Performance Improvement of Honing Machine Using Six Sigma

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Abstract –There has been number of papers published related to Six Sigma applications in manufacturing and service organizations. However, very few studies are done on honing machine in all the areas including manufacturing, construction, education, financial service, BPOs and healthcare etc. Considering the contribution of Six Sigma in recent time, a more comprehensive review is presented in this paper. A systematic approach needs to be adopted, which optimizes systems as a whole, focusing the right strategies in the correct places. In this paper it is show how a honing process can be improved and optimized using six sigma. Even applications of Six Sigma tools are observed in this paper. In the research paper DMAIC Cycle is been used for process characterization & process optimization,

This paper contributes to knowledge by providing an insight into the evolution of the Six Sigma. A very few paper are available related to analysis of honing machine using six sigma. Literature exploring the environmental/green impact of quality management methods commonly used in industry is limited. There is also a lack of studies aiming to investigate the green impact of Six Sigma in top operations and quality management journals.

Keywords - Six sigma, DMAIC, honing machine, Productivity, Quality.

I. INTRODUCTION

In this competitive scenario, the markets are becoming global & economic conditions are changing fast. Customers are very quality conscious & demand for high quality product at competitive prices with product variety and reduced lead-time. Companies are facing tough challenge to respond to the needs of customer while keeping manufacturing & other related costs down .The companies are striving for their very survival. Companies can cut down their costs by reducing the production of defective parts.

Quality is a necessary characteristic for Industrial Engineers to observe, study, and understand. For organizations that offer products and services to customers, a system within this company is a process that produces, maintains, or supports a product or service. According to Kirkpatrick (1970), a system is a physical or conceptual entity comprised of interdependent parts that interact within boundaries established to achieve some common goal or goals. This definition of system aids a proper definition of quality within the realm of Industrial Engineering topics. According to El-Haik (2005), quality can be defined as .the degree to which the design vulnerabilities do not adversely affect product performance. It is important to note that this definition is universally applicable to not simply products and product design, but also service and service process design. Also, the design vulnerabilities of a product or service can either be inherit in the type of product or services being created, or perhaps established by improper conceptual design. Regardless of which type of vulnerability may exist, the quality of a product or service is only decreased when it affects either the process that creates it by increasing costs, time, and constraints, or by affecting the end product or service that a customer uses. This implies that quality is not merely achieving the perfection of a product or service, but rather, high quality is achieving perfection of product or service performance, or getting as close to it as possible.

Productivity is an average measure of the efficiency of production. It can be expressed as the ratio of output to inputs used in the production process, i.e. output per unit of input. When all outputs and inputs are included in the productivity measure it is called total productivity. Outputs and inputs are defined in the total productivity measure as their economic values. The value of outputs minus the value of inputs is a measure of the income generated in a production process. It is a measure of total efficiency of a production process and as such the objective to be maximized in production process.

Productivity measures that use one or more inputs or factors, but not all factors, are called partial productivities. A common example in economics is labor productivity, usually expressed as output per hour. At the company level, typical partial productivity measures are such things as worker hours, materials or energy per unit of production.

Honing is an abrasive machining process that produces a precision surface on a metal work piece by scrubbing an abrasive stone against it along a controlled path. Honing is primarily used to improve the geometric form of a surface, but may also improve the surface texture. Typical applications are the finishing of cylinders for internal combustion engines, air bearing spindles and gears. There are many types of hones but all consist of one or more abrasive stones that are held under pressure against the surface they are working on. In terms of sharpening knives, a honing steel does not actually hone knives, but simply realigns the metal along the edge.

Other similar processes are lapping and super finishing.

Six Sigma Methods -

Six Sigma is based on six basic principles that help the implementation of Six Sigma method to production companies or service industries. Six Sigma uses the base tools to improve the quality of products and processes as Measurement System Analysis (MSA), IPO Diagram (Input-process-output), Cause-and- Effect diagram (CE), Histogram, Pareto diagram, Define, Measure, Analyze, Improve, Control (DMAIC), Run chart, Control chart, Scatter diagram, Regression Analysis, Designing of Experiments (DOE), Failure Mode and Effect Analysis (FMEA), Standard Operating Procedure (SOP) and Quality Function Deployment (QFD).

Measurement system analysis

Diffusion of the watched commodities' parameter can be connected by the commodity itself or the system of measuring. The system of measuring is made by operator, benchmark and the method of measuring.

