it should be pointed that HEV has been considered as 'high starting cost' system by researchers. In any case, these examinations that recorded the 'high initial cost' as the primary disadvantage had almost no information about the cost of different segments, such as the cost of establishing the EVs' production line, the expenses of maintenance and expenses of building the refuelling or recharging facilities.

2.2 Grid-able HEV (PHEV)

Contrasted with the decent measure of power from the battery pack in traditional HEV, grid-able HEV can be straightforwardly associated with the power networks. Specialists have concentrated on the grid-able HEV, named as PHEV, for a really long time. By and large, the valuable change in PHEV is to change the proper battery pack (utilized in conventional HEV) with rechargeable battery-powered batteries. These outcomes in re-energizing the battery from an



outer power source and simultaneously speed up in the electricity capacity. PHEV can give a more extended pure electric driving reach like both PEV and ICEV.

Despite the fact that it is created from regular HEV, the working mode of PHEV considerably differs from traditional HEV. The traditional HEV is gasoline subordinate, and that implies the power from the battery and generator help somewhat for the motor. Running against the norm, power from the battery-powered battery will be a main part in PHEV while the fuel engine is kept up propulsion unit.

3 Plug-in hybrid electric vehicle technologies

3.1 The propulsion motor technology in PHEV

3.1.1 Connecting status of motors in PHEV

There are three kinds of hybrid systems based on various connections between ICE (engine motor) and electric generator in PHEV – parallel connection, series connection, and series-parallel connection. The series PHEV is straightforwardly determined from the power delivered by ICE to the electric generator and the battery. The power goes through a control unit, which will drive the electromotor and will change over into motor energy.

Figure 3 illustrate the series system in PHEV. In the series connection, the function of the battery should be adjust and maintain a stable between the engine and the electric generator.

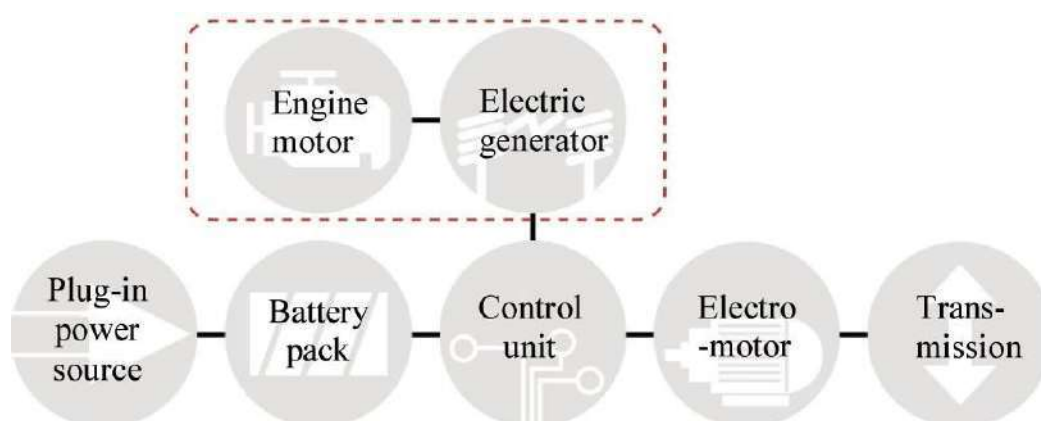


Figure 3 Series connecting system of PHEV (see online version for colours)

There are two arrangement of driving framework in parallel connection: Conventional ICE system and electric motor system. These two frameworks could either drive the vehicle own or propel in cooperation. The benefits of the parallel connection are simple in development and lower initial cost. Honda Accord and Civic take on the parallel HEV mode. Figure 4 shows the parallel connection method of PHEV.

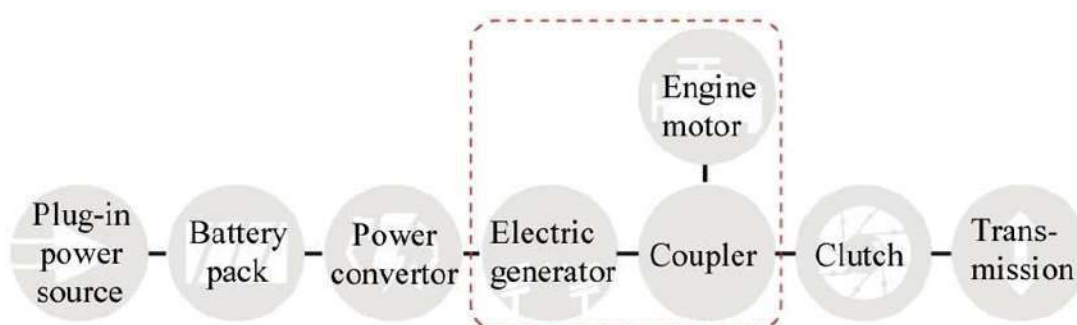


Figure 4 Parallel connecting system of PHEV (see online version for colours)



The major feature of a hybrid system with the parallel-series connection is that both IC Engine and electric motor drive the system at the same time. They keep up with their own arrangement of precisely factor speed organizations independently. The two systems are connected with one another through a gear train or a planetary wheel structure. Subsequently, PHEV extensively manages the speed connection between the ICE and the electric engine. Compared with the parallel hybrid system, the series-parallel hybrid system is adaptable to change the output power from ICE and electric-motor as per different working conditions. Figure 5 shows the blended transmission of mechanical energy and electric energy in series-parallel PHEV.

3.1.2 Electromotor selection for PHEV

There are two critical factors impacting the determination of the motor for PHEV: driver expectation and vehicle imperatives. The driver expectation is characterized as driving profile, which addresses five attributes: speed increase, maximum speed, climbing limit, braking, and the driving reach. The vehicle imperatives refer to vehicle type, vehicle weight and payload.

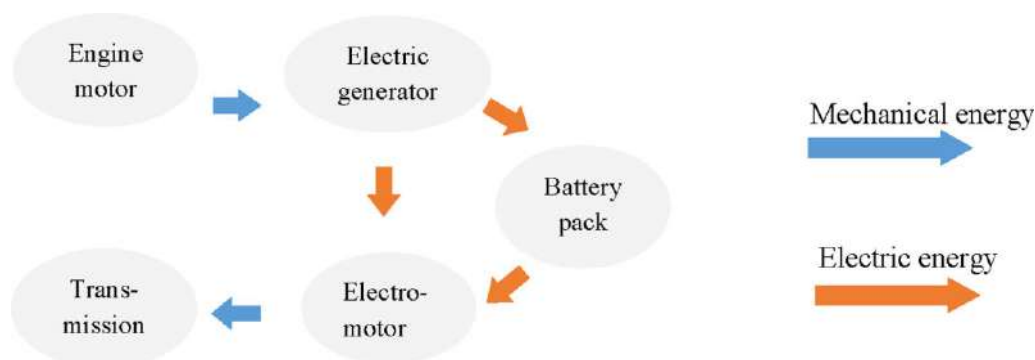


Figure 5 Parallel connecting system of PHEV (see online version for colours)

A few kinds of electro-motors could be utilized in PHEV for various performances. Concerning functional simplicity, direct current (DC) series motor is appealing however experiences unfortunate ability to weight ratio. Higher ability to weight ratio shows in DC brush-less motor, which likewise has a high effectiveness of ~95%.

For support free activity, alternate current (AC) induction motors appear to be an appropriate choice with minimal expense and high unwavering quality. The inherent drawback of related motors, notwithstanding, is the difficulties in speed control. The high speed activity capacity has been demonstrated in switched reluctance motors.

3.2 Range-extended hybrid electric vehicle

One of the disputable issues in the research of PHEV is the range-extended hybrid electric vehicle (REV). In this paper, we characterize REV as an EV that allots an additional small-size engine, known as the range-extender, combined with the electric generator to recharge the battery pack. As far as grid-ability, REV configures the charging socket that permits charging from external power source. In other words, REV is developed as a serial mode PHEV. The working mode in REV is based on PEV with an auxiliary power unit.

Normally, the measurable information indicates that 90% urban driving range is lower than the range of 60–70 km, while the everyday driving range more prominent than 100 km is under than 5%. To cover the 5–10% of the occasionally longer driving range (>100 km), the vehicle must be designed with excess than 150 kg battery bank, which utilizes Li-ion battery to give almost 160 km driving range. This outcomes in diminishing the efficiency. Such difficulties have limited the PEV and full or dual-mode HEV also. The design of REV, however, incorporates the benefits of both EV and HEV to



use the range-extender to recharge when the battery runs low. It is important to specify that the range-extender just helps battery without providing any propulsion. GM Chevrolet Volt successfully presented REV technology, which keeps 64 km pure electric driving range with 16 kWh capacities and a 1.4 l four-cylinder engine. Essentially, the plan of Audi A1 REV utilizes a 15 kW spin motor as the APU when the pure electric driving range is 50 km and the battery limit is 12 kWh.

4 The energy mechanism in plug-in hybrid electric vehicle

Based on the parts utilized in EV, the internal energy transfer mechanism can be portrayed by three basic units: energy source, electric power (converter/inverter), and energy storage. The energy source is considered as the provider or an energy transfer mode to help the running of the entire system. The energy storage ought to be a huge part of storing the excess energy (regenerative braking and recharged electricity) and keeping up the system when confronting a greater energy demand. Different converters channel the extension between each every part from the energy source to storage. In terms of operating regulations, the condition of charging (SOC) will be a basic innovation for HEV.

4.1 Energy resources model in HEV

4.1.1 Battery model

For HEV, three kinds of energy sources modes can be utilized. The lead acid battery, which is generally used in HEV, gives propulsion. Basically, the qualities of battery firmly impact the SOC, like battery capacity, temperature, and lifecycle. Figure 6 shows three typical battery models – an improved simple battery model, mathematical model and dynamic battery model.

The improved simple battery model comprises of a constant resistance and an ideal voltage source in series. R_1 , R_2 and R_3 with C_1 , C_2 and C_3 replace the constant resistance with a variable resistance to act as the internal resistance.

The mathematical model (Figure 6(b)) has been created by Salameeh et al. (1992) to consider about the temperature dependence. The mathematics model takes the voltage and current drops separate among internal and over-voltage resistances for charging into account. The dynamic model (Figure 6(c)) presents two real-time blocks that give a reasonable practical discharging current and the battery energy I_{bat} and E_{bat} , respectively. This block additionally incorporates the battery temperature data real-time updating.

The battery model can be applied to different classifications; the most well known application is the polymer Li-ion battery, which starts from the lithium-ion battery with a polymeric material electrolyte replacing the natural dis-solvable. The storage capacity limit of a polymer Li-ion battery is 150–190 W h kg⁻¹, while the power density range is from 300 W kg⁻¹ to 1500 W kg⁻¹. An extraordinary number of test system models have adopted polymer Li-ion battery (TCL PL 383562) in simulation concentrates on that include the dynamic battery model. With the improvement of the battery technology, zinc-bromide batteries are generally acknowledged in vehicular applications due to higher energy densities (approximately 300 – 600 W kg⁻¹). Compared to different batteries, the electrode of the zinc-bromide battery prohibits chemical reaction in the charging process. It acts as the medium for zinc metal plating – zinc is broken down in the electrolyte during the discharging process. Simultaneously, the lifecycle of the zinc-bromide battery is higher than other conventional batteries. For example, the lifecycle which includes the charging and discharging times of nickel-cadmium (Ni-Cd) rechargeable battery is around 500, while zinc-bromide battery could be charged/discharged 1000–1500 times. The Ni-Cd battery model, to act as an illustration for a battery model showed in Figure 6(a), has been studied with the mimicked information by several researchers. The Ni-Cd model, however, is not great for vehicular executions since the ‘memory effect’ adversely influences the lifecycle when the battery is not totally depleted during the discharging process.

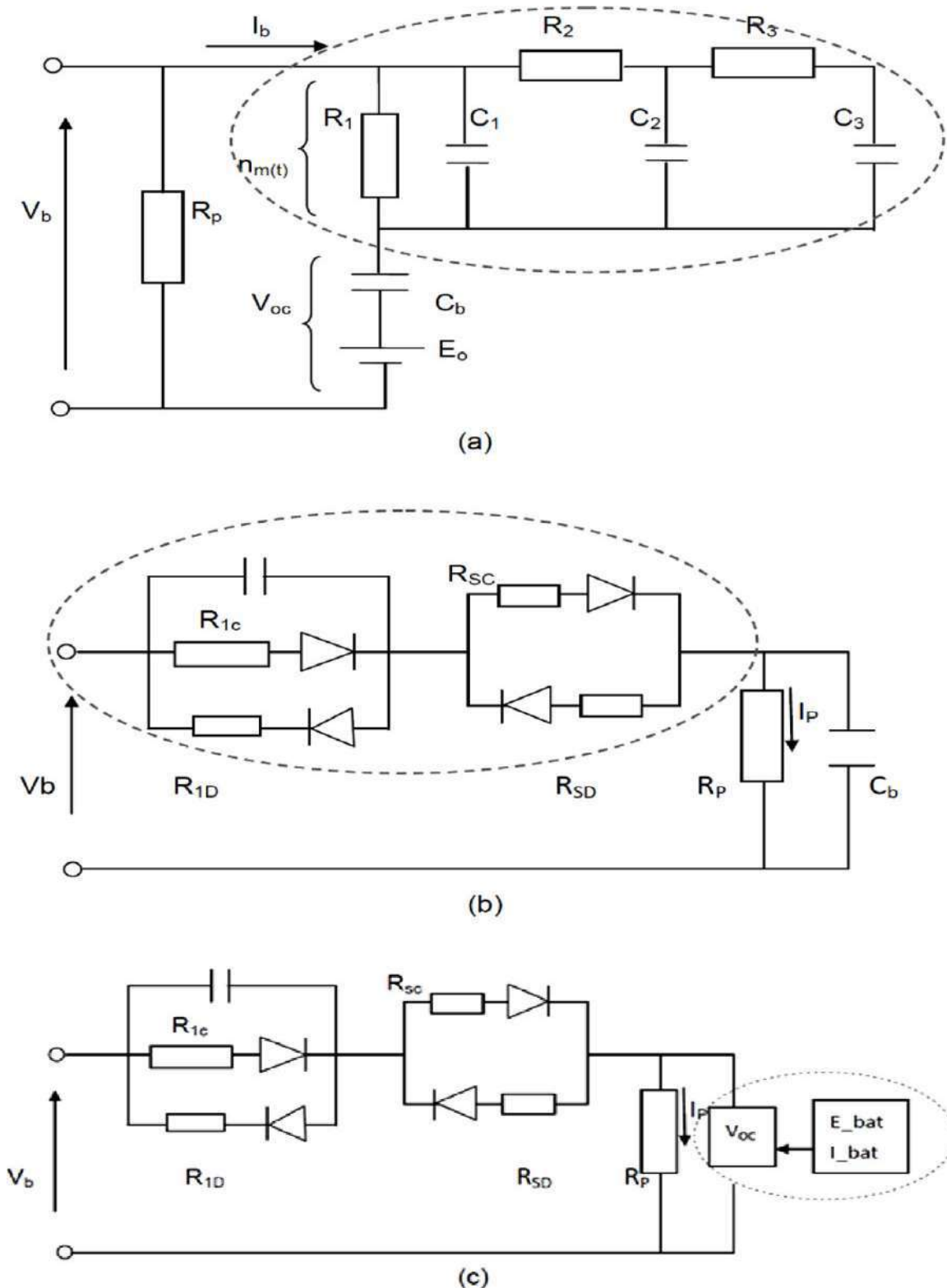


Figure 6 (a) improved simple battery model; (b) mathematical model and (c) dynamic model

4.1.2 Fuel cell model

Hypothetically, a single FC can deliver around 1.23 V under ordinary working states of 25°C at 1 atm pressure). FC depends on pure chemical reaction and 4.1.3 Photovoltaic model The major rule of the sun oriented cell is using the semiconductor sun based cell to deliver power (DC) by engrossing the energy from the solar radiation. An large number



of studies have shown different huge qualities of photovoltaic which include the I-V curve, current/voltage output, effects of temperature and irradiance, sun powered collecting studies, and so on.

In summary, contrasted with FC and PV models, the regular battery model is to be relatively mature like industrial processing. For the financial reasonableness, the battery model is likewise appealing in light of the fact that the high beginning expense of FC appears to be as yet unsuitable. One more test for FC model could be an absence of refilling station/power bank or to the station to trade FC model. For PV model, the sunlight based vehicle leave is unequivocally required, which could likely be the principal re-energizing technique. All the while, innovations to further develop the PV effectiveness are likewise fundamental, for example, the maximum power point tracking (MPPT). The interests in PV and FC models could represent a huge trouble for enormous scope execution.

4.2 Energy storage technology of super capacitor in PHEV

Regarding energy storage technologies, super capacitor (SC) or ultra-capacitor can be an appealing choice to expand the capacity limit. Contrasted and other capacity devices, SC gives higher power densities. SC likewise shows a more extended charge/release lifecycle (multiple times), while the lead-acid and lithium-ion batteries have a normal lifecycle of 1500 and 2500 times, individually. The SCs are impacted by the working temperature, the depth of discharge and the quantity of discharge times. Research likewise demonstrates that SC keeps a high effectiveness of around 90%. The properties of least intensity of heat loss and great reversibility are additionally considered as benefits of SC. Nevertheless, the drawback of SCs is the low energy density. A few ventures and organizations have created numerous new innovations and materials for SCs to further develop their energy densities. Exploratory information has shown that the SCs possibly accomplish more than 400 W-h/kg, comparable to the energy densities of lithium-ion batteries. Moreover, the high charging rate of SCs can build the effectiveness of regenerative braking.

4.3 Power electronics technology in PHEV

The power electronics describe to converters and inverters – AC/DC converter, DC/AC inverter, AC/AC, and DC/DC converters executed in various scenarios. To improve the work reliability and steadiness of the internal system in EV and HEV, DC/DC converter ought to be a huge component. In terms of mileage, it is feasible to include a power electronic system. For a PHEV, the characteristics of the power electronic system are critical for effectiveness, which incorporates different features depending on choices of power semiconductor devices, converters/inverters, controlling techniques, packing strategies for individual units, and the coordination of the whole system.

Recent research has uncovered that buck converter, boost converter, and cuk converters have been created with present day in advance, both concerning of packaging and integration. With the utilization of such DC/DC converter advancement in different vehicular situations, the prerequisites on high-frequency, high-voltage operations, high working temperature, high wave current capability, and low equivalent series obstruction to be tended to. A few examinations have presented a multilevel converter coupled with the cascaded cell for higher drive interest to coordinate the super capacitor to improve the efficiency and the energy capacity.

4.4 Internal energy management in PHEV

The internal energy management demonstrated for PHEV system is not quite the same as the EMS for the whole system that incorporates the charging processing from a power station or smart grids. The meaning of internal energy management for PHEV in this paper is an streamlines system to accomplish the best control on the energy transmission. Firstly, it is important to introduce a vital function of SOC. As a basic segment in HEV, SOC is an association between the energy source and the energy storage system. Taking an illustration of the super-capacitor in HEV or PHEV, the SOC can be communicated as follows:

$$SOC = \frac{V_{sc,oc} - V_{sc,min}}{V_{sc,max} - V_{sc,Min}}$$

where $V_{Sc,OC}$ is the open circuit voltage of SC,

$V_{Sc,max}$ and $V_{Sc,min}$ are the maximum and minimum open circuit voltages, respectively.

In a reasonable or pragmatic situation in HEV, the plan of SOC is as per the following: the battery is keeping up with when SOC is generally steady (charge-supporting mode). At the point when ICE is ruling or during a regenerative



slowing down, the battery is just re-energized from installed power (charge-draining mode). These two modes ought to be worked synergistically in PHEV.

In view of the plan of SOC, control methodology is likewise a critical issue for working on the proficiency of inner energy the board in PHEV. For instance, the energy source model of a PHEV embraces a FC model - all the while the energy stockpiling model purposes SC. Figure 7 shows the energy the Energy management System (EMS) working techniques.

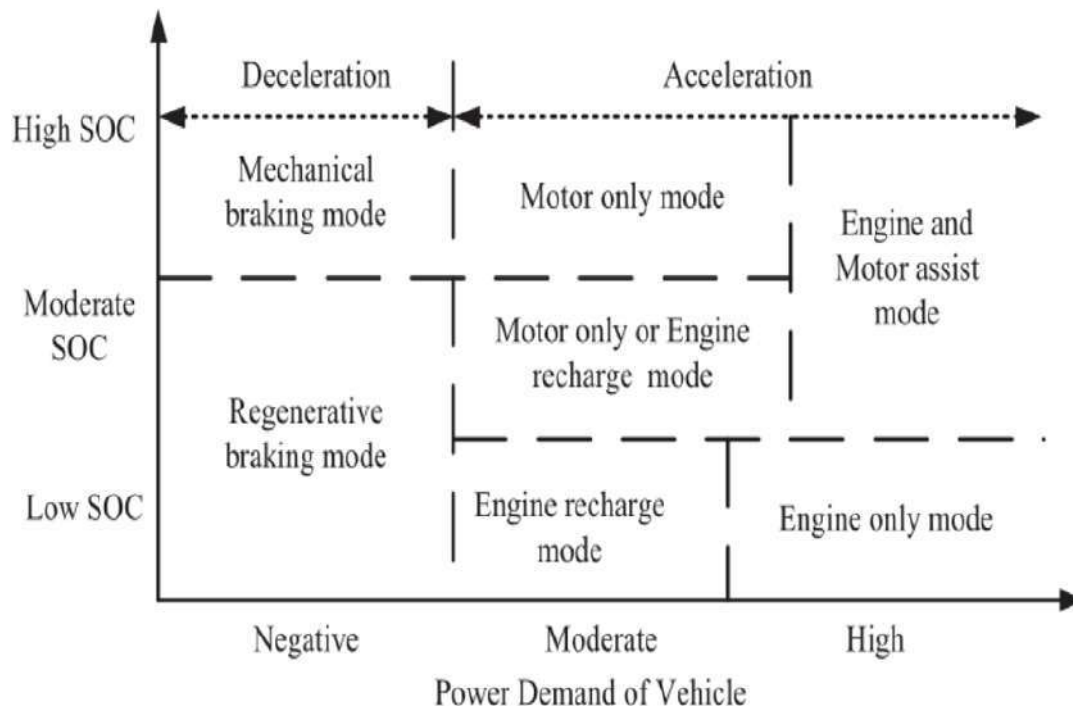


Figure 7 PHEV energy management system operating methods

4.5 Summary analysis on the PHEV

To minimize the pollution problem and to postpone the depletion of non-renewable energy sources, there is an urgent and immediate requirement for replacing the ICEVs with EVs. All reviews inspected so far, however, fail to significantly improve the vehicular functions and driving experiences for different types of EVs. A crucial issue is the battery innovation.

If the battery technology could accomplish adequate energy densities and keep up appropriate power densities at the same time, the utilization of BEV and FCEV will significantly increase. Accordingly, the conventional HEVs have taken on sophisticated and complex vehicle-mounted systems at the expense of dramatically increasing the initial cost.

The PHEV is appealing a result of specialized forward leaps in battery-powered battery innovation. PHEV further develops power limit involving module charging to give nonstop power. With the extra utilization of ICE and the outer power supply, the size and weight of the battery could be considerably diminished and furthermore decrease the expense. The issue looked by PHEVs is the advancement of inner resources. As far as internal operations, PHEV could accomplish the ideal effectiveness through establishing or changing a progression of working standards of ICE, electric generator and the battery packs.

Another test is on the EMS for outside power sources. The issues of the ideal frameworks for the organizations for charging stations in different conditions ought to likewise be addressed. Assuming it is feasible to develop an internal resource optimization system and the EMS simultaneously, the PHEV addresses a huge portion of the issues for the transport system, even with the limitations that right now exist in current battery advancements.



5 Conclusion

The features of EVs have been reviewed in this paper. The PEV and FCEV exhibit the most potential to reduce the pollution and green house effect. However, the PEVs have been restricted by the lack of current battery technologies, while the use of FCEVs show reduced reliability. For the different levels of the conventional HEVs, the driving EV seems very close to the ICEVs. However, the problem on the high initial cost and heavy weight are unacceptable for the current market situation.

The hybrid electric vehicles have most advanced current technologies and important contributes to the environmental savings. PHEVs are considered as prospective candidates to compete with ICEVs in terms of driver experience, driving range, efficiency and fuel economy. In this research shows that super-capacitor, having high electricity capacity, likely to be very appropriate for applying in PHEV. To reduce the total cost in BEV and PHEV, advanced materials and technologies should be explored and researched. The power electronics innovation expected for the internal energy transmission ought to likewise be explored to work on the overall efficiency.

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Microwave Processing of Metallic Material

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Abstract -Processing of metallic materials using microwave energy has been a challenge. However, exploiting the size factor of particles in these candidate materials opened up further opportunities. The amount of heat evolved inside a particle per unit volume primarily depends upon its size, shape, electromagnetic and thermal properties. Finer particles can potentially absorb more microwave energy than coarser units and get heated rapidly with higher uniformity. It results in better properties in the processed part and energy economy. This work reviews the relevant literature and summarizes fundamentals of microwave heating of metallic materials. Roles of particle size in processing these materials have been discussed. Challenges in microwave processing of finer metallic particles have been identified; opportunities for future research are outlined.

Keywords- Microwave–material interaction; size effect; metallic materials; composite; heating uniformity; sintering; joining; cladding

Introduction

The need for improved material processing techniques has been on the rise owing to stringent product specifications and enhanced perception of the customers about product quality. Consequently, there has been a continuous endeavor to improve the existing processes or develop advanced material processing techniques. Microwave energy-based material processing techniques are advanced processing techniques that work on the principles of heat generation at atomic level rather than heat transfer [1]. Heating effects in a material due to microwave–material interaction were first observed in the year 1946. Studies revealed that the use of microwave energy in material processing is a better alternative for heating applications due to more uniform and rapid heating characteristics of microwaves than the conventional energy sources [2]. In the past few decades, there has been a surge in the literature of microwave processing of the characteristically different materials. The popular materials which were processed using microwave energy include food stuffs [3,4], chemicals [5,6], polymers [7,8], ceramics [9–12] and metallic materials [12,13]. Due to its eco-friendly and rapid heating characteristics, microwave energy caught the researchers' attention in processing engineering materials (such as metals, ceramics, polymers and composites).

The first work on microwave processing of the metallic materials was reported in the year 1999 by Roy et al. while sintering metallic powders using microwave energy at 2.45 GHz [14]. Latter, it was demonstrated by many researchers that the metallic powders couple with microwaves well due to higher surface area and offer rapid heating of green compacts as compared to conventional sintering [12,13]. Currently, microwave processing of the metallic materials is gaining fast popularity and microwave-based processes like heating [15–24], melting [25–28], casting [29–34], sintering [35–61], joining [62–71], and coating/cladding [72–81] have been reported. However, most of these processes are still in the developing phase and need to be industrialised [11]. Microwave sintering is the most matured process in terms of the reported literature among the microwave-based processes for metallic materials. The size of the metallic particles used for sintering is one of the most important parameters which influences product attributes and microwave absorption in the target metallic materials [13,17–19,43].

Microwaves–material interactions and material types



Heating phenomenon in microwave processing is different from conventional processing. In microwave processing, heat generation with heat transfer from (inside) core of the material to (outside) surface of the material takes place, which is reverse in the case of conventional heating [1,2]. Heat generation inside the target material reduces heat transfer effect due to heat generation at atomic level and heating becomes more uniform and rapid [2,8]. Other advantages of microwave processing are less processing time, energy efficient, eco-friendly processing and selective heating [1–10].

Microwave absorption in materials depends upon their electromagnetic properties, whereas thermal properties control their heating characteristics during microwave irradiation. Consequently, materials can be categorised into four principal groups depending on the microwave–material interactions [2,8,9].

Microwave processing of metallic material systems

The techniques which are used to process metallic material systems through microwave energy include: direct heating, hybrid heating and selective heating [2]. The typical processing conditions and heating patterns in these techniques are schematically illustrated in Figure 3. The metallic powder/compacts are directly exposed to microwaves during direct heating and the material gets heated inside out (Figure 3(a)) in ideal case due to the dissipation of power and heat transfer by conduction. Microwave hybrid heating (MHH) technique improves heating of the target material due to more controlled and uniform heat interaction with a material using a ‘susceptor’ (category ‘A’, Figure 1) [20,105]. Heating pattern in a material during MHH is two-directional (Figure 1(b)) as compared to direct heating (Figure 1(a)). Thus, more uniform heating of the material is expected in the MHH than direct heating. Selective heating technique necessitates the use of special fixture to control material heating, as shown in Figure 1(c). It involves selective and hybrid heating to heat the target material. A specific tooling design is required depending upon the target material system’s characteristics and the heating types – selective or full exposure.

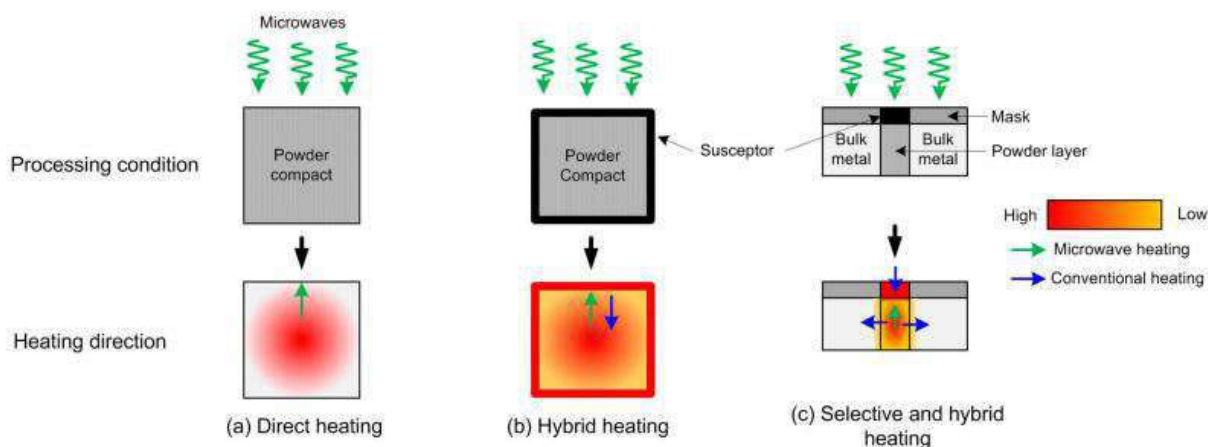


Figure 1. Types of microwave heating techniques used for metallic material systems

Microwave joining and cladding

In microwave joining, effects of particle size (macro, micro and nano) on joint properties were reported. It was reported that the use of nano-interfacing powders improves mechanical and metallurgical properties of the joints. Decrease in the size of interfacial powder during microwave joining reduces porosity and improves tensile strength and micro hardness of the developed joints [63]. Improvements in joint homogeneity, hardness and tensile strength of SS304 joints were recorded as the interfacial Ni powder size decreased, while the joints’ ductility reduced [70]. Effects of clad powder size on clad properties were also reported in microwave cladding of austenitic stainless steel by using micro- [76] and nano-sized [78–81] WC-12Co powder particles. The decrease in WC-12Co powder size (from micro to nano) resulted in improved hardness and wear resistance of the clad surface. This was attributed to enhanced uniform distribution and effective surface area of nano-sized clad powder for better microwave absorption.

Future research directions



A significant growth in the literature has been observed in the area of microwave processing of materials during the last two decades. Recent literatures indicate that future research will encompass the development of tailored materials using microwave processes for improved metallurgical and mechanical properties. An approach in microwave processing of the metallic materials is needed for developing materials for specific industrial requirements. A few authors have experimentally demonstrated that the use of nano-materials during microwave processing of materials offers better properties in processed materials apart from enhanced processing ease. The use of nano-materials improves overall product qualities and contributes to time compression. The presence of nano-materials in the lattice structure of a microwave-processed material reduces defects and improves its properties. It is, thus, expected that the combination of nano-materials and microwave energy will result in energy-efficient processing of the metallic materials with tailored properties. It also offers an opportunity, as an enabling technology, to address environmental concerns. However, quantification of the properties vis-à-vis the processing conditions is far from well documented.

Conclusions

Microwave–material interaction during microwave processing causes generation of heat inside microwaveabsorbing materials. Microwave energy absorption in materials can be controlled by different input parameters, such as – designing particle size, dielectric/magnetic loss factors and penetration/skin depth. The particle size has significant effect on microwave processing of the metallic material systems. The ratio of particle radius to skin depth is a dominant parameter in estimating heat released in the metallic particles. Most of the improvements in material properties during various microwave processing techniques like microwave sintering, microwave joining and microwave cladding were reported with finer particle size. Therefore, there exist ample opportunities for further studies for optimum exploitation of microwave energy for efficient material processing.

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Effect of Sample Size on Micro magnetic Properties of Mild Steel

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Abstract -Objective of current study is to analyze the effect of frequency, magnetic field intensity, and waveform on the hysteresis loop and Barkhausen Noise signals. As the property of ferromagnetic material, especially the hysteresis loop and BN depends on the microstructure, MFI, and frequency. In this study, the HL and BN of the mild steel sample were experimentally measured by varying the frequency, MFI, and wave form using magnetic Barkhausen noise analyzer. . First, all samples of base metal are cut into a different size, and later, all sample was subjected to annealing. The Barkhausen test has been performed in two steps; first frequency varies, magnetic field intensity kept constant, and second magnetic field intensity varies, frequency remained constant. First Barkhausen noise analysis frequency were applied from 20 Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500Oe, 750Oe, 1000 Oe at 25 Hz constant whereas sinusoidal and triangular waveform varies from 0.1 Hz to 0.4 Hz at 500 Oe constant and 150Oe, 300Oe, 400Oe, 600Oe at 0.1 Hz constant. In the second part of the work, the Barkhausen noise technique has been applied to analyze the surface integrity of the mild steel after annealing process. The Barkhausen noise parameter depends upon surface residual strain and hardness.

Introduction

Ferromagnetic material composed of magnetic domain (refer fig.1) in order to minimize the magnetostatic energy. When a changing magnetic field is applied on ferromagnetic material, the magnetization and demagnetization of the material form a closed curve known as hysteresis loop, the movement of the magnetic domain wall is hindered by the pinning sites such as precipitates, grain boundary, inclusions, dislocations, small volume of second phase material and remains pinned until the applied magnetic field is increased enough to overcome it.

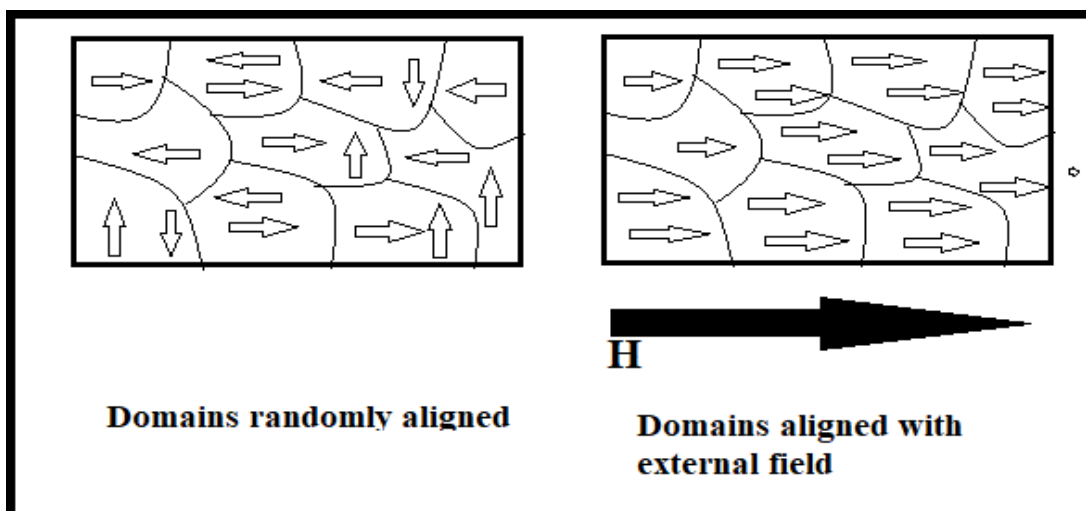


Fig.1 Magnetic Domain Wall movement in external magnetic field.



When such condition is reached, change in magnetization is produced by the abrupt movement of domain wall. Various experimental studies have been undertaken to relate the characteristics of hysteresis loop such as coercivity, permeability, remanence, and core loss with excitation frequency, magnetic field intensity, and waveform. Dependence of hardness, stress state, and grain size can also be related to characteristics of hysteresis loop. In 1919 Barkhausen noted that, when a ferromagnetic material is magnetized by an increasing field, noise in the form of voltage pulses are induced in a coil placed near the material. [1]

Magnetic Barkhausen noise is produced due to irreversible discontinuous domain wall bowing, irreversible discontinuous domain wall translation, and irreversible discontinuous domain rotation [2]. Out of these, irreversible discontinuous domain wall translation is mainly responsible for Barkhausen noise. The signals of Barkhausen noise are represented in the form of voltage pulses [3]. Various experimental studies have been undertaken to relate the characteristics of Barkhausen noise such as Peak value, RMS value with excitation Frequency [4,5]. MBN can be related to grain size, microstructure, residual stress, and applied stress [6, 7]. Therefore MBN can be used as a non-destructive method of Material Characterization.

Experimentation

The sample was polished using a different grade of emery paper. Magnetic Barkhausen noise measurement was performed using Master system supplied by Techno four, India. Measurement system as shown in Fig.2 consist of a flat-surface probe with U shape magnetizing yoke to generate magnetic field inside the test sample with the help of current from the power supply. A pick of coil (ferrite) at the center was use to gather the signal generated as the magnetic response of the work material. Table 1 enlist the detail of parameter considered for the Barkhausen noise analysis. The selection of frequency and magnetic field intensity were based on the various trail runs so as to avoid distortion in the magnetizing signal due to magnetic coupling between the magnetizing coil and work sample. First to analyze the effect of frequency, MFI on Barkhausen noise, frequency was varied 20Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500 Oe, 750 Oe, 1000 Oe at 25 Hz constant. Further to analyze the frequency, MFI and waveform on hysteresis loop and its parameter were applied where frequency varies from 0.1 Hz to 0.4 Hz at 500 Oe constant, and MFI varies as 150 Oe, 300 Oe, 400 Oe, 600 Oe. Fig.3 represent the typical magnetic Barkhausen noise burst along with superimposed external magnetic excitation field as received. In the second part of work, again Barkhausen noise technique has been applied to analyze surface integrity of base sample of mild steel after annealing process. Annealing process is done at 850 °C and hold at this temperature for 15 minutes and cooled in furnace.

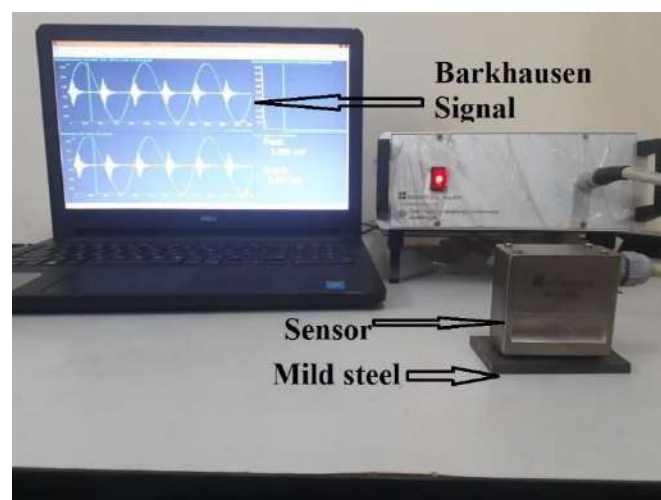


Fig.2 Magnetic Barkhausen noise analyzer used in work.

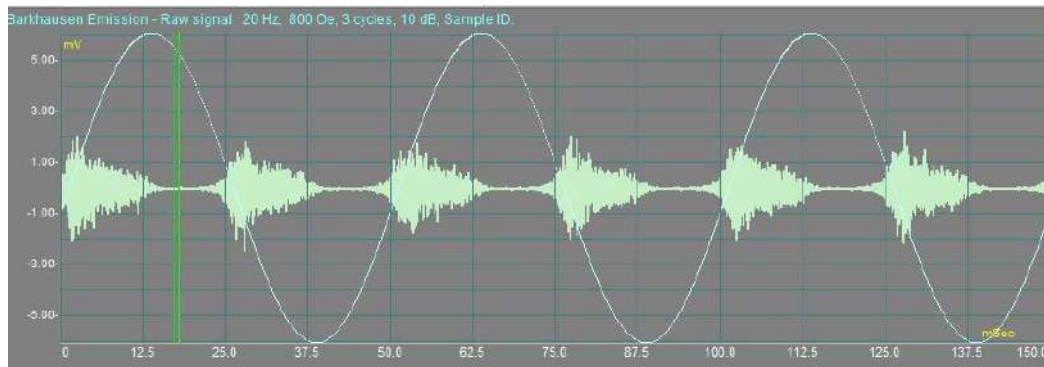


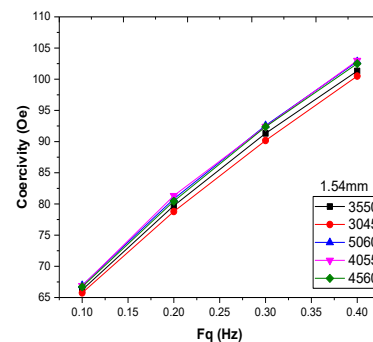
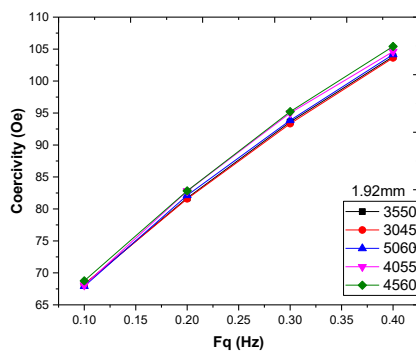
Fig.3 Barkhausen noise burst as received from work sample (mild steel).

Table 1: Details of parameter for MBN analysis

Magnetizing frequency	50Hz
Magnetic field intensity	1000 Oersted
Gain	10dB
No. of burst	6
Filter frequency	10-300 KHz

Result and discussion

The coactivity of ferromagnetic materials can be correlated to hardness and increase in dislocation density. Moreover, coercivity also depends on the frequency and MFI [8,9]. Increase in frequency decrease the amount of penetration of magnetic field into the material, which is turn represents the increase in the amount of reverse magnetic field needed to drive the magnetization to zero after saturation(also know as coercivity). Thus coercivity increase with the increase in frequency and magnetic field intensity and coercivity has a little amount in a variation on the material size and thickness as shown in fig.3.



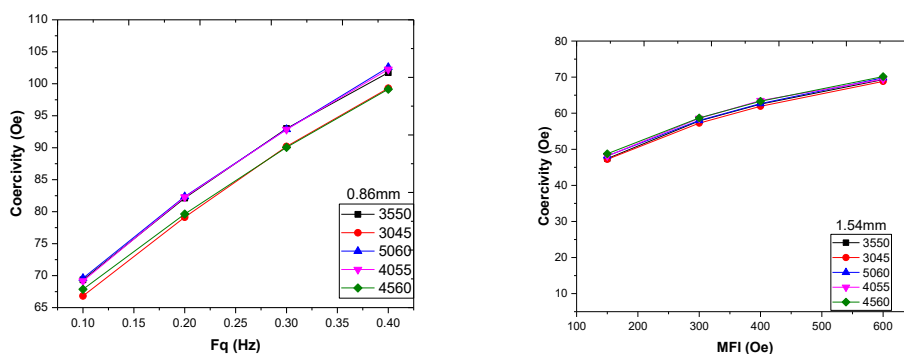


Fig.3 Variation of coercivity with frequency and magnetic field intensity.

Generally, permeability is reciprocal of coercivity and is represented by the slope of the curve at starting point of Hysteresis loop in such a way that the slope of tangent at starting point reduces, which turn cause reduction in permeability. Average permeability decrease with increase in frequency and has a little amount in variation with size and thickness of mild steel sample and also decrease with increase in magnetic field intensity, and larger size sample has a greater value of average permeability as shown in fig.4.

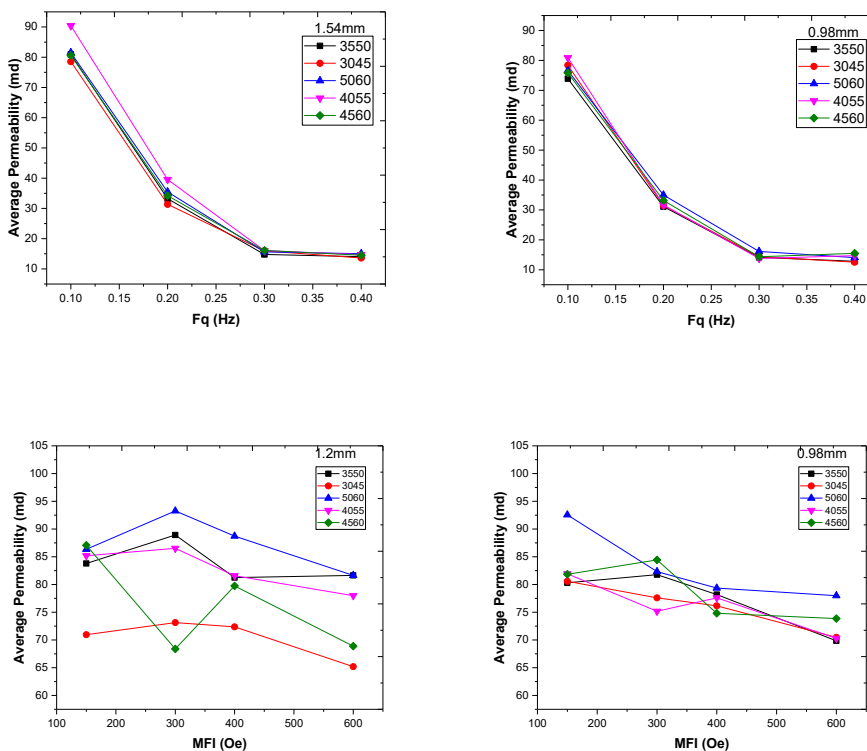


Fig.4 Variation of Average permeability with frequency and MFI.



Remanence is residual magnetic field left in material when external applied field reduces to zero. Remanence decreases with an increase in frequency due to shielding effect of eddy current, which prevent magnetization at greater depth, as shown in fig.5 and has no effect on thickness and size of the sample. Remanence increase with an increase in magnetic field intensity due to greater size of material magnetized as shown in fig.6.

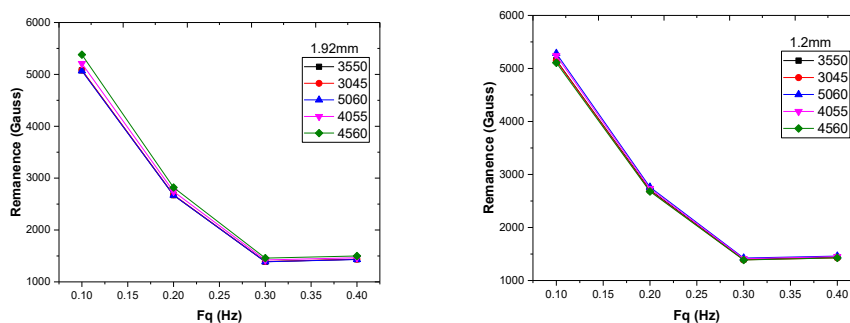


Fig.5 Variation of Remanence with frequency.

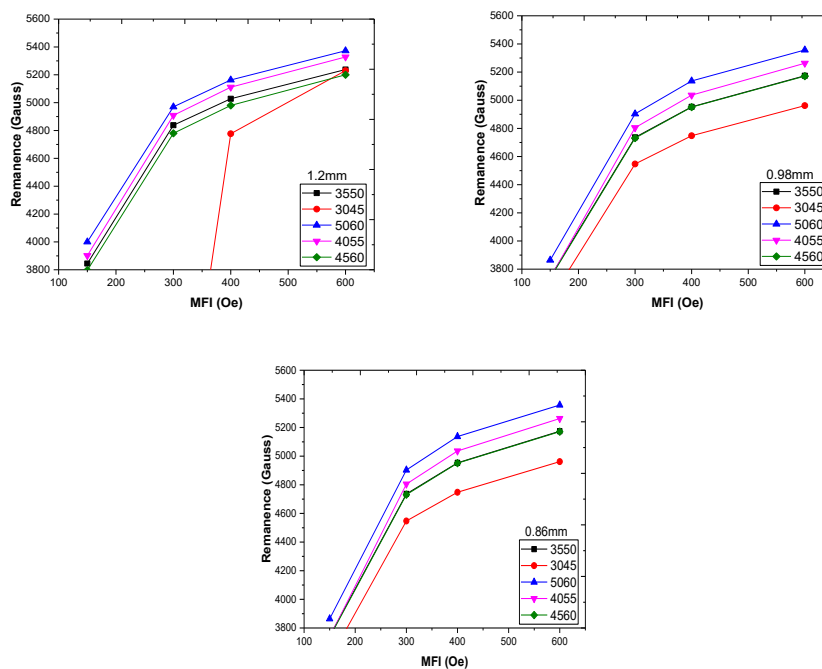


Fig.6 Variation of Remanence with MFI.

Peak and RMS value BN increase with an increase in frequency due to increase in number of domain walls frequency. Similarly, with an increase in magnetic field intensity peak and RMS of BN increase. Larger size of sample shows lower value of peaks as compared to small size sample as shown in fig.7.

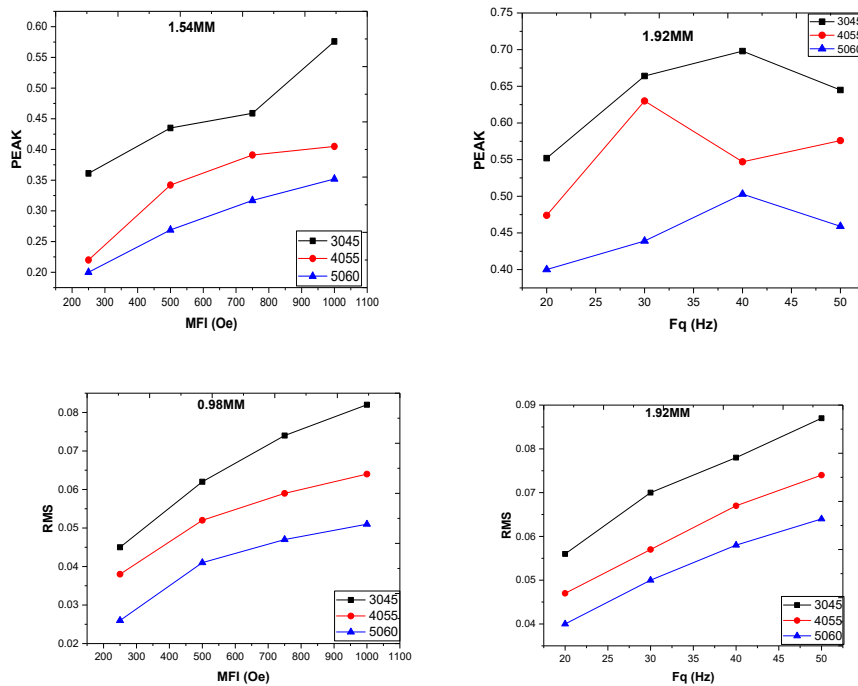


Fig.7 Variation of Paek and RMS with frequency and MFI

Skewers and Kurtosis decrease as frequency increase, and if magnetic field intensity increase Skewness and Kurtosis also increase.

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Analysis and Prediction of Tensile Strength and Hardness of Shielded Metal Arc Welded Joints under External Magnetic Field

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Abstract- Applications of magnetic field in welding processes have drawn attention of researchers. However, effect of external magnetic field on properties of weld is still lack of understanding. Present study concerned with effect of welding current, voltage & speed and effect of magnetic field on hardness, tensile strength of shielded metal arc welded mild steel joints. Mild steel plates of 6 mm thickness were used as the base material for preparing single pass butt welded joints. Speed of weld was provided by cross slide of a lathe, external magnetic field was produced by bar magnets. Tensile strength and hardness properties of the joints fabricated by E-6013 electrodes as filler metals were evaluated and the results were reported.. From investigation, it was noticed that the joints fabricated have increased hardness and tensile strength if either speed of weld or external magnetic field was increased and these mechanical properties decreased if either voltage or current was increased.

Keywords- shielded metal arc welding, tensile strength, welding current.

I- INTRODUCTION

Since ancient times process of welding has seen various phases, world wars caused a major changes in application of welding processes, various advance welding methods for different alloys so for various methods are available. Joining method has been used in manufacturing, since materials having different mechanical properties are required to be efficiently joined to increase the performance. As per Anik [1] most suitable way of joining two different alloyed steel is welding. After welding, properties of welding zone become different from properties of alloyed steels and this difference may create some challenges. Yilmaz [2] investigated that using melting method of welding also increases these problems. Bargeland & Schulze [3] analyzed that phase diagrams and properties of joining materials are important factors in determining welding properties. Some problems also arise since materials to be joined are different alloys and some other components are needed to join them effectively. Several zones connecting region as per the composition and properties of the material. Creation of porosity is the important disadvantage of this method due to which strength of weld is reduced. Tulbentci and Yilmaz [4] described that solid state welding methods are more appropriate since melting welding faults do not significantly occur there. Kim and Kim [5] told that arc welding involves a large number of interdependent variables that can affect product quality, productivity and cost effectiveness. Many studies and researches have been done so far to determine the effect of welding parameters on weld properties and quality. Funderburk [6] studied that heat input affects the mechanical properties of the weld for shielded metal arc welding. Cavaliere, Campanile, Panella and Squillace [7] wrote that the welding parameters affect the mechanical properties of the weld. Shielded metal arc welding is one of the most common joining processes used in the world. Most of the engineering materials require high tensile strength and sufficient amount of hardness for their performance. The welding parameters in electric arc welding influence the tensile strength and hardness of the weld metal. In order to optimize these properties, in this study four welding parameters current, voltage, speed of welding & external magnetic field were taken.



Due to the influence of welding arc, Lorentz force is deflected in plane normal to the field. The magnetic field exerts force on the electrons and ions within the arc, that causes arc to be deflected away from the normal path. External magnetic field deflects the arc in the direction of welding, whereas along longitudinal external magnetic field deflects the arc perpendicular to the bead. Hughes and Walduck[8] saw that .If unidirectional magnetic field is applied to an AC arc, or an alternating field is applied to a DC arc, then the arc can be oscillated in the position normal to the direction of welding.

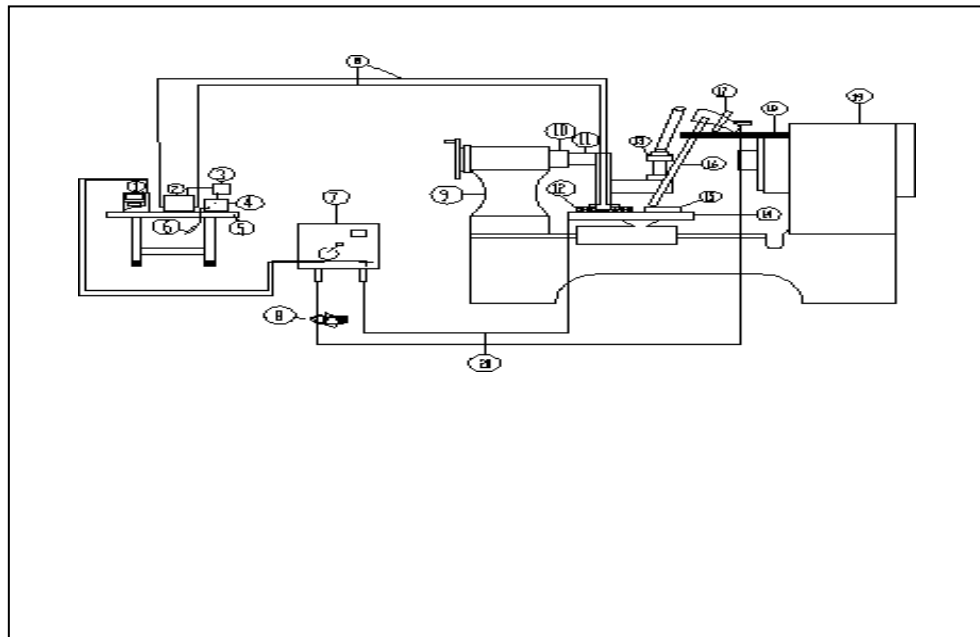
Tensile strength is the amount of tension a material can withstand without rupture. Tensile strength varies from material to material, depending upon the structure of material. Due to welding of the work-pieces, the alignment of the molecules of the material changes and hence the tensile strength also changes. The hardness in heat-affected zone (HAZ) of a weld is critical to the performance of that weld in the field. In case the weld is too hard it will lose ductility and will be susceptible to cracking; if it is too soft then it will be susceptible to collapse or tensile failure. Hardness has a close relationship with the strength. Very much or very less heat during the welding process can change hardness and thus the strength of the weld. Thus the hardness must be right; it should not be more or less than the required value. Experience has indicated that limitations should be place the hardness of the base metal, heat affected zone (HAZ), weld interface and weld metal. If the hardness is too much, these will not have sufficient ductility for the service conditions, their corrosion resistance may be impaired or some other factor may dictate this limitation.

II- EXPERIMENTATION

M.S plates of 6 mm thickness were cut into the required dimension (150 mm×50 mm) by oxy-fuel cutting and grinding. The initial joint was obtained by securing the plates in position using tack welding. Single ‘V’ butt joint configuration was used to fabricate the joints using shielded metal arc welding process. All the necessary cares were taken to avoid the joint distortion and the joints were made with applying clamping fixtures. The specimens for testing were sectioned to the required size from the joint comprising weld metal, heat affected zone (HAZ) and base metal regions and were polished using different grades of emery papers. Final polishing was completed using the diamond compound (1µm particle size) in the disc polishing machine. The welded joints were sliced using power hacksaw and then machined to the required dimensions (100 mm x 10mm) for preparing tensile tests and (10mmx6mm)for hardness test.

Hardness was determined using Rockwell hardness testing machine. Test specimen was placed on the anvil, and by slowly turning the hand wheel; the specimen was raised until it touched the indenter. The numbers were read directly from the dial indicator and converted to the Rock well number. The etching of the prepared test area was done carefully. The acid for etching purpose was prepared by taking 96 cubic centimeter of 95% de natured ethanol and 4 cubic centimeter of 65% nitric acid. A wad of cotton wool was impregnated with the readymade acid. The impregnated cotton wool was then lightly dabbed on to the test surface. The complete test area was covered with acid. After etching the individual weld components could be clearly distinguished from each other. Unclean etchings cause phantom structural formations. After etching was completed the affected area was Rinsed off with Ethanol and dried off using a dryer.

Singh, Gupta and Sarkar [12] intimated that specimen without notch can scan be prepared to evaluate transverse tensile properties of the joints such as yield strength and tensile strength. The gripping of tensile specimens on universal testing machine was made easy by welding both ends of specimens with circular rods. Tensile test was conducted with a 40 ton electro-mechanical controlled universal testing machine. Since the plate thickness was small, sub-size specimens were prepared.



- | | | | |
|----------------|-----------------------|---|-----------------|
| 1. Multi-meter | 2. Battery Eliminator | 3. Electric Board | 4. Gauss Meter |
| 5. Table | 6. Measuring Prob | 7. Transformer Welding Set | |
| 8. Clamp meter | 9. Tail Stock | 10. Sleeve | 11. Link (Wood) |
| 12. Solenoid | 13. Tool post | 14. Iron sheet | 15. Workpiece |
| 16. Electrode | 17. Electrode Holder | 18. Metal Strip Connected with head stock | |
| | 19. Headstock | 20. Connecting Wires | |

Fig.1 Welding Set-up (Line Diagram)



TABLE I
DATA FOR TRAINING AND PREDICTION

	Serial Number	Current(A)	Voltage(V)	Welding Speed(mm/min)	Magnetic Field	RockwellHardness(B)	TensileStrength (MPa)
Data for Training	1	90	24	40	0	90	266
	2	90	24	40	20	90	266
	3	90	24	40	40	90	266
	4	90	24	40	60	91	268
	5	90	24	40	80	92	272
	6	95	20	60	60	89	284
	7	95	21	60	60	88	282
	8	95	22	60	60	87	280
	9	95	23	60	60	86	278
	10	95	24	60	60	85	276
	11	100	22	40	40	90	254
	12	100	22	60	40	91	258
	13	100	22	80	40	92	262
	14	90	20	80	20	88	282
	15	95	20	80	20	86	280
	16	100	20	80	20	84	278
	17	105	20	80	20	82	274
	18	110	20	80	20	80	272
Data for Prediction	1	90	23	40	0	91	268
	2	95	22	60	40	86	278
	3	95	21	80	60	89	284
	4	100	24	40	40	89	252
	5	105	21	60	40	81	272
	6	105	22	60	20	78	270
	7	110	21	60	20	79	270

TABLE II
MEASURED AND PREDICTED VALUES WITH PERCENTAGE ERROR

S.N.	Current(A)	Voltage(V)	Welding Speed(mm/min)	Magnetic Field(Gauss)	RockwellHardness(B) Measured	RockwellHardness(B) Predicted	Error in Hardness %age	Tensile Strength(MPa) Measured	Tensile Strength(MPa) Predicted	Error in Tensile Strength %age
1	90	23	40	0	91	85.6	-5.53	268	274.5	2.43
2	95	22	60	40	86	85.1	-1.05	278	275.2	-1.01
3	95	21	80	60	89	85.4	-4.04	284	276.1	-2.78
4	100	24	40	40	89	85.2	-4.27	252	273.3	8.45
5	105	21	60	40	81	84.8	4.44	272	274.1	0.77
6	105	22	60	20	78	84.6	8.46	270	273.3	1.22
7	110	21	60	20	79	83.9	6.20	270	273.6	1.33



III- RESULTS

A.TENSILEPROPERTY

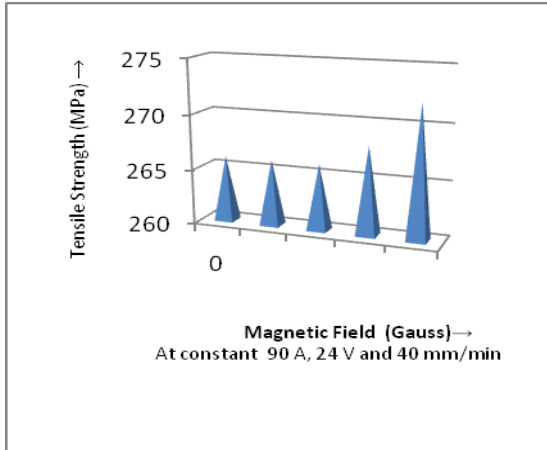


Fig.3 Tensile Strength vs Magnetic Field

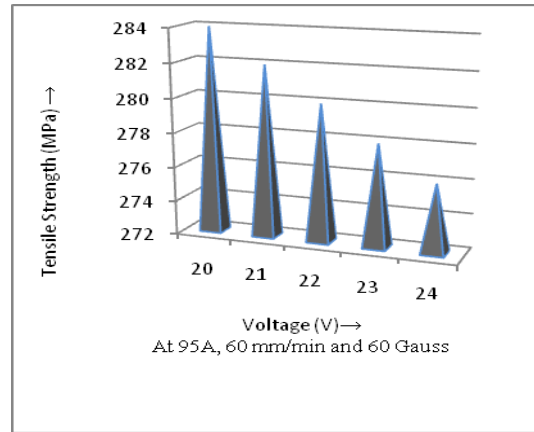


Fig.4 Tensile Strength vs Voltage

The tensile strength of the welded joints was unaffected if,

Transverse tensile property of the joints was evaluated. The specimens were tested, and the results were presented in table 1. The yield strength and tensile strength of un welded base metal weremeasuredas359and524MPa, respectively. But the yield strength and tensile strength of mild steel (fabricated using E-6013, futile electrode flier metal) joints were reduced by about 50% in both the cases the magnetic field was changed from 0 to 20 gauss or from20 to 40 gauss. If the field was increased from 40 gauss to 60 gauss, the tensile strength increased from 266 M Pa to 268 M Pa. and if it was increased from 60 gauss to 80 gauss, the tensile strength increased from 268 M Pa to 272MPa. If the speed of welding was increased from 40mm/min to 60 mm/ min, the tensile strength increased from

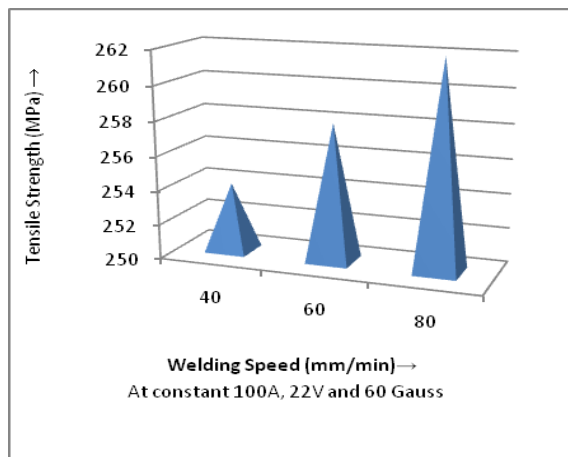


Fig.5 Tensile Strength vs Welding Speed

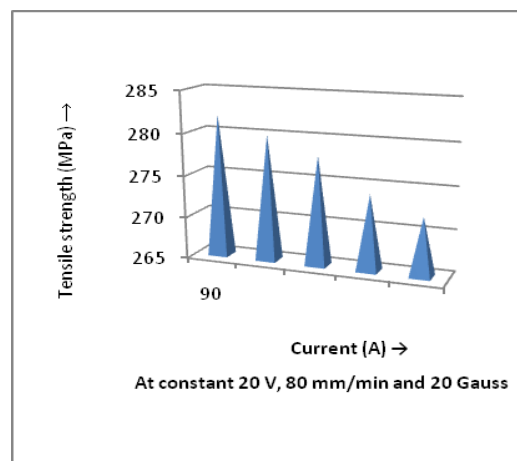


Fig.6 Tensile Strength vs Current



B HARDNESS PROPERTY

The hardness across the weld cross-section was measured using a Rockwell hardness testing machine, and the results were displayed in table 1. The hardness of weld metal (wm) region was found greater than the affected zone region, but lower than the base metal region, irrespective of filler metals used. There was no effect of magnetic field on hardness if the strength of the field was less than 40 Gauss and if it was increased from 40 Gauss to 80 Gauss the

Hardness increased from 90 RHB to 92 RHB. If the speed of welding was increased from 40 mm/min to 80 mm/min the hardness increased from 90 RHB to 92 RHB. If the voltage was increased from 20V to 24 V the hardness decreased from 89 RHB to 85 RHB. If the current was increased from 90 A to 110 A, the hardness decreased from 88 RHB to 80 RHB. The variation of hardness properties with magnetic field, voltage, welding speed and current were shown in figures 7, 8, 9 and 10 respectively.

