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A Review on Utilization of Solar Energy in Solar Water Heaters Integrated With Phase Change Materials

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Abstract – *The uncontrolled use of non-renewable energy resources is of major concern in the world as once they are depleted it cannot be replenished also the problem with use of non-renewable energy is by product generated from non-renewable energy production contribute to environmental damage and an increase in greenhouse gas emissions . so nowadays researchers focus is on utilization of renewable energy sources like solar ,wind, tidal energy etc. one of the most abundantly available energy resource among all the natural resource is solar energy. solar energy plays vital role in domestic and industrial applications as it is freely and easily available source of energy. Solar water heating is one of the common applications of using solar energy around the world for both industrial and domestic purpose. But the core problem with solar water heaters is supply of hot water is possible only in day time from the storage tank. But pcm installed solar water heaters is solution to above stated problem. Phase change materials are used for storing the heat energy in the heaters to get efficient system pcm used in this systems are used as thermal energy storage(TES).the objective of this paper is to review the utilization of pcm in solar heating process for both industrial and domestic applications.*

Keywords: *Renewable energy, phase change materials (pcm), thermal energy storage (TES)*

I- INTRODUCTION

Energy is the background for every activity of life. This energy comes from either renewable or non renewable source of energy. The demand for energy is increasing drastically as population increases day by day. This increasing demand forces us to use non renewable sources like coal, lignite, petrol diesel and dangerous nuclear energy[6]. But limitation of use of non renewable source is these sources are available in very less quantity and may get deplete soon. Also non renewable energy sources are responsible for lot of pollution in the world today. Burning them releases harmful chemicals into the air, including carbon dioxide and sulfur dioxides. These gases are responsible for climate change and respiratory problems. Renewable energy is the ultimate solution for this concern renewable energy often referred as clean energy comes from natural sources that are constantly replenished. For example sunlight and wind keep shining and blowing even if their availability depends on time and whether[1]. But the core problem with renewable energy is it is time dependent for example in case of solar energy sun available only during day time.so reservoir required to store solar energy to use t during night time or during cloudy condition. There are several methods to store solar energy .one of the way is use of pcm for active storing of solar energy[4]. The aim of this paper is to review one of application of solar energy which is solar water heating process and to study use of phase change material in thermal energy storage applications.

SOLAR WATER HEATING SYSTEM

Solar water heating system uses solar energy to generate heat which can then be used to heat water. This heated water can be utilized in many domestic applications .hot water can also be utilized in space heating and pool heating application. Many industrial processes also have the requirement of heated water solar water heating system are useful in such industrial applications. Therefore solar water heating system is cost effective and reliable technique which helps in reducing bills for home and businesses ultimately increasing profit.

Solar water heating systems heats water using solar radiations. Simple and very common application of solar water heating system is domestic water heating. The focus of this review paper is on solar water heating for domestic purpose, industrial application and for high temperature applications.

There are 2 types of solar water heating systems 1) active system 2) passive system

Active system

Circulating pumps are used for circulating water or heat transfer fluid through out the system in active system. The advantage of active system is active system are more efficient than passive system but these system are expensive as it incurred cost of circulating pumps and cost of operating pumps.

Passive system

Gravity and thermo siphon properties of fluids are used in passive system instead of circulating pumps for circulating fluid throughout the system. Passive systems are cost effective than active system but these system are not as effective as active system. also passive system are not useful in cold areas where temperature falls below freezing point temperature of fluid used in system.

Active solar water systems are used in Domestic and commercial applications.

PROBLEM ASSOCIATED WITH SOLAR WATER HEATING

Long term availability of hot water using solar water heater system is very important for efficient use of solar water system. The important problem with use of solar water heater system is hot water is available during day time only and water heating is not possible during night. Hence there are limitations on use of solar water heaters.to overcome this problem it is necessary to store solar energy during daytime and use it during night. One of the solutions to this problem is use of thermal energy storage system to store solar energy. A latent heat thermal energy storage system comprises mainly of 3 main components

- A pcm that would be effectively store solar energy
- Container with proper insulation to store pcm
- Surface for heat exchange from surrounding to pcm

PHASE CHANGE MATERIALS:

Phase Change Materials are substances designed to absorb thermal energy, preserve it, and gradually release it upon solidification. PCMs exploit this phenomenon, allowing the material to conserve heat while changing state without losing energy. This method allows the PCM to absorb and release heat efficiently, and as a result, they are vital elements in various applications. Thanks to its high latent heat capacity, PCMs are commonly employed in thermal insulation and thermal management. Engineers use different PCM solutions to control heat transfer and realize a variety of cooling objectives. To accomplish this, SHS and LHS are the two primary methods. People prefer LHS to SHS when the substance can preserve and disperse more heat energy throughout a temperature range.

PCMs are typically classified into two forms: hydrated salts and organic.

