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PROCESS CAPABILITY IMPROVEMENT FOR GEAR PRIMARY HUB: AN INDUSTRIAL RESEARCH ARTICLE

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Abstract - *A starter clutch gear is a crucial component of the starter assembly in almost all modern motorcycle gearboxes. It is also known as gear a primary hub (GPH) whose main function is, allowing the starter to crank the engine in the forward direction. The objective of this research is to conduct a case study on process capability for the most critical parameter and suggest possible changes to the manufacturing process to improve the quality and perform process capability again after implementing suggested changes to validate the improvement in a process. Hereafter initial observations were recorded, $\bar{X}$ and R control charts were plotted and comments on process capability were made by calculating process capability indices Cp, Cpk, Cpm, and Cpmk. Based on these values, process improvements were suggested and implemented by the industry. Another set of data was collected and was analyzed to validate the changes and the quality was improved.*

Key Words: Process capability; Quality Control; Statistical process control; MINITAB; Sampling plan; Inspection data; Quality improvement.

1. INTRODUCTION

A production line is a set of sequential operations established in a series, parallel or, a combination of manufacturing. The statistical measurement of a process's ability to produce parts within a specified limit on a consistent basis is called its process capability. In a production line, each process has its own process capability that affects the overall capability of a production line. Here the process of manufacturing of a Gear Primary Hub by Siddheshwar Industries for BAJAJ AUTOMOTIVE P.V.T. in a local mass-production industry is chosen for study and improvement of its overall process capability. With the fast progression of the manufacturing innovation, suppliers require their items to be of high calibre with an exceptionally low portion of defectives generally estimated in parts per million. Gear Primary Hub (GPH) is manufactured in a mass production line for an automotive by a sub-vendor. The component has an internal diameter of the GPH (Gear Primary Hub is the critical quality parameter. The observed inner diameter has a tolerance of 35.990 +0.016. Studying each step in the production line and performing Process Capability Analysis to check if the process is in control and whether it meets the specifications. In case the specifications are not met satisfactorily by the process, find the cause of the defects affecting the quality which would improve the process capability for the industry.

2. METHODOLOGY

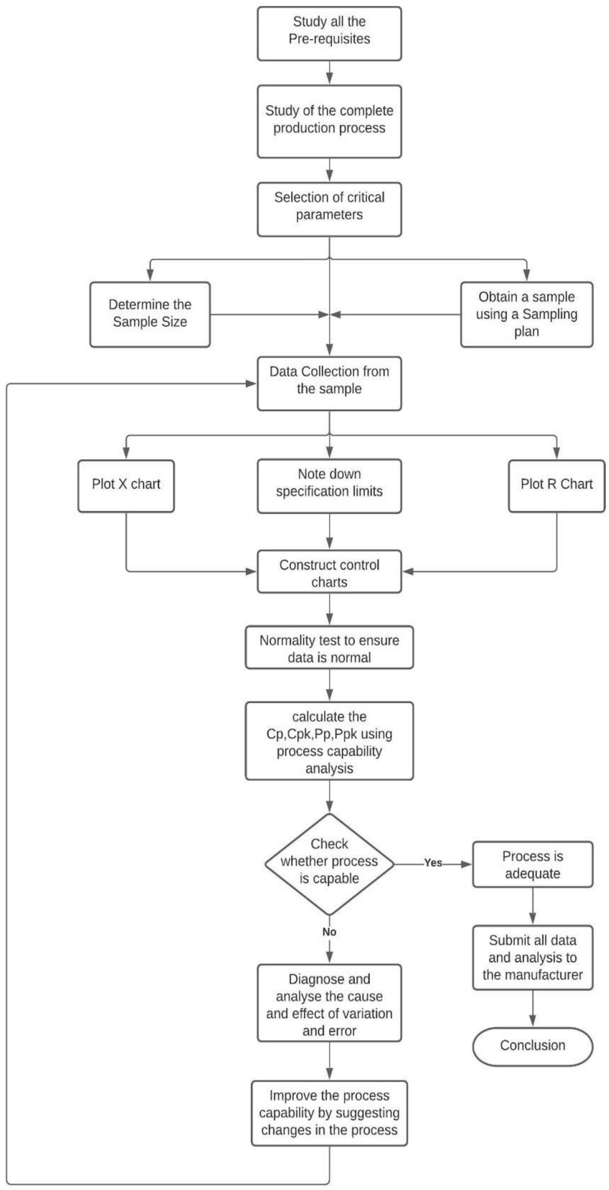

Chart -2: Methodology

3. DATA COLLECTION

A Case study was conducted on the gear primary hub (GPH) which was manufactured at Siddheshwar Industries Pvt. Ltd. for process capability analysis. The product description is mentioned in Table 1.

Table -1: Product description

Company Name	Siddheshwar Industries Pvt. Ltd.
Component	Gear Primary Hub
Instrument used	Digital gauge
Dimension with tolerance	35.990+0.016 mm

The number of samples to be selected at random is decided by using a single sampling plan. The data was collected over a period of a month to get 5 observations in a batch size of 100 each. Likewise, the data was collected from 20 subgroups. The critical parameter of Gear primary Hub is the internal diameter which has a unilateral tolerance of 35.990+0.0016mm. The internal diameters were measured with a specially designed digital gauge.

