

Improving the Process Capability of a Boring Operation by the Application of Statistical Techniques

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Abstract- In this paper we have discussed what Process Capability is and how it is implemented. All the steps are listed out in an easy to understand manner. Process Capability Methodology is presented representing the important phases of it. A case study has also been discussed involving a commonly used product of bath fittings used in our day to day life. Process-capability indices are effective tools for the continuous improvement of quality, productivity and managerial decisions. Statistical Process Control (SPC) techniques improve the quality in mass production. In this study, a process-capability analysis was carried out in the machining line of a medium-sized company that produces machine and spare parts. For this purpose, normal probability plots and histograms were prepared and the process capability

indices C_P and C_{Pk} were calculated. It is shown that the process capability for the whole process was inadequate and that the mass production was unstable. In order to satisfy the process-capability measures it is necessary to improve the quality level by shifting the process mean to the target value and reducing the variations in the process.

Key Words- Boring Operation, Control Chart, Process Capability Indices, Process Capability Analysis, Quality improvement, Statistical Quality Control.

1. INTRODUCTION

PROCESS capability study (PCS) is a scientific and a systematic procedure that uses control charts to detect and eliminate the unnatural causes of variation until a state of statistical control is reached [1]. When the study is completed, you will identify the natural variability of the process. Process-capability analysis is a technique applied in many stages of the product cycle, including process, product design, manufacturing and manufacturing planning, since it helps to determine the ability to manufacture parts within the tolerance limits and engineering values. There are several capability indices, including C_P , C_{PU} , C_{PL} and C_{Pk} , that have been widely used in manufacturing industry to provide common quantitative measures of process potential and performance. Process-capability indices are powerful means of studying the process ability for manufacturing a product that meets specifications [2, 3]. There is considerable theoretical and experimental research work on improving product quality and process efficiency using a process-capability analysis. Kane [4] described six areas of application for capability indices: the prevention of the production of nonconforming products, the continuous measure of improvement, communication, prioritization, the identification of directions for improvement, and the auditing of the quality system. Wright [5] discussed the

cumulative distribution function of process capability indexes.

The process-capability indices, including C_P , C_{Pk} and C_{PM} , have been proposed in manufacturing industry to provide a quick indication of how a process has conformed to its specifications, which are preset by manufacturers and customers. Pearn et al. [6] indicated the index of capability for monitoring the accuracy of the manufacturing process. Singhal [7] introduced the multi process performance-analysis chart (MPPAC) based on process capability indices for controlling and monitoring multiple processes. The MPPAC provides an easy way to process improvement by comparing the locations on the chart of the processes before and after the improvement effort. Pearn and Chen [8] proposed a modification to the MPPAC, combining the more advanced process capability indexes C_{PM} and C_{PMK} to identify the problems causing the process failing to centre on the target. Pearn et al [9] introduced the MPPAC based on the capability index, which is a simple transformation of C_{PMK} . They developed the multi-process performance-analysis chart based on process capability indices to analyze the manufacturing performance for multiple processes.

2. OBJECTIVE

The overall objective of this project is for the development of basic in-house process competence and is broken down into specific sub-objectives. They are as follows:

- The prevention of the production of nonconforming products.
- The continuous measure of improvement.

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- c) Prioritization between the processes.
- d) The identification of directions for improvement.
- e) The auditing of the quality system.

3. METHODOLOGY

Process capability studies recognized and recommended as able aids in improving a process. By PCS it is possible to establish quality standard for the process & further improvement will so possible.

Certain precautions are necessary before conducting PCS:
 Process should be in statistical control.
 Independent data should be collected.
 Make control charts.

The general process capability study steps are follows [10]:

In step one, the Critical parameters need to be selected before the study begins. Critical parameters may be established from drawings, contracts, inspection instructions, work instructions, etc. critical parameters are usually correlated to product.