Measuring System Analysis (MSA) is a tool for the evaluation of accuracy and advisability of the measuring system. It goes with testing or measuring the chosen parameter by the operator. It monitors the influence of repentance and reproducibility of the total variance. The goal of MSA is to estimate how the system of measuring contributes to the total variance of watched parameter. Most of the time, analysis of the measurement system is used in the phase of Measurements.

Analysis of the causes and consequences

CE is a tool to solve problems through finding the cause of their occurrence. It helps to find all possible causes, to split causes into categories and organize their relationships and impact on output, and to identify opportunities for improvement. In general, these categories are commonly known as

7 M causes:

• Man -people, job;
• Methods and mechanics, process;
• Machine – machines, equipment;
• Measurement;
•Management - system of organization and management;
• Material; and
• Mother Nature - environment.

Histogram

Histogram is a perfect tool for visualization of the frequency of the watched phenomenon in process. It is a bar chart made from number of categories, showing their splitting. Customer tolerance can be added (LSL, USL) to watched process.

Pareto diagram

Pareto diagram is a bar chart for discrete data, indicating the frequency of non-digital data. These categories are arranged in descending order. The tool that allows determining the impact of input factors to an endpoint.

DMAIC

It is the common option for the model of improving the process based on Deming's circle Plan-Do-Check-Act (PDCA). DMAIC is in the Six Sigma methodology being used as the standard routine for planning and implementation of the project.

II.   METHODOLOGIES IN SIX SIGMA

The various researchers have applied different methodologies for the estimation of six sigma. The literatures are classified on the basis of methodology applied for the particular applications. From the literature it is proved that DMAIC are very popular in the field of six sigma. Lean six sigma is a modern and

advance concept. As compare to DMADV is also familiar in the field of six sigma.

The phase of Six Sigma implementation

In order to reduce process variation and the associated high defect rate, Six Sigma focuses on improvement methodology application, then the DMAIC is mentioned most frequently now and a lasting improvement method (Starbird, 2002). The representative's meanings of five English letters are as follows:

Define
The top management shall identify the problem according to customer feedback, strategy and mission of company, define customer requirements, and set goal.

Measure
Measurement is a key transitional step on Six Sigma road, one that helps the project team refined the problem and being the search for root causes which will be the objective of Analyze step in DMAIC. Therefore, the project team needs to validate problem/process, refine problem/goal, and measure key steps/input.

Analyze
In analyses stage, the project team shall use data analysis tools and process analysis techniques to identify and verify root causes of the problem. For the reason, the project team needs to develop causal hypotheses, identify vital few root causes, and validate hypothesis

Improve
The goal of the improve stage is to find and implement solutions that will eliminate the causes of problems, reduce the variation in a process, or prevent a problem from recurring. So the project team needs to develop ideas to remove root causes, test solutions, and standardize solution/measure result.

Control
Once the improvement has been made and results documented, continue to measure the performance of the process routinely, adjusting its operation. It is very important for the project team needs to establish standard measures to maintain performance and correct problems as needs. Without control efforts, the improved process may well revert to its previous state.

III-MEASUREMENT, OBSERVATION & ANALYSIS

The Measurement, Observation & Analysis using six sigma is show below. We have specified the application of six sigma on a specific process i. e. honing process which is done over a honing machine. The honing machine is used for the finishing of the engine cylinder internal surface i. e. liner. In the workshop where the honing machine is used for precise machining. But there are lot of quality problems observed. So for the analysis six sigma is applied on the honing process. Initially 25 readings were taken and one defect was observed. These readings were taken without any changes and only regular readings were taken. While taking these readings various problems were also identified and even the report was made. After taking initial readings, the reasons and causes were identified & controlled. Group discussion was organised and all the parameters were discussed and revised. After this again 25 readings were taken & six sigma standard was achieved. But this time our guidelines were used for the process.

Formulas:-

$$\overline{X} = \frac{\Sigma X}{n}$$

Range R = (Max R – Min R)

Where,

$\overline{X}$ is Average of Six cylinder (X).

R is Range of Six Cylinder (X).

n is Subgroup (6).

