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REDUCING PROCESS VARIATION IN A MANUFACTURING INDUSTRY USING LEAN APPROACH

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ABSTRACT

This paper presents a work undertaken in a drum closure manufacturing industry which produces different models of drum closures and cap seals which are used in drum barrels. The work aim was to reduce the process variation observed with respect to wall thickness during milling operation and thread height during rolling operation. Statistical tools such as control charts, normality tests were used to determine the effect of variation. The identified problems were analyzed and improvement actions were scheduled. These improvement actions were based on application of Lean tools. A locking plate was modelled and a by-pass filter was suggested to be implemented.

KEYWORDS

Process variation, Control charts and Normality test.

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INTRODUCTION

The concept of variation states that no two products will be perfectly identical even if extreme care is taken to make them identical in some aspect. The variation in the quality of product in any manufacturing process results because of two reasons namely, Chance cause and Assignable cause. A process which is operating with only chance causes of variation is considered to be in a state of statistical control. This means, chance causes results in only minor variation in the process. The major objective of Statistical Process Control (SPC) is to quickly detect the occurrence of assignable causes so that investigation of process and corrective action may be taken before many non-conforming units are manufactured.

The process capability studies are helpful in analyzing the quality and efficiency of the process. The process capability analysis is a measure of performance to evaluate the ability of a process. It is necessary to use the six sigma prime spread in the distribution of the product quality characteristic as a measure of process capability. The Six sigma spread is related with the difference of Upper Specification Limit (USL) and the Lower Specification Limit (LSL) in process capability study.

The following are the three possible cases.

6s `> (USL - LSL) - The process spread is greater than the tolerance. Hence the process is incapable of meeting the specification.

6s `= (USL - LSL) -The process spread is exactly equal to the tolerance. Hence the process is exactly capable of meeting the specifications.

6s `< (USL - LSL) -The process spread is less than the tolerance. Hence the process is capable of meeting the specifications.

This paper represents a method to eliminate the process variation observed during milling operation with respect to wall thickness and thread height variation during rolling operation in the PROMAT machine by the use of statistical tools and lean tools.

Literature Survey

According to Cherly Hild *et al*[1], to achieve optimal outcomes in continuous process, nonlinear and complex relationships among process factors must be managed. Charles Ribardo and Theodore T Allen[2] reported that the desirability function do not explicitly account for the combined effect of the mean and dispersion of quality. According to Nam P Suh[3], the decisions made during the design stage of a product and process development profoundly affect product quality and process productivity. According to Saravanan *et al*[4], the process capability analysis has been applied in the textile industry to assess the variation in the ability of the process. Gopala Raju *et al*[5] stated that the cause and effect analysis is one of the simplest and cheapest measurement tools for improving the production system quality efficiency which gives tangible benefits in the shortest possible time for any Organization. In a company producing 3000 units of compressors per month, almost 8-10% defective compressors were identified by Santosh Garbayl *et al*[6]. The authors have conducted root cause failure analysis and corrective action was taken which reduced the defectives by 3-4%. To prioritize process improvement process, a multistage process capability analysis algorithm is developed by Richard Linn, *et al*[7]. The application of this algorithm is demonstrated with 2 stage and 4 stage examples for its expandability. Mc Cormack *et al*[8] observed that the most common and earliest forms of process capability indices assume that the process under examination is normally distributed and violation of this assumption often leads to inappropriate results.

The literatures provided wide information about the process variation and application of various tools in various business enterprises. The information gathered from the papers was very useful in analysing the current problem regarding process variation and also gave useful information about the modifications that must be made to the processes to reduce the variation.

Case Study

A closure manufacturing company that provides quality closures for the steel drum industry. The company has a substantial market share in India for its products. The company is ISO 9001 Certified and it has 2008 accreditation by TUV NORD, Germany. The company is certified by various International certifying agencies. The company is acclaimed as the quality products supplier among leading drum/barrel manufacturers and oil refineries.

Process flow in the manufacturing of 2” flange line

The present work is carried out in a 2” zinc plated flange manufacturing line. This line consists of 9 machines and is sequentially arranged. As clearly shown in Figure No.1, the process starts with blanking operation and ends with milling and rolling operation. The milling and rolling operations are done on a Special Purpose Machine (SPM) called PROMAT machine and are three in numbers in the line. The output flanges from the PROMAT machines are taken to the oil cleaning system by means of trolley in barrels and finally stored for zinc plating process which is outsourced.

METHODOLOGY

As shown in Figure No.2, this article involves eight stages of process in order to obtain the expected result.

Objective

The process from the PROMAT machine was observed and there is a variation with respect to wall thickness during milling operation and variation with respect to thread height during rolling operation. Thus the main objective is to reduce these variations by the use of statistical analysis and lean tools.

Data collection for wall thickness during milling operation

As shown in Table No.1 sample size estimation is done using Minitab 17 software by providing an input of standard deviation of the readings of wall thickness collected randomly. Batch size of 20 was taken with 50 samples in each batch which is shown in Table No.2.

Normality test

The data collected is checked for normality and based on the p-value it can be seen that the data is normal. The P-value is found to be 0.521 which is greater than 0.05, thus the data can be taken as normal or the data follows normality. Figure No.3. shows the result of normality test.

Control Chart

The data collected is checked whether the process is in control or not. This is done by using control chart. X-bar and S chart is preferred since standard deviation gives accurate measures of deviation. As shown in Figure No.4, the S-chart can be seen that all the data points are within the control limits, but the variation from the mean center line of the chart is more. This chart depicts the variation depending on the distribution of data-bar chart can be interpreted only if the process is under control and this is possible when all the data points of the S-chart are within the control limits. X-bar chart shown in Figure No.4, describes part to part variation and even this variation for certain samples under each subgroup size are more from the mean centerline. Thus it is necessary to identify the voice of the customer, that is whether the process is good or bad and this cannot be depicted by the use of control charts.

Histogram

Histogram is used to identify whether the process is good or bad, that is whether the process is taking place within the specification limits provided (voice of the customer). From the histogram shown in Figure No.5, it can be seen that the data follows normal distribution, but the process is not taking place within the limits specified. USL=1.05mm and LSL=0.75mm. Thus the possibility of this variation may be due to:

- Part to part variation.
- Variation due to measurement system

Check for calibration

Gauge R and R study is conducted to check whether the measuring system used for measuring wall thickness of the 2” flange is calibrated properly or not. This is done using 3 operators and using 10 parts each operator measuring it twice. From the gauge study it can be seen that, the percentage of contribution to variation is with respect to part to part variation. The variation with respect to measurement system is less and this least variation is due to variation observed during repeatability. Figure No.6 shows the result of Gauge R and R study. Overall the measurement system is calibrated properly and this leaves the reason to find out the causes for part to part variation.

Process capability analysis

From the process capability analysis C_{pk} value is determined. The process capability chart for milling is shown in Figure No.7. C_{pk} is called as the process capability index and this index determines the sigma level of the process. C_{pk} values depict the performance of the process. It is based on the C_{pk} value, the current sigma level of this process 1.75.