3.1 Sampling Plan

The process here has contained variables hence a single sampling plan is chosen. The total production of approximately 1000 products each production cycle gives us a population size of 1000, based on this the sample size is calculated from the Confidence level of 95% and Margin of error of 10% which gives a minimum recommended sample size to be 88 to get more accurate results for the survey. Thus, a sample size of 100 was chosen and stratified into 5 observations taken during successive production cycles further divided into 20 subgroups.

Table -2: Sampling plan table.

Population Size	1000
Confidence level	95% (1-alpha risk where alpha risk = 0.05)
Margin of error	10 %
Response distribution	50% (conservative approach for calculations)
Minimum recommended sample size	88
Final Sample Size	100
Number of Observations	5
Number of Sub- groups	20

In our chosen lot,

C = Acceptance number = 2

N = Number of Articles in the lot = 1000

n= number of randomly drawn sample articles = 100

D = Number of defectives = 5

Thus, the lot was accepted since (D < c)

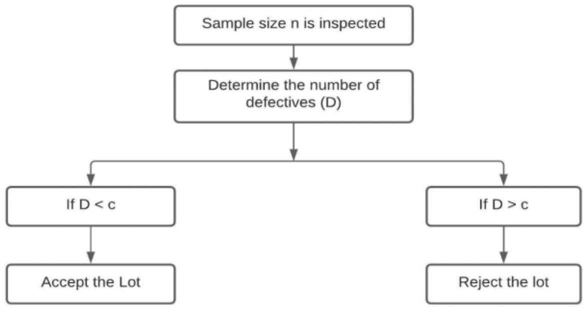

Chart -1: Single sampling plan.

3.2 Process Study

Before working on the process capability study, it was important that the process of manufacturing of gear primary hubs was studied in detail. This also helped us to gather the required data to start our study and played an important role in detecting the causes of errors.

The manufacturing process starts with receiving the raw material from various vendors. We also came to know that the raw material which was the discs or pallets were manufactured using the forging process and the material of this raw material was 16MnCr5H steel BAS 03 The received raw material was in the shape of discs with the required profile. The first process that takes place after receiving the raw material is the punching of centre hole using a hydraulic press. After the pressing of the pallets, they are sent to the lathe machine where the holes are turned to an internal diameter of 35mm. The lathe is pre-programmed to turn the internal diameter to 35mm. The Gears are further heat-treated at 450° C for 2 hours in the furnace. The next steps are mostly performed on the CNC Lathe. First, the internal diameter is turned to a perfect dimension, setting the centre of the job. For the next processes, the job is held by the internal diameter and all other dimensions are perfected with respect to it.

Fig -1: Gear Primary Hub.

Table -3: Pre-Process Capability Data (Internal Dia.)

Sample	1	2	3	4	5	$\bar{X}$	R
1	35.998	35.999	35.997	35.994	35.995	35.9966	0.0050000
2	35.996	36.002	36.002	36.005	35.998	36.0006	0.0090000
3	35.994	35.996	36.003	36.004	36.002	35.9998	0.0100000
4	35.990	35.995	35.997	36.000	36.005	35.9954	0.0180000
5	36.001	35.998	35.998	35.995	36.000	35.9984	0.0060000
6	35.995	35.986	36.001	36.001	36.002	35.9970	0.0160000
7	35.994	36.005	36.000	36.000	36.003	36.0004	0.0110000
8	36.002	35.996	35.996	36.004	36.004	36.0004	0.0080000
9	35.998	36.006	35.995	36.001	36.001	36.0002	0.0110000
10	35.996	35.991	35.990	36.004	36.000	35.9962	0.0140000
11	35.996	35.997	36.000	35.996	36.004	35.9986	0.0080000
12	36.004	36.002	35.999	36.001	35.998	36.0008	0.0060000
13	36.004	35.999	36.003	35.999	36.003	36.0016	0.0050000
14	36.000	35.995	36.002	35.998	36.002	35.9994	0.0070000
15	35.996	36.001	36.000	35.994	35.998	35.9978	0.0070000
16	36.001	35.995	35.998	35.999	36.003	35.9992	0.0080000
17	35.998	35.999	35.999	36.000	36.002	35.9996	0.0040000
18	35.992	35.998	36.000	35.997	35.998	35.9970	0.0080000
19	35.998	35.999	35.998	36.001	35.998	35.9988	0.0030000
20	35.997	35.997	35.998	35.998	36.000	35.9960	0.0120000

Table -4: Control charts constants

Sample Size = m	A_2	A_3	d_2	D_3	D_4	B_3	B_4
2	1.880	2.659	1.128	0	3.267	0	3.267
3	1.023	1.954	1.693	0	2.574	0	2.568
4	0.729	1.628	2.059	0	2.282	0	2.266
5	0.577	1.427	2.326	0	2.114	0	2.089
6	0.483	1.287	2.534	0	2.004	0.030	1.970
7	0.419	1.182	2.704	0.076	1.924	0.118	1.882
8	0.373	1.099	2.847	0.136	1.864	0.185	1.815
9	0.337	1.032	2.970	0.184	1.816	0.239	1.761
10	0.308	0.975	3.078	0.223	1.777	0.284	1.716

5. PROCESS CAPABILITY ANALYSIS (Pre-Improvement)

Process capability study is a modern method of quality control that industries are opting to reduce the rejection rate. This method helps maximize the profits as the rejection decreases and also the material wastage is lowered, thus improving the sustainability of the industry. The turning operation was performed on GPH using a lathe machine and observations were recorded. $\bar{X}$ and R Control charts were plotted and commented on process control. Along with histogram plots to understand the distribution of data. Probability plot to validate the type of distribution the data follows. The process capability indices Cp, Cpk, Cpm, and Cpmk were calculated using MINITAB 19 statistical software. This technique helps us in reducing the rejection rate and finding out the key elements of the manufacturing process. An operation route sheet is also made to understand all the processes in the correct chronology.