Table 1 - Example

Job No	Cylinder 1 (X1)	Cylinder 2 (X2)	Cylinder 3 (X3)	Cylinder 4 (X4)	Cylinder 5 (X5)	Cylinder 6 (X6)	$\overline{X}$	R
1	97	97	97.01	97.01	97.01	97	97.005	0.01
2	97	97.01	97	97	97.01	97.01	97.005	0.01

$$\overline{X} = \frac{97+97+97.01+97.01+97.01+97}{6} = 97.005$$

$$R = (97.01-97) = 0.01$$

Table 2 – Initial Observation Table

Job No	Cylinder 1 (X1)	Cylinder 2 (X2)	Cylinder 3 (X3)	Cylinder 4 (X4)	Cylinder 5 (X5)	Cylinder 6 (X6)	$\overline{X}$	R
1	97	97	97.01	97.01	97.01	97	97.005	0.01
2	97	97.01	97	97	97.01	97.01	97.005	0.01
3	97.01	97	97	97	96.99	97	97	0.02
4	97	97	96.99	97	97.01	97.01	97.00167	0.02
5	97	97	97.01	97	96.99	97	97	0.02
6	97.01	97	97.01	97	97	97	97.00333	0.01
7	96.99	97	97.01	97	97	97	97	0.02
8	97	97	97.01	97.01	97	97	97.00333	0.01
9	97	97	97.01	97	97	97	97.00167	0.01
10	97	97	97.01	97.01	97	97	97.00333	0.01
11	97	97.01	96.99	97.01	97	97	97.00167	0.02
12	97	97	97	97.01	97	96.99	97	0.02
13	97	97	97	97.01	97	97.01	97.00333	0.01
14	97	97	97	97	97.02	97.02	97.00667	0.02
15	97.01	97	97	97	97.01	96.99	97.00167	0.02
16	97.01	97.01	96.99	97	97	97.01	97.00333	0.02
17	97	97.01	97.01	97.01	97	97	97.005	0.01
18	97	97.01	97.01	97.01	97.02	97.02	97.01167	0.02
19	97.01	97	97.01	96.99	97	97	97.00167	0.02
20	97	97	97.01	97.01	97.01	97	97.005	0.01
21	96.99	97.01	97	97	97.01	97	97.00167	0.02
22	97	97	97	97.01	96.99	97	97	0.02
23	97.01	97	97	97.01	97	97.01	97.005	0.01
24	97	96.99	97	97	97.01	97	97	0.02
25	96.99	97	97	97	97.01	97.01	97.00167	0.02

Formulas:-

$$\overline{\overline{X}} = \frac{\sum \overline{X}}{n} = 97.00286667$$

$$\overline{R} = \frac{\sum R}{n} = 0.016$$

Where,

$\overline{\overline{X}}$ is Average Of Average for 25 Jobs.

$\overline{R}$ is Average Of Range for 25 Jobs.

n is 25

Table 3-- Formulas

For R Chart	
UCL_R	$D4*\overline{R}$
CL_R	$\overline{R}$
LCL_R	$D3*\overline{R}$

UCL_R is Upper Control Limit.

CL_R is Control Limit.

LCL_R is lower Control Limit.

$\overline{R}$ is Average of Range

Where,

CL_R is Control Limit.

LCL_R is lower Control Limit.

$\overline{R}$ is Average of Range

Table 4 – Appendix

=6 From Table of Control Chart Constants	
A2	0.48
D2	2.534
D3	0
D4	2

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Table 5 – R Chart

R Chart				
JOB No	R	UCL_R	CL_R	LCL_R
1	0.01	0.032064	0.016	0
2	0.01	0.032064	0.016	0
3	0.02	0.032064	0.016	0
4	0.02	0.032064	0.016	0
5	0.02	0.032064	0.016	0
6	0.01	0.032064	0.016	0
7	0.02	0.032064	0.016	0
8	0.01	0.032064	0.016	0
9	0.01	0.032064	0.016	0
10	0.01	0.032064	0.016	0
11	0.02	0.032064	0.016	0
12	0.02	0.032064	0.016	0
13	0.01	0.032064	0.016	0
14	0.02	0.032064	0.016	0
15	0.02	0.032064	0.016	0
16	0.02	0.032064	0.016	0
17	0.01	0.032064	0.016	0
18	0.02	0.032064	0.016	0
19	0.02	0.032064	0.016	0
20	0.01	0.032064	0.016	0
21	0.02	0.032064	0.016	0
22	0.02	0.032064	0.016	0
23	0.01	0.032064	0.016	0
24	0.02	0.032064	0.016	0
25	0.02	0.032064	0.016	0
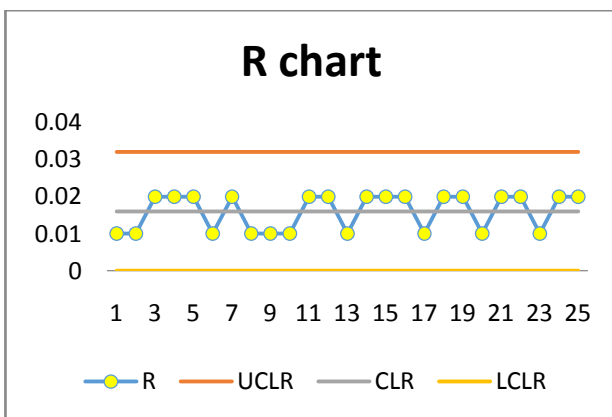
Fig.1 – R Chart