Cause and effect diagram

The root causes identified which results in the process variation are represented in Figure No.8. The parameters with their respective causes are listed in the Table No.3.

Actions taken to reduce the variation

The variation in the wall thickness is mainly due to the rough finish on the flange and more Material

Removal Rate due to improper filtration as shown in Figure No.9. An online viscosity sensor is suggested to be provided at the tank where hydraulic oil is stored so as to maintain the optimum level of viscosity by controlling cooling rate accordingly thereby reducing the variation. A bypass filter of 25 to 30 micron rating is suggested. This suggestion was given by the dealer based on the viscosity, temperature at which the cutting fluid is operating, material used and the flow rate of the cutting fluid.

A locking plate is to be designed to avoid the movement of the flange during clamping.

Design of locking plat

The CAD model of the locking plate was designed. This was modeled using Pro-E wildfire 5.0 software and the clamp in which it has to be fixed is also shown in the Figure No.10.

Data collection for thread height

Sample size estimation as in Table No.4, is done using Minitab 17 software by providing an input of standard deviation of the readings of thread height collected randomly.

Thus a batch size of 16 was taken with samples of 50 in each batch as represented in Table No.5.

Normality test

The data collected is checked for normality and based on the p-value it can be seen that the data is normal. The P-value is found to be 0.821 which is greater than 0.05, thus the data can be taken as normal or the data follows normality. Figure No.11 shows the result of normality test.

Control chart

The data collected is checked whether the process is in control or not. This is done by using control chart. X-bar and S chart is preferred since standard deviation gives accurate measures of deviation. As in Figure No.12, S-chart it can be seen that all the data points are within the control limits, but the variation from the mean center line of the chart is more. This chart depicts the variation depending on the distribution of data. X-bar chart can be interpreted only if the process is under control and this is possible when all the data points of the S-chart are within the control limits. X-bar chart shows part to part variation and even this variation for certain samples under each subgroup size are more from the mean centerline. Thus it is necessary to identify the voice of the customer, that is whether the process is good or bad and this cannot be depicted by the use of control charts.

Histogram

Histogram is used to identify whether the process is good or bad, that is whether the process is taking place within the specification limits provided (voice of the customer). From the histogram shown in Figure No.13, it can be seen that the data follows normal distribution, but the process is not taking place within the limits (10.6 and 11mm) specified. Thus the possibility of this variation may be due to part to part variation only since the measuring device is precise and accurate and thus Gauge R and R study is not conducted.

Process Capability analysis

From the process capability analysis C_{pk} value is determined. The process capability chart for rolling operation is shown in Figure No.14. C_{pk} is called as the process capability index and this index determines the sigma level of the process. C_{pk} values depict the performance of the process. It is based on the C_{pk} value, the current sigma level of this process 1.875.

Cause and effect diagram

Figure No.15 shows the cause and effect diagram for process variation in thread height of the flange during rolling operation. From the diagram it can be seen that the roller is not held properly in the anchor which results in the movement about its position and the O-rings are worn out which are shown in Figure No.15(a) and 15(b).

Anchor holding the tool worn out which resulted in the movement of the roller about its position as shown in Figure No.15(a) and O-ring encircling the Roller tool is worn out which resulted in the expansion of the roller tool during operation is shown in Figure No.15(b).

Actions taken to avoid thread height variation

New set of Anchors were replaced and the O-ring encircling the tap tool was also replaced and it was recommended to replace the anchors and the O-ring after the production of every 40000 units. Figure No.16 a, b and c shows the replaced anchors and O-ring.

RESULTS AND DISCUSSION

The sigma level is increased by reducing the variation from 1.875 to 2.00. The reduction in variation in wall thickness of the 2" flange during milling operation can be noted only after the development of the locking plate and by providing a By-pass filter in the line. The comparison between the C_{pk} for before and after conditions is illustrated in Figure No.17.

Table No.1: Sample size estimation

Sample Size Estimation		
S.No	**Method**	
1	Parameter	Standard deviation
2	Distribution	Normal
3	Confidence level	0.06
4	Confidence interval	two-side
Results		
5	Margin of Error	0.05
6	Sample Size	20

Table No.2: Wall thickness values

S.No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0.79	0.94	0.79	0.90	0.84	0.89	0.83	0.970	0.79	0.92	0.80	0.86	0.76	0.86	0.85	0.97	0.86
2	0.81	0.85	0.77	0.86	0.80	0.89	0.84	1.000	0.82	0.87	0.80	0.92	0.79	0.91	0.82	0.92	0.84
3	0.79	0.90	0.77	0.87	0.82	0.93	0.87	0.960	0.85	0.91	0.77	0.84	0.75	0.88	0.87	0.94	0.80
4	0.80	0.89	0.75	0.82	0.82	0.91	0.91	1.070	0.85	0.96	0.74	0.85	0.80	0.86	0.88	0.97	0.85
5	0.78	0.92	0.76	0.86	0.82	0.96	0.89	1.100	0.84	0.90	0.69	0.93	0.73	0.87	0.86	1.08	0.82
6	0.77	0.92	0.88	0.92	0.77	0.89	0.74	0.890	0.82	0.93	0.68	0.94	0.80	0.90	0.90	0.94	0.79
7	0.84	0.92	0.89	0.94	0.83	0.88	0.79	0.880	0.82	0.90	0.76	0.84	0.79	0.86	0.88	0.94	0.77
8	0.81	0.92	0.89	0.97	0.76	0.90	0.81	0.860	0.79	0.87	0.79	0.84	0.84	0.90	0.86	0.83	0.77
9	0.78	0.87	0.86	1.08	0.86	0.92	0.81	0.890	0.85	0.88	0.78	0.84	0.84	0.91	0.85	0.97	0.75
10	0.78	0.91	0.87	0.94	0.83	0.92	0.78	0.850	0.80	0.89	0.76	0.83	0.83	0.91	0.86	0.92	0.72
11	0.80	0.92	0.86	0.94	0.74	0.93	0.86	0.960	0.81	0.92	0.82	0.91	0.81	0.90	0.88	0.94	0.88
12	0.88	0.93	0.77	0.83	0.81	0.97	0.87	0.950	0.82	0.95	0.79	0.93	0.70	0.85	0.94	0.98	0.89
13	0.83	0.94	0.83	0.97	0.79	0.89	0.86	1.020	0.84	0.92	0.86	0.92	0.80	0.87	0.88	0.92	0.89
14	0.79	0.92	0.84	0.92	0.76	0.93	0.90	0.950	0.87	0.94	0.88	0.92	0.77	0.97	0.88	0.94	0.86
15	0.77	0.96	0.81	0.87	0.76	0.86	0.88	0.960	0.89	0.93	0.87	0.94	0.83	0.97	0.88	0.96	0.87
16	0.84	0.90	0.88	0.97	0.76	0.92	0.89	1.070	0.79	0.94	0.78	0.92	0.82	0.90	0.89	0.95	0.86
17	0.80	0.91	0.87	0.94	0.79	0.90	0.78	0.871	0.78	0.86	0.81	0.91	0.79	0.94	0.86	0.97	0.77
18	0.79	0.91	0.79	0.85	0.79	0.95	0.89	1.000	0.79	0.91	0.88	0.93	0.76	0.84	0.88	0.93	0.83
19	0.79	0.99	0.80	0.97	0.80	0.95	0.78	1.000	0.78	0.90	0.82	0.92	0.81	0.92	0.84	0.94	0.84
20	0.84	1.02	0.87	0.95	0.82	0.90	0.89	0.850	0.80	0.91	0.81	0.91	0.81	0.89	0.77	0.99	0.81