5.1 $\bar{X}$ & R charts

Variations are inevitable and the variability is monitored through mean value and its spread around the target. Process variability can be examined through control charts based on standard deviation in $\bar{X}$ Charts, and range in R chart. From the observed data, first of all, the control limits are calculated based on average ($\bar{\bar{x}}$) and
Control limits for $\bar{X}$ Chart and R charts have been calculated.
Where, n =5, A2 =0.577, d2= 2.326, D3=0.00 and D4 =2.114.
Control limits for $\bar{X}$ Chart
UCL= $\bar{\bar{x}}$+ $A2$ R = 36.0038
LCL= $\bar{\bar{x}}$– $A2$ R = 35.9939

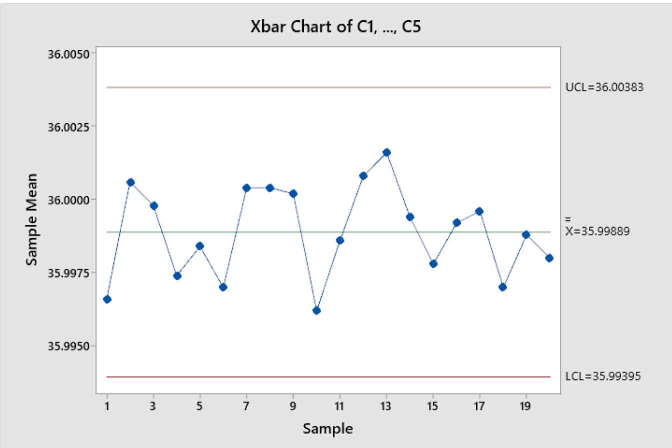

Fig -2: $\bar{X}$ Chart.

Control limits for R Chart
UCL=$D4\bar{R}$= 0.01734
LCL=$D3\bar{R}$= 0

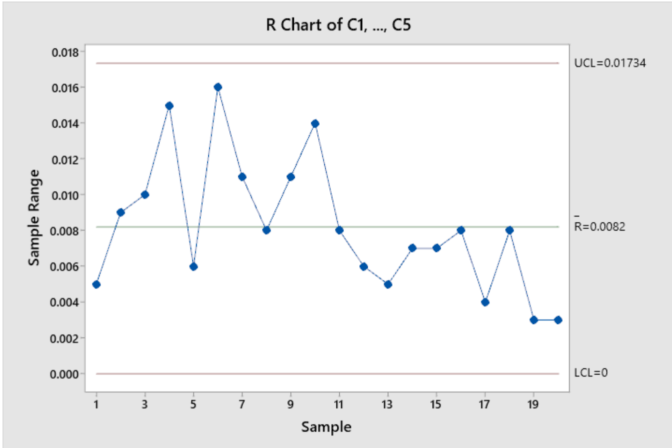

Fig -3: R Chart

It has been observed from figure 2 and figure 3, that the process is in control. There is no indication of shift occurred in $\bar{X}$ Chart; however, in R chart slight shift after sample number size was observed. Hence, it depicts that the process is under control and no external factor is influencing on the process thus the process is stable.

5.2 Histogram and Normal Probability Plot

To check whether the recorded data in this case is normal, a graphical method of normal probability plot and the histogram is used. This data is analysed in MINITAB-19. The data appears to be normal in the histogram diagram

The normal probability plot yields the Anderson Darling test p-value of 0.062 which is greater than the significance level α= 0.05 as shown in Fig 4 and Fig 5 hence, we can conclude that the data is normal and the curve is normally distributed. There is no abnormality observed in the sample data.

Further X bar and R chart were plotted using MINITAB 19 through which we found out samples are under control limits thus we concluded our process is stable and in control. Further to understand the variance and type of distribution of our samples we have plotted histograms and probability plots of each sub group on MINITAB 19. The histogram shows a bell-shaped curve hinting it is a normal distribution further the Probability plot yields Anderson Darling test which shows the p-value or the significance level value of each subgroup greater than 0.05 which permits us to analyse it as the normal distribution of the sample.