Table 6 - Formulas

For X Chart	
UCL_X	$\bar{\bar{X}}$+(A2*$\bar{R}$)
CL_X	$\bar{\bar{X}}$
LCL_X	$\bar{\bar{X}}$-(A2*$\bar{R}$)

Using table 4 & 6 we get,

Table 7 – X Chart

X Chart				
JOB No	$\bar{X}$	UCL_X	CL_X	LCL_X
1	97.005	97.0105	97.002	96.99
2	97.005	97.010	97.0028	96.995
3	97	97.0105	97.002	96.995
4	97.001	97.0105	97.002	96.995
5	97	97.0105	97.0028	96.995
6	97.003	97.0105	97.002	96.99513
7	97	97.0105	97.002	96.995
8	97.003	97.0105	97.0028	96.995
9	97.001	97.0105	97.002	96.995
10	97.003	97.010	97.0028	96.995
11	97.001	97.0105	97.002	96.9951
12	97	97.0105	97.0028	96.9951
13	97.003	97.0105	97.002	96.995
14	97.066	97.010	97.00286	96.995
15	97.0016	97.0105	97.0028	96.9951
16	97.003	97.0105	97.002	96.995
17	97.005	97.0105	97.002	96.9951
18	97.0116	97.0105	97.002	96.995
19	97.001	97.0105	97.002	96.995
20	97.005	97.01059	97.0028	96.995
21	97.0016	97.0105	97.0028	96.9951
22	97	97.0105	97.002	96.9951
23	97.005	97.010	97.002	96.995
24	97	97.0105	97.0028	96.9951
25	97.0016	97.01059	97.0028	96.9951

Process Capability

Formulas

$$\sigma^{'}=\frac{\bar{R}}{D2}=\frac{0.016}{2.534}= 0.006314$$
$$3\sigma^{'}= 3*0.006314= 0.018942384$$
$$6\sigma^{'}= 6*0.006314= 0.037884$$

Where,

$\sigma^{'}$ is standard Deviation.

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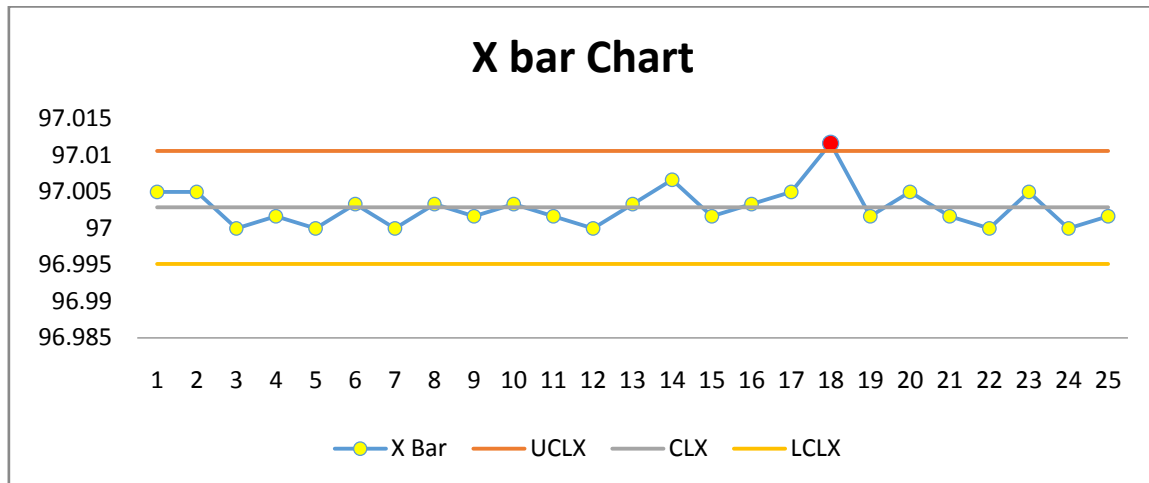*www.ijies.net*