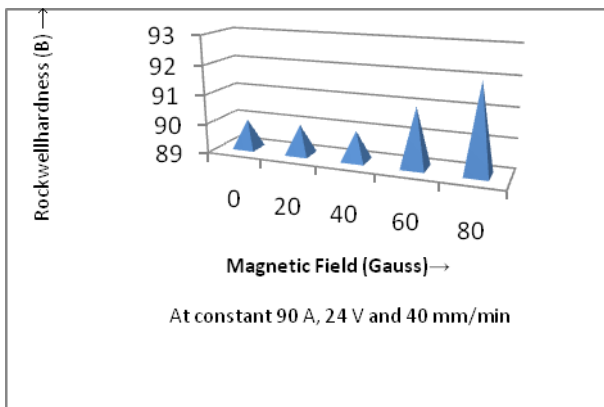


Fig.7 Rockness Hardness vs Magnetic Field

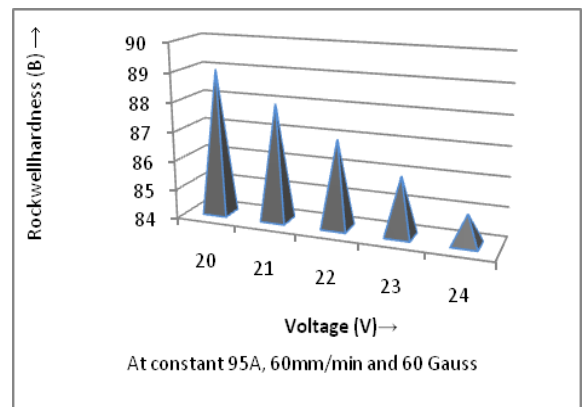


Fig.8 Rockwell vs Hardness Voltage

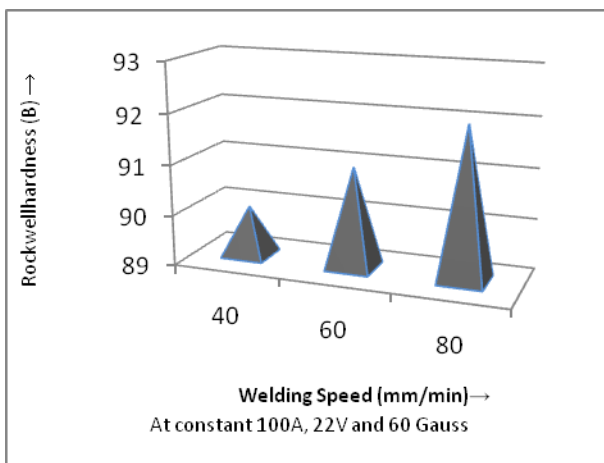


Fig.9 Rockwell Hardness vs Welding Speed

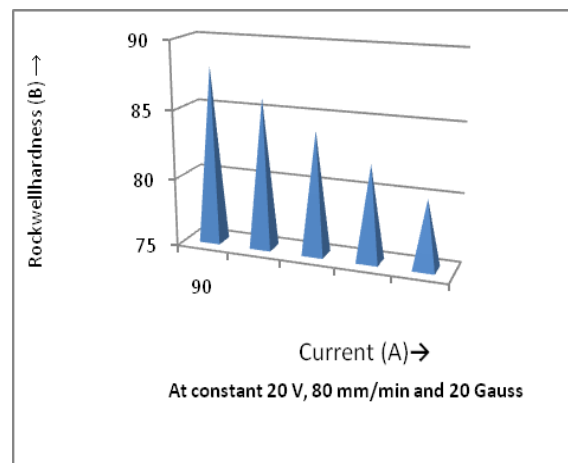


Fig.10 Rockwell Hardness vs Welding Current



IV -DISCUSSION

In this investigation, an attempt was made to find out the best set of values of current, voltage, speed of welding and external magnetic field to produce the best quality of weld in respect to hardness, tensile strength and impact strength.

R. P. Singh and S. C. Sarkar [13] told that the shielded metal arc welding is a universally used process for joining several metals. Generally in this process speed of welding and feed rate of electrode both are controlled manually but in the present work the speed of welding was controlled with the help of cross slide of a lathe machine hence only feed rate of electrode was controlled manually which ensures better weld quality. In the present work external magnetic field was utilized to distribute the electrode metal and heat produced to larger area of weld which improves several mechanical properties of the weld. The welding process is a very complicated process in which no mathematical accurate relationship among different parameters can be developed. In present work Random Forrest, a bagging technique was used which works on the weak-learner principle and divides the data into multiple subsets for training and further provides the most likely event as a result. The maximum occurring prediction out of n number of sample events is picked to provide a concrete prediction.

V- CONCLUSIONS

Based on the experimental modeling the following conclusions are drawn:

1. A strong joint of mild steel is found to be produced in this work by using the SMAW technique.
2. If amperage is increased, hardness and tensile strength of weld, both generally decrease.
3. If voltage of the arc is increased, hardness and tensile strength of weld, both generally decrease.
4. If travel speed is increased, hardness and tensile strength of weld, both generally increase.
5. If magnetic field is increased, hardness and tensile strength of weld, both generally increase.
6. Bagging based approaches can be used successfully for predicting the output parameters like hardness of weld and strength of weld as shown in table 2. The accuracy is 93~% predicting hardness and tensile strength, which is more than 8 percent in some instances. Increasing the number of experiments and further usage of hyper parameter tuning can lead to reduction in the error.

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Using Six Sigma DMAIC to Improve the Quality of the Production Process: A Case Study

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Abstract -Objective of current study is to analyze the effect of frequency, magnetic field intensity, and waveform on the hysteresis loop and Barkhausen Noise signals. As the property of ferromagnetic material, especially the hysteresis loop and BN depends on the microstructure, MFI, and frequency. In this study, the HL and BN of the mild steel sample were experimentally measured by varying the frequency, MFI, and wave form using magnetic Barkhausen noise analyzer. . First, all samples of base metal are cut into a different size, and later, all sample was subjected to annealing. The Barkhausen test has been performed in two steps; first frequency varies, magnetic field intensity kept constant, and second magnetic field intensity varies, frequency remained constant. First Barkhausen noise analysis frequency were applied from 20 Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500Oe, 750Oe, 1000 Oe at 25 Hz constant whereas sinusoidal and triangular waveform varies from 0.1 Hz to 0.4 Hz at 500 Oe constant and 1500e, 3000e, 4000e, 6000e at 0.1 Hz constant. In the second part of the work, the Barkhausen noise technique has been applied to analyze the surface integrity of the mild steel after annealing process. The Barkhausen noise parameter depends upon surface residual strain and hardness.

Introduction

Ferromagnetic material composed of magnetic domain (refer fig.1) in order to minimize the magnetostatic energy. When a changing magnetic field is applied on ferromagnetic material, the magnetization and demagnetization of the material form a closed curve known as hysteresis loop, the movement of the magnetic domain wall is hindered by the pinning sites such as precipitates, grain boundary, inclusions, dislocations, small volume of second phase material and remains pinned until the applied magnetic field is increased enough to overcome it.

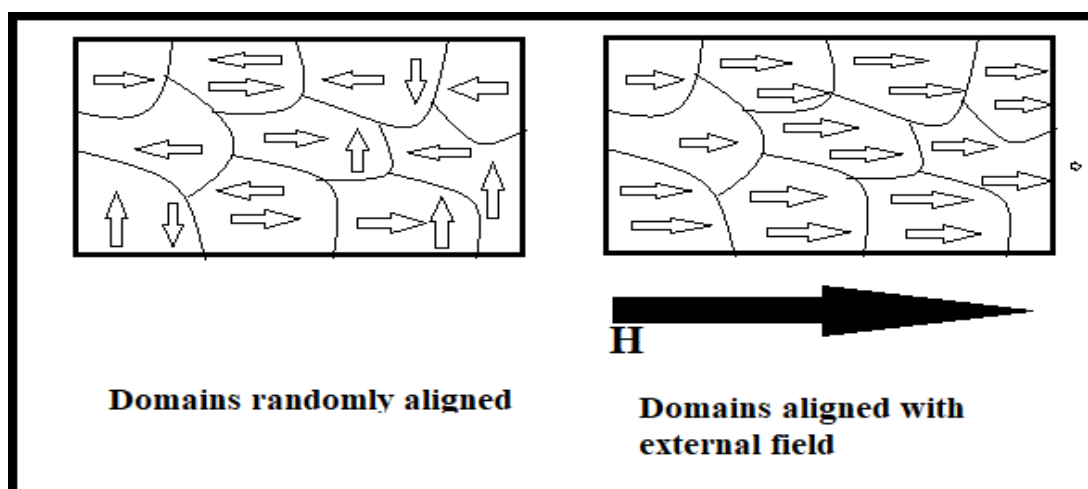


Fig.1 Magnetic Domain Wall movement in external magnetic field.



When such condition is reached, change in magnetization is produced by the abrupt movement of domain wall. Various experimental studies have been undertaken to relate the characteristics of hysteresis loop such as coercivity, permeability, remanence, and core loss with excitation frequency, magnetic field intensity, and waveform. Dependence of hardness, stress state, and grain size can also be related to characteristics of hysteresis loop. In 1919 Barkhausen noted that, when a ferromagnetic material is magnetized by an increasing field, noise in the form of voltage pulses are induced in a coil placed near the material. [1]

Magnetic Barkhausen noise is produced due to irreversible discontinuous domain wall bowing, irreversible discontinuous domain wall translation, and irreversible discontinuous domain rotation [2]. Out of these, irreversible discontinuous domain wall translation is mainly responsible for Barkhausen noise. The signals of Barkhausen noise are represented in the form of voltage pulses [3]. Various experimental studies have been undertaken to relate the characteristics of Barkhausen noise such as Peak value, RMS value with excitation Frequency [4,5]. MBN can be related to grain size, microstructure, residual stress, and applied stress [6, 7]. Therefore MBN can be used as a non-destructive method of Material Characterization.

Experimentation

The sample was polished using a different grade of emery paper. Magnetic Barkhausen noise measurement was performed using Master system supplied by Techno four, India. Measurement system as shown in Fig.2 consist of a flat-surface probe with U shape magnetizing yoke to generate magnetic field inside the test sample with the help of current from the power supply. A pick of coil (ferrite) at the center was use to gather the signal generated as the magnetic response of the work material. Table 1 enlist the detail of parameter considered for the Barkhausen noise analysis. The selection of frequency and magnetic field intensity were based on the various trail runs so as to avoid distortion in the magnetizing signal due to magnetic coupling between the magnetizing coil and work sample. First to analyze the effect of frequency, MFI on Barkhausen noise, frequency was varied 20Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500 Oe, 750 Oe, 1000 Oe at 25 Hz constant. Further to analyze the frequency, MFI and waveform on hysteresis loop and its parameter were applied where frequency varies from 0.1 Hz to 0.4 Hz at 500 Oe constant, and MFI varies as 150 Oe, 300 Oe, 400 Oe, 600 Oe. Fig.3 represent the typical magnetic Barkhausen noise burst along with superimposed external magnetic excitation field as received. In the second part of work, again Barkhausen noise technique has been applied to analyze surface integrity of base sample of mild steel after annealing process. Annealing process is done at 850 °C and hold at this temperature for 15 minutes and cooled in furnace.

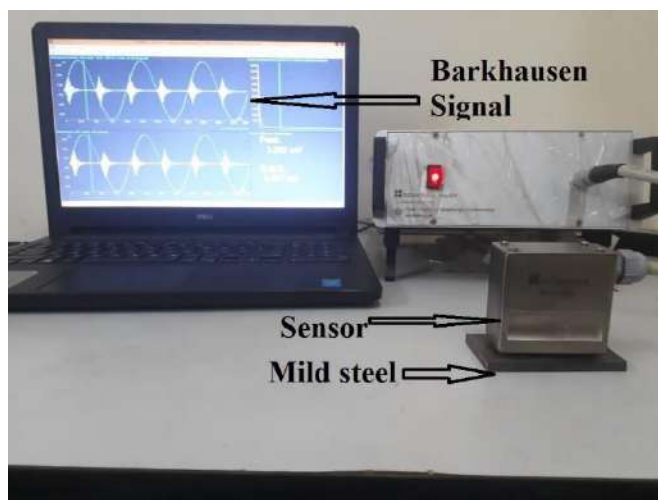


Fig.2 Magnetic Barkhausen noise analyzer used in work.

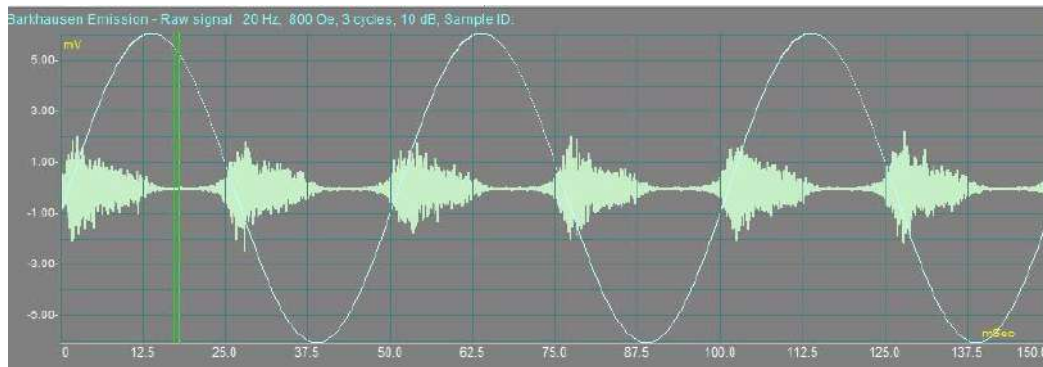


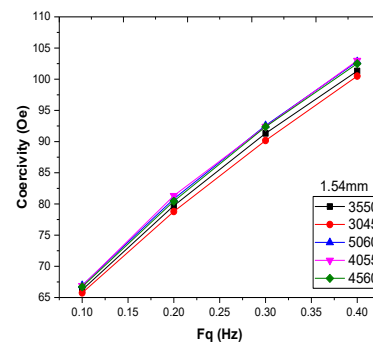
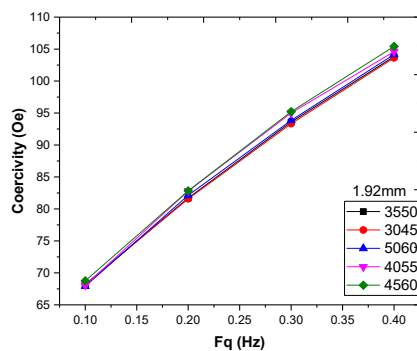
Fig.3 Barkhausen noise burst as received from work sample (mild steel).

Table 1: Details of parameter for MBN analysis

Magnetizing frequency	50Hz
Magnetic field intensity	1000 Oersted
Gain	10dB
No. of burst	6
Filter frequency	10-300 KHz

Result and discussion

The coactivity of ferromagnetic materials can be correlated to hardness and increase in dislocation density. Moreover, coercivity also depends on the frequency and MFI [8,9]. Increase in frequency decrease the amount of penetration of magnetic field into the material, which is turn represents the increase in the amount of reverse magnetic field needed to drive the magnetization to zero after saturation(also know as coercivity). Thus coercivity increase with the increase in frequency and magnetic field intensity and coercivity has a little amount in a variation on the material size and thickness as shown in fig.3.



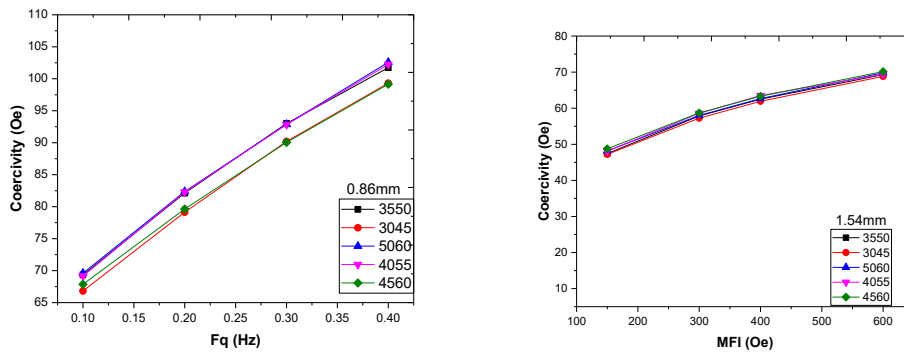


Fig.3 Variation of coercivity with frequency and magnetic field intensity.

Generally, permeability is reciprocal of coercivity and is represented by the slope of the curve at starting point of Hysteresis loop in such a way that the slope of tangent at starting point reduces, which turn cause reduction in permeability. Average permeability decrease with increase in frequency and has a little amount in variation with size and thickness of mild steel sample and also decrease with increase in magnetic field intensity, and larger size sample has a greater value of average permeability as shown in fig.4.

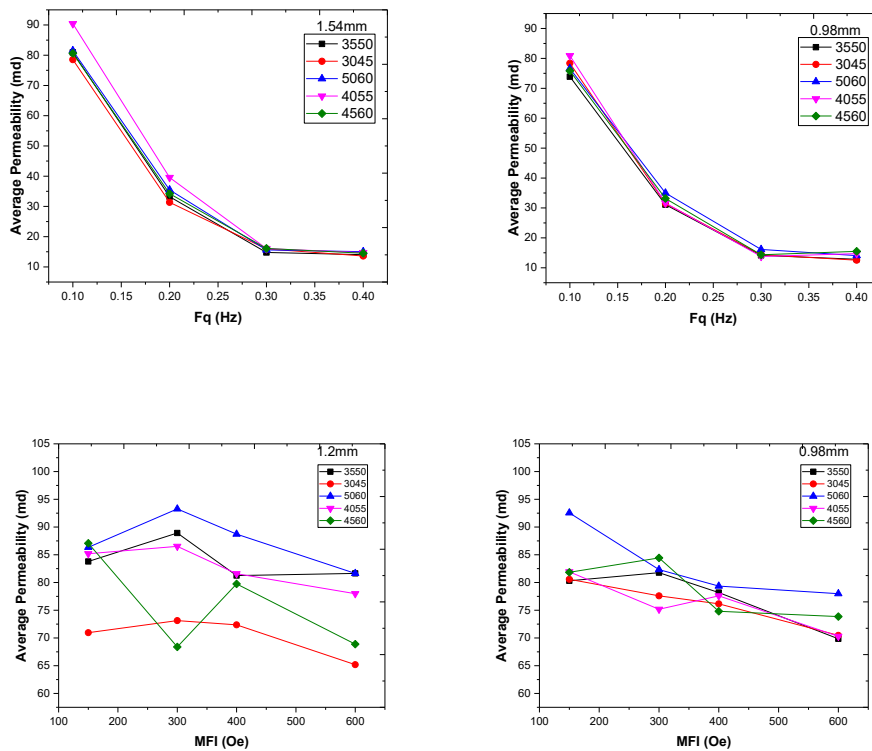


Fig.4 Variation of Average permeability with frequency and MFI.



Remanence is residual magnetic field left in material when external applied field reduces to zero. Remanence decreases with an increase in frequency due to shielding effect of eddy current, which prevent magnetization at greater depth, as shown in fig.5 and has no effect on thickness and size of the sample. Remanence increase with an increase in magnetic field intensity due to greater size of material magnetized as shown in fig.6.

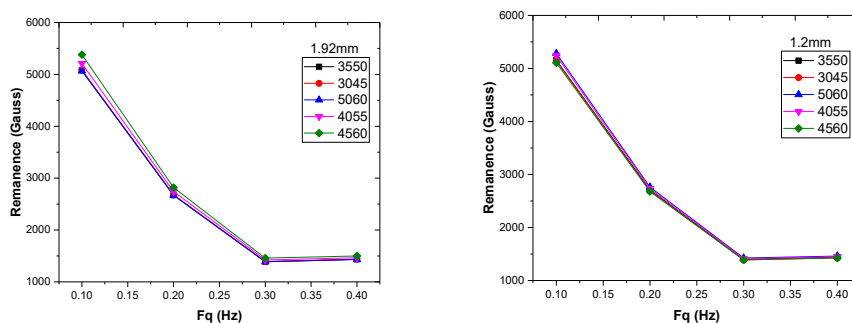


Fig.5 Variation of Remanence with frequency.

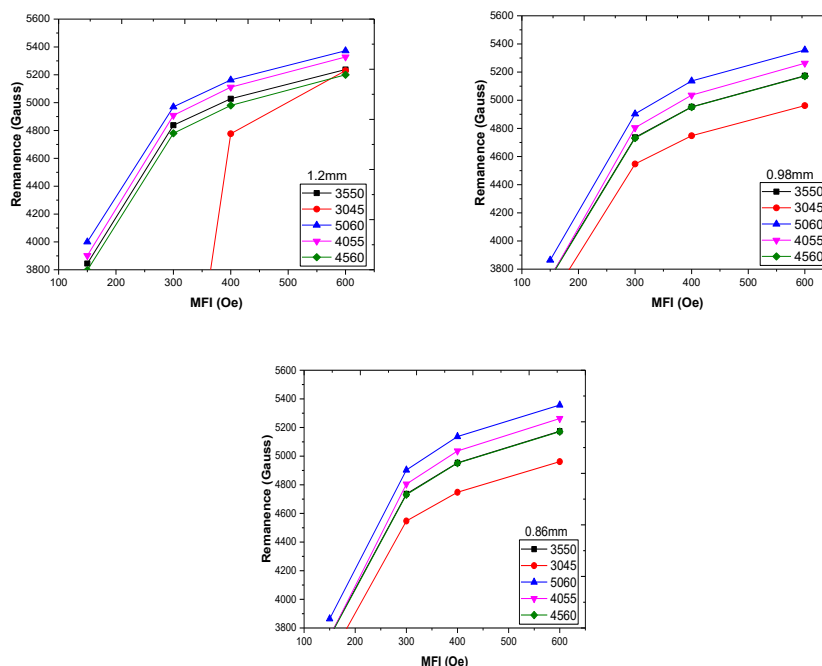


Fig.6 Variation of Remanence with MFI.

Peak and RMS value BN increase with an increase in frequency due to increase in number of domain walls frequency. Similarly, with an increase in magnetic field intensity peak and RMS of BN increase. Larger size of sample shows lower value of peaks as compared to small size sample as shown in fig.7.

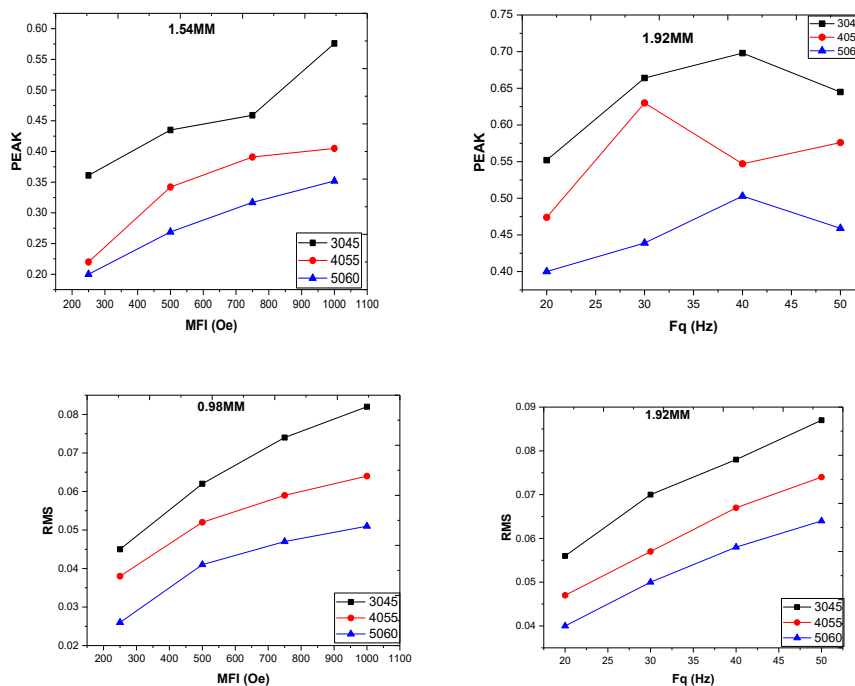


Fig.7 Variation of Paek and RMS with frequency and MFI

Skewers and Kurtosis decrease as frequency increase, and if magnetic field intensity increase Skewness and Kurtosis also increase.

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The Concepts of Quality, Quality Assurance and Quality Enhancement

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ABSTRACT

The purpose of this paper is to present critical perspectives on the literature and to critically review and discuss various definitions of the concepts of quality, quality assurance (QA), and quality enhancement (QE) in higher education (HE). The need for both QA and QE as ongoing processes in higher education institutions was demonstrated in this paper, which argued that they should be approached in a continuum. The meaning of quality, QA, and QE in the context of higher education is examined in this paper. It examines and critiques the various definitions of these essential concepts. The paper provides a one-of-a-kind analysis of the research that has been cited a lot about quality, quality assurance, and quality evaluation. It helps improve comprehension of those important concepts in the higher education sector, including their origin and mean stream view. It demonstrates how difficult it can be to come up with a single definition and stresses how crucial it is to have a firm grasp on these terms.

INTRODUCTION

In order to improve comprehension of their application in the context of higher education (HE), the purpose of this paper is to critically examine the various definitions of the key concepts of quality and to contribute to the debates surrounding these concepts. With a critical perspective on the research that has received a lot of attention, the study examines various definitions of quality and quality assurance (QA) in higher education that have been discussed in the educational literature. In addition, the disagreement that exists between students' and academics' understandings of what QA means is brought to light. The main argument is that it is hard to define quality because it is hard to define. Two problems with defining quality are discussed. In addition, QA and QE are distinguished from one another to demonstrate that they are necessary as ongoing processes and that they should be viewed as two concepts of the same continuum. The history of the concept of quality is shown in the following section.

Quality has become a popular topic, and the terms "quality assurance" (QA) and "quality enhancement" (QE) are frequently employed in higher education institutions (HEIs). The significance of quality assurance (QA) issues can be seen in the widespread concern about quality; Several international organizations around the world share this interest. The World Bank, the Organization for Economic Co-operation and Development, and a number of other international organizations frequently make mention of quality assurance (QA) in their reports. For instance, the United Nations Educational, Scientific, and Cultural Organization expresses significant concern regarding QA in education. In particular, the International Network for Quality Assurance Agencies in Higher Education serves as a professional organization that provides assistance to QA agencies worldwide. The significance of quality issues is demonstrated by the establishment of several regional QA organizations. The European Network for Quality Assurance, the Arab Network for Quality Assurance in Higher Education, and other similar regional agencies can be found in Asia, the Caribbean, and Africa, among other places.



THE ORIGIN OF THE CONCEPT OF QUALITY

Quality is certainly not a cutting edge idea, and it has been utilized through the ages and through various developments. For instance, ancient food gatherers had to figure out which foods were nutritious and which weren't, and hunters had to figure out which tools worked best for them. In addition, various civilizations, including the Egyptian, Greek, and Roman, utilized the concept of quality. For instance, quality was "a sign of perfection" in ancient Egypt because the Egyptians were in charge of building the pyramids, and paying attention to quality in architecture was necessary for these structures.

THE MEANING OF QUALITY

The relevant literature contains a wealth of studies on defining quality; Consequently, the issue is discussed in two interconnected sections of the current analysis of the concept of quality. First, the approaches to defining it that are represented in the literature are criticized; second, the significance of value from the view of HE partners is talked about.

APPROACHES OF DEFINING QUALITY CONCEPT

Numerous authors have defined quality in a variety of ways because the literature suggests that quality is not a single concept (Van Kemenade et al., 2008; 2002 and 2000, Newton; 1993 (Harvey and Green) Green (1994), a widely cited piece of literature, identified five approaches to the definition of quality, and this section provides a critique of each of them.

QUALITY AS THE CONFORMANCE TO STANDARDS

In the HE area, the idea of "norms" signifies the degree of conditions that should be met by establishments or projects to be authorize by a certification office (Chea, 2002). This suggests that, if the answer to the question, "Is it good?" is quality, The answer to the question, "Is it good enough?" is provided by standards (Page 142 of Brink, 2010, Because standards are about outcomes and quality is about process, the job of quality assurance is to ensure that the educational process will maintain high standards. In higher education, efforts have been made to "benchmark" academic standards by using externally set examinations, specifying the content of syllabi, and external examiners to guarantee that awards can be compared between institutions (Harvey and Newton, 2004, p. 150). According to a study that sought to demonstrate how to comprehend quality based on the perceptions of academics and students, some academics "interpreted quality as relating to academic standards" (Cheng, 2011, p. 11), demonstrating the significance of this method of definition. Green (1994, p. 14) was of the opinion that this approach to quality had both advantages and disadvantages. The advantage of this approach was that it implied that the quality of a service could be defined in terms of standards that could be easily measured, which may not be the case in higher education. However, the disadvantage of this approach was that it gave all HEIs the opportunity to aspire to quality. Different standards could be set for different types of institutions.

QUALITY AS FITNESS FOR PURPOSE

The meaning of value as "readiness for intention" was embraced by most policymakers in the HE area, as it contended that quality had no significance besides according to the motivation behind the item or administration. However, numerous academics have refuted the fitness for purpose method. As a result, Gibbs (2011) proposed the "good-enough practice," a different method of definition. He emphasized that fit for purpose and the implementation of good enough practices share superficial similarities. In any case, not at all like that approach where the emphasis was on coordinating authoritative purposes (as may be the situation in assembling), sufficient practices expected that quality satisfied the assumptions for the reference bunch, however it didn't make it happen impeccably.

THE TRADITIONAL CONCEPT OF QUALITY

This method defines quality as the provision of a unique product or service that grants the owner or user special status. In higher education, it may correspond to the majority's perception of Oxford or Cambridge Universities in terms of the



unique student experience and graduate and research output. However, when it comes to evaluating quality in HE as a whole, this concept is useless.

DIFFICULTIES IN DEFINING QUALITY

Determining quality is not as straightforward as it may appear, and there is no universally accepted definition, despite the concept's age and widespread application in everyday life. As a result, some authors claimed that the term "quality" has become "used and abused" (Shanahan and Gelber, 2004). On the other hand, others argued that "there is now more general agreement on the elements which together make up a judgment about quality in HE" (Perry, 1991, p. 92).

According to a review of the literature, there are two factors that make crystallizing the definition of quality challenging. They are:

(1) the idea of quality is relative; (2) Quality is utilized in a variety of settings.

THE MEANING OF QA

According to Cheng (2003), there are three distinct QA paradigms in education: Quality waves marked "Internal," "Interface," and "Future." The "Internal QA" focused on making the internal environment and processes better so that learning and teaching can be made to be effective and the goals that were planned can be achieved. The "Interface QA" makes sure that education services are accountable to the public and meet the needs of stakeholders. The "Future QA" emphasizes ensuring that educational goals, content, practice, and outcomes are applicable to future generations. The first wave reflects the first approach, which is "quality as the conformance to standards," and the third approach, which is "quality as effectiveness in achieving institutional goals" (Green, 1994), as the conception of education quality in the first paradigm sees education as effectiveness in achieving planned goals, and indeed, those two approaches focus on the need to have a list of specific goals. If these three waves are connected with the approaches of defining quality that were discussed earlier, it can be seen that the first wave reflects the first approach. In any case, the "Connection point" worldview is near the fourth methodology (fulfillment) high level by Green (1994). According to Cheng (2003, p. 203), the relationship is viewed throughout the conception of education quality as stakeholders' satisfaction with education services. According to the author, Green's methods do not take into account the third wave because Cheng describes it as the development of contextualized multiple intelligence throughout the entire process of globalization, localization, and individualization in education. This third wave is relevant to a new paradigm in education.

In addition, Harvey (2011) defined quality assurance (QA) in higher education as "a process of establishing stakeholder confidence that provision (input, process, and outcomes) fulfils expectations or measures up to threshold minimum requirements." This definition focussed on the partners' assumptions, which was reflected in Cheng's (2003) study, as talked about prior. The "enhancement" component, on the other hand, is not included in this definition because it only focuses on measuring the minimum threshold requirements.

THE RELATIONSHIP BETWEEN QA AND QE

In the literature, the term "QE" typically refers to quality assurance; As a result, the researcher suggests considering the two concepts as a continuum (see Figure 1) rather than as two distinct processes; Several researchers concur with this opinion. In contrast, CBE Williams (2010) believes that QA is an umbrella term that encompasses a multitude of activities, one of which is QE. For instance, Lomas (2004) believed that QA and QE should be considered as "two major approaches" to quality improvement. It is thought that QA focuses on emphasizing prevention rather than curing and is about the effectiveness of the educational process (Brink, 2010, p. 142).

It is imagined that one saw method for upgrading the quality is to utilize institutional QA systems that energize great showing practice (Cheng, 2011, p. 14). This indicates that QE is more transformative and necessitates a deliberate process of change.

Interestingly, the previous discussion of academics' and students' perceptions of quality can be concluded that academics may consider QA more than QE when considering quality, while students may mean QE more than QA. The findings of



a number of studies lend credence to this assertion. Examples include Iacovidou et al. 2009) used "dimensions of quality" as identified by staff and students to define and evaluate quality in a university case study.

CONCLUSION

The paper came to the conclusion that the idea of quality assurance (QA) is difficult to define because, like many other concepts in the social sciences, it is subjective and can mean different things in different situations. Despite these challenges, it is essential to comprehend what quality is because the definition will determine how to improve.

Consideration of QA and QE as a continuum is another major finding from this study. The author argued that, although quality assurance (QA) places a greater emphasis on quality assessment in order to identify the strengths and weaknesses of HEIs, it could also be understood as a diagnostic procedure in an institution. QE is concerned more with further developing the quality as a relieving cycle of the restrictions that may be found when the quality was guaranteed, and at the equivalent time, foster the qualities in HEI, in the event that there is any. Being on a continuum of QA-QE, essentially implies any place you go to evaluate an establishment as well as a cycle, you are going to QA; However, QE is followed wherever efforts are made to improve a system or institution. Accordingly, they are incorporated and successive ideas and furthermore intelligent cycles.

The purpose of this paper was to improve comprehension of important ideas in the field of education quality. The author is of the opinion that rather than attempting to develop a single definition, research into quality definitions ought to be carried out by researchers with diverse backgrounds in order to enhance our comprehension of the topic from a variety of perspectives. Accreditation, standards, bench marking, quality criteria, and quality assessment and evaluation are all areas that could benefit from additional attention.

Albeit quality was initially gotten from ventures and organizations, its definition in an instructive setting ought to be unique in relation to its importance in different regions. This is mostly due to the fact that education is a very complicated process with many moving parts, like students, teachers, administrators, curriculum, teaching, and assessment methods that interact in a complicated way. Instead of focusing on products, as is the case in industry, education addresses students' attitudes, values, and minds; Students' own experiences and perceptions of instruction shift as a result. As a result, one of the main findings of this study is that understanding the educational process should be consistent with understanding quality in education.

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Analysis of the Mechanical Properties of ‘U’ Notched Aluminum Alloy

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ABSTRACT

Analysis has been carried out to find the impact of notch offset distance on the crack impact and weight holding capacity of aluminum alloys under bending load. All the experiments are performed on 100 kN servo-hydraulic universal testing machine under displacement mode of control. The changes in mechanical properties with notch length ‘a’ and notch offset distance ‘H’ were studied on specimens under bending load. The stiffness and ultimate load of the material is maximum for a single notched specimen and decreases as the notch offset distance was increased.

Keywords: Analysis, Aluminum alloys, ‘U’ notched, Bending Load.

1. INTRODUCTION

The load carrying capacity and toughness of assemblies may be affected by the initiation of cracks. Due to the high stress concentration in the vicinity of a crack tip it can result in the failure of the structure. The fracture mechanics theory can be used to analyze structures and machine components with cracks and to obtain an efficient design. The fracture mechanics has obtained a desirable want in studying the nature of the crack growth under the influence of static and dynamic loads. Several types of failures have resulted due to the effect of the cracks and stress raiser in the manufactured parts on their failure strength. Reason for the fracture of the stressed component containing cracks has been an interesting and challenging analysis for the designers in the field of fracture mechanics. Multiple cracking is one of the most common problems in ageing aircraft, pressure vessel and piping components. Such cracking often occurs in localized patches or colonies owing to various types of material failure, such as in stress corrosion cracking (Leis, 1997), fatigue (Soboyejo, 1990) and corrosion fatigue (Wang, 1996). U or V-shaped notches are extensively used in the design of engineering components. Gears, screws, bolts and nuts are some of the well-known machine elements that contain sharp or rounded-tip V-notches. Since V-notches decrease dramatically the load bearing capacity of components due to the concentration of stress at the vicinity of their tips, sudden fracture is one of the major failure modes in V-notched brittle materials (Ayatollahi, 2010).

Several investigators have studied the problem of interaction of multiple cracks using the numerical techniques like the finite element method, boundary element method, integral transform approach, etc. The studies conducted on the interaction of multiple cracks using the numerical techniques have found that the interaction of the cracks depend upon the geometric parameters like the crack tip distance, crack offset distance, angle of inclination, crack length etc. In the present scenario, the effect of the notch on the specimen is the main area of concern for predicting the life of the component. Because of the factor that as the cracks or notches are generated in the metal, it decreases its strength. The effect of the multiple notches, notch length and notch offset distance are the main variants to predict the overall strength of the material. For that, the experiment was performed on different notch length and notch offset distance in aluminum alloy under three point bending. Aluminum is taken as a material of the specimen due to its high ductility, high strength weight ratio and good machinability.

There are mainly two major areas used in the present investigation i.e. material testing, fracture mechanics and result evaluation. Testing is used to determine the mechanical properties such as ultimate load, yield load, flexural stress, flexural strain, flexural modulus and fracture toughness under three point bent test and tensile test. Evaluation is



used to determine the error factor between the predicted and the actual values of different parameters as described above. It is also used to see effect of the notch length and notch offset distance from the notch at the centre of the specimen on the ultimate load, yield load, flexural stress, flexural strain, flexural modulus and fracture toughness of the specimen.

2. EXPERIMENTAL ANALYSIS

2.1. Method of Specimen Preparation

The mechanical properties (shown Table 2) have been determined by tensile tests on 100 kN servo hydraulic control Universal Testing Machine (100 kN ADMET, USA make) under displacement control mode as shown in the Fig. 1. All specimens (shown Fig 2. And Table 3) is prepared according to the ASTM-E8 standard. The specimens are prepared for tensile and three point bending test of thickness of 7 mm from the aluminum alloy plate. The dimension of the specimen is 150 mm x 30 mm x 7 mm. The gauge length for this case is kept 150 mm and the span length is 120mm (between the roller supports). All tests are conducted in accordance with ASTM-E8 standard at cross head speed 1 mm/min.

2.2. COMPOSITION OF ALUMINUM ALLOY

Aluminum alloy is used to conduct the experiments for present investigation. Aluminum alloy used has a composition shown below in Table 1. As determined on the basis of energy dispersive spectrometry with equipment JSM-6610IV.



Fig 1. Specimen loaded on Universal Testing Machine

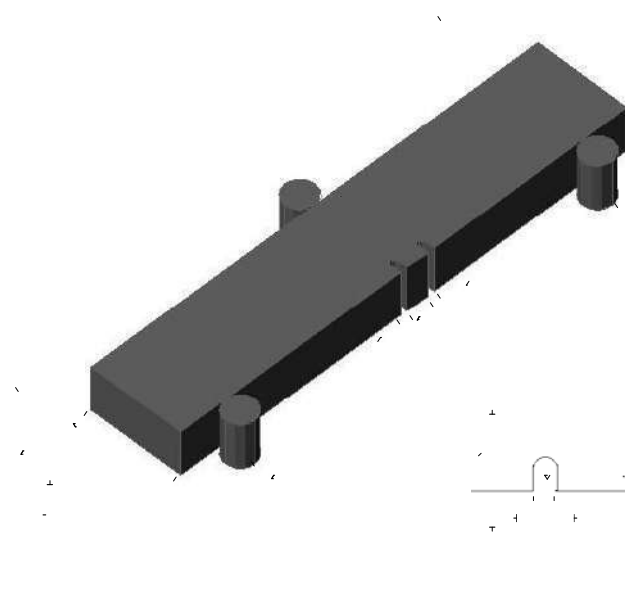


Fig 2. Specimen geometry in mixed mode loading under three point bending (All dimensions are in mm)

Table 1. Chemical composition of Aluminum alloys (wt %)

Material	Width (mm)	Al	Ag	Mg	Fe	Zn	Si	Cu	Ti	Mn	Cr	Other Elements
Al alloy	7	82.4	1.55	0.95	0.48	0.25	0.6	0.3	0.12	0.05	0.05	13.5



Table 2. Mechanical properties of Aluminum alloy

Sl. No.	Depth (mm)	Yield Strength (MPa)	Ultimate strength (MPa)	Modulus of Elasticity (MPa)	% Elongation
1	7	98.98	105.5	13526.65	4.49

Table 3. Specimen Geometry and there Relative Positions for B= 7mm

Sl. No.	Notch size (mm)		Span length L(mm)	Width W(mm)	Relative Position H(mm)
	a ₁	a ₂			
1	3	0	120	30	0
2	3	3	120	30	3
3	3	3	120	30	4
4	3	3	120	30	5
5	3	3	120	30	6
6	3	3	120	30	10

Mechanical U-notches were made at the center of the plate at different notch offset distances. The actual notch radius is measured by help of Auto CAD software. The measured values of Notch radius (R) = 0.64 and Angle = 14.2 degree

3. RESULT AND DISCUSSION

The uniaxial stress-strain behavior of the specimen has been studied on servo-controlled computerized universal testing machine under displacement control mode. The variation of the load-deformation for different configuration with notches at constant notch depth ratio and different notch offset distances at constant crosshead speed of 1 mm/min for 7 mm thick specimen have been shown in the Fig5-6. We see that the notch offset distances (H=4, 5, 6) give variation.

3.1. Load-Deformation Behavior For Different Notch Offset Distance (H)

Figure 5. Shows the effect of notch offset distance on the load-deformation behavior for aluminum alloys of plate thickness B= 7 mm. The modulus of elasticity, ultimate load and area under the load- deformation curve are found 3735.3 MPa, 5800.3 N and 8.774 N-mm respectively for notch length a₁= 3mm and H= 0. At H= 3 mm, the modulus of elasticity, ultimate load and area under the load deformation are found as 3212.4 MPa, 5259.5 N and 10.34 N-mm respectively. From these results it can be seen that the modulus of elasticity and ultimate load are decreased by 14% and 9% respectively for H= 3 mm as compared to H= 0. while area covered under the load-deformation curve is increased by 18%. On further increase of offset distance to 4 mm, 5 mm, 6 mm and 10 mm, the modulus of elasticity are found as 3504.9 MPa, 3635.6 MPa, 3677.7 MPa and 4147.4 MPa. These results overall shows that there is an decrease and increase of modulus of elasticity at H= 4 mm, H= 5 mm, H= 6 mm and H= 10 mm respectively as compared to single notched three point bend specimen by 6.16%, 2.66%, 11.03 % and 1.54% respectively. Similarly, at notch offset distance of 4 mm, 5 mm, 6 mm and 10 mm, the ultimate load is found as 4266.3 N, 5566.6 N, 2771 N and 4942.8 N respectively. This shows that the ultimate load decreases as compared to single notched three point bend specimen by 26.44%, 4.02%, 52.22% and 14.78%. The area under the load deformation curve at notch offset distance of 4 mm, 5 mm, 6 mm and 10mm are observed as 9.27 N-mm, 12.85 N-mm, 5.15 N-mm and 8.33 N-mm. It is seen that the area under the curve increases as compared to single notched three point bend specimen by 5.74%, 46.45%, 41.23% and 5.03% respectively.

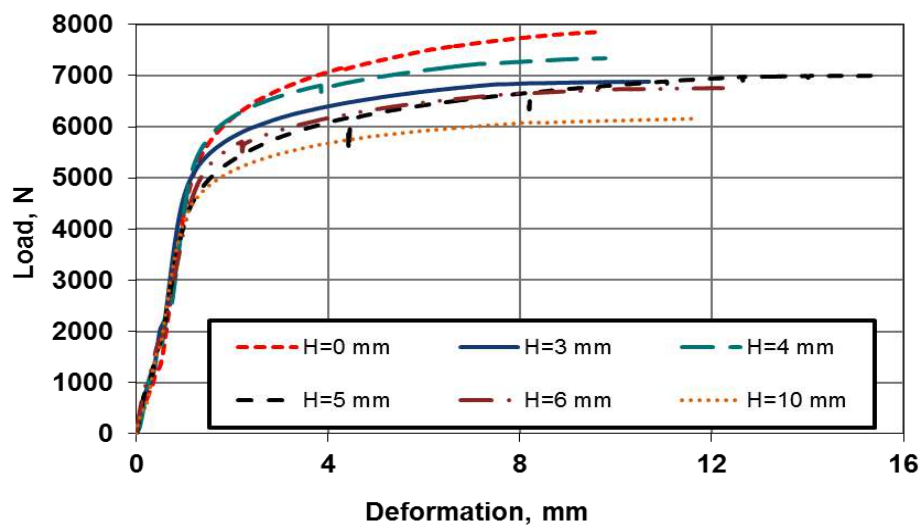


Fig 6. Load-deformation behavior for different notch offset distance (H) at U-notch depth ratio (a_2/a_1) of 1 and $B= 7$ mm

4. CONCLUSION

4.1. Effect Of Notch Offset Distance On The Mechanical Properties

At $B= 7$ mm, the notch offset distance increases $H= 0$ to $H= 3$ that the modulus of elasticity and ultimate load are decreased by 14% and 9% respectively. While area covered under the load-deformation curve is increased by 18%. On further increase of offset distance to 4 mm, 5 mm, 6 mm and 10 mm, the modulus of elasticity start decreasing on further increase notch offset distance 6.16%, 2.66%, 11.0 and 1.54% respectively. The ultimate load decreases on increases the offset distance by 26.44%, 4.02%, 52.22% and 14.78%. The area under the load deformation curve on increasing the notch offset distance are increases 5.74%, 46.45%, 41.23% and 5.03% respectively.

5. CONCLUSION

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Air Pollution & Health

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Abstract:

Air pollution is one of the biggest environmental and public health issues in India. The country is facing alarming levels of pollution in many cities, especially in the northern part of the country. Air pollution has a significant impact on the health of people, and it is one of the leading causes of respiratory diseases, cardiovascular diseases, and other health problems. This research paper aims to provide an overview of the air pollution situation in India and its impact on the health of the people. The study also highlights the measures taken by the government to address the issue and suggests some recommendations to mitigate the problem.

Introduction:

Air pollution is a critical environmental and public health issue in India. The country is facing severe air pollution levels in many cities, especially in the northern part of the country. The high levels of air pollution in India are primarily caused by industrialization, urbanization, and transportation. Pollution levels are increasing at an alarming rate, and it is becoming a significant concern for public health.

Air pollution has a significant impact on the health of the people. Exposure to polluted air can cause various respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer. Air pollution also increases the risk of cardiovascular diseases, stroke, and other health problems. The World Health Organization (WHO) estimates that air pollutants cause seven million premature deaths worldwide every year, and a significant proportion of these deaths occur in India.

Air Pollution in India:

India is one of the maximum polluted international locations within the world. The country has some of the highest levels of air pollution in the world, especially in its cities. According to the Global Burden of Disease Study 2019, air pollution is the third leading cause of death in India after malnutrition and high blood pressure. The study also estimates that 1.67 million deaths in India were attributable to air pollution in 2019.

India's primary sources of air pollution are industrialization, urbanization, and transportation. Industries, especially in the northern part of the country, contribute significantly to air pollution levels. Burning fossil fuels in industries, power plants, and vehicles also increase pollution levels. Vehicular emissions are a significant contributor to air pollution levels in cities.

Impact of Air Pollution on Health:

Air pollution severely impacts people's health, and it is one of the leading causes of respiratory diseases, cardiovascular diseases, and other health problems. Exposure to polluted air can cause various respiratory diseases such as asthma, chronic obstructive pulmonary disease (COPD), and lung cancer. Air pollution also increases the risk of cardiovascular diseases, stroke, and other health problems. Children, elderly people, and people with pre-existing health conditions are more vulnerable to the health effects of air pollution. Children are extra at risk of respiratory illnesses because of their growing respiratory systems. Elderly people are more vulnerable to cardiovascular diseases and other health problems due to their weakened immune systems.



Measures were taken by the Government:

The Indian government has taken several measures to address the issue of air pollution in the country. The government has launched several programs and policies to reduce pollution levels in the country. The National Clean Air Programme (NCAP) is a comprehensive program launched by the Indian government in 2019 to address the issue of air pollution in the country. The program aims to reduce particulate matter (PM) levels by 20-30% in the next five years. The program also aims to increase the air quality monitoring stations in the country and create public awareness about the issue. The government has also launched several other programs such as the Pradhan Mantri Ujjwala Yojana, which aims to provide clean cooking fuel to poor households. The government has also implemented the Bharat Stage VI emission.

New technology of air pollutants studies in India:

India has been grappling with the issue of air pollution for several years, with the situation worsening each year. The country has some of the highest levels of air pollution in the world, and the impact of air pollution on public health is becoming increasingly evident. However, there is hope for a new era of air pollution research in India, with various initiatives and efforts being undertaken to address this critical issue.

The need for air pollution research in India:

Air pollution is a complex and multifaceted issue, and understanding its causes and effects requires a deep understanding of the scientific and technical aspects of the problem. While India has been aware of the problem of air pollution for some time, there has been a lack of comprehensive research and analysis on the issue. This has limited the government's ability to develop effective policies and programs to address the problem.

Moreover, while air pollution affects people of all age groups and socio-economic backgrounds, the impact is more severe on vulnerable populations such as children, the elderly, and those with pre-existing health conditions. Therefore, there is a need for research that focuses on the impact of air pollution on these populations and identifies effective ways to mitigate the effects of air pollution on their health.

Recent initiatives to address the issue:

Several initiatives have been launched in India to address the issue of air pollution, including those related to research and development. One such initiative is the National Clean Air Program (NCAP), launched by the Ministry of Environment, Forest, and Climate Change in 2019. The program aims to reduce particulate matter (PM) pollution levels by 20-30% in 122 cities across India by 2024. The program also includes a focus on research and development, with the establishment of a National Knowledge Network on Air Pollution (NKAP) to facilitate research and information sharing.

Another notable initiative is the Joint Air Pollution Studies (JAPS) program, a collaboration between the Indian and US governments, which focuses on improving air quality monitoring and scientific understanding of the causes and effects of air pollution in India. The program includes research projects on topics such as the health effects of air pollution and the impact of different sources of pollution on air quality.

In addition to these initiatives, there have also been efforts to promote citizen science and community-based monitoring of air quality. For instance, the Indian Institute of Technology, Delhi, has developed a low-cost air quality tracking tool that may be utilized by residents to screen air high-satisfactory in their neighborhoods.

Challenges and the manner forward:

Despite these initiatives, several challenges need to be addressed to ensure that air pollution research in India can contribute effectively to addressing the issue. One of the key challenges is the lack of a coordinated approach to research and development, with different agencies and organizations working independently on different aspects of the problem. This can lead to duplication of efforts and a lack of synergy in addressing the issue.

Another challenge is the lack of adequate funding for air pollution research and development. While there have been some initiatives to promote research, such as the NCAP and JAPS programs, more resources are needed to support a sustained effort to address the issue comprehensively.



In conclusion, the issue of air pollution in India is complex and multifaceted, and addressing it will require a concerted effort from various stakeholders, including government agencies, researchers, and civil society organizations. While there have been several initiatives launched to address the issue, more needs to be done to ensure that air pollution research in India can contribute effectively to addressing the problem. With a coordinated and sustained effort, it is possible to usher in a new era of air pollution research in India and mitigate the impact of air pollution on public health.

Pollutants of present-day interest:

Ozone, particulates, nitrogen dioxide Ozone, particulates, and nitrogen dioxide are all pollutants of current interest due to their significant impacts on human health and the environment.

1. Ozone: Ozone is a gas composed of three oxygen atoms (O₃) that can be found in both the Earth's atmosphere and at ground level. Ground-level ozone is a major component of smog and is formed when pollutants emitted by cars, power plants, and other sources react in the presence of sunlight. Ozone can cause a range of health problems, including respiratory irritation, coughing, and aggravation of asthma symptoms. It can also damage crops and other vegetation.

2. Particulates: Particulate matter (PM) is a mixture of tiny particles and droplets suspended in the air. These particles can be emitted by sources such as car exhaust, wildfires, and industrial processes. Particulates can penetrate deep into the lungs and cause a variety of health problems, including lung cancer, heart disease, and stroke. They can also harm the environment by reducing visibility, harming plant life, and contributing to climate change.

3. Nitrogen dioxide: Nitrogen dioxide (NO₂) is a gas that is primarily emitted by motor vehicles and power plants. It is a major component of air pollution and can cause respiratory problems, particularly in people with pre-existing lung conditions. Nitrogen dioxide can also contribute to the formation of acid rain and smog.

All three of these pollutants are a cause for concern due to their negative impacts on human health and the environment. Governments and environmental organizations around the world are taking action to reduce their emissions and limit their effects on the planet.

Main findings from epidemiological studies:

Epidemiological studies of air pollution have consistently found that exposure to high levels of air pollution is associated with a range of adverse health outcomes. Here are some of the key findings from these studies:

1. Cardiovascular disease: There is strong evidence that exposure to air pollution is a risk factor for cardiovascular disease, including heart attacks and strokes. Long-term exposure to air pollution is also associated with an increased risk of hypertension and heart failure.
2. Respiratory disease: Air pollution is a major risk factor for respiratory disease, including asthma, chronic obstructive pulmonary disease (COPD), and lung cancer. Exposure to air pollution can cause inflammation in the lungs, which can exacerbate these conditions.
3. Premature death: Numerous studies have found that exposure to air pollution is associated with an increased risk of premature death, particularly from cardiovascular and respiratory causes. One study estimated that air pollution is responsible for over 7 million premature deaths each year globally.
4. Cognitive decline: Recent studies have suggested that exposure to air pollution may be a risk factor for cognitive decline and dementia. One study found that people living in areas with high levels of air pollution had a 40% higher risk of developing dementia compared to those in areas with lower levels.
5. Adverse pregnancy outcomes: Exposure to air pollution during pregnancy has been linked to a range of adverse outcomes, including low birth weight, preterm birth, and fetal growth restriction. Some studies have also suggested that air pollution may be associated with an increased risk of miscarriage.

Overall, the evidence from epidemiological studies of air pollution indicates that reducing exposure to air pollution could have significant public health benefits.



Air quality guidelines and standards of India:

India has established air quality guidelines and standards to protect public health from the harmful effects of air pollution. The key air quality guidelines and standards in India include:

1. **National Ambient Air Quality Standards (NAAQS):** These are the national standards for ambient air quality in India, which were first introduced in 1982 and revised in 1994, 2009, and 2018. NAAQS set limits on the concentration of pollutants in the air, including particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone, among others.
2. **Air Quality Index (AQI):** AQI is a tool that measures air quality on a daily basis and provides information to the public on the health effects of air pollution. AQI is based on the concentration of pollutants in the air and ranges from 0 to 500, with higher values indicating worse air quality.
3. **National Clean Air Program (NCAP):** NCAP is a national program launched by the Indian government in 2019 to reduce air pollution and improve air quality. The program sets targets to reduce particulate matter (PM) concentrations by up to 30% in 102 cities by 2024.
4. **State-specific air quality standards:** Some states in India have established their own air quality standards, which may be more stringent than the national standards. For example, the state of Delhi has introduced its own air quality standards, which set stricter limits on particulate matter and other pollutants than the national standards.

Overall, India's air quality guidelines and standards reflect the country's commitment to addressing air pollution and protecting public health. However, more needs to be done to achieve and maintain clean air in India, particularly in urban areas where air pollution is a major problem.

Current issues:

Air pollution continues to be a major public health issue around the world. Here are some of the current issues related to air pollution and health:

1. **COVID-19 pandemic:** There is growing evidence that air pollution may increase the severity and mortality of COVID-19. Exposure to air pollution can weaken the respiratory system, making it more vulnerable to respiratory infections like COVID-19.
2. **Wildfires:** The increasing frequency and severity of wildfires around the world are contributing to high levels of air pollution, particularly in areas near or downwind of the fires. Exposure to wildfire smoke can cause respiratory and cardiovascular health problems.
3. **Urbanization:** Rapid urbanization in many parts of the world has led to increased air pollution, particularly from transportation and industrial activities. This has resulted in higher levels of particulate matter, nitrogen oxides, and other pollutants in urban areas, which can have serious health consequences.
4. **Climate change:** Climate change is expected to exacerbate air pollution, particularly in areas that are already heavily polluted. Rising temperatures and changes in weather patterns may lead to increased levels of air pollutants and worsen the health impacts of air pollution.
5. **Inequities:** Air pollution disproportionately affects low-income and marginalized communities, who often live in areas with higher levels of pollution. This can exacerbate health disparities and contribute to unequal health outcomes.

Overall, addressing air pollution and its health impacts requires a comprehensive approach, including reducing emissions from transportation and industry, improving access to clean energy, and ensuring equitable access to clean air for all.



Disputing the evidence:

Disputing the evidence of air pollution is not supported by scientific evidence. There is overwhelming scientific evidence linking air pollution to a range of adverse health effects, including respiratory and cardiovascular diseases, premature death, cognitive decline, adverse pregnancy outcomes, and more.

The evidence comes from a large body of research, including epidemiological studies, toxicological studies, and controlled human exposure studies, conducted over several decades in different countries around the world. This study always suggests that publicity of excessive tiers of air pollutants is related to an improved threat of negative fitness outcomes.

The scientific community, including major public health organizations like the World Health Organization and the American Lung Association, has recognized the risks of air pollution and called for action to address this issue. Governments around the world have also established air quality guidelines and standards to protect public health.

While there may be different opinions about the most effective policies and interventions to address air pollution, disputing the evidence of its harmful effects is not a valid scientific position. Ignoring the evidence and failing to take action to address air pollution can have serious consequences for public health and the environment.

Government Initiatives:

The Government of India has implemented a range of policies to address air pollution and protect public health. Some of the key policies include:

1. **National Clean Air Program (NCAP):** Launched in 2019, NCAP is a five-year action plan aimed at reducing air pollution in 102 cities in India. The program sets targets to reduce particulate matter (PM) concentrations by up to 30% by 2024 and includes measures such as expanding monitoring and surveillance of air quality, promoting cleaner technologies and transportation, and improving public awareness and participation.
2. **National Ambient Air Quality Standards (NAAQS):** Established in 1982, NAAQS set legal limits on the concentration of pollutants in the air, including particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and ozone, among others. NAAQS has been revised several times, most recently in 2018, to reflect the latest scientific evidence on the health impacts of air pollution.
3. **Swachh Bharat Abhiyan:** Launched in 2014, Swachh Bharat Abhiyan is a national cleanliness campaign aimed at improving sanitation and environmental hygiene. The campaign includes initiatives such as building toilets, managing waste and promoting behavioral change to reduce littering and open defecation.
4. **Bharat Stage VI Emission Standards:** Introduced in 2020, Bharat Stage VI Emission Standards set limits on the emissions of pollutants from vehicles. The new standards are more stringent than the previous Bharat Stage IV standards, and require the use of cleaner fuels and advanced emission control technologies.
5. **Odd-Even Scheme:** Implemented in Delhi in 2016 and 2017, the Odd-Even Scheme restricted the use of private vehicles on alternate days based on the last digit of their license plate numbers. The scheme aimed to reduce traffic congestion and air pollution during peak traffic hours.

Overall, while India has made significant progress in addressing air pollution and improving air quality, more needs to be done. To gain and preserve easy air within the country, mainly in city regions in which air pollutants is a chief problem. Ongoing efforts are needed to implement and enforce policies, invest in cleaner technologies and infrastructure, and promote public awareness and participation in addressing air pollution.

Conclusion:

Air pollution is a major environmental and public health challenge in India. The country's rapid industrialization, urbanization, and increased energy consumption have led to a significant increase in air pollution levels, particularly in its cities. Air pollution is associated with a range of adverse health effects, including respiratory and cardiovascular diseases, premature death, adverse pregnancy outcomes, and cognitive decline.



To address the problem of air pollution, the Government of India has implemented a range of policies and programs, including the National Clean Air Program (NCAP), National Ambient Air Quality Standards (NAAQS), Swachh Bharat Abhiyan, Bharat Stage VI Emission Standards, and the Odd-Even Scheme, among others. These efforts have helped to reduce air pollution levels in some parts of the country, but more needs to be done to achieve and maintain clean air, particularly in urban areas.

There is a need for continued investment in cleaner technologies and infrastructure, as well as the promotion of public awareness and participation in addressing air pollution. Measures such as expanding monitoring and surveillance of air quality, promoting cleaner technologies and transportation, improving waste management, and promoting sustainable practices can help to reduce air pollution and protect public health.

In addition, there is a need for greater collaboration between government agencies, civil society organizations, academic institutions, and the private sector to address the complex and multidimensional problem of air pollution. This requires a concerted effort to develop and implement integrated and coordinated strategies that address the root causes of air pollution and the various factors that contribute to its persistence.

In conclusion, air pollution is a critical environmental and public health challenge in India, and urgent action is needed to address this issue. While the government has taken several steps to address air pollution, there is still much to be done to achieve and maintain clean air. It is important for all stakeholders to work together to find innovative solutions and implement effective policies that can help to reduce air pollution levels and protect public health in India.

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Effect of Sample Size on Micro Magnetic Properties of Mild Steel

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Abstract

Objective of current study is to analyze the effect of frequency, magnetic field intensity, and waveform on the hysteresis loop and Barkhausen Noise signals. As the property of ferromagnetic material, especially the hysteresis loop and BN depends on the microstructure, MFI, and frequency. In this study, the HL and BN of the mild steel sample were experimentally measured by varying the frequency, MFI, and wave form using magnetic Barkhausen noise analyzer. . First, all samples of base metal are cut into a different size, and later, all sample was subjected to annealing. The Barkhausen test has been performed in two steps; first frequency varies, magnetic field intensity kept constant, and second magnetic field intensity varies, frequency remained constant. First Barkhausen noise analysis frequency were applied from 20 Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500Oe, 750Oe, 1000 Oe at 25 Hz constant whereas sinusoidal and triangular waveform varies from 0.1 Hz to 0.4 Hz at 500 Oe constant and 150Oe, 300Oe, 400Oe, 600Oe at 0.1 Hz constant. In the second part of the work, the Barkhausen noise technique has been applied to analyze the surface integrity of the mild steel after annealing process. The Barkhausen noise parameter depends upon surface residual strain and hardness.

Introduction

Ferromagnetic material composed of magnetic domain (refer fig.1) in order to minimize the magnetostatic energy. When a changing magnetic field is applied on ferromagnetic material, the magnetization and demagnetization of the material form a closed curve known as hysteresis loop, the movement of the magnetic domain wall is hindered by the pinning sites such as precipitates, grain boundary, inclusions, dislocations, small volume of second phase material and remains pinned until the applied magnetic field is increased enough to overcome it.

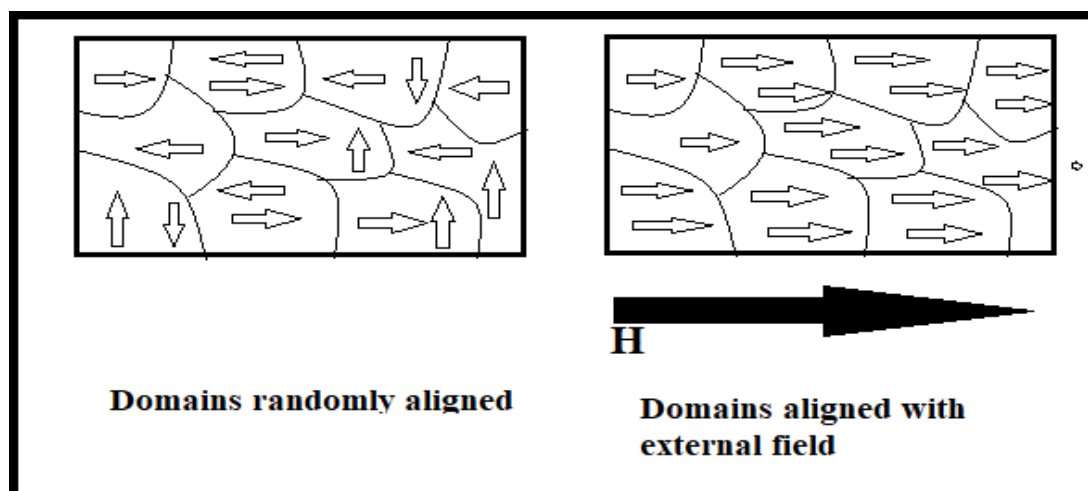


Fig.1 Magnetic Domain Wall movement in external magnetic field.



When such condition is reached, change in magnetization is produced by the abrupt movement of domain wall. Various experimental studies have been undertaken to relate the characteristics of hysteresis loop such as coercivity, permeability, remanence, and core loss with excitation frequency, magnetic field intensity, and waveform. Dependence of hardness, stress state, and grain size can also be related to characteristics of hysteresis loop. In 1919 Barkhausen noted that, when a ferromagnetic material is magnetized by an increasing field, noise in the form of voltage pulses are induced in a coil placed near the material. [1]

Magnetic Barkhausen noise is produced due to irreversible discontinuous domain wall bowing, irreversible discontinuous domain wall translation, and irreversible discontinuous domain rotation [2]. Out of these, irreversible discontinuous domain wall translation is mainly responsible for Barkhausen noise. The signals of Barkhausen noise are represented in the form of voltage pulses [3]. Various experimental studies have been undertaken to relate the characteristics of Barkhausen noise such as Peak value, RMS value with excitation Frequency [4,5]. MBN can be related to grain size, microstructure, residual stress, and applied stress [6, 7]. Therefore MBN can be used as a non-destructive method of Material Characterization.