Table No.3: Parameters and its causes

S.No	Parameters	Causes
1	**Feed rate not optimized**	The chip thickness per tooth varies during the run. This is due to change in the viscosity of the hydraulic oil.
2	**Micro filter rating less**	Due to improper filtration, small mild steel particles along with the cutting oil gets sprayed on to the carbide tip which results in poor material removal and surface finish.
3	**Improper Seating**	No locking plate which results in movement of the flange about its position during clamping.

Table No.4: Sample size estimation

Sample Size Estimation		
S.No	**Method**	
1	Parameter	Standard deviation
2	Distribution	Normal
3	Standard deviation	0.09
4	Confidence level	95%
5	Confidence interval	two-side
Results		
5	Margin of Error	0.05
6	Sample Size	20

Table No.5: Data values of thread height

S.No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	10.61	10.77	10.93	10.79	10.80	1101	10.87	10.82	10.89	10.79	10.81	10.85	10.64	10.83	10.68	10.84	10.85
2	10.75	10.87	10.81	10.84	10.69	1100	10.79	10.89	10.58	10.78	10.80	10.68	10.79	10.76	10.78	10.78	10.83
3	10.89	10.83	10.99	10.82	10.68	1096	10.77	10.77	10.63	10.75	10.81	10.84	10.83	10.85	10.84	10.68	10.84
4	10.80	10.84	10.83	10.83	10.84	1070	10.79	10.70	10.85	10.67	10.77	10.79	10.74	10.85	10.86	10.73	10.86
5	10.76	10.79	10.71	10.94	10.93	1096	10.82	10.84	10.74	10.65	10.64	10.85	10.84	11.06	10.87	10.73	11.04
6	10.72	10.77	10.94	10.75	10.92	1092	10.87	10.97	10.72	10.80	10.79	10.83	10.71	10.93	10.73	10.70	10.69
7	10.69	10.73	10.75	10.74	11.03	1079	10.72	10.74	10.73	10.66	10.83	10.76	10.70	10.89	10.65	10.65	10.97
8	10.82	10.74	10.73	10.77	10.87	1088	10.86	10.64	10.67	10.76	10.74	10.85	10.83	10.84	10.80	10.77	10.73
9	10.79	10.66	10.69	10.64	10.81	1062	10.74	10.97	10.81	10.79	10.84	10.85	10.70	10.86	10.75	10.60	10.77
10	10.71	10.73	10.78	11.00	11.00	1074	10.83	10.77	11.00	10.69	10.71	10.93	10.77	10.89	10.77	10.72	10.91
11	10.77	10.86	10.72	10.96	10.79	1087	10.77	10.86	10.94	10.67	10.70	10.89	10.82	11.08	10.68	10.59	10.87
12	10.78	10.85	10.67	11.01	11.00	1085	10.74	10.95	10.83	10.76	10.83	10.84	10.62	10.80	10.66	10.60	10.82
13	10.71	10.88	10.74	10.77	10.85	1078	10.76	10.76	10.77	10.70	10.70	10.86	10.73	10.70	10.68	10.82	10.86
14	10.69	10.62	10.81	10.88	10.88	1076	10.76	10.66	10.92	10.67	10.77	10.89	10.81	10.92	10.77	10.82	10.65
15	10.72	10.66	10.72	10.78	11.06	1067	10.70	10.80	10.80	10.76	10.82	11.00	10.75	10.83	10.73	10.74	10.85
16	10.72	10.84	10.72	10.88	10.96	1081	10.73	10.70	11.01	10.80	10.62	11.00	10.80	10.90	10.64	10.65	10.80
17	10.81	10.72	10.72	11.00	10.86	1074	10.73	10.56	10.98	10.80	10.73	11.00	10.79	10.89	10.74	10.75	10.79
18	10.85	10.74	10.65	10.80	10.79	1086	10.61	10.87	10.82	10.73	10.81	10.80	10.81	10.67	10.80	10.78	10.88
19	10.82	10.76	10.85	10.70	10.90	1074	10.82	10.82	10.79	10.72	10.75	10.70	10.72	10.95	10.80	10.87	10.64
20	10.76	10.56	10.70	10.99	10.97	1071	10.58	10.75	10.95	10.90	10.80	10.92	10.72	11.03	10.74	10.90	10.82
21	10.79	10.80	10.82	10.78	11.08	1085	10.72	10.76	10.75	10.86	10.79	10.83	10.75	10.88	10.77	10.67	10.80
22	10.77	11.04	10.83	10.79	10.89	1080	10.55	10.71	10.82	10.69	10.81	10.90	10.85	10.92	10.85	10.62	10.85
23	10.85	10.93	10.68	10.77	10.74	1081	10.54	10.72	10.80	10.80	10.72	10.89	10.68	10.64	10.85	10.86	10.83
24	10.91	10.90	10.77	10.76	11.04	1063	10.88	10.92	10.62	10.75	10.72	10.67	10.84	10.70	10.72	10.73	10.75
25	10.78	10.80	10.82	10.69	10.96	1078	10.85	10.60	10.74	10.81	10.75	10.95	10.79	10.87	10.87	10.68	10.72