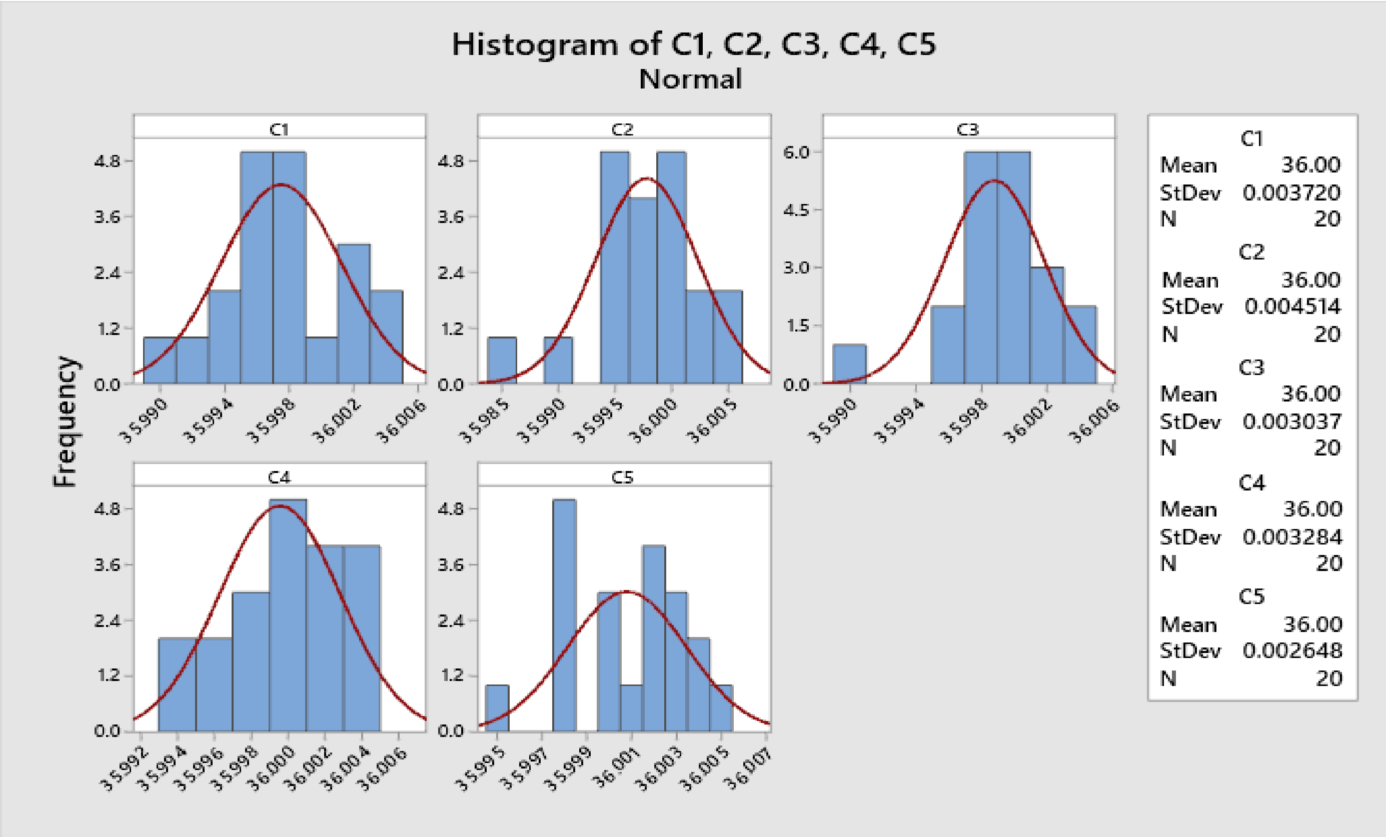

Fig -4 Initial histograms

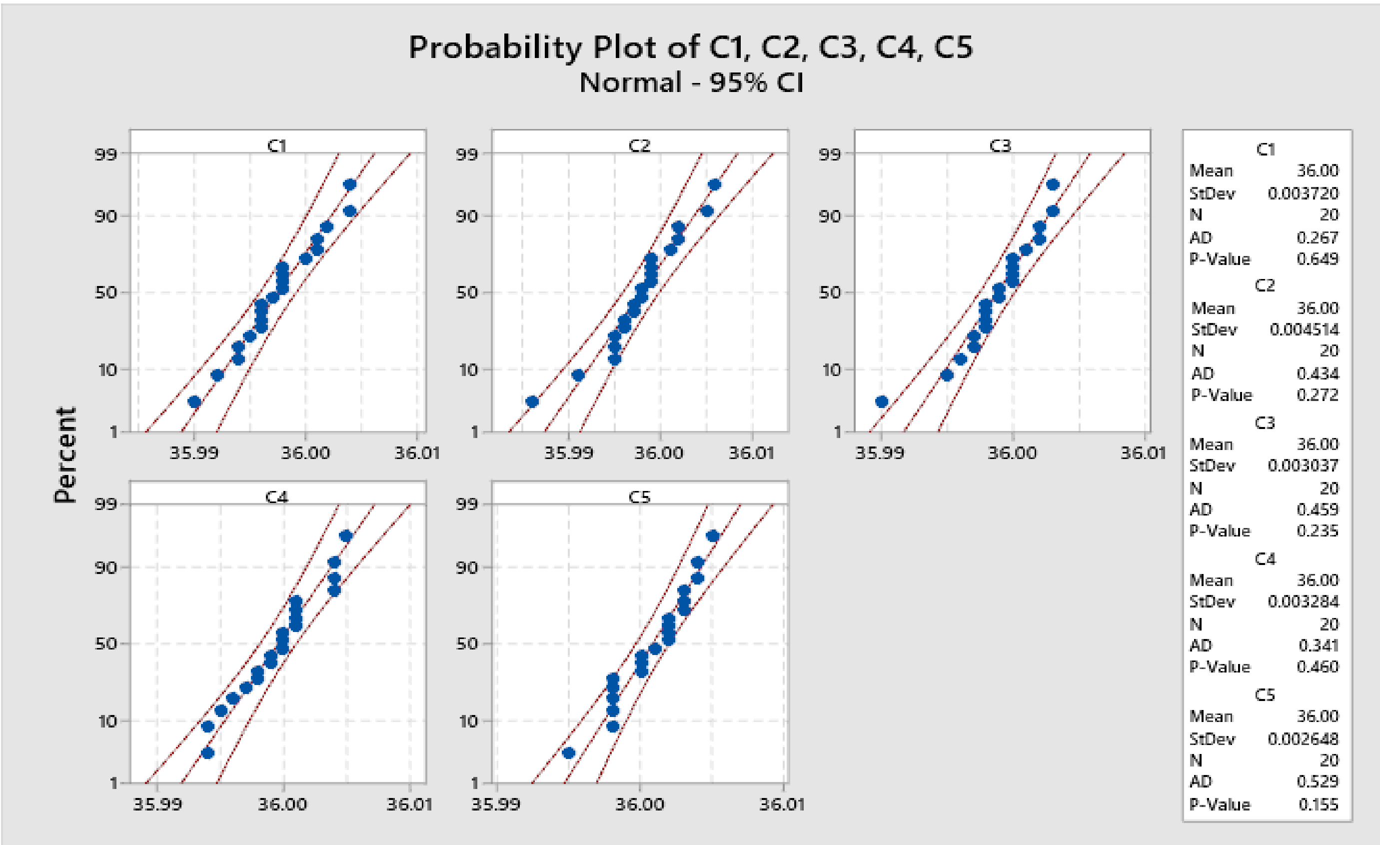

Fig -5: Probability plot

5.3 Process capability report (Pre-improvement)

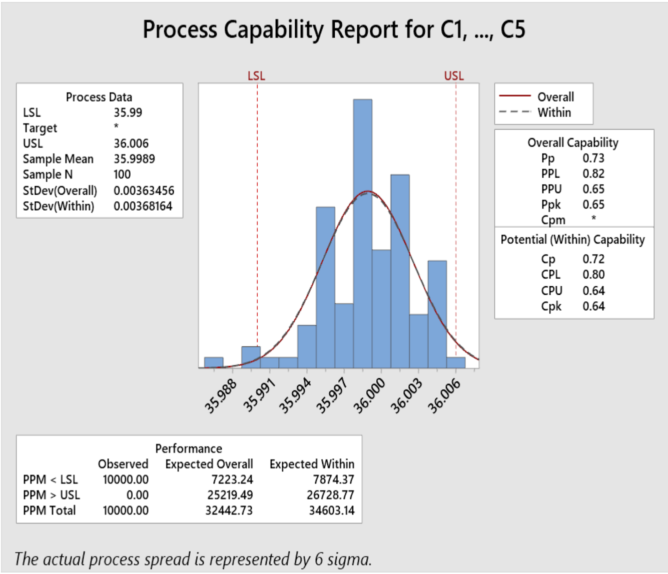

Fig -6: Initial process capability report

After plotting the process capabilities, we have found that the Cp and Cpk values indicate the process is almost inadequate. Since this is a normally distributed curve where a normal curve extends beyond the given limits the solution is to improve the process capability by reducing the variability and maintaining the same average. This process can be improved by detecting the cause of defects and suggesting changes in a manufacturing process to the concerned industry to reduce variability in turn bringing the process mean to the center of a tolerance range. $Cp \geq 1.33$ indicates that the process is adequate to meet the specifications. If $1.33 \leq Cp \geq 1.00$ indicates the adequacy of the process provided that it is under close control. If the value of $Cp < 1.00$ then the process is not capable.

Further, we have plotted the Process Capability Graph which has given us the conclusion that the process is almost adequate but not satisfactory which gives us room to study the manufacturing and since by implementing changes in the manufacturing process.

6. AREAS OF PROCESS IMPROVEMENT

Measurement- During the inspection of GPH, it was observed that the parts were rejected due to the wearing of gauges and improper calibration.
Due to inaccurate measurements, the final results will differ and the quality of the product will be Sub -Standard.

People- Another cause affecting the process is inexperienced labour which is why there are more chances of rejection. Health issues of the workers also affect the process. If the inspection procedure is not followed properly the rejection rate will increase.

Environment- The workplace has to be kept clean to avoid any errors while inspection. Other factors which also affect the process are a noisy environment, insufficient light, etc.

Machines- If the machines are not maintained at a regular time interval, an error will occur hence increasing the rejection rate. After a particular time, the machines need to be changed. Exceeding operating life will lead to inadequate Process.
During the manufacturing of GPH, the worker needs to check if the machine malfunctions i.e., if the machine is faulty.

Methods- Ineffective machining, Positioning of Gauge, Tool shape, Tool offset, manually input machine setting and other factors increase rejection rate. These factors need to be checked at a regular time interval to improve the process.