Experimentation

The sample was polished using a different grade of emery paper. Magnetic Barkhausen noise measurement was performed using Magstar system supplied by Techno four, India. Measurement system as shown in Fig.2 consist of a flat-surface probe with U shape magnetizing yoke to generate magnetic field inside the test sample with the help of current from the power supply. A pick of coil (ferrite) at the center was use to gather the signal generated as the magnetic response of the work material. Table 1 enlist the detail of parameter considered for the Barkhausen noise analysis. The selection of frequency and magnetic field intensity were based on the various trail runs so as to avoid distortion in the magnetizing signal due to magnetic coupling between the magnetizing coil and work sample. First to analyze the effect of frequency, MFI on Barkhausen noise, frequency was varied 20Hz, 30Hz, 40Hz, 50 Hz at 800 Oe constant and MFI varies from 250 Oe, 500 Oe, 750 Oe, 1000 Oe at 25 Hz constant. Further to analyze the frequency, MFI and waveform on hysteresis loop and its parameter were applied where frequency varies from 0.1 Hz to 0.4 Hz at 500 Oe constant, and MFI varies as 150 Oe, 300 Oe, 400 Oe, 600 Oe. Fig.3 represent the typical magnetic Barkhausen noise burst along with superimposed external magnetic excitation field as received. In the second part of work, again Barkhausen noise technique has been applied to analyze surface integrity of base sample of mild steel after annealing process. Annealing process is done at 850 °C and hold at this temperature for 15 minutes and cooled in furnace.

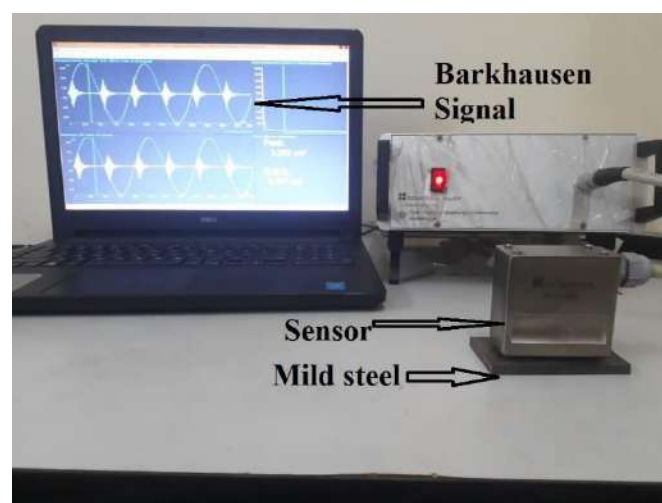


Fig.2 Magnetic Barkhausen noise analyzer used in work.

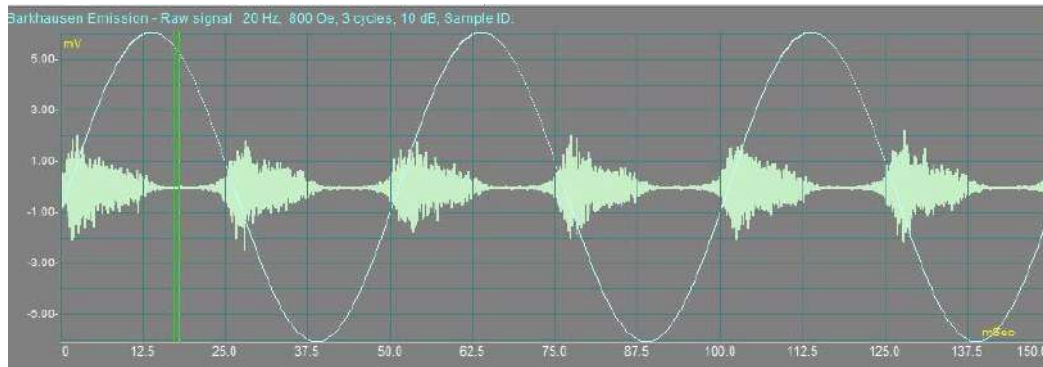


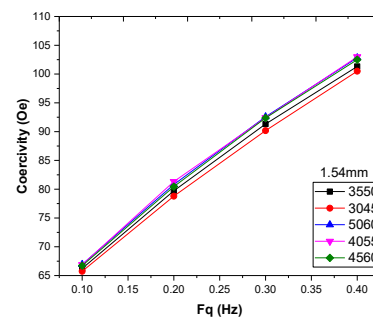
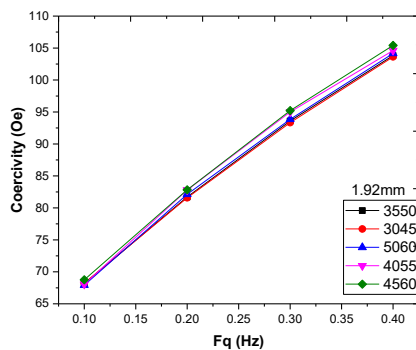
Fig.3 Barkhausen noise burst as received from work sample (mild steel).

Table 1: Details of parameter for MBN analysis

Magnetizing frequency	50Hz
Magnetic field intensity	1000 Oersted
Gain	10dB
No. of burst	6
Filter frequency	10-300 KHz

Result and discussion

The coercivity of ferromagnetic materials can be correlated to hardness and increase in dislocation density. Moreover, coercivity also depends on the frequency and MFI [8,9]. Increase in frequency decrease the amount of penetration of magnetic field into the material, which is turn represents the increase in the amount of reverse magnetic field needed to drive the magnetization to zero after saturation(also know as coercivity). Thus coercivity increase with the increase in frequency and magnetic field intensity and coercivity has a little amount in a variation on the material size and thickness as shown in fig.3.



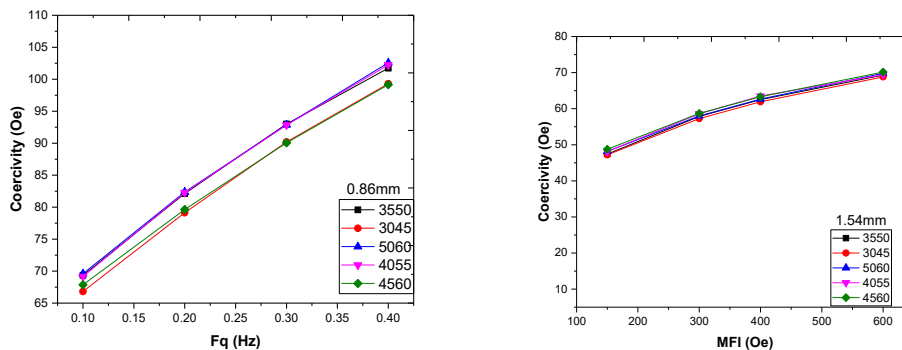


Fig.3 Variation of coercivity with frequency and magnetic field intensity.

Generally, permeability is reciprocal of coercivity and is represented by the slope of the curve at starting point of Hysteresis loop in such a way that the slope of tangent at starting point reduces, which turn cause reduction in permeability. Average permeability decrease with increase in frequency and has a little amount in variation with size and thickness of mild steel sample and also decrease with increase in magnetic field intensity, and larger size sample has a greater value of average permeability as shown in fig.4.

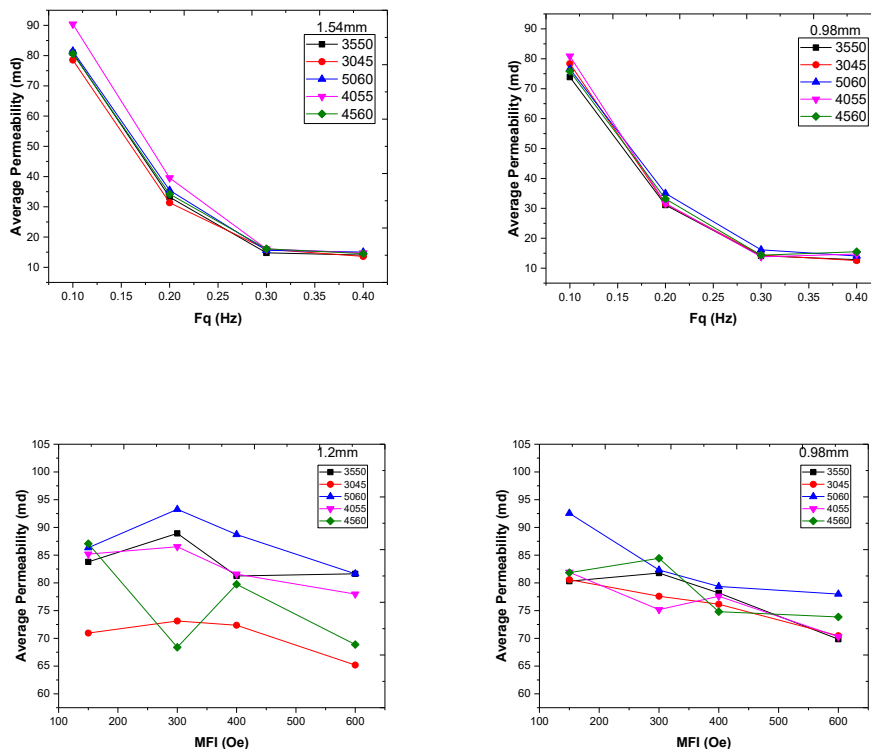


Fig.4 Variation of Average permeability with frequency and MFI.

Remanence is residual magnetic field left in material when external applied field reduces to zero. Remanence decreases with an increase in frequency due to shielding effect of eddy current, which prevent magnetization at greater depth, as



shown in fig.5 and has no effect on thickness and size of the sample. Remanence increase with an increase in magnetic field intensity due to greater size of material magnetized as shown in fig.6.

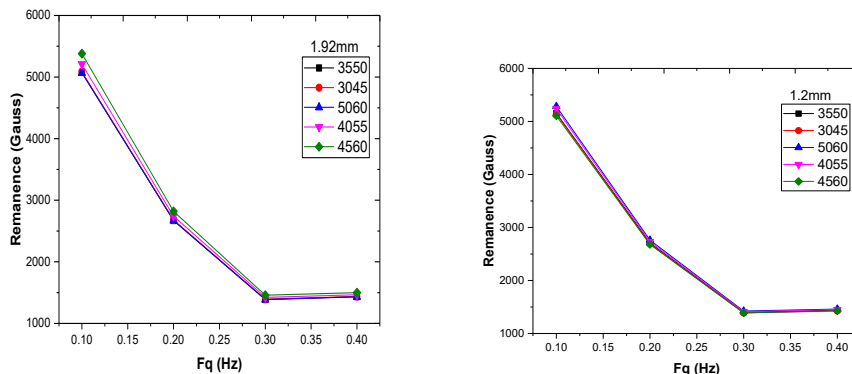


Fig.5 Variation of Remanence with frequency.

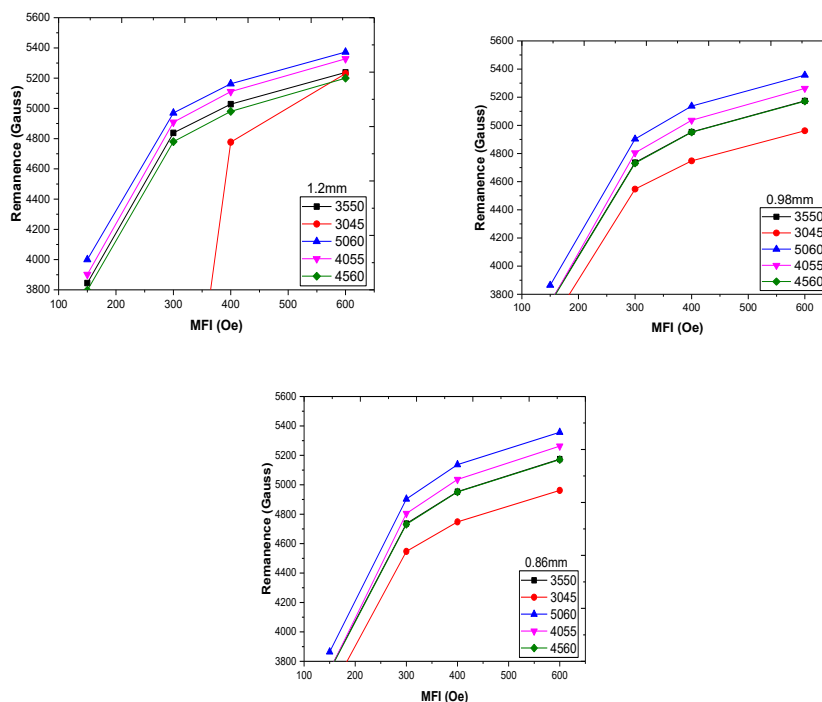


Fig.6 Variation of Remanence with MFI.

Peak and RMS value BN increase with an increase in frequency due to increase in number of domain walls frequency. Similarly, with an increase in magnetic field intensity peak and RMS of BN increase. Larger size of sample shows lower value of peaks as compared to small size sample as shown in fig.7.

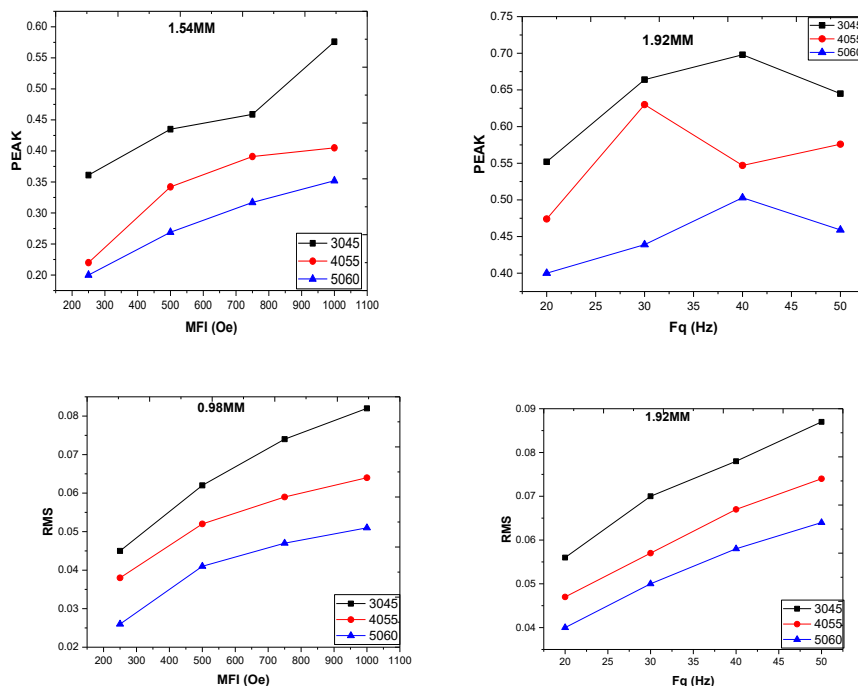


Fig.7 Variation of Paek and RMS with frequency and MFI

Skewness and Kurtosis decrease as frequency increase, and if magnetic field intensity increase Skewness and Kurtosis also increase.

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Review of TIG Welding Process

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Abstract

In present competitive environment mass production is a challenge for industries. A review on TIG Welding Process. Gas tungsten arc welding is essential for industries controlling bead shape and metallurgical characteristics. Shallow penetration of TIG welding limits for welding only thick structures in a single pass thus its productivity is relatively low and there is need for skill welders. Using activated flux in conventional GTAW (i.e. A-TIG) process is one of the most significant advancements for overcoming the shortcomings of TIG welding, increases the depth of penetration in single pass and to also increase depth to width ratio of the weld pool, thereby increasing the productivity of the process and also it helps in achieving better mechanical properties.

Keywords- GTAW, A-TIG, Activated Flux, Penetration

Introduction

Tungsten Inert Gas (TIG) welding process (or GTAW) is used for better appearance and good quality. Arc is formed between tungsten electrode and the base metal in this process, active flux is used in the A-TIG welding, which is only difference from the conventional TIG welding. Flux can be prepared by using different oxides in powdered form about 30-60 μm particle size. These powders mixed with acetone, methanol, ethanol etc. to produce a paint. Before welding, a thin layer of paint is applied on the surface of the joint to be welded. The density of flux should be about 5-6 mg/cm^2 . Specific activated flux has been developed for enhancing the penetration performance of the TIG welding process for welding of type 304L and type 316L stainless steels. Penetration of over 300% was observed in single pass TIG welding. The significant improvement in penetration was attributed to constriction of the arc and the reversal of Marangoni flow. Using flux helped to overcome the variable weld penetration noticed during autogenously TIG welding of austenitic stainless steel with less than 50 ppm silver. There is no degradation in the microstructure and mechanical properties of welds produced by A-TIG welding compared to that of conventional TIG welding process. The activated flux which gets vaporized during welding will constrict the arc by capturing electrons in the outer regions of the arc. Electron attachment can take place in the cooler peripheral regions where the electrons have low energy in a weak electric field. Towards the center of the arc where there is a strong electric field, high temperatures and very high energy electrons and ionization will dominate. Thus restricting current flow to the central region of the arc will increase the current density in the plasma and at the order resulting in a narrower arc and a deeper weld pool. A reversal in the Marangoni flow caused by the change in the coefficient of surface tension from negative to a positive value due to an increase in the dissolved oxygen content creates a narrow and deep weld pool. Combined operation of the above two mechanisms only lead to increased penetration by 300% in A-TIG welding. For improving penetration of TIG welding, thorough analysis has been done A-TIG welding (Active flux TIG welding) because the weld shape is sensitive to the free oxygen content in the weld pool. A-G TAW process can achieve, in a single pass, a full penetration weld in stainless steel up to 10 mm thickness without the use of bevel preparation and the addition of filler wire. The weld metal aesthetics are observed to be unaffected. Although the A-TIG welding is still under consideration, the effects of the oxide flux quantity on the weld penetration showed that the arc constriction and the reversed Marangoni convection on the top surface of the weld pool were the main mechanism for changing the weld shape according to the experimental



investigation. Comparison was made between mechanical and metallurgical properties of welds with flux and without flux. The A-GTAW process has been exploited to improve production efficiencies in a wider range of industries, including power generation, chemical, aerospace and marine manufacturing and in nuclear plant.

Determinant factors.

Joint gap

The joint gap (which can be only butt-weld) has great importance from the point of view of the faultlessness of the

Joint. A-TIG welding is applicable only with about zero joint gap. However this condition would query the industrial.

Method of applying of activating flux

The quantities of the applied activating fluxes (0,1... 0,25g/m and 0,1... 0,15 mm) found in the international literature of A-TIG Welding.

Sensitivity for the measure of the activating flux

It is obvious that the human factorial ways contains the possibility of faults. That is why the effects of applying of not suitable quantity of activating fluxes had to be determined.

Choosing of tungsten electrode

The A-TIG welding needed 25% lower amperage (84 Amperes) than the TIG welding (110 Amperes) when we welded 3 mm thick, 1.4301 type stainless steel plates with 13,5cm/min welding speed by one root. For faster electrode amortization other tungsten electrode choosing method had to be developed than is usable for TIG welding.

Motorization of A-TIG welding

TIG welding is sensible for arc length hence motorized method is used. A thicker plate is used manually without joint preparation. So question arises

.What are the mechanical properties of the joints of TIG and A-TIG welding?

- What nature of the microstructure of the welded joint and the heat affected zone (HAZ) has?
- What effects do the activating fluxes left on the joint's surface have on the degradation of corrosion resistance?

1. Advantages of A-TIG Welding

- Existing welding machine, similar welding procedures, but greatly improved productivity
- Usage of this flux results in 1.5– 3 times increase in weld penetration compared to single pass regular TIG welding.
- Overall heating put to the joint significantly reduces, giving extra security against sensitization of low carbon austenitic stainless steels.
- Higher penetration welds obtained using this flux satisfactorily meets the nondestructive tests –DPI, RT&UT.
- Mechanical properties of the weld meet the requirements.
- Application of thin layer of this flux (<100microns) on the area to be welded is enough to get the above benefits.
- Reduction in bevel preparation requirements
- Decrease in number of weld passes.
- Shortening of welding times.
- Reduced consumption of welding filler wire.
- Elimination of back gouging and grinding.
- Reduced distortion.

2. Disadvantages of A-TIG Welding Process



- The use of the flux is seen as an additional cost and its application an additional operation.
- The commercial fluxes tend to produce an inferior surface finish compared to conventional TIG welding in mechanized welding operations but in manual welding operations, the surface roughness similar.

3. Applications

- Pipes and tubes in nuclear industry.
- Fabrication of pressure vessels and tube to tube sheets in heat exchangers .
- Power and chemical industries.
- Hydraulic cylinders and under carriage legs in aerospace industry.

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A study to Evaluate the Utilization of E- Resources of National Digital Library (NDL) Among Learners in DIT University Dehradun, Uttarakhand, India

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Abstract - The Ministry of Education, Govt. of India created the National Digital Library (NDL) as part of its National Mission on Education via Information and Communication Technologies. It is a virtual learning resource framework with a single-window search feature from numerous national and international digital libraries as well as other pertinent resources. The goal of NDL is to make it easier for people to learn from and to prepare using industry best practices from around the globe and to speed up the process of interdisciplinary research from many sources by researchers. Yet it has been noticed that in actual practice, NDL use and usefulness are not promoted among researchers and among different learner segments. This study aims to examine how users in DIT University library, use NDL's electronic resources.

Keyword: NDL, DIT University, Library Science, National Digital Library.

Introduction

National Digital Library (NDL) is an online resource that offers free access to variety of learning media, including fiction, simulations, lectures, films, audio books, textbooks, and other types of learning media. English and several Indian languages are both available for all educational media. Projects of the National Mission on Education via Information and Communication Technologies include NDL (NMEICT). The NDL was created to provide researchers worldwide a single point of access to all types of learning media. The National Digital Library (NDL) is a platform where all educational resources are available for users, including students, researchers teachers, library users, professionals, and all other lifelong learners. It is made available in a 24*7 integrated environment where students can quickly and easily find the appropriate resource. NDL repository, which has content from a variety of subject areas including the arts, sciences, commerce, management science, humanities, agriculture, etc., serves as a national knowledge asset. The learning media are available in more than 400 languages and Repository integrates contents from different Indian Institutional Repositories. NDL India has teamed up with libraries in Indian institute of educational and research, various public libraries as well as with international libraries to get admittance to various educational materials on a wide range of subjects. A digital library called NDL India boasts a collection of over one billion articles and 2 crore resource materials, of which 40 lakh are books. One of the largest online treasure troves at the moment is the NDLIndia. NDL should be able to bring a paradigm shift in education movement in India covering all stages from kindergarten to cutting edge research to life-long learners as general awareness about the benefits of using ICT solutions among the masses is increasing exponentially and there is expectation that the Digital India movement will lead to a stronger and wider reach of the ICT infrastructure across the country. As a result,



knowledge is crucial in the information era for a variety of human undertakings, including education, research and development, decision-making, and policy formation. One of the best platforms for all types of learners is the NDL. Whoever is on the other side, it is a fact that the majority of students are unaware of the benefits of e-resources even if the students are aware of NDL, they either do not use it or do not have the resources to use the e-resources in NDL. This research study is an attempt to discover learner's awareness on NDL, utilization of e-resources available in NDL, an assortment of users of NDL among researchers in DIT University Dehradun, Uttarakhand.

This study aims to identify the learner's awareness of NDL, their usage of the e-resources offered by NDL, and the variety of NDL users among researchers at DIT University Dehradun Uttarakhand.

Review of Literature

Since a few years ago, the teaching and learning system has undergone a significant transformation. Almost all institutions now use a digitalized teaching and learning system in place of more traditional ones. The educational system underwent a tremendous upheaval that shattered NDL's particular powerlessness. Therefore, it is now more important than ever to investigate the precise function of NDL in this evolving educational system and how learners use it. Yet, there haven't been many researches done to fully understand the numerous facets of NDL. The study looks at reviews of publications that deal with various facets of digital libraries and resources. It can be seen that numerous research studies have emphasized the value of digital resources and libraries. Yet, the MHRD, India, National Digital Library Initiative has not been the subject of any such study.

In some authors have checked that The MHRD initiative aims to make the National Digital Library accessible to the public. He encourages all scholars, academics, and students in India to take advantage of this chance and strive to work with him to advance the nation. Rani, N.S.(2020) outlined the goals and benefits of providing search functionality for many user categories in a single window and highlighting the steps for granting access to e-content. Bashir, B., Nasreen et al. (2019) carried out the research study to assess an overview of the National Digital Library of India (NDL India) to comprehend its benefits, characteristics, and collection in the worldwide digital environment. Darandale A. G. (2017) in his study he verified a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis of the National Digital Library of India.

He discovered that the SWOT analysis identified many strengths in the NDL, but that attention must also be paid to its weaknesses and threats if those weaknesses are to be turned into strengths.

Munavalli Sanjay B. (2017) conducted research on the subject areas that NDL content and collection metadata covers in terms of learning resources. NDL search and membership features. NDL has become a blessing for lifelong learners. Via the NDL app, anybody, anywhere, at any time, can access these resources. Majumdar, A. (2017) performed a survey in order to understand how Indian students utilize the NDL mobile app. She also examined student reviews of the NDL. In his study, Puttaswamy, R.M., (2014) highlights the value of e-resources for instructors and students at engineering colleges in the Bangalore area that are part of Visvesvaraya Technological University (VTU), Belgaum, Karnataka. With the aid of questionnaires, survey methodology has been employed as the primary research tool for data collecting. The results show that e-resources are beneficial for engineering college professors and researchers in their scholarly and research

endeavors. According to a research by Tunji Bashorun M. I. et al. (2011) there was little usage of online resources. They identified a number of issues, including how improper use of library services was hampered by users' lack of knowledge of the e-resources the library offer. Mahesh, G. et al. (2008) analysis of India's efforts to establish digital libraries, 63 published papers on digital libraries in India have been analyzed in order to acquire insight, assess, and comprehend the growth, progress, and present status of digital library activities in India as reflected via scholarly journals. The analysis finds that, with the exception of a few studies on copyright issues and management of digital libraries, the majority of papers concentrate on creating digital libraries and digital collections, Digital rights management, security, and digital library rules have not been the subject of any studies. A survey was conducted by Mahesh, G. et al. (2008), he found that NDL would be useful in evaluating the current status as well as in creating an action plan for the establishment of targeted digital libraries in India, also, there aren't many user and use studies on digital libraries in India.



Research Methodology

The goal of this study is to ascertain how well-aware and how often learners - Undergraduate, Postgraduate, research scholar and faculty- at DIT University in Uttarakhand, India- use online resources relevant to NDL. Using the following goals, the current study is assessed.

Research Objectives

- To find out what students expect from NDL.
- To assess learners knowledge of NDL
- To assess the importance of how NDL users use online resources in relation to their gender, and educational level.

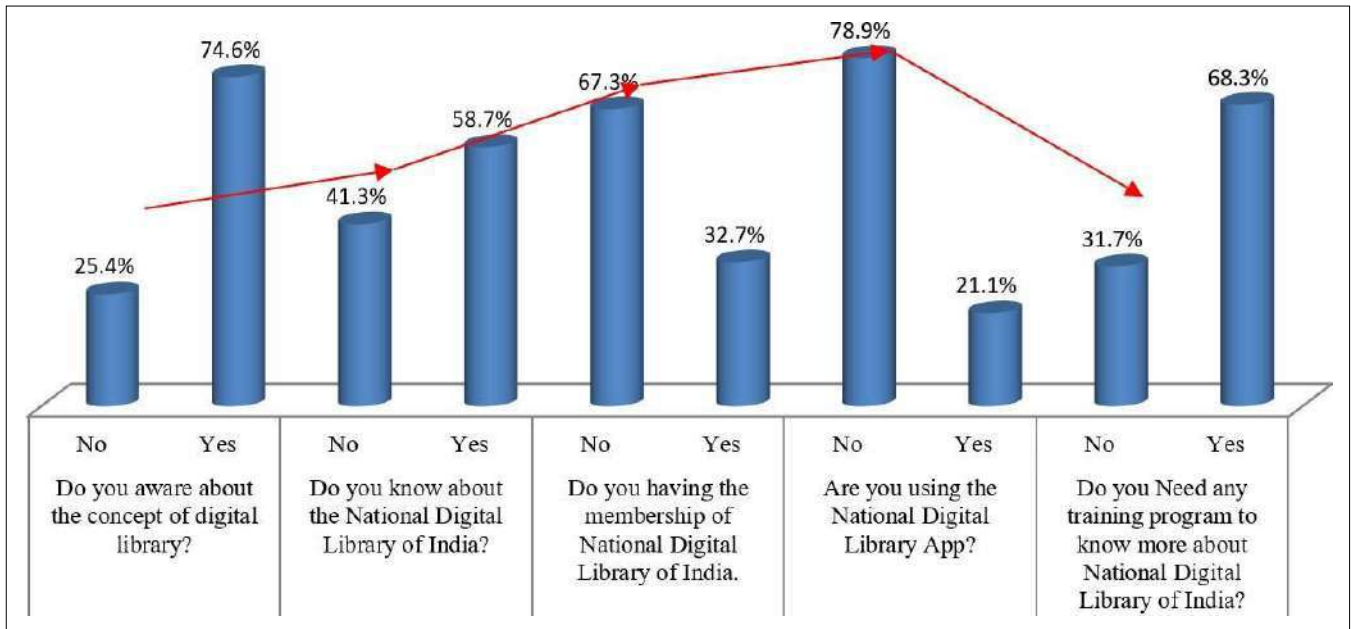
Research Design

The core data for this study was gathered using a survey technique based on questionnaires. The samples are chosen at random. The survey's total sample size of 606 students & faculty member received responses. The survey was conducted among students (UG, PG, research scholar) and faculty members at DIT University, Dehradun, Uttarakhand, India a strategy for data analysis the qualitative variables in this study are counted and reported as a percentage (%) and an ordinal scale (N). The same descriptive statistics are graphically displayed.

Table 1: Awareness of learners on NDL

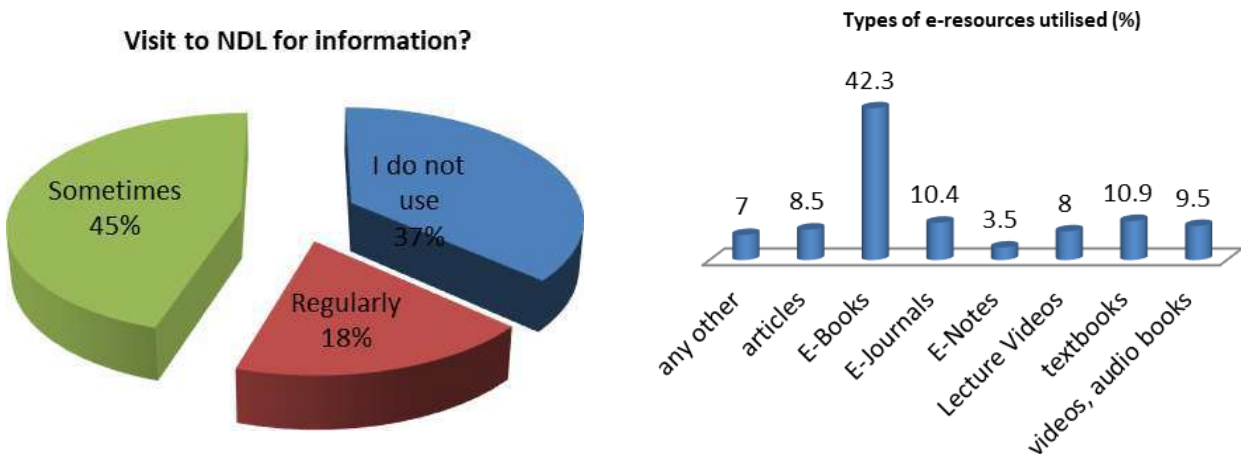
	Do you aware about the concept of "Digital Library"?		Do you know about the "National Digital Library of India"?		Do you having the membership of National Digital Library of India.		Are you using the National Digital Library App?		Do you Need any training program to know more about National Digital Library of India?	
	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Gender (%)										
Female	26.20	73.80	35.00	65.00	44.00	56.00	75.00	25.00	29.80	70.20
Male	24.40	75.60	37.80	62.20	31.90	68.10	69.30	30.70	34.10	65.90
Occupation (%)										
UG Stu.	15.00	85.00	53.70	46.30	77.90	22.10	50.50	49.50	44.20	55.80
PG Stu.	9.90	90.10	40.40	59.60	66.1	33.90	75.20	24.80	29.40	70.60
Research	5.60	94.40	30.60	69.40	47.20	52.80	63.90	36.10	22.20	77.80
Teacher	4.20	95.80	32.80	67.20	65.50	34.50	82.80	17.20	24.10	75.90

As discussed above in this study 606 learners responded to various research questions on NDL of India. In order to compare the responses of learners towards the NDL we collected demographic information. The result in Table-1 indicates the Consciousness of NDL of India among the scholars. The results shows that around 73.80% females and 75.60% males are aware about the "Digital Library", however it's interesting to that 65.00% females and 62.20% males are aware about NDL of India out which 56 % females and 68.10% males are having membership of NDL of India. In addition only 25.00% females are using the mobile application of NDL of India, which is lesser than male (30.70%). Hence in real time sufficiently large amount of learners are having an awareness of NDL of India, however significantly smaller number of scholars are avail the e- resources of NDL. Overall only 58.70% of learners are aware about the NDL of India, out of which only 32.70% of learners have the membership. That is around 44% of scholar only avail the digital facilities available by NDL of India, remaining 66.00% scholars are not avail the digital facilities available by NDL of India even though they are aware of it. Whereas, only 21.10% learners utilize the NDL mobile application which is a serious concern for National Mission on Education through Information and Communication Technology. Occupation wise analysis results shows that 85% of UG students are aware about digital library concept and NDL of India even when approximately more than 90 % of PG students, 94 % research scholars and 95.80 % teachers are having the awareness. As our study results shows that only 34.50% teachers and 52.80% research scholar having the membership of NDL of India, indicated real reason due to which less utilization of e-resources of NDL. At end all most 68% learners are seeking for training programs on various facilities available in NDL of India in order to enhance the knowledge.



Graph 1: Consciousness of learners on NDL.

Graph-1 relive that roughly 74.60% of scholars awake about the digital library, only 58.7% are having information about NDL of India, out of which only 32.7% of Scholars having membership of NDL of India. That means only around 33% of scholars are appropriate use the real time facilities of NDL to fulfill their literacy needs, which is significantly low. Hence with extension of above discussion NDL authority should plan for achieve benefit of the virtual repository of learning resources.



Graph 2: Use of NDL in DIT University, Dehradun

The Graph-2a indicated the frequency of visiting NDL of India. It's clear that the scholars who are having membership of



NDL of India, only 18% of scholars are appropriate use of e- resources on frequently, around 45% are avail on uneven basis and 37% are not using NDL.

Graph-2b indicates the distribution of various e-resources avail by scholar. From Graph-2a it's clear that approximately 63% of scholar are avail the e- resources of NDL of India out of which 42.3% are avail the E-books, 10.4% using for E-journals, 10.9% scholars accessing it for text book and only 9.5% are avail for audio video lectures. It is clear that distant from E-book, use of other e-resources of NDL of India is lesser.

Conclusion

This exploration study would help not only in understanding the present situation of NDL of India but will help in drawing up an action plan for concentrated for the sustainable utilization of NDL of India among scholar. The NDL of India is a digital library that possess of more than 2 Crore resource materials, out of which 40 lakh are books and has a collection of 1.26 Core articles (Falak, 2018). The NDL of India is 24X7 platform that result of whichscholars can find out the right resource and hence it is a major treasure trove in the global cyberspace. The NDL should be potential to change and support the Indian education system from conventional way to digital platform of education. However this study results indicates that only 58.7% of scholars are awake about the existence of NDL of India, out ofwhich only 32.7% of scholar having holding the membership of NDL of India. Also it is observed that approximately only 63% of scholars are avail the e-resources of NDL of India out of which 42.3% are avail the E-books and 68% scholars are in quest of training programs on various facilities accessible in NDL of India. Hence on the basis of study results and discussion here we conclude that, its real time necessity to develop some mindfulness companying and training program in University for successful utilization of NDL.

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Antibacterial and Phytochemical Examination of Datura Stramonium L Leaf Concentrates Against Clinical Injury Tests

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Abstract: Datura stramonium Linn is one of the most widely recognized Indian restorative plants ordinarily Utilized as medication to fix different illnesses. This study decided the presence of destructiveness factors in the organic entity, associates it with the multi-drug opposition (MDR) and antibacterial, phytochemical exercises of the leaf of Datura stramonium against wound causing microorganisms.

Aims:

The point of the accompanying review is assess the antibacterial, phytochemical action of the various concentrates of D. stramonium leaf test against chose bacterial separates.

Subjects and Methods: Purulent materials from various injury contaminations tests got were handled according to standard microbiological techniques. Destructiveness elements of biofilm were examined. Anti-microbial awareness test was performed by standard Kirby Bauer plate dispersion procedure. Antimicrobial movement of different concentrates of plant leaves was explored by agar circle and well-dissemination strategy against wound causing bacterial separates. The phytochemical exercises of leaf extricate were finished according to Clinical and Research facility Standard Organization Rules.

Results: Each collected wound tests showed at least one bacterial disengage, absolutely 78.9% of tests displayed 43 disconnects. Among the 18 antibacterial specialists, the vast majority of the antibacterial specialists had exceptionally obstruction action and a few specialists had profoundly touchy movement against the separates. All detaches were being able to deliver biofilm, among them 58% of separates areas of strength for were makers. The antibacterial examinations, the CH₃)₂CO concentrate of Datura stramonium introduced the most elevated enemy of S. aureus movement and was viable. Against all bacterial strains tested. Phytochemical screening of the plant revealed the presence of alkaloids, trapezoid, steroids, flavonoid, triterpenes, phenolic compounds and tannins.

Conclusions: The general results observed consider the plant as natural source of phytoconstitution quality for antimicrobial effectiveness.

KEYWORDS: Wound, Clinical bacteria, extracts, antibacterial, photochemical, *Datura stramonium*.

INTRODUCTION



An injury is a break in the skin and the openness of subcutaneous tissue following loss of skin honesty gives a damp, warm, and nutritive climate that is helpful for microbial colonization and proliferation.[1] Disease in an injury postpones recuperating and may cause wound breakdown, herniation of the injury and complete injury dehiscence.[2] despite mechanical advances that have been made in a medical procedure and wound administration, wound contamination has been viewed as the most widely recognized nosocomial contamination particularly in patients going through surgery.[3] It is a significant reason for sickness bringing about a prolongation of emergency clinic stay; expanded injury care, therapy expenses, and general injury the executives rehearses become more asset demanding.[1] The seriousness of the complexities relies to a great extent upon the tainting microorganism and on the site of infection[4, 5] and by and large, an injury can be thought of as tainted in the event that purulent material is seen without the affirmation of a positive culture. The control of wound diseases has become more testing because of far reaching bacterial protection from anti-infection agents and to a more noteworthy rate of contaminations brought about by Polymicrobial greenery.

The board of wounds is a confounded and costly program and examination on drugs that increment wound mending is a creating region in present day biomedical sciences. A few medications got from plant sources are known to build the mending of various sorts of wounds. However a portion of these medications have been evaluated for assessment of their injury recuperating movement, the capability of a significant number of the customary utilized natural specialists stays neglected. In couple of cases dynamic synthetic constituents were identified.[6]

The restorative plant *D. stramonium* is in many cases utilized as a pain relieving plant in legends medication in the "Old world".[7] *Datura stramonium* is an erect yearly spice shaping a shrub up to 1.5 m tall. The leaves are delicate, sporadically undulate and toothed. The blossoms are trumpet-formed, white to velvety or violet and 6 to 9 cm long.[8] The alkaloid content of *D. stramonium* has been underlined by the phytochemical examiners managing the biochemical organization of different pieces of the plant.[9] Atropine, hyoscyamine and scopolamine (hyoscine) are the tropane alkaloids of all types of the variety *Datura* and their fixations showed varieties relying upon species and with respect to the plant. Duke (1992a) introduced information on the examination the convergence of all out alkaloids in leaves and blossoms of *D. metel* (Hindu datura), *D. stramonium* (Jimson weed) and *D. innoxia* (Thistle apple). The accentuation on tropane alkaloids is because of their significance in drug industry. Proteins, fats, unsaturated fats, lessening sugars, oxalates, nitrates and tannin are among the compound elements that have been portrayed in the plant.[12,13] Chlorogenic corrosive, an antihistaminic, an allantoin, an immunostimulant[14], Lectin agglutinin, a glycoprotein[15, 16], gamma amino-butyric corrosive, a hypotensive and neuro-inhibitor[17], are inside the rundown of the dynamic fixings present in *D. stramonium*.

In allopathic medications separate injury mending antibacterial mixtures were involved where as harbors may considered as single wellspring of cells. Having known the customary utilization of this plant as an injury recuperating specialist. The current review endeavor was made to screen antibacterial movement of *D. stramonium* against the injury. The microorganism segregated from the straightforwardly apparent injury (discharge) tests. To comprehend the impact of this plant primer phytochemical study Was finished alongside antimicrobial movement against would microbes.

SUBJECTS AND METHODS

Sample population: This study was done from twisted patients of medical clinics in and around Dehradun area during the review time frame (July 2021 to Walk 2022). Patients (n=100) both male and female remembered for this study were occupants of Dehradun, UTTRAKHAND.

Collection of wound pus samples: A sum of 100 discharge swabs were gotten from twisted locales before the injury was cleaned utilizing 70% liquor. The example was gathered on sterile q-tip without sullying them with skin commensals. Various kinds of wound examples were gathered to be specific mishap wound, post-activity sepsis, skin contamination, abscesses and consume wound. All examples were gathered from medical clinics in Dehradun and appropriately named showing the source and period of patients. The examples were shipped soon to the research center in the wake of being acquired. In the research center, the examples were enrolled and swabs were refined on different media and brooded at



37°C for 24 h.[18]

Isolation and identification of wound bacterial isolates: Culture plates of Eosin methylene blue agar, MacConkey agar, Supplement agar, Cetrimide agar and Mannitol salt agar (Greetings Media, India) were utilized. The swab sticks utilized for the assortment of the examples were streaked straightforwardly on the marked agar plates and brooded at 37°C for 24 h. After brooding, societies were inspected for critical development. Subcultures were then made into plates of supplement agar and brooded for another 24 h. The essential recognizable proof of the bacterial detaches was shown up and pigmentation. Biochemical tests were performed to recognize the disengages. Biochemical tests applied were standard catalase test, citrate use, coagulase, oxidase, methyl red, Voges-Proskauer, indole creation, motility, carb aging test utilizing glucose, sucrose, maltose and lactose. Portrayal and recognizable proof of the segregates was finished utilizing the techniques.

Antibiotic sensitivity assay: The standard Kirby-Bauer circle dissemination technique was utilized to decide the antibacterial profiles of the segregates. The supplement stock was ready and sanitized at 121°C at 15 min and immunized the disconnects then hatched at 37°C for 24 hrs. After brooding period the stock culture were cleaned into surface of the Mueller-Hinton agar plates and anti-microbial circles were set, then Plates were hatched at 37°C for 18 to 20 h. The zone of restraint and opposition was estimated, recorded and deciphered by the proposal of the circle assembling's standard chart.[19]

Collection and Drying of plant materials: Clearly sound leaves of *Datura stramonium* were gathered from Sansarpur town, Dehradun locale, Uttarakhand, India. The leaves of *D. stramonium* were washed completely multiple times with water and once with refined water. The plant leaf were dried for a considerable length of time and afterward ground to powder with a mechanical processor.

Extraction of Powdered Plant Material: Clearly sound leaves of *Datura stramonium* were gathered from Sansarpur town, Dehradun locale, Uttarakhand, India. The leaves of *D. stramonium* were washed completely multiple times with water and once with refined water. The plant leaf were dried for a considerable length of time and afterward ground to powder with a mechanical processor.

Antimicrobial Activity of the Crude Extract: The antibacterial screening of the different concentrates was surveyed against clinical bacterial strains separated from different injuries contamination. The bacterial secludes include: *Streptococcus* sp, *Pseudomonas aeruginosa*, *Escherichia coli*,

S. aureus, *Klebsiella pneumonia*, *Proteus mirabilis* and *Enterococcus faecalis*. Supplement agar and supplement stock were utilized for the sub refined of the bacterial secludes. Mueller-Hinton agar (Himedia) was utilized for the bacterial responsiveness screening. The antibacterial screening of the rough concentrates were assessed by agar well diffusion.[20] The unrefined concentrates were reconstituted in 5% V/V fluid dimethylsulphoxide (DMSO) at centralization of 20mg/ml. The inocula of the test bacterial disengages were ready from 24h stock culture. The absorbance was perused at 530nm and changed with sterile refined water to match that of 0.5Mc Farland standard arrangement. From the pre-arranged bacterial suspension, different weakenings were ready to give a last convergence of 10.⁶ 1ml every one of the bacterial suspension was gotten with sterile needle and needle and spread plated with Mueller-Hinton agar. The plates were permitted to represent 1.5h for the test bacterial detaches to be completely implanted and appropriately settled in the cultivated medium. With a sterile plug drill, well of equivalent profundity ($\Delta = 5$ mm measurement) were dug with a formerly disinfected No 4 stopper drill. Each all around was aseptically topped off with the individual concentrates abstaining from sprinkles and stuffing. The plates were hatched at 37°C for 24 - 48h. The awareness of the test life forms to every one of the concentrates were demonstrated by clear radiance around the well. The radiances breadth as a record of the level of responsiveness, were estimated with a straightforward plastic ruler. Clean 5% fluid DMSO was utilized as regrettable control while methicillin and streptomycin (10mg/ml) were utilized as the positive control. The base hindrance focuses (MIC) of the leaf removes was just resolved in light of the fact that they showed higher inhibitory exercises of the concentrated on plant. 1ml of the concentrates focuses at 1.25-20mg/ml were blended in with 8ml of Mueller-Hinton stock, 1ml of 24h culture of the test bacterial creatures (1.0×10^6 cells/ml) was immunized into each test container of the various fixations and blended completely. The test tubes were then hatched at 37°C for 24h. The cylinder containing the most reduced weakening of the concentrate with no discernible bacterial development by the unaided eye was considered as the place of least inhibitory focus (MIC). One milliliter every one of the MIC positive cylinders were pour plated with newly pre-arranged supplement agar. The plates were brooded for conceivable development at 37°C for 96h. Plates without development were considered as bactericidal fixations and those with development as bacteriostatic centralizations of the concentrates. All tests were done in sets of three.



Preliminary Photochemical Analysis: The phytochemical was determined using chemical methods and by adopting standard protocols to identify the constituents as described.^[21]

RESULTS

A total of 100 patients with different types of wounds samples were collected during the study period. Seven types of bacterial species were isolated and identified by selective culture medium and standard biochemical tests. Each wound samples showed one or more bacterial isolate, totally 78.9% of samples exhibited 24 isolates (Table 1). Among them, *Staphylococcus aureus* (37.2%) was the predominant isolate, second most was *Pseudomonas aeruginosa* (18.6%) followed by *Streptococcus pyogenes* (13.9%) and the lowest percentage was recorded by *Proteus vulgaris* (2.3%). Bacterial isolates were identified using biochemical tests and cultural characteristics.

All bacteria have developed resistance to antibiotics that were once commonly used to treat them. For example, *Staphylococcus aureus* (S7 & S8) ('golden staph') are now almost always resistant to Methicillin, Carbacillin, Clintamycin, Tetracyclin, Gentamycin. In the past, these infections were usually controlled by Tetracyclin (Table 2). The most serious concern with antibiotic resistance is that all bacteria have become resistant to almost all of the easily available antibiotics. These bacteria are able to cause serious disease and this is a major public health problem. Important examples are methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE) and Erythromycin resistant *E.coli* (ERE).

Table 1: Isolation of bacteria from different types of wound samples

Name of the samples	Name of the isolates							Total	%
	CO3	CO7	CO6	CO4	CO1	CO5	CO8		
Burn	4	-	3	4	1	-	-	12	27.9
Accident wound	3	-	1	1	1	-	1	7	16.3
Abscesses	1	1	-	-	-	-	1	3	7
Skin infection	7	5	4	-	2	1	-	19	44.2
Post operative sepsis	1	-	-	-	1	-	-	2	4.7
Total	16	6	8	5	5	1	2		
(%)	37.2	14	18.6	11.6	11.6	2.3	4.7		

Higher antibiotic resistance in biofilm producing bacteria than non-biofilm producers (Table 2).

The next part of the study was prevalence of biofilm formation (Table 3). Among 12 isolates, detected 7 as strong, 1 as moderate and 2 as weak biofilm producers. The majority of the organisms associated with biofilm production were *S. aureus* (S7 & S8) followed by *E. coli* (E3), *K. pneumoniae* (Kp2), *E. faecalis* (En2) and *P. aeruginosa* (Pa2 & Pa7). Very different results were observed by this method, with which only seven isolates showed black colonies with crystalline appearance.

Table 2: Antibiotic susceptibility patterns

Sample Id	M	C	CL	T	G	% of Resistance
S7	R	R	R	R	R	100
S8	R	R	R	R	R	100
St4	R	R	R	R	R	100
St2	R	S	R	R	S	60
Pa2	R	R	R	R	R	100



Pa7	R	R	R	R	R	100
Kp2	R	R	R	S	R	80
Kp4	R	R	R	R	S	80
E3	S	R	R	R	R	80
E4	R	R	R	R	R	100
P1	S	R	S	R	S	40
En2	R	R	R	R	R	100

S-*Staphylococcus sp.*, St-*Streptococcus sp.* Pa-*Pseudomonas sp.* Kp-*Klebsiella sp.* E-*E.coli*, P-*Proteus sp.* En-*Enterococcus sp.*

M-Methicillin, C- Carbacillin, CL- Clintamycin, T- Tetracyclin, G- Gentamycin.

The leaf extracts of *D. stramonium* were studied for Antibacterial activity and results were observed by presence or absence of zone of inhibition (Table 4). All six extracts aqueous, methanol, acetone, petroleum ether, chloroform and ethanol of *D. stramonium* showed high antibacterial activity. As zone of inhibition were measured in triplicates so mean values \pm Standard Deviation values were calculated.

Table 3: Biofilm formation of isolates

Isolates name	Biofilm result		
	Strong	Moderate	Weak
S7	Positive	Negative	Negative
S8	Positive	Negative	Negative
St2	Negative	Negative	Negative
St4	Negative	Positive	Negative
Pa2	Positive	Negative	Negative
Pa7	Positive	Negative	Negative
Kp2	Positive	Negative	Negative

CH₃)₂CO concentrate of *D. stramonium* showed viable movement against *Staphylococcus aureus* (S7) around 29 \pm 0.7 and 28 \pm 1.6mm against *P. aeruginosa* (Pa2), 25 \pm 0.7mm against *E.coli* (E4) and was 24 \pm 0.3mm against *K. Pneumonia* (Kp4).

The ethanol separate showed great movement against *P. aeruginosa* (Pa2) around 25 \pm 0.7, 23 \pm 0.4mm against *Staphylococcus aureus* (S7) and *Streptococcus pyogene* (St2) 21 \pm 0.1mm against *K. Pneumonia* (Kp4) and was 17 \pm 0.7mm against *E.coli* (E3).

Among the tried plant separates CH₃)₂CO remove showed most elevated movement of 29mm (20mg/ml) zone of restraint against S7 of *Staphylococcus aureus* followed by ethanol (23mm) and chloroform (16mm). Then again, S7 strain were generally delicate to different solvents of *Datura stramonium* followed by S8, Pa2, Pa7, E4,Kp4,E3 and En2 STRAIN (Table 4).

The MIC of the *D. stramonium* not entirely settled by agar weakening strategy. In the event of CH₃)₂CO remove the MIC was 1.56mg/ml against *S. aureus* and 3.12mg/ml against *P. aeruginosa* and 4.25mg/ml against *E.coli*. Ethanol remove displayed 2.40mg/ml least inhibitory focus against *S. aureus* and 3.12mg/ml against *E.coli* and *P. aeruginosa* and of 12.5 mg/ml against *K. Pneumonia*.



Table 4: Antibacterial Activity of *Datura stramonium* leaves extract

Isolates name	Types of solvents – Inhibition zone in mm									
	AE		CE		PE		EE		ME	
	20	At	20	At	20	At	20	At	20	At
S7	21	8	13	9	15	9	23	9	20	9
S8	22	8	14	8	16	9	18	9	16	9
St2	29	21	16	21	-	21	23	21	-	22
St4	28	21	19	20	-	20	18	21	-	22
Pa2	28	9	18	9	15	9	25	9	18	10
Pa7	25	9	18	9	15	10	22	10	18	10
Kp2	22	17	-	16	13	16	19	16	18	16
Kp4	24	15	-	15	15	15	21	16	19	16
E3	24	10	16	10	-	9	17	9	22	9
E4	25	10	18	10	13	9	15	8	21	9
P1	22	18	17	18	-	18	-	18	15	18
En2	22	16	18	17	-	16	-	17	14	17

AE-Acetone; CE-Chloroform; PE-Petroleum ether; EE-Ethanol; ME-Methanol (mg); At-Antibiotics

Table 5: Preliminary Phytochemical screening of various extracts

Test	Reagents	Results
Saponin	Water shake	Present
Tannin	Lead acetate solution	Absent
Sterol	Acetic anhydride + Sulphuric acid	Present
Terpene	Tin + Thinoyl chloride	Absent
Flavonoid	Mg bits+ HCl	Present
Coumarins	10 % NaOH	Present
Quinone	Conc. H ₂ SO ₄	Present
Lignin	Alc. phloroglucinol + dil.HCl	Absent
Alkaloid	Dragendroff's reagent	Present
Protein	Xanthoproteic test	Negative
Reducing Sugar	Benedict's test	Positive

The phytochemical mixtures of *Datura stramonium* remove were dissected in the current review and the outcomes were displayed in Table-5. The phytochemical examination of *Datura stramonium* showed the presence of alkaloids, steroids, flavonoid, quinine, Coumarins mixtures and saponins.

DISCUSSION

The wide utilization of conventional medication by especially country Asian people group is ascribed to its openness and moderateness and accordingly the utilization of natural medication is turning out to be continuously more well known worldwide.[22] The commonness of microscopic organisms in 150 consume wound swabs were displayed in the bacterial secludes were viewed as in 100 (66.66%) injury swabs, and just 50 examples (33.33%) were pessimistic in bacterial development, that contain *P. aeruginosa* was



the commonest detach (35 confines; 23.33%) trailed by *S. aureus* (15.33%), *Enterobacter* spp (8.66%), *P. vulgaris* (8 %) *Corynebacterium* spp. *E. coli* (4.66 %) And both *Micrococcus* spp and *Klebsiella* spp., (3.33 %).[23] The mean age of the healers (41.93±22.26) was fundamentally lower (p-esteem 0.0035) than that of non-healers (63.67±14.19). All non-recuperating wounds were tried positive for somewhere around one creature by biochemical test, while just 60% of the mending wounds showed the presence of bacterial species. A sum of 54 clinically pertinent bacterial separates were distinguished and the outcomes are Coagulase-positive *Staphylococcus aureus* (56.7%) and *Pseudomonas aeruginosa* (23.3%) were the most predominant injury microscopic organisms. The predominance of *Staphylococcus aureus* was essentially higher in non-mending wounds than in recuperating wounds (p=0.003).[24]

The following piece of the review was anti-toxin obstruction designs; among the 5 antibacterial specialists, Methicillin had most noteworthy opposition against *S.aureus* followed by Neomycin against *Streptococcus* sp, Ciproflaxcin of *P.aeruginosa*, Erythromycin of *K.pneumoniae*, Tetracyclin of *E.coli*, Cefataxime of *Proteus* sp. furthermore, Nitrofurantain against *Enterococcus faecalis*. Out of 43 species *S.aures* had most noteworthy anti-microbial obstruction against 6 anti-microbials. In the event of source wise the most elevated anti-infection obstruction had second most injury infection.[25] Our outcome was in opposition to that report; *S.aures* had most elevated anti-infection opposition contrasted with other detaches. The fundamental elements liable for destructiveness of these microscopic organisms are their capacity to stick to have cells, biofilm creation. Biofilms are an assortment of microorganisms encompassed by the sludge they emit. The capacity to frame biofilms is related with the pathogenicity and as such ought to be considered as a significant destructiveness determinant during wound disease. Biofilms might assist with keeping up with the job of microorganisms as commensals and microbe, by avoiding host insusceptible components, opposing antibacterial treatment, and enduring the serious tension from other organisms.[26] Subsequently, biofilm related diseases are hard to treat. The biofilm creation is additionally connected with elevated degree of antimicrobial opposition of the related creatures. In this current concentrate all confines were produce the Biofilm yet a similar time firmly biofilm delivering detaches were high in injury swabs. As anticipated by before work[27], unequivocally biofilm separates had most elevated anti-toxin opposition. In the current review bacterial detaches were read up for their capacity to create biofilm. Biofilm creation was more in *S.aureus* than different species. There were no huge contrasts in biofilm creation while gathering the strains as per the patients' age, and site of contamination. The comprehension of microbial biofilm structure and the utilization of current innovation to achieve change of the clinical gadgets will prompt diminished microbial contamination of clinical gadgets. Antibacterial action of the plant materials showed different hindrance range against the segregated bacterial microorganisms. Directed orally, the antibacterial mixtures might have the option to control extensive variety of microorganisms yet there is additionally the possibility that they might cause an unevenness in the stomach microflora permitting pathogenic coliforms to become laid out in the injury region with result malicious impacts. Among them leaf CH₃CO separate showed great antibacterial movement contrasted and other concentrate. the antibacterial action of the methanol concentrates of the elevated pieces of the *D. innoxia* and *D. stramonium*, removes showed movement against Gram (+) microorganisms in a portion subordinate way and next to zero antibacterial action was found against *E. coli*. Present review uncovered that *D. stramonium* has most extreme antibacterial movement against *Enterobacter* (chloroform remove) and antifungal action against *S.cereviceae* (ethanol extricate) while it has least against *E.coli* (ethanol separate) and *A.niger* (benzene extricate). The distinctions between the outcomes are might be because of purpose of various dissolvable for extraction as well as utilization of various cell culture types.[28] Phytochemical examination of *Datura stramonium* was because of the presence of phytochemical intensifies like alkaloids, tripenoid, steroids, flavonoid, triterpenes, phenolic compounds and tannins.[29] Phytochemical screening of leaf methanol concentrate of *Datura stramonium* showed positive outcomes for tannins, saponins, flavonoids and alkaloids. From the plant of *Datura metel*, saponin, flavonoids, tannins, phenols and alkakoids glycocides, steroids and terpenoids were distinguished as phytochemical intensifies present. In the interim, saponins, flavonoids glycocides, phenols and alkaloids were normal to the test plant ethanol and watery concentrates. Steroid, terpenoids and tannins were missing in the ethanol extract.[30]

CONCLUSION

The primer antimicrobial movement of *D. stramonium* concentrated on here should be visible as the expected wellspring of valuable medications. In the current review, the starter phytochemical screening of the different synthetics uncovered the presence of alkaloids, steroids, flavonoids, saponins, diminishing sugar, quinone and coumarins. The plant



concentrated on here can be a wellspring of high pharmacological significance and likely wellspring of new medications. Further examinations on such bioactive mixtures screening and their antimicrobial action will unwind the probability of these customary drugs. The promising outcome acquired has oppressed this plant concentrate to additional examinations to evaluate for its harmfulness and aftereffect for conceivable amazing remedial worth.

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Review on Traditional bi-layer tablets Freeze Dried Orally Disintegrating Tablets

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Abstract-

This review planned to foster techniques for the manufacture and testing of next to each other layers freeze dried (lyophilized) orally breaking down tablets (ODT) for same or different stage detailing. These next to each other layers tablets will give It opens doors for mix treatments for patients who experience gulping trouble (for example geriatrics and pediatrics) and could improve the bioavailability and contradiction of certain medications. Two unique arrangements (A and B) were prepared independently and every arrangement was to make an alternate formed layer to get different delivery profiles. The primary layer was manufactured by infusing the arrangement A to an unfilled tablet rankle to the half and freezing at - 80°C for one hour in an outer cooler. After the principal layer was totally frozen, the arrangement B was infused into the rest half of the tablet rankle and frozen at - 80°C for one hour in an outside cooler to make the subsequent layer. Then, at that point, frozen next to each other layers tablet was freeze dried and the subsequent multi-facet tablets were researched. The review has shown that one next to the other layers freeze dried orally crumbling tablets can be manufactured and figured out for same or different stage and with various deteriorating time for each layer to give different delivery profiles. The streamlining of grip between layers is required. The review has likewise demonstrated the way that centralizations of gelatin and mannitol can influence the plan attributes.

Introduction

The majority of patients favor oral medication conveyance course for organization their prescriptions because of the consistence and accommodation. For sure, the inclination of oral course by most patients is because of a few benefits of the oral course (for example self-regulated, torment free contrasted with parenteral, simple to take and don't bother preparing, modest contrasted with most different courses, and assimilated in wide surface region through gastrointestinal lot (GIT) contrasted with different courses).

Traditional bilayer tablets, which are created by the compaction of granules and additionally powders, give open doors to mix treatment while expanding patient consistence. Instances of the fundamental benefits of bilayer tablets are (i) the detailing of two synthetic contrary medications in a single tablet, (ii) control discharge (for example tablets with a drawn out discharge and a quick delivery profiles), (iii) synergistic impact, and (iv) working on tolerant consistence by diminishing the dosing unit load accordingly. Nonetheless, the challenges that a few patient gatherings have in gulping a regular tablet (for example older, kids and oblivious patients) is one of the significant hindrances of these conveyance frameworks.

In any case, gulping trouble or dysphagia is one of the impediments of the oral medication conveyance course. Besides, trouble in gulping tablets or dysphagia is in a high level of occupants as Patients Affiliation has revealed up to 75% of occupants are capable by gulping trouble to direct their meds in a new report. Hence, the interest of ODTs has been expanded because of the giving helpful arrangements in many instances of trouble in gulping (for example pediatric and geriatric), improvement the bioavailability of certain medications by the pregastric retention, and address patients' issues.



Orally deteriorating tablets (ODTs) or orodispersible tablets or quick crumbling tablets are strong measurement structures which break down in the mouth quickly once put on the tongue without the necessity for water. As per the Indian Pharmacopeia, orodispersible or ODTs are tablets scatter quickly prior to being gulped and deteriorate in somewhere around 3 minutes [8]. According to the US Pharmacopeia (USP), ODTs break down in less than 30 seconds, and tablet weight shouldn't surpass 500 mg. Furthermore, the medication portion in freeze dried ODTs should be under 400 mg for insoluble medication and under 60 mg for the solvent medication.

ODTs enjoy a ton of benefits (for example improved satisfactoriness, upgraded bioavailability, quick beginning, accurate dosing contrasted with fluids, no actual hindrances since there is compelling reason need to swallow the tablet, and great compound solidness) .The bioavailability of ODTs is superior to regular tablets because of the keeping away from of the primary pass digestion, which is displayed in the lyophilized orally deteriorating selegiline hydrochloride tablets which is dosed at 1.25 mg selegiline hydrochloride per single portion rather than 10 mg ordinary tablets seeing comparable pharmacokinetic profiles.

Beside the immediate pressure strategy, there are different advances for getting ready ODTs; for instance, freeze drying (lyophilization), splash drying, and shaping. Crumbling times fluctuate between this multitude of advances, from 3 seconds to 3 minutes, with the freeze-drying innovation giving the quickest. The business ODTs that arranged by freeze drying crumble quickly in couple of moments because of high porosity that permits the entrance of spit through pores when put on the tongue. Freeze drying or lyophilization is a dissolvable expulsion process from a frozen medication arrangement or suspension to frame an exceptionally permeable design [14]. Claritin (loratadine) shaped by Zydus was the main ODT which got endorsement from the US Food and Medication Organization (FDA) in 1996.

Regardless, as of not long ago, the likelihood that one close to the next layer tablets might be expected to function as an orally separating tablet has by and large been disregarded. There are licenses to make the orally weakening tablet in regular multi-facets (layers are upward on the highest point of one another), one of these licenses by direct pressure while others by freeze drying. One of these licenses is to make a lyophilized quick dissolving in a multi-phasic measurements structure which implies one stage plan is containing a non-gelling lattice while the other detailing is containing a gelling gelatin.

Consequently, the primary point of this examination was to foster procedures for the creation and testing of one next to the other layers freeze dried orally crumbling tablet for same or different stage plan (arrangement, jam, and suspension). These next to each other layers tablets will give valuable open doors to blend treatments for patients who experience gulping trouble (for example geriatrics and pediatrics) and could upgrade the bioavailability and inconsistency of certain medications. Also, unique crumbling time can be accomplished by getting ready various groupings of excipients of the definition of each layer to get different delivering profiles (prompt and broadened discharge). One next to the other layers freeze dried orally breaking down tablets enjoy a benefit of guaranteeing the dryness of all layers during the freeze-drying cycle over the traditional multi-facets freeze dried orally crumbling tablets which the drying of the base layer can be obstructed by the top layer, and probability of creation all layers from similar stages or various stages (multi-phasic).

One next to the other layer tablet can be consolidated of two layers or multiple layers. These layers blend can be (I) two distinct layers joined by a cement interface layer (ii) three layers, two are various layers and the third one is a glue layer (iii) three unique layers consolidated by a cement interface layer FIG. 1. There are a few difficulties that confine the improvement and plan of the ODTs for example mechanical strength, tablet size, deterioration time, water solvency, taste covering, and mouth feel. The amazing chance to advance at least one of these difficulties can assist with working on the orally crumbling tablets as one layer or multi-facets which give opportunities to blend treatments for patients who engaged with gulping trouble case.


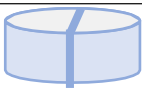

Two different layers	
Two different layers + adhesive layer	
Three different layers	



FIG. 1. Layers combination options of the side by side layers freeze dried orally disintegrating tablet.

Materials and Methods

Materials

Gelatin and mannitol powder were tracked down in lab HB3.16. Green S 0.01%w/v watery arrangement and Carmoisine 0.01%w/v fluid arrangement were acquired from lab HB3.08. All materials were involved with next to no alterations regarding this situation as they were provided by the individual organizations.

Formulation of tablets: Two distinct arrangements (A and B) were arranged independently to make an alternate formed layer to get different delivery profiles. Arrangement A was ready by dissolving 5 g of gelatin in a twofold refined water at 50°C utilizing a water shower and afterward 5 g of mannitol was added to the answer for get a convergence of 5%w/v of gelatin and 5%w/v of mannitol. Arrangement B was ready by dissolving 4 g of gelatin in twofold refined water at 50°C utilizing a water shower and afterward 6 g of mannitol was added to the answer for get a convergence of 4%w/v of gelatin and 6%w/v of mannitol. Arrangement B was colored by a green S 0.01%w/v watery answer for recognize layers by colors after the finishing of the freeze-drying cycle. Arrangements were left to be cooled at room temperature.

Injecting layers: The primary layer was made by filling 1 ml of the arrangement A by needle into an unfilled tablet rangle volume 2 ml to be half filled. The tablet rangle was upward held by a made shape holder and fixed with a foil tape to forestall the leakage of the arrangement while vertical holding (FIG. 2).

The infused first layer was frozen at - 80°C in an outside cooler for 60 minutes. Then, the second layer (1 ml) was injected inside the external freezer, to minimize the effects of temperature changes on the frozen first layer, and was frozen in the external freezer at -80°C for one hour.