Fig.2 – X Chart   Table 8 – Limit table

Table 8-Limit Table

USL (Upper Specification Limit)	Specification Limit	LSL (Lower Specification Limit)
97.01	±0.012	96.988

$$cP = \frac{(USl-LSL)}{6\sigma'} = \frac{(97.01-96.988)}{0.037884} = 0.6335$$

$$CpU = \frac{(USl-\bar{\bar{X}})}{3\sigma'} = \frac{(97.01-97.00286667)}{0.018942384} = 0.482164$$

$$CpL = \frac{(\bar{\bar{X}}-LSL)}{3\sigma'} = \frac{(97.00286667-96.988)}{0.018942384} = 0.784836111$$

CpK = Minimum (CpU,Cpl) = 0.482164

Table 9 – Second Observation

Job No	Cylinder 1 (X1)	Cylinder 2 (X2)	Cylinder 3 (X3)	Cylinder 4 (X4)	Cylinder 5 (X5)	Cylinder 6 (X6)	$\bar{X}$	R
1	97	97	97.01	97	97	97.01	97.00333333	0.01
2	97	97	97	97.01	97.01	97	97.00333333	0.01
3	97.01	97	97	97	97	97.01	97.00333333	0.01
4	96.99	97	97.01	97	97	97	97	0.02
5	97	97	97	97	97.01	97.01	97.00333333	0.01
6	97	97	97	97	97.01	97.01	97.00333333	0.01
7	97.01	96.99	97	97	97.01	97.01	97.00333333	0.02
8	97	97	97.01	96.99	97	97	97	0.02
9	96.99	97	97	97	97	97.01	97	0.02
10	97	97	97	97	97	97.01	97.00166667	0.01
11	97	97	97.01	97	97.01	97	97.00333333	0.01
12	97	97.01	97	97.01	97	97	97.00333333	0.01
13	97.01	97	97.01	97.01	96.99	97	97.00333333	0.02

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14	97	97	97.01	97	97.01	97	97.00333333	0.01
15	97.01	97	97.01	97.01	97	97	97.005	0.01
16	97.01	96.99	97	97	97	97	97	0.02
17	97	97.01	97	97	97	97.01	97.00333333	0.01
18	97.01	97.01	97	97	97	97	97.00333333	0.01
19	97.01	97.01	97	96.99	97	97.01	97.00333333	0.02
20	97.01	97	97.01	97.01	97	97	97.005	0.01
21	97	97	97.01	97.01	97	97.01	97.005	0.01
22	97	97	97	97	97	97.01	97.00166667	0.01
23	97.01	97	97.01	97.01	97	97	97.005	0.01
24	97.01	97	97.01	97	97	97	97.00333333	0.01
25	97	97	97.01	96.99	97.01	97.01	97.00333333	0.02

Table 10 - Example

Job No	Cylinder 1 (X1)	Cylinder 2 (X2)	Cylinder 3 (X3)	Cylinder 4 (X4)	Cylinder 5 (X5)	Cylinder 6 (X6)	$\overline{X}$	R
1	97	97	97.01	97	97	97.01	97.00333333	0.01
2	97	97	97	97.01	97.01	97	97.00333333	0.01

$$\overline{X} = \frac{97+97+97.01+97+97+97.01}{6} = 97.00333$$

$$R = (97.01-97) = 0.01$$

Formulas:-

$$\overline{\overline{X}} = \frac{\Sigma \overline{X}}{n} = 97.00293333$$

$$\overline{R} = \frac{\Sigma R}{n} = 0.0132$$

Where,

$\overline{\overline{X}}$ is Average Of Average for 25 Jobs.
$\overline{R}$ is Average Of Range for 25 Jobs.
n is 25.
Using table 3 & 4