Material- The first step of production starts with material selection. So, if the material itself is defective the whole process will cause an error in the final finished product. Parameters like Rust, Impurity, Residual Stresses, Hardness has to be verified before production to reduce error.

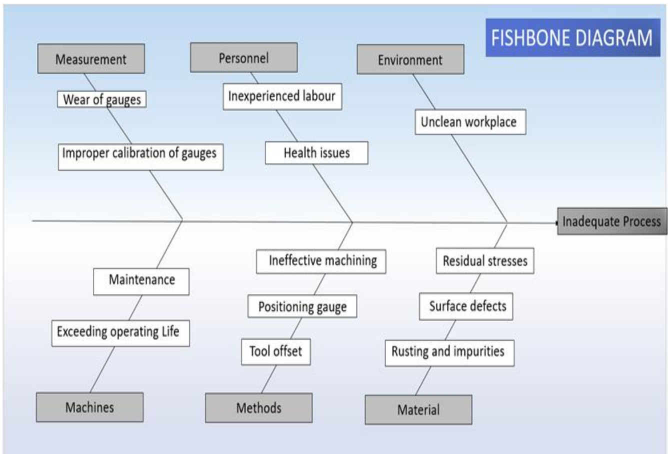

Fig -7: Fishbone diagram

The fishbone diagram or Ishikawa diagram is a cause-and-effect diagram that helps managers to track down the reasons for imperfections, variations, defects, or failures. The diagram looks just like a fish's skeleton with the problem at its head and the causes for the problem feeding into the spine.

The cause and effect diagram lists out in a systematic and classified manner, all the variables which are responsible for a problem or condition. In the above diagram, each bone represents a category of the root cause. The causes responsible for inadequate process are Measurement of gauges, People, Environment, Machines, Methods used, and Material Properties.

7. POST PROCESS IMPROVEMENT

7.1 Data collection

Table -5 Post process change data (Internal Diameter)

Sample	1	2	3	4	5	X̄	R
1	35.998	35.999	35.997	35.994	35.995	35.9966	0.0050000
2	35.996	35.999	36.002	36.005	35.998	36.0000	0.0090000
3	35.994	35.996	35.999	35.997	36.002	35.9976	0.0080000
4	35.990	35.995	35.997	36.000	35.999	35.9962	0.0100000
5	36.001	35.998	35.998	35.995	36.000	35.9984	0.0060000
6	35.995	35.999	36.001	36.001	36.002	35.9996	0.0070000
7	35.994	35.997	36.000	36.000	36.003	35.9988	0.0090000
8	36.002	35.996	35.996	35.997	35.997	35.9976	0.0060000
9	35.998	36.006	36.001	36.001	36.001	36.0014	0.0080000
10	35.996	35.991	35.996	36.004	36.000	35.9974	0.0130000
11	35.996	35.997	36.000	35.996	36.004	35.9986	0.0080000
12	35.997	36.002	35.999	36.001	35.998	35.9994	0.0050000
13	35.997	35.999	36.003	35.999	36.003	36.0002	0.0060000
14	36.000	35.995	35.999	35.998	36.002	35.9988	0.0070000
15	35.996	36.001	36.000	35.993	35.998	35.9976	0.0080000
16	36.001	35.995	35.998	35.999	36.003	35.9992	0.0080000
17	35.998	35.999	35.999	36.000	36.002	35.9996	0.0040000
18	35.992	35.998	36.000	35.997	35.998	35.9997	0.0080000
19	35.998	35.999	35.998	36.001	35.998	35.9988	0.0030000
20	35.997	35.997	35.999	35.998	36.000	35.9982	0.0030000

7.2 X̄ & R charts

Control limits for X̄ Chart
UCL= $\bar{\bar{x}} + A2$ R = 36.0024
LCL= $\bar{\bar{x}} - A2$ R = 35.9946

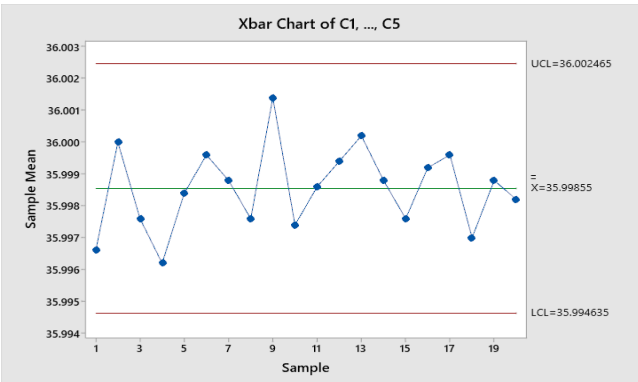

Fig -8: X̄ Chart.