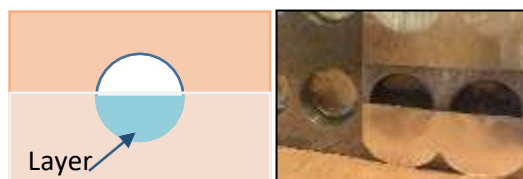


FIG. 2. A tablet blister sealed with foil tape and filled with layer A, ready to be frozen in an external freezer at the vertical position.

Freeze drying: The primary layer was made by filling 1 ml of the arrangement A by needle into an unfilled tablet rangle volume 2 ml to be half filled. The tablet rangle was upward held by a made shape holder and fixed with a foil tape to forestall the leakage of the arrangement while vertical holding (FIG. 2).

The infused first layer was frozen at - 80°C in an outside cooler for 60 minutes. Then, the second

Mechanical properties

Side by side layers freeze dried orally disintegrating tablets were investigated by direct eye watching and handling by hands directly.

Determination of the diameter and thickness of the tablet

The breadth and the level (thickness) of the next to each other layer freeze dried orally deteriorating tablet were estimated utilizing a ruler. Likewise, the component of each layer was estimated independently. Values were accounted for estimations of five next to each other layer freeze dried orally crumbling tablets and the mean was acquired \pm standard deviation.

Tablet disintegrating test

The in vitro deteriorating season of the one next to the other layer freeze dried ODTs was resolved utilizing the Pharma Test DIST3 type crumbling testing instrument. Refined water (800 ml) was utilized as a plunging liquid, and was warmed to and kept up with at



a temperature of 37°C, which like the human internal heat level. The temperature of the water inside the shower was persistently checked with a thermometer. The breaking down time was characterized as the need might have arisen for each layer of every tablet of ODTs to totally deteriorate with practically no strong buildup stays (3 minutes as indicated by the authority Indian Pharmacopeia monograph). A sum of five next to each other layer freeze dried orally breaking down tablets was tried and the outcomes revealed are mean \pm standard deviation.

Friability test-

A sum of five tablets were cleaned and pre-gauged (Wa). Then, at that point, tablets were tried in ERWEKA 'ROCHE' FRIABILATOR analyzer at a speed of 25 rpm for 4 minutes. Then, at that point, tablets were taken out, cleaned and rechecked (Wb). The level of weight decrease was determined by the Situation 1 underneath. The acknowledged limit of friability test for ODTs isn't over 1% .

$$F = \frac{(W_a - W_b)}{W_a} \times 100$$

Equation 1: Friability test calculation formula (F=Friability).

Texture analysis test (hardness)

The TA.XT Plus surface analyzer instrument connected to a PC was utilized to assess the hardness of each layer of the tablet. The hardness was tried utilizing a pressure test (6 mm breadth) at a speed of 2 mm/sec and a profundity of 3 mm. The power in Newton (N) was estimated at a profundity of 1 mm after pressure. The hardness of the one next to the other layer freeze dried orally deteriorating tablet was estimated for each layer of every one tablet by pressure the test in the surface center of each layer in each tablet. When the estimation was finished, the information was sent out and examined utilizing the Microsoft Succeed programming. Sums of five next to each other layer freeze dried orally crumbling tablets were tried and the outcomes detailed are the mean.

Scanning electron microscopy

Checking electron microscopy (SEM) was performed on cross-area tests for each layer of the tablet to examine the internal primary morphology of each layer of the tablet. Cuts tests of each layer were ready by cutting a slender cut of the top and the side segment of each layer of the tablet utilizing a surgical tool. The top examples were taken in even segment while the side examples were in vertical area. Tests were covered by gold falter utilizing Majority contraption (15 nm) and estimated by SEM (ZEISS EVO instrument) at 500, and 1 K amplifications. Wetting time test and water absorption ratio

The wetting time test was determined by setting five round tissue papers of 10 cm measurement in a 10-cm width Petri dish. Then, at that point, ten milliliters of a colored refined water arrangement was added to the Petri dish. Tablets were put on the tissue paper surface exclusively. The expected time for water to spread on the upper surface of the tablet was estimated as the wetting season of every tablet. The water ingestion proportion (R) was determined by the Situation 2 underneath. A sum of five one next to the other layer freeze dried orally deteriorating tablets were pre-weighed prior to setting in the Petri dish (Wb) and rechecked after water retention (Wb).

$$R = \frac{(W_a - W_b)}{W_b} \times 100$$

Results and Discussion

Mechanical properties

Tables showed up in a uniform shape and OK size with a level (thickness) mean of \pm 7.9 mm, and breadth mean of \pm 18.8 mm. The method for aspects of layers were \pm 10.25 mm and \pm 8.6 mm for layer An and layer B individually (TABLE 1). Tablets were in a springy nature and a smooth surface inclination. Layers stuck together entirely through a connection point flimsy layer. A slight hole between layers of certain tablets (~10% of tablets) was noticed. The leakage of the layer B subsequent to infusing was not introduced around the frozen layer A.



TABLE 1. Diameter, thickness, and weight of side by side layers freeze dried orally disintegrating tablets.

The represented values are mean \pm standard deviation (n=5).

Diameter(mm)			Thickn ess (mm)	Wei ght (gra m)
Whole tablet	Layer A	Layer B		
18.8 \pm 0.3	10.25 \pm 0.21	8.6 \pm 0.38	7.9 \pm 0.25	0.22 \pm 0.01

Disintegration time

TABLE 2 presents the mean crumbling season of the layers of one next to the other layers tablet was 36.2 seconds (Layer A) and 26 seconds (Layer B). As each layer of the tablet was made by various detailing, tablets gave two different deteriorating times and that different delivery profile was a direct result of the convergence of gelatin which layer B with low gelatin fixation (4%) crumbled quicker than layer A 5% gelatin focus [20]. The different delivery type of one tablet can be utilized to accomplish further developed solvency of medications, permit satisfactory ingestion as the surface area of mouth is somewhat little, and upgrade compound incongruence of medications.

Albeit, the crumbling season of each layer was inside the constraint of the orally breaking down tablet as per the European Pharmacopeia, tablets expected to be improved to match the deterioration season of the other freeze-dried items which deteriorate like a flash.

TABLE 2. Disintegrating time in seconds for each layer of the side by side layers tablet.

Tablets	Layer A (Disintegrating time in seconds)	Layer B (Disintegrating time in seconds)
1	33	25
2	35	22
3	40	29
4	36	26
5	37	28
Mean	36.2	26

Factorability

The estimation of factorability was displayed on the constraint of acknowledged friability. As per the Condition 1, friability (F) was determined as 1%, as evaluated the factorability increments with an expansion in manifold focus [20]. Albeit the friability inside the restricted reach, the bond between layers in a single tablet should be improved as was seen feeble (half of tablets' layers were broken during the factorability test).

Hardness

As displayed in FIG. 3, methods for hardness estimations were 25 N and 16 N for layer An and layer B individually at the distance of 1 mm of infiltration. The sufficient hardness could because of the great convergence of gelatin which caused expansions in



general hardness of ODT on the grounds that the 3D organization framed by gelatin fiber permitted the caught frozen water to sublimate [21]. Furthermore, mannitol gives a synergistic impact to improve the hardness of ODTs that generally often from gelatin, and as displayed in the satisfactory hardness of layer B in FIG. 3 which the grouping of gelatin in layer B was not as much as layer A .

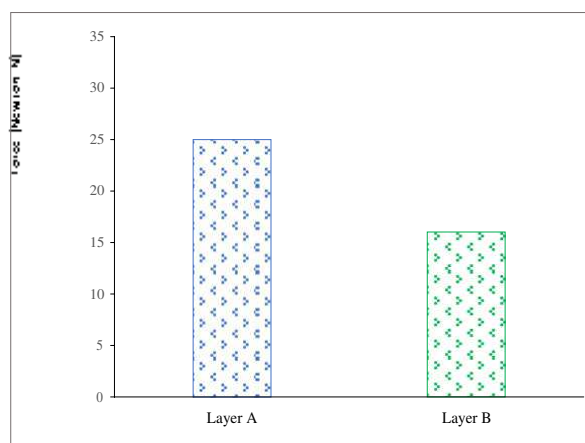


FIG. 3. The mean of the hardness of forces comparison (Newton) between layers.

Scanning electron microscopy

FIG. 4 shows the construction of the tablet in the top and side area. SEM micrographs uncover that examples present an exceptionally permeable and framed structure. The construction of pores, huge size, and high framed number were seen increment with expanding the gelatin focus what's more of mannitol as the development of 3D cross section which gives an opportunity of large piece of caught water to sublimate during freeze drying cycle which bring about improved breaking down . Pores pictures of layer A present a greater size than layer B as a result of the different in gelatin fixation between layers.

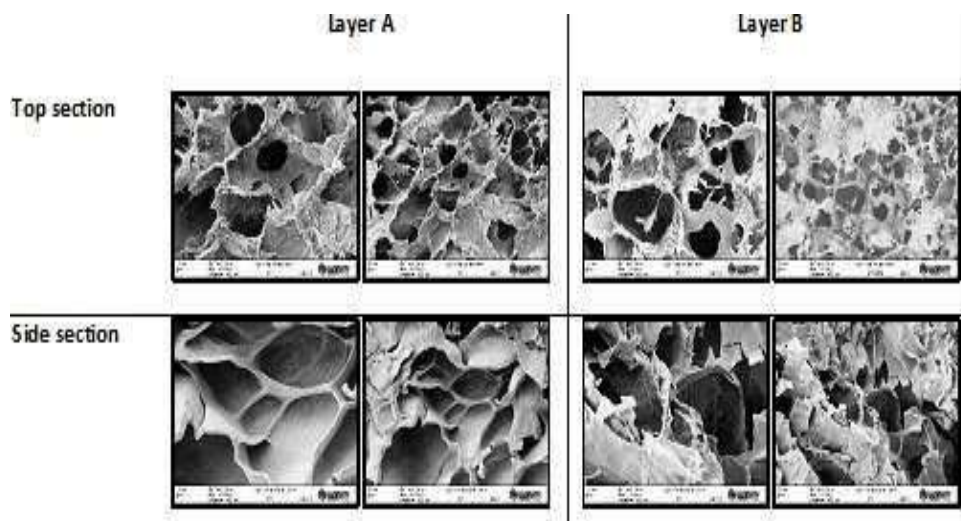


FIG. 4. SEM images of the top and side sections of layers of the tablet at 1 K and 500 magnifications.

Wetting time and water absorption ratio



The estimations of wetting season of the two layers of tablets were in a scope of 115-170 seconds with a mean of 130 seconds and 155 seconds of layer An and layer B separately. The distinction in the wetting time between layers may be because of the centralization of gelatin as additional pores shaped. The water retention proportion as indicated by the mean of computing a sum of five tablets was 86% of the entire tablet. Wetting time helps with the examination of the impacts of a few excipients on the crumbling season of the tablet, as a lower wetting time uncovers quicker breaking down time.

Conclusion

The review expected to track down a system to create a multi-facet freeze dried orally deteriorating tablets with acknowledged mechanical and compound properties and with various delivery profiles to give potential open doors to blend treatments for patients who experience gulping trouble. The review has shown that one next to the other layers freeze dried orally crumbling tablets can be manufactured and figured out for same or different stage and with various deteriorating time for each layer to give different delivery profiles. The bond between layers of each single tablet requires more examination and advancement. The review has additionally shown that centralizations of gelatin and mannitol impact plan qualities, like construction porosity, fracturability, and breaking down time.

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Fast Dissolving Tablets: A Review

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Abstract -Tablets that dissolve quickly are solid dosage forms. Because it dissolves, disintegrates, or disperses the API in saliva within a few seconds, whether or not water is consumed, it is sometimes referred to as an orally disintegrating tablet. In the pharmaceutical industry, oral medication delivery is thought to be the most reliable, practical, and affordable route with the highest patient compliance. Because they are made to dissolve in saliva amazingly quickly, within a few seconds, tablets are referred to as real fast dissolving tablets. Specially formulated mouth-dispersing tablets are available for children, the elderly, and patients who are bedridden. Because some people have trouble swallowing traditional oral dosage forms due to hand tremors and dysphagia, these kinds of preparations offer a chance for product line extension in many elderly people. Younger people frequently experience swallowing issues due to their immature neurological and muscular systems. The mentally ill and physically crippled can both use mouth-dispersing tablets. In many instances, such as with motion nausea, abrupt attacks brought on by an allergy or coughing, and occasionally when water is not readily available. There are various ways to make fast-dissolving tablets, including vacuum drying, spray drying, lyophilization, sublimation, etc. Mouth dissolving tablets are a soft, friable, hygroscopic dosage form that needs specific packaging since they dissolve quickly in mouth saliva.

Keywords: Water, Fast dissolving tablets, mouth dissolving tablets, swallowing

INTRODUCTION

The original drug administration methods used conventional dosage forms. The oral route of drug delivery is the most often employed and also well. Because they are simpler to administer on one's own and are less expensive than other dosage forms, oral dosage forms are very popular. [1] However it also has certain drawbacks, including dysphagia (difficulty swallowing), limited bioavailability, and a slow onset of effect. Researchers have long studied the "oral cavity" in an effort to use its disadvantage to increase the drug's permeability and absorption. Because the buccal mucosa's mucosal lining is substantially less keratinized than the rest of the "oral cavity," it has good permeability. [2]. Drug absorption through the "oral cavity" avoids first pass metabolism, causes drug breakdown in the gastric region, and causes enzymatic hydrolysis in the intestine, all of which ensure a quick commencement of action [3]. An oral dispersible tablet, also referred to as a fast-dissolving tablet, is a widely used formulation that takes into account the benefits of the "oral cavity". "ODT (Oral Dispersible Tablet) should scatter or disintegrate in less than 3 minutes when placed on tongue," according to the European Pharmacopoeia. A more recent idea called the fast dissolving drug delivery system (FDDDS) combines the benefits of both liquid and solid formulations while also providing advantages over conventional dose forms. [4]

2. Requirements for a Drug Delivery Mechanism that Dissolves Quickly:

Table 1 outlines the FDT requirement as follows: [5]



Parameter	Acceptance/Rejection
Water required for swallowing	No
Fragility concern	No
Portable	Yes
Suitable for conventional tablet processing and packaging	Yes
Good mouth feel	Yes
Patient compliance	Yes
Compatible with taste masking	Yes
Sensitive to environmental factors (humidity, temperature)	No
Leave residue in oral cavity/Grittiness	No
Economic	Yes

Table 1: Criteria for FDT

3. Salient Feature of Fast Dissolving Drug Delivery System:

- Ease of administration for mentally ill, physically handicapped, and uncooperative patients.
- The solid dose form can be swallowed without any liquid [6].
- The dose form dissolves and degrades quickly.
- Medicines that are taken by the stomach when the saliva descends from the mouth, throat, and oesophagus. In these circumstances, the drug's bioavailability is enhanced.
- A greater bioavailability, especially for medications that are insoluble and hydrophobic, as a result of the tablets' quick disintegration and dissolution [7].
- Overcomes the medications' unpleasant taste.
- By preventing physical obstruction during oral administration of the standard formulation, the risk of choking or asphyxia is reduced, improving safety.
- When administered, they may be made to leave little to no residue in the tongue and to provide the user a satisfying mouth feel [8].
- Possibility of offering liquid medicine benefits in the form of a solid preparation.
- Ability to be modified to fit current processing and packaging equipment [9]
- Beneficial when a very quick response is needed, such as in cases of motion sickness, acute allergic reactions, or coughing.
- New commercial opportunities such as life cycle management, product differentiation, and product promotion [10].

4. Medications Eligible for Fast Dissolving Tablet's-

The eligibility criteria for drugs to be formulated as Fast Dissolving Tablets are low dose, good stability in aqueous media, good mechanical strength [11] and compatibility with excipients [12,13]

Table 2

Class of drug	Drug
Analgesic/Anti-inflammatory Agents	Picroxicam, Ibuprofen, Mefenamic Acid
Anti-Bacterial Agents	Erythromycin, Tetracycline, Doxycycline, Rifampin
Anti-Emetic	Ondansetron, Dolasetron, Granisetron, Promethazine
Anti-Fungal	Griseofulvin, Miconazole
Anti-Malarial	Chlorquine, Amodiaquine



Anti-Gout	Allopurinol, Probenecid
Anti-Hypertensive	Amlodipine, Nefidipine
Anti-Coagulants	Glipizide, Tolbutamide
Anti-Protozoal	Benznidazole, Tinidazole
Anti-Thyroid	Carbimazole
Cardiac Inotropic Agents	Digitoxin, Digoxin
Gastro-Intestinal Agents	Omeprazole, Ranitidine, Famotidine
Nutritional Agents	Vitamin A, Vitamin B, Vitamin D, etc
Oral Vaccines	Influenza, Hepatitis, Polio, Tuberculosis, etc.

2. Methods for Making Tablets that Dissolve Quickly

For the creation of fast-dissolving tablets or oro-dispersible tablets, a variety of methods have been documented. Here, we've covered the six main methods that are frequently utilized to create these tablets. [14, 15].

1. Freeze-drying/Lyophilisation
2. Tabletmoulding
3. Spraydrying
4. DirectCompression
5. Sublimation
6. MassExtrusion

Freeze-Drying or Lyophilisation

Water is removed from the product after it has been frozen by a process called freeze drying. By using this method, an easily dissolvable amorphous porous structure is produced. Here is a typical process used in the production of FDT made with this technology. [16].

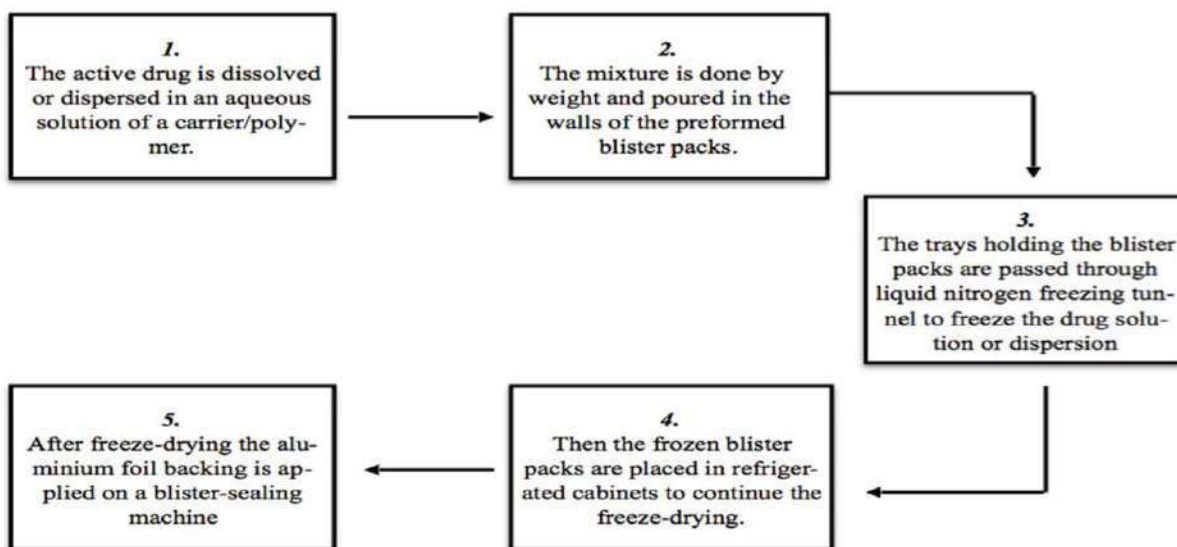


Figure 2 Step by step procedure of Lyophilisation of FDT

The freeze-drying method has shown to increase bioavailability and improve absorption. The primary disadvantages of the lyophilisation technology are its cost and time requirements, the fragility of these items making traditional packaging unsuitable for them, and its poor stability under stressful circumstances. [17, 18]

Tablet Molding

There are two different types of moulding processes: solvent method and heat method. The solvent approach produces less



compact tablets with a porous structure that speeds up dissolve than compressed tablets do. The mechanical durability of tablets that have been moulded raises serious concerns. Binding agents must be added to the tablets in order to increase their mechanical strength [19]. This technique has the additional issue of masking the flavour of the medication particles, which are made by spray congealing a molten mixture of sodium carbonate, cottonseed oil, lecithin, and hydrogenated polyethylene glycol into a lactose-based tablet triturate form. Comparatively to the lyophilisation approach, the moulding technique for producing tablets is simple to scale up for industrial manufacturers. [20]

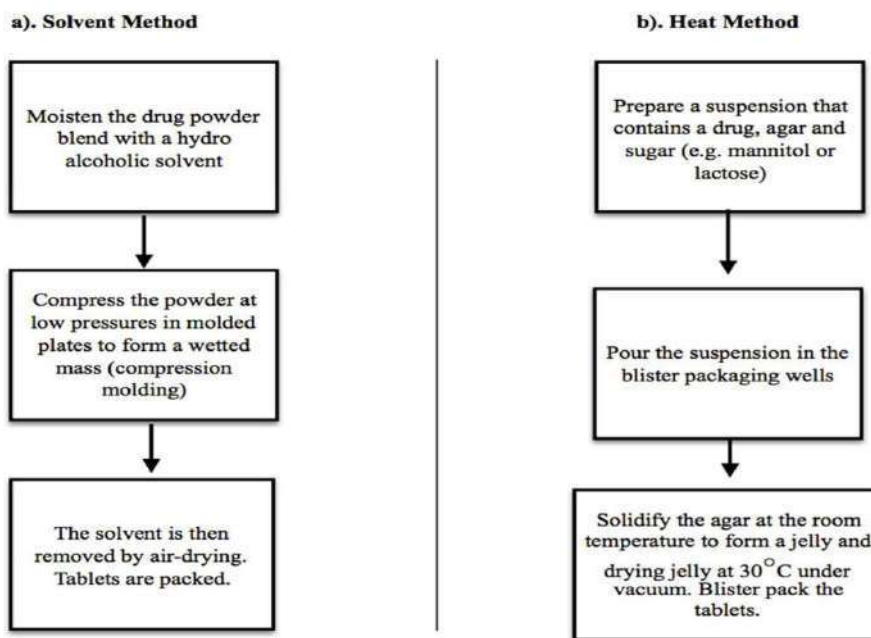


Figure-3 Procedure of Tablet Molding

Spray Drying:

In this method, manifold serves as a bulking agent, gelatin serves as a matrix and superdisintegrants such crosscarmellose, sodium starch glycol ate, or crospovidone serve as disintegrates. The tablets made from spray-dried powder including a superdisintegrant, a bulking agent, an acidic component (citric acid), and/or an alkaline ingredient (such as sodium bicarbonate), have been reported to dissolve in aqueous medium in under 20 seconds. This spray-dried powder, which was made into tablets, disintegrated quickly and had better solubility. [21]

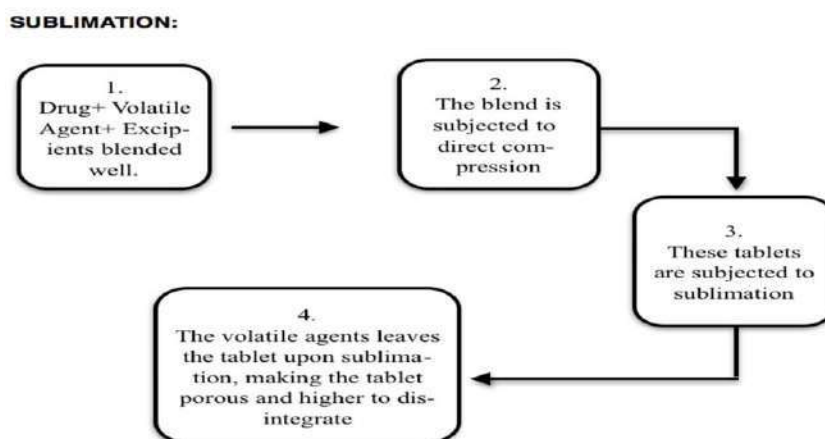


Figure-4 Step by Step Formation of FDT's by sublimation



Sublimation

Sublimation is a procedure that is applied to the incorporation of volatile chemicals to create a porous combination. A tablet's excipients and volatile components, such as benzoic acid, ammonium bicarbonate, ammonium carbonate, camphor, naphthalene, urea, and phthalic anhydride, may be compacted together. This volatile substance is subsequently eliminated through the sublimation process, leaving behind a very porous matrix. Tablets made by this manufacturer technique have been found to typically collapse after 10–20 seconds. As pore-forming agents, solvents like benzene and cyclohexane can be utilized. [22].

Direct Compression:

The simplest and most affordable method of producing tablets is direct compression. This method can now be used to create Quick Dissolving Tablets due to the availability of better excipients, particularly super-disintegrants and sugar-based excipients. [23].

Super-disintegrants:

Fast dissolving tab- allows' disintegration and eventual dissolution are mostly impacted by superdisintegrants, particularly for direct compression approaches. The disintegration process is accelerated by the presence of additional substances such effervescent agents and water-soluble excipients.

Sugar Based Excipients:

This is an alternative strategy for approaching the direct compression method. the use of sugar-based excipients, in particular bulking agents like lactilol, dextrose, isomalt, fructose, maltitol, maltose, mannitol, sorbitol, polydextrose, xylitol, and starch hydrolysate that exhibit high aqueous solubility and sweetness, and thus impart taste-masking properties and a pleasant mouth feel. Sugar-based excipients have been divided into two categories by Mizumito et al. based on moulding and dissolution rates.

Type1saccharides(mannitolandlactose)exhibitlowmould-abilitybuthighdissolutionrate.

Type2saccharides(maltitoland maltose)exhibithighmould-abilityandlowdissolutionrate [24]

Mass-Extrusion:

Using a solvent mixture of water-soluble methanol and polyethylene glycol, the active blend is softened in this technology. The softened mass is then expelled through an extruder or syringe to produce a cylinder product, which is then divided into even segments using a heated blade to create tablets. The dried cylinder can also be used to coat bitter medicine pellets in order to hide their flavour. [25].

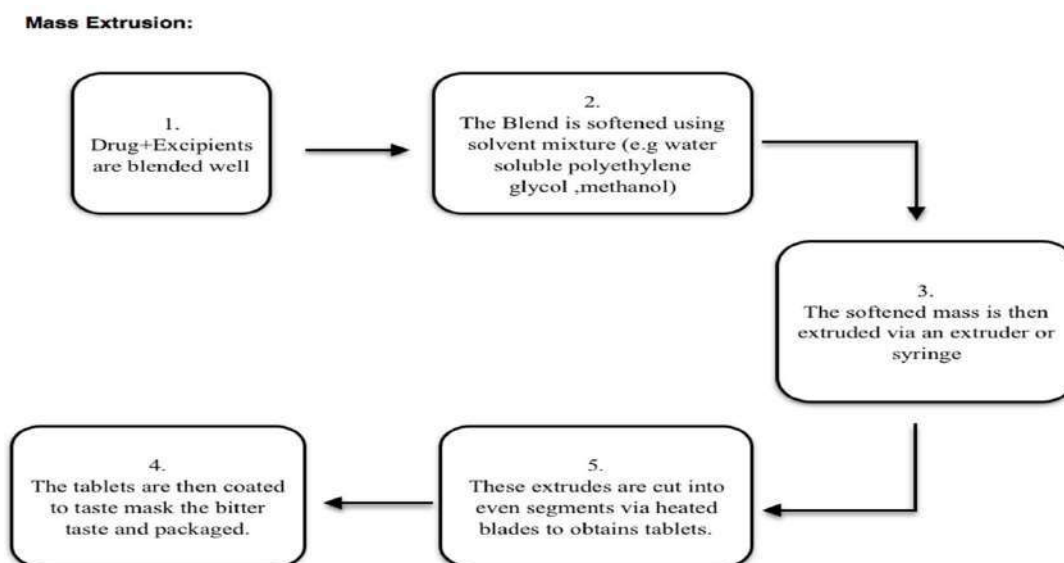


Figure 5 –Formulations by Mass Extrusion



6. Patented Technologies for Fast Dissolving Tablets:

Zydis Technology

Zydis formulation is a special method of creating tablets that dissolve quickly. The medication components are physically trapped or dissolved within the matrix of quickly dissolving carrier polymers in this type of freeze-dried tablet technology. Since the freeze-dried structure quickly disintegrates in the mouth when the "zydis unit" is inserted there, water is not needed to be swallowed. Zydis material is made up of a variety of ingredients to accomplish a variety of goals [26]. Gelatin, alginate, and dextran polymers are used to provide strength during handling. Including saccharides like sorbitol or mannitol results in products with good elegance, hardness, and crystallinity. To avoid material shrinking Glycine is typically utilised as collapse protectants in "zydis units" during freeze drying processes or long-term storage to defend [27]

Durasolv Technology

It is a patented invention of CIMA LAB (US patent no. 6,024,981) and is based on direct compression technology. Super-disintegrants, which quicken the rate of disintegration and therefore dissolution, are used as suitable excipients with improved characteristics. [51]. this approach is based on the use of common non-direct compression fillers (such dextrose, mannitol, sorbitol, etc.) that dissolve swiftly without leaving a gritty or sandy taste in the mouth. It is also possible to utilize substances that are water soluble and occasionally effervescent to aid in the process of disintegration. With no special packaging requirements, stronger tablets made with the DuraSolv® technology can be blister-packed. The tablet in this technology is made of drug components, lubricants, and fillers. [28].

Orasolv Technology

Orasolv technology was created by CIMA LAB. Orasolv is an effervescent direct compression tablet that dissolves in mouth saliva with the help of nearly imperceptible effervescence and releases the coated medication powder after less than a minute. Coating of the medicine powder and effervescence are used to mask the drug's disagreeable flavour. Orasolv's mechanical strength from light compression is a big drawback. [52]

The matrices are created by flash heat processing in flash dose technique. Fuisz holds a patent for this method. For instance, Biovil Corporation's launch of Nurofen is the technology's first commercial product. [29].

Wow Technology

Where wow seems to mean "without water," Yamanouchi Pharmaceutical Corporation has patented it. To create a rapidly melting, powerful tablet, high mouldability saccharides such oligosaccharide and mannitol are combined with low mouldability saccharides like glucose, lactose, and mannitol. [30].

Shear form Technology:

The preparation of floss is the technology's foundation. By applying a flash heat procedure to feed stock that contains a sugar carrier, floss is created. Surfactant is combined with either mannitol or dextrose and thoroughly blended. The main floss mixture is this. In the flash heat process, the carrier materials exhibit an internal flow state that is induced by heat and exits through a spinning head. At the same time, the floss is thrown under the force of centrifugal force. The floss created using the aforementioned method is made of longer fibres that are then diced into tiny particles using a high shear mixer granulator. The process of recrystallization involves treating ethanol (1%), spraying out floss, and then evaporating the solution, which improves the flow and cohesive qualities. Then, this matrix is combined to recrystallize it. After being recrystallized; the matrix is combined with medication and other excipients before being compressed. This method results in tablets that are highly porous, have a pleasant mouthfeel, and instantly dissolve sugar when they come into contact with saliva [31].

Flash dose Technology:

This method creates crystalline floss structure using a special spinning mechanism, much like cotton candy. This crystalline sugar can then be combined with the medication and crushed into a tablet. Such a substance easily disperses, dissolves quickly on the tongue, and has a large surface area for dissolution. The self-binding shear form matrix known as "floss". [32].



Ceform Technology:

The key step in this procedure is adding a dry powder mixture of pure medication and excipients to a machine that is quickly spinning. Dry drug powder is blended at high speed through a small heated aperture by the revolving head of this ceform machine. This medication mixture liquefies to form a sphere as a result of the tiny heat explosion produced by the properly adjusted temperature. The drug's stability is unaffected by this. The microspheres are combined and/or compressed in the predetermined oral dose form. [33].

Flashtab Technology:

With the use of this technology, the medicine should release quickly into the gastrointestinal tract, be microencapsulated with effervescence, and be simple to flash disperse. For quick release, Eudragit is often the polymer used. This technology follows a traditional way of compression with a traditional wet/dry granulation process. Drug formulation involves the use of micro-granules of the medicine, taste-masking ingredients, dissolving agents, and swelling agents [34]. These tablets are physically robust and are highly recommended for use with hygroscopic materials for blister packaging because they provide superior moisture protection than ordinary polyvinyl chloride or polypropylene foils.

Nano- crystal Technology:

By reducing particle size and increasing surface area, the method increases dissolving rate. Drug particles (less than 1000 nm in diameter) known as nano-crystal particles are generated by milling the drug ingredient using a weight milling process.

Broad range of dosages per unit (up to 200 mg of API per unit) is provided by nano-crystal quick dissolving technology. Based on proprietary and patent-protected technical aspects, solutions can be well categorised. Improved oral medication pharmacokinetics. Using moisture-resistant active ingredients is economical and cost-effective. Wafers of the lyophilized product are created by mixing water-soluble GRAS (Generally Regarded as Safe) components with medication Nano crystal colloidal dispersions. Despite being quite strong, they quickly disintegrate in relatively small amounts of water. [35].

Advantol200:

Developed especially for use in nutraceutical products Advantol 200 is a "Soft-Melt" functional immediately compressible excipient solution that doesn't need any specialised production tools or equipment. It takes a basic rotary tablet press, standard equipment, and typical tableting temperature and humidity conditions to produce sturdy "soft-melt" tablets.

Advatab:

Orally dissolving tablets based on a unique tablet composition are produced by Kyowa Hakko Kogyo's (Tokyo, Japan) AdvaTab™ technology (Eurand). Each pill is thoroughly lubricated during the manufacture process using a spray. Advatab™ can be 30–40% stronger than typical tablets and is made with 10–30 times less hydrophobic lubricant [36].

Tablets made in this way are:

- Hard and durable, yet easily wettable when in contact with saliva;
- High drug loading; • Coated drug particles for better mouth feel;
- Not need special packaging; they can be packed in standard packaging systems (push-through blisters and bottles);
- Special because they can be combined with Eurand's technologies like Microcaps (taste-masking) and Diffucaps; (controlled release)

Frosta Technology:

The core of this technology involves compressing highly plastic granules at low pressures to create robust tablets with high porosity that melt quickly. These plastic granules can be divided into three groups: binder, enhancer of water penetration, and porous and plastic substance.



Water soluble or water dispersible describes a porous plastic substance. Powders are deformed plastically to increase the inter-particle interactions that are necessary for the creation of connections between particles. A porous, plastic substance is polymerized if. It is essential to prevent the formation of a viscous coating of the material at the tablet surface when it comes into contact with the aqueous media. [37].

Ora-QuickTechnology:

According to KV Pharmaceutical, its Micro Mask microsphere technology uses a distinctive, patented taste-masking technique. It does not use any type of solvent, thus leading to more quick and efficient tablet production. Moreover, it produces less heat, which is advantageous for medications that are sensitive to heat. This technology promises quicker tablet dissolutions and improved tablet flavor masking. There aren't any other items made with this technique accessible on the market outside KV pharmaceuticals. This technique assesses factors like the rate of absorption and dissolution, flavour, physical strength, bioavailability, and stability.[38].

PharmaburstTechnology:

This invention has a patent from SPI Pharma in New Castle. It uses coprocessor excipients and dissolves in 30 to 40 seconds. This technology incorporates, dry blending after which the medication, taste, and lubrication are compressed into tablets. The resultant tablets are strong enough to be packaged in blister packs and bottles. [39].

Lyoc:

Farmlyoc has patented the technology known as Lyoc. The approach intends to create an oil-in-water emulsion that is porous and firm enough to be inserted in the blister alveolus through lyophilization. After being frozen, this emulsion paste contains bulk medication or drug microparticles in blisters. Due to its porousness, Loco products have poor mechanical strength but good disintegration rates. The product Phloroglucinol Hydrate-Farmlyco is an illustration. In contrast to Zydis, Lyoc uses a freeze drying process; however their product is frozen on the freeze dryer shelves. These formulations call for a significant amount of undissolved inert filler (mannitol) to increase the viscosity of the in-process suspension in order to prevent inhomogeneity via sedimentation during this procedure. By directly compressing a powdered combination with external lubricant, tablets are created. [48].

7. Mechanism of Superdisintegrants:

There are four major mechanisms for tablet disintegration as follows:

Swelling

Superdisintegrants which act by this mechanism work on the fundamental of “swell” and “burst”

In comparison to other excipients and the medicine, the aqueous phase exerts more adhesive force on the superdisintegrant when it comes into contact with water or saliva, causing swelling and/or the tablet to break apart. [41].

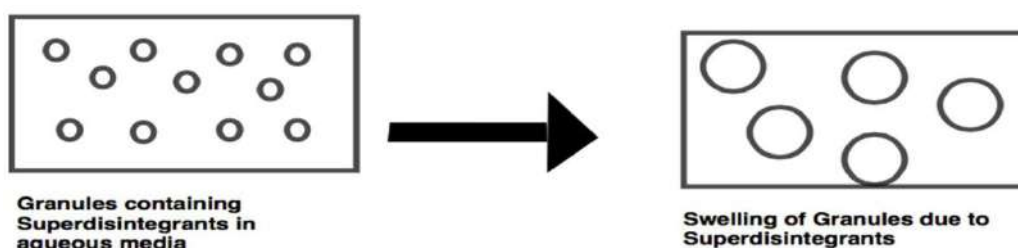


Figure 6 -Diagrammatic Depiction of Mechanism of Swelling

Most of the Superdisintegrants follow this mechanism. Of them, the widely used are starch and its modifications. Given below is the list of the natural as well as the synthetic Superdisintegrants having swelling mechanism.



Table 3

Synthetic Superdisintegrants	Natural Superdisintegrants
Starch	Pectin
Modified Starch	Agar
Cross-linked PVP	Veegum
Cross-linked sodium CMC	Bentonite
Sodium Starch Glycolate	Ion exchange Resin (Indion 414)
StaRX 1500 (Pregelatinized Starch)	

Porosity and Capillary Action (Wicking)

According to this mechanism, the surface of every tablet particle in the supplied aqueous medium seems to be moist. The inter-particle link is then reduced as water seeps into the tablet's core, assisting in the tablet's breakage. The process is known as capillary action or wicking because the tablet gradually becomes wet, eventually breaking.

Here, the tablet's porosity is crucial because it is a vital prerequisite for quick and simple wetting and water absorption. The rate of wetting and material disintegration increases with material porosity.

Particle/Particle Repulsive Forces

A particle repulsion theory has been put out by Guyot-Hermann. According to this notion, a tablet made of "non-swelling" disintegrants causes swelling. This operates according to the idea of a particle's electric repulsive force. The tablet must come into touch with water in order to create an attractive force that causes particles to reject one another and cause the tablet to disintegrate. [42].

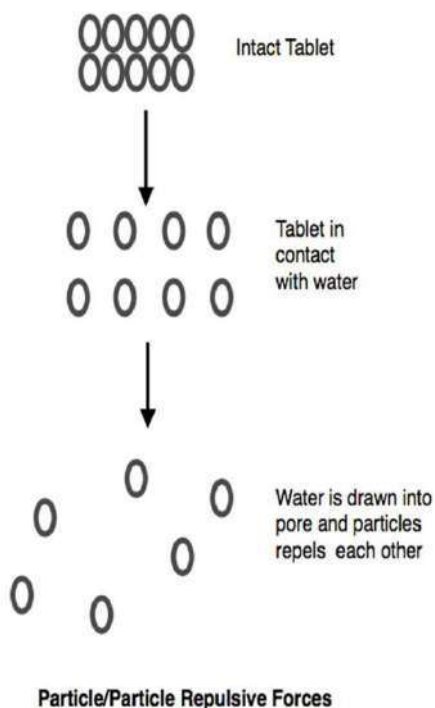


Figure 7 - Diagrammatic description of Mechanism of Particle/Particle Repulsion



The biological enzymes are used as disintegrates in this process. The pill contains binders that are easily broken down by salivary enzymes. These binders are catalyzed when they come into touch with saliva, which causes the pill to dissolve. The swelling and burst phenomena are coupled with this mechanism, causing the binder to swell and burst, releasing the medication as granules. Examples include the metabolism of gums by hemicellulose, binder starch by amylase, sucrose by invertase, and alginate by carrageen's.

Deformation

The prevailing consensus is that starch grains have an "elastic" character, meaning that when pressure is applied, they will return to their former shape. These grains, however, are reported to be "energy rich" and to be permanently deformed due to the compression forces used in tableting. This energy is said to be released upon contact with water. In other words, starch grains that have been created under pressure have a stronger capacity to swell than starch grains. [43].

8. EvaluationParameters:

It is important to evaluate the formulated drugs in order to determine the quality of the tablet. Given below are thefundamentalevaluationparameters [44, 45].

Table4: Evaluation parameter of FDT

Paramet ers	Criteria
WeightVariation	WeightVariationtestsarecarriedoutaccordingtoeitherUSP,IP,BP.
Hardness	Hardness ofthetabletshouldbelesserthanconventionaltabletfallingintherangeof3-4kg/cm^2
Friability	Friabilityshouldbewithintherangeof0.1-0.9%.
MechanicalStrength	Shouldpossessadequatemechanicalstrengthtoabsorbthetransportationshock andavoidbreakageoftablet
TabletPorosity	Tabletporosityisconducted(asperICHguideline)
Wettingtimeandwaterabsorp- tion	Useofsimulatedsalivatocheckthewettingtimeoftablet aswellaswater absorption
In-vitroDispersiontime	At optimum and fixed pH and temperature, time taken fordispersionoftablet inmediaisdetermined
DisintegrationStudies	Thetimeperiodatwhichthetabletstartstodisintegrate i n givenaqueousmediaisdetermined
DissolutionStudies	DissolutionStudiescarriedoutaccordingtoUSP,IP,BP.
StabilityStudies	Stabilitystudies(includingAcceleratedStabilitystudies)areconductedaccord ingtotheICHguidelines
	ContentuniformityaccordingtoeitherUSP,IP,BP.

9. LIMITATIONSOFMOUTHDISSOLVINGTABLETS:

- Fragility and low mechanical strength need for careful handling [41]
- Grittiness, lingering flavour, or insufficient pill evaporation in the mouth [42]
- Manufacturing large doses is difficult. Individuals on anticholinergic drugs and those with Sjogren's syndrome



who have less saliva in their mouths may not experience the desired disintegration and effects from the tablet. [43].

10. Challenges of Fast Dissolving Tablet's:

Despite the advantages of this formulation, it faces number parameters that come across as a challenge. These are listed below [44].

Table 5: Challenges faced while preparing FDT

Parameter	Description
Palatability	Drug should be made palatable to the patient, for easy administration, and should be sweet in nature. This is a challenge as most drugs are bitter in taste.
Mechanical Strength	The tablet should have optimum mechanical strength, along with excipients added, should not break easily, nor be friable. This is a challenge as the drug should rapidly disintegrate in oral cavity and yet have good mechanical strength.
Hygroscopicity	This formulation is hygroscopic in nature as it should dissolve/disintegrate when it comes in contact with water. Thus the vital mechanism of the formulation is a challenge and a limiting step.
Aqueous Solubility	Aqueous solubility becomes a major issue if the drug is hydrophobic in nature or highly lipophilic, thus it won't dissolve/disintegrate in mouth leading to grittiness and residue in mouth.
Tablet Size	Oral dissolving tablets should have an optimum tablet size of 7-9mm, and should not exceed it.
Drug Concentration	Only potent drugs or drugs having a narrow therapeutic index, can be made into FDT's. These tablets are small in size utilizing minimum excipients and drug concentration. Hence all drugs are not suitable for this formulation.

CONCLUSION

Fast-dispersing tablets are regarded as modern dose formulations. Better efficacy, a quicker beginning of action, increased bioavailability, and higher patient compliance are the outcomes of these dosage formulations and their method of administration. There are numerous marketed products in this area that have just recently been introduced. For quick reference, a table lists some of the most recent products available on the Indian and international markets (Table 6). Quick disintegration in the oral cavity without the use of water and enough mechanical strength are the main benefits of MDT. This property elevates the formulation as a highly suggested option for people with geriatric and pediatric conditions. FDT is anticipated to expand greatly and quickly in the next years due to the growth of scientific research and discovery.

Table 6: Some FDT products in global market

Trade Names	Active Drug	Manufacturer
Alavert	Loratadine	Wyeth, U.S
Aricept ODT	Donepezil	Eisai Co, Japan
Allegra ODT	Fexofenadine	Sanofi Aventis, France
Clonazepam ODT	Clonazepam	Par Pharmaceutical, U.S
Dolib MD	Rofecoxib	Panacea
Domray MD	Domperidone	Ray Remedies, Ahmedabad



Febrectol	Paracetamol	Prographarm,Chateaneuf,France
FeldeneFastMelt	Piroxicam	PfizerInc.,NY,U.S.A
Insure-MD	Nimesulide	SuzenPharma,HyderabadIndia
MirtazapineODT	Mirtazapine	TevaPharmaceuticals
MaxaltMLT	Rizatriptan	MerckandCo.,NJ, U.S.A
Mosid-MT	Mosapridecitrate	TorrentPharmaceuticals,Ahmedabad,India
Niravam	Alprazolam	SchwarzPharma
Nimulid-MD	Nimesulide	PanaceaBiotech,NewDelhi,India
OrapredODT	Prednisolone	Scielepharma,AtlantaU.S
OlanexInstab	Olanzapine	RanbaxyLabsLtd.,NewDelhi, India
PepcidRPD	Famotidine	MerckandCo.,NJ, U.S.A
RofadayMT	Rofecoxib	Lupin
Romilast	Montelukast	RanbaxyLabsLtd.,NewDelhi,India
Valus	Valdecocix	Glenmark
ZelaparTM	Selegiline	AmarinCorp.,London,UK
ZofranODT	Ondansetron	GlaxoWellcome,Middlesex,UK
ZotacetMD	CetirizineHCl	ZotaPharma

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Evaluation of Analgesic and Anti Inflammatory Effect Of “Ripare” A Poly Herbal Formulation in Wistar Rats

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Abstract:

RIPARE is a polyherbal Ayurveda formulation that is used for the cure of pain and inflammation disorder by the Indian Population, formulation believed to be having the capacity, this formulation is developed from the part of 9 different plants. It is individually found in the literature of traditional medication. The aim of the present study was to assess the analgesic and anti-inflammation influence of “RIPARE” a polyherbal formulation in wistar rats. The anti-inflammatory has been determined by using the standard drug Indomethacin to model carrageenan induced paw edema and ulcerogenic activity. The analgesic activity was tested by using hot plate method and tail flick method Diclofenac sodium was used drug respectively for these models. Polyherbal formulation RIPARE was two groups Test-1 and Test-2 lower dose 150mg/kg and higher dose 300mg/kg against the standard Indomethacin (10mg/kg) and diclofenac sodium 10 mg/kg body weight of rats for all models. The result of this shows that significant ($p < 0.001$) inhibit the carrageenan induced paw edema. And analgesic activity showed at significant ($p < 0.001$) increase the reaction time after drug. The oral administration of polyherbal RIPARE of eddy's hot plate method and tail flick method. The study's findings strongly prove that the polyherbal ayurvedic formulation has significant anti-inflammatory and analgesic properties; making it a good alternative to presently available allopathic treatments such as nonsteroidal anti-inflammatory drugs (NSAIDs).

Keywords: Carrageenan, RIPARE, anti-inflammatory, analgesic activity

Introduction:

Pain and inflammation are usually the result of various diseases and disorders. Pain can be described as the sensation or uncomfortable feeling usually occurred because of some injury or illness in the body. Inflammation is a defence mechanism in the body against the infection or some injury which is an important response against the viral or bacterial infections. For ancient times various traditional medicines were used to provide some relief from pain and discomfort. In the modern medicine the widely and most popular drugs for the inflammation and pain is the non steroidal anti-inflammatory drugs (NSAIDs).¹



These drugs affects the aggregation of the neutrophils, inhibits the cytokine formation and metabolism of the cartilage and also they blocks the synthesis of the prostaglandis and also stops the development of the lipooxygenase superoxide. These drugs show their analgesic and anti-inflammatory property by blocking the COX-1 and COX-2 enzymes. But the inhibition of the COX-1as well may lead to some adverse effects.²

RIPARE an herbal medication was used for pain and inflammation and is mentioned in various systems like Siddha, Ayurveda and Unani. RIPARE a polyherbal medication which is widely used in the Indian society for a very long period of time to treat various kind of pain and inflammation may have the potential. This formulation is a composition of nine different plants and each plants of this composition is mentioned in the CharakaSamhita and every plant has some sort of the anti-inflammatory and analgesic property³

This plants are used in study polyherbal formulation RIPARE contain various plant like *Boswelliaserrata* , *commiphoramukul* *3 cucuma longa* *4 Tinosporacordifolia*, *5 vitexnegundo* *6 Euphorbia hirta* , *7Cissus quadrangularis*, *8 Centellaasiatica* & *9 Piper nigrum*, have shown analgesic and anti-inflammatory properties and have been found quite effective in inflammation and many studies and journals have also mentioned the anti-inflammatory and analgesic property.

MATERIALS OF METHODS:

Drugs and chemicals:

Poly Herbal Formulations RIPARE was a gift sample from Pinkhealth Life Sciences, Surat, Gujrat, India. The dry powder of RIPARE was reconstituted using 0.1% Carboxy Methyl Cellulose (CMC). The suspension was freshly prepared before use and received Carageenan also as a gift sample from SNAP Natural & Alginate Products Pvt Ltd Mumbai, Maharashtra, India, including with Indomethacin from Meenaxy Pharma Pvt.Ltd. Hyderabad And the Diclofenac sodium from Bala ji Drug, Vadodra.⁴

Experimental animals:

Albino wistar rats of male sex weighing 100-200 g were selected for analgesic and anti-inflammatory activity. The animals were acclimatized in the pharmacology research laboratory, for seven days before the start of experiments. (12:12 h light: dark cycle at 25±2 °C) and were provided with standard pellet diet and water given ad libitum. Food was withdrawn 12 h before experiments. Cycle in a group at six rats in hygienic cages.⁵

Dose selection and preparation:

Dose preparation of “RIPARE” a polyherbal formulation and dose selection: “RIPARE” suspension was prepared in 0.5% CMC carboxyl methylcellulose, by adding distilled water. The dose quantitative of RIPARE 150mg/kg and 300mg/kg body weight which is selected on the basis of a therapeutically equivalent doses according body surface area. For the human, required of the dose RIPARE 1-2 two times in a day for the rat of each capsule 700 mg. According to the dose of human, is the dose is 1400 mg/kg/day. 23 mg/kg/day animal equivalent dose by (mg/kg) by for rat was determined by multiple of human equivalent dose mg/kg by the factor of 6.2 and 12.3 respectively. The dose was selected on the basis of previous study on the basis of the therapeutic dose for rats were getting to be approximately 150 and 300 mg/kg. How it is two different doses for rat which was selected i.e. (TEDs) and HD (high dose)⁶

Anti- Inflammatory Screening method:

1. Carrageenan induced paw edema:⁷

The method of was used to study acute inflammation animal were divided into four groups of six animals each.

GROUP I (Disease control) - NaCl 0.9% (10ml/kg) of (b.w) orally + 0.1% Carageenan sub plantar administration and 0.9% normal saline (10ml/kg)

GROUP II (Standard) - were given Indomethacin (10mg/kg) of (b.w) orally +0.1% Carageenan sub plantar route.

GROUP III (TEST-1) - RIPARE (150mg/kg) of (b.w) orally + 0.1% Carageenan sub plantar route

GROUP IV (TEST-2) - RIPARE (300 mg/kg) of (b.w) + 0.1% Carageenan sub plantar route

The animal will divide into four groups (n=6) viz. group I treated with carrageenan alone served as a negative control¹⁸ 1ml of carrageenan (1%). The animals will be deprived of food and water for 12 h before the experiment from date of initiation, then group III, IV, V the animals will be treated with standard Indomethacin 10mg/kg and Polyherbal formulation “RIPARE” 150mg/kg & 400 mg /kg. In 1ml of 1 % carrageenan were induced to all hind paw rats of group



II, III, IV & V At 1 h after oral administration of drug, 0.1 ml 1% Carrageenan in normal saline was administered in the sub-plantar region of the rat hind paw. Paw volume will be measured at 1, 2, 4 and 5 h after Carrageenan administration the paw thickness was measured by using a plethysmograph

Inflammation inhibition (%) = [(control group mean – test group mean)/control group mean] × 100

Analgesic Screening methods:

1. Eddy's hot plate method:⁸

The hot plate will be used to measure response latencies according to the method described by Eddy. All the animals divided into four groups each comprising six animals

GROUP I (Normal control) - Normal saline 0.9% (10ml/kg) of (b.w) orally.

GROUP II (Standard) – were treated with Diclofenac Sodium (10mg/kg) of (b.w) orally.

GROUP III (TEST-1) - received the lower dose RIPARE (150mg/kg) of (b.w) orally.

GROUP IV (TEST-2) - received the higher dose RIPARE 300 mg/kg of (b.w) orally.

The rats were being placed on a hot plate maintained at the temperature set to 55°C ± 1°C. The animal received Diclofenac sodium (10mg/kg body weight, orally.) with polyherbal formulation test-1 and test-2 respectively served as standard group. They were placed on hot plate and time until jumping occurs was recorded by a stop- watch. The latency time was recorded before and after 30, 60, 90, and 120 min following oral administration of the standard or the test compound. 15sec was taken as maximum analgesia and animal were removed from the hot plate to avoid injury to the paw^[9].

2. Tail flick method:⁸

In this method rats will be divided into four groups is follow-

GROUP 1-(Normal control) - Normal saline 0.9% (10ml/kg) of (b.w) orally.

GROUP 2- (Standard) – were treated with Diclofenac Sodium (10mg/kg) of (b.w) orally.

GROUP 3-(TEST-1) - received the lower dose RIPARE (150mg/kg) of (b.w) orally.

GROUP 4- (TEST-2) - received the higher dose RIPARE (300 mg/kg) of (b.w) orally.

A tail-flick result would cause each rat tail to be placed on an electrically heated wire by utilizing analgesiometer, the heat intensity were modified so that the tail-flick latency is the same as the baseline across all animals average to 3-4 sec at the deadline time was 12s, in sequence to avoid the injury to the tails. The polyherbal formulation and the reference standards would be orally administered until the tail temperature was controlled for 55 OC. The latency time is recorded before and after 30, 60, 90, and 120 minutes after oral route of standard or test compound responses. Responses were assessed by the Diclofenac Sodium (10mg/kg) Standard drug of body weight was prior intake.

4. Ulcerogenic activity The rats of 150-200 gm of body weight was divided in to four group each as follows are:

Group I (Normal control) - Normal saline 0.9% (10ml/kg) of (b.w) orally.

GROUP II (Standard) – were treated with Indomethacin (10mg/kg) of (b.w) orally.

GROUP III (TEST-1) - received the lower dose “RIPARE” (150mg/kg) of (b.w) orally.

GROUP IV (TEST-2) - received the higher dose “RIPARE” 300 mg/kg of (b.w) orally.

After the fasting of 12 hrs, the test standard and control drugs as administered orally in everyday for 3 consecutive days. Animals are sacrificed on 4th days and stomach is intersect out and measured the ulcer lesion. Score the as below:

- 0- Normal coloured stomach
- 0.5- Red colouration
- 1- Spot ulcers
- 1.5- Haemorrhagic streaks
- 2- Ulcers ≥ 3 but ≤5
- 3- Ulcer ≥ 5

RESULT:



Carrageenan induced paw edema:

Anti-inflammatory effect of polyherbal formulation RIPARE was used carrageenan induced paw edema. RIPARE at dose 300 mg/kg shown highly 5 hrs and at the dose of 150 & 300 mg/kg shown significant effect. 2hr, (1.49 ± 0.016sec, p < 0.05) at 3 hr, (1.45 ± 0.014sec p < 0.01), 4 hr, (1.49 ± 0.008sec, p < 0.01) 5 hr, (1.53 ± 0.022sec, p < 0.01) and shown no significant effect at 1hr (1.53 ± 0.022sec) when compare to control 300 mg/kg shown significant effect 1 hr, (1.42 ± 0.010sec, p < 0.05) 2 hr, (1.40 ± 0.086sec, (p < 0.01)) 3 hr, (1.42 ± 0.021sec, (p < 0.01)) 4hr, (1.46 ± 0.033sec, (p < 0.001)) and 5hr, (1.39 ± 0.018sec, (p < 0.001)) when compare to control Indomethacin at the dose of 10mg/kg shown the highly significant (p < 0.001) 1 hr (1.32 ± 0.017) 2 hr (1.35 ± 0.010) and 5(1.41 ± 0.024) hr when it compare to control inhibited paw edema. When compare to control.

The anti-inflammatory activity of polyherbal formulation was in significant at 300 mg/kg percentage inhibition of edema was 13.939% at 1 hr 16.167% at 2 hr 16.470% at 3hr 16.571% at 4 hr and 21.910% at 5 hr as compared to the standard drug Indomethacin where inhibition percentage of edema 20.00%, 19.16%, 16.470%, 15.428%, 20.786 at 1,2,3,4, & 5 hours respectively in Table no.1, Graph no.1.

Table No. 1: Effect of polyherbal formulation "RIPARE" on Carrageenan induced paw Edema in rats.

Treatment				
	Group 1	Group 2	Group 3	Group 4
	Control	Standard Indomethacin (10mg/kg)	RIPARE Capsule (150 mg/kg)	RIPARE Capsule (300 mg/kg)
1 hr	1.65 ± 0.012	1.32 ± 0.017 ^{***}	1.53 ± 0.022 ^{ns}	1.42 ± 0.010 [*]
2 hr	1.67 ± 0.011	1.35 ± 0.010 ^{***}	1.49 ± 0.016 [*]	1.40 ± 0.086 ^{**}
3 hr	1.70 ± 0.010	1.42 ± 0.020 ^{**}	1.45 ± 0.014 ^{**}	1.42 ± 0.021 ^{**}
4 hr	1.75 ± 0.014	1.48 ± 0.027 ^{**}	1.49 ± 0.008 ^{**}	1.46 ± 0.033 ^{**}
5 hr	1.78 ± 0.038	1.41 ± 0.024 ^{***}	1.53 ± 0.022 ^{**}	1.39 ± 0.018 ^{***}

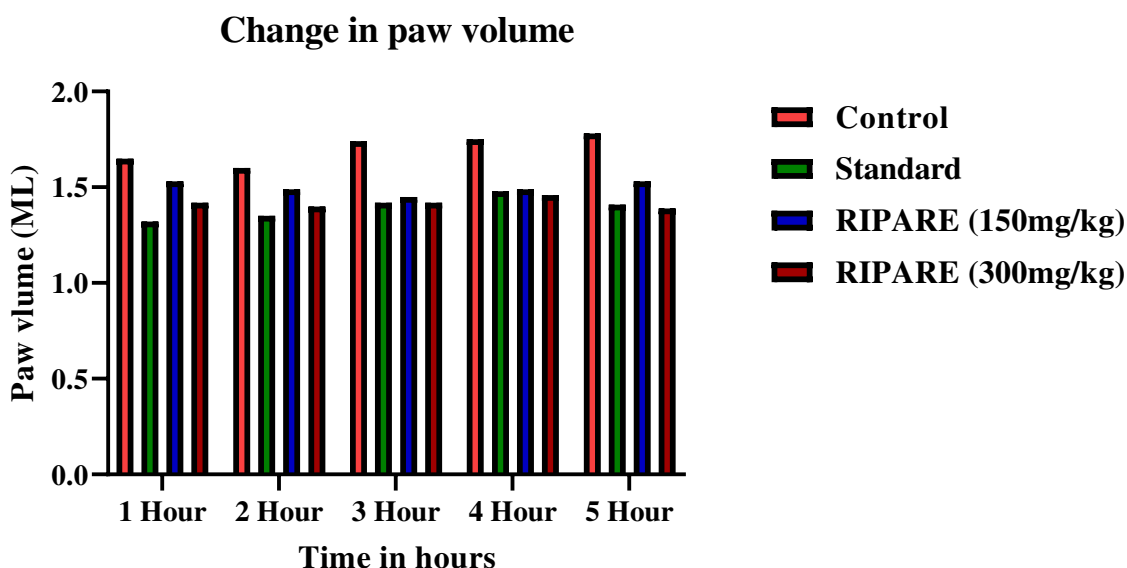
Values are mean ± SEM; n=6 in each group, *** p < 0.001 Ns= not significant * p < 0.05 ** p < 0.01 when compared to normal.

Table No. 2: % inhibition of treated group compared with control group.

% inhibition of treated group			
	Group 2	Group 3	Group 4
	Satandrad Indomethacin (10mg/kg)	RIPARE capsule (150mg/kg)	RIPARE capsule (300mg/kg)
1 hr	20	0.072	13.939
2 hr	19.161	10.778	16.167
3 hr	16.470	14.705	16.470
4 hr	15.428	14.857	16.571



5 hr	20.786	14.044	21.910
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Graph. No.1: Effect of polyherbal formulation “RIPARE” on Carrageenan induced paw edema.

Eddy’s hot plate method:

Analgesic effect of RIPARE polyherbal formulation at the dose of 300 mg /kg shown highly significant effect at 90 min ($p < 0.001$ 7.31 ± 0.046 sec) and 120 min ($p < 0.001$ 7.49 ± 0.026 sec), 60 min ($p < 0.01$ 7.29 ± 0.053 sec) and shown no significant effect at 30min. when compare to control.

RIPARE at the dose of 150mg/kg shown highly significant effect at 30min ($p < 0.001$ 5.20 ± 0.031 sec) and 90min ($p < 0.001$ 6.31 ± 0.032 sec), 120 min ($p < 0.01$ 6.81 ± 0.054 sec) and shown no significant effect at 60min when compare to control. Diclofenac sodium was given 10mg/kg shown highly significant effect 30min ($p < 0.001$ 5.93 ± 0.015 sec) 60 min ($p < 0.001$ 8.67 ± 0.024 sec) 90min ($p < 0.001$ 9.56 ± 0.056 sec) and 120 min ($p < 0.001$ 10.22 ± 0.0629) when compare to control. Table no. 3, Graph no. 2.

Table No.3: Analgesic activity of hot plate method.

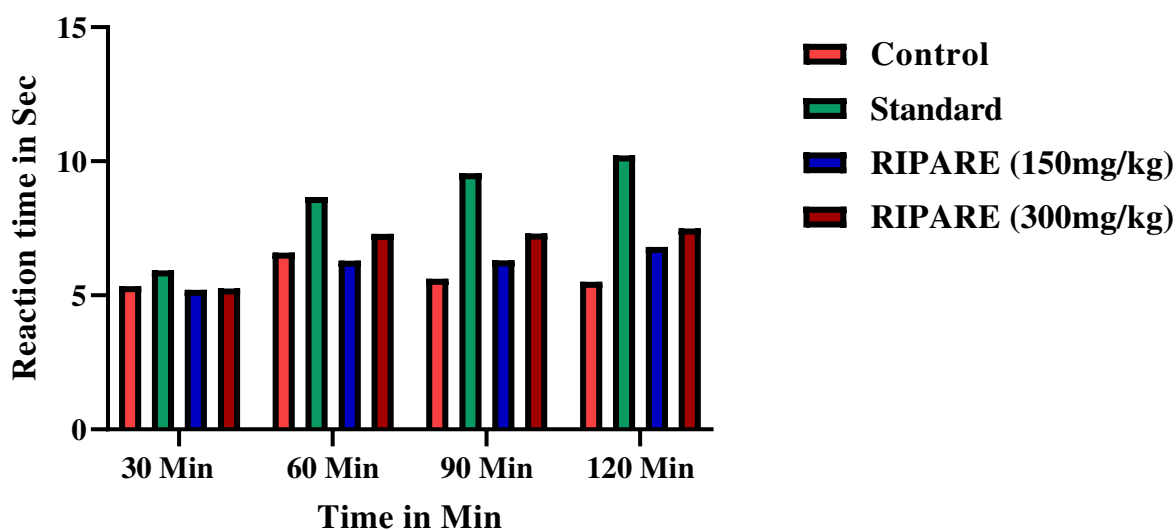
S.No.	Groups	Basal reaction time (sec)	Reaction-time(sec) after drug administration				Average mean
			30 min	60 min	90 min	120 min	
1.	Control	3.9 ± 0.152	5.34 ± 0.029	6.60 ± 0.085	5.62 ± 0.048	5.51 ± 0.041	5.7657
2.	Diclofenac Sodium 10mg/kg	4.1 ± 0.031	$5.93 \pm 0.015^{***}$	$8.67 \pm 0.024^{**}$	$9.56 \pm 0.056^{***}$	$10.22 \pm 0.0629^{***}$	8.595



3.	RIPARE 150mg/kg	4.1±0.031	5.20±0.031 ***	6.30±0.084 3 ^{ns}	6.31±0.03 2 ^{***}	6.81±0.054 ^{**}	6.155
4.	RIPARE 300mg/kg	4.2 ±0.048	5.25±0.074 ns	7.29±0.053 [*]	7.31 ±0.046 ^{***}	7.49±0.026 ^{**} [*]	6.835

Values are mean ± SEM; n=6 in each group, n=6 in each group, *** p < 0.001 Ns= not significant ** p < 0.01 when compared to normal.

Effect of Formulations on Hot plate test in rats



Graph. No.2: Effect of polyherbal formulation "RIPARE" on Hot plate method.

Tail flick Method:

RIPARE polyherbal formulation at the dose 300mg/kg shown highly significant at 90min (p < 0.01 6.62±0.045sec) and 120min (p < 0.01 7.54±0.066sec) 30 min (p < 0.056.22±0.018sec) 60 min (p < 0.056.41±0.046sec) when compare to control.

RIPARE at the dose of 150mg/kg shown shown significant at 120min ((p < 0.01 7.12±0.056sec) 90,min (p < 0.05, 6.53±0.052 sec) 60,min (p < 0.05, 6.35±0.087) and shown no significant effect at 30min when compare to control. Diclofenac sodium was given 10mg/kg shown highly significant effect 120min (p < 0.001 8.72±0.058sec) 90 min (p < 0.001 7.51±0.059sec) 60min shown significant (p < 0.01 6.87±0.043sec) and 30min (p < 0.05 6.63±0.101sec) when compare to control Table no. 4 graph no. 3

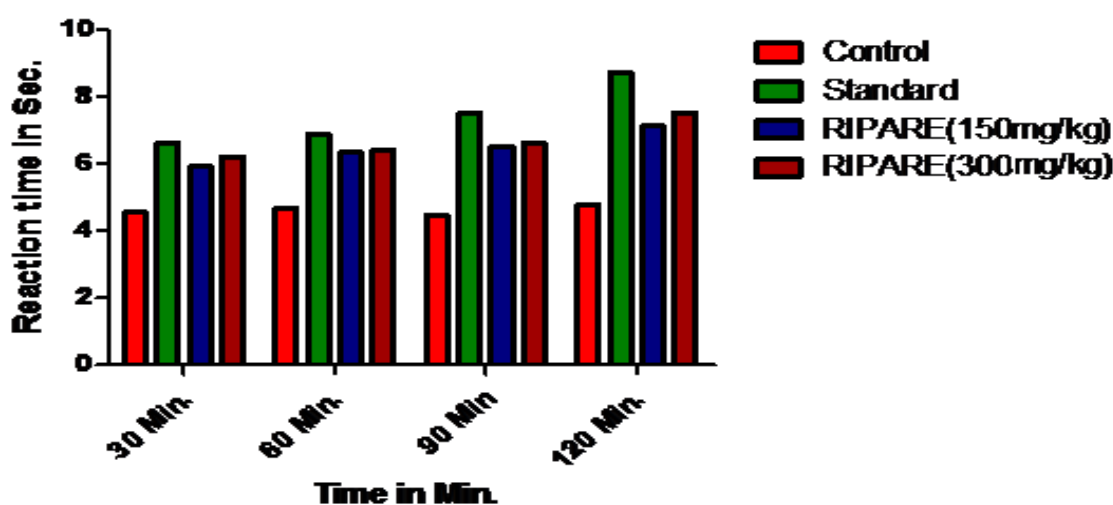
Table No. 4: Analgesic activity of Tail flick method.