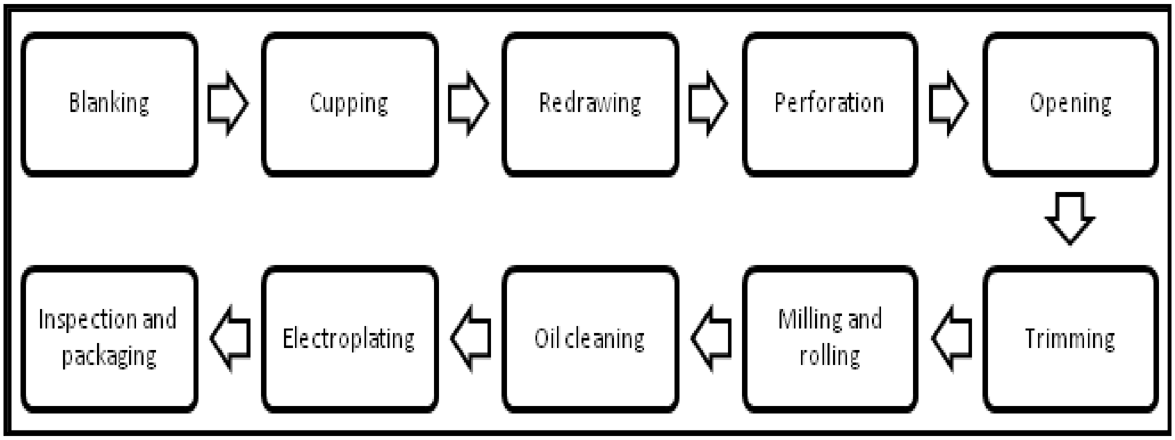

Figure No.1: Process flow in the manufacturing of 2" flange line

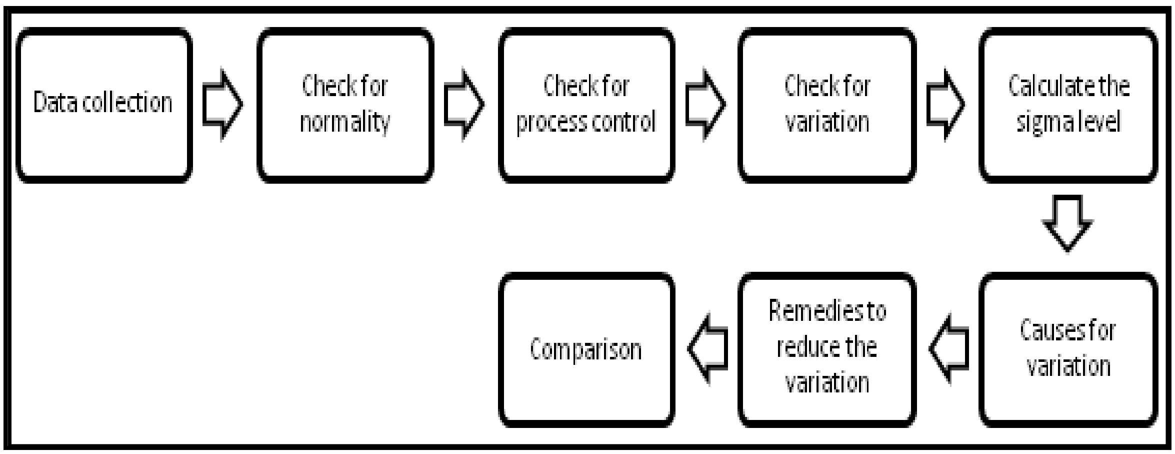

Figure No.2: Methodology

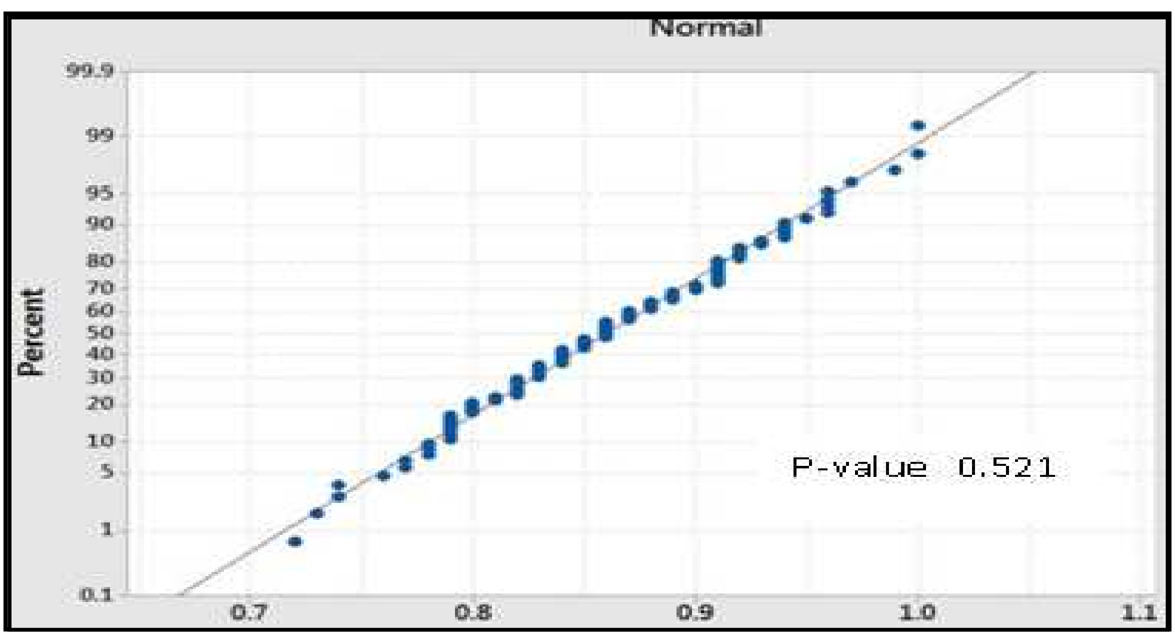

Figure No.3: Normality test