1) Hydrated salts: Hydrated salts are PCMs with melting temperatures above that of water, capable of reaching 117°C. Among other benefits, they exhibit high heat of fusion, modest volume phase changes, non-flammability, and, in some cases, high affordability. At the same time, they may be corrosive and unreliable over several cycles. They are typically applied for large thermal storage

facilities like solar heating and customer-oriented products like pre-filled ice bags.

2. Paraffin Wax: One of the most popular PCMs, paraffin wax has a melting point that ranges from 6 to 108 degrees Celsius, but it usually falls between 46 and 68 degrees. It is available in encapsulated or shape-stable forms. The high heat of fusion, latent heat capacity, chemical inertness, non-corrosiveness, and consistent thermal cycling are some of its advantages. Paraffin wax is preferred in electronics thermal management and energy storage systems; nevertheless, it is not suitable for high-temperature situations due to its flammability.

3. Non-paraffin Organics: Polyethylene glycol (PEG), polyalcohol, polyethylene, and fatty acids are a few examples. These PCMs have low flash points, which makes them extremely flammable, which makes them inappropriate for high-temperature applications even though they have advantages like high energy storage capacity.

.4) Metalics: PCMs made of metal alloys have melting points between 150°C and 800°C. They work well in high-power, transient settings because they effectively divert heat from important components. Concentrated solar power (CSP) plants and other modern electrical generation systems frequently use metallic PCMs.

These varied PCM alternatives provide efficient solutions for heat storage and transfer while meeting the demands of a wide range of sectors in terms of thermal management.

II -REVIEW OF SOME OF THE RESEARCH WORK DONE SO FAR

R. Dhinakaran R.muraliraja s bhaskar s satish[6]

A phase change material (PCM) of choice was used in this study by R. Dhinakaran, R. Muraliraja, S. Bhaskar, and S. Satish to build a heat storage system. The system was made up of connecting pipes, a solar collector, a Thermal Energy Storage (TES) tank that had paraffin wax as the PCM, and a cold water tank with a timing valve that allowed water to flow to the collector at regular intervals.

A copper coil was placed in an open area of the experimental setup. Three 250-gram PCM cylinders, each containing three grams of aluminum oxide as a nanofiller, were stored in the PCM tank. Both a version of the experiment and one without these nanofillers were run.

The procedure began with cold water traveling via pipes to the copper coils that were outside. The water entered the TES tank after it had heated. The paraffin wax's phase changed from solid to liquid as the ambient temperature rose, starting the charging process. This was done until the temperature of the PCM and the water were equal. The water was then taken out of the tanks, starting the process of discharge to heat the water for use in different applications.

III- RESULT

The system's thermal efficiency increased as a result of using nanofillers, according to the results, which raised the hot water's final temperature during the process compared to studies done without them.

T.bouhal, t. El rhafiki, a jamil, y zeraouli [8]

Under normal load conditions, T. Bouhal, T. El Rhafiki, A. Jamil, and Y. Zeraouli investigate the operating cycle of solar water heaters and possible enhancements in thermal energy storage through phase change materials (PCMs). To investigate the transient behavior of phase change energy storage components, the researchers have developed two numerical models. The goal of these models is to predict the distribution of temperatures inside the PCM-containing storage tank.

To model the phase transition events, two methods were used: the enthalpy approach and the apparent specific heat capacity. To assess heat transfer during the melting of PCM integrated into the solar storage tank, a comparison of various techniques was carried out. To evaluate the numerical performance of these techniques and predict improvements in energy storage tank efficiency and thermal performance, important parameters like temperature profiles and liquid fraction were examined.

Results

The researchers concluded that, in comparison to the apparent heat capacity model, the heat transfer model that used the enthalpy technique required more computing time. They propose that when the heat capacity of PCM is known during the phase change

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process, the apparent heat capacity technique is appropriate.

Mario palacio anggie Rincon Mauricio carmona [3]

Mario Palacio, Anggie Rincon, and Mauricio Carmona carried out a comparative experimental study of a prototype that was identical to the standard flat plate solar collector but had a phase change material (PCM) thermal storage device installed. The goal of the study was to evaluate the outcomes from both configurations. A pair of flat plate solar collectors (FPSCs) were built, with exact measurements and design features. Whereas the other collector was a conventional FPSC, the first one had a PCM container underneath the absorber plate. The two collectors were intended to function at a flow rate of 0.2 liters per minute and each had a surface area of 1 meter.

There were four test cases taken into account:

1. Case 1: Using an Ecopetrol semirefined PCM to operate the solar collector.

Examining the solar collector using the Rubitherm RT-47 PCM in Case 2.

3. Case 3: To lessen thermal contact resistance, place thermal paste between the absorber plate and PCM container.

Examining the impact of collection inclination both with and without PCM in Case 4.