S.No.	Groups	Tail- flick latency in Sec (Mean ± S.E.M.) at time (min)				Average mean
		30 min	60 min	90 min	120 min	
1.	Control	4.55±0.032	4.68±0.021	4.46±0.023	4.77±0.034	4.615



2.	Diclofenac Sodium 10mg/kg	6.63±0.101*	6.87±0.043**	7.51±0.059**	8.72±0.058***	7.432
3.	Ripare 150mg/kg	5.91±0.068 ^{ns}	6.35±0.087*	6.53±0.052*	7.12±0.056**	6.477
4.	Ripare 300mg/kg	6.22±0.018*	6.41±0.046*	6.62±0.045**	7.54±0.066**	6.697

Values are mean ± SEM; n=6 in each group, n=6 in each group, *** p < 0.001 Ns= not significant ** p < 0.01 and * p < 0.05 when compared to normal.



Graph. No.3: Effect of polyherbal formulation "RIPARE" on Tail flick method.

Ulcerogenic activity:⁹

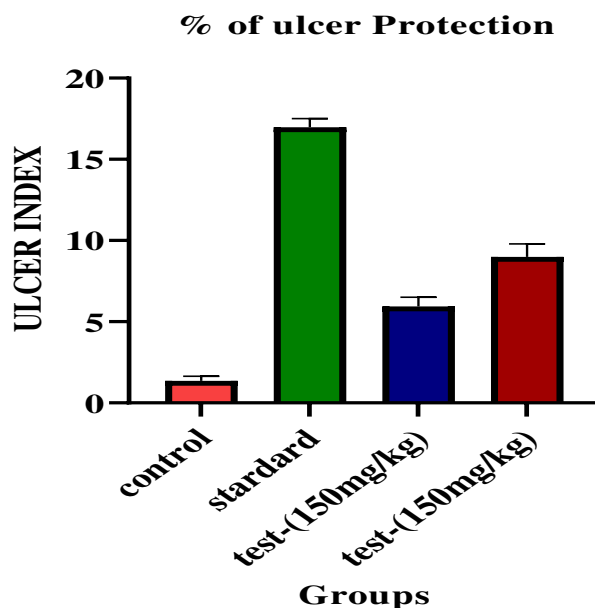
The route of oral drug indomethacin in amount of 10mg/kg was used as standard drug which showed highly significant ($P \leq 0.001$) $16.98 \pm 0.212\%$ when compared to control 1.35 ± 0.116 that may result in the increase degree of ulceration as ulcer index, however show such response and the gastric mucosa in the polyherbal formulation RIPARE at a dose of 150mg/kg highly significant ($P \leq 0.001$) 5.93 ± 0.235 and 300mg/kg highly significant ($p < 0.001$) 8.98 ± 0.329 treated group was found almost free of lesions as in the solvent control group. The inhibit ulcer formation due to the standard drug Indomethacin highly significant ($P \leq 0.001$) that show a protective response against this result certify with previous study Table no. 5 graph no. 3.

Table no 5: Ulcer index and percentage % of ulcer protection in pylorus ligated model.

Groups	Dose (mg/kg)	Ulcer index	% protection
Control	1.35 ± 0.116	
Standard Indomethacin	10mg/kg	$16.98 \pm 0.212^{***}$	92.0%
Test -1 RIPARE 150mg/kg	150mg/kg	$5.93 \pm 0.235^{***}$	77.4%
Test -2 RIPARE 300 mg/kg	300mg/kg	$8.98 \pm 0.329^{***}$	84.9%



Values are mean \pm SEM; n=6 in each group, n=6 in each group, *** p < 0.001 when compare to normal



Graph. No.4: Effect of polyherbal formulation "RIPARE" on ulcer index

Statistical Analysis:

The data are articulated as mean \pm SEM. Statistical analysis was done by using graph pad prism version 9.0.2(161) software.

A one – way analysis of variance (ANOVA) followed by Dunnett's multiple comparison adjusted P.values ≤ 0.05 were considered to be statically significant when compared to control.

DISCUSSION:

The effect observed with polyherbal for mulation RIPARE could possibly be due to synergistic actions of these compounds. In the present study, RIPARE demonstrated a highly significant ((P ≤ 0.001) anti- inflammatory and analgesic activity at different dose levelly in rat model of inflammation and pain the anti- inflammatory RIPARE was evaluated by popular screening model widely used for NSAIDs namely carrageenan induced rat paw edema¹⁸ the biphasic effect first phase is due to release of histamine & serotonin (5-HT) (0-2 hr), plateau phase is maintained by kinin like substance (3hrs) and second accelerating phases of swelling is attributed the validation of the carrageenan paw edema test, rats were administered. Indomethacin orally of a positive control at a dosage of 100 mg/kg before carrageenan injection as expected, Indomethacin was highly significant ((P ≤ 0.001) decrease paw edema.¹⁰

The central analgesic activity of RIPARE was studies using hot plate method and peripheral activity second model RIPARE (150,300 mg/kg) significant increased the reaction time in hot plate test¹¹ the tail flick method in rats analgesic effect of suggestions that it has central as well as peripheral mechanism of action in our study we got analgesic activity of RIPARE in peripheral and central mechanism animal model. In comparison to standard drugs it was showing significant analgesic action tail flick which is used to induce causes analgesic by liberation of endogens substance which them excite the pain nerve ending the extract produced significant writhing inhibiting comparable to standard drug Diclofenac sodium based on this, it could be concluded that it might possess analgesic activity.¹²

CONCLUSION:

This research has shown the analgesic and anti-inflammatory activity of polyherbal RIPARE dose-dependent way. The dose 150mg/kg and 300mg/kg of RIPARE was highly significant. In the treatment of inflammation, it has been found to



be more effective. The mechanism of action in the production of a potent analgesic and anti-inflammatory compound, further investigations are required. Though the additive present in the formulation have been reported to anti-inflammatory & analgesic activities the formulation was not evaluated preclinical or clinically for the claimed activity in our study we have made an attempt to prove its effect in experiment animals.

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CONFLICT OF INTEREST:

Nil

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Nanomaterial and Their Interaction with Environment

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The subject of nanomaterial is very topical, with advances in knowledge made at a very rapid pace, making dissemination of this new knowledge a need of the hour. Although it is widely recognized that nanotechnology is playing a key role in many areas of societal endeavor, it is still unclear what risks certain nanomaterial may pose to humans and the environment. While nanotechnology has brought enormous benefits to humankind, its impact on human health and the environment is yet to be fully understood.

Nanomaterial are considered as emerging environmental contaminants. Their origin can be natural [1], incidental [2], or from manufacturing processes [3]. Incidental nanomaterial are those generated as side products of anthropogenic processes [4, 5], whereas manufactured nanomaterial are deliberately produced with specific properties [3, 6]. Exposure to both types is currently being investigated and these may enter air, water, and soil media from a range of routes. Physicochemical and biological transformations make nanomaterial's potentially highly reactive in both environmental and biological systems, which may alter their fate, dispersion, and toxicity compared with their larger counterparts [7, 8].

Recent years have seen an enormous increase in the number of publications, indicating an exponential increase over the past decade in nonmaterial-related research, in terms of manufacturing, applications, exposure, and hazard (Figure 1). These studies have focused on various aspects of nanomaterial, such as their novel applications as adsorbents, ion exchangers and disinfectants in water and air for removing ions, and organic compounds and pathogens [9, 10], as well as assessing risks associated with them to human health, ecology, and environment [11]. This special issue was designed to highlight recent advances in the area of nan safety as well as present studies on the application of nanomaterial for environmental remediation, such as removal of ions and organic compounds from aqueous and air media. We believe that the articles published in this special issue are of great interest to scientists engaged in cross-disciplinary research and other stakeholders alike.

Given the highly interdisciplinary nature of the topic, a broad range of researchers from the scientific community were invited to contribute original research articles as well as review articles that could stimulate the continuing efforts to understand the advances in nanomaterial characterization, emissions, transformation, dispersion, fate, and effects in different environmental compartments (air, water, and soil). A particular focus of the issue was on articles that can deal with their environmental and health impacts, and the implications for policy and regulations for both the indoor and outdoor environments.

A broad range of the scientific community participated in this special issue, starting from material scientists working on the development of novel materials to those using them in various applications. Scientists involved in carrying out environmental and health impact assessment of nanomaterial made their contributions too. The other very interested community participating in this special issue was



pollution emitted by road vehicles. The work concluded that modelling can help with prediction of hot-spots by using atmospheric data. Results from this modelling can help minimise exposure in busy street canyons by careful selection of the best pedestrian paths. The contribution from M. Mohan and S. Payra investigated the relationships between ambient aerosol number concentrations (ANC) and meteorological parameters to study the fog conditions in Delhi. Their findings suggested a threshold minimum value of ANC for foggy conditions and obtained a relationship in power form between the ANC and visibility.

J. Matulevicius et al. investigated electrospun polyamide 6 (PA 6) and polyamide 6/6 (PA 6/6) nanofibers for air filtration applications. Experimental results enabled the response surfaces for desirable characteristics of useful nanofiber filters to be derived while modelling results showed that electrospun polyamide 6/6 fibre media derived from 8% (w/vol) solutions of formic acid/acetic acid (3 : 2 vol/vol) have the smallest fibre diameters. Therefore, they had the highest filtration efficiencies (up to 90%) and displayed the best filtration quality factors (up to 0.0749 Pa^{-1}). The paper highlights the potential role of modelling in predicting suitable characteristics of fibers for air filtration applications.

A. Zeino et al. studied the removal of bromate from drinking water by different types of carbon nanotubes (CNTs). These authors compared raw CNTs and CNTs oxidised with nitric acid, with CNTs impregnated with Fe. The latter CNTs had higher adsorption capacities. Nitric acid was found to be a better acid for the adjustment of the pH and the adsorption capacities of all CNTs decreased with adsorbent dose and pH of the solution but increased with the bromate concentration.

The work of Sk. S. Hossain et al. experimentally investigated copper loaded CNTs as electrocatalysts for the electrochemical reduction of carbon dioxide. Their results found that copper loaded CNTs (20% by weight) showed maximum activity among other catalysts tested, and the faradaic efficiency for methanol formation was estimated to be 38.5%.

E. S. Agorku et al. reported the use of various sulfur/gadolinium-codoped TiO_2 nanoparticles for the visible light photocatalytic degradation of indigo carmine as a model organic pollutant. Appreciable visible light degradation was observed in all cases, with $\text{TiO}_2\text{-S/Cd}^{3+}$ showing more activity than commercial TiO_2 . The photocatalytic efficacy of codoped TiO_2 nanoparticles increased with the percentage of Cd^{3+} up to 0.6% Cd^{3+} , with $\text{TiO}_2\text{-S/Cd}^{3+}$ (0.6% Cd^{3+}) showing the highest activity and degrading indigo carmine completely in 50 minutes.

N. Shandilya et al. evaluated the release of TiO_2 nanoparticles from two commercial photocatalytic nanocoatings using abrasion tests. One of the nanocoatings inhibited the release of nanoparticles while the other did not. No free TiO_2 nanoparticles were released from either of the nanocoatings. The study introduced two particle release parameters that can be used to assess the tendency of nanocoatings to hold or release particles. O. L. C. Le Bihan et al. reported the aerosolization of a multiwalled CNT, by a vortex shaker. Their aims were to develop and evaluate vortex shaker techniques as a tool for the determination of the exposure potential to suspensions of inhalable particles and powders from nanomaterials. The study demonstrated that the geometry of the device and speed of agitation influenced the experimental outcome and concluded that although the method has the potential to be used for dustiness assessments further evaluation would be required before it can be routinely used for toxicological investigations.

X. Zhou et al. fabricated and characterised CdS/H- TiO_2 nanotube (TNT) arrays to investigate their photocatalytic properties during degradation of a methyl orange dye. The photodegradation of methyl orange was carried out under visible-light irradiation. They found that the CdS/H-TNTs exhibited greater efficiency than the H-TNTs and pure TNTs. In particular, the CdS/H-TNTs gave 88.7% decoloration rate compared to pure TNTs with only 6.4% decoloration rate. Their work also showed that the CdS/H-TNTs were approximately 13-times more effective than pure TNTs under visible light, indicating that these TNTs could successfully be used for decomposing methyl orange from water.

D. N. Chung et al. synthesised Ce-doped $\text{Y}_3\text{Al}_5\text{O}_{12}$ (YAG: Ce) nanopowders using a sol-gel low temperature combustion method, followed by thermal annealing and used for solid-state lighting. They found that the white light emitting diodes (WLEDs) made from the blue light emitting diode (LED) chip coated with the nano-YAG: Ce + MEH-PPV composite epoxy exhibited white light with a broad band luminescent spectrum and a high colour rendering index. These findings indicated potential application of the prepared nanostructured YAG: Ce phosphor in energy-efficient solid-state lighting as well as in organic composite solar cells. These findings also indicate their application for the enrichment of uniform inorganic nanoparticles.

A few articles were submitted on nanomaterials used as adsorbents and ion exchange materials for removing dyes, metal ions, and inorganic ions from water. These studies showed that removal of ions and dyes from water using



nanomaterial-based adsorbent and ion exchange material is a suitable and very promising approach. For example, M. A. Shaheed and F. H. Hussein studied adsorption of reactive black 5 on synthesized titanium dioxide nanoparticles using equilibrium isotherm and kinetic studies that TiO_2 -NPs could be a promising adsorbent as it showed removal of RB 5 from aqueous solutions through a chemical adsorption method. The study found a Langmuir monolayer adsorption capacity of 88.495 mg/g at pH 5.5 and 30°C. M. F. Elkady et al. assessed the potential of synthesized nanozirconium tungstovanadate as cation exchanger and tested it in the removal of lead ions from water. They noticed 96% removal of lead ions from water and showed that the new material can act as cation exchanger (ion exchange capacity = 2.5 milliequivalent/g). C. S. Ciobanu et al. synthesized porous methyltrimethoxysilane coated nanoscale-hydroxyapatite and investigated its potential for removal of lead ions from aqueous solutions. This study characterized the prepared material using X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectrometer (EDS) and then studied lead removal in adsorption studies at different solution pH values. They noticed that at Pb concentrations from 0.5 g/L to 1.5 g/L, the removal efficiency reached nearly 100% (i.e., complete removal). In general, removal was found to be higher in acidic pH conditions, which decreased as solution pH increased.

A few submissions presented the effect of nanomaterials on growth of plants and metals uptake by plants. This topic is particularly interesting given the fact that there are still very few studies assessing the effects of nanomaterials on soil systems, and particularly on plants. For example, Z. Li and

J. Hunag studied effect of the nanoparticle hydroxyapatite (nHAP) on the growth and antioxidant system in Pakchoi (*Brassica chinensis* L.) from cadmium-contaminated soil by using different nHAP concentrations. Results indicated that increasing levels of nHAP led to improved plant growth and reduced Cd uptake by the plant. Also, exposure of higher nHAP levels resulted in an increase in levels of chlorophyll and vitamin C and decrease in the level of malondialdehyde (MDA) in plant shoots. The findings of their study indicated that nHAP can be used to reduce the uptake of Cd by Pakchoi from Cd-contaminated soil which reduces exposure risk in higher food web levels.

The team of guest editors also contributed a comprehensive review article. This article presented a comprehensive summary of state of the art on the fate, exposure, and toxicity of engineered nanomaterials in air and water environments, highlighting research gaps and suggesting directions for future research. The review recognised the need to develop a combination of different analytical methods for determining nanomaterial number and mass concentration, conducting toxicity studies, obtaining relevant data for developing quantitative nanostructure toxicity relationships (QNTR), and initiating efforts to formulate guidelines for the regulation of ENMs in the environment.

Overall, we believe that the collection of these scientific articles provides a solid contribution to the understanding of nanomaterials and their impacts on the environment. Research findings from the published work will be useful for material scientists, environmental scientist and engineers, risk assessors, and regulators for addressing nanomaterial-related issues in the environment.

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Biofuel Production with Wastewater by Algal Action

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Abstract- Microalgae has been well received by the international scientific community as a food source for good carbon, high lipid content, and renewable energy that is more beneficial than any other biofuel source. Although microalgae are considered useful for biofuel and bio product production in many parts of the world, they have not achieved sustainable large-scale algae biofuel production. Wastewater contains organic and inorganic additives that algae need for growth. Incorporation of microalgae into wastewater is an effective method of waste treatment and cost-effective microalgae biofuel production. In this article, we will discuss the possibilities and current status of microalgae cultivation along with biofuel production and show the latest developments in this field.

1. Introduction

Global biofuel production has increased sevenfold since 2000, but still only meets 2.3% of final liquid fuel demand [1]. Global energy consumption is expected to increase by 49%, from 522 exajoules (EJ) in 2007 to 780 EJ in 2035 [2]. Crude oil and natural gas, two main sources of energy, are expected to fall by 45.7 and 62, respectively.8 years, it is estimated that energy demand will triple by 2025 [3]. Transport is one of the fastest growing industries, using 27% of primary energy in the current scenario, while in India the annual oil consumption is around 5.5%, which will increase over the next ten years [4]. Diesel alone currently meets about 73% of transport fuel demand in India, followed by gasoline at 20%; moreover, the average transport fuel demand is expected to increase from 117 billion liters in 2013 to 1,670 billion liters by the end of this decade billion liters, which will reach another 195 million liters by 2023 [5]. Fossil fuels accounted for 88% and 86% respectively.2% of the energy consumed by the world and the United States [6]. The transport and energy sectors are the most important sources in the European Union (EU), accounting for 20% and 60% of greenhouse gas (GHG) emissions respectively [7]. It is well accepted that global warming will increase due to (GHG) emissions [8], highlighting the urgent need for cleaner alternatives to fossil fuels. Due to the continued depletion of natural resources, the emerging energy crisis, and rising fuel prices, there is a need for an alternative, scalable, and sustainable energy source. Moreover, the whole world is facing two major challenges of fresh water scarcity and energy crisis [9]. Recently, renewable energy sources including hydro, wind, solar, geothermal and especially biofuels have received a lot of attention as an alternative to traditional energy sources due to their sustainability, their respect for the environment and their carbon neutrality, as well as their potential to Meet the energy needs of the transport sector. Microalgae have the potential to be an alternative source of petroleum diesel due to their sustainable photosynthetic efficiency, environmentally friendly methods, increased depletion of non-renewable energy sources, and use of non-arable land. The combination of wastewater with the cultivation of microalgae could be a promising method for the



production of biofuels. This integration can provide an economically viable and environmentally friendly means for the sustainable production of algal biofuels, as large amounts of water and nutrients such as nitrogen and phosphorus can be recycled for algal growth in the wastewater-based algal culture systems [10, 11]. Microalgae have a double application for the production of biomass, for the sustainable production of biofuels and the regulation of plants [12]. They have higher photosynthetic efficiency and lipid content and can be used in biofuels including biodiesel, bioethanol, biohydrogen and fuel gases. Microalgae-based biofuel systems enable the production of clean, sustainably produced fuels for the future while eliminating the fuel supply and fuel forest issues associated with first-generation biofuels and lignocellulosic-based processes. wood raw materials [13]. Although there has been enough debate about algal biofuels, they are still not commercialized because their economic viability is questionable. Although highly beneficial, the technical economics of current microalgal biofuel production systems are not effective when competing with conventional petroleum-based fuels, as they are associated with high production costs. The highest cost of current algae biofuel technology depends on the algae cultivation system, harvesting methods and lipid extraction. But their prospects are certainly promising, and both developed and emerging economies are interested in algebraic fuels [14].

2. Microalgae: Beneficial as a Source of Biofuel

Microalgae are prokaryotic or eukaryotic photosynthetic microorganisms, some of which can also form chains or colonies ranging from a few microns to hundreds of microns, and are ubiquitous in nature. Algae are a large class without proper taxonomic classification [15]. They are primitive plants (thallophytes), that is to say cells without roots, stems and leaves, without a sterile envelope around them, and whose chlorophyll is the main photosynthetic pigment [16]. Algae can be divided into two large groups, macroscopic multicellular algae, which can measure several meters, and microalgae, which are small organisms ranging in size from $0.2 \mu\text{m}$ to $100 \mu\text{m}$ or more [17]. Compared to traditional crops such as corn and soybean, microalgae have a higher areal biomass productivity and the oil content of microalgae can exceed 80% of the biomass dry weight [18]. In general, algae are divided into five main groups: blue-green algae (Cyanophyceae),

- (i) brown algae (Phaeophyceae)
- (ii) diatoms (Bacillariophyceae),
- (iii) red algae (Rhodophyceae),
- (iv) green algae (Chlorophyceae),

Although cyanobacteria (blue algae) belong to the category of bacteria and are photosynthetic prokaryotes, they are often referred to as “algae” [19]. Microalgae have many promising properties that make them ideal for the production of biofuels. The main source of carbon for the growth of microalgae is carbon dioxide in the atmosphere [20]. Some microalgae can grow well in non-potable waters (salt water, waste water and sea water); in the future, it may be possible to link the production of biofuels to one of these systems. This link does not compete with arable land that can be used for agricultural purposes, nor does it eliminate the use of freshwater resources. Producing biofuels from algae can be accompanied by reductions in CO₂ emissions from flue gases, waste water treatment and the production of high-value chemicals [21, 22]. Many species of microalgae produce large amounts of lipids which can be converted into biodiesel through the process of transesterification. Microalgal biodiesel has properties associated with petroleum-based diesel, including density, viscosity, flash point, cold flow and calorific value. Microalgae can be harvested in colonies almost year-round, providing a reliable and continuous supply of oil [20]. Microalgae do not require the use of chemicals, unlike terrestrial plants which require herbicides or pesticides, which can harm the environment and increase production costs. Microalgae and other macro-biopolymers (found in woody biomass) often lack lignin, which hampers biomass processing and conversion [23]. In addition to this, the remaining algal biomass, mostly protein and carbohydrates, can be converted into a variety of biofuels, including methane and alcohol fuels, and it can also produce other non-



combustible by-products that can be recovered and formulated. have a high market value of the equivalent nutritional value of the product. , therapy and animal feed [24].

3. Cultivation of microalgae for the production of biofuels from wastewater

Due to the expansion of the world's population and the improvement of people's living standards, serious water pollution has occurred. produced worldwide. Wastewater is essentially an end product generated from domestic, municipal, agricultural and industrial sources [25]. The composition of wastewater reflects lifestyles and technologies that produce social practices [26]. Wastewater typically contains organic materials such as proteins, carbohydrates, lipids, volatile acids, and inorganic materials including sodium, calcium, potassium, magnesium, chlorine, sulfur, phosphate, bicarbonate, ammonium salts and heavy metals [27]. Excessive loads of these nutrients in surrounding water bodies often result in eutrophication or algal blooms due to anthropogenic waste generation.

More than 300 million tonnes of biodegradable household and household-like wastes, industrial wastes, and other wastes are generated every year in the European Union and stay mostly unexploited [45]. Human beings generate approximately ~3 billion tonnes of domestic wastewater every year [46]. In India, annually, due to migration of people into cities, the figures are expected to reach about 600 million by 2030 making and simultaneously increasing pressure on urban return flow (wastewater) which is usually about 70–80% of the water supply [47]. The recent reports of Central Pollution Control Board [48], New Delhi, India, revealed that the wastewater generation in the nation is around 40 billion litres per day largely from urban areas and ironically only 20–30% of the generated wastewater is subjected to treatment. In majority of the developing nations, the main sources of wastewater generation are domestic, municipal, agricultural, and industrial activities which are foremost released into environment without having sufficient treatment steps. Many species of microalgae are able to efficiently grow in wastewater environment through their capability to use abundant organic carbon and inorganic N and P in the wastewater [11]. Algae take up these nutrients along with CO₂ and produce biomass through the process of photosynthesis.

3.1 Production of biomass from microalgae grown in wastewater-

Species selection, growth optimization, lipid content and large-scale harvesting are important factors that govern the commercial potential of algal biofuels. The algal biomass produced and harvested from these wastewater treatment systems can be converted into biofuels through various pathways, for example, anaerobic digestion into biogas, transesterification of lipids into biodiesel, fermentation of carbohydrates into bioethanol and conversion at high temperature in crude oil [56]. Compared to commercial algal production by HRAP, which consumes fresh water and fertilizers, the economic feasibility of algal biofuel production by wastewater treatment can be achieved through high efficiency (HRAP), with less environmental impact [57]. A major challenge in existing research on microalgae in high-flow ponds is to design an efficient and economical carbonation system to meet high CO₂ demand and thus increase biomass productivity [58]. Viswanath and Bux [59] used *Chlorella*. Extracted from wastewater ponds and screened for the efficiency of lipid production by cultivation in bioreactors under photoautotrophic and heterotrophic conditions. The greatest amount of biomass is obtained from *Chlorella*. 8.90 gL⁻¹ were grown under heterotrophic growth conditions compared to photoautotrophic growth conditions, about 3.6 times less than the former, resulting in high lipid accumulation . 4.4 times higher in cells compared to autotrophic growth by increased lipid production. This study demonstrates that heterotrophic growth of microalgae is an efficient method of producing biomass with high intracellular lipid content, which can reduce the cost of microalgal biomass production.

1. Microalgae harvesting Methods

Dehydration and harvesting of algal biomass is an important step to concentrate algal biomass and further release triacylglycerol (TAG), which can then be re-esterified to produce biodiesel (as shown in Fig. 1) . Harvesting and dewatering is one of the challenging areas of current biofuel technology due to the small size and low density of microalgae, which increases investment costs. The problem is to release lipids from intracellular locations in the most



energy efficient and economical way, avoiding the use of large amounts of solvents such as hexane and capturing as much biomass carbon as possible from liquid biofuels. Take advantage of , potentially recovering small, high-value products [60]. The main techniques currently applied to harvest and recover microalgae include centrifugation, flocculation, filtration and flotation.

Flocculation. Flocculation is a process of forming aggregates known as algae flocs that are often performed as a pre-treatment to destabilize algae cells from water and to increase the cell density by natural, chemical, or physical means. Chemicals called flocculants are usually added to induce flocculation, and commonly used flocculants are inorganic flocculants such as alum [61, 62] or organic flocculants such as chitosan [63] or starch [64]. The surface charge of microalgal cells is generally negatively charged due to the ionization of functional groups on the microalgal cell walls and also by the adsorption of ions from the culture medium which can be neutralized by applying positively charged electrodes and cationic polymers, also commonly used to flocculate the microalgal biomass. This harvesting method is pretty expensive because of the cost of flocculants; hence flocculants need to be inexpensive, easily produced, and nontoxic.

Centrifugation. Centrifugation is a widely used method of separation on the basis of particle size and density separation. Separation efficiency is dependent upon the size of desired algal species. Numerous centrifugal techniques have been employed in various types and sizes depending on the uses such as tubular centrifuge, multichamber centrifuges, imperforate basket centrifuge, decanter, solid retaining disc centrifuge, nozzle type centrifuge, solid ejecting type disc

Centrifuge, and hydro cyclone [65]. Despite being energy intensive method, it is rapid and a preferred method for microalgal cell recovery, whereas cell viability was found to be significantly dependent on the microalgal species and the method of centrifugation [66]. Even though it is very effective, centrifugation is considered unfeasible in large-scale algal culture system due to the high capital and operational costs.

Filtration. Filtration harvests microalgal biomass through filters on which the algae accumulate forming thick algae paste and allow the liquid medium to pass through. Filtration systems can be classified as macrofiltration (pore size of $>10 \mu\text{m}$), microfiltration (pore size of $0.1\text{--}10 \mu\text{m}$), ultra-filtration (pore size of $0.02\text{--}2 \mu\text{m}$), and reverse osmosis (pore size of $<0.001 \mu\text{m}$) [67]. There are many different forms of filtration, such as dead end filtration, microfiltration, ultrafiltration, pressure filtration, vacuum filtration, and tangential flow filtration (TFF) [68]. Nevertheless, it is accompanied with extensive running costs and time consuming.

Flotation. Microalgae cells are trapped on microair bubbles and float at the surface of water [69]. Generally, the flotation efficiency is dependent on the size of the created bubble: nanobubbles ($<1 \mu\text{m}$), microbubbles ($1\text{--}999 \mu\text{m}$), and fine bubbles ($1\text{--}2 \text{mm}$) [70]. Dissolved air flotation is a widely used technique in which microalgal cells are usually flocculated first and then air is bubbled through the liquid causing the flocs to float to the surface for easier harvesting. Hydrophobic interaction and surface charge of microalgae play crucial role for attachment of microalgae to the bubbles.

4. Lipid Extraction Methods

Lipid is polymer of fatty acids which is generally hydrophobic in nature and is classified as a polar (membrane lipids) and nonpolar lipid (neutral lipids). Polar lipids interact with polar solvents like ethanol and methanol and similarly nonpolar lipids interact with nonpolar solvents like chloroform and benzene which is the basis of designing solvent system for lipid extraction methods [71]. This solvent system mainly disrupts noncovalent interactions, hydrophobic interactions, and hydrogen bonding between lipid and associated macro-molecule like protein. Lipids are mainly composed of 90–98% (weight) of TAGs, small amounts of mono- and diglycerides, free fatty acids (1–5%), and residual amounts of phospholipids, phosphatides, carotenes, tocopherols, sulphur compounds, and traces of water [72]. The majority of the lipid fraction is comprised of TAG content, an important parameter for biodiesel production. The saturated (16 : 0) and monounsaturated (18 : 1) fatty acids also play essential role in determining the fuel properties of biodiesel such as cetane number, oxidative stability, and cold flow [73]. Usually, extraction of lipid from microalgae consists of dual steps: cell disruption and solvent extraction. The lipid extraction methods might work differently on a variety of algal species as algae have an enormous variation in cell shape, size, cell wall composition, and types of algal lipids.

Microalgae cell disruption can be achieved by sonication, homogenization, grinding, bead beating, or freezing [74]. The Folch et al. [75] method was originally optimized for isolation and purification of total lipids from animal tissues is also



used for the extraction of total lipids from microalgae using chloroform-methanol 2 : 1. The most commonly used method for total lipid extraction from microalgae is the Bligh and Dyer method [76] which uses chloroform and methanol in 1 : 2. Another method for extraction of biooil or other molecule is to carry out extraction using safe and nonflammable solvent supercritical carbon dioxide (SC-CO₂) which solubilizes non polar compounds; when the molecule of interest is not soluble, the solvent power can be increased using a safe and polar modifier, such as ethanol [77]. But it has few disadvantages; it is uneconomical for large-scale, energy-consuming step of drying pretreatment which limits its application for biofuel production. Rycke- bosch et al. [78] optimized procedure for extraction of total and nonpolar lipids from microalgae showing chloroform- methanol 1 : 1 to be the best solvent mixture for extraction of total lipids from microalgae. Sathish and Sims [79] developed wet lipid extraction procedure capable of extracting 79% of transesterifiable lipids from wet algal biomass (84% moisture) via acid and base hydrolysis (90°C and ambient pressures), and 76% of extracted lipids were further converted to FAMES. Ultimately, it is necessary to develop extraction method having less organic solvent use, reduce contamination, and avoid drying of algae to obtain significant cost reduction for scaling up mass algal culture system for biodiesel production.

Lipid Analysis Methods. After lipid extraction, it is important to identify and quantify lipid contents to screen the desirable algal strains for their biofuel efficiency. Further quantification of lipids requires separation of the crude extract and quantification of the lipid fraction by thin-layer chromatography (TLC), HPLC, or gas chromatography (GC)[80]. The Nile red fluorescence method is also employed for the determination of both neutral and polar lipids in algae but has been unsuccessful in many others, particularly in those with thick rigid cell walls that prevent the penetration of this lipid soluble fluorescence dye [81]. Mostly, microalgal lipid profiling is done by gas chromatography with flame ionization detector (GC-FID) and is carried out using the methylated ester form of the lipid [82].

Transesterification. Transesterification or alcoholysis is the reaction of a lipid with an alcohol to form esters and a by-product, glycerol [71]. This reaction actually converts highly viscous raw lipid/oil into low molecular weight molecules in the form of fatty acid alkyl esters which can be used as an alternative fuel for diesel engines. Biodiesel is a term used to describe “fuel comprised of monoalkyl esters of long-chain fatty acids that are derived from vegetable oils or animal fats” [83]. In a typical biodiesel reaction, TAGs enter into a reaction with methanol which yields fatty acid methyl esters (biodiesel) and glycerol as a waste product (as shown in Figure 1). Mainly three approaches are used to produce biodiesel; they are base catalyzed trans esterification acid.

2. Lipid Productivity from Wastewater Grown Algae

Lipid productivity takes into account both the lipid concentration within cells and the biomass produced by these cells and is therefore a more useful indicator of the potential costs of liquid biofuel production [86]. High lipid productivity is a key characteristic of a microalgal species for biodiesel production [87]. Generally, algae produce lipids between microalgae used in this study were *Chlorella*, *Scenedesmus* sp., *Cosmarium* sp., and facultative heterotrophs (centric and pinnate diatoms) along with few photoautotrophs (*Cyclotella* and *Oedogonium*) and obligate photoautotrophs (*P. boryanum*). Effect of nutrient supplementation and the results showed that in growth phase (GP) operation with maximum N

+ P condition higher biomass (1.69 mg/mL) was observed, while higher lipid productivity was observed in starvation phase with maximum in C condition (28.2%) showing good wastewater treatment efficiency in terms of substrate degradation and nutrient removal during the growth phase operation.

Nevertheless, deliberately, cultivation of algae in stressful conditions can inhibit cell division, leading to decrease in overall lipid productivity [33, 90]. This is one of the reasons that it is difficult to maximize both high biomass and lipid productivity simultaneously. But still to achieve substantial cost reduction for the commercialization of biofuel production; it is suggested that the near-term research should be focused on maximizing lipid content with the help of altering the physiological metabolism of the microalgal cell and manipulation of cultivation system with the application of advanced engineering and design system.

Although, in many cases, most of the microalgal species reported with high lipid content does not adapt well to grow in



wastewater, many researchers had screened microalgal isolates able to grow in wastewater effluents showing high lipid content. Xin et al. [54] isolated a freshwater microalga *Scenedesmus* sp. LX1 with high lipid content (around 25– 35%) from low nutrient environment, and they compared *Scenedesmus* sp. LX1 with other reported 11 oily microalgal species based on the growth and lipid accumulation properties while growing in the secondary effluent of domestic wastewater. *Scenedesmus* sp. LX1 showed best growth and accumulated the maximum lipid content in microalgal cells in comparison to other microalgal species which could not grow in the secondary effluent of domestic wastewater. Zhou et al. [35] screened 17 top-performing strains isolated from water bodies including wastewater from Minnesota which grew well in centrate (highly concentrated municipal) wastewater. Five strains were promising, that is, *Chlorella* sp., *Heynigia* sp., *Hindakia* sp., *Micractinium* sp., and *Scenedesmus* sp., regarding their ability to adapt to centrate municipal wastewater showing high growth rates (0.455–0.498 d⁻¹) and higher lipid productivities (74.5–

77.8 mg L⁻¹ d⁻¹). Bhatnagar et al. [52] isolated three robust mixotrophic microalgae isolated from industrial wastewater and evaluated their growth potential in media supplemented with different organic carbon substrates and wastewaters, which showed 3–10 times more biomass production relative to phototrophy. Devi et al. [53] evaluated the effect of sequential growth phase (GP) and starvation phase (SP) on the lipid productivity of heterotrophically grown mixed microalgae using domestic wastewater as a substrate. The mixotrophic

mixotrophic microenvironment. Sparging period of 120 s documented maximum biomass growth (GP, 3.4 mg/mL) and lipid productivity (SP, 27.3%), while, in intervals, 4 h (120 s) condition showed maximum biomass (3.2 mg/mL) and lipid productivity (27.8%). Fatty acid composition revealed high degree of saturated fatty acids (SFAs) varied with the experimental variations signifying their utility as biodiesel [91]. They also documented microalgal efficiency to utilize acid-rich effluents from biohydrogen production process as carbon source for lipid accumulation under heterotrophic nutritional mode. Two types of substrates, namely, synthetic volatile fatty acids (SVFAs) and fermentative fatty acids (FFAs) collected from acidogenic H₂ producing bioreactor were used for evaluating the lipid accumulation potential in microalgae. Comparatively, FFAs documented higher biomass and lipid productivity (1.42 mg/mL (wet weight); 26.4%) than SVFAs 0.60 mg/mL; 23.1%) [92].

In another study, fatty acid methyl ester (FAME) analysis of *A. protothecoides* UMN280 showed that the microalgal lipids were mainly composed of C₁₆/C₁₈ fatty acids (accounting for over 94% of total fatty acid) making it suitable for high-quality biodiesel production [36]. He et al. [93] checked the feasibility of cultivating *Chlorella vulgaris* with wastewater containing high ammonia nitrogen concentrations. This study found that increasing NH₄⁺-N from 17 to 207 mg L⁻¹ yielded additional short-chain and saturated fatty acids. Lipid productivity peaked in its value of 23.3 mg L⁻¹ d⁻¹ at 39 mg L⁻¹ NH₄⁺-N. Hence, microalgae components could be manipulated by NH₄⁺-N concentration of the initial feeds. The biomass and lipid productivities of some of the microalgal species grown in different wastewater resources reported till date is given in Table 1.

3. Nutrient Removal Efficiency

Growing algae depends on the availability of principal nutrients like nitrogen, phosphorus, carbon, sulphur and micronutrients including silica, calcium, magnesium, potassium, iron, manganese, sulphur, zinc, copper, and cobalt. Algal cells have the capability to uptake nitrogen and phosphorus from water [94, 95]. Microalgae can be efficiently used to remove significant amount of nutrients because they need high amounts of nitrogen and phosphorus for protein (45– 60% of microalgae dry weight), nucleic acid, and phospholipid synthesis [12]. The nitrogen in sewage effluent arises.

TABLE 1: Biomass and lipid productivities of microalgae grown in different wastewater resources

		(mg L ⁻¹ d ⁻¹)	(% DW)	(mg L ⁻¹ d ⁻¹)	
<i>Chlorella pyrenoidosa</i>	Activated sludge extract	11.55	NA	NA	[28]
<i>Chlorella pyrenoidosa</i>	Digested sludge	51.82	NA	NA	[28]
<i>Chlorella pyrenoidosa</i>	Settled sewage	275	NA	NA	[29, 30]
<i>Chlorella pyrenoidosa</i> and <i>Scenedesmus</i> sp.	Activated sewage	92.31	NA	NA	[29, 30]



<i>Botryococcus braunii</i>	Secondarily treated sewage	35.00	NA	NA	[31]
<i>Scenedesmus</i> sp.	Artificial	126.54	12.80	16.2	[32]
Polyculture of <i>Chlorella</i> sp., <i>Micractinium</i> sp.,	Dairy Wastewater	NA	29.00	17	[33]
Polyculture of <i>Chlorella</i> sp., <i>Micractinium</i> sp.	Primary clarifier	NA	9.00	24.4	[33]
<i>Chlorella ascharophila</i>	Carpet mill	23	18.10	4.2	[34]
<i>Scenedesmus</i> sp.	Carpet mill	126.54	12.80	16.2	[34]
<i>Chlorella</i> sp.	Centrate Muinicipal	231.4	33.53	77.5	[35]
<i>Hindakia</i> sp.	Centrate Muinicipal	275.0	28.30	77.8	[35]
<i>Chlorella</i> sp.	Centrate Muinicipal	241.7	30.91	74.7	[35]
<i>Scenedesmus</i> sp.	Centrate Muinicipal	247.5	30.09	74.5	[35]
<i>Auxenochlorella protothecoides</i>	Concentrated Muinicipal	268.8	28.9	77.7	[36]
<i>Chlamydomonas Mexicana</i>	Piggery Wastewater	NA	33 ± 3.4 ^a	0.31 ± 0.03 ^a	[37]
<i>Scenedesmus obliquus</i>	Piggery Wastewater	NA	31 ± 0.8 ^a	0.24 ± 0.03 ^a	[37]

Primarily from metabolic interconversions of extra derived compounds, whereas 50% or more of phosphorus arises from synthetic detergents [27]. Nitrogen and phosphorus are the two important nutrient compounds to analyze a water source for potential algae growth. The principal forms in which they arise in wastewater are NH_4 (ammonia), NO^{-2} (nitrite), NO^{-3} (nitrate), and PO_4^{3-} (orthophosphate). The nutrient removal efficiency of some of the microalgal species reported till date is given in Table 2.

Algal growth and nutrient removal characteristics of microalgae *Chlorella vulgaris* using artificial wastewater in batch experiments showed that *C. vulgaris* can completely

remove up to 21.2 mg L⁻¹ ammonia-nitrogen concentration but showed low phosphorus removal with 7.7 mg L⁻¹ initial $\text{PO}_4\text{-P}$ concentration with 78% efficiency [94]. A promising strain *A. protothecoides* UMN280 isolated from a local municipal wastewater plant shows high nutrient removal efficiency as well as its high growth rate and lipid productivity. The results of the six-day batch cultivation showed that the maximal removal efficiencies for total nitrogen, total phosphorus, chemical oxygen demand (COD), and total organic carbon (TOC) were over 59%, 81%, 88%, and 96%, respectively, with high growth rate (0.490 d⁻¹), high biomass productivity (269 mg L⁻¹ d⁻¹), and high lipid productivity (78 mg L⁻¹ d⁻¹) [36]. Studies have demonstrated ability of *Euglena* sp. originally isolated from the sewage treatment plants and showing good lipid content of 24.6% (w/w), efficient nutrient uptake within a short span of eight days, and profuse biomass productivity (132 mg L⁻¹ d⁻¹) [44].

Sturm and Lamer [96] do an assessment on energy balance of microalgal production in open ponds coupled with nutrient removal from wastewater energy for algal biodiesel production. They studied microalgal yields and nutrient removal rate from four pilot scale reactors (2500 gallons each) fed with wastewater effluent from a municipal wastewater treatment plant for six months, using a total of 12 million gallons per day processed by the wastewater treatment plant. Hence, it shows that the direct combustion of algal biomass may be a more viable energy source than biofuel production, especially when the lipid content of dry biomass (10% in this field experiment) is lower than the high values reported in lab scale reactors (50-60%). Yang et al. [97] examined nutrient usages to generate 1 kg of microalgae biodiesel using nonrecycled freshwater. It will require 3726 kg



TABLE 2: Nutrient removal efficiency of microalgal species.

Microalgal species	Wastewater type	Nitrogen	Phosphate	COD	Reference
<i>Chlorella vulgaris</i>	Textile wastewater	(44.4–45.1%)	(33.1–33.3%)	(38.3–62.3%)	[38]
<i>Scenedesmus</i> sp. LX1	Modified effluent of a wastewater treatment plant of an electric factory by photo-membrane bioreactor	46%	100%	NA	[39]
<i>Chlorella sorokiniana</i> and aerobic	Potato processing industry	>95	80.7	84.8	[40]
<i>Chlorella sorokiniana</i> and aerobic	Pig manure	82.7	58.0	62.3	[40]
<i>Chlamydomonas</i> sp. TAI-2	Industrial wastewater	100%	33%	NA	[41]
<i>Auxenochlorella protothecoides</i>	Concentrated municipal wastewater	59%	81%	88%	[36]
<i>Chlorella Mexicana</i>	Piggery wastewater	62%	28%	NA	[37]
<i>Scenedesmus obliquus</i>	Piggery effluent	23–58%	48–69%	NA	[42]
<i>Chlamydomonas Polypyrenoideum</i>	Dairy industry wastewater	74%–90%	70%	NA	[43]
<i>Euglena</i> sp.	Sewage treatment plant	93%	66%	NA	[44]

of water, 0.33 kg of nitrogen, and 0.71 kg of phosphate and also shows decrease of water and nutrients usage by 84% and 55% using recycling harvest water and reduction in 90% of water requirement, eliminating the need for all the nutrients except phosphate by using sea/wastewater as culture medium. In another study, 1L biodiesel was produced consuming nutrient between 0.23 and 1.55 kg nitrogen and 29–145 g of phosphorus depending on the cultivation conditions for microalgae [98]

4. Conclusion

Currently, the main bottleneck in the production of biofuels from microalgae is that current technologies do not allow the production of economical and sustainable biofuels at current energy prices, despite the high biomass, the production rate of lipids and nutrient removal efficiency of microalgae grown in wastewater, making them promising raw materials for renewable energies. In addition, analysis of nutrient consumption rates of wastewater-derived algal biofuels and bioprospecting of different wastewater habitats are needed to explore native oil-producing microalgae strains. In addition, efforts should be made to focus research on the development of profitable large-scale cultivation systems. Integrating microalgae cultivation with wastewater could provide the opportunity for phytoremediation, carbon dioxide sequestration, and low-cost nutrient supply for the use of algal biomass, which would improve the economic prospects of the systems. Production of biofuels based on microalgae.

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A Critical Study of Complex Analysis With Reference To Applied Mathematics

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Abstract : *The study of complex numbers, their derivatives, manipulation, and other properties is known as complex analysis. Complex analysis is a very powerful tool that has a surprising number of practical applications in solving physical problems. Complex analysis is a branch of mathematics that studies functions of complex numbers. It is also known as the theory of functions of a complex variable. Many branches of mathematics, such as algebraic geometry, number theory, analytic combinatorics, and applied mathematics, as well as physics, such as hydrodynamics, thermodynamics, and especially quantum mechanics, benefit from it. Complex analysis has applications in engineering fields such as nuclear, aerospace, mechanical, and electrical engineering by extension.*

KEYWORDS - *Complex, Analysis, Numbers, Mathematics*

INTRODUCTION

The study of complex numbers, their derivatives, manipulation, and other properties is known as complex analysis. Complex analysis is a very powerful tool that has a surprising number of practical applications in solving physical problems. Complex analysis is a branch of mathematics that studies functions of complex numbers. It is also known as the theory of functions of a complex variable. Many branches of mathematics, such as algebraic geometry, number theory, analytic combinatorics, and applied mathematics, as well as physics, such as hydrodynamics, thermodynamics, and especially quantum mechanics, benefit from it. Complex analysis has applications in engineering fields such as nuclear, aerospace, mechanical, and electrical engineering by extension.

The solution of certain algebraic equations by the Italian mathematicians Girolamo Cardano and Raphael Bombelli in the 16th century provided the first indication that complex numbers might be useful. They were fully established as sensible mathematical concepts by the 18th century, after a long and contentious history. They remained on the mathematical periphery until it was discovered that analysis can be applied to the complex domain as well. The result was such a powerful addition to the mathematical toolbox that philosophical questions about the meaning of complex numbers were lost in the rush to use them. Soon, the mathematical community had grown so accustomed to complex numbers that it was difficult to remember that here had ever been a philosophical issue.

Complex analysis is a branch of mathematics that investigates the analytical properties of complex variable functions. It



sits at the crossroads of several branches of mathematics, both pure and applied, and has ties to asymptotic, harmonic, and numerical analysis. Complex variable techniques are extremely powerful, with a wider range of applications in the solution of physical problems. Solution methods for free-boundary problems such as Hele-Shaw and Stokes flow, conformal mappings, Fourier and other transform methods, and Riemann-Hilbert problems are all covered by this discipline. Due to a number of special properties of the complex domain, many problems that are difficult to solve in the real domain can be solved more easily when transformed into complex variables.

Complex numbers are defined as the set of all numbers $z = x + yi$, where x and y are real numbers. We denote the set of all complex numbers by C . (On the blackboard we will usually write C –this font is called black board bold.) We call the real part of z . This is denoted by $x = \text{Re}(z)$. We call by the imaginary part of z . This is denoted by $y = \text{Im}(z)$.

THE EVOLUTION OF COMPLEX ANALYSIS

Complex analysis is a classical branch of mathematics that dates back to the 18th century and even earlier. In the twentieth century, notable mathematicians associated with complex numbers include Euler, Gauss, Riemann, Cauchy, Weierstrass, and many others. Complex analysis, specifically the theory of conformal mappings, has a wide range of physical applications and is used extensively in analytic number theory. Complex dynamics and the images of fractals produced by iterating holomorphic functions have given it a new lease on life in recent years. String theory, which investigates conformal invariants in quantum field theory, is another important application of complex analysis.

Complex analysis is an important subject for engineering and physical science students, as well as a central subject in mathematics. Complex analysis provides powerful tools for solving problems that are either very difficult or virtually impossible to solve in any other way, in addition to being mathematically elegant.

Importantly, there has been a flurry of activity in recent years in the advancement of complex analysis methods, fueled by applications in engineering, biology, and medicine. The propagation of acoustic waves, which is important for jet engine design, and the development of boundary-integral techniques, which are useful for solving a variety of problems in solid and fluid mechanics, as well as conformal geometry in imaging, shape analysis, and computer vision, are examples of real-world applications of these methods.

FUNCTIONS OF COMPLEX ANALYSIS

1. **Complex Functions:** A complex function is a function that goes from one complex number to another. To put it another way, it's a function with a subset of complex numbers as a domain and the complex numbers as a codomain. A nonempty open subset of the complex plane is supposed to be present in the domain of complex functions.
2. **Holomorphic Functions:** Complex functions are said to be Holomorphic on Ω if they can be differentiated at every point of an open subset Ω of the complex plane. This definition appears to be formally equivalent to that of a real function's derivative. Complex derivatives and differentiable functions, on the other hand, behave very differently than their real-world counterparts.

THE FUNDAMENTAL THEOREM OF COMPLEX ANALYSIS

The Fundamental Theorem of Algebra, which is not very aptly named, is one of the most famous theorems in complex analysis.

This seems like a good place to begin our exploration of the theory.



Theorem 1 (The Fundamental Theorem of Algebra) Every non constant polynomial $p(z)$ over the complex numbers has a root.

Theorem 2 (Liouville's theorem) A bounded entire function is constant. Assuming this result, if $p(z)$ is a polynomial with no root, then $1/p(z)$ is an entire function. Moreover, it is bounded, since as we noted before $\lim_{|z| \rightarrow \infty} |p(z)|/|z|^n = |a_n|$, so $\lim_{|z| \rightarrow \infty} 1/p(z) = 0$. It follows that $1/p(z)$ is a constant, which then has to be 0, which is a contradiction.

THE CAUCHY-RIEMANN EQUATIONS

In addition to the geometric picture associated with the definition of the complex derivative, there is yet another quite different but also extremely useful way to think about analyticity, that provides a bridge between complex analysis and ordinary multivariate calculus. Remembering that complex numbers are vectors that have real and imaginary components, we can denote $z = x + iy$, where x and y will denote the real and imaginary parts of the complex number z , and $f = u + iv$, where u and v are real-valued functions

of z (or equivalently of x and y) that return the real and imaginary parts, respectively, of f .

CAUCHY'S THEOREM AND LINE INTEGRALS

The basic idea is that complex line integrals will resemble multivariable calculus line integrals in many ways. However, complex line integrals are easier to work with than their multivariable analogues, just as working with e^I is easier than working with sine and cosine. At the same time, they will provide a deep understanding of how these integrals work. We'll need the following ingredients to define complex line integrals:

- i. The complex plane is defined as $z = x + iy$.
- ii. The $dz = dx + i dy$ complex differential
- iii. complex plane curve defined for t as $z(t) = x(t) + iy(t)$.
- iv. $f(z) = u(x, y) + iv(x, y)$ is a complex function $f(x, y)$

CONCLUSION

Complex analysis is an important part of the mathematical landscape because it connects many topics from the undergraduate curriculum. It can be used as a capstone course for mathematics majors as well as a stepping stone to independent research or graduate school study of higher mathematics. The Complex Method is a general optimization technique that can be used to solve a wide range of nonlinear problems with inequality constraints directly. Inequality constraints are a problem with this method.

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Environmental pollution: Causes, Effects and the Remedies

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Introduction -

Pollution can be defined as any human activity that has a negative impact on the quality of the natural environment. Although environmental pollution is not a new phenomenon, it is still the world's most pressing issue and one of the leading environmental causes of disease and death. Most of the time, middle- and low-income nations pollute the environment more than developed nations do, possibly due to poverty, inadequate legislation, or ignorance of pollution types. It's possible that humans deal with pollution on a daily basis without realizing it, or that our fast-paced lives have made us immune to it. Air, land, and water pollution are all caused by deforestation, bush burning, dumping of agricultural and household waste in water bodies, the use of chemicals to harvest aquatic animals, and improper disposal of electronic waste. Particularly so, as human population density rises, so do human activities and their effects on the environment. Not only do the effects affect humans, but also other aquatic and terrestrial animals, including microorganisms, which, due to their abundance and diversity, tend to keep their biochemical function, which is important for the ecosystem's survival, going on. The reasons for ecological contamination are not restricted to industrialization, urbanization, populace development, investigation, and mining, yet in addition trans-boundary development of contamination from created to non-industrial nations or the other way around. Pollution has remained a global problem in part because of trans-boundary pollution. In addition, harmful substances like gaseous pollutants, toxic metals, and particulate matter (PM) are introduced into the atmosphere, resulting in environmental pollution; sewage, effluents from industries, runoff from farms, and electronic waste into water bodies; and activities that pollute the soil, such as mining, deforestation, landfills, and illegal waste disposal. Air pollution, in particular, has alarming consequences, with a disproportionate impact on low-income earners, children, the elderly, and other vulnerable groups in developing nations. The information on the causes and outcomes of natural contamination is fundamental, in any case, the expense of inaction is colossal. Different physical and synthetic methodologies have been applied to free the climate of contamination, however a large portion of them make extra environmental issues and are costly.

Major types of pollution

Air pollution

The presence of toxic chemical compounds in the atmosphere at concentrations that could be harmful to humans, animals, vegetation, and buildings is known as air pollution. In general, air pollution refers to the presence of chemical compounds in the air that were not originally present but have altered its quality. Through global warming and ozone layer depletion, air pollution also impacts the quality of life on Earth. Sulphur oxides (especially SO₂), nitrogen oxides (including NO and NO₂), volatile organic compounds (VOCs), and carbon monoxide (CO) are typical gaseous pollutants. Primary and



secondary pollutants are the two types of gaseous pollutants. Examples of primary pollutants include carbon monoxide (CO), carbon dioxide (CO₂), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂). On the other hand, secondary pollutants are gases and particulates that also form in the atmosphere, largely as a result of the primary pollutants. The breakdown of ammonium nitrate aerosols, sulfuric acids, and hydrocarbons, for instance, results in the production of ozone (O₃), atmospheric sulfur, and nitrogen oxide gases, respectively.

The chemical composition of air pollutants, such as their oxidizing capacity, solubility, concentration, and susceptibility, as well as the susceptibility of the affected person or thing, determine the extent of damage. Because they are soluble in water, SO₂ gases can harm the skin and upper airways of humans; Due to their lower solubility, O₃ and NO₂ can penetrate the lungs further. CO is a colorless, odorless, highly soluble, non-irritating gas with a higher affinity for hemoglobin than oxygen. As a result, it easily enters the bloodstream to form carboxy-haemoglobin, which has negative effects.

Wind can carry large dust-like particles that settle on buildings, structures, and people's eyes. Emissions from incomplete combustion of organic materials frequently contain a number of harmful pollutants, including persistent organic pollutants (POPs) and polyaromatic hydrocarbons (PAHs), which are known to be harmful to health.

Soil pollution

Industrial and domestic wastes are the primary contributors to soil contamination, along with earthquakes, erosion, and other natural disasters that typically cause soil damage. Heavy metals, hydrocarbons, and both organic and inorganic solvents are examples of soil pollutants. Soil pollution is primarily caused by open land disposal, waste burning, and inadequate landfills.

Soil pollution is also aided by fossil fuels from petrochemical, petroleum, and power-generating facilities. Soil contamination is frequently the result of petroleum exploration, refining, and distribution via road transport. Due in part to the toxic nature of the additives used in their production and the direct effects that plastics have on animals and plants, land pollution caused by plastics is beginning to receive global attention. The sight of plastic litter on land is unpleasant, as is the possibility that it will seep into the soil, preventing plants from absorbing nutrients and entangling terrestrial animals.

In addition to affecting human health, soil pollution may also alter plant metabolism, resulting in lower crop yields. It is also possible for pollutants to enter the food chain through plant absorption.

Water pollution

Man-made and natural sources both contribute to water pollution. Natural ores found in underground water sources may contain toxic metals that leach into water bodies and cause pollution. These ores are linked to high levels of arsenic and lead contamination in groundwater sources. Pesticides, hydrocarbons, POPs, and heavy metals are examples of chemicals that can have negative health effects like cancer, hormonal imbalance, impaired reproduction, and severe damage to the liver and kidneys. Eutrophication, the growth of plants and occasionally algae as a result of nutrients in the water, can increase pollution by reducing oxygen levels.

Examples of high arsenic and lead pollution of groundwater sources are connected to such metals. The elevated concentrations of the elements that are causing water pollution may be the result of the geological formations found in various regions, which play a significant role in determining the water bodies' elemental compositions. Domestic waste, insecticides and herbicides, food processing waste, pollutants from livestock operations, volatile organic compounds (VOCs), heavy metals from electronic waste, chemical waste, and medical waste are all examples of anthro-pogenic sources of contamination.

Airborne toxins like PM additionally bring other natural poisons into surface water. Typhoid, stomachaches, vomiting, and other health issues can be brought on by these pollutants.

Causes of environmental pollution

Mining and exploration

Air, water, and land quality are all impacted in varying degrees by mining and exploration processes. The phase and scope of the work being done at the site determine the degree of pollution. The excavation of the mine site by itself may



result in the loss of habitat, the formation of sinkholes, and the production of waste. Other harmful elements like lead (Pb) could explode during the mining of gold ore, a valuable material, and pollute the soil and water.

Vandals have taken to illegally bursting oil pipelines and siphoning oil for refining in illegal refineries in the majority of oil-producing states in Africa. In most cases, security agencies burn down these illegal refineries with the intention of stopping bunkering. However, this burning process generates enormous quantities of toxic metals, organic pollutants, carbon compounds, and sulfur compounds, all of which have negative effects on aquatic and terrestrial life. Due to the presence of greenhouse gases, acid rain, heat waves, and the death of fish and other aquatic animals in surface waters are just a few examples.

Agricultural activities

Any nation's economic development is fueled by agriculture, which also provides for the people's daily needs. Even though agriculture plays an important role, agricultural activities still cause pollution, which poses a number of health and environmental risks. Certain farming practices that have a tendency to harm, contaminate, and degrade the environment and ecosystem may be the cause of agricultural pollution. The burning of waste materials from agricultural activities like clearing land, applying more fertilizer to plants than they need, and using pest control chemicals that aren't biodegradable are all ways that farming contributes to pollution. The introduction of particular chemical substances into the food web, the production of PM and smoke, and the destabilization of habitats are all outcomes of these processes. Besides, nitrates from horticultural cycles are known substance contaminations in groundwater springs.

The environment is also polluted by the raising of terrestrial or aquatic animals, in addition to the pollution caused by farmland cultivation. Unused animal feed or excrement, for instance, may have unpleasant odors that could be harmful to health.

Urbanization and industrialization

The rapid expansion of urbanization, modernization, and industrialization all likely contribute to environmental pollution worldwide, with a greater impact in developing nations. Due to indifference to water conservation and water wastage, water resources are beginning to dwindle, and as the population grows, there is a risk that this trend will continue or even worsen.

Additionally, pollution contaminates water bodies, rendering them unusable for drinking. Furthermore, industrialization results in an overwhelming amount of waste being dumped into land and water bodies. Large quantities of wastewater, heavy metals, toxic sludge, solvents, and other pollutants enter streams and rivers as a result of rapid urbanization and industrialization.

Air pollution is a major concern due to the exponential growth of automobiles and motor vehicles as a result of urbanization. Lastly, industrialization encourages extensive habitat destruction through the construction of roads, houses, and the cutting down of trees for their lumber, all of which contribute to the devastation of ecosystems and the extinction of some animal and plant species.

Environmental degradation is one of the results of uncontrolled urbanization in non-industrial countries. This happens very quickly, which causes a slew of other issues like polluted air and water, increased difficulties with waste disposal, and fertile farmlands.

Burning of fossil fuels

Before they are burned, fossil fuels may release harmful pollutants into the air. At the point when petroleum derivatives are consumed, various air toxins are discharged, which cause natural contamination and concomitant annihilation of the biological system. We burn gas, oil, and coal to meet our energy needs, and these fuel the current climate crisis. The burning of fossil fuels releases a wide range of primary and secondary pollutants into the air, including SO₂, CO₂, CO, hydrocarbons, organic compounds, chemicals, and nitrogen oxides (NO_x). The major greenhouse gases, such as carbon dioxide, methane (CH₄), nitro-oxide, and fluoridated gases, are present in emissions from fossil fuels. As a result, these activities' air pollution not only threatens air quality but also contributes to climate change and global warming.

Particulate matter



PM contributes significantly to the atmosphere. PM can come from either natural or human-made sources. There are various regular sources that infuse a large number of lots of PM into the climate. Volcanic eruptions, dust and wind storms, forest fires, salt spray, rock debris, reactions between gaseous emissions, and soil erosion are just a few examples.

Plastics

The extent to which plastics have contributed to environmental pollution is becoming increasingly apparent to the general public. Polypropylene, polyethylene, polystyrene, poly-amides, and polyesters are examples of plastics that can be found in nature. Due to their durability and affordability, plastic bags are primarily utilized for food shopping and storage in the majority of developing nations.

Effects of environmental pollution

The impacts of natural contamination are to date underreported in most creating countries that endure contamination the most. This is partly due to a lack of awareness of the potentially harmful effects that pollution could have on health and the environment, as well as poor, unreliable database management systems.

Effects on the environment

The environment is made up of land, water, the atmosphere, and the biosphere. It stores all pollutants. Damage to trees, the death of wildlife species, soil infertility that results in poor plant yield, destruction of roofing sheets, impacts on historical monuments and buildings, and discoloration of vehicles and automobiles are among the effects on the land. Other effects include littering the land surfaces with wastes, which has a repulsive odor and a negative impact on the appearance of the land.

Soil's chemical properties are altered, and important cat-ionic nutrients like magnesium, potassium, and calcium are lost, which lowers the pH of the soil. All of these things either directly or indirectly cause a lack of food for humans and other animals; Death and starvation are possible outcomes.

Changes in a water body's chemical, microbiological, and physical properties are typically the results of pollution. For instance, the sun's increased heat raises the water's temperature; Oil covers the water's surface in exploration areas, preventing sunlight and oxygen; increases in water salinity as a result of drilling with NaCl; an increase in the quantity of harmful metals; eutrophication, and the bio-network is destroyed, water quality and quantity are reduced, biodiversity is diminished, nutrient levels become too high, and plant growth is stunted. Due to the introduction of sulfur- and nitrogen-containing compounds and other anaerobic processes as a result of pollution, water bodies become noxious, repulsive, and abandoned.

Air in the atmosphere is known to carry a variety of pollutants and deposit them on land and water. Haze forms when sunlight strikes certain pollutants like PM and gases, making it difficult to see colors and shapes clearly. MP's effects on aquatic and soil environments are being studied. However, there is a possibility that MP's contain hazardous additives and chemicals that can enter the soil ecosystem and accumulate in soil invertebrates.

Effects on animal health

Wildlife and marine organisms both suffer sub-lethal health effects from oil spills that occur during exploration, refinement, and transportation on land, through pipelines, and/or marine vessels.

When these organisms breathe in or ingest petroleum products containing harmful substances, their digestive, respiratory, and circulatory systems suffer. Oil slicks pose a threat to seabirds and other marine mammals because they can clog their skin or feathers, preventing them from moving quickly enough to find food or escape predators, resulting in death. The difficulties of plastics in the climate have turned into a subject of talk in late times. It harms ecosystems, reduces biodiversity, and, ultimately, has the potential to affect the lives of most marine animals, including birds, fish, crabs, turtles, and others.

The genetic diversity and biodiversity of the natural population are affected by pollution. According to research, the ribosomal sequences in fish genomes that live in polluted environments are extremely complex. In response to changes in



the environment, there is a systematic increase in the number of copies of the ribosomal DNA. This is because these sequences are primarily responsible for maintaining genome integrity.

Effects on microorganisms

Zooplankton and other microscopic communities found in flowing water ecosystems are crucial to the nutrient cycle and energy transfer in aquatic food webs.

As a consequence of this, the biotic responses of microscopic organisms to the conditions of their environment made it possible to accurately assess environmental degradation in aquatic ecosystems.

However, the effectiveness of zooplankton biodiversity has been diminished as a result of pollution's significant influence on its geographic distribution.

Effects on human health

The majority of human illnesses have been linked to environmental pollution due to its detrimental effects on health. More evidence is being found in recent studies linking pollution to a number of serious health conditions. The number of studies examining the health effects of air pollution exposure is rising at an alarming rate. The World Health Organization's report made it abundantly clear that fires used for cooking and heating caused 3.8 million deaths in the indoor air.

It has been discovered that some recalcitrant pollutants, like POPs and PAHs, bind with particulate matter (PM), particularly PM_{2.5}, causing a variety of cardiopulmonary diseases, respiratory diseases, cancer, and effects on humans that are not related to cancer.

Because they reach the population they are intended for by breathing, settling in drinking water, or being exposed to food, airborne pollutants tend to travel further and cause more harm.

Although epidemiological studies are pointing the finger at a number of women's health issues as the result of pollution, particularly air pollution, several other health problems associated with pollution may not have been discovered. Uterine fibroids may result from exposure to PM_{2.5} and O₃ due to specific genetic or epigenetic abnormalities, according to the literature.

Remedies

There have been suggestions made for a variety of remediation strategies, including biological, chemical, and physical ones. However, the most important thing is to figure out how to stop pollution in its tracks so that the environment that has already been affected can be fixed quickly and easily. The physio-chemical properties of the pollutants that have built up in the environment that needs to be cleaned are unaffected by physical methods of soil reclamation.