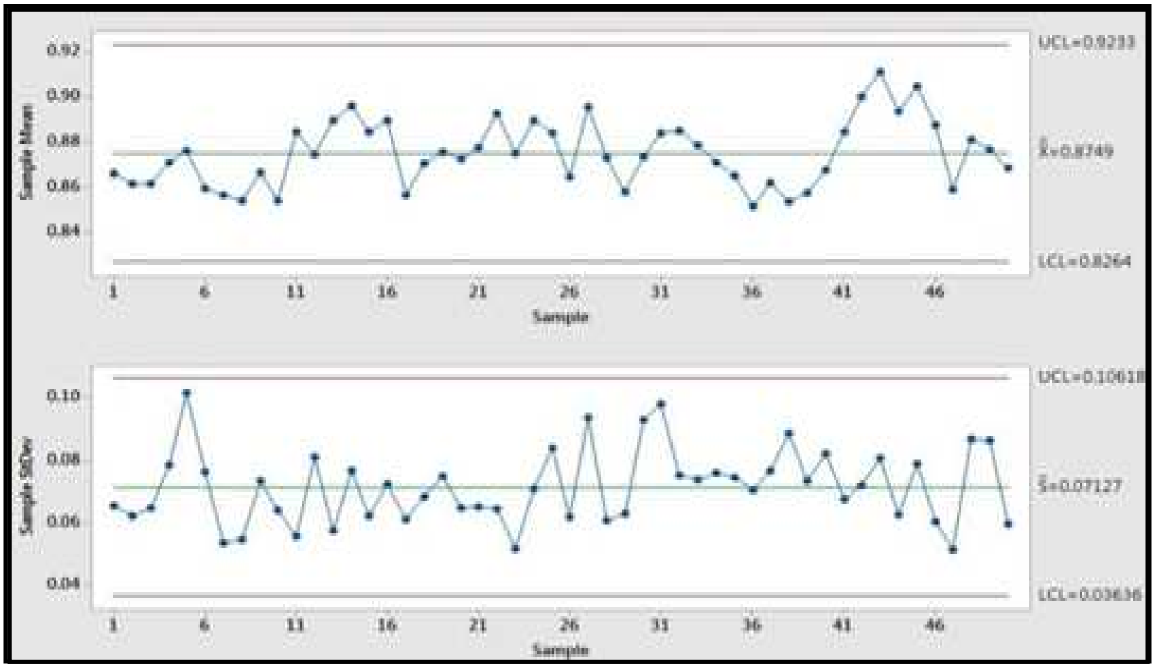

Figure No.4: X-bar and S chart

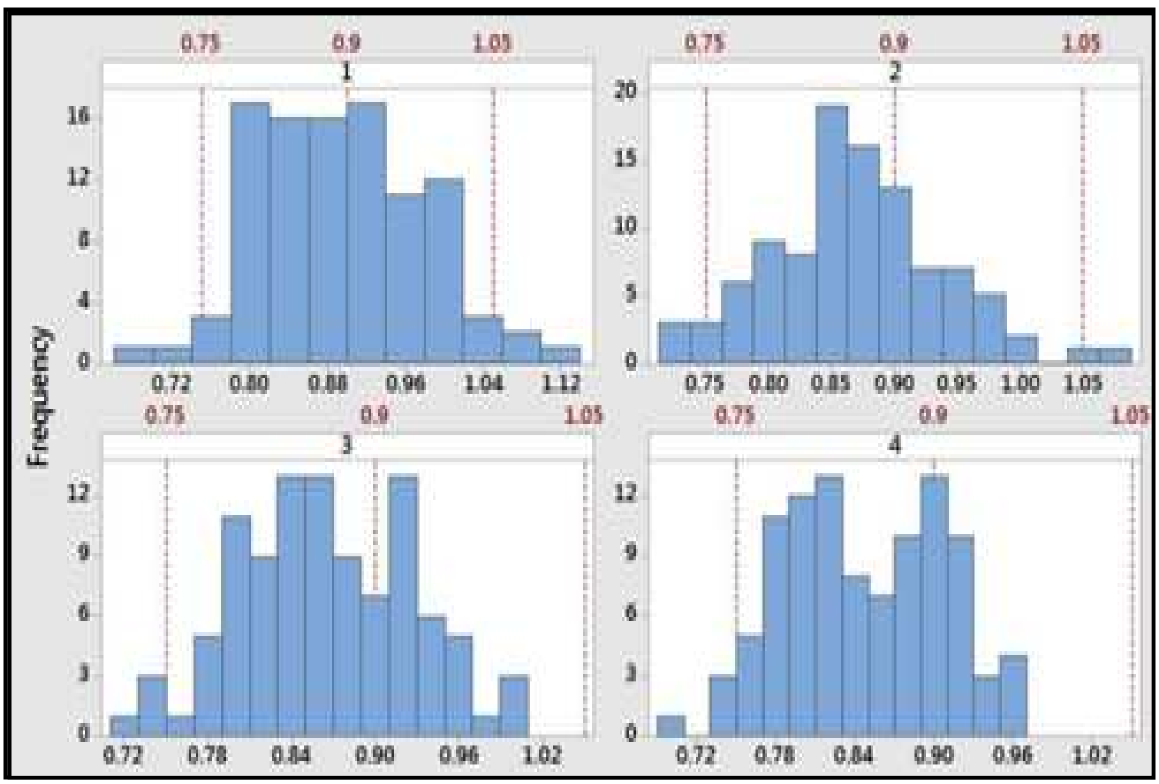

Figure No.5: Histogram

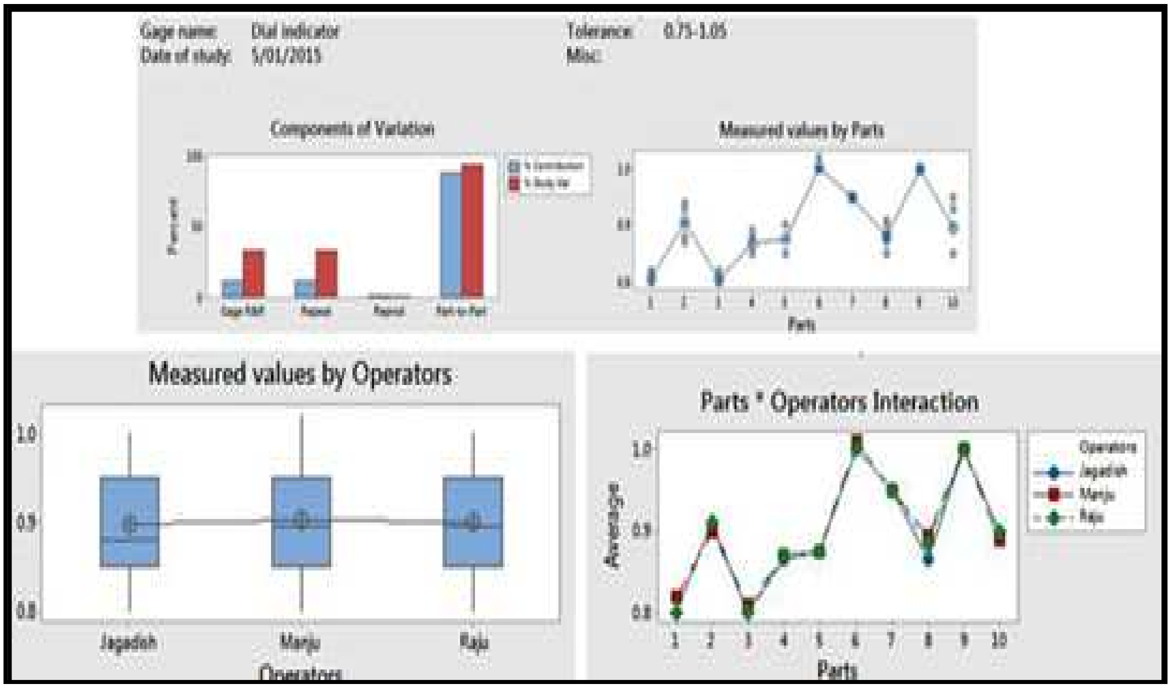

Figure No.6: Gauge R and R study

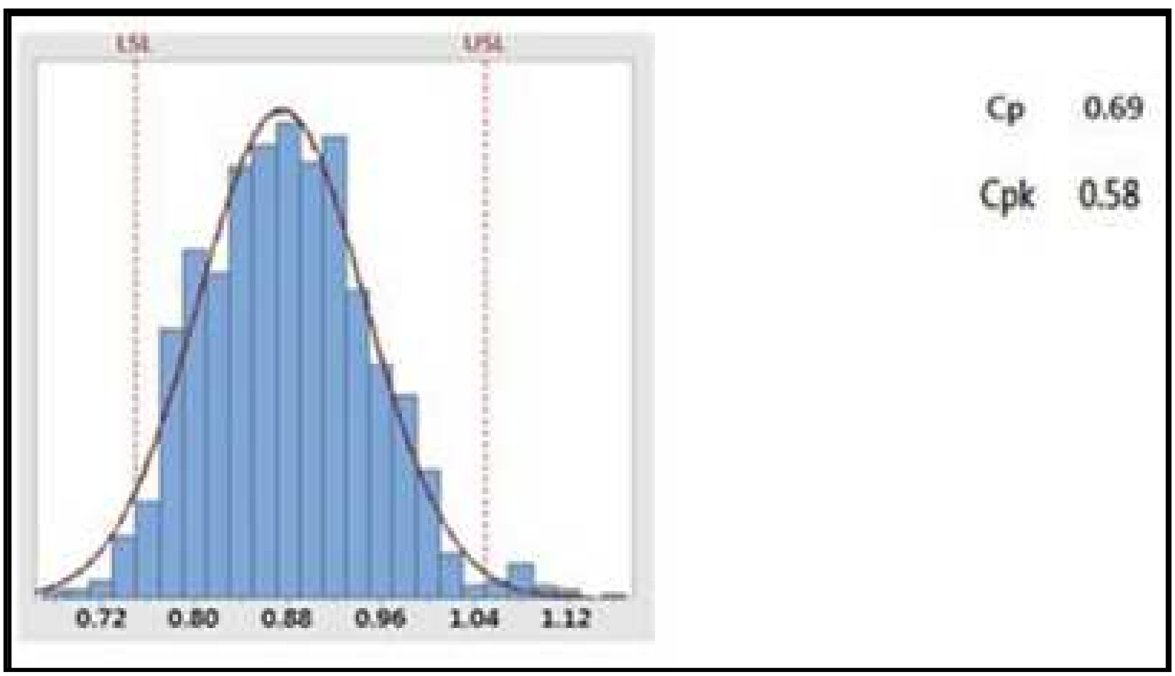