Results:

The study's outcomes show that the behavior of the solar collector is greatly impacted by the use of PCM as a thermal storage device. Temperatures were greater at night and lower during the day in collectors that had PCM installed. Although the addition of PCM resulted in reduced amounts of usable heat during the day, it made up for this by providing thermal energy at night. The results of the studies demonstrated how crucial it is to choose the right PCM to ensure the thermal storage system operates effectively. Despite PCM 2's lower density, latent heat of fusion, and melting point, PCM 1 outperformed it in terms of thermal energy storage and usable heat supply.

Moreover, lowering the thermal contact resistance significantly improved every variable under study and had a substantial impact on the storage system's performance. The temperature of the water exit rose as the thermal contact resistance decreased, stabilizing the amount of usable heat.

Furthermore, modifying the system's inclination decreased the amount of stored energy, melted PCM, and shortened the storage system's discharge time. When compared to collectors without PCM, it was found that the thermal efficiency was reduced in situations when the collector was inclined.

Arvind Kumar Singh, Nitin Agarwal , Abhishek Saxena[4]

Phase change material (PCM) was used in four different configurations of two unique absorber plates for a solar air heater (SAH), which Arvind Kumar Singh, Nitin Agarwal, and Abhishek Saxena set out to experimentally test. An absorber plate with tiny hollow circular tubes filled with PCM inserted inside the SAH was used in the experimental setting. It was set up on a wooden and tin-constructed stand.

The absorber plate, comprising 66 hollow cylindrical vertical tubes arranged in six columns, was tightly insulated with glass wool at the bottom and sides. The entire setup was enclosed in a wooden frame, with 4 mm rugged glass serving as a substitute for glazing. A rectangular tapered air duct was formed between the absorber plate and the transparent cover, diverging at the inlet and converging at the outlet. The small cylindrical tubes had a height of approximately 5 cm, with an inner diameter of about 30 mm and an outer diameter of 32 mm.

The research encompassed four distinct cases:

SAH with a flat plate absorber without PCM.

SAH with a flat plate absorber with PCM.

SAH with a bed of small cylindrical hollow tubes (extended surfaces).

SAH with a bed of small cylindrical tubes filled with PCM.

Results:

The study's conclusions showed that using PCM had a considerable impact on the air exit temperature. Comparing the extended geometry SAH with PCM to the flat plate SAH filled with PCM, the researchers found that PCM started to discharge 1-1.5 hours earlier in the former. Furthermore, it discharged more quickly than the PCM-filled flat plate, which may have helped in unfavorable environmental circumstances. It was discovered that the heater's average performance when using cylindrical tubes with PCM was 12% better than when using the same settings without PCM, and roughly 18% and 22% better than when using flat plates with and without PCM, respectively.

S. Vasanthaseelan, . Manoj Kumar R. Anandkumar , K. Hari Ramb, Ram Subbiah , V. Suresh , A.S. Abishek , R. Anith , P. Aravinth , S.V. Balaji [1]

S. Vasanthaseelan, P. Manoj Kumar, R. Anandkumar, K. Hari Ram, Ram Subbiah, V. Suresh, A.S. Abishek, R. Anith, P. Aravinth, and S.V. Balaji conducted a study to examine the impact of turbulators on the performance of evacuated tube collector (ETC)-based solar water heaters. Two types of turbulators, specifically coiled turbulator and matrix turbulator, were investigated within the ETC setup. The experiments were conducted in three modes: ETC without turbulator (Simple-ETC), ETC with coiled turbulator (CT-ETC), ETC with matrix turbulator (MT-ETC).

Both types of turbulators were fabricated for this study. The coiled turbulator was designed as an open coiled helical spring with a mean diameter of 28 mm, a wire diameter of 1 mm, and a length of 1750 mm. The matrix turbulator, on the other hand, was procured from the local market and comprised a centrally twisted wire rod surrounded by wire loops forming a mesh. Both matrix and coiled turbulators were constructed using aluminum wire to enhance heat conduction cost-effectively.

The study's conclusions revealed that the temperature at the bottom of the tubes increased, along with the middle and upper portions, with the assistance of both coiled and matrix turbulators. These turbulators facilitated the regulation of ETC tube temperatures to achieve uniformity through induced turbulence inside the tubes. Overall, the average tube temperature was enhanced, with the matrix turbulators exhibiting performance twice as effective as the coiled turbulators.

IV-CONCLUSION AND FUTURE SCOPE

The primary emphasis of this review paper lies in exploring the utilization of phase change materials (PCMs) within the realm of solar water heating and its diverse applications. While considerable advancements have been made in thermal energy storage, there remains substantial room for improvement within this domain. Further research is warranted, particularly in the areas of solar water heater geometry and enhancing heat transfer rates when employing PCMs

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