Chemical methods, on the other hand, break down the pollutants that have built up and change their physio-chemical properties to make them less harmful to the environment. Importantly, biological techniques based on the biological activity of higher plants and microorganisms can break down pollutants that have built up over time and further lead to their mineralization, immobilization, or removal.

Understanding and reducing the use of plastics, cleaning up oceans and beaches, replacing materials, and comprehending the effects on the health of humans and animals are just a few of the areas that have been suggested for future research and development in recent studies.

Conclusion

An overview of pollution, its causes and effects, and strategies for reducing pollution have been presented in this paper. Air pollution seems to be the most studied type of pollution and has received more attention. This could be because air pollution is linked to an increased rate of morbidity and premature death. While pollution affects both developed and developing nations, poverty, ineffective legislation, and a lack of awareness are to blame for the majority of the latter's problems.

In countries with middle and low incomes, polluted areas disproportionately affect vulnerable populations.



In order to make it possible to remediate an environment that has already been impacted, it is necessary to raise awareness of the dangers posed by pollution and to mobilize all resources to prevent activities that contribute to environmental pollution. The use of microorganisms in biological remediation techniques has been deemed environmentally friendly, cost-effective, and long-lasting for human and environmental safety.

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Increasing the Durability of Building Structures with Microbial Concrete

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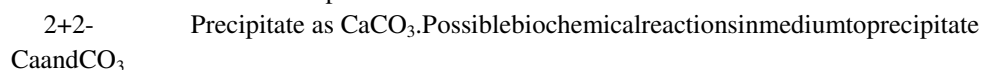
Abstract-Concrete structures can develop cracks and fissures due to weathering, faults, ground subsidence, earthquakes, and human activity, which can shorten the structures' useful lives. Using microorganisms like *Bacillus* species to biomineralize calcium carbonate is a revolutionary method for repairing or cleaning up such structures. *Bacillus* sp. CT-5, which was isolated from cement, was employed in the current investigation to examine tests for compressive strength and water absorption. According to the findings, bacterial cells increased the compressive strength of cement mortar by 36%. When compared to control cubes, calcite deposition on treated cubes absorbed almost six times less water. The current research shows that *Bacillus* sp. generation of "microbial concrete" on built facilities improved the durability of building materials.

INTRODUCTION

The requirements for high durability for structures exposed to harsh environments, such as seafloor, offshore structures, tunnels, highway bridges, sewage pipes, and structures for solid and liquid wastes containing toxic chemicals and radioactive elements, may not be met using today's common Portland cement (OPC). It is widely acknowledged that the features of concrete's pore structure affect how long it lasts. Concrete deterioration mechanisms frequently depend on the potential for aggressive substances to harm the concrete by penetrating it. Concrete's permeability is influenced by its porosity and the connectivity of its pores. Concrete is more susceptible to the deteriorating processes brought on by penetrating substances the more open its pore structure is. In order for concrete structures to deteriorate, aggressive gases and/or liquids from the environment must first move into the concrete, which is followed by physical and/or chemical reactions that may cause irreparable damage. As a result, mechanical (compressive strength) and transport properties are crucial components of concrete durability.

Researchers' interest has recently started to grow in the microbiologically induced calcium carbonate precipitation (MICCP) that is caused by the metabolic activities of some particular microorganisms in concrete and improves the overall behaviour of concrete. The compressive strength of cement mortar was significantly improved (by about 18%) in earlier studies using aerobic microorganisms (*Bacillus pasteurii* and *Pseudomonas aeruginosa*) [Ramakrishnan et al. 1998; Ramachandran et al. 2001].

A number of intricate biochemical processes make up MICCP [Stocks-Fischer et al. 1999]. Some bacterial species produce urease as part of their metabolism, which catalyses the breakdown of urea into CO₂ and ammonia, raising the pH of the environment where ions are present



CaCO₃ at the cell surface that provides a nucleation site can be summarized as follows.



Utilizing a selective microbial plugging process in which microbial metabolic activities promote the precipitation of calcium carbonate in the form of calcite, a novel method for the remediation of damaged structural formations has been developed [Gollapudi et al. 1995]. CaCO₃ demonstrated its positive potential as a microbial sealant by selectively consolidating simulated fractures, surface fissures, and sand plugging in granites [Zhong and Islam 1995; Achal et al. 2009a].

The most significant factors affecting concrete's durability and, ultimately, its performance, the compressive strength and concrete permeability tested using water absorption are the focus of the current work. This study looked into how cement-derived bacteria affected the compressive strength and water permeability of cement mortar.

MATERIALS AND METHODS

Materials

Used was regular Portland cement that complied with IS 12269-1987. As fine aggregate, clean, properly graded, naturally occurring river sand that complies with IS 383-1970 standards and has a fineness modulus of 2.89 was used.

Microorganism

In this study, *Bacillus* sp. CT-5, which was isolated from cement sold commercially, was used. The Nutrient Agar (pH 8.0) medium was used routinely to maintain the culture. The isolate was grown in nutrient broth-urea (NBU) medium (8 g nutrient broth, 2% urea, and 25 mM CaCl₂). CaCl₂ and filter-sterilized urea were added to the medium for the nutrient broth. Information about the preparation and content of NBU medium was previously published [Achal et al., 2009a]. At 37 degrees Celsius, bacteria were grown in a shaking environment (130 rpm).

Compressive strength test

Bacillus sp. CT-5 was grown in NBU media in order to research the compressive strength test of cement mortar. The ratio of bacterial culture to water to cement was 0.47, and the ratio of cement to sand was 1:3 (by weight). According to IS 4031-1988, a 70.6 mm cube mould was used. With the addition of a grown culture of *Bacillus* sp. CT-5 that corresponds to an optical density of 1.0 (600 nm), sand and cement were thoroughly mixed. A vibration machine was used to cast and compact the cubes. All specimens were demolded and then allowed to cure in NBU medium at room temperature until compression testing was performed after 3, 7, and 28 days. Control samples were also made in a similar manner, but instead of using bacterial culture, they used water and NBU medium. Automatic compression testing was carried out.

Water absorption test

A sorptivity test using the RILEM 25 PEM (II-6) was performed to ascertain the increase in resistance to water penetration. To ensure unidirectional absorption through the treated side, the mortar specimens were coated at the four edges that were closest to the treated side. The test cubes were coated, then dried at 45 °C in a ventilated oven to achieve a mass equilibrium of less than 0.1% between two measurements taken 24 hours apart. The treated side of the specimens was facing downward as they were submerged in 101 mm of water (water level about 2 mm above the base of the specimen). Every 15 minutes, 30 minutes; 1 hour, 1.5 hours, 3 hours, 5 hours, 8 hours, 24 hours, 72 hours, 96 hours, 120 hours, and 144 hours and 168h) the specimens were removed from the water and weighed, after drying the surface with a wet towel. Immediately after the measurement the test specimens were submerged again. The sorptivity coefficient, k [cm.s^{-1/2}], was obtained by using the following expression:

$$Q/A = k\sqrt{t} \quad (4)$$

where Q is the amount of water absorbed [cm³]; A is the cross section of the specimen that was in contact with water [cm²]; t is the time [s], Q/A was plotted against the square root of time, then k was calculated from the slope of the line are relation between the former.



RESULTS AND DISCUSSION

Compressive strength test

Figure 1 summarises the compressive strength of various cement mortar specimens after 3, 7, and 28 days. The compressive strength had significantly increased for the microbially-filled mortar cubes. The strongest mortar cubes (31 MPa) were made with *Bacillus* sp. CT-5 and incubated for 28 days, as opposed to those made with water (23 MPa) and NBU medium (24 MPa). At 28 days, mortar specimens made with bacterial cells had 36.15% greater compressive strength than the control. The cubes cured in microbial growth medium were stronger than those cured in water in the cell-free control groups, despite the fact that there was no discernible difference. The mortar cubes' strength appeared to be improved by the medium's high ionic strength, which contains urea and calcium chloride.

According to Ramakrishnan et al. (1998), Ramachandran et al. (2001), Ghosh et al. (2005), and Achal et al. (2009a), the deposition of CaCO_3 on the microorganism cell surfaces and inside the pores of cement-sand matrix, which plug the pores within the mortar, is probably the reason why *Bacillus* sp. CT-5's compressive strength increased.

To determine whether the microbial calcite precipitation was the cause of the mortar samples' increased compressive strength, the mortar samples were taken out and subjected to SEM inspection. Figures 2a and 2b show scanning electron micrographs of a cement mortar matrix devoid of bacteria and a specimen made with *Bacillus* sp. CT-5, respectively. The sample showed that calcite crystals had formed into rod-shaped structures and had grown everywhere (typical shape of *Bacillus* species). The edges of the crystals were distinct and sharp, indicating that they had fully developed. We have previously described and documented *Sporosarcinapasteurii*'s rod-shaped structure, which aided in the precipitation of calcite in sand columns [Achal et al. 2009b].

At 3 and 7 days, the compressive strengths of mortar cubes with all media did not significantly increase. The overall trend of an increase in compressive strength up to 28 days may be attributed to the behaviour of microbial cells within the cement mortar matrix. Although the mortar was still porous during the initial curing period due to the cement, the environment for microbes had completely changed, inhibiting proper growth. It's also possible that the high pH of the cement rendered the cells inactive, but as the curing time was prolonged, the cells slowly started to grow. Because of the various ions present in the media, calcite would precipitate during cell growth on both the surface of the cells and inside the cement mortar matrix. As a result, the cement mortar lost some of its porosity and permeability. The bacterial cells eventually either died or changed into endospores, which served as an organic fibre and increased the compressive strength of the mortar cubes, once many of the matrix's pores had been plugged. This explains how cement mortar cubes made with microbial cells behaved at day 28 in terms of their increased compressive strength. An increase in matrix strength would have reduced mean expansion for concrete made with bacterial cells, enhancing the concrete's overall durability performance [Ramakrishnan et al. 2001]. This led to the conclusion that the main reason for the increase in compressive strengths is the consolidation of the pores within the cement mortar cubes with microbiologically induced calcium carbonate precipitation.

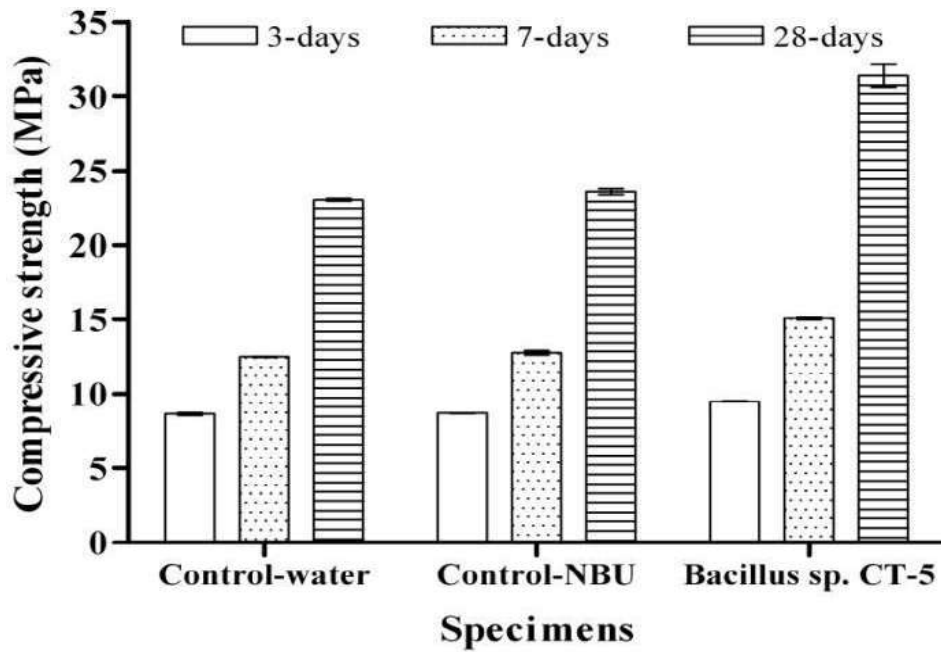


Fig.1.Effect of CT-5 on Cement Mortar Cube Compressive Strength at 3, 7, and 28 Days prepared with a 0.47 w/c ratio. (Controlling Bacillus sp. and NBU. Water is Replaced with Media in CT-5 Treatments and Media is Replaced with Bacterial Cells, respectively.

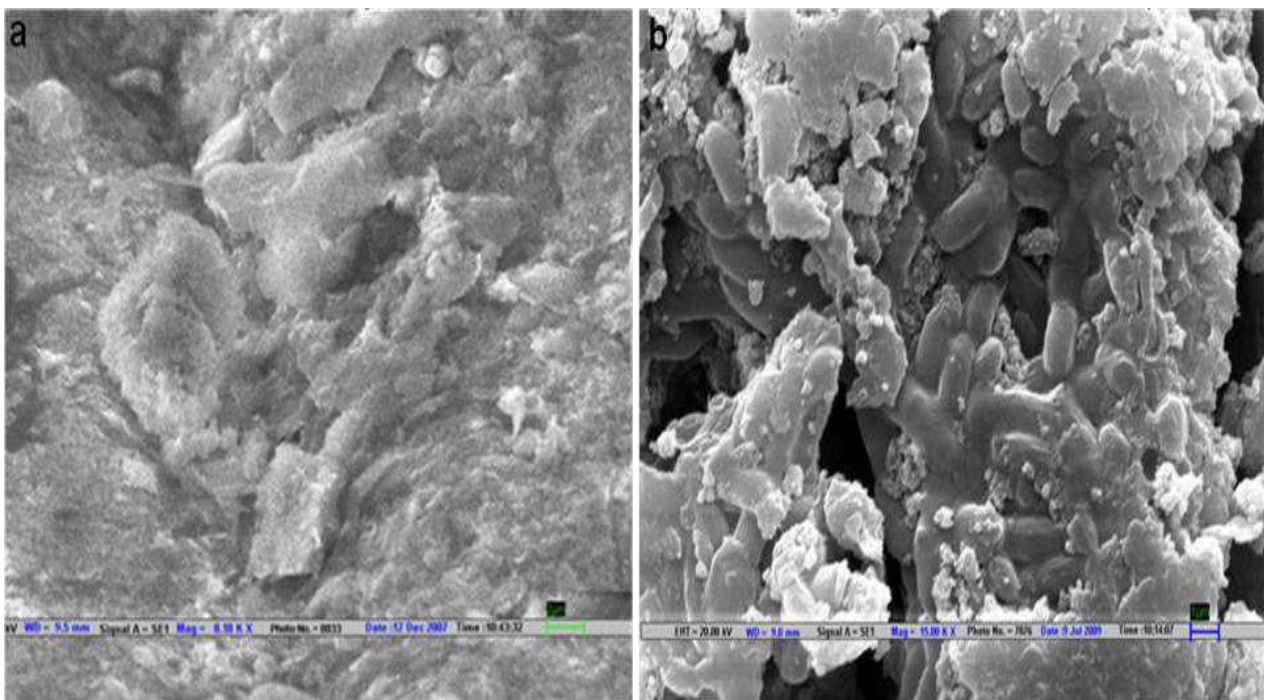


Fig. 2.Specimens of cement mortar captured in scanning electron micrographs. Matrix of Cement Mortar Prepared Without Bacteria and Dense Calcite Precipitation as Calcite Crystals with Rod Shaped Impressions Housed by Bacillus sp. CT-5



Water absorption test

For mortar cubes with a w/c of 0.47, Fig. 3 illustrates the impact of the surface treatment on the rate of water absorption. The cubes treated with *Bacillus* sp. CT-5 absorbed almost six times less water over 168 hours than the control cubes. Compared to untreated specimens, the water uptake significantly decreased when bacteria were present (control).

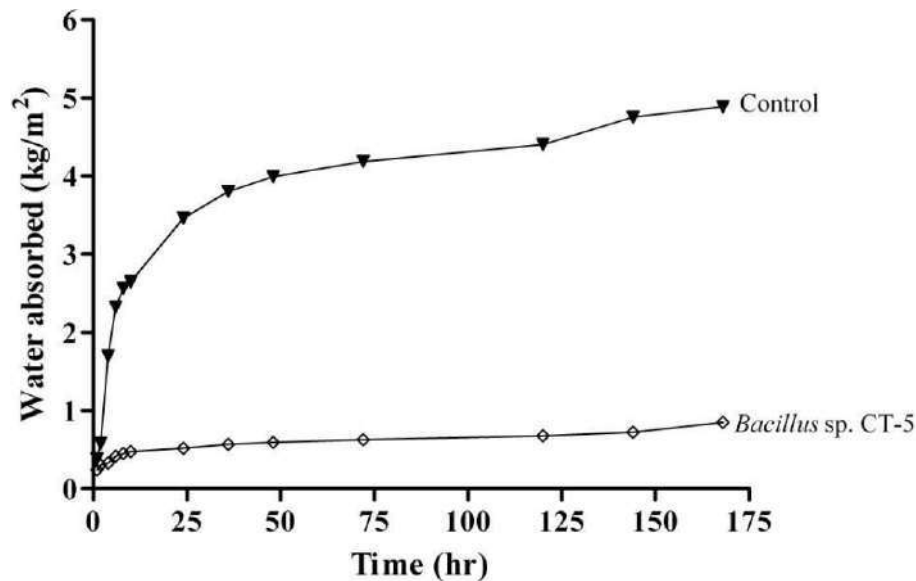


Fig.3. The Influence of the Bacterial Treatment on the Rate of Water Absorption versus Time for Mortar Cubes

The water absorption experiment showed that the permeability of mortar specimens treated with bacteria decreased. a layer of calcium carbonate crystals being deposited on.

The permeation properties were reduced as a result of the surface. As a result, the entry of dangerous substances may be restricted. After injecting CaCO₃-forming reactants, Nemati and Voordouw [2003] observed a decrease in the permeability of sandstone cores. It is evident from this experiment that the presence of a layer of carbonate crystals on the surface by a bacterial isolate has the potential to enhance cementitious materials' resistance to processes that cause their degradation.

CONCLUSION

The use of bacterial isolates like *Bacillus* species that produce urease in concrete remediation is the significance of this study. *Bacillus* sp. CT-5 had a beneficial impact on the compressive strength of Portland cement mortar cubes, according to the study, which also showed an increase in strength. In order to assess the effectiveness of the bacterial isolate, a greater resistance to water penetration has been made. The creation of "Microbial Concrete" will serve as the foundation for a superior, alternative concrete sealant that is economical, environmentally safe, and ultimately increases the durability of building materials.



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Reinforced Fibre Polymer Bars: A Look at Recent Developments In Civil Applications

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Abstract- It is common knowledge that corrosion has a detrimental impact on the structural integrity of concrete structures such as buildings, bridges and other man-made structures. Damage caused by corrosion is both hazardous to members of the general public and financially burdensome to the person who owns the structure. This study investigates the potential for improving the structural performance of concrete that has been damaged by corrosion by employing a material known as Fiber Reinforcement Polymer, or FRP for short. Both the moment capacity and the ductility of the tested steel bars are enhanced when polymer fibres are incorporated into the steel. It is essential to first have an understanding of the effects that corrosion damage has on regular reinforced concrete, and this is something that is explored. Fiber Reinforced Polymer (FRP) rebars has emerged as a possible answer to the issue of corrosion experienced by steel reinforcement in RC structures. Glass Fiber Reinforced Polymer (GFRP) demonstrates outstanding corrosion resistance, a very high strength-to-weight ratio, a non-conductive, magnetizing nature and other desirable properties. However, the durability and usability of this brand-new material is still one of its characteristics that are poorly understood. Earlier investigations in nature have demonstrated that GFRP has a low immunity to alkaline environments, a low modulus of elasticity, and brittle characteristics.

Keywords- Reinforcement, Corrosion, Structure, Steel, Reinforced Polymer.

INTRODUCTION

Reinforcement has become the fundamental unit of construction today which is used in numerous ways, some of the larger and better known uses including roadways, bridges, car parks, residential buildings and in industry; for example it is widely used in nuclear power plant. It is in general an excellent construction material. Concrete alone is good in compression, but reinforced concrete greatly increases the scope for making structures required to withstand other form of mechanical forces. In a small percentage of instances reinforced concrete may deteriorate prematurely, but so widespread is the use of the material that problems can be encountered in a wide range of individual applications. It is reliably reported that in North America there are now some 300,000 concrete bridges requiring repairs, with costs estimated in terms of billions of dollars, in addition to the roadways and car parks requiring remedial attention. There are also lesser but significant problems with reinforced concrete in Europe and the Middle East. In India too around 60% of reinforced concrete structures require repair work which is harm to economy of our country. From a financial aspect the future costs over the next few decades for repairs and replacement throughout the world are likely to be staggeringly high. One is tempted to ask why, if reinforced concrete has been used for so long, is it only now that problems are arising, predominantly, though not exclusively, associated with corrosion of the reinforcing steel bars, or rebars as they are commonly called. Corrosion loss consumes considerable portion of the budget of the country by way of either restoration measures or reconstruction. Moreover, the repair operation themselves are quite complex and require special treatments of the cracked zone, and in most instances the life expectancy of the repair is limited.



Accordingly, corrosion monitoring can give more complete information of changing condition of a structure in time. Hence, protection of reinforcement from corrosion will ensure that the structure serves for desired service life. Engineers need better techniques for assessing the condition of the structure when the maintenance or repair is required. These methods need to be able to identify any possible durability problems within structures before they become serious.

CORROSION MECHANISM & REASONS

Corrosion is an electrochemical process. In this process oxidation of Iron (Fe^{++}) molecules naturally occurs immediately after the bars are manufactured and exposed to the atmosphere and will continue long as sufficient oxygen and moisture are available to react with the steel. So corrosion consists of an anode and cathode process. Following are some reasons of corrosion of reinforcement.

Water Permeability:

It is the single largest factor for ignition and propagation of corrosion. Water not only takes part in chemical reaction but also works as a carrier for transporting harmful chemicals to concrete and rebars such as chloride ions. Higher permeability reduces resistivity of concrete. If the surface of the concrete is subject to long-term wetting, the water will eventually reach the level of the reinforcement, either through diffusion through the porous structure of the concrete, or by traveling along cracks in the concrete. Concrete roof decks, by their nature, are meant to be protected from moisture. However, the presence of moisture on roofing systems may result from failure of the roofing membrane, poor detailing of drainage facilities, or lack of maintenance of drainage facilities.



Fig.1: Corrosion in reinforcement

Oxygen Permeability

Oxygen is very much an essential part for corrosion to occur; it also plays an important role in setting up corrosion cells. Oxygen permeability produced due to cracks, difference in cover thickness and heterogeneity of concrete.

Carbonation

In the major cause of corrosion, Carbonation of concrete has dual effect of reducing the alkalinity of concrete as well as releasing more water. Effect of carbonation increases with porosity of concrete, period of exposure and reduces with moisture in surrounding area. It is well known that if bright steel is left unprotected in the atmosphere a brown oxide rust quickly forms and will continue to grow until a scale flakes from the surface. This corrosion process will continue unless some external means is provided to prevent it. One method is to surround the steel with an alkaline environment having a pH value within the range 9.5 to 13. At this pH value a passive film forms on the steel that reduces the rate of corrosion to a very low and harmless value. Thus, concrete cover provides chemical as well as physical protection to the steel. Concrete is permeable and allows the slow ingress of the atmosphere; the acidic gases react with the alkalis (usually calcium, sodium and potassium hydroxides), neutralizing them by forming carbonates and sulphates, and at the same time reducing the pH value. If the carbonated front penetrates sufficiently deeply into the concrete to intersect with the concrete reinforcement interface, protection is lost and, since both oxygen and moisture are available, the steel is likely to



corrode. The extent of the advance of the carbonation front depends, to a considerable extent, on the porosity and permeability of the concrete and on the conditions of the exposure.

Chloride Ingress:

The best known and most damaging factor leading to corrosion is the chloride ingress (i.e. chloride entrance) most of failures are attributed it this structures in cold climates where salt is used as deicing agent has reportedly shown distress due to this factor. The chloride ingress can be by diffusion, capillary suction as well as by permeation. Diffusion of chloride ions occurs through slow moments through simple absorption can suck in large amounts of chloride permeation of chloride ions is through cracks in concrete. Chloride ions react with iron compound and create an iron – chloride complex ($FeCl_2$) which also react with hydroxides (OH^-) and form hydrated iron oxide compounds. Simultaneously oxygen (O_2) reacts with water (H_2O) and formed hydroxides. Together, this two reactions form a corrosion cell. At low levels of chloride in the aqueous phase, the rate of corrosion is very small, but higher concentration increases the risks of corrosion.

COROSION IN RCC STRUCTURES



Fig.2 Corrosion in RC structure

Remedial Measures

The deterioration of concrete may be due to either corrosion of concrete/ reinforcement steel or formation of expansive chemical compounds such as calcium silicate hydrate (C-SH) or ettringite in aggressive environments. The loss due to corrosion of steel is heavy. To produce the durable concrete and resist the harmful effects of aggressive environment, the concrete should be produced with almost care. The following steps, implemented scientifically will help to produce durable concrete.

By Adopting the rich mix:

Adopting the Best Mix Proportion:

Increasing Depth of Concrete Cover to Reinforcement Concrete Coating and Sealers

Galvanizing

Fusion Bonded Epoxy Coating (FBEC) Coating of Re bars

Fiber Reinforced Polymer Reinforcing bars (FRP)

FRP Bars are intended for use as concrete reinforcing in areas where steel reinforcing has a limited life span due to the effects of corrosion. They are also used in situations where electrical or magnetic transparency is needed. In addition to reinforcing for new concrete construction, FRP bars are used to structurally strengthen existing masonry, concrete or wood members. Corrosion of steel reinforcement in concrete structures causes deterioration of concrete resulting in costly maintenance, repairs and shortening of the service life of structures. Government agencies throughout the world have recognized the potential benefits to society if our infrastructure can last longer and are thus funding significant amounts of research in the field of FRP's. Corrosion of steel reinforcement in RCC makes its use very limited in corrosive environment, and it becomes important to choose such a reinforcing material which is non-corrosive. FRP re bars have demonstrated strong promises in this context. The main advantage of FRP is its excellent corrosion resistance, very high



strength to weight ratio, and its non-Magnetizing/conductive nature, etc. FRP has also become more popular because of its diverse varieties available in the market. However for these advanced composite material with above advantages having some limitations also, FRP is a material having low elastic modulus, it shows linear stress vs strain behavior up to failure with no discernible yield point, and hence shows large deflections and wide cracks when loaded, reduced ductility of RCC members causes brittle failure. FRP is typically a two-component composite material consisting of high strength fibres embedded in a polymer matrix.



Fig.3 FRP bar

The use of FRP reinforcements for concrete structures depends on their ability to perform reliably under service loads, the mechanical properties, e.g., strength and toughness properties, of the reinforcements are the most important properties if the reinforced structures are used as load-bearing members. It is known that for reinforced concrete structures the presence of FRP reinforcements may have little effect on the initiation of a crack, but they do provide considerable resistance to both propagation and opening of the crack. Cracks generally initiate at the locations where the principal tensile stress (or the strain energy release rate) exceeds the material tensile strength (or the fracture toughness) under service loads. Further propagation of these cracks will depend on the distributions and magnitudes of both principal tensile stress and material fracture resistance. In general, the mechanical performance, failure modes, and loading capacity of a reinforced concrete structure depend on, not only its structural geometry and loading conditions, but also the amount, location, and orientation of the FRP reinforcement used.

Fiber Reinforced Polymer (FRP) Composites

Fiber-reinforced plastic (FRP) (also *fiber-reinforced polymer*) is a composite material made of a polymer matrix reinforced with fibers.

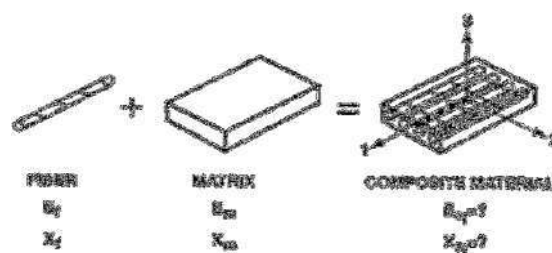


Fig.4 FRP Composites

The fibers are usually glass, carbon, basalt or aramid although other fibers such as paper or wood or asbestos have been sometimes used. The polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic and phenol formaldehyde resins are still in use. In the last decade, there has been a considerable increase in the interest of FRP (Fibre Reinforced Polymers) for concrete reinforcement in the construction industry. The most frequently used fibres for FRP reinforcement are carbon (CFRP), aramid (AFRP) and glass (GFRP). The most obvious benefit of FRP is that, unlike steel it is not susceptible to carbonation- or chloride initiated corrosion in concrete. This fact makes the use of FRP reinforcement an interesting option for increasing the service life of concrete structures in severe environments. However, unlike steel FRP reinforcement may deteriorate due to the alkaline environment of concrete. The following chart shows the stress-strain relationship for various fiber materials in use.

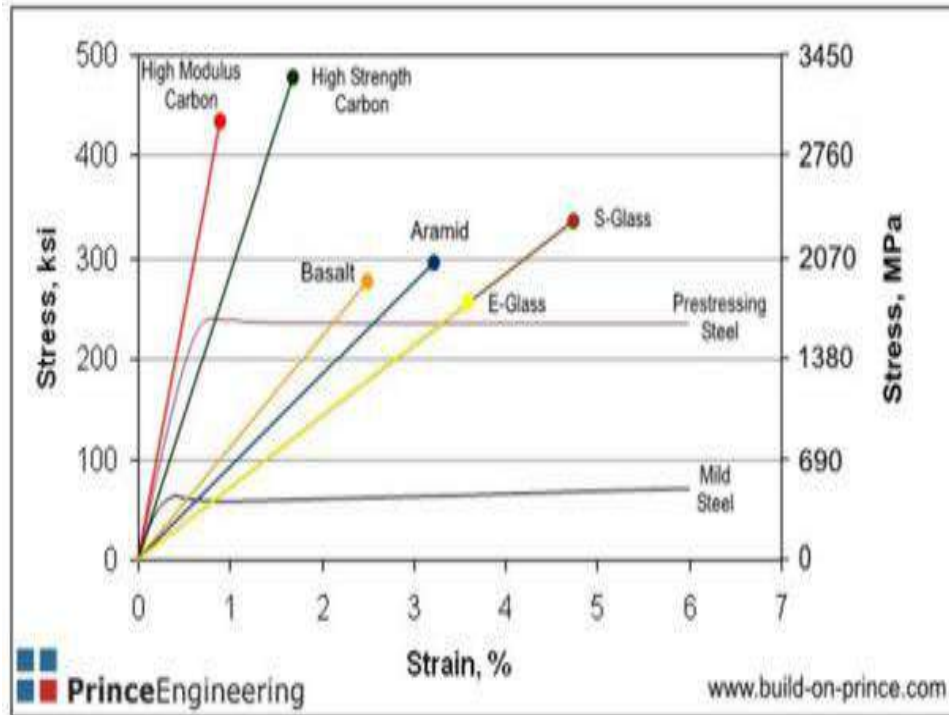


Fig.5 Stress-strain curve of FRP bar

Durability of FRP Reinforcement

FRP rebar is a composite material made up of high strength fibers embedded in a protecting matrix. It possesses very high strength to weight ratio and non-conductive/magnetizing nature. Glass Fiber Reinforced Polymer (GFRP) is an economically viable form of FRP and is being promoted widely as reinforcement for concrete. GFRP rebars are available in the market with high ranges of strength (up to 1500 MPa). FRP rebars are available in different surface texture (i.e. ribbed, sand coated, deformed, etc.) to achieve better bond strength with concrete and are manufactured by pultrusion process. GFRP bars can be used in the area like coal and mining industries, tunneling, coastal construction, road construction, corrosive construction, etc. Fibre reinforced polymer (FRP) reinforcing bars offer a potentially attractive alternative to steel reinforcing bars. The former are non-corrosive and generally of a higher strength than their steel counterparts, however, at the expense of no ductility (i.e. no yield point and plastic plateau) and a reduced modulus of elasticity in the case of glass FRP (GFRP) bars. Fibre reinforced polymer bars have most commonly been used in aggressive environments such as coastal environments and water treatment plants instead of steel. Such structures may include dry-docks, sea walls, wharfs, box-culverts, reinforced piles, floating piers, tanks, facades, and retaining walls. Use of FRP bars has been made in Canada in recent years in bridge decks and roads owing to the seasonal use of de-icing salts which causes traditional steel reinforcement to corrode. Some concrete structures may be required to be devoid of metal, like all other engineering materials, FRP reinforcements can also be subjected to mechanical and physical deterioration throughout its life. When FRPs are used as reinforcement within concrete members, they can be expected to be exposed to a variety of potentially harmful physical and chemical environment. Although FRPs are not susceptible to electrochemical corrosion, it can be significantly damaged by other chemical or physical form of degradation if used improperly. The mechanical, physical and bond properties of FRP reinforcement may alter or remain unchanged in a particular combination of chemical and physical exposure condition. Unfortunately durability of FRPs is not a straight forward issue and even might be more complex than corrosion of steel. Durability of FRPs depends on fiber type, resin type and their interface bond behavior. Furthermore, there are a variety of types of FRPs available commercially in the market thus different fibers and resins are characterized by their different behavior in elevated temperatures, environmental exposure and long-term phenomena. Durability of this material is severely affected by highly alkaline environment of concrete (pH=12.4-13.7), moisture and aqueous solutions, elevated temperature, freeze-thaw cycles, ultra-



violet (UV) radiation, fatigue and impact loads Lots of research are going on in this context, but reliable design rules are still lacking.

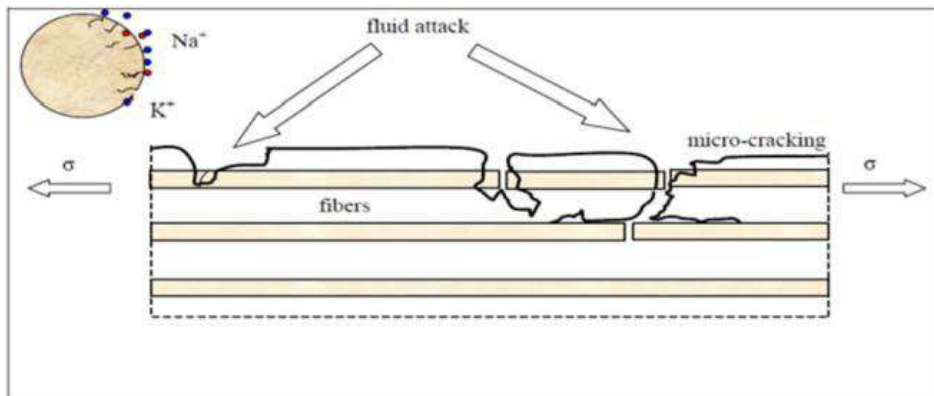


Fig.6 Effect of Environmental Exposure

CONCLUSION

FRP seems to outperform steel reinforcement in corrosion resistance. Yet, past investigations show this material has major limits that make it incompatible with concrete. This experiment will examine these constraints. This study examines GFRP reinforced concrete beam durability and serviceability. Serviceability was determined by deflection and cracking. Three exposures tested the durability of GFRP reinforced beams.

Recent research has focused on the durability and serviceability of GFRP reinforcement and GFRP reinforced concrete members. Despite contradicting literature, no consensus has been achieved. This context's results are restricted and unclear. . Note that a durable material does not necessarily have good serviceability and vice versa. So, both features must be examined to determine this material's compatibility with concrete.

Hence, this work describes GFRP reinforced beam durability and serviceability experiments. This study examined FRP properties and exposure types for GFRP and steel tensile specimens and GFRP reinforced beams. Based on this, the study examines GFRP reinforced concrete beam serviceability and durability.

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Environmental Pollution: Causes, Effects and the Remedies

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Abstract- Environmental pollution is a growing concern worldwide as it poses a significant threat to the health and well-being of humans, animals, and the planet. The causes of environmental pollution are diverse and include industrial activities, transportation, agricultural practices, and waste disposal. The effects of pollution can be devastating, ranging from respiratory illnesses to climate change. To combat this issue, several remedies have been proposed, including reducing emissions through the use of clean energy sources, implementing stricter regulations on industries and transportation, promoting sustainable agriculture practices, and encouraging the adoption of eco-friendly waste management strategies. While progress has been made in addressing environmental pollution, it remains a complex and urgent issue that requires immediate action from individuals, businesses, and governments alike.

Keywords: Pollution, Environment, causes, effects, remedies.

INTRODUCTION

Pollution can be defined as any human activity that has a negative impact on the quality of the natural environment.

Although environmental pollution is not a new phenomenon, it is still the world's most pressing issue and one of the leading environmental causes of disease and death. Most of the time, middle- and low-income nations pollute the environment more than developed nations do, possibly due to poverty, inadequate legislation, or ignorance of pollution types. It's possible that humans deal with pollution on a daily basis without realizing it, or that our fast-paced lives have made us immune to it.

Air, land, and water pollution are all caused by deforestation, bush burning, dumping of agricultural and household waste in water bodies, the use of chemicals to harvest aquatic animals, and improper disposal of electronic waste. Particularly so, as human population density rises, so do human activities and their effects on the environment. Not only do the effects affect humans, but also other aquatic and terrestrial animals, including microorganisms, which, due to their abundance and diversity, tend to keep their biochemical function, which is important for the ecosystem's survival, going on.

The reasons for ecological contamination are not restricted to industrialization, urbanization, populace development, investigation, and mining, yet in addition trans-boundary development of contamination from created to non-industrial nations or the other way around. Pollution has remained a global problem in part because of trans-boundary pollution. In addition, harmful substances like gaseous pollutants, toxic metals, and particulate matter (PM) are introduced into the atmosphere, resulting in environmental pollution; sewage, effluents from industries, runoff from farms, and electronic waste into water bodies; and activities that pollute the soil, such as mining, deforestation, landfills, and illegal waste disposal.

Air pollution, in particular, has alarming consequences, with a disproportionate impact on low-income earners, children, the elderly, and other vulnerable groups in developing nations. The information on the causes and outcomes of natural contamination is fundamental, in any case, the expense of inaction is colossal. Different physical and synthetic



methodologies have been applied to free the climate of contamination, however a large portion of them make extra environmental issues and are costly.

MAJOR TYPES OF POLLUTION

Air Pollution

The presence of toxic chemical compounds in the atmosphere at concentrations that could be harmful to humans, animals, vegetation, and buildings is known as air pollution. In general, air pollution refers to the presence of chemical compounds in the air that were not originally present but have altered its quality. Through global warming and ozone layer depletion, air pollution also impacts the quality of life on Earth. Sulphur oxides (especially SO₂), nitrogen oxides (including NO and NO₂), volatile organic compounds (VOCs), and carbon monoxide (CO) are typical gaseous pollutants. Primary and secondary pollutants are the two types of gaseous pollutants. Examples of primary pollutants include carbon monoxide (CO), carbon dioxide (CO₂), nitrogen dioxide (NO₂), and sulfur dioxide (SO₂). On the other hand, secondary pollutants are gases and particulates that also form in the atmosphere, largely as a result of the primary pollutants. The breakdown of ammonium nitrate aerosols, sulfuric acids, and hydrocarbons, for instance, results in the production of ozone (O₃), atmospheric sulfur, and nitrogen oxide gases, respectively.

The chemical composition of air pollutants, such as their oxidizing capacity, solubility, concentration, and susceptibility, as well as the susceptibility of the affected person or thing, determine the extent of damage. Because they are soluble in water, SO₂ gases can harm the skin and upper airways of humans; Due to their lower solubility, O₃ and NO₂ can penetrate the lungs further. CO is a colorless, odorless, highly soluble, non-irritating gas with a higher affinity for hemoglobin than oxygen. As a result, it easily enters the bloodstream to form carboxy-haemoglobin, which has negative effects.

Wind can carry large dust-like particles that settle on buildings, structures, and people's eyes. Emissions from incomplete combustion of organic materials frequently contain a number of harmful pollutants, including persistent organic pollutants (POPs) and polycyclic aromatic hydrocarbons (PAHs), which are known to be harmful to health.

Soil Pollution

Industrial and domestic wastes are the primary contributors to soil contamination, along with earthquakes, erosion, and other natural disasters that typically cause soil damage. Heavy metals, hydrocarbons, and both organic and inorganic solvents are examples of soil pollutants. Soil pollution is primarily caused by open land disposal, waste burning, and inadequate landfills.

Soil pollution is also aided by fossil fuels from petrochemical, petroleum, and power-generating facilities. Soil contamination is frequently the result of petroleum exploration, refining, and distribution via road transport. Due in part to the toxic nature of the additives used in their production and the direct effects that plastics have on animals and plants, land pollution caused by plastics is beginning to receive global attention. The sight of plastic litter on land is unpleasant, as is the possibility that it will seep into the soil, preventing plants from absorbing nutrients and entangling terrestrial animals.

In addition to affecting human health, soil pollution may also alter plant metabolism, resulting in lower crop yields. It is also possible for pollutants to enter the food chain through plant absorption.

Water Pollution

Man-made and natural sources both contribute to water pollution. Natural ores found in underground water sources may contain toxic metals that leach into water bodies and cause pollution. These ores are linked to high levels of arsenic and lead contamination in groundwater sources. Pesticides, hydrocarbons, POPs, and heavy metals are examples of chemicals that can have negative health effects like cancer, hormonal imbalance, impaired reproduction, and severe damage to the liver and kidneys. Eutrophication, the growth of plants and occasionally algae as a result of nutrients in the water, can increase pollution by reducing oxygen levels.

Examples of high arsenic and lead pollution of groundwater sources are connected to such metals. The elevated concentrations of the elements that are causing water pollution may be the result of the geological formations found in various regions, which play a significant role in determining the water bodies' elemental compositions. Domestic waste, insecticides and herbicides, food processing waste, pollutants from livestock operations, volatile organic compounds



(VOCs), heavy metals from electronic waste, chemical waste, and medical waste are all examples of anthropogenic sources of contamination.

Airborne toxins like PM additionally bring other natural poisons into surface water. Typhoid, stomachaches, vomiting, and other health issues can be brought on by these pollutants.

CAUSES OF ENVIRONMENTAL POLLUTION

Mining And Exploration

Air, water, and land quality are all impacted in varying degrees by mining and exploration processes. The phase and scope of the work being done at the site determine the degree of pollution. The excavation of the mine site by itself may result in the loss of habitat, the formation of sinkholes, and the production of waste. Other harmful elements like lead (Pb) could explode during the mining of gold ore, a valuable material, and pollute the soil and water.

Vandals have taken to illegally bursting oil pipelines and siphoning oil for refining in illegal refineries in the majority of oil-producing states in Africa. In most cases, security agencies burn down these illegal refineries with the intention of stopping bunkering. However, this burning process generates enormous quantities of toxic metals, organic pollutants, carbon compounds, and sulfur compounds, all of which have negative effects on aquatic and terrestrial life. Due to the presence of greenhouse gases, acid rain, heat waves, and the death of fish and other aquatic animals in surface waters are just a few examples.

Agricultural Activities

Any nation's economic development is fueled by agriculture, which also provides for the people's daily needs. Even though agriculture plays an important role, agricultural activities still cause pollution, which poses a number of health and environmental risks. Certain farming practices that have a tendency to harm, contaminate, and degrade the environment and ecosystem may be the cause of agricultural pollution. The burning of waste materials from agricultural activities like clearing land, applying more fertilizer to plants than they need, and using pest control chemicals that aren't biodegradable are all ways that farming contributes to pollution. The introduction of particular chemical substances into the food web, the production of PM and smoke, and the destabilization of habitats are all outcomes of these processes. Besides, nitrates from horticultural cycles are known substance contaminations in groundwater springs.

The environment is also polluted by the raising of terrestrial or aquatic animals, in addition to the pollution caused by farmland cultivation. Unused animal feed or excrement, for instance, may have unpleasant odors that could be harmful to health.

Urbanization And Industrialization

The rapid expansion of urbanization, modernization, and industrialization all likely contribute to environmental pollution worldwide, with a greater impact in developing nations. Due to indifference to water conservation and water wastage, water resources are beginning to dwindle, and as the population grows, there is a risk that this trend will continue or even worsen.

Additionally, pollution contaminates water bodies, rendering them unusable for drinking. Furthermore, industrialization results in an overwhelming amount of waste being dumped into land and water bodies. Large quantities of wastewater, heavy metals, toxic sludge, solvents, and other pollutants enter streams and rivers as a result of rapid urbanization and industrialization.

Air pollution is a major concern due to the exponential growth of automobiles and motor vehicles as a result of urbanization. Lastly, industrialization encourages extensive habitat destruction through the construction of roads, houses, and the cutting down of trees for their lumber, all of which contribute to the devastation of ecosystems and the extinction of some animal and plant species.

Environmental degradation is one of the results of uncontrolled urbanization in non-industrial countries. This happens very quickly, which causes a slew of other issues like polluted air and water, increased difficulties with waste disposal, and fertile farmlands.



Burning Of Fossil Fuels

Before they are burned, fossil fuels may release harmful pollutants into the air. At the point when petroleum derivatives are consumed, various air toxins are discharged, which cause natural contamination and concomitant annihilation of the biological system. We burn gas, oil, and coal to meet our energy needs, and these fuel the current climate crisis. The burning of fossil fuels releases a wide range of primary and secondary pollutants into the air, including SO₂, CO₂, CO, hydrocarbons, organic compounds, chemicals, and nitrogen oxides (NO_x). The major greenhouse gases, such as carbon dioxide, methane (CH₄), nitro-oxide, and fluoridated gases, are present in emissions from fossil fuels. As a result, these activities' air pollution not only threatens air quality but also contributes to climate change and global warming.

Particulate Matter

PM contributes significantly to the atmosphere. PM can come from either natural or human-made sources. There are various regular sources that infuse a large number of lots of PM into the climate. Volcanic eruptions, dust and wind storms, forest fires, salt spray, rock debris, reactions between gaseous emissions, and soil erosion are just a few examples.

Plastics

The extent to which plastics have contributed to environmental pollution is becoming increasingly apparent to the general public. Polypropylene, polyethylene, polystyrene, poly-amides, and polyesters are examples of plastics that can be found in nature. Due to their durability and affordability, plastic bags are primarily utilized for food shopping and storage in the majority of developing nations.

EFFECTS OF ENVIRONMENTAL POLLUTION

The impacts of natural contamination are to date underreported in most creating countries that endure contamination the most. This is partly due to a lack of awareness of the potentially harmful effects that pollution could have on health and the environment, as well as poor, unreliable database management systems.

Effects On the Environment

The environment is made up of land, water, the atmosphere, and the biosphere. It stores all pollutants. Damage to trees, the death of wildlife species, soil infertility that results in poor plant yield, destruction of roofing sheets, impacts on historical monuments and buildings, and discoloration of vehicles and automobiles are among the effects on the land. Other effects include littering the land surfaces with wastes, which has a repulsive odor and a negative impact on the appearance of the land.

Soil's chemical properties are altered, and important cat-ionic nutrients like magnesium, potassium, and calcium are lost, which lowers the pH of the soil. All of these things either directly or indirectly cause a lack of food for humans and other animals; Death and starvation are possible outcomes.

Changes in a water body's chemical, microbiological, and physical properties are typically the results of pollution. For instance, the sun's increased heat raises the water's temperature; Oil covers the water's surface in exploration areas, preventing sunlight and oxygen; increases in water salinity as a result of drilling with NaCl; an increase in the quantity of harmful metals; eutrophication, and the bio-network is destroyed, water quality and quantity are reduced, biodiversity is diminished, nutrient levels become too high, and plant growth is stunted. Due to the introduction of sulfur- and nitrogen-containing compounds and other anaerobic processes as a result of pollution, water bodies become noxious, repulsive, and abandoned.

Air in the atmosphere is known to carry a variety of pollutants and deposit them on land and water. Haze forms when sunlight strikes certain pollutants like PM and gases, making it difficult to see colors and shapes clearly. MP's effects on aquatic and soil environments are being studied. However, there is a possibility that MP's contain hazardous additives and chemicals that can enter the soil ecosystem and accumulate in soil invertebrates.



Effects On Animal Health

Wildlife and marine organisms both suffer sub-lethal health effects from oil spills that occur during exploration, refinement, and transportation on land, through pipelines, and/or marine vessels.

When these organisms breathe in or ingest petroleum products containing harmful substances, their digestive, respiratory, and circulatory systems suffer. Oil slicks pose a threat to seabirds and other marine mammals because they can clog their skin or feathers, preventing them from moving quickly enough to find food or escape predators, resulting in death. The difficulties of plastics in the climate have turned into a subject of talk in late times. It harms ecosystems, reduces biodiversity, and, ultimately, has the potential to affect the lives of most marine animals, including birds, fish, crabs, turtles, and others.

The genetic diversity and biodiversity of the natural population are affected by pollution. According to research, the ribosomal sequences in fish genomes that live in polluted environments are extremely complex. In response to changes in the environment, there is a systematic increase in the number of copies of the ribosomal DNA. This is because these sequences are primarily responsible for maintaining genome integrity.

Effects On Microorganisms

Zooplankton and other microscopic communities found in flowing water ecosystems are crucial to the nutrient cycle and energy transfer in aquatic food webs.

As a consequence of this, the biotic responses of microscopic organisms to the conditions of their environment made it possible to accurately assess environmental degradation in aquatic ecosystems.

However, the effectiveness of zooplankton biodiversity has been diminished as a result of pollution's significant influence on its geographic distribution.

Effects On Human Health

The majority of human illnesses have been linked to environmental pollution due to its detrimental effects on health. More evidence is being found in recent studies linking pollution to a number of serious health conditions. The number of studies examining the health effects of air pollution exposure is rising at an alarming rate. The World Health Organization's report made it abundantly clear that fires used for cooking and heating caused 3.8 million deaths in the indoor air.

It has been discovered that some recalcitrant pollutants, like POPs and PAHs, bind with particulate matter (PM), particularly PM_{2.5}, causing a variety of cardiopulmonary diseases, respiratory diseases, cancer, and effects on humans that are not related to cancer.

Because they reach the population, they are intended for by breathing, settling in drinking water, or being exposed to food, airborne pollutants tend to travel further and cause more harm.

Although epidemiological studies are pointing the finger at a number of women's health issues as the result of pollution, particularly air pollution, several other health problems associated with pollution may not have been discovered. Uterine fibroids may result from exposure to PM_{2.5} and O₃ due to specific genetic or epigenetic abnormalities, according to the literature.

REMEDIES

There have been suggestions made for a variety of remediation strategies, including biological, chemical, and physical ones. However, the most important thing is to figure out how to stop pollution in its tracks so that the environment that has already been affected can be fixed quickly and easily. The physio-chemical properties of the pollutants that have built up in the environment that needs to be cleaned are unaffected by physical methods of soil reclamation.

Chemical methods, on the other hand, break down the pollutants that have built up and change their physio-chemical properties to make them less harmful to the environment. Importantly, biological techniques based on the biological activity of higher plants and microorganisms can break down pollutants that have built up over time and further lead to their mineralization, immobilization, or removal.



Understanding and reducing the use of plastics, cleaning up oceans and beaches, replacing materials, and comprehending the effects on the health of humans and animals are just a few of the areas that have been suggested for future research and development in recent studies.

CONCLUSION

An overview of pollution, its causes and effects, and strategies for reducing pollution have been presented in this paper. Air pollution seems to be the most studied type of pollution and has received more attention. This could be because air pollution is linked to an increased rate of morbidity and premature death. While pollution affects both developed and developing nations, poverty, ineffective legislation, and a lack of awareness are to blame for the majority of the latter's problems. In countries with middle and low incomes, polluted areas disproportionately affect vulnerable populations. In order to make it possible to remediate an environment that has already been impacted, it is necessary to raise awareness of the dangers posed by pollution and to mobilize all resources to prevent activities that contribute to environmental pollution. The use of microorganisms in biological remediation techniques has been deemed environmentally friendly, cost-effective, and long-lasting for human and environmental safety.

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Small Hydro Power: Technology and Current Status

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Abstract- With 19% of the world's electricity coming from hydro-power—both large and small—it remains by far the most significant of the "renewable" for electrical power generation. Limited scope hydro is by and large "run-of-stream", with no dam or water stockpiling, and is quite possibly of the most financially savvy and naturally harmless energy innovations to be thought of as both for provincial zap in less evolved nations and further hydro advancements in Europe. By 2010, the European Commission intends to increase small hydro capacity by 4500MW (or 50%). There are at least 400MW of untapped potential and 100MW of existing small hydro capacity (under 5MW) in approximately 120 locations in the UK. With positive strategies presently being upheld by good taxes for 'green' power, the industry accepts that little hydro will have serious areas of strength for an in Europe in the following 10 years, following 20 years of decline. The various small hydro technologies, upcoming innovations, and obstacles to further development are compiled in this paper.

INTRODUCTION

Hydro-power on a small-scale is one of the most cost-efficient energy technologies to be thoughtful for rural electrification in less industrial countries. It is also the main possibility for hydro developments in the future in Europe, where large-scale opportunities have either already been taken advantage of or would be deemed environmentally unacceptable right now. Little hydro innovation is incredibly hearty (frameworks can keep going for quite a long time or more with little upkeep) and is likewise quite possibly of the most ecologically harmless energy advances accessible. Large dam construction was typically linked to the 20th century's rise of hydroelectricity. To create enormous artificial lakes, hundreds of massive barriers made of concrete, rock, and earth were erected across river valleys all over the world. The dams flooded vast tracts of fertile land and forced tens of thousands of locals to flee, despite providing a significant, dependable power supply as well as benefits for irrigation and flood control. The dam's productivity and lifespan have frequently been reduced as a result of rapid silting up. A significant disruption to river flows can also lead to a number of environmental issues

SMALL-SCALE HYDRO

Most of the time, small hydro is "run-of-river"; To put it another way, a dam or barrage typically only consists of a weir and stores very little water. The civil works are only there to keep the water level at the hydro-plant's intake level stable. As a result, run-of-river installations do not have the same negative effects on the environment as large hydroelectric projects. There are varying degrees of hydro-power's "smallness." There is not yet a globally agreed-upon definition of "small" hydro; The maximum power output ranges from 2.5 to 25 MW. Although the official definition in China is 25 MW, the most widely accepted value is a maximum of 10 MW. These are arbitrary divisions, and many of the principles involved



apply to both smaller and larger schemes. "Mini" hydro typically refers to schemes below 2 MW, "micro" hydro below 500 kW, and "pico" hydro below 10 kW, respectively, in industry jargon.

HISTORICAL BACKGROUND

Before oil became the dominant source of energy, the first half of the 20th century saw the peak of hydro-power's potential. Europe and North America utilized up to fifty percent of the technically available potential by rapidly building dams and hydro-power stations. In order to supply this expanding market, hundreds of equipment manufacturers emerged. The small hydro industry has been declining since the 1960s, whereas the large hydro manufacturers have maintained their operations on export markets, particularly in developing nations. Small hydro-power generally cannot compete with existing fossil fuel or nuclear power stations. As a result, there has been no firm market for small hydro-power in developed countries for many years without environmental incentives to use non-polluting power sources. Some countries, including Germany, have boosted this sector in recent years with attractive policies that favor "green" electricity supply.

The wooden waterwheel was the beginning of hydro-power. For roughly 2,000 years, various kinds of waterwheels had been in use in many parts of Europe and Asia, mostly for milling grain. By the time of the Industrial Revolution, the technology of waterwheels had been perfected to a fine art, and the many tens of thousands of waterwheels that were commonly used were achieving efficiency levels close to 70 percent. Modern turbines were developed as a result of the need to develop smaller and faster devices to generate electricity and improved engineering skills in the 19th century.

CURRENT STATUS

For the production of electrical power around the world, hydro-power, both large and small, remains by far the most significant of the "renewable." According to the World Hydro-power Atlas 2000 [2] that was published by the International Journal of Hydro-power and Dams, the technically feasible hydro potential of the world is estimated to be 14,370 TWh/year, which is equivalent to 100 percent of the current global demand for electricity. At this time, 8080 TWh/year is thought to be the proportion that is economically feasible.

In 1999, 2650 TWh/year of hydro-power potential was utilized, providing 19% of the world's electricity from an installed capacity of 674 W. In the years 2001–10, 135 W of new hydro-power capacity is anticipated to be put into operation. Less than 2% of global consumption was supplied by all other renewable sources taken together.

Over 40 GW of global capacity currently comes from small hydro (ten megawatts). The worldwide little hydro potential is accepted to be more than 100 GW. Over 15 GW have been developed by China alone, and another 10 GW are planned for the upcoming decade.

Europe

Hydro-power gives around 17% of EU power supply. There is an estimated 18 GW of additional small hydro potential, including refurbishment projects, and small hydro provides over 8 GW of capacity. By 2010, the European Commission intends to increase small hydro capacity by 4200 MW (or 50%).

Small hydro-power with a capacity of 100 MW is available in the UK from approximately 120 locations. Although England has many tens of thousands of small low-head sites, which were once watermills, with an aggregate potential of over 50 MW, the majority of the remaining potential of interest is in Scotland and Wales.

Basics

Hydro-turbines turn the pressure of water into mechanical shaft power that can be used to drive machinery or an electricity generator. The sum of the pressure head and volume flow rate determines the available power. The following general formula describes the power output of any hydro system:

$$P = \eta \rho g Q H$$



P is the mechanical power generated at the turbine shaft in Watts, η is the hydraulic efficiency of the turbine, ρ is the density of water (kg/m^3), g is the acceleration caused by gravity (m/s^2), Q is the volume flow rate passing through the turbine in millimeters per second, and H is the effective pressure head of water across the turbine in millimeters.

All that turbines can have water driven efficiencies in the reach 80 to more than 90% (higher than most other central players), albeit this will lessen with size. The efficiency of micro-hydro systems typically ranges from 60 to 80 percent.

TECHNOLOGY

Water's energy is transformed into power for a rotating shaft by a turbine. The head and flow that are available are the most important factors in determining which turbine is best for a given hydro site. The generator or another device loading the turbine's desired speed is another factor in selection. The selection is also heavily influenced by other factors, such as whether the turbine will be expected to produce power in low flow conditions.

Power-speed and efficiency-speed characteristics are shared by all turbines. They will typically run at a particular speed, head, and flow when it is most effective.

CLASSIFICATION

Turbines can be inexpertly classified as high-head, medium-head, or low-head machines. However, this is dependent on the machine's size: A large turbine's low head may be a small turbine's high head; For instance, a 10 kW system might use a Pelt-on Turbine at 50 m head, but a 1 MW system would need a minimum head of 150 m.

The fact that electricity generation necessitates a shaft speed as close as possible to 1500 rpm in order to minimize the speed change between the turbine and the generator is the primary reason that various types of turbines are utilized at various heads. Because the square root of the head decreases the speed of any given type of turbine, low-head sites require turbines that are naturally faster under certain operating conditions.

In addition, turbines are classified according to their mode of operation, which can be impulse or reaction. A pressure casing surrounds the reaction turbine's rotor, which is completely submerged in water. The profile of the runner blades causes lift forces, similar to those found on aircraft wings, that cause the runner to rotate. An impulse turbine runner, on the other hand, operates in the air under the direction of a water jet or jets, and the water remains at atmospheric pressure both before and after coming into contact with the runner blades.

Impulse Turbines

Impulse turbines are used in three main ways: the Cross-flow, also known as the Bank turbine, the Pelt-on, and the Turbo. The Pelt-on Turbine comprises of a wheel with a progression of divided cans set around its edge; A tangentially aimed high-velocity water jet is directed at the wheel.

When the jet reaches each bucket, it splits in half, causing each half to turn and deflect almost 180 degrees back. The bucket propels almost all of the water's energy, and the deflected water falls into a discharge channel below.

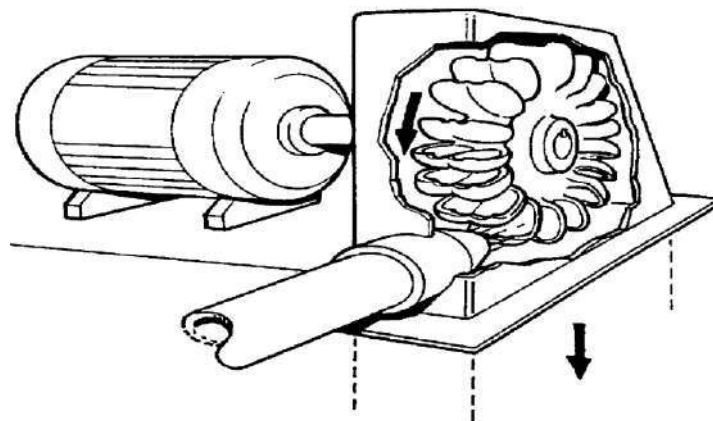


Figure 1 Pelton Turbine



Similar to the Pelton, the Turbo turbine is designed to strike the runner plane at an angle (typically 20 degrees) so that water enters and exits the runner on opposite sides. As opposed to Pelton turbines, the discharged fluid's interference with the incoming jet does not limit the flow rate. For the same amount of power, a Turbo turbine's runner can be smaller in diameter than a Pelton.

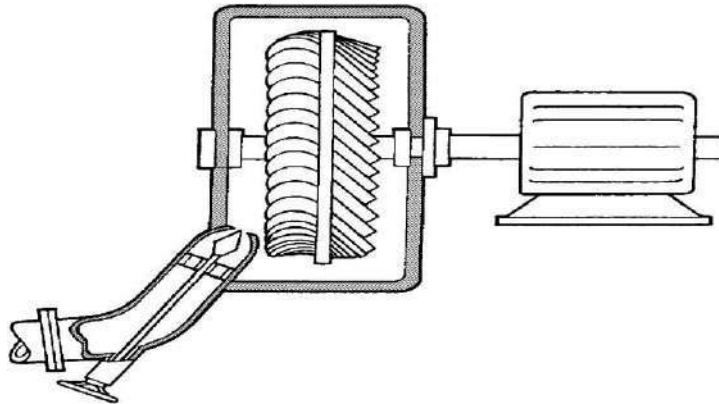


Figure 2 Turbo Turbine

The Cross-flow turbine has a drum-like rotor with a strong plate at each end and drain molded 'supports' joining the two plates. Through the curved blades, a jet of water enters the top of the rotor and exits on the opposite side by going through the blades twice. The shape of the blades causes the water to transfer some momentum as it moves around the rotor's perimeter, where it then disappears with little energy left.

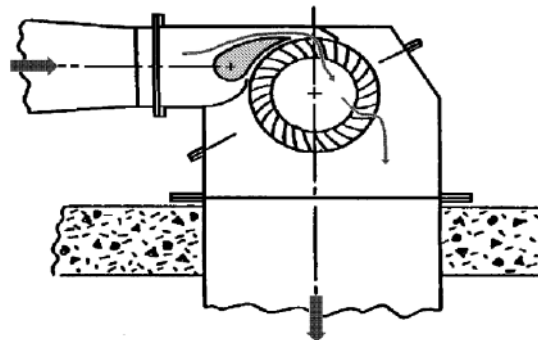


Figure 3 Cross-flow Turbine

Reaction Turbines

The runner blades of reaction turbines are propelled by hydrodynamic lift forces generated by the oncoming water flow. A runner that always functions within a completely water-filled casing sets them apart from the impulse type.

Under the runner of each reaction turbine, a diffuser known as a "draft tube" discharges water. The effective head is raised because the draft tube slows the discharged water and lowers the static pressure below the runner. The propeller (with the Kaplan variant) and the Francis turbine are the two primary types of reaction turbines.

Propeller-type turbines are comparative on a fundamental level to the propeller of a transport, however working in switched mode. Different arrangements of propeller turbine exist; a key component is that for good effectiveness the water should be given some whirl prior to entering the turbine sprinter. The water that emerges from the swirl flows directly into the draft tube with little angular momentum remaining if the design is correct.

The Francis turbine is essentially a modified propeller turbine in which water is turned to emerge axially after flowing radially inside the runner. The most common way to mount the runner is in a spiral casing with internal, movable guide vanes.

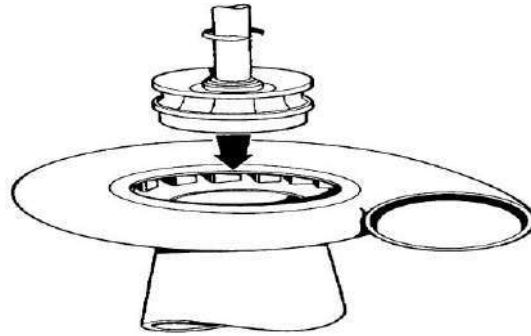


Figure 4 Francis Turbine

Relative Efficiencies

The fact that the Pelton, Crossflow, and Kaplan turbines maintain extremely high efficiencies even when operating below design flow is an important point to note. The Francis turbine, on the other hand, loses a lot of its efficiency if it is run at less than half its normal flow, and fixed pitch propeller turbines only work well above 80% of full flow.

Speed Control

In developing nations, numerous small hydroelectric stations supply a nearby town or village rather than being connected to the national grid. An effective speed regulation system is necessary to ensure that the voltage and frequency remain constant as the electrical load changes throughout the day because there is no strong grid to keep the generator at the correct frequency (50 or 60 Hz).

A governing mechanism may, in some instances, automatically drive a valve to adjust the flow to the turbine in response to changes in power demand. In other instances, speed control is achieved by adjusting the electrical power output rather than the water power input, and the turbine always operates at full power. An Electronic Load Controller, or ELC, is used to switch excess electrical power into and out of a ballast load in this scenario. In the 1980s, the availability of dependable ELCs significantly enhanced the reliability of small, off-grid hydro projects.

Economics

High head hydro by and large gives the most financially savvy projects, since the higher the head, the less water is expected for a given measure of force, so more modest what's more, consequently less exorbitant hardware is required. Therefore, even very small streams can produce significant power levels at attractively low costs in mountainous regions when used at high heads. However, high head sites are typically located in low-density areas with a low demand for electricity, and the low cost of remote high head systems may be negated by long transmission distances to major population centers. Additionally, high head sites are uncommon, with the majority of Europe's best and other developed regions already exploited. Therefore, low-head sites increasingly offer the greatest potential for expanding the use of small hydro.

Sadly, the majority of low head sites are currently only marginally economically appealing in comparison to conventional fossil fuel power generation, so many potential sites remain untapped. For instance, there are approximately 20,000 low-head water mill sites in the United Kingdom that have been used in the past but have not yet been redeveloped; Similar circumstances exist in numerous other nations.

Oddly, under the present shows for monetary and financial examination, a new hydro establishment seems to deliver rather costly power, since the high capital expenses are generally discounted over just 10 or 20 years. An older hydro site where the initial investment has been paid off is extremely competitive because the only costs are the low O&M costs. Such systems typically last for 50 years or more without significant maintenance.

Unfortunately, due to the widespread short-termism of today's business world, economic analysis of hydro-power projects does not adequately take into account the small hydro's exceptionally long lifespan and low operating costs.

FUTURE DIRECTIONS



Even though turbine manufacturers rightly take pride in the high efficiency and quality of their products, these attributes are irrelevant if the machinery cannot be purchased. The most important factor is the difference between the cost of the investment and the energy that is delivered.