Control limits for R Chart
UCL=$D4\bar{R}$= 0.01491
LCL=$D3\bar{R}$= 0

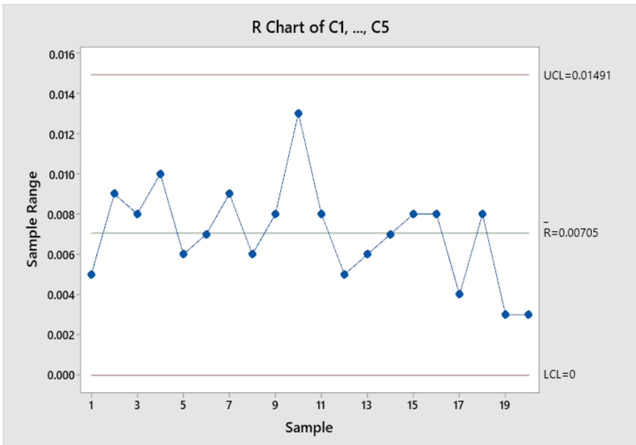

Fig -9: R Chart

7.3 Histogram and Normal Probability Plot

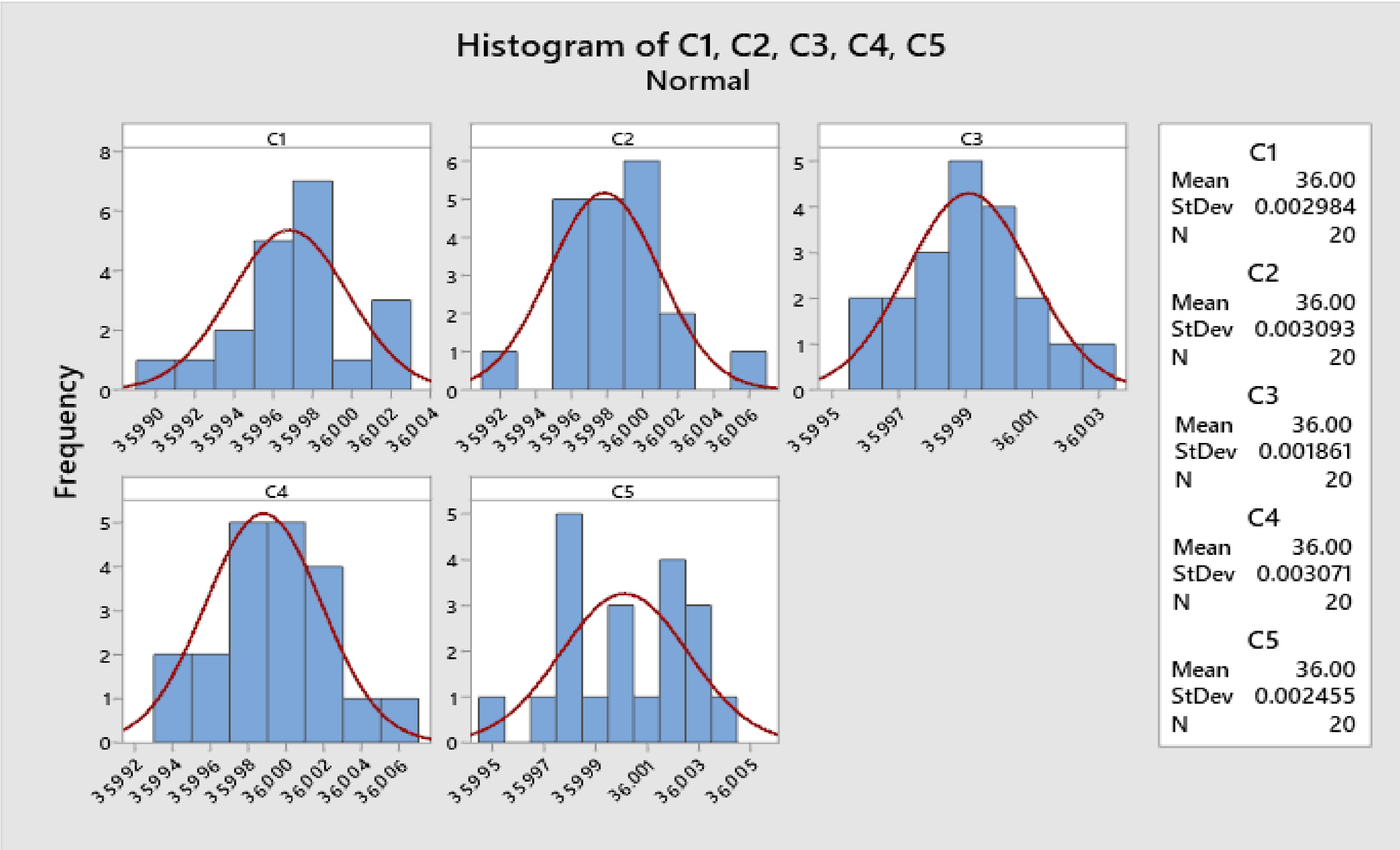

Fig -10: Histogram plot

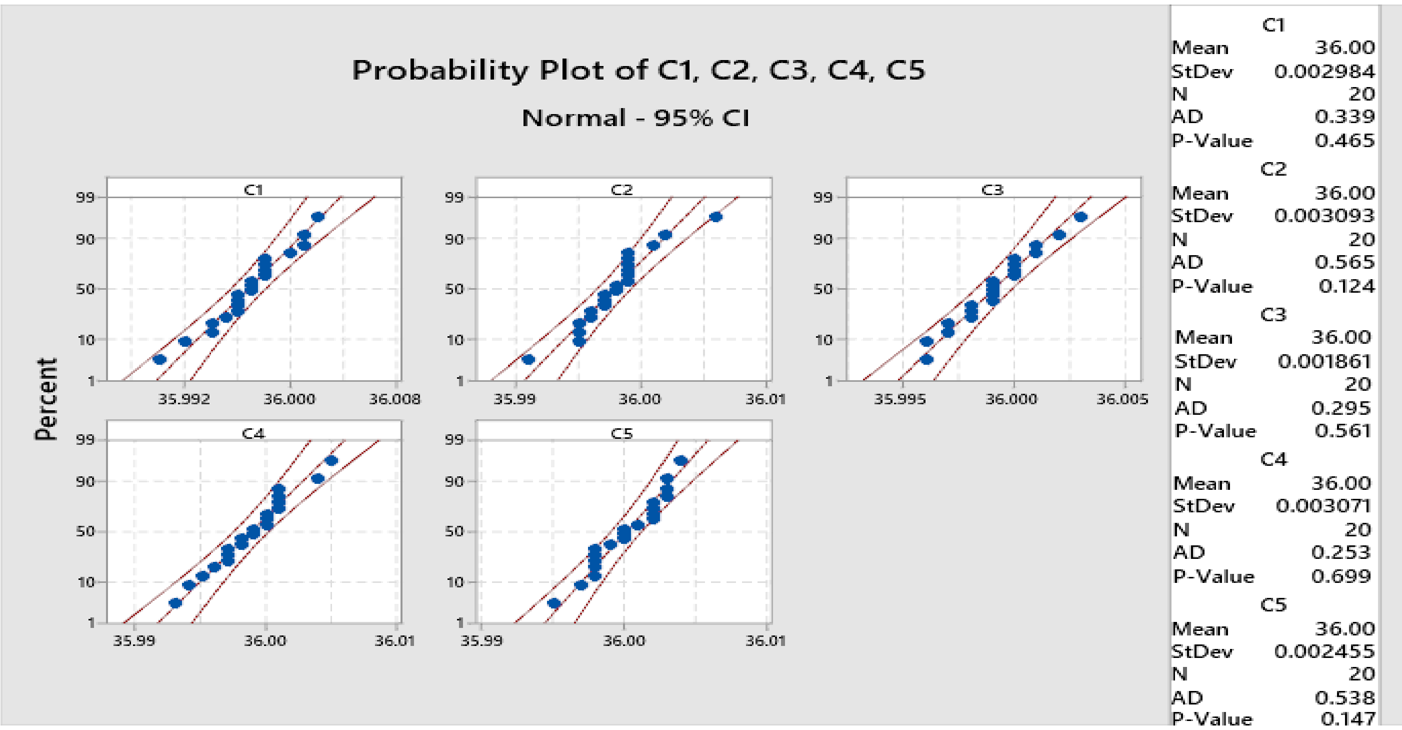

Fig -11: Probability plot

7.4 Process capability report (Post improvement)

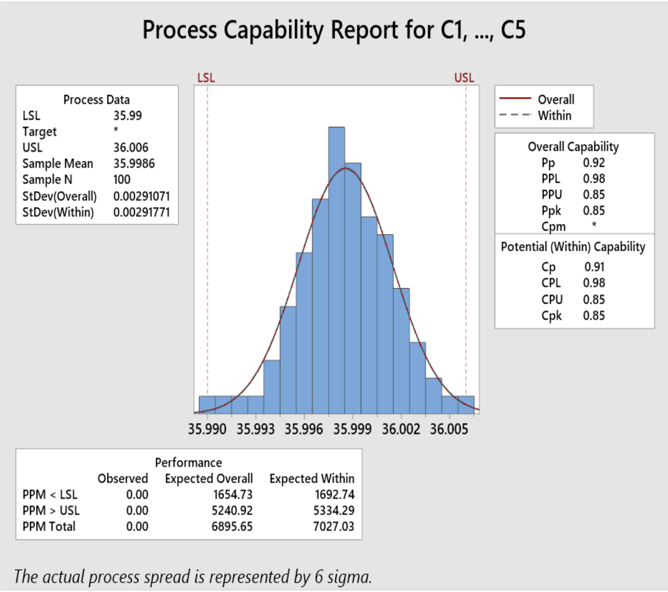

Fig -12: Post process capability report

The Post improvement Process Capability Report indicates better process capability for the implemented process changes. Since the previous process capability report had shown the normal bell curve exceeding the limits and is closer to the mean the optimum way was to shift the process mean towards center, therefore as seen above the mean value of the range and values closer to the mean have higher frequencies bringing the process mean closer the center. The standard deviation has reduced which states the variation of the data has reduced as well. The Cp is enhanced from 0.72 to 0.91and Cpk from 0.64 to 0.85.

This report validates the changes in the process explained above whether they have a significant and positive effect on overall process capability.

8. CONCLUSIONS

This study concludes the overall quality control of Gear Primary Hub. The validation of capability of the process and analysis of the process to identify the potential cause of the variation and improve process capability results. Control charts were plotted to learn whether the process is in control or not. Afterwards the process capability indices were calculated using MINITAB 19 statistical software for monitoring variations. The analysis helps us understand the complete manufacturing process and also detect potential causes within it, which is then validated by the analysis showing us promising results for the process such as improving the Cp 0.72 to 0.91 bringing the Cp closer to the desired value of 1 and number of defective products reductions of 2.75% which is 27,576 PPM.

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