14	0.01	0.0264528	0.0132	0
15	0.01	0.0264528	0.0132	0
16	0.02	0.0264528	0.0132	0
17	0.01	0.0264528	0.0132	0
18	0.01	0.0264528	0.0132	0
19	0.02	0.0264528	0.0132	0
20	0.01	0.0264528	0.0132	0
21	0.01	0.0264528	0.0132	0
22	0.01	0.0264528	0.0132	0
23	0.01	0.0264528	0.0132	0
24	0.01	0.0264528	0.0132	0
25	0.02	0.0264528	0.0132	0

Table 11 - R Chart

R Chart				
JOB No	R	UCL_R	CL_R	LCL_R
1	0.01	0.0264528	0.0132	0
2	0.01	0.0264528	0.0132	0
3	0.01	0.0264528	0.0132	0
4	0.02	0.0264528	0.0132	0
5	0.01	0.0264528	0.0132	0
6	0.01	0.0264528	0.0132	0
7	0.02	0.0264528	0.0132	0
8	0.02	0.0264528	0.0132	0
9	0.02	0.0264528	0.0132	0
10	0.01	0.0264528	0.0132	0
11	0.01	0.0264528	0.0132	0
12	0.01	0.0264528	0.0132	0
13	0.02	0.0264528	0.0132	0
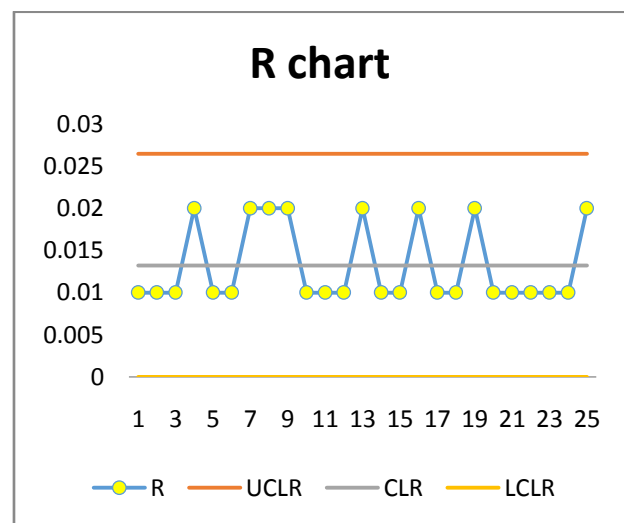
Fig.3 – R Chart

Table 12 - X Chart

JOB No	$\overline{X}$	UCL_X	CL_X	LCL_X
			X Chart	
1	97.00333333	97.00930893	97.00293333	96.99655773
2	97.00333333	97.00930893	97.00293333	96.99655773
3	97.00333333	97.00930893	97.00293333	96.99655773
4	97	97.00930893	97.00293333	96.99655773
5	97.00333333	97.00930893	97.00293333	96.99655773
6	97.00333333	97.00930893	97.00293333	96.99655773
7	97.00333333	97.00930893	97.00293333	96.99655773
8	97	97.00930893	97.00293333	96.99655773
9	97	97.00930893	97.00293333	96.99655773
10	97.00166667	97.00930893	97.00293333	96.99655773
11	97.00333333	97.00930893	97.00293333	96.99655773
12	97.00333333	97.00930893	97.00293333	96.99655773
13	97.00333333	97.00930893	97.00293333	96.99655773
14	97.00333333	97.00930893	97.00293333	96.99655773
15	97.005	97.00930893	97.00293333	96.99655773
16	97	97.00930893	97.00293333	96.99655773
17	97.00333333	97.00930893	97.00293333	96.99655773
18	97.00333333	97.00930893	97.00293333	96.99655773
19	97.00333333	97.00930893	97.00293333	96.99655773
20	97.005	97.00930893	97.00293333	96.99655773
21	97.005	97.00930893	97.00293333	96.99655773
22	97.00166667	97.00930893	97.00293333	96.99655773
23	97.005	97.00930893	97.00293333	96.99655773
24	97.00333333	97.00930893	97.00293333	96.99655773
25	97.00333333	97.00930893	97.00293333	96.99655773