As a result, efforts to increase the technology's cost-effectiveness have been the focus of much of the recent technical effort to develop small hydro-power. As a result, there are a few promising developments that can be briefly summarized here:

- Normative practices: offering standard turbine sizes that share components wherever possible rather than designing a new system for each site.
- Innovative use of existing infrastructure: plans are arising which keep away from a lot of the common development costs by cunningly using the common works currently set up at existing stream structures, for instance siphon turbine plans.
- Low head turbines' operation at variable speeds: Power electronics innovations recently made it possible to run a turbine and a generator at different speeds instead of the synchronous speeds required to produce the mains standard of 50 Hz AC. As a result, Kaplans can be substituted for propeller turbines, which are simpler.
- Telemetry and electronic control: permit hydro-plant operation without supervision.
- Turbo-generators that can be submerged: These typically function as "bulb" propeller turbines, with the generator enclosed in the flow and submerged. a powerhouse might not be necessary at all with this.
- New supplies: new anti-corrosion materials, plastics, etc. offer options for turbines, penstock pipes, bearings, seals, and other items that are less expensive. Small system optimization by computer: enables a system's more precise and rational sizing in order to maximize a site's financial return (rather than energy capture).
- Weirs with inflatables: On low-head sites, water-filled rubber weir crests are being used to raise the available head; They have the ability to deflate to let floodwaters pass through.
- New turbine designs: A lot of research has been done on using mass-produced pumps that run backwards as turbines, as well as a variety of novel turbine types or modifications to existing types.
- Streamlining and enhancing trash racks: To prevent intake screens from becoming clogged with debris, innovations like self-cleaning trash-racks and self-flushing intakes are being developed.
- Techniques that have been improved to prevent interference or damage to fish: The possibility that new hydro systems will harm fish is perhaps the most common reason people oppose them. Novel structures of fish stepping stool and physical or supersonic screening guarantee more financially savvy arrangements.

CONCLUSIONS

This technology is unique to each location; There aren't many sites that are both good for harnessing water power and close to a place where it can be used. There is always a maximum useful power output from a given hydropower site, which limits the amount of power-using activities. River flows often change a lot with the seasons, especially in monsoon-like climates. This can limit the firm power output to a small fraction of the possible peak output. There can be conflicts with fisheries interests on low-head schemes, and with irrigation.

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Study of Soil Stabilization Technique

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Abstract - Stabilization is a wide sense for the different techniques utilized and changing the properties of a dirt to further develop its designing presentation and utilized for an assortment of designing works. In the present soil stabilization is the serious issue for structural designers, either for development of street and furthermore for expanding the strength or dependability of soil and lessens the development cost. Soil stabilization can be made sense of as the modification of the dirt properties by compound or actual means to improve the designing nature of the dirt. The primary target of the dirt stabilization is to build the bearing limit of the dirt, its protection from enduring cycle and soil porousness. Because of fast development of urbanization and industrialization, minimization of modern waste is difficult issue in present days. To experience this inventive and modern examination on squander usage is acquiring significance now a days. Soil improvement utilizing the waste material like Slags, Rice husk debris, Silica rage and so on. In geotechnical designing has been recommended according to natural perspective.

This paper audits because of impact heater slag, Fly ash and miniature silica when utilized as admixtures with dark cotton soil to work on different properties of soil.

Keywords: Stabilization, Fly ash, Micro Silica, Blast Furnace Slag, C.B.R., U.C.S., B.C. Soil

INTRODUCTION

Structural designing tasks situated in regions with delicate soil are quite possibly of the most well-known issue in many areas of the planet. The old common technique to delicate soil stabilization is to eliminate the delicate soil and supplant it with more grounded materials. The significant expense of this strategy has driven the scientists to search for elective techniques and one of these techniques is the course of the dirt stabilization. Soil stabilization is the strategy presented quite a long time back with primary reason to deliver the dirt equipped for meeting the necessities of the particular designing ventures. Furthermore, when the dirt at site are poor or when they have unfortunate property making them unacceptable for use in a geotechnical projects, they might need to be balanced out.

The improvement of soil can be characterized into a few classes, change or stabilization or both. The alteration can be directed by compaction or substitution of the first soil or blending soil in with another. While stabilization is the treatment of soils to empower their solidarity and strength to be worked on with the end goal that they turn out to be absolutely reasonable for development. Many waste materials are utilized to adjust the attributes of delicate soils. The dirt is balanced out by lime, concrete, fly ash and so on. The designing properties of delicate soil subgrade layer might should be improved to make like soil really great for development by utilizing stabilization strategy. Asphalt subgrade stabilization depended on treatment with Impact heater slag, concrete, fly debris, and miniature silica seethe.

METHODOLOGIES

1. Mechanical Techniques for Stabilization:



In this methodology, soils of various degrees are combined as one to get the ideal property in the soil. This might be finished at the site or at another spot from where it very well may be shipped without any problem. The last mix is then compacted by the ordinary systems to get the necessary thickness.

2. Additive Technique For Stabilization:

The expansion of fabricated items into the dirt, which in suitable sums works on the idea of the soil. Materials, for example, concrete, lime, bitumen, fly ash and so on, are utilized as manufactured added substances.

-It improves the amount of the dirt thus, growing the dirt bearing breaking point.

-Stabilization upgrades the functionality and the strength of the dirt.

- It assists in reducing the dirt volume with evolving.

MATERIALS

1) Blast Heater Slag:-

Granulated Impact Heater Slag (GGBS) Impact heater slag is created as a side-effect during the production of iron in an impact heater. Liquid impact heater slag has a temperature of 1300-1600°C and is chilled quickly to forestall crystallization. The granulated material subsequently delivered is known as granulated impact heater slag. Impact heater slag has a lustrous, confused, glasslike structure which should be visible to minute assessment which is liable for creating a solidifying result.

2) Fly Debris:-

Fly ash and base debris are important for ignition of non-flammable build-up or burning of sub-bituminous coal which had been created in a particularly colossal amount in electric plants and they are result of consuming coal that can be utilized without activators for soil stabilization.

3) Micro silica:-

Miniature silica smoulder is a modern waste delivered from the purifying system of silicon metal and ferrosilicon combination creation. It contain high measure of incredibly fine and amphrous size particles. Miniature silica rage has been utilized in structural designing fills in as a cover material in a mix with concrete materials or individual for soil stabilization and given extraordinary outcomes. Miniature silica see the works on compressive strength, bond strength, scraped spot obstruction, and diminish penetrability, and its accessible in two circumstances: dry and wet.

LITERATURE REVIEW

- Amanpreet Tangri, Gagandeep "Impact of Impact Heater Slag on Different Properties of Clayey Soil: A Survey", Worldwide Diary for Logical Exploration and Improvement, ISSN (on the web): 2321-0613, Vol. 6, Issue 03,2018

In the present structural designing world once in a while the establishment soil isn't reasonable for development reason. This makes bunches of issue to structural architect during the execution. To make the risky soil appropriate for designing ventures is known as ground improvement. So with the end goal of ground improvement we utilize various kinds of admixtures like concrete, lime, impact heater slag, rice husk debris, Fly ash and so forth. This paper audits because of impact heater slag when utilized alone or for certain different admixtures on different properties of clayey soil. From the trial results it has been found that by utilizing impact heater slag with admixtures like lime builds the worth of U.C.S and C.B.R. furthermore, the variety is additionally tracked down in the compaction qualities of soil. In the wake of doing a survey of different examination papers we can finish up the by utilizing the impact heater slag we can lessen the natural contamination and it very well may be utilized for the stabilization of clayey soil. As we add Impact heater slag the

U.C.S and C.B.R esteem increments since cementation of soil by pozzolanic intensifies delivered during the response of soil with impact heater slag

- J Bala Krishna, "Soil Stabilization with Flyash", Global Diary of Exploration Sciences and High level Designing,



Volume 2, Issue 19, PP: 196 - 208, Jul - Sep:2017

This exploration work presents the viability of sodium based soluble activators and class F Fly ash as an added substance in further developing the designing qualities of far reaching Dark cotton soils. Sodium hydroxide centralizations of 10, 12.5 and 15 molal alongside 1 Molar arrangement of sodium silicate were utilized as activators. The activator to debris proportions was kept somewhere in the range of 1 and 2.5 and debris rates of 20, 30 and 40 %, somewhat to the absolute solids. The viability of this cover is tried by leading the Unconfined compressive strength (UCS) at restoring times of 3,7 and 28 days and is contrasted and that of a typical Fly ash based fastener, likewise the best combinations were investigated for mineralogy with XRD. Reasonableness of soluble enacted Fly ash blend as a grouting material is likewise found out by concentrating on the rheological properties of the grout, for example, setting time, thickness and consistency and is contrasted and that of normal concrete grouts. Results shows that the ease of the grouts correspond very well with UCS, with an expansion in the previous bringing about a decline in the last option. In this work a groundbreaking thought of settling the extensive soil utilizing soluble base enacted Fly ash was examined. The compound sodium hydroxide and sodium silicate were utilized as a synthetic activator for the fly debris. The strategy for test planning, extent of substance added substance, relieving of test and changes in essential geotechnical properties of far reaching soil

- Trama center. Rehana Rasool , trama center. Kshipra Kapoor , "Similar Concentrate on Stabilization of Soil with Ground Granulated Impact Heater Slag (GGBS)", Global Diary of Most recent Exploration in Science and Innovation, ISSN (Online):2278-5299, Volume 6, Issue 3, May-June 2017

Use of modern waste materials in the improvement of risky soils is an expense proficient and furthermore ecological cordial technique as in it helps in lessening removal issues brought about by the different modern squanders. The primary target of the current review is to further develop different designing properties of the dirt by utilizing waste material Ground Granulated Impact Heater Slag (GGBS) as a choice to lime or concrete, to make it equipped for taking additional heaps from the establishment structures. This paper incorporates the assessment of soil properties like unconfined compressive strength test and California bearing proportion test. The dirt example was gathered from Lalru and expansion to that, various rates of GGBS (0%, 6%, 12%, 18 % and 24%). was added to track down the variety in its unique strength. In view of these outcomes CBR test was performed with the GGBS rates (0%, 6%, 12 %, 18 % and 24%). From these outcomes, it was seen that as ideal GGBS (18%) gives the most extreme addition in the CBR esteem contrasted and the wide range of various blends.

The review has been led to survey the capability of GGBS for stabilization of a similar sort of soil. Utilization of slag as an admixture for further developing designing properties of the dirt is a practical answer for utilize the locally accessible unfortunate soil.

- S.W.Thakare, Priti Chauhan, "Stabilization of Extensive Soil with Miniature Silica, Lime and Fly ash for Asphalt", Global Diary of Designing Exploration, ISSN:2319-6890(online), 2347-5013(print), Volume No.5IssueSpecial1pp:09-13 8 and 9 Jan 2016

Geotechnical Designing properties of delicate clayey soil stores, for example, dark cotton soil might should be improved by stabilization to make such soils appropriate for development of street asphalts. Stabilization of such soils has been generally depended on treatment with lime, concrete and waste materials like fly debris. Miniature silica is squander material gotten from electric bend heaters. This paper presents the aftereffects of stabilization of neighborhood dark cotton soil with lime, Fly ash and miniature silica. Series of research center tests have been directed with fluctuating level of these stabilizers, added separately and in mixes, to decide their ideal rates. From the outcomes, it is seen that CBR esteem, for both splashed and unsoaked conditions, increments significantly by expansion of 5% miniature silica alongside 3% Fly ash and 3% lime. The asphalt planned with these better upsides of CBR demonstrated a noticeable decrease in its thickness prompting economy in the development of street asphalts on or utilizing delicate clayey soils.

Stabilization of dark cotton soil with lime, fly debris, lime and their mixes shows critical improvement in the unconfined compressive strength of soil to the degree of 3.8 times that of unstabilized soil. Ideal rates of miniature silica, lime and Fly ash for settling dark cotton soil are viewed as 5%, 3% and 3% separately. Dark cotton soil settled with lime, fly debris, miniature silica and their mixes shows observable improvement in absorbed CBR of soil to degree of 6.5 seasons of



unstabilized soil. Dark cotton soil settled with lime, fly debris, miniature silica and their blends shows observable improvement in unsoaked CBR of soil up to degree of 1.8 seasons of unstabilized soil.

- Dayalan J, "Relative Concentrate On Stabilization of Soil With Ground Granulated Impact Heater Slag (GGBS) and Fly Debris", Global Exploration Diary of Designing and Innovation, e-ISSN: 2395 - 0056, p-ISSN: 2395-0072, Volume: 03 Issue: 05 , May-2016

Stabilization is a wide sense for the different strategies utilized and changing the properties of a dirt to get to the next levelits designing presentation and utilized for an assortment of designing works. Soil stabilization has turned into the significant issue in development designing and the explores in regards to the viability of involving modern squanders as a stabilizer are quickly expanding. This concentrate momentarily depicts the reasonableness of the locally fly ash and ground granulated impact heater slag (GGBS) to be utilized in the nearby development industry in a method for limiting how much waste to be arranged to the climate causing natural contamination. In this current review, different measure of Fly ash and GGBS are added independently for example 5, 10, 15 and 20% by dry load of soil are utilized to concentrate on the stabilization of soil. The presentation of settled soil are assessed utilizing physical and strength execution tests like explicit gravity, Atterberg limits, standard delegate test and California Bearing Proportion (CBR) test at ideal dampness content. From the outcomes, it was observed that ideal worth of Fly ash is 15% and GGBS is 20% for stabilization of given soil in light of not entirely settled.

The review has been led to evaluate the capability of fly ash and GGBS for stabilization of a similar sort of soil. It is seen that with the increments of fly ash and GGBS rate, ideal dampness content continues diminishing while greatest dry thickness continues expanding, consequently smaller capacity of soil increments and making the dirt more thick and hard.

- Abdelzaher E. A. Mostafa, Mohamed. S. Ouf and MokhtarF. Elgendy "Stabilization of Subgrade Asphalt Layer Utilizing Silica Smoke and Nano Silica" Worldwide Diary of Logical and Designing Exploration, Volume 7, Issue 3, Walk 2016

Numerous examinations have been completed on earth subgrade soil; utilizing a few kinds of stabilizers. Because of the expansion in rush hour gridlock loads and the significance of subgrade layer in fortify the asphalt segment to forestall the prior harm. In this study the initial step (in view of the planned exploratory program) tests were ready with and with no added substances; the pre-owned added substances were lime (L), silica seethe (SF), and nanosilica (NS). The attempted rates of lime were 2, 4, 6 and 8% and 5, 10 and 15% for SF, while 1, 2 and 3% utilized for NS. The subsequent step was to inspect the physical and mechanical properties of the pre-arranged blends utilizing changed delegate test, Atterberg limits test, free enlarging (FS%) test, unconfined compressive strength (UCS) and California Bearing Proportion (CBR) tests. At last, direct shear (DS) test was completed on the ideal blends from the subsequent step. All blends were tried after two restoring periods 7 and 28 days utilizing UCS and FS%. The outcomes demonstrated that the ideal dampness content (OMC) expanded, while the most extreme dry thickness (MDD) emphatically diminished for every single utilized added substance and versatility list (private investigator) diminished. The FS% diminished, and the most extreme decrease in FS% was happened at the two mixes (8% L + 15% SF) and (8%L+3%NS).

The UCS expanded by adding both SF and NS actuated by lime to the test soil , and the ideal rates of the two mixes were happened at 6%L+10%SF and 6%L+3%NS for customary and nanomaterials added substances individually. Thus, control tests and the two ideal blends have been arranged for CBR and DS tests. The DS test was completed at dry and lowered conditions, while CBR test was done at splashed condition. The outcomes showed that the greatest worth of CBR happened at 8% L + 10% SF, while DS results demonstrated that adding 6L+10SF and 6L+3NS, the dirt boundaries (union and inward grinding point) have been moved along

- Anil Kumar Sharma, P.V. Sivapullaiah , "Ground granulated impact heater slag changed Fly ash as an extensive soil stabilizer" The Japanese Geotechnical Society Soils and Establishments, 2016; 56(2):205-212

The capability of involving a fastener for stabilization of far reaching soils that comprises of a combination of Fly ash and ground granulated impact heater slag (GGBS) is assessed in this review. The cooperative utilization of these two materials to shape a cover gives new chances to upgrade pozzolanic exercises that might lessen the swell potential and increment the unconfined compressive strength of sweeping muds. The impact of various rates of cover on as far as possible, compaction



qualities and unconfined compressive strength of a misleadingly blended soil were inspected. The expansion of fastener was displayed to achieve a huge improvement in these dirt properties. It was found that as far as possible and versatility record of the extensive soil diminished impressively with the expansion of cover, while the strength gotten to the next level. Adding a limited quantity of lime (one percent) further superior the dirt properties by upgrading the pozzolanic reactivity of the cover. In view of the consequences of the unconfined compressive strength tests, the expansion of 20% folio is suggested as ideal substance. Moreover, the mineralogical and morphological investigations of soil example balanced out with ideal folio content recommended the development of hydrated particles and cementitious mixtures because of the response between the mud and the cover. Test results show that the utilization of GGBS blended Fly ash as fastener to balance out extensive is appropriate for supportable development other than financial advantages.

In this review, a falsely blended far reaching soil was balanced out with various measures of folio, basically comprising of fly ash and GGBS at a blending proportion of 7:3. The goal of this exploration was to survey the impact of Fly ash GGBS put together cover with respect to the actual properties and unconfined compressive strength of the dirt.

- Chhaya Negi , R.K.Yadav , A.K. Singhai, "Impact of Silica Smoke on Designing Properties of Dark Cotton Soil", Worldwide Diary of Computational Designing Exploration, Vol, 03, Issue, 7.

Because of quick development of urbanization and industrialization, minimization of modern waste is difficult issue in present days. To experience this ennovative and forward thinking research on squander use is acquiring significances now a days. Soil improvement utilizing the waste material like Slags, Rice husk debris, Silica rage and so on, in geotechnical designing has been recommended according to ecological perspective. The primary goal of this study is to assess the practicality of utilizing Silica seethe as soil stabilization material. In this paper the impact of Silica rage on designing attributes of far reaching earth like Dark Cotton Soil has been introduced. A progression of research center examination has been led on dark cotton soil mixed with Silica smoulder content from 5% to 20% by weight of dry soil. The trial results showed a huge expansion in California bearing proportion and Unconfined compressive strength. The Differential free swell of the earth is decreased from half to 7% with expansion in Silica seethe content from 0% to 20% separately. The Delegate compaction results showed a little reduction in greatest dry thickness and expansion in Ideal dampness content. From this examination it very well may be presumed that the Silica smoulder as a possibility to work on the qualities of dark cotton soil.

The BC soil-Miniature Silica change the delegate compaction boundaries. The expansion of silica smoke to the dark cotton soil increment the ideal dampness content and diminishes the greatest dry thickness with the expansion in silica seethe content. The expansion of silica smoke to the dark cotton soil further develop the doused CBR significantly. The expansion of 20% silica smoke to the dark cotton soil builds the CBR strength by 72% around. There is a critical reduction in the enlarging characteristics of the dirt. The level of breadth reduces from "High to Low"

CONCLUSION

Subsequent to doing a survey of different examination papers we can finish up the by utilizing the impact heater slag we can diminish the natural contamination and it very well may be utilized for the stabilization of clayey soil. The essential advantages of involving these added substances for soil stabilization are Cost Reserve funds: since slag is commonly less expensive than concrete and lime; and Accessibility: since slag sources are effectively accessible the nation over from adjacent steel plants. Squander the board one of the modern squanders should be possible monetarily. Utilization of slag as an admixture for further developing designing properties of the dirt is a prudent answer for utilize the locally accessible unfortunate soil.

Stabilization of dark cotton soil with lime, fly debris, lime and their mixes shows critical improvement in the unconfined compressive strength of soil to the degree of 3.8 times that of unstabilized soil.

It is seen that with the increments of fly ash and GGBS rate, ideal dampness content continues diminishing while most extreme dry thickness continues expanding, subsequently smaller capacity of soil increments and making the dirt more thick and hard



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A Study on Ground Water Problems, Artificial Recharge Techniques in Musunuru

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Abstract-

Artificial groundwater recharge is a process of induced replenishment of the groundwater via the assist of human activities. It's far the planned, human activity of increasing the quantity of groundwater available via works designed to grow the natural replacement or percolation of surface water into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for the concept. In an area like Musunuru Mandal in Andhra Pradesh, there is a need for recharge of groundwater identified by Jal Shakti Abhiyan. This study explains the demand and consumption of water and estimates the water budget in Musunuru village. In this study, the major source of water for agriculture is rainfall or borewells (tube wells). To identify the water demand in the village and suggesting the best practice approach to reduce the risk of Musunuru with an experimental study on groundwater recharge techniques. Among all the recharge techniques this study chooses the low budget soak pit method with materials like a reused plastic drum and locally available construction materials in Musunuru. By using this proposed low budget soak pit method 85% of groundwater recharge contributes.

Keywords: Artificial groundwater recharge; Water budget; Low budget soak pit; Agriculture; Jal Shakti Abhiyan.

INTRODUCTION

Groundwater is the main source of Indian rural domestic, urban water requirements and irrigation requirements, is rapidly decreasing in many regions due to its wide-ranging withdrawal for different sectors. As per the central ground water board (CGWB) 2017, the government of India identified the 9 districts of Andhra Pradesh that are facing critical or overexploited groundwater levels and groundwater scarcity for different purposes like drinking, domestic and agricultural[1]. For the case study the Musunuru village of Krishna districts by considering the present status and by applying different recharge techniques for increasing the groundwater levels. Continued efforts have been made in India to develop groundwater resources to meet the increasing demands of water supply, especially in the last few decades[2]. Groundwater production has already reached a critical stage in certain high demand areas, resulting in extreme water resource scarcity[3]. Overuse of groundwater services leads to lower groundwater levels, depletion in the groundwater supply.

Artificial recharge is proving to be one of the groundwater management methods. There are different artificial recharging methods[3]. This study considers some of the techniques in detail like site characteristics and design guidelines, check dams, percolation tanks / spreading basins, recharge of dug wells/hand pumps, recharge shafts, injection wells, recharge trenches and Soak pits[4]. The methods include in this study and suggesting some of the daily use and cost-effective techniques that can be implemented for conserving the ground water[5].

Soak pits also called as soak away or leach pits is a sealed, porous-walled hollow space allowing water to soak step by step into the floor. Pre-settled effluent is discharged to the underground chamber from which it infiltrates into the encompassing soil from a group and storage/treatment area[6]. Soak pit method finds a low cost-effective method to increase/recharge groundwater in rural and urban areas[7]. It could be built and repaired with domestically available materials and this techniques easy to apply for all the members.



GROUNDWATER RECHARGE TECHNIQUES/METHODS

Groundwater is a precious and the most broadly dispensed useful resource of the earth and unlike some other mineraloid, it gets its annual replenishment from the meteoric precipitation. Different groundwater recharge techniques for urban and rural regions are shown in Table 1. In the present scenario, nearly one-fifth of water used within the global is obtained from groundwater sources. Agriculture is the finest user of water accounting for 75% of all consumption [1]. Due to fast urbanization, infiltration of rainwater into sub-soil has considerably decreased and recharging of groundwater as dwindled over the years.

This creates a critical impact on the socio-economic and environmental degradation of the place. Therefore, it has to turn out to be vital to selling in-situ water harvesting to augment groundwater recharge. Groundwater recharge is the technique whereby the amount of water found in or flowing via the interstices of the sub-soil will increase via natural or artificial methods. Rainfall is the essential source for the replenishment of the recharge of floor water. Other sources include recharge from rivers, streams, irrigation water, and so forth.

Table 1. Groundwater recharge techniques for urban and rural regions.

Urban Regions	Rural Regions
Recharge pits	Checkdams
Recharge trenches	Dugwell recharge
Tubewells	Recharge shaft
Recharge wells	Soakpits
	Percolation tank
	Surface spreading

Description of Study Area

Musunuru is a large village located in Musunuru Mandal of Krishna district, Andhra Pradesh with a total number of 1495 families residing [9]. The Musunuru village has a population of 6095 of which 2883 are males while 3212 are females as per Population Census 2011. Musunuru is located at latitude 16°50'34''N and longitude 80°57'44''E. There are 16 villages come under the Musunuru Mandal they are Ramanakkapeta, Surepalli, Lopudi, Gullapudi, Chakkapalli, Akkireddigudem, Chintalavalli, Korlagunta, Tallavalli, Musunuru, Yellapuram, Katrenipadu, Gopavaram, Balive, Chillaboyinapalle, Velpucherla. Musunuru Mandal map is presented as Appendices B. The total population is around 55,036 of which the urban population is zero and the rural population is 55,036, the number of borewells is 5250 and 55 different types of crops are cultivated throughout the year [10]. As per Jal Shakti Abhiyan in Musunuru Mandal 13 out of 16 villages are found out of exploited the groundwater and there this study considers the groundwater recharge technique to increase the groundwater level in the Musunuru [10]. The last five years of rainfall data in Musunuru Mandal are shown in Table 2. The major cultivated crops are paddy, mangoes, maize, palmoil, banana, and cotton, etc. These crops consume more water for cultivation purposes from the borewells.

Table 2. The last five years of rainfall data in Musunuru Mandal.

Year	Normal/inmm	Actual rainfall received inmm	Deviation%
2015	1039	869.4	-19.5
2016	1039	998.8	-4.02
2017	1039	810.2	-28.23
2018	1039	1087.8	+4.48
2019	1039	891.3	-14.21



Normalized water depth of rain fall in Musunuru Mandal (for last five years) = 931.5 mm

SOAK PIT DESIGN AND DIMENSIONS

Based on this study performed in Musunuru village the method low budget Soak Pit was adopted as an efficient and suitable technique to recharge the groundwater. The schematic diagram of the low budget soak pit is shown in Fig. 1. Soak pits were able to construct at the backyards of every house in Musunuru village. Greywater and rainwater are collected from the houses and they were diverted into the installed soak pit to recharge the groundwater. The budget of soak pit is around 2000 rupees for each soak pit and constructed within two days with the help of two workers. This study suggests 1.5 m diameter and depth of 3 m trench with 3 feet diameter of a drum which is appropriate for one family around five contributors and it takes 300 consistent liters per day. Excavation accomplished manually. The reused plastic drum used for gathering the wastewater, made 10 holes on the perimeter of the drum with 7 rows of 14 mm diameter each hole as shown in Fig. 2. After that, filled the trench with the aid of trade layers of brickbats and boulders with a mesh internet among of length 2 mm, every layer's thickness of 200 mm. The water gets a lot filtered with the aid of this approach. Filling aggregate approximately depth 15 to 25 cm after the position of the drum which used for gathering the wastewater. Thereafter 10 to 15 cm height of the sand layer is provided after the aggregate. Kindly test the height of the drum which has to be 15 to 20 cm below the floor level. Attach the PVC elbow to source pipe and another end connected to the soak pit. Fix the pipe well and keep cover on the drum. Cover the pit and make certain that pit will no longer damage from any outside sources and if possible that assemble within the residence for its safety. Process of making the pit use like that we can open that once a few times for its maintenance purpose [11]. When we disposed of the wastewater through soak pit it needs to be dealt with by some means the amount of quality has to be accelerated [6]. Wastewater after handled it could percolate into the ground and it will acquire the groundwater level as shown in Fig. 3. The efficiency of the soak pit is around 80 to 90%.

Advantages of soak pit method

This method allows recharging the nearest groundwater source.
Locally available materials will be used for the construction of design economically.
For the installation of the design, a small area is only required.
The village becomes drainage free.
The village becomes mosquito-free which enables to lower the risk of various diseases.
It creates healthy environmental surroundings.

Disadvantages of soak pit method

Primary treatment is required to prevent clogging, if primary treatment is not given wastage will clog and deplete the percentage of water percolation.
It requires a periodic renovation at least twice a year.
It is a tough attempt to clean the soak pit.
It should be avoided for high daily volumes of discharge.

METHODOLOGY

Collection Of Data

This research finds out the problem statement and select the location (Musunuru village) and then collects the required data like number of households, number of population, number of borewells, geographical area, crop details, and rainfall data.

Segregation Of Data

The collected data from the Musunuru village would be sorted out for the project to have a detailed understanding of the problem in the village and then analysed the data to find out the water demand in the village and separated into two categories.



Domestic Water Demand

This study finds out the average domestic water consumption per each household in Musunuru village.

Agricultural water demand

This study finds out the total water demand for all the seasonal crops for agricultural purposes in Musunuru village.

Geo-tagging of borewells

Geo-tagging of borewells is performed to have a clear understanding of villages and borewells in the Musunuru Mandal responsible for the depletion of groundwater, Where the larger number of borewells are present there the water consumption is more. Geo-tagging was performed by the help of data having latitudes and longitudes as seen in Appendices A.

The flow chart is made to organize and describe all the key tasks that were conducted during the research work as presented below in Fig. 4.

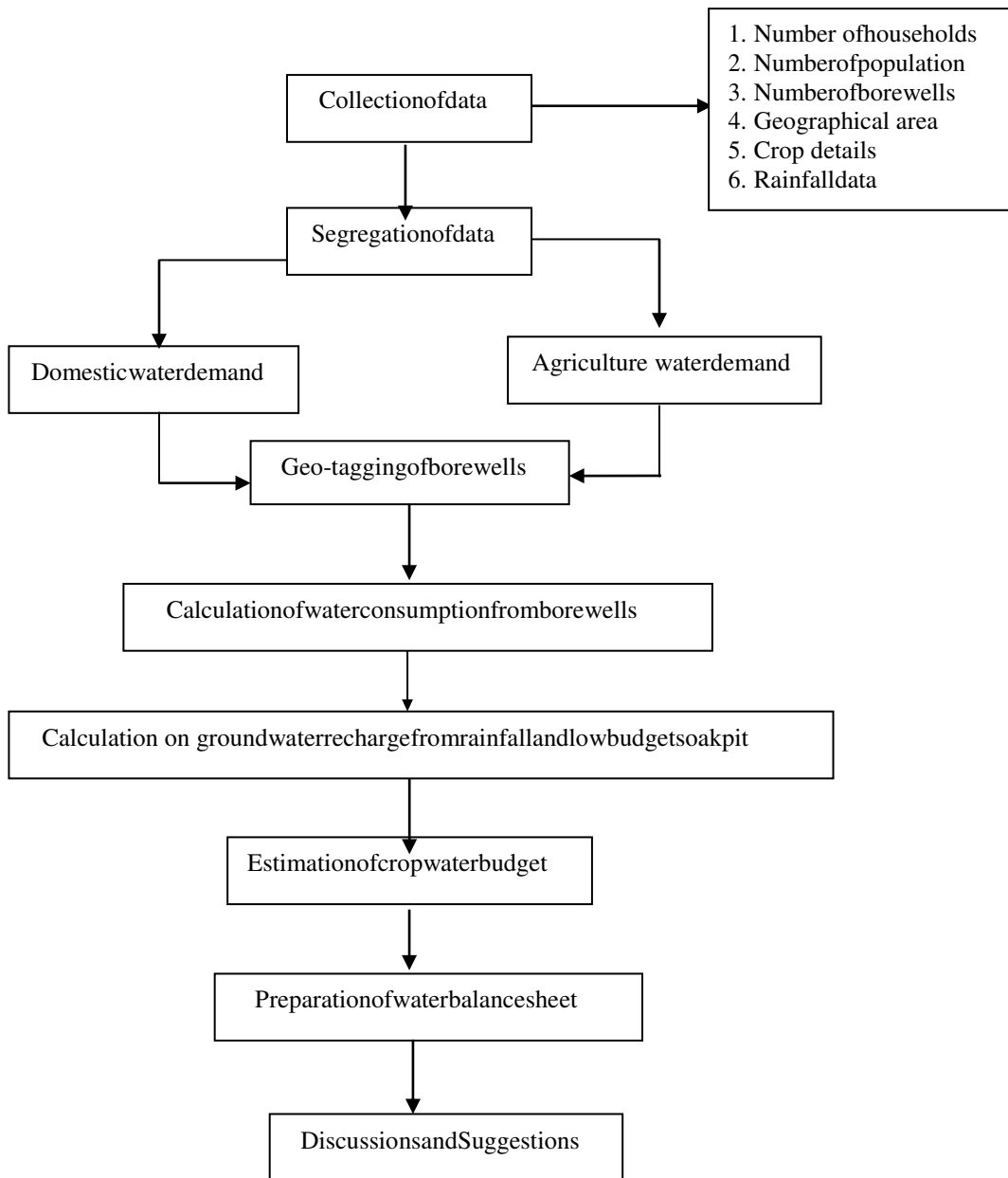


Fig.1. Step by Step process for a detailed study of the groundwater in Musunuru village.



CalculationOfWaterConsumptionFromBorewells

This research carries out the calculation and finds out the water consumption for domestic and agricultural purposes from the village borewells.

Calculation OnGroundwaterRecharge FromRainfallAndLowBudgetSoakPit

This research performs the groundwater recharge estimation from the village rainfall and finds out the efficiency of groundwater recharge by implementing the low-budget soak pit method per annum.

EstimationOfCrop WaterBudget

By studying on major cultivated crops in Musunuru village estimation of crop water requirement is prepared as shown in Table 3.

PreparationOfWaterBalanceSheet

This research performs a water balance sheet for crop water demand, domestic water demand, groundwater recharge percolated from rainfall for the total area (5%), groundwater recharge percolated from the installation of low budget soak pit in Musunuru village.

DiscussionsAndSuggestions

In this study discussions and suggestions have been taken for the better improvement of the research work.

CALCULATIONS

Water demand for Musunuru village

Water requirement in Musunuru village for domestic purpose

Total population = 6,095 Number of households = 1,495

Number of borewells (tubewells) = 453

Average domestic water consumption per each household in Musunuru village = 350 lit/day
Estimated percentage of wastage of water (80%) = 280 lit/day

Total wastage of water per day = $1495 \times 280 = 4,18,600$ lit/day

Total wastage of water per annum = $365 \times 4,18,600 = 15,27,89,000$ lit/year = 152 MLY

Efficiency of groundwater recharge by Soak pit method (80 – 90%) = $0.85 \times 4,18,600 = 3,55,810$ lit/day
Efficiency of groundwater recharge by Soak pit method per annum = $3,55,810 \times 365 = 12,98,70,650$ lit/year = 129.87 MLY

Water requirement in Musunuru village for agricultural Purpose

Geographical area of Musunuru village = 5461.3 acres
Wetland of Musunuru village = 851.31 acres

Dryland of Musunuru village = 3960.58 acres

Total Agricultural area (cropped area) = 4811.89 acres

= 1948.13 Ha



Rainfall data in Musunuru village

Average rainfall data for last five years in Musunuru village = 822.50 mm

Average quantity of water obtained from the rainfall = $16016579.64 \text{ m}^3 = 16016579.64 \times 1000 = 16016.57 \text{ MLY}$
Average groundwater recharge in Musunuru village = 5%

Quantity of water percolated from rainfall for agricultural area in Musunuru village = 800.82 MLY
Quantity of water from rainfall for total area in Musunuru village = 18178.16 MLY

Quantity of water percolated from rainfall for total area in Musunuru village = 908.908 MLY

Table 3. Water requirement for agriculture area in Musunuru village.

S. No	Crop	Area (ha)	Area (ha)	Area (ha)	Water requirement (for crop growth in mm/ha)	Total water requirement (mm/ha)
1	Paddy	232	28	260	1240	322400
2	Palmoil	158	158	316	900	284400
3	Cotton	150	0	150	1300	195000
4	Banana	79	22	101	2200	222200
5	Maize	40	180	220	800	176000
6	Chillies	20	65	85	500	42500
7	Guava	18	4	22	432	9504
8	Groundnut	10	2	12	700	8400
	Total			1166		1260404

Total water demand for all these seasonal crops = 829.08 MLY

RESULTS

The water budget sheet is prepared by comparing both negative water demand and positive water demand for the Musunuru village as shown in Table 4.

Table 4. Water budget sheet.

Water requirement data	Negative water demand	Positive water demand
Crop water demand	830 MLY	0
Domestic water demand	152 MLY	0
Ground water recharge percolated from rainfall for total area (5%)	0	908.908 MLY
Ground water recharge percolated from the installation of soak pit	0	129.87 MLY
Total water	-982 MLY	+1038.778 MLY



CONCLUSION

This study identifies the water demand in Musunuru village and installation of a low-cost soak pit method to recharge the groundwater that costs around 2000 rupees which serves a period of around 10-20 years. It recharges about 130 million liters per year. It calls for a periodic renovation for every six months and it could take a tough attempt to clean the soak pit. Based on this study this paper suggests that this method of disposing of the wastewater in rural regions is effective and gives the top result of recharging the groundwater table. By using this method, the trouble of unhygienic circumstances close to the houses is prevented and the production of mosquitoes is avoided. Hence the one of a kind illness came about due to unhygienic situation and mosquitoes are averted. This method offers a healthful lifestyle to human beings living in that particular vicinity.

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Groundwater Assessment: A Case Study in Patna and Gaya District of Bihar, India

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Abstract – Assessment of groundwater is an effective tool for proper planned and optimal utilization of water resources in the context of future national requirement and expected impact of climate changed, its variability is critical for relevant national and regional long term development strategies and sustainable development. Our main purpose for the assessment of groundwater in Patna and Gaya district is to compute a complete evaluation of groundwater resources and produce information that can be incorporated for future requirement. The study was undertaken based on the recommendation of groundwater estimation committee, 1997 (GEC-97). Methodology used the estimation of annual groundwater recharge from rainfall and other sources, including irrigation, water bodies and artificial recharge, determination of present status of groundwater utilization and categorization of assessment units based on the level of groundwater utilization and long- term water level trend. Water level fluctuation techniques and empirical norms were used for recharge estimation. The data collected for investigation were water table fluctuation data, rainfall data cropping pattern, number of groundwater structures, hydrogeology of area, specific yield, groundwater draft, pond area etc. The study computes the following result for Patna District and Gaya District respectively. Total annual groundwater recharge is 91924.33 ha-m and 98648.29 ha-m, net annual replenish able groundwater resource is 82731.93 ha-m and 88783.47 ha-m, groundwater draft for all uses is 47328.6 ha-m and 43140.2 ha-m. The net annual groundwater available for future irrigation development is 35403.325 ha-m and 45643.27 ha-m. The stage of groundwater development is 57.20 % and 48.59 % which falls in safe category for both. The study recommended that there is a good scope for future groundwater development and keeping in view of rapid increase in groundwater draft, roof top rainwater harvesting needs to be taken up to recharge the aquifer in Patna and Gaya district particularly in urban areas.

Keywords- Groundwater, Irrigation.

INTRODUCTION

Groundwater, which is 38.5 % of the available water sources of the country, plays a major role in irrigation, rural and urban drinking water supply and industrial development. Groundwater meets nearly 55% irrigation, 85 % of rural and 50 % of urban and industrial needs (Government of India 2007). Groundwater resources are under increasing pressure caused over-exploitation of groundwater for meeting the rising demand from agriculture and rapid growth in urbanization and industrialization. Over- exploitation of groundwater leads to: reduction in water yield in the well. Access to groundwater can be a major engine for food security, poverty alleviation and economic development in the rural areas. The effective management and utilization of groundwater not only as a source of water for agriculture and other consumptive purposes, but also as a supplementary source of surface water flows, wetlands and wildlife habitats. The ground water management is the major challenge facing the water resources because once it modified and contaminated, groundwater can be very costly and difficult to restore.

The Bihar state forms a part of mid-Ganga plain. About 33% of the geographical area of the state in the south of the Ganga River is covered by alluvial deposits often referred to as marginal alluvial plain. Bihar is becoming very important state for pushing agriculture production of the country. The stage of ground water development in the state is only 39%. In light of the above mentioned points this study is taken up to assess the ground water situation of Patna and Gaya district which is located in south of Bihar.



METHODOLOGY

The methodology used for ground water resource assessment is based on the recommendation of ground water estimation committee, 1997 (GEC-97). The basic principle followed in this methodology is the estimation of annual groundwater recharge from rainfall and other sources, including irrigation, water bodies and artificial recharge, determination of present status of groundwater utilization and categorization of assessment units based on the level of groundwater utilization and long-term water level trend. These estimations are widely used in formulating various groundwater development and management plans.

Physiographic and soils

Patna and Gaya district is situated in the south Bihar alluvial plains (Zone III B) of divided Bihar. This zone is located in south of river Ganga. The Patna district has mainly four types of soil ranging from moderately well drain to poorly drain, acidic to slightly alkaline and medium to heavy texture while Gaya district consists mainly calcareous alluvial soil. It is deficient in nitrogen, phosphoric acid and humus texturally the soils are sandy to loam and the ph value is on the alkaline side.

Irrigation structures

There are 4971 dug wells, 27930 shallow tube wells and 308 deep tube wells in Patna district. Similarly for Gaya district there are 17882 numbers of dug wells, 24810 numbers of shallow tube wells and 59 deep tube wells.

Cropping pattern

Cultivation is practice in all three cropping seasons i.e. rabi (66.62%), kharif (57.8%) and summer (2.38%) in its net cultivated area. The main crops of Patna district are wheat, paddy, maize, mustard, sunflower, chickpea, arhar and vegetables. Agriculture is main occupation of Gaya district. Cultivation is in practice in all three cropping season. The main crops of Gaya district are paddy, wheat, potato, lentils, sorghum, millet, cowpea, ground nut.

Specific yield

It is defined as the actual volume of water that can be extracted by the force of gravity from a unit volume of aquifer material is known as the specific yield.

Net ground water availability

It is the difference of annual ground water recharge and natural discharge during non-monsoon season. An allowance is kept for natural discharge in the non-monsoon season by deducting 5 % of total annual ground water recharge, of water table fluctuation method is employed to compute rainfall recharge during monsoon season and 10 % of the annual ground water recharge if rainfall infiltration method is employed.

Table.1 Ground water resource and development potential of Patna and Gaya districts of Bihar (ha-m)

S. No.	Component	District	
		Patna	Gaya
1.	Recharge from rainfall during monsoon season	68517.79	74213.26
2.	Recharge from other sources during monsoon season	6298.525	5868.82
3.	Recharge from rainfall during non-monsoon season	10636.99	12526.88
4.	Recharge from other sources during non-monsoon season	6471.05	6039.34
5.	Total annual ground water recharge	91924.36	98648.29
6.	Natural discharge during non-monsoon season	9192.43	9864.83
7.	Net ground water availability	82731.93	88783.47
8.	Existing ground water draft for irrigation	40152.6	37309.2
9.	Existing ground water draft for domestic and industrial water supply	7176	5831
10.	Existing gross ground water draft for all uses	47328.6	43140.2
11.	Net ground water availability for future irrigation development	35403.33	45643.27
12.	Stage of ground water development (%)	57.20	48.59
13.	Category	Safe	Safe



CONCLUSION

The details of various components of ground water recharge in Patna and Gaya district are depicted in Table 1. Data shows that total annual ground water recharge is 91924.33 ha- m and 98648.29 ha-m for Patna and Gaya district respectively. The existing ground water draft for irrigation is 40152.6 ha-m for Patna district and 37309.2 ha-m for Gaya district. The ground water draft for all uses is 47328.6 ha-m for Patna district and 43140.2 ha-m for Gaya district. The net annual replenish able ground water resource is worked out to be 82731.93 ha-m for Patna district and 88783.47 ha-m for Gaya district. The net annual ground water available for future irrigation development is 35403.325 ha-m for Patna district and 45643.27 ha-m for Gaya district. The stage of ground water development is 57.20 % for Patna district and 48.59 % for Gaya district. According to definitions used by CGWB both Patna Gaya district falls in safe category.

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Comparative Study of Design Charts for Flexible Pavement

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Abstract- Various methods for development of design charts have been discussed. In Group Index Method the total thickness of pavement (surfacing, base and sub-base) is determined. Also the thickness of sub-base is determined. The CBR method is probably the most widely used method for the design of flexible pavement. The CBR method is based on strength parameter of the material and is, therefore, more rational than the Group Index Method. North Dakota Method is similar to the CBR method. Pavement thickness is found from the design curve which is between pavement thickness and cone bearing ratio. The Burmister's Design Method is based on the concept of two-layer system, consisting of road surfacing, base course and the sub-base as top layer of thickness h , and the sub-grade as bottom layer of infinite extent. In this method, the thickness corresponding to deflection of 5 mm has been recommended by Burmister as the required thickness of pavement. U.S. Navy Plate Bearing Test Method is also based on Burmister's two-layer theory. This method uses modulus of elasticity of base course and sub-grade. California Resistance Value Method uses California Resistance value, called R-value. In McLeod Method curves are plotted between depth of construction and CBR for traffic conditions. Maharaj and Gill have performed axisymmetric finite element analysis by varying different parameters to develop design charts. The parameters varied are thickness of pavement, pressure and elastic modulus of subgrade. Based on finite element analysis varying above parameters four types of design charts have been developed. Each of the design charts has three parameters. For two known parameters, the third parameter can be obtained.

Keywords: Design Chart, Finite Element Analysis, CBR, Group Index Method, Thickness.

INTRODUCTION

The flexible pavements consist of wearing surface built over a base course and they rest on compacted subgrade. The design of a flexible pavement is based on the principle that a surface load is dissipated by carrying it deep into the ground through successive layer of granular materials. Flexible pavements with a asphalt concrete surface courses reused all around the world.

LITERATURE REVIEW

Khan (1998) describes the Group Index Method and California Bearing Ratio Method for design of flexible pavements. In Group Index Method the thickness is obtained by first determining the Group Index of soil. The curves are plotted between Group Index of subgrade and thickness for various traffic conditions. In California Bearing Ratio Method, the curves are plotted between California Bearing Ratio Percent and depth of construction.

Arora (2003) have reported various methods for design of flexible pavements. These various methods are Group Index Method, CBR Method, California Resistance Value Method and McLeod Method. In the Group Index Method, the thickness of base and surfacing is related to the volume of traffic. In CBR Method the curves are plotted between CBR and pavement thickness for light, medium and heavy traffic. California Resistance Value Method uses California Resistance value, called R-value. In McLeod Method curves are plotted between depth of construction and CBR for traffic conditions.



Punmia et. al (2005) have reported stresses in homogeneous mass; elastic deformation under circular load and Burmister analysis for flexible pavement. Charts for vertical deflections have been developed. The design curves by Group Index Method and California Bearing Ratio Method have been developed. In Group Index Method, the curves are plotted between Group Index and thickness. In California Bearing Ratio Method curves are plotted between thickness of construction and California Bearing Ratio.

Subagio et.al (2005) discusses a case study for multi-layer pavement structural analysis using methods of equivalent thickness. An approximate method has been developed to calculate stresses and strains in multilayer pavement systems by transforming this structure into an equivalent one-layer system with equivalent thicknesses of one elastic modulus. This concept is known as the method of equivalent thickness which assumes that stresses and strains below a layer depend on the stiffness of that layer.

Das (2008) discusses the reliability issues in bituminous pavement design, based on mechanistic-empirical approach. Variabilities of pavement design input parameters are considered and reliability, for various proposed failure definitions, of a given pavement is estimated by simulation as well as by analytical method. A methodology has been suggested for designing bituminous pavements for a given level of overall reliability by mechanistic empirical pavement design approach.

Tarefderet.al (2010) present that reliability is an important factor in flexible pavement design to consider the variability associated with the design inputs. In this paper, subgrade strength variability and flexible pavement designs are evaluated for reliability. Parameters such as mean, maximum likelihood, median, coefficient of variation, and density distribution, function of subgrade strength are determined. Design outputs are compared in terms of reliability and thickness using these design procedures. It is shown that the AASHTO provides higher reliability values compared to the probabilistic procedure. Finally, the reliability of the flexible pavement design is evaluated by varying hot mix asphalt properties. Alternative designs are recommended for the existing pavement thickness by modifying material and subgrade properties to mitigate different distresses.

According to Rahman et. al (2011), design of flexible pavement is largely based on empirical methods using layered elastic and two-dimensional finite element analysis. Currently a shift is underway towards more mechanistic design techniques to minimize the limitations in determining stress, strain and displacement in pavement analysis. In this study, flexible pavement modeling is done using ABAQUS software in which model dimensions, element types and meshing strategies are taken by successive trial and error to achieve desired accuracy and convergence of the study.

Ameri et. al (2012) have used finite element method to analyse and design pavements. Finite element method is able to analyse stability, time dependent problems and problems with material nonlinearity. In this paper, a great number of the prevalent pavements have been analyzed by means of two techniques: Finite element method and theory of multilayer system. Eventually, from statistical viewpoint, the results of analysis on these two techniques have been compared by significance parameter and correlation coefficient. The results of this study indicate that results of analysis on finite elements are most appropriately compiled with results from theory of multilayer system and there is no significant difference among the mean values in both techniques.

Jain et. al (2013) discuss about the design methods that traditionally being followed and examine the "Design of rigid and flexible pavements by various methods and their cost analysis by each method". Flexible pavements are preferred over cement concrete roads as they have a great advantage that these can be strengthened and improved in stages with the growth of traffic and also their surfaces can be milled and recycled for rehabilitation. The flexible pavement is less expensive also with regard to initial investment and maintenance. Although rigid pavement is expensive but less maintenance and have good design period. It is observed that flexible pavements are more economical for lesser volume of traffic. The life of flexible pavement is near about 15 years whose initial cost is less needs a periodic maintenance after a certain period and maintenance costs very high. The life of rigid pavement is much more than the flexible pavement of about 40 years, approximately 2.5 times life of flexible pavement whose initial cost is much more than flexible pavement but maintenance cost is very less.



Dilip et.al (2013) discuss the uncertainty in material properties and traffic characterization in the design of flexible pavements. This has led to significant efforts in recent years to incorporate reliability methods and probabilistic design procedures for the design, rehabilitation, and maintenance of pavements. This study carries out the reliability analysis for a flexible pavement section based on the first-order reliability method and second-order reliability method techniques and the crude Monte Carlo Simulation. The study also advocates the use of narrow bounds to the probability of failure, which provides a better estimate of the probability of failure, as validated from the results obtained from Monte Carlo Simulation.

Dr. Arora (2014) performed axisymmetric finite element analysis by varying different parameters to develop design charts. The parameters varied are thickness of pavement, pressure and elastic modulus of subgrade. The pavement and base course has been idealized as a linear elastic material while the subgrade has been idealized as a nonlinear material by Drucker-Prager yield criterion. The pavement, base course and soil have been discretized by four nodal isoparametric finite elements. Four types of design charts have been developed. Each of the design charts has three parameters. For two known parameters, the third parameter can be obtained.

Based on literature review it is found that very few literatures are available on design chart of flexible pavements. Important design charts have been discussed in the following section.

IMPORTANT METHODS FOR DEVELOPMENT OF DESIGN CHARTS FOR FLEXIBLE PAVEMENT

Group Index Method

The group index method was suggested by the Highway Research Board for making an approximate estimation of thickness of the pavement. The strength of the subgrade is determined by the group index method. The higher the group index of subgrade, the lower its strength and the greater the thickness of sub base required. Fig.1 gives the designed charts. The description of the various curves in the design charts are as follows:

Curve A: Thickness of sub-base required.

Curve B: Total thickness of surface, base and sub-base for light

traffic. Curve C: Total thickness of surface, base and sub-

base for medium traffic. Curve D: Total thickness of surface, base and sub-base for heavy traffic.

Curve E: Thickness as additional base which may be substituted for sub-base of curve

A Light traffic = < 50 commercial vehicles/day

Medium traffic = 50-300 commercial

vehicles/day Heavy traffic = > 300

commercial vehicles/day.

California Bearing Ratio (CBR) Method

The method combines a load penetration test performed in the laboratory or in-situ with the empirical design charts to determine the thickness of pavement and of its constituent layers. This is probably the most widely used method for the design of flexible pavement. The thickness of the different elements comprising a pavement is determined by CBR values. The California bearing ratio, abbreviated as CBR is defined as the ratio of the test load to the standard load, expressed as percentage, for a given penetration of the plunger.

$$CBR = (\text{Test load} / \text{standard load}) \times 100$$

Generally CBR values of both soaked as well as unsoaked samples are determined. The CBR values are usually calculated for penetration 2.5 mm and 5 mm. Generally the CBR values at 2.5 mm penetration will be greater than that at 5 mm penetration and in such case the former is to be taken as the CBR value for design purposes. If the CBR value corresponding to a penetration of 5 mm exceeds that for 2.5 mm, the test is repeated. If identical results follow, the bearing ratio corresponding to 5 mm penetration is taken for design. Fig.2 gives the design charts for determining the appropriate thickness of construction required above a material with a given CBR, for different wheel loads and traffic conditions. These design charts for roads have been proposed by the Road Research Laboratory, England, and are also followed in India.



North Dakota Method

This method, similar to the CBR method has been developed by the North Dakota State Highway Department. The method consists in finding out the in-situ bearing power of the subgrade by means of a cone penetrometer, of the North Dakota Cone apparatus. The thickness is then found from the design chart (Fig.3). The North Dakota cone apparatus consists essentially of a shaft with a sharp cone attached to lower end. The movement of the shaft into the soil measured with the help of a vernier. The load carried by the shaft, during penetration into the soil, divided by the area of the cone at the surface level is termed as the cone bearing value, q_c . Knowing the bearing value, the thickness of pavement is determined from Fig.3. A minimum thickness of 24 cm is provided for bearing values of 28 kg/cm^2 or more.

Burmister's Design Method

Burmister's design method is based on the concept of a two-layer system, consisting of the road surfacing, base course and the sub-base as the top layer of thickness h , and the subgrade as the bottom layer of infinite extent. The displacement of such a system, under a loaded area of radius a with load intensity p is given by

$$\Delta = 1.5(p a / E_2) F$$

Where E_2 = modulus of elasticity of the subgrade F = deflection factor, determined from Fig.4.

The method consists in selecting various values of thickness h of the top layer and finding the value of the deflection corresponding to each value of h from above equation, the value of factor F being taken in each case from Fig.4. The thickness h corresponding to an arbitrary deflection of 5 mm has been recommended by Burmister as the required thickness of pavement. Tentative design curves for flexible runway pavement, using 5 mm as limiting deformation have been drawn assuming approximate value of modulus of elasticity for various types of sub-grades.

U.S Navy Plate Bearing Test Method

This method is also based on Burmister's two layer theory. It has the following steps:

Step 1. The thickness h of the base course is calculated on the basis of the two-layer theory. From two plate bearing tests the values of modulus of elasticity E_1 and E_2 for the base course and sub-grade are determined. It is necessary first of determining the value of E_2 by the plate bearing tests on the sub-grade. A 30 inch diameter plate is recommended for this test. The load P corresponding to a deflection of 0.2 inch is determined from the test, and the modulus of elasticity E_2 is calculated from following equation by taking the plate to be rigid.

$$\Delta = 1.18(p a / E_2) F$$

Where F is the deflection factor depending upon E_2/E_1 ratio. p is pressure and a is radius. From above equation

$$F = (\Delta \cdot E_2) / (1.18 p a)$$

After having known E_2 and E_2/E_1 , the value of F corresponding to a given wheel load intensity is computed from equation

$$\Delta = 1.5(p a / E_2) F, \text{ by taking } \Delta = 0.2 \text{ inch}$$

$$\Delta = 0.2 \text{ inch} = 1.5(p a / E_2) F$$

In this equation Δ , E_2 , p and a are known. Knowing F and E_2/E_1 ratio, the thickness h of the base course is determined from Fig.4.

Step 2. In the next step, trial sections are constructed of thickness h , $(2/3)h$ and $(3/2)h$. Each trial section of a given thickness is constructed for three different soil conditions. Thus, in all, nine trial sections are built.

Step 3. Plate bearing tests are performed on these trial sections. The data then are used to determine the required pavement thickness which will result in the assumed deflection of 0.2 inch.

Maharaj and Gill Method



Axisymmetric finite element analysis has been done by varying different parameters to develop design charts. The parameters varied are thickness of pavement, pressure and elastic modulus of subgrade. The pavement and base course has been idealized as linear elastic material while the subgrade has been idealized as nonlinear material by Drucker-Prager yield criterion. The pavement, base course and soil have been discretized by four noded isoparametric finite elements. First type of design chart has been plotted between thickness of pavement and nodal deflections for various pressures for a particular elastic modulus of soil. Second type of design chart has been plotted between thickness of pavement and element stress for various pressures for a particular elastic modulus of soil. The third type of design chart has been plotted between thickness of pavement and nodal deflections for various elastic moduli of subgrade for a particular pressure. Fourth type of design chart has been plotted between thickness of pavement and element stress for various elastic moduli of subgrade for a particular pressure. Each of the design charts has three parameters. For two known parameters, the third parameter can be obtained. From the design charts developed, the effect of thickness, elastic modulus of soil and pressure on nodal deflection and element stress has been studied. Typical design charts for pavement thickness and element stress for various pressures for a particular elastic modulus of subgrade have been shown below:

CONCLUSIONS

The advantages of Group Index Method are that the total thickness of pavement (Surfacing, base and subbase) is determined. Also the thickness of subbase is determined.

Higher the group index, poorer is the sub-grade and lower the group index, stronger is the subgrade. The CBR method is probably the most widely used method for the design of flexible pavement. The CBR method is based on strength parameter of the material and is, therefore, more rational than the Group Index Method. The shortcoming of the method is that it gives the same total thickness above a material irrespective of the quality of the overlying layers. North Dakota Method is similar to the CBR method. Pavement thickness is found from the design curve which is between pavement thickness and cone bearing ratio. The Burmister's Design Method is based on the concept of two-layer system, consisting of road surfacing, base course and the sub-base as top layer of thickness h , and the sub-grade as bottom layer of infinite extent. In this method, the thickness corresponding to deflection of 5 mm has been recommended by Burmister as the required thickness of pavement. U.S. Navy Plate Bearing Test Method is also based on Burmister's two-layer theory. This method also uses modulus of elasticity of base course and sub-grade. California Resistance Value Method uses California Resistance value, called R-value. In McLeod Method curves are plotted between depth of construction and CBR for traffic conditions. Maharaj and Gill have performed axisymmetric finite element analysis by varying different parameters to develop design charts. The parameters varied are thickness of pavement, pressure and elastic modulus of subgrade. The finite element method is a versatile tool for solving complex problems like various layers of pavement. Four types of design charts have been developed. First type of design chart has been plotted between thickness of pavement and nodal deflections for various pressures for a particular elastic modulus of soil. Second type of design chart has been plotted between thickness of pavement and element stress for various pressures for a particular elastic modulus of soil. The third type of design chart has been plotted between thickness of pavement and nodal deflections for various elastic moduli of subgrade for a particular pressure. Fourth type of design chart has been plotted between thickness of pavement and element stress for various elastic moduli of subgrade for a particular pressure. Each of the design charts has three parameters. For two known parameters, the third parameter can be obtained.

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Self-Healing of Cracked Concrete by Bacterial Method

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ABSTRACT: Crack occurrence in reinforced concrete should be minimized for both durability and economical reasons as crack repair is costly. Autogenously repair, or self-healing, of concrete would save a substantial amount of money, as manual inspection and crack repair could be minimized. Thus, a reliable self-healing mechanism for concrete would not only result in more durable structures, but would also be beneficial for the global economy. This study exploited the potential to apply calcite-precipitating bacteria as a crack-healing agent in concrete. The potential of different species to precipitate calcite, produce end spores, survive concrete-production, and heal cracks by sealing them with calcite was investigated. Furthermore, the mechanical properties of 'bacterial concrete' were tested. ESEM studies showed that alkali-resistant spore-forming bacteria embedded in the concrete matrix can precipitate substantial amounts of calcite. The bacterial approach thus seems a highly promising mechanism to mediate self-healing in concrete structures.

Keywords: self-healing, crack-healing agent, bacterial concrete, ESEM.

INTRODUCTION

Cracks can occur in concrete structures due to multiple reasons such as autogenous shrinkage, freeze-thaw reactions, mechanical compressive- and tensile forces. Although micro-cracks do not necessarily result in significant strength loss of concrete, the ingress of water and other reactive chemicals such as chloride and water may pose a threat to the steel reinforcement as these strongly enhance its corrosion rate. Thus for durability reasons and potential repair costs, crack occurrence should be minimized or, alternatively, occurring cracks should ideally be healed directly after formation by an autonomous repair mechanism. Different autonomous repair systems are feasible. One such a self-healing mechanism could involve secondary hydration reactions of still present but not fully reacted cement particles. Although a high percentage of non-reacted cement particles within its matrix may result in a concrete with a substantial self-healing capacity, the material characteristics of the initial concrete structure may not be satisfactorily as it may be more brittle and initially weaker as wanted. Another self-healing mechanism could be based on the addition of a self-healing agent that would make up a part of the concrete matrix without or insignificantly affecting its structural and mechanical characteristics. In this study the potential of bacteria to act as a self-healing agent in concrete is investigated. Although the idea to use bacteria and integrate them in the concrete matrix may seem odd at first, it is not from a microbiological viewpoint. Bacteria naturally occur virtually everywhere on earth, not only on its surface but also deep within, e.g. in sediment and rock at a depth of more than 1 km (Jorgensen & D'Hondt 2006). Various species of so-called extremophilic bacteria, i.e. bacteria that love the extreme, are found in highly desiccated environments such as deserts (Dorn & Oberlander 1981; DeLaTorre et al 2003), but also inside rocks (Fajardo-Cavazos & Nicholson 2006) and even in ultra-basic environments (Pedersen et al 2004; Sleep et al 2004) which can be considered homologous to the internal concrete environment. Typical for many desiccation- and/or alkali-resistant bacterial species is their ability to form endospores. These specialized cells are characterized by an extremely low



metabolic activity, are known to be able to resist high mechanically- and chemically induced stresses (Sagripani & Bonifacino 1996) and are viable for periods up to 200 years (Schlegel 1993). In some previously published studies the application of bacteria for cleaning of concrete surfaces (DeGraef et al 2005) and strength improvement of cement-sand mortar (Ghosh et al 2005) was reported. Furthermore, in some studies the crack-healing potential by mineral-precipitating bacteria on degraded limestone (Dick et al 2006) and ornamental stone surfaces (Rodriguez-Navarro et al 2003) as well as on concrete surfaces (Bang et al 2001; Ramachandran et al 2001) was investigated and reported. Although promising results were reported, the major drawback of the latter studies was that the bacteria and compounds needed for mineral precipitation could only be applied externally on the surface of the structures after crack-formation had occurred. This methodological necessity was mainly due to the limited lifetime (hours to a few days) of the (urease-based) enzymatic activity and/or viability of the applied bacterial species. In the present study the application of alkali-resistant spore-forming bacteria to enhance the self-healing capacity of concrete is investigated. Tensile- and compressive strength characteristics of reference (no bacteria added) and bacterial concrete are quantified. Furthermore, the viability of bacteria immobilization in concrete is quantified and, finally, calcite precipitation potential of bacterial concrete is demonstrated by ESEM analysis.

METHODS

Cultivation of alkali-resistant spore-forming bacteria:

Four strains of alkaliphilic spore-forming bacteria were purchased from DSMZ (German Collection of Microorganisms and Cell Cultures), Braunschweig, Germany: *Sporosarcina pasteurii* DSM 33; *Bacillus cohnii* DSM 6307; *Bacillus halodurans* DSM 497 and *Bacillus pseudofirmus* DSM 8715 and cultivated according to the suppliers recommendations (medium DSMZ-2 for *S.pasteurii* and DSMZ-31 for the others).

Endospore-forming potential was determined in mineral medium. This medium contained per liter of Milli-Q ultra pure water: 0.2g NH₄Cl, 0.02g KH₂PO₄, 0.225g CaCl₂, 0.2g KCl, 0.2g MgCl₂.6H₂O, 1 ml per liter trace elements solution SL12B, 0.1g yeast extract, 6.45g citric acid trisodium salt and 8.4g sodium bicarbonate. The pH of this medium was 9.2. Aerobic batch cultures were incubated in 2-l Erlenmeyer flasks on a shaker table at 150 rpm. Growth was monitored by microscopy and cell numbers and percentage of sporulating cells were quantified by microscopy using a Burger-Turk counting chamber.

Preparation and strength characteristics of bacterial concrete:

Concrete bars with and without (control) added bacteria were prepared for tensile- and compressive strength determination. The aim of these tests was to check whether the strength of the concrete was not negatively affected by the bacteria. Firstly, for the preparation of bacterial concrete, a dense culture of *S.pasteurii* was obtained after growth in medium DSMZ-2. Total cell number was quantified by microscopy using a Burger-Turk counting chamber. Subsequently, cells were washed twice by centrifugation (20 min x 10000g) and resuspension of the cell pellet in tap water. Washed cells were finally re-suspended in a 20-ml aliquot of tap water. This cell suspension was applied as part of the needed water for concrete bar preparation.

Concrete bars for tensile- and compressive strength determination were prepared as follows. Two sets (bacterial concrete and control concrete without bacteria) of nine bars each (bar dimensions 16 x 4 x 4 cm) were made using ordinary portland cement (ENCI CEMI 32.5R), a water-cement ratio of 0.5 and aggregate composition (sand and gravel) as listed in Table 1. The bars were initially cured for 24 hours in plastic foil-sealed molds at room temperature, subsequently uncased and further cured in tap water-filled separate plastic containers at room temperature. Subsets of three bars each were tested for flexural tensile- and compressive strength after 3, 7 and 28 days curing following the procedure according to EN 196-1 Standard Norm.

Table 1. Cement, water and aggregate composition needed for the production of 9 concrete bars of dimensions 16 x 4 x 4 cm used for tensile- and compressive strength characterization of bacterial- and control (no bacteria added) concrete. For bacterial concrete, the 20-ml cell suspension was part of the total water volume needed.