Figure No.7: Process capability chart for Milling operation

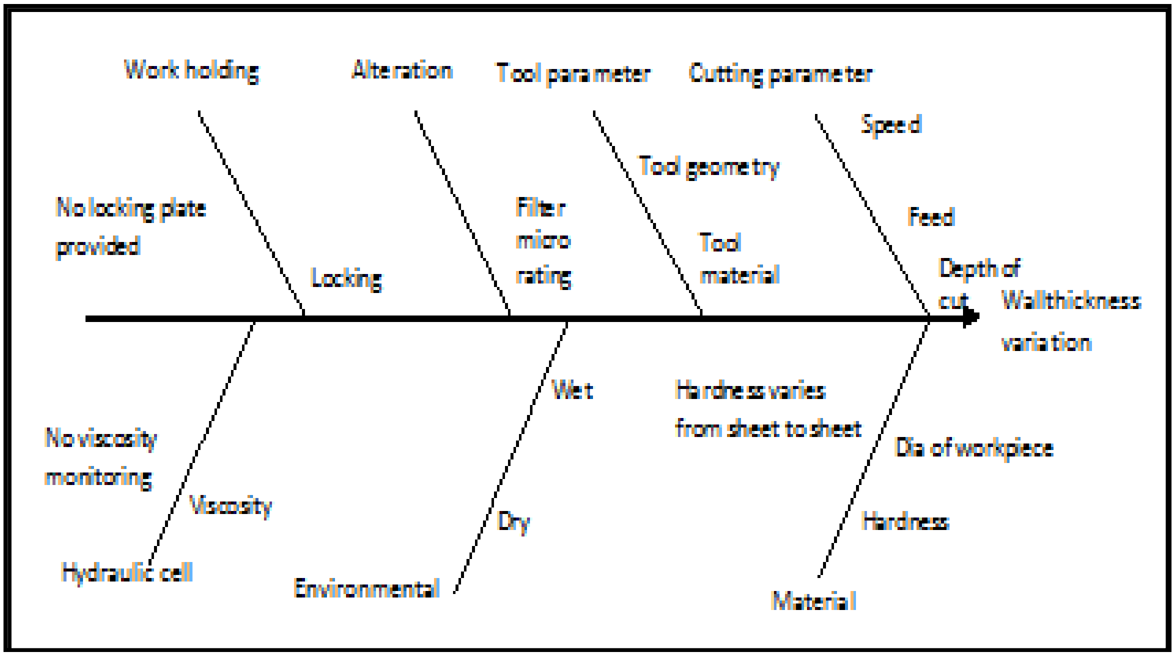

Figure N.8: Cause and effect diagram

Figure No.9: Rough finishes on the flange and more Material Removal Rate due to improper filtration resulting in variation in wall thickness