Xbar Chart

Fig.4 – X Chart
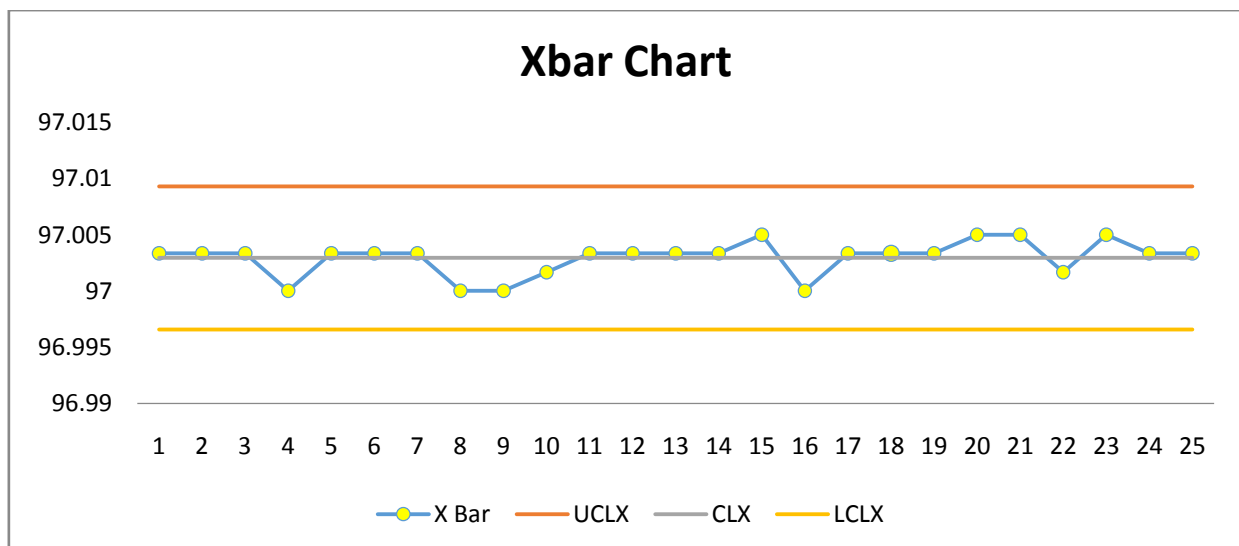
Process Capability

Formulas: $\sigma' = \dfrac{\overline{R}}{D2} = \dfrac{0.0132}{2.534} = 0.005209155$

$3\sigma' = 3*0.005209155 = 0.015627466$

$6\sigma' = 6*0.005209155 = 0.031254933$

Where, σ' is standard Deviation.

USL (Upper Specification Limit)	Specification Limit	LSL (Lower Specification Limit)
97.01	±0.012	96.988

$cP = \dfrac{(USl - LSL)}{6\sigma'} = \dfrac{(97.01 - 96.988)}{0.031254933} = 0.767878788$

$CpU = \dfrac{(USl - \overline{\overline{X}})}{3\sigma'} = \dfrac{(97.01 - 97.00293333)}{0.015627466} = 0.580175084$

$CpL = \dfrac{(\overline{\overline{X}} - LSL)}{3\sigma'} = \dfrac{(97.00293333 - 96.988)}{0.015627466} = 0.955582492$

CpK = Minimum (CpU,Cpl) = 0.580175084

Where,
cP is Process Capability.
CpU is Upper Limit of Process Capability.
CpL is Lower Limit of Process Capability.
CpK is Process Capability Index.

Conclusion:-

With any position, practically all the products manufactured will meet specification as long as the

process stays in control.

Reasons of variations

Over use of tool causing tool wear
Machine vibrations
Loose bearing
Play between screw & nuts of m/c table
Faulty jigs & fixtures
Carelessness of the operator
Lack of training
Poor maintenance
Measuring errors
Weather change
Difference in materials

III.   GAPS IN LITERATURE RESEARCH

The following are few research gaps in the literature

- The methodologies used by different authors are difficult to understand and to apply.

- The simplified and precise methodology for training and application purpose was not available.
- There are many papers available in the field of six sigma but very few papers are available in the field of honing machine or honing operation & even based on X chart & R Charts.
- Very few papers explain basic application of six sigma.
- Comparative analysis is not done in most of the papers.
- The areas for future research can be summarized as Applications of Six Sigma in manufacturing & service sectors areas which are not explored yet with full potential, areas of Six Sigma enhancement and integration of Six Sigma with other quality initiatives, critical success factors for successful deployment of Six Sigma and Six Sigma implementation strategies.
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IV.   OBJECTIVE OF RESEARCH PAPER

- To study the concept of six sigma.
- To present simplified way of application of six sigma.
- To prepare a research paper on honing machine or honing operation.
- To prepare a paper in which X chart & R Charts application is explained
- To apply the concept of six sigma in case of automated assembly. Example, TATA Motor bus assembly.

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