Compound / Aggregate size (mm):	Weight (g):
Cement (ENCI CEM I 32.5)	1170
Water	585
Aggregate size fraction:	
4 - 8	1685
2 - 4	1133
1 - 2	848
0.5 - 1	848
0.25 - 0.5	730
0.125 - 0.25	396

The viability (ability to germinate) of spores of the alkaliphilic bacterial species *B.cohnii*, *B.halodurans* and *B.pseudofirmus* immobilized in cement stone was determined. Cultures of the respective species were firstly grown in mineral medium (see above). These cultures were washed twice by centrifugation (20 min x 10000g) and resuspension of the cell pellet in tap water after the number of spores formed was quantified by microscopy. Obtained spore suspensions were divided in two parts, one part was stored in a fridge at 4°C and served as non-concrete immobilized control for determination of spore viability during storage (see below), and one part was used for cement stone sample preparation. For the latter, the spore suspension was used as part of the make up water, and bacterial and control (no bacterial spores added) cement stone specimen were prepared. Number of spores added to cement stone as determined by microscopic counting was 10^9 cm^{-3} . Ordinary portland cement (ENCI CEMI 32.5R) and a water-cement ratio of 0.5 was used for the preparation of cement stone disks (4 cm diameter, 1 cm height), cast in plastic vials closed with a plastic lid. After 24 hours curing at room temperature, disks were further cured in tap water at room temperature. Disks were removed from the plastic vial molds after ten days curing, chipped to pieces with a chisel and further crushed to powder using a robust pharmaceutical stone mortar. Powdered cement stone (1.84 g representing 1 cm^3 , containing 10^9 spores) was subsequently slurried and diluted 10-fold by addition of 9 volumes sterile mineral medium. In parallel, the endospore-containing cell suspensions which were kept in a fridge at 4°C were diluted to a spore density of 10^9 ml^{-1} and also 10-fold diluted by addition of 9 ml sterile mineral medium. Cement stone slurries and original spore suspensions were further homogenized by three cycles of vigorous mixing at 2500 rpm and 20 seconds ultrasonic treatment in a Branson 1210, 47 KHz, 80 Watts Ultrasonic bath. Number of viable spores in cement stone slurries and spore suspensions was estimated according to the Most Probable Number (MPN) dilution technique. For this procedure, 8 x 12 wells sterile micro-titer plates were filled with mineral medium, 180 μl per well. Four consecutive wells of the first row were inoculated with 20- μl slurry or control cell suspension aliquots, and these were subsequently serially diluted in ten-fold dilution steps up to the 10^{11} dilution level, leaving the last (12th) row as non-inoculated control to check for medium contamination. Thus, each cement stone slurry and corresponding control cell suspension was serially diluted in four parallel series. During the following incubation period at room temperature, growth occurred in the lower but not in the higher dilution levels due to dilution-to-extinction of the viable cells present in the samples. Growth could easily be determined visually due to increased turbidity of positive wells during the following 2-weeks incubation period. Viable number of cells in cement stone slurries and their corresponding spore suspensions was calculated from the number of positive wells using the MPN computer program of Clarke and Owens (1983).

Calcite precipitation potential of bacterial concrete:

Chips of 10 days cured cement stone samples (see under 2.3) were incubated in rich medium (yeast-extract and peptone based medium) after pasteurizing for 30 min at 70°C. Pasteurization of bacterial and control cement stone chips before incubation was done to inactivate bacteria that potentially came into contact with the cement stone samples during curing period or non-sterile handling of the cement stone samples and chips after curing. As bacterial endospores are not killed by the pasteurization procedure, this treatment ensured that potential differences between control and bacterial concrete samples after incubation were mediated by added bacteria and not by accidentally introduced contaminants. Rich medium contained 5 g peptone, 3 gram yeast extract and 8.4g sodium bicarbonate and had a pH of 8.6. Individual chips were incubated aerobically in 100-ml medium aliquots on a shaker table at 100 rpm at 25°C for 12 days. Chips were rinsed with tap water after incubated



and stored wet in closed plastic vials until ESEM analysis, what was done within two days after incubation without any further treatment. Chips were mounted on a 1-cm² metal support and kept in place with adhesive tape and observed with a Philips XL30 Series Environmental Scanning Electron Microscope.

RESULTS

Cultivation of alkali-resistant spore-forming bacteria

Three out of four strains produced copious spores in mineral medium, except for *S.pasteurii*, which did not grow in this medium. Spore production was considerably less in rich yeast extract- and peptone- containing medium. Percentage of cells with endospores was quantified by microscopic counting, and amounted to 75, 50 and 25% for *B.cohnii*, *B.halodurans* and *B.pseudofirmus* respectively.

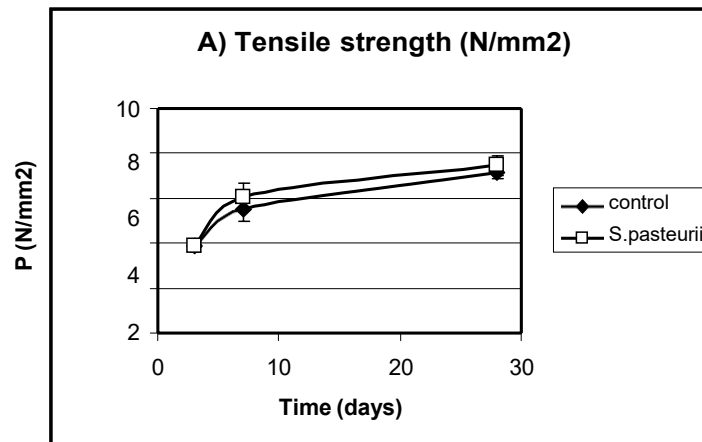
Strength characteristics of bacterial concrete

The 20-ml washed cell suspension of the *S.pasteurii* culture used for the making of bacterial concrete bars contained 3.48×10^{12} cells, what resulted in a final density of 1.14×10^9 cells cm⁻³ concrete. As the average volume of an *S.pasteurii* cell equals about

$2.5 \mu\text{m}^3$, the total cell volume amounts to 0.3% of the bacterial concrete volume. Tensile- and compressive strength tests after 3, 7 and 28 days curing revealed no significant difference between control- and bacterial concrete (Fig 1).

Viability of cement stone-immobilized spores

The number of viable spores in cement stone samples after 10 days curing as well as original spore suspensions, both with a spore density of 10^9 cm⁻³, were estimated (Table 2). Results revealed that about one percent of the spores in the spore suspensions (10^7 ml⁻¹) could be retrieved as viable (Table 2). The number of viable spores in the corresponding cement stone samples appeared significantly lower, i.e. between 10^5 and 10^6 cm⁻³. Compared to spore suspensions, estimated viable spores in cement stone slurries amounted to 1.9, 7.0 and 2.0% for *B.halodurans*, *B.pseudofirmus* and *B.cohnii* respectively. Number of viable bacteria in control cement stone samples (no bacterial spores added) and tap water used for concrete sample preparation were below detection limit (<500 cells cm⁻³).



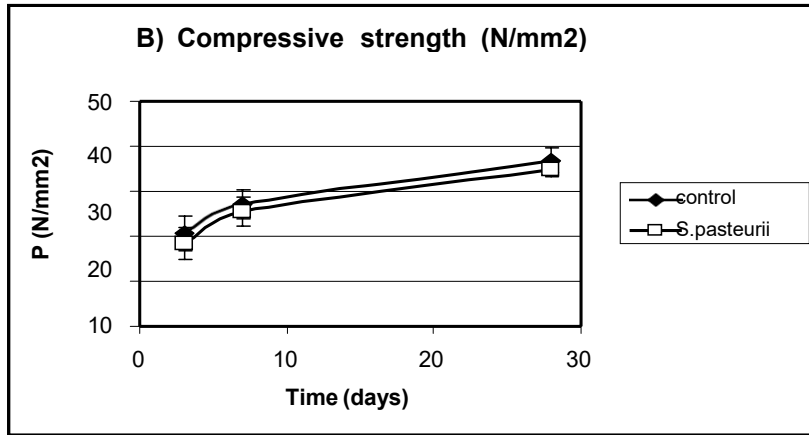


Figure 1. Flexural tensile- (A) and compressive- (B) strength testing, after 3, 7 and 28 days curing, revealed no significant difference between control- and bacterial concrete. The latter contained $1.14 \cdot 10^9$ *S.pasteurii* cells cm⁻³ concrete.

Calcite precipitation potential of bacterial concrete

ESEM analysis revealed that bacterial cement stone, in contrast to control cement stone samples, precipitated substantial amounts of calcite-like crystals on its surface when incubated in peptone- and yeast extract containing medium. An example is shown in Figure 3, depicting control and *B.pseudofirmus* endospore-containing cement stone pieces incubated for 12 days.

DISCUSSION AND CONCLUSIONS

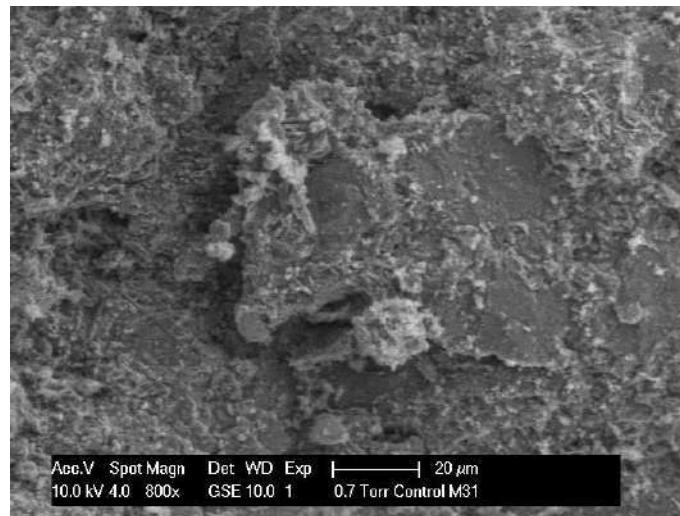
Application of self-healing concrete, i.e. concrete that is able to repair, seal or plug newly formed cracks autogenously, will not only result in more durable structures but will also save a significant amount of money as labor intensive check and repair can be minimized. In this study we investigated the potential of bacteria-mediated calcium carbonate production as a possible healing mechanism. In contrast to some previous studies where bacteria were externally applied for concrete and monument crack repair (Bang et al. 2001; Ramachandran et al. 2001; Dick et al. 2006; Rodriguez-Navarro et al. 2003), we here incorporated bacterial spores, i.e. dormant or resting cells, in the concrete matrix. The results of our study are promising. The estimated number of viable spores retrieved from young cement stone, i.e. after ten days curing, was between 1.9 and 7.0% of the number of viable spores present in the original spore suspension used for the preparation of cement stone samples.

Table 2. Estimate of number of viable (cultivable) bacterial spores in spore suspension and cement stone in which spores of respective bacterial species were immobilized. In brackets: confidence interval; In square brackets: percentage of number in spore suspension.

Spore suspension and tap water (control):	Number cm ⁻³ :
<i>B.cohnii</i>	5.73 E7 (1.76-18.58)
<i>B.halodurans</i>	5.63 E6 (1.74-18.17)
<i>B.pseudofirmus</i>	7.98 E6 (2.63-24.24)
Tap water (control)	< 500
Cement stone samples:	
<i>B.cohnii</i>	1.15 E6 (3.80-34.80) [2.0]
<i>B.halodurans</i>	1.07 E5 (0.36-3.20) [1.9]
<i>B.pseudofirmus</i>	5.62 E5 (1.74-18.14) [7.0]
Control	< 500



These numbers are substantial, considering the mechanical forces (grinding) needed to liberate and suspend the cement stone-immobilized bacterial spores. Moreover, even if the percentages retrieved reflect truly viable spores, absolute numbers are still high, i.e. between 1.7 and 7.5×10^7 spores cm^{-3} cement stone, realizing that one viable cell is theoretically enough to start microbial growth and calcite precipitation, providing that suitable conditions prevail. Incubation experiments with 10-days cured cement stone samples demonstrated the mineral precipitation potential of bacterial concrete. We hypothesize that the actual bacterial mineral precipitation mechanism is as follows. Once into contact with copious amounts of water and growth substrates (yeast extract and peptone), bacterial endospores germinate and start to produce CO_2 due to metabolic turnover of growth substrates. CO_2 , what can locally reach high concentrations due to rapid metabolic conversion of organic compounds, will chemically react with $\text{Ca}(\text{OH})_2$ produced from C_2S and C_3S hydration reactions. The $\text{Ca}(\text{OH})_2$ that leaks out of the concrete's pore system reacts with CO_2 and precipitates as calcite or any other calcium carbonate based mineral. The calcite-like crystals found on the surface of bacterial- but not on the surface of control cement stone samples support this hypothesis.



A: Control

B: + Bacteria

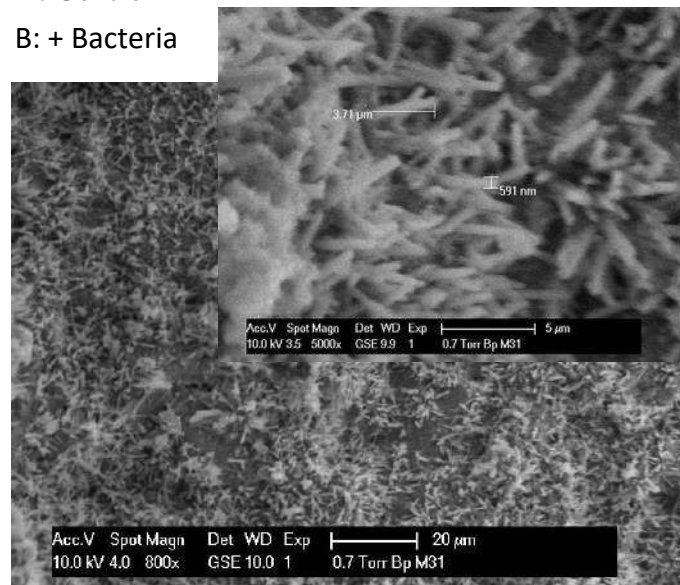




Figure 2. Concrete samples incubated in yeast extract- and pep- tone-containing medium. A: Control (concrete with no bacteria added) and B: Concrete containing 10^9 cm^{-3} *B.pseudofirmus* endospores. The inset in Figure 2B (5000x magnification) shows a close up of the massive calcite-like crystals formed on the concrete surface.

The experiments done in this study show that al- kaliphilic endospore-forming bacteria integrated in the concrete matrix can actively precipitate calcium carbonate minerals. Water, needed for the activation of endospores, can enter the concrete structure through freshly formed cracks. Furthermore, for mineral precipitation, active cells need an organic substrate that can metabolically be converted to in- organic carbon what can subsequently precipitate with free calcium to calcium carbonate. Free cal- cium is usually present in the concrete matrix, but organic carbon is not. In the present experiments or- ganic carbon was applied externally as a part of the incubation medium, while ideally it should also be part of the concrete matrix.

In that case only external water is needed to activate the concrete-immobilized bacetria which can then convert organic carbon present in the concrete ma- trix to calcium carbonate and by doing so seal freshly formed cracks. We currently investigate which specific kind of organic compounds are suit- able to include in the concrete matrix. This is cer- tainly not trivial as such compounds should be a suitable food source for bacteria as well as be com- patible with concrete. Certain classes of organic compounds are less- or not suitable at all, e.g. com- pounds such as carbohydrate derivatives that are known to inhibit the setting of concrete even at low concentrations. We furthermore presently investigate the long-term viability and potential possibilities to increase the viability of concrete immobilized en- dospores to ensure long-lasting bacterially enhanced self-healing. Other ongoing investigations address the possible decrease in concrete permeability and the change of mechanical characteristics of healed cracked concrete due to bacterial calcite precipita- tion.

To conclude we can state that the bacterial approach has potential to contribute to the self-healing capac- ity of concrete. We have shown that bacteria incor- porated in high numbers (10^9 cm^{-3}) do not affect concrete strength, that a substantial number of added bacteria remain viable and, moreover, that these vi- able bacteria can precipitate calcium carbonate needed to seal or heal freshly formed cracks.

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An Examination of the Cement-Based Materials' Early-Age Properties

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Abstract- *From a materials science point of view, this paper provides an overview of the early-age properties of cement-based materials. Strategies for reducing early-age cracking are presented, as well as a review of the most important physical and chemical processes that take place at early ages.*

Keywords: Curing;Drying;Early-agecracking(nominated);Hydration;Shrinking

INTRODUCTION

Gravitational forces and the local drying environment immediately after placement begin to influence the (micro)structure of a cement paste, mortar, or concrete. This is followed by swelling, bleeding, and evaporative water loss. The initial freshly cast material can be thought of as either a concentrated suspension of rigid parts in water or as a granular water-filled porous media depending on the mixture's water-to-cementitious materials mass ratio (w/c) and aggregate volume fraction. In the previous case, huge settling will be supposed to happen, joined by drying. For instance, at water-to-cement ratios (w/c) ≥ 0.4 , measurable bleeding and settling are typically observed in contemporary Portland cement pastes that do not contain any admixtures. As the strong particles settle and a comparing volume of water ascends to the highest point of the example, a microstructural (porosity/thickness) slope will be laid out through the thickness of the example. The specifics of this gradient will also be affected by the evaporative water loss from the specimen's top surface, such as the drying conditions, in addition to the solids' concentricity and particle size distribution (PSD). The examination of these microstructural gradients for cement using X-ray absorption measurements previously assumed a fairly linear profile (with significant local variations) ranging from a higher concentration of particles at the specimen's bottom to a lower concentration at its top. Figure demonstrates this. 1 that gives estimated X-beam transmission profiles for a w/c = 0.40 mixed concrete glue accomplished after 2.5 h and 4.5 h of fixed restoring. Cement particles have a much higher X-ray absorption coefficient than water, so a lower transmission of the X-ray signal (lower normalized counts, where the transmitted counts have been normalized by the counts transmitted through a reference specimen) indicates a higher concentration of particles. The lower concentrations of solids (higher water-filled porosity) that were established at the top surface during the first few hours of sealed curing may continue throughout the lifetime of the material, resulting in a surface layer that is weaker and may be much more susceptible to scaling phenomena, for instance.

When the specimen's top surface is also drying (water evaporation), the situation gets even more complicated. Menisci will form between the particles at the specimen's top if the rate of evaporative water loss is even

slightly higher than the rate of bleeding. This will result in a capillary tension in the water. According to the Kelvin—Laplace equation:

$$\frac{2\sigma_{\text{cap}} \cos \alpha}{r} = \frac{1}{V_m} \ln \frac{RH}{RT}$$

where σ_{cap} is the capillary tension (Pa), γ is the surface tension of the pore solution (N/m), α is the contact angle between the pore solution and the capillary pore walls, V_m is the pore solution molar volume (m³/mol), r is the meniscus radius (m), RH is the relative humidity (with values between 0 and 1), R is the universal gas constant (or 8.314 J/mol K), and T is the absolute temperature in K. In the equation, 1) Most of the time, a contact angle of 0° is assumed, which indicates that the liquid completely wets the pore walls. This fine strain will pack the granular permeable media, especially close to the top surface. As the X-ray transmission results in Figure show, in this instance, in addition to the densification that takes place at the specimen's bottom during settling and bleeding, significant local densification may also take place close to the specimen's top surface. 2, for a $w/c = 0.45$ concrete glue promptly presented to drying conditions. When comparing the normalized counts profiles shown in Fig. 2, a preferential densification at the top (exposed) surface can be easily observed. According to the American Concrete Institute (ACI), applying a curing compound only when the top surface of the concrete first appears "dry and free of surface water" [4] should also help promote the formation of a superior-quality surface layer in field concrete. Cement-based plastic shrinkage cracking may also be caused by the formation of this capillary tension. The rate of evaporation, the initial water content of the mixture, and the surface tension of the pore solution will all play a role in this cracking [5].

During the first few hours of curing, the cement will hydrate slightly but significantly concurrently with settling, bleeding, and evaporation. The general impact of this hydration will be to hurry the progress of the material from a suspension of unbending particles in answer for a "granular" permeable strong, by locally (and eventually worldwide) interfacing particles together into agglomerates. At these very early stages of the curing process, however, the pore size reductions caused by settling and local particle rearrangement are likely to outweigh any reductions in capillary pore sizes that would result in increased capillary pressures. Due to the associated chemical shrinkage, these hydration reactions will also cause the system's total volume to decrease; The following sections will provide a comprehensive examination of this subject. After the initial settlement, X-ray absorption measurements have also been used to observe the distribution of water in cement pastes during subsequent drying and hydration [2, 3, 6].

Drying is observed to occur uniformly across the specimen's thickness rather than as a front that extends inward from the exposed surface. Cement paste and mortar drying appears to follow more closely the convective drying of a porous medium theory that was previously presented [7] than the drying of gels theory [8]. Run of the mill results are given in Fig. 3 that shows the X-beam transmission profiles for a $w/c = 0.45$ concrete glue quickly presented to a drying climate.

In bilayer composites, water is always observed to be removed first from a coarser pore structure during the initial stages of drying/hydration before being removed from the finer one [6]—similar to previous observations made on non-reactive bead packs [9]. This holds true regardless of whether the use of a cement with a coarser PSD (at a constant w/c) or a higher w/c ratio is the cause of the coarser pore structure [6]. A shrinkage-reducing admixture (SRA) has significant effects on this drying procedure [5,10], which will be discussed in a subsequent section.

Cement hydration and early-age properties The hydration of cementitious materials is what transforms concrete from a viscous suspension into a rigid, durable, and load-bearing solid. The effects of temperature, moisture (saturation), and physical/microstructural hydration will be the focus of this paper. The effects of mixture parameters like weight to volume and cement PSD on the magnitudes of these effects will also be presented.

PHYSICAL/MICROSTRUCTURAL EFFECTS

Setting

Cement setting is a percolation process in which the formation of hydration products connects isolated or weakly bound particles together (percolation) [11,12]. When the microstructure has a finite mechanical resistance to penetration or shear, the initial and final setting are typically defined by Vicat measurements, for example. Using a three-dimensional microstructural model, three previous studies estimated a quantitative relationship between measured Vicat needle

penetrations and solids percolation [13–15]. In Fig. 2, this equivalence is further illustrated. 4 that compares the volume fraction of percolated solids for the same cement used to prepare pastes with four different w/c to the needle resistance (determined as 40 — the measured needle penetration in mm) [16]. Because of the larger initial particle spacing, higher w/c pastes will require more hydration (and probably more time) to achieve set, as shown by these results. However, the effect of cement PSD on setting is less apparent at constant w/c. Although a coarser cement may take longer to set due to its slower hydration rate, it can actually set at a lower degree of hydration because fewer (but larger) particles are present in the initial paste, necessitating the construction of fewer "bridges" between particles [17].

Early mechanical property development The formation of measurable solid mechanical properties occurs simultaneously with the formation of a percolated solids network. It includes versatile modulus, strength, stress unwinding, and creep. It has been extended to predict compressive strength gains at early ages using the same ultrasonic measurements that can be used as a setting indicator [12] [18]. Because they frequently change throughout the course of the physical measurement, these mechanical properties are significantly more challenging to measure in general at earlier ages than later in the hydration process. It is particularly difficult to measure relaxation and creep in tension, but progress is being made [19]. Conventional creep loading has typically been utilized in compression [20]. One key to a fundamental materials science-based prediction of early-age cracking is an understanding of how these mechanical properties develop because they control the resistance half of the load/resistance paradigm [20,21].

Warm Impacts

Accepting legitimate relieving and hence disregarding vanishing, one of the two significant reasons for early-age breaking is warm impacts, the other being autogenous shrinkage. A concrete will typically first heat up and expand due to heat produced during early-age cement hydration, which varies depending on the exposure to the environment. The concrete may crack if the subsequent cooling is too quick, especially if it is strained locally or globally. Quantitative characterization of the concrete's thermophysical properties, its heat of hydration, and its interaction with the environment are all crucial for comprehending the role that these thermal effects play in early-age cracking.

The hydration of Portland cement significantly alters the volume fractions and spatial arrangement of solids, liquids, and gases (air voids and empty capillary pores) within the three-dimensional microstructure, so it would be expected that the thermophysical properties of cement paste such as heat capacity, thermal conductivity, and coefficient of thermal expansion.

The amount of water would affect the expansion. As depicted in Fig. 5, the intensity limit of concrete glue is areas of strength for an of both w/c and relieving conditions [22]. This is primarily because water has a high heat capacity—4.18 J/(g K) compared to 0.75 J/(g K) for dry cement powder—and that capacity decreases as water is (chemically and physically) bound into hydration products. More water (higher w/c) brings about a higher intensity limit as does soaked relieving (with its going with water imbibition) comparative with fixed restoring.

As depicted in Fig. 6, for the two w/c values and the two curing conditions used, the thermal conductivity of hydrating cement pastes is basically constant at 1.0 W/(m K) within the measurement's experimental error [22]. The starting materials' thermal conductivities (water): Cement, 0.604 (W/m K), and 1.55 W/(m K) at 20 °C) and those of the hydration products appear to be sufficiently close to one another that, despite the solid and liquid pathways being percolated, depercolated, and repercolated throughout the process of hydration and aging, the thermal conductivity remains virtually unchanged (e.g., within 10 percent). Ionic diffusivity and electrical conductivity, on the other hand, undergo dramatic changes as a result of hydration [15,23].

An accurate description of the concrete's coefficient of thermal expansion is equally crucial to the prediction of early-age thermal cracking. Due to the conflating effects of ongoing hydration, among other factors, this property is particularly challenging to measure at early ages. 24]. An in-situ, non-destructive solution to this issue could be provided by fiber optic-based methods [25]. Upsides of 10×10^{-6} [1/K] to 12×10^{-6} [1/K] are regularly utilized for concrete.

Heat produced by hydration A significant amount of energy is released as heat as cement hydrates. Any early-age model of heat transfer in concrete must incorporate this hydration heat. The cement's phase composition influences the amount of heat released; Table 1 contains the published values for the various phases of cement clinker [26,27]. The mineral admixture used in blended cements can either increase or decrease the mass-normalized heat release. For instance, silica fume has a heat of hydration of approximately 780 kJ/kg fume when pozzolanically reacted with Ca(OH)₂ [28], whereas fly ash and slag reactions typically generate less heat than Portland cement reactions.

Table I Enthalpies of complete hydration for major phases of Portland cement

Phase	Enthalpy (kJ/kg phase)
C ₃ S	517
C ₂ S	262
C ₃ A	908,1672,1144 ^a
C ₄ AF	418,725 ^a

^aFor C₃A and C₄AF hydration, values are for conversion to C₃AH₆, ettringite, and monosulfate (AFm) phase (only for C₃A), respectively.

Heat of hydration is typically measured using a standardized heat of solution technique [29] or semi-adiabatic methods; a new standard method based on isothermal calorimetry has been developed in the Nordic countries [30] and is now being considered by the American Society for Testing and Materials (ASTM) C01.26 Heat of hydration subcommittee. In addition, virtual test methods for heat of hydration of ordinary Portland cement are also under development within ASTM [31].

Environmental Factors At Early Ages

A number of computer models have been developed and are either commercially or freely available for predicting the temperature and stress/strain response of concrete exposed to a variable environment at early ages [28, 32–37]. In addition to a quantitative understanding of the properties of concrete discussed above and in the following section, accurate predictions by such models are requisite on having a detailed quantitative characterization of the exposure environment, including temperature, relative humidity, wind speed, and solar radiation, and the applied curing conditions (curing membrane, water misting, etc.) [37]. While further research in these latter areas is clearly needed, the models have been used successfully in many cases over the past decade.

MOISTURE EFFECTS

Chemical Shrinkage

The volume of the hydration products is smaller than that of the starting materials (including water) as cement hydrates. The early-age performance of cement-based materials is significantly affected by this chemical shrinkage, which will be explained in detail in the following sections. In 1935, Powers was the first to quantify the chemical shrinkage (also known as the imbibition of water) of the various phases of cement clinker [38].

The ASTM Standard Test Method C1608 [40] for quantifying chemical shrinkage, which was thoroughly investigated by Geiker [39], has recently been approved. It is based on measuring the volume of water absorbed by a known mass cement paste (or mortar) sample during isothermal saturated hydration. A comparable method has been normalized in Japan [41]. Both the specimen thickness and the w/c need to be within a small range (typically a few millimeters and 0.4, respectively) in order to obtain meaningful results at later ages due to the depercolation of the capillary porosity that may occur during hydration and limit this water transport [42, 43].

Assuming a set of cement hydration reactions and molar volumes for each cement component, chemical shrinkage can also be calculated. Numerous authors have utilized this strategy [44–46], with varying degrees of agreement between their published values. However, in general, the chemical shrinkages of the aluminate phases (C₃A and C₄AF) are approximately 50% higher than those of the calcium silicates (approximately 0.07 mL/g CnS) per unit mass. During its pozzolanic reaction with Ca(OH)₂, silica fume experiences a particularly high chemical shrinkage of 0.22 mL/g [47]. A typical Portland cement paste that hydrates can ultimately shrink chemically by as much as 10% by volume.

Chemical shrinkage can result in the formation of empty porosity and a decrease in the internal RH when cured under sealed, partially saturated, or saturated conditions but where depercolation of the capillary porosity has already occurred. This process is known as self-desiccation. During self-desiccation, the cement paste microstructure's largest pores typically empty first [44, 48]. As shown by Equation (1) The formation of menisci in these (partially empty) pores will result in a decrease in the specimen's internal relative humidity and capillary tension. This self-parching process is consequently enormously answerable for the autogenous shrinkage of concrete based materials that has come to the front lately because of field issues with early-age breaking, especially of elite execution cements (HPC). However, self-desiccation can be

advantageous in accelerating the drying of concrete floors prior to the application of carpeting and other coverings, and it may also increase the frost. Self-desiccation is not always harmful.

Cement-based materials' internal relative humidity can provide valuable insight into their internal stresses, as previously mentioned. Only a few data from actual field exposures have been published to date, though experimental methods for laboratory measurements (50) and, more recently, field use (51) have been developed. The decrease in interior RH will likewise diminish the hydration paces of the leftover concrete clinker stages [44,53]. Due to the initially larger spacing between cement particles (larger pores), this internal RH reduction will be significantly less pronounced in systems with a higher water-to-carbon content. As depicted in Figure, the RH reduction at later ages (degree of hydration $N \approx 0.4$) will be greater the finer the cement PSD at a constant w/c and the same degree of hydration [54]. 7, once more because of interparticle spacing issues. During early-age hydration, silica fume can significantly increase the measured RH reduction because of its extremely small particle size and pozzolanic reaction's high chemical shrinkage [50,55].

Autogenous shrinkage of cement systems and early-age cracking Until about set, the "fluid" material experiences an equivalent overall volumetric reduction as a result of the chemical shrinkage that occurs during cement hydration [56,57]. After setting, the cement paste develops a limited resistance to further volumetric reductions, and the measured autogenous deformation is much smaller than the chemical shrinkage (up to two orders of magnitude less). Autogenous shrinkage has previously been measured using either a volumetric (latex membrane) or linear (sealed corrugated tube) method [57–59]. However, a recent comprehensive study by Lura and Jensen suggests that the first method is inadequate due primarily to the confounding influence of water ingress through the membrane during the measurement time [60]. The linear approach for mortars and cement pastes [58].

The slim pressure (σ_{cap}) made in the pore arrangement during self-drying up brings about the autogenous twisting of the permeable material (concrete). The deformation can be estimated as [61,62] in this instance:

K is the bulk modulus of the porous material (Pa) with empty pores (dry), K_s is the bulk modulus of the solid framework within the porous material (Pa), and e is the linear strain or shrinkage. S is the saturation (fraction with values between 0 and 1) or fraction of water-filled porosity. While Equation 2) is an approximate representation of a material that is only elastic; it has been utilized with some success with cement-based materials [63]. Recently, extensions have also been made to include a creep, or visco-elastic, component [20]. Autogenous shrinkage caused by internal drying and drying shrinkage caused by external drying share many similarities, according to Baroghel–Bouny [64].

In Portland cement systems, autogenous deformation increases dramatically as the w/c ratio drops below 0.35 due to the fact that the capillary stresses are a function of the size of the pores being emptied. Systems with silica fume and slag additions show even more dramatic increases [59,65–67]. As depicted in Fig., at a constant w/c and hydration level. 8, systems prepared with a finer cement exhibit significantly greater autogenous shrinkage. In point of fact, the two cements in Fig. 8 shows early autogenous expansion, probably caused by swelling caused by the formation of hydration products like ettringite [54].

Predicting early-age cracking in addition to measuring autogenous shrinkage is not an easy task. A considerable lot of the properties that should be appropriately represented are examined in a new paper by Moon et al. [68]. However, several of the existing models for predicting early-age cracking field performance already include thermal and autogenous effects in some way [32,34,35].

Mitigation Of Early-Age Cracking Via Internal Curing

A cautious assessment of Eqs. (1) and (2) suggest one approach to autogenous shrinkage-induced early-age cracking prevention or reduction. The incorporation of a reservoir or reservoirs of water in the concrete, contained in pores larger than the capillary pores in the hydrating cement paste, should significantly reduce the autogenous stresses, which are controlled by the size of the pores that are being emptied during self-desiccation. As a result, the idea of internal curing (IC) was born. Philleo first proposed this concept in the literature in 1991 [69]. Saturated lightweight fine aggregates (LWA) [70] (Philleo's original suggestion), superabsorbent polymers (SAP) [71], and water-saturated wood products [72] have all been attempted to serve as IC reservoirs. In 2005, the thought moved from being a research center idea to being a field reality at a few places of work in the U.S., including an enormous clearing project in Texas where 238 000 cubic yards (181 000 cubic meters) of cement proportioned with IC by means of soaked LWA were clustered and put throughout a couple of months [73]. The concrete was examined by the author in December 2005, probably during its initial freeze-thaw cycle; There were only two cracks that could be seen, one of which was where a missing expansion joint meant that

the concrete had only made one crack of its own. The IC water will not only change the size of the empty pores that are being made in the concrete microstructure, but it will also make the cement paste around it more hydrated. Therefore, measurements of compressive strength, degree of hydration, internal relative humidity, autogenous shrinkage, and restrained shrinkage and creep [21,71,74,75] have been used to evaluate the effectiveness and efficiency of IC. For instance, Fig. Measured autogenous deformations over time are depicted in Figure 9 for a collection of high-performance mortars made without and with a variety of IC reservoirs [74]. The measured autogenous shrinkage at early ages was significantly reduced in each case when the IC water reservoirs were added. It is evident that the LWA and SAP additions can significantly reduce autogenous shrinkage. As of late, four-layered (3 spatial and time) X-beam microtomography tests have been led to straightforwardly notice water development from satu-evaluated fine LWA to the encompassing concrete glue during the firsttwo days of fixed isothermal hydration (30 °C) [76].

The chemical shrinkage of the cementitious materials in a concrete has a direct correlation with the amount of internal curing water required to maintain saturation of the capillary porosity.

On bilayer (SRA over no SRA and no SRA over SRA) composite specimens, confirmatory measurements of these phenomena have previously been carried out [10]. In a system with an SRA, the evaporation rate is lower than in a system where: Cf is the cement factor (content) for the concrete mixture (kg/m³ or lb/yd³), MLWA is the amount of dry LWA needed per unit volume of concrete, CS is the chemical shrinkage of cement (grams of water/gram of cement or lb/lb) at a degree of hydration equal to 100 percent, max is the maximum expected degree of hydration of cement, S is the degree of aggregate saturation (0–1), and LWA is Comparative computations can be utilized for SAPs [71] or different hotspots for the IC water. The water's spatial distribution is just as crucial as the quantity of curing water supplied. Due to its more uniform and closely spaced distribution of the individual IC reservoirs throughout the concrete volume, fine LWA is preferred over coarse LWA in this regard [78,79].

Autogenous shrinkage and early-age cracking mitigation through shrinkage-reducing admixtures In the previous section, a method for increasing the r term in Equation () was presented. 1). Reduce the magnitude of, or the pore solution's surface tension, for an additional option. A shrinkage-reducing admixture (SRA) can be easily added to the mixture to achieve this reduction. SRAs were first used to reduce drying shrinkage more than two decades ago in Japan [80]. In the United States, they have been used for about ten years [81,82]. The measured surface tension of the concrete pore solution can be decreased by a factor of two when a small amount of SRA (by mass of cement) is added [5,10]. every other property (such as the contact angle) This will equalize to half the capillary tension, according to Equation (). 1), which ought to convert into around 50% of the autogenous strain as per Eq. (2). As shown in Fig., the experimental confirmation of this hypothesized reduction in autogenous shrinkage for systems containing SRA is available. 10 [10,83–85].

A cement-based material's early-age properties are also significantly influenced by the addition of an SRA. As per X-beam transmission estimations, the drying profile created within the sight of a SRA is boundlessly not quite the same as that produced in a framework with no SRA (see Fig. 3 for instance) at young ages (less than 8 h). From the specimen's surface that is exposed to the drying environment, the SRA produces a drying front that penetrates the specimen while maintaining saturation inside [10]. It would appear that the remaining solution at the surface will contain a higher concentration of SRA than the solution inside the specimen because the pore solution is initially drawn to the surface by capillary forces to evaporate. Similar to how water moves from a pore system with a coarser surface to a pore system with a finer surface in bilayer composites [6] due to the differential in without SRA [10,85]. When it comes to the movement of pore solutions within a specimen, it is also important to note that the measured viscosity of a typical 10% SRA solution in distilled water is about 50% higher than that of distilled water alone [86]. This suggests that the internal "flow rate" is moving at a slower rate. According to Lura et al. Consistent with the experimental findings of Esping and Löfgren for self-consolidating concretes [85], the addition of the SRA results in "less evaporation, reduced settlement, reduced capillary tension, and lower crack-inducing stresses at the topmost layer of the mortar." When put together, these effects make it less likely that plastic shrinkage cracks will form in a drying environment [5,85]. A similar reduction in evaporative water loss has been demonstrated recently [87] by topical application of an SRA solution as a curing solution (10 percent or 20 percent by mass in water). Timely application of the SRA solution to the top surface of mortars subjected to a 50% relative humidity environment led to significant reductions in evaporative water loss and significant increases in the degree of hydration achieved in the specimens over longer periods of time [87].

The early-age properties of cement-based materials can be significantly altered by merely altering the surface tension (and viscosity) of the pore solution. SRAs have a negative impact on the early-age frost resistance of cement pastes that have been cured under saturated conditions [1,86] in addition to having an impact on drying rates and the development of internal stresses. The significance of water menisci in cement-based partially saturated materials' performance at early ages

and beyond is emphasized in this study. More research on this subject ought to lead to both more durable concrete in the long run and improved early-age performance, particularly in terms of preventing early-age cracking.

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Increasing the Durability of Building Structures with Microbial Concrete

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ABSTRACT-Concrete structures can develop cracks and fissures due to weathering, faults, ground subsidence, earthquakes, and human activity, which can shorten the structures' useful lives. Using microorganisms like *Bacillus* species to biomineralize calcium carbonate is a revolutionary method for repairing or cleaning up such structures. *Bacillus* sp. CT-5, which was isolated from cement, was employed in the current investigation to examine tests for compressive strength and water absorption. According to the findings, bacterial cells increased the compressive strength of cement mortar by 36%. When compared to control cubes, calcite deposition on treated cubes absorbed almost six times less water. The current research shows that *Bacillus* sp. generation of "microbial concrete" on built facilities improved the durability of building materials.

INTRODUCTION

The requirements for high durability for structures exposed to harsh environments, such as seafloor, offshore structures, tunnels, highway bridges, sewage pipes, and structures for solid and liquid wastes containing toxic chemicals and radioactive elements, may not be met using today's common Portland cement (OPC). It is widely acknowledged that the features of concrete's pore structure affect how long it lasts. Concrete deterioration mechanisms frequently depend on the potential for aggressive substances to harm the concrete by penetrating it. Concrete's permeability is influenced by its porosity and the connectivity of its pores. Concrete is more susceptible to the deteriorating processes brought on by penetrating substances the more open its pore structure is. In order for concrete structures to deteriorate, aggressive gases and/or liquids from the environment must first move into the concrete, which is followed by physical and/or chemical reactions that may cause irreparable damage. As a result, mechanical (compressive strength) and transport properties are crucial components of concrete durability.

Researchers' interest has recently started to grow in the microbiologically induced calcium carbonate precipitation (MICCP) that is caused by the metabolic activities of some particular microorganisms in concrete and improves the overall behaviour of concrete. The compressive strength of cement mortar was significantly improved (by about 18%) in earlier studies using aerobic microorganisms (*Bacillus pasteurii* and *Pseudomonas aeruginosa*) [Ramakrishnan et al. 1998; Ramachandran et al. 2001].

A number of intricate biochemical processes make up MICCP [Stocks-Fischer et al. 1999]. Some bacterial species produce urease as part of their metabolism, which catalyses the breakdown of urea into CO₂ and ammonia, raising the pH of the environment where ions are present. Ca²⁺ and CO₃²⁻ precipitate as CaCO₃. Possible biochemical reactions in medium to precipitate CaCO₃ at the cell surface that provides a nucleation site can be summarized as follows. Utilizing a selective microbial plugging process in which microbial metabolic activities promote the precipitation of calcium carbonate in the form of calcite, a novel method for the remediation of damaged structural formations has been developed [Gollapudi et al. 1995]. CaCO₃ demonstrated its positive potential as a microbial sealant by selectively



consolidating simulated fractures, surface fissures, and sand plugging in granites [Zhong and Islam 1995; Achal et al. 2009a].

The most significant factors affecting concrete's durability and, ultimately, its performance, the compressive strength and concrete permeability tested using water absorption are the focus of the current work. This study looked into how cement-derived bacteria affected the compressive strength and water permeability of cement mortar.

MATERIALS AND METHODS

Materials

Used was regular Portland cement that complied with IS 12269-1987. As fine aggregate, clean, properly graded, naturally occurring river sand that complies with IS 383-1970 standards and has a fineness modulus of 2.89 was used.

Microorganism

In this study, *Bacillus* sp. CT-5, which was isolated from cement sold commercially, was used. The Nutrient Agar (pH 8.0) medium was used routinely to maintain the culture. The isolate was grown in nutrient broth-urea (NBU) medium (8 g nutrient broth, 2% urea, and 25 mM CaCl₂). CaCl₂ and filter-sterilized urea were added to the medium for the nutrient broth. Information about the preparation and content of NBU medium was previously published [Achal et al., 2009a]. At 37 degrees Celsius, bacteria were grown in a shaking environment (130 rpm).

Compressive strength test

Bacillus sp. CT-5 was grown in NBU media in order to research the compressive strength test of cement mortar. The ratio of bacterial culture to water to cement was 0.47, and the ratio of cement to sand was 1:3 (by weight). According to IS 4031-1988, a 70.6 mm cube mould was used. With the addition of a grown culture of *Bacillus* sp. CT-5 that corresponds to an optical density of 1.0 (600 nm), sand and cement were thoroughly mixed. A vibration machine was used to cast and compact the cubes. All specimens were demolded and then allowed to cure in NBU medium at room temperature until compression testing was performed after 3, 7, and 28 days. Control samples were also made in a similar manner, but instead of using bacterial culture, they used water and NBU medium. Automatic compression testing was carried out.

Water absorption test

A sorptivity test using the RILEM 25 PEM (II-6) was performed to ascertain the increase in resistance to water penetration. To ensure unidirectional absorption through the treated side, the mortar specimens were coated at the four edges that were closest to the treated side. The test cubes were coated, then dried at 45 °C in a ventilated oven to achieve a mass equilibrium of less than 0.1% between two measurements taken 24 hours apart. The treated side of the specimens was facing downward as they were submerged in 101 mm of water (water level about 2 mm above the base of the specimen). Every 15 minutes, 30 minutes; 1 hour, 1.5 hours, 3 hours, 5 hours, 8 hours, 24 hours, 72 hours, 96 hours, 120 hours, and 144 hours and 168 h) the specimens were removed from the water and weighed, after drying the surface with a wet towel. Immediately after the measurement the test specimens were submerged again. The sorptivity coefficient, k [$\text{cm}\cdot\text{s}^{-1/2}$], was obtained by using the following expression:

$$Q/A = k \sqrt{t} \quad (4)$$

where Q is the amount of water absorbed [cm^3]; A is the cross section of the specimen that was in contact with water [cm^2]; t is the time [s], Q/A was plotted against the square root of time, then k was calculated from the slope of the linear relation between the former.

RESULTS AND DISCUSSION

Compressive strength test

Figure 1 summarises the compressive strength of various cement mortar specimens after 3, 7, and 28 days. The compressive strength had significantly increased for the microbially-filled mortar cubes. The strongest mortar cubes (31 MPa) were made with *Bacillus* sp. CT-5 and incubated for 28 days, as opposed to those made with water (23 MPa) and NBU medium (24 MPa). At 28 days, mortar specimens made with bacterial cells had 36.15% greater compressive strength than the control. The cubes cured in microbial growth medium were stronger than those cured in water in the cell-free control groups, despite the fact that there was no discernible difference. The mortar cubes' strength appeared to be improved by the medium's high ionic strength, which contains urea and calcium chloride.

According to Ramakrishnan et al. (1998), Ramachandran et al. (2001), Ghosh et al. (2005), and Achal et al. (2009a), the deposition of CaCO₃ on the microorganism cell surfaces and inside the pores of cement-sand matrix, which plug the pores within the mortar, is probably the reason why *Bacillus* sp. CT-5's compressive strength increased.

To determine whether the microbial calcite precipitation was the cause of the mortar samples' increased compressive strength, the mortar samples were taken out and subjected to SEM inspection. Figures 2a and 2b show scanning electron micrographs of a cement mortar matrix devoid of bacteria and a specimen made with *Bacillus* sp. CT-5, respectively. The



sample showed that calcite crystals had formed into rod-shaped structures and had grown everywhere (typical shape of *Bacillus* species). The edges of the crystals were distinct and sharp, indicating that they had fully developed. We have previously described and documented *Sporosarcina pasteurii*'s rod-shaped structure, which aided in the precipitation of calcite in sand columns [Achal et al. 2009b].

At 3 and 7 days, the compressive strengths of mortar cubes with all media did not significantly increase. The overall trend of an increase in compressive strength up to 28 days may be attributed to the behaviour of microbial cells within the cement mortar matrix. Although the mortar was still porous during the initial curing period due to the cement, the environment for microbes had completely changed, inhibiting proper growth. It's also possible that the high pH of the cement rendered the cells inactive, but as the curing time was prolonged, the cells slowly started to grow. Because of the various ions present in the media, calcite would precipitate during cell growth on both the surface of the cells and inside the cement mortar matrix. As a result, the cement mortar lost some of its porosity and permeability. The bacterial cells eventually either died or changed into endospores, which served as an organic fibre and increased the compressive strength of the mortar cubes, once many of the matrix's pores had been plugged. This explains how cement mortar cubes made with microbial cells behaved at day 28 in terms of their increased compressive strength. An increase in matrix strength would have reduced mean expansion for concrete made with bacterial cells, enhancing the concrete's overall durability performance [Ramakrishnan et al. 2001]. This led to the conclusion that the main reason for the increase in compressive strengths is the consolidation of the pores within the cement mortar cubes with microbiologically induced calcium carbonate precipitation.

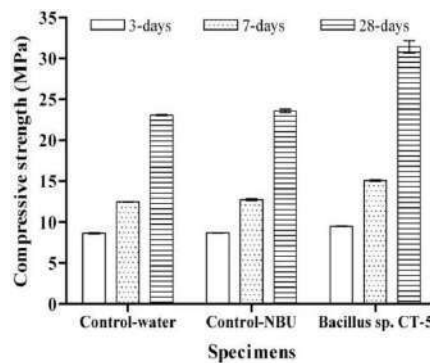


Fig. 1. Effect of CT-5 on Cement Mortar Cube Compressive Strength at 3, 7, and 28 Days prepared with a 0.47 w/c ratio. (Controlling *Bacillus* sp. and NBU. Water is Replaced with Media in CT-5 Treatments and Media is Replaced with Bacterial Cells, respectively).

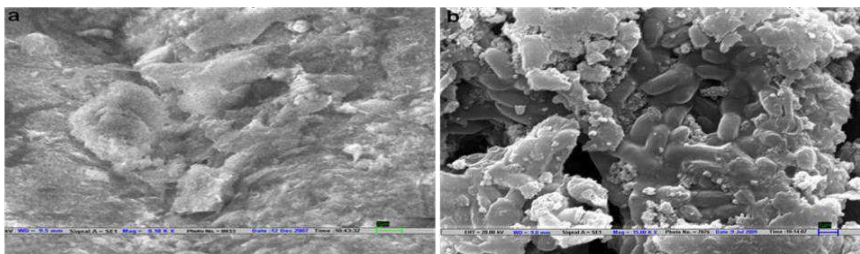


Fig. 2. Specimens of cement mortar captured in scanning electron micrographs. Matrix of Cement Mortar Prepared Without Bacteria and Dense Calcite Precipitation as Calcite Crystals with Rod Shaped Impressions Housed by *Bacillus* sp. CT-5.



Water absorption test

For mortar cubes with a w/c of 0.47, Fig. 3 illustrates the impact of the surface treatment on the rate of water absorption. The cubes treated with *Bacillus* sp. CT-5 absorbed almost six times less water over 168 hours than the control cubes. Compared to untreated specimens, the water uptake significantly decreased when bacteria were present (control).

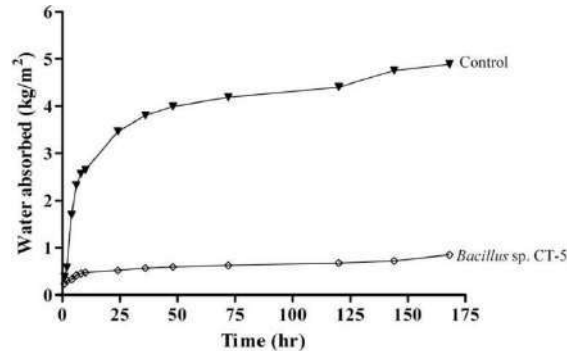


Fig. 3. The Influence of the Bacterial Treatment on the Rate of Water Absorption versus Time for Mortar Cubes

The water absorption experiment showed that the permeability of mortar specimens treated with bacteria decreased. A layer of calcium carbonate crystals being deposited on the surface. The permeation properties were reduced as a result of the surface. As a result, the entry of dangerous substances may be restricted. After injecting CaCO₃-forming reactants, Nemati and Voordouw [2003] observed a decrease in the permeability of sandstone cores. It is evident from this experiment that the presence of a layer of carbonate crystals on the surface by a bacterial isolate has the potential to enhance cementitious materials' resistance to processes that cause their degradation.

CONCLUSION

The use of bacterial isolates like *Bacillus* species that produce urease in concrete remediation is the significance of this study. *Bacillus* sp. CT-5 had a beneficial impact on the compressive strength of Portland cement mortar cubes, according to the study, which also showed an increase in strength. In order to assess the effectiveness of the bacterial isolate, a greater resistance to water penetration has been made. The creation of "Microbial Concrete" will serve as the foundation for a superior, alternative concrete sealant that is economical, environmentally safe, and ultimately increases the durability of building materials.

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Crack Repair by Concrete-Immobilized Bacteria

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Abstract : Cracks in concrete allow water and chemicals to enter, a process that may lead eventually to the unwanted corrosion of the steel reinforcement and the deterioration of the concrete structure. Within the framework of the Self-Healing Materials Research Project of the Delft Center for Materials, the possible application of bacteria to extend the lifetime of concrete is studied. The goal of this project is to incorporate dormant but viable bacteria in the concrete matrix which will contribute to the concrete's self-healing potential. Water entering freshly formed cracks will activate the dormant bacteria which in turn will seal these cracks through the process of metabolically mediated calcium carbonate precipitation. Concrete, however, is due to its high internal pH (>12), relative dryness and lack of nutrients needed for growth, a rather hostile environment for common bacteria. Yet, certain extremophilic bacteria may be able to endure this artificial environment. In this study we tested the applicability of alkaliphilic spore-forming bacteria of the genus *Bacillus* as self-healing agent in concrete. We found that incorporation of high numbers of bacteria (10^9 cm^{-3}) as well as some suitable organic growth substrates in concrete did not negatively affect compressive- and flexural tensile strength. ESEM analysis revealed furthermore the self-healing potential of immobilized cells, as bacterial- but not control cement stone samples were found to deposit a new layer of calcium carbonate minerals on its surface. We therefore conclude that these specific bacteria are promising candidates to act as self-healing agent in concrete structures.

Keywords: Self-healing concrete, bacteria

INTRODUCTION

The durability of steel reinforced concrete structures is substantially affected by cracking. Cracks in concrete occur due to various mechanisms such as shrinkage, freeze-thaw reactions and mechanical compressive- and tensile forces. Cracking of the concrete surface may enhance the deterioration of embedded steel rebars as ingress rate of corrosive chemicals such as water and chloride ions into the concrete structure is increased. An active and rapid crack-healing mechanism can therefore be expected to substantially decrease chemical ingress and thus rebar corrosion, resulting in a significant increase in lifetime of concrete structures. Such an autonomous repair or self-healing mechanism would also be beneficial for economical reasons as manual inspection and repair of large structures is costly. However, the self-healing mechanism, or the nature of the self-healing agent in concrete should be such that it would not negatively affect the original structural- and mechanical characteristics of the material. One possible repair agent could be non-reacted or not fully hydrated cement particles. Water ingress through cracks would result in secondary hydration reactions of these particles which could result in sealing-, or plugging, of the cracks.

A disadvantage of application of cement particles is that their healing properties are limited to single events as the agent itself will be consumed in the process. Moreover, application of larger quantities to improve structures self-healing potential will negatively affect concrete characteristics as the initial structure may be weaker and more brittle. In this study we test the application of an alternative healing agent, i.e. bacteria which have the potential to seal cracks through the production and precipitation of calcium carbonate minerals. The advantage of application of bacteria over cement particles as healing agent is that the former only mediate the self-healing process and are thus not converted in the process themselves. This characteristic therefore potentially allows a virtually endless repetition of the self-healing process.

The application of bacteria for the repair or maintenance of various materials is not new. In previous studies the potential of bacteria to clean concrete surfaces (DeGraef et al 2005), improve the strength of cement-sand mortar (Dick et al 2006; Ghosh et al 2005), repair of degraded limestone and ornament stone surfaces (Rodriguez-Navarro et al 2003) and crack repair on surfaces of concrete structures (Bang et al 2001; Ramachandran et al 2001)



was investigated. One methodological limitation of these studies, however, was that bacteria with a relatively short lifetime and temporal activity (days rather than weeks or months) were used. For this reason the bacteria had to be manually applied on the surface of the target area and such an approach can therefore be considered as a natural, but not as a truly self-healing mechanism. In the present study we therefore investigated whether specialized bacteria characterized by a long-term viability can be integrated in the concrete matrix and act there as potential self-healing agent for autonomous crack repair. We tested for the application in concrete the suitability of some spore-forming alkali-resistant bacteria of the genus *Bacillus* as self-healing agent. Bacterial spores are specialized cells which can endure extreme mechanical- and chemical stresses and spores of this specific genus are known to remain viable for up to 200 years (Schlegel 1993). We hypothesize that dormant but viable bacterial spores immobilized in the concrete matrix will become metabolically active when revived by water entering freshly formed cracks. These cracks will subsequently be rapidly plugged and sealed through metabolically mediated microbial calcium carbonate precipitation, hampering further ingress of water and other chemicals. As revived bacteria also need a suitable substrate that can metabolically be converted to calcium carbonate, this also needs to be part of the concrete matrix. Thus, besides bacterial spores, additional substrates need to be tested for concrete compatibility, i.e. whether they will not negatively affect initial concrete mechanical and structural qualities.

MATERIALS AND METHODS

Bacterial strains and spore formation

Starter cultures of alkaliphilic (i.e. alkali-resistant) spore-forming bacteria were obtained from the German Collection of Microorganisms and Cell Cultures (DSMZ), Braunschweig, Germany. These cultures were initially cultivated according to the suppliers' recommendations in yeast extract based medium (medium DSMZ-2 for *Sporosarcina pasteurii* DSM33 and DSMZ-31 for *Bacillus cohnii* DSM6307; *Bacillus halodurans* DSM497 and *Bacillus pseudofirmus* DSM8715). Subsequently, growth and spore-forming potential (sporulation) was further tested in mineral medium amended with different organic carbon sources (6 g Na-citric acid or 5 g peptone plus 3 g yeast extract per liter).

Mineral medium contained per liter of Milli-Q ultra-pure water: 0.2g NH₄Cl, 0.02g KH₂PO₄, 0.225g CaCl₂, 0.2g KCl, 0.2g MgCl₂.6H₂O, 1 ml per liter trace elements solution SL12B, 0.1g yeast extract and 8.4g sodium bicarbonate. The pH of this medium was 9.2. Aerobic batch cultures were incubated in 2-l Erlenmeyer flasks on a shaker table at 150 rpm. Growth was monitored by microscopy and cell numbers and percentage of sporulating cells were quantified by microscopy using a Burger-Turk counting chamber.

Concrete compatibility of bacteria and organic substrates

A series of tests were performed in order to investigate whether the incorporation of bacteria or organic substrates (needed for bacterial calcium carbonate formation) in the concrete matrix do not negatively affect strength characteristics. Therefore concrete bars with and without (control) bacteria or organic substrates were prepared for flexural tensile- and compressive strength determination. For the preparation of bacterial concrete, a dense culture of *S. pasteurii*, grown in DSMZ-2 medium, was obtained and total cell number was quantified by microscopy using a Burger-Turk counting chamber. Cells were harvested after a double washing step by centrifugation (20 min x 10000g) and suspension of the cell pellet in tap water. The washed cells were finally suspended in a 20-ml aliquot of tap water which was used as part of the needed make up water for concrete bar preparation. The quantity of the tested organic compounds was 0.5% of cement weight. The individual organic compounds (Na-aspartate, Na-glutamate, Na-polyacrylate, Na-gluconate, Na-citric acid and Na-ascorbic acid) were firstly dissolved in the needed make up water, prior to concrete bar preparation.

Bacterial-, organic compound- and control sets of concrete bars for flexural tensile- and compressive strength testing were prepared. Each set consisted of three replicate bars (dimensions 16 x 4 x 4 cm) made from ordinary portland cement (ENCI CEMI 32.5R), make up water and aggregates. Aggregate (gravel and sand) composition and quantities of used components are listed in Table 1.

Table 1: Cement, water and aggregate composition needed for the production of 3 concrete bars of dimensions 16x4 x4cm used for flexural tensile- and compressive strength characterization of bacterial-, organic compound-, and control (no bacteria added) concrete



Compound:	Weight(g):
Cement(ENCI CEMI 32.5)	390
Water	195
Organics (see text)	19.5
Aggregate(gravelsandsand):	
4-8mm	562
2-4mm	378
1-2mm	283
0.5-1mm	283
0.25-0.5mm	243
0.125-0.25mm	132

Self-healing bacterial concrete

An experiment to test the hypothesis, that concrete immobilized bacterial spores are able to revive and start biomineral production in cracked- and water-entrained concrete, was set up. A dense culture of *Bacillus pseudofirmus* grown in mineral medium amended with 6 g/l Na-citrate was harvested after sporulation had occurred. The number of spores in the cell suspension, after a double washing step in tap water, was quantified by microscopic counting. Cement stone samples (with and without bacteria) were prepared using the cell suspension as part of the make up water for the bacterial samples. Spore density in the bacterial samples amounted to 10^9 cm^{-3} . Ordinary portland cement (ENCI CEMI 32.5R) and a water-cement ratio of 0.5 was used for the preparation of cement stone samples (disks with dimensions of 4cm diameter and 1 cm height), cast in plastic vials closed with a plastic lid. After 24 hours curing at room temperature, disks were further cured in tap water at room temperature. After ten days curing disks were removed from their plastic molds and chipped to pieces with a chisel. Chips of bacterial- and control samples were subsequently incubated in rich medium (mineral medium amended with 3 g yeast extract and 5 g peptone per liter) after pasteurizing for 30 min at 70°C. Pasteurization of bacterial- and control cement stone chips before incubation was done to inactivate bacteria that potentially came into contact with the cement stone samples during the non-sterile handling of the cement stone samples and chips. As bacterial spores are not killed by the pasteurization procedure, this treatment ensured that potential differences between control- and bacterial samples after incubation were mediated by added bacteria and not by accidentally introduced contaminants. Individual chips were incubated aerobically in 100-ml medium aliquots on a shaker table at 100 rpm at 25°C for 12 days. The chips were subsequently rinsed with tap water and stored wet in closed plastic vials until ESEM analysis was done within two days after sampling. For ESEM analysis, chips were mounted on a 1-cm² metal support and kept in place with adhesive tape and observed with a Philips XL30 Series Environmental Scanning Electron Microscope without any further sample treatment.

RESULTS

Cultivation of alkaliphilic spore-forming bacteria

The four selected species of alkaliphilic resistant strains grew well in rich (yeast extract and peptone amended) medium. However, spore formation appeared much better in mineral medium with Na-citrate as growth substrate (Figure 1).

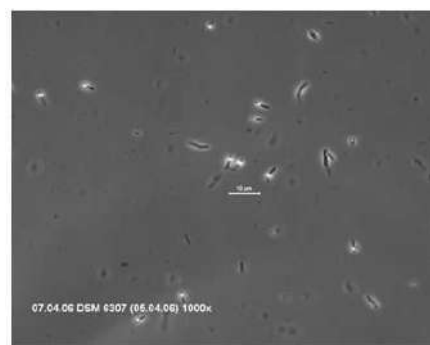


Figure 1: Spore formation by *Bacillus cohnii* grown in mineral medium with sodium citrate as growth substrate. Bright dots are spores formed by the vegetative cells (dark rods)



Strength characteristics of bacterial-, organic compound- and control concrete

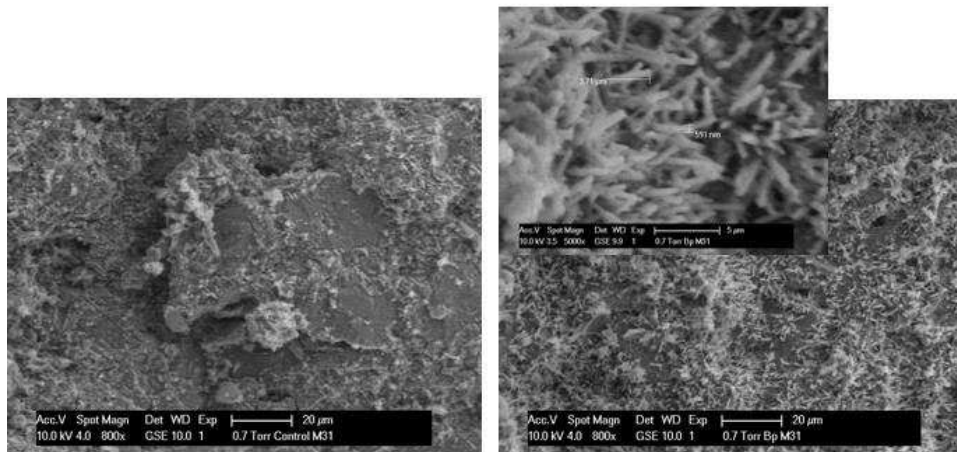
Concrete bars made for flexural tensile- and compressive strength testing contained 10^9 cm⁻³ *S.pasteurii* cells (bacterial concrete) or 19.5g (0.5% of cement weight) organic carbon compounds. No additions were made to control concrete bars. After 28 days curing, no significant difference was found in flexural tensile- and compressive strength between control-, bacterial- and amino acid (aspartic acid and glutamic acid)-containing concrete bars (Table 2). Concrete to which polyacrylic acid and citric acid was added suffered significant strength loss, while gluconate- and ascorbic acid amended concrete did not develop any strength during 28 days curing period.

Table 2: Flexural tensile- and compressive strength characteristics of control-, bacteria-, and organic carbon amended concrete bars after 28 days curing period

Type of concrete:	Tensile strength (N/mm ²):	Compressive strength (N/mm ²):
Control	7.78 ± 0.38	31.92 ± 1.98
<i>S.pasteurii</i>	7.45 ± 0.45	34.78 ± 1.52
Na-aspartate	7.33 ± 0.37	33.69 ± 1.89
Na-glutamate	7.16 ± 0.19	28.52 ± 3.56
Na-polyacrylate	6.42 ± 0.47	20.53 ± 4.50
Na-citrate	3.48 ± 1.72	12.68 ± 1.82
Na-gluconate	0	0
Na-ascorbate	0	0

Biomaterial production by bacterial concrete

Cement stone samples with immobilized *B.pseudofirmus* spores produced copious amounts of mineral crystals on its medium-exposed surface as was revealed by ESEM analysis (Figure 2). No crystal formation was observed on control samples which were incubated under identical conditions in peptone- and yeast extract-containing medium.



A. Control (no bacteria)

B. Concrete with immobilized bacteria

Figure 2: Copious formation of mineral on the surface of cement stone with *B.pseudofirmus*-immobilized spores

DISCUSSION AND CONCLUSIONS

The main objective of this study was to investigate whether bacteria can potentially act as a self-healing agent in concrete. The bacteria tested are known to be alkali-resistant, i.e. they grow in natural environments characterized by a relatively high pH (10-11). In addition, these strains can produce spores which are resting cells with sturdy cell walls that protect them against extreme environmental mechanical- and chemical stresses (Schlegel 1993). Therefore these specific bacteria may have the potential to resist the high internal concrete pH values (12-13 for portland cement-



based concrete), and remain viable for a long time as well, as spore viability for up to 200 years is documented (Schlegel 1993). We hypothesized that concrete-immobilized spores of such bacteria may be able to seal cracks by biomineral formation after being revived by water and growth nutrients entering freshly formed cracks. The experimental data presented support our hypothesis, as cement stone samples with immobilized bacteria but not control samples precipitated minerals on surfaces exposed to growth medium. Although the exact nature of the produced minerals still needs to be clarified, they appear morphologically related to calcite precipitates. The mechanism of bacterially-mediated calcite production likely proceeds via organic carbon respiration with oxygen what results in carbonate ion production under alkaline conditions. The produced carbonate ions which can locally reach high concentrations at bacterially active 'hot spots' precipitate with excess calcium ions leaking out of the concrete matrix. This microbial calcium carbonate precipitation mechanism is well studied and occurs worldwide in natural systems such as oceans, biofilms, microbial mats and stromatolites (Krumbein et al 1977; Riding 2000; Arp et al 2001; Ludwig et al 2005). For an autonomous self-healing mechanism all needed reaction components, or self-healing agents, must be present in the material matrix to ensure minimal externally needed triggers. In the biomineral precipitation experiment, however, the organic substrate needed for bacterial carbonate ion production was still supplied as part of the incubation medium. As it should ideally also be part of the concrete matrix we tested the compatibility of bacteria as well as different organic components, which can act as bacterial growth substrates.

The obtained flexural tensile- and compressive strength data indicate that the incorporation of high numbers of bacteria (10^9 cells cm^{-3}) and the amino acids aspartate and glutamate (0.5% of cement weight) in the concrete matrix, do not result in a significant loss of strength after 28 days curing period. However, the same experiment also revealed that apparently only specific organic components are suitable for incorporation, as some others resulted in dramatic strength loss. Another aspect that was not considered in this study but what is of major importance for the long term self-healing potential of bacterial concrete is the long term viability of concrete-immobilized bacterial spores. As most concrete structures are built to last for 50 years or more the viability of immobilized spores should keep up with that. One advantage of application of bacteria as self-healing agent is that a healing event not only revives bacterial cells but also potentially results in the production of fresh spores what resets the viability status.

To conclude we can state that the application of bacteria as a self-healing agent in concrete appears promising. We have demonstrated that concrete-immobilized bacterial spores revive and produce copious minerals after stimulation by suitable medium, i.e. water containing an organic growth substrate. To further improve the autonomous bacterial self-healing mechanism current research focuses on long term viability and selection of best adapted bacterial species to the concrete environment as well as the incorporation of compatible biomineral-producing organic substrates to the concrete matrix.

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