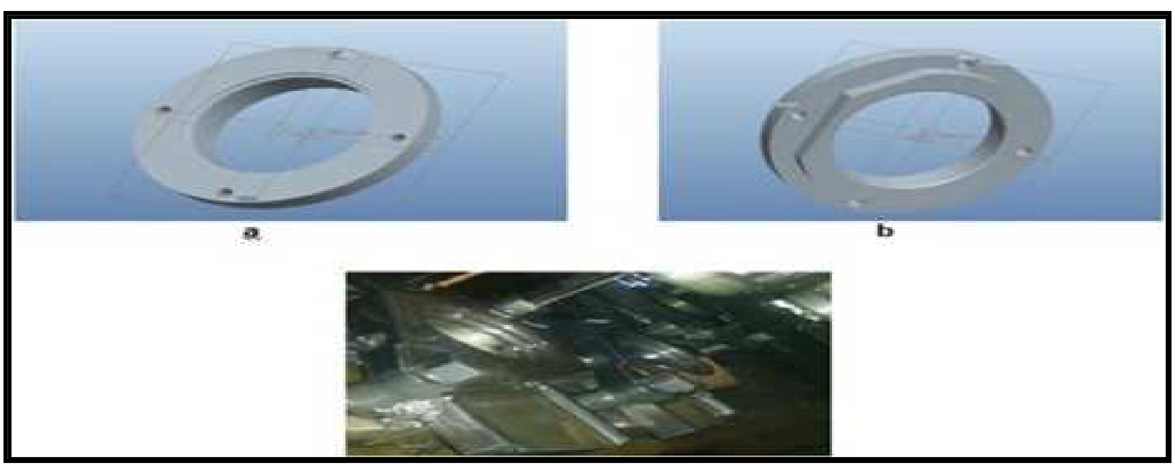

Figure No.10: CAD model of locking plate and clamp

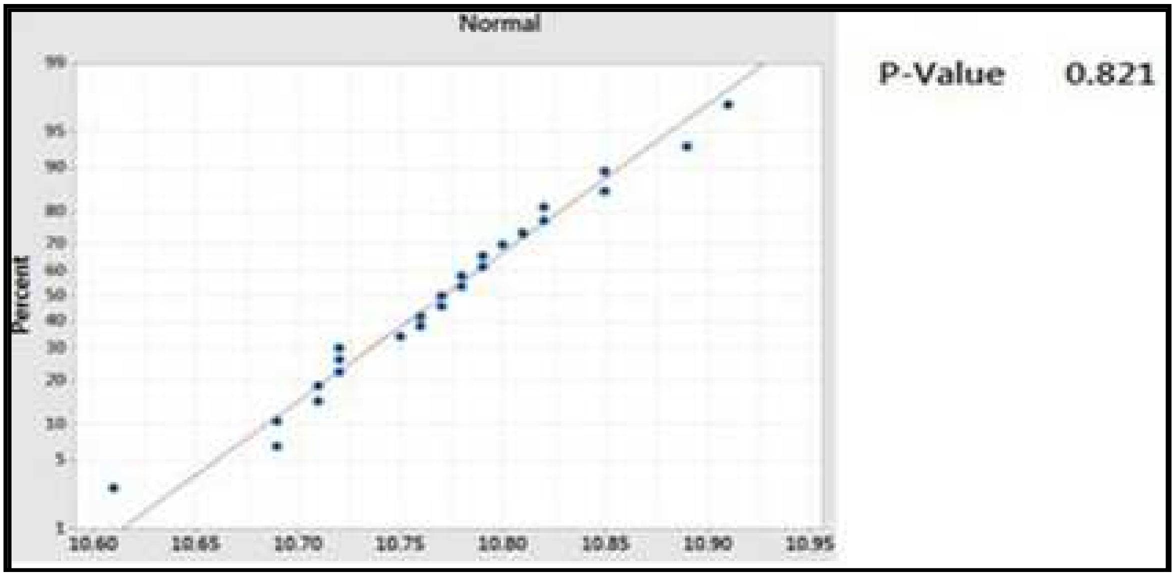

Figure No.11: Normality test

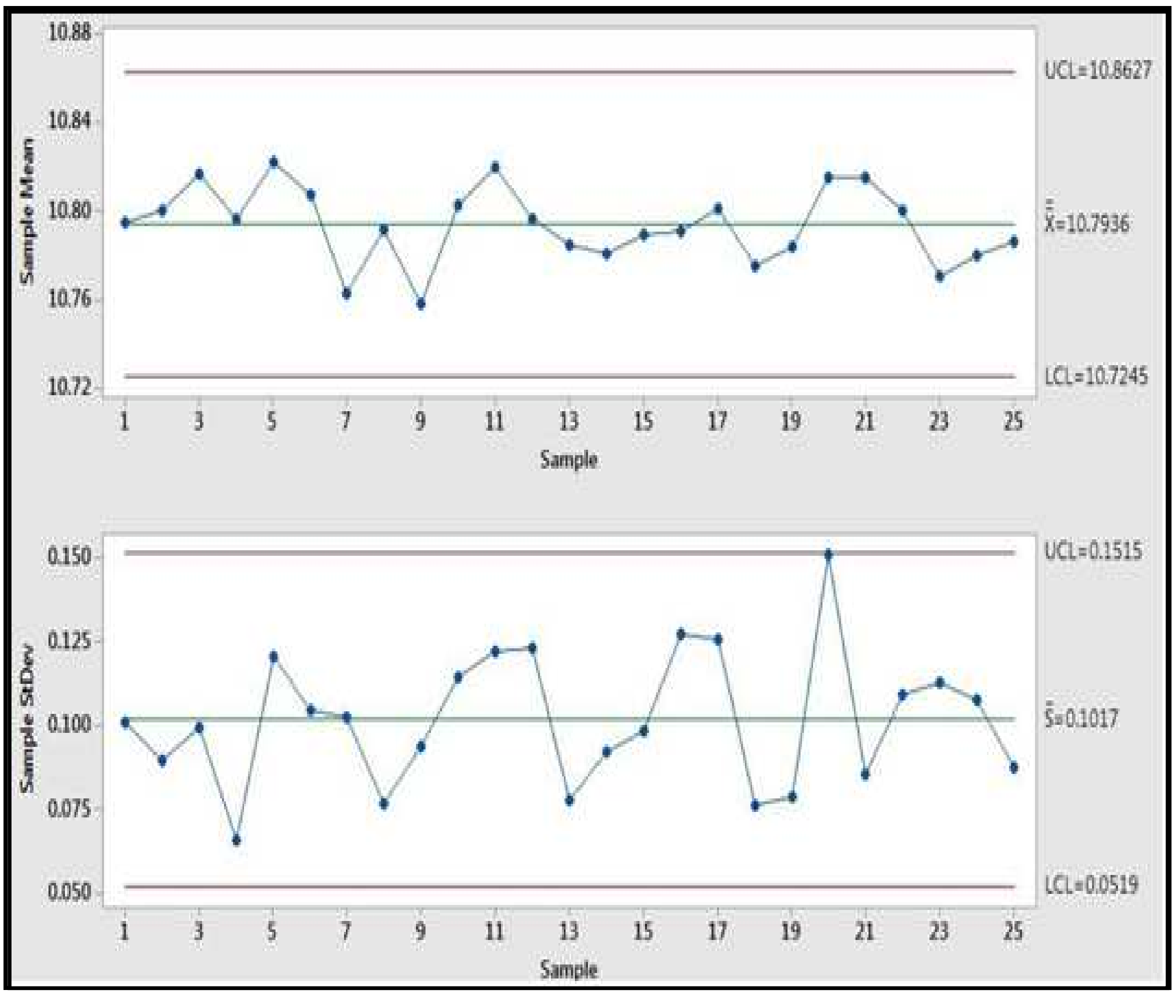

Figure No.12: X-bar and S chart

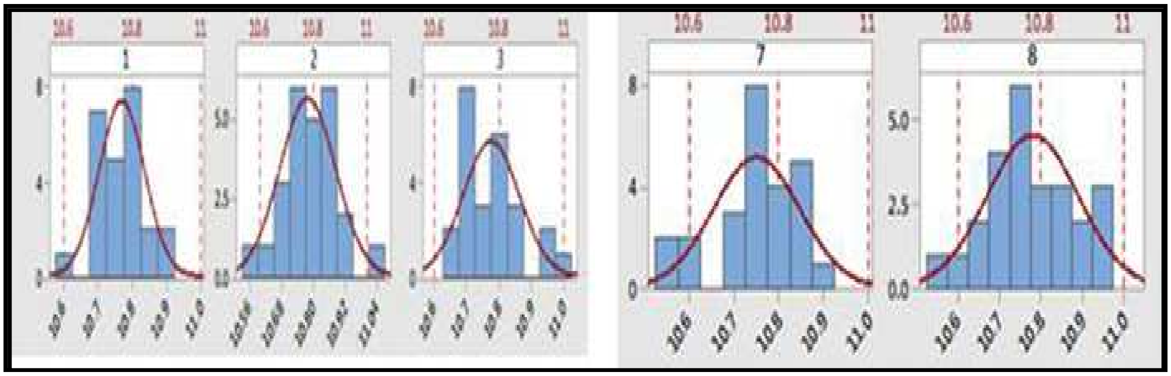

Figure No.13: Histogram

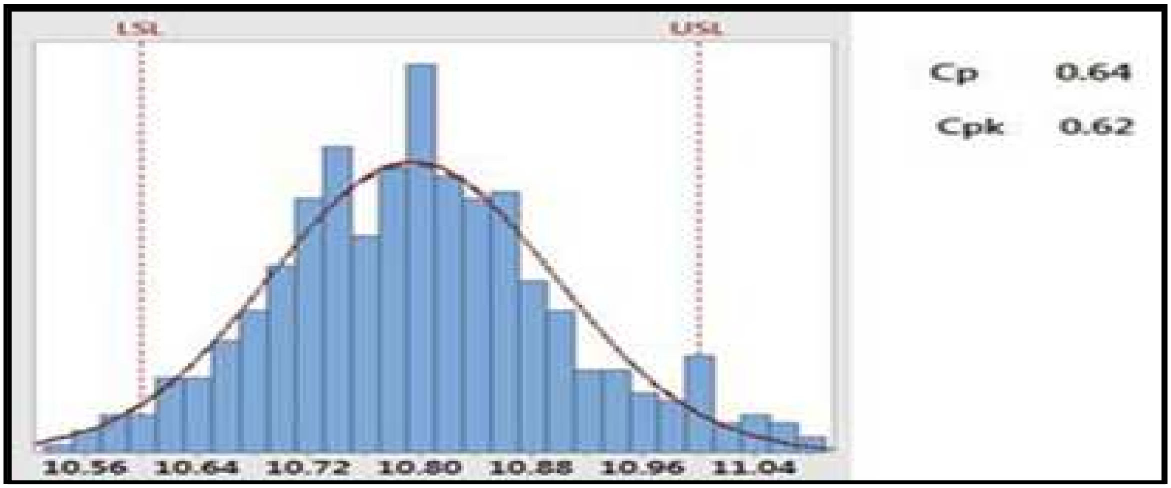

Figure No.14: Process capability chart for rolling operation

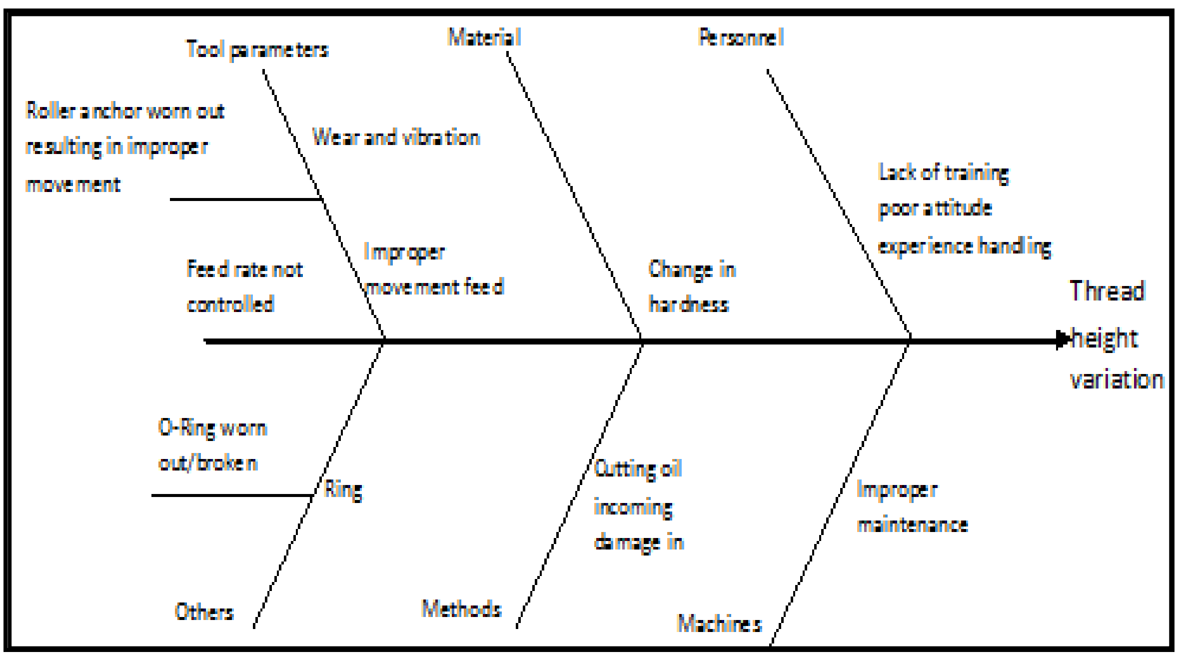

Figure No.15: Cause and effect diagram

Figure No.15(a): Anchor holding the roller

Figure No.15(b): Worn-out O-ring

Figure No.16: Replaced anchors and O-ring

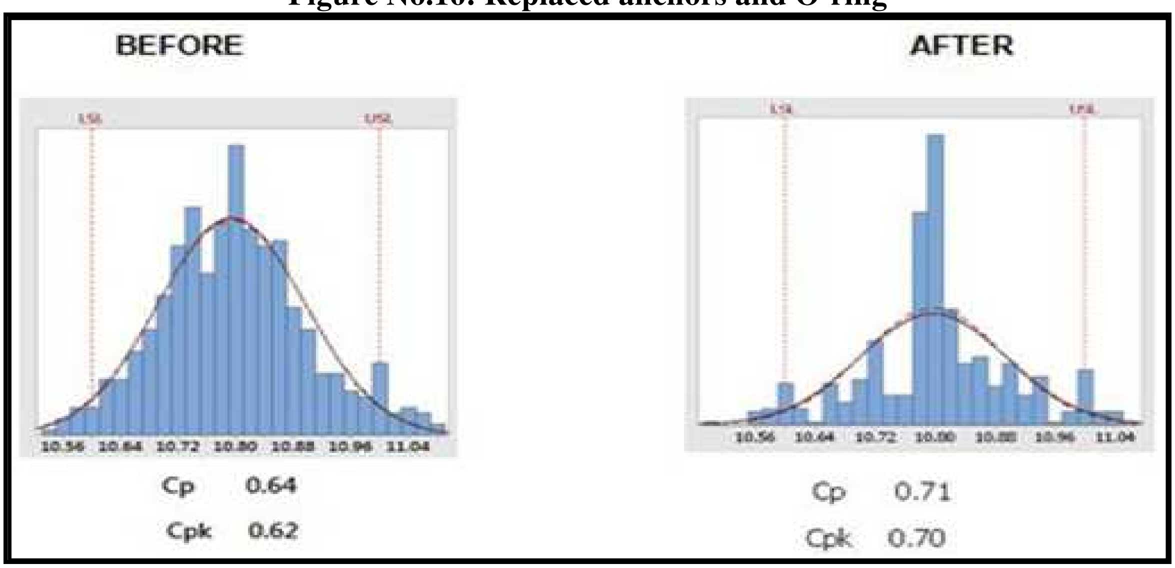

Figure No.17: Comparison in C_{pk} values

CONCLUSION

In this work steps were taken to reduce the process variation with respect to wall thickness on the milling operation and thread height during the rolling operation. Statistical analysis was conducted and resulting causes in the process variation was found out and actions were taken and suggested. A locking plate and a by-pass filter can suggested to be provided to avoid variation in wall thickness during milling operation. The locking plate also helps to avoid variation in thread height during rolling operation.

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CONFLICT OF INTEREST
We declare that we have no conflict of interest.

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