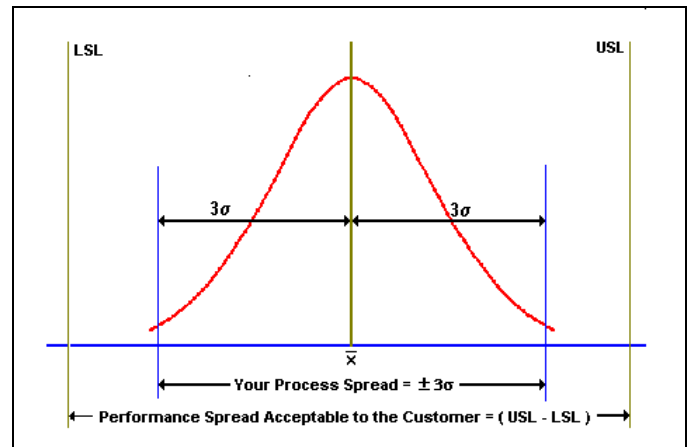
Now step two is collect data. Assure that the appropriate data is collected for study. It is preferable to collect at least 60 data values for each critical parameter. If this is not possible, corrections can be made to adjust for the error that is introduced when less than 60 data values are collected.

In step three, a distinction between product and process should be made at this point. The product is the end result from the process. It is ultimately desirable to establish control over the process by controlling the process inputs. The statistical control of the process can be studied by using control charts.

In step four, calculate the process capability indices, estimates of the process average and standard deviation must be obtained from the process data. In addition, the formulas for process capability indices assume that the process data came from a normal statistical distribution.

After that the step five is analyzing sources of variation involves determining what process factors affect the natural process spread (process variation) and the process centering. With this knowledge, it may be possible to improve the process' capability. Analyzing sources of variation always involve careful planning and data collection. Once the process capability indices indicate a capable process, a routine process control technique should be employed to assure that the process remains stable. This may be done by a variety of methods such as establishing a statistical process (SPC) program.

Following are the graphical details and equations quantifying process capability:



Where:

USL = Upper Specification Limit

LSL = Lower Specification Limit

\bar{X} = Mean of the Process

σ = Standard Deviation of the Process

The Equations Quantifying Process Capability:

Index	Estimated Equation	Usage
C_P	$\frac{USL - LSL}{6\sigma}$	Process Capability for two - sided specification limit, irrespective of process center.
C_{PU}	$\frac{USL - \bar{X}}{3\sigma}$	Process Capability relative to upper specification limit.
C_{PL}	$\frac{\bar{X} - LSL}{3\sigma}$	Process Capability relative to lower specification limit.
C_{Pk}	$\min \left[\frac{USL - \bar{X}}{3\sigma}, \frac{\bar{X} - LSL}{3\sigma} \right]$	Process Capability for two - sided specification limits accounting for process centering.

Note:

If \bar{X} is at target, then $C_P = C_{Pk}$.

C_{Pk} will always be equal to or less than C_P .

The defect levels or parts per million non-conforming were computed for different C_{Pk} values using the Z scores and the percentage area under the standard normal curve using normal deviate tables. [21]

This process is so good that even if the process mean shifts by as much as +/- 1.5 sigma the process will produce no more than 3.4 non-conforming parts per million.

Capability index	Estimation of the process
$C_{P_k} = C_P$	Process is placed exactly at the centre of the specification limits.
$C_P < 1$	Process is not adequate.
$1 \leq C_{P_k} < 1.33$	Process is adequate.
$C_P \geq 1.33$	Process is satisfactory enough.
$C_P \geq 1.66$	Process is very satisfactory.
$C_{P_k} \neq C_{P_k}$	Process is inadequate, new process parameters must be chosen.

4. PROCESS CAPABILITY ANALYSIS IN BORING

In this paper we have discussed a Bath Fitting product named BIB COCK manufactured in MOHALI, INDIA. This company is making a wide range of products conforming to international standards. It is ISO 9001:2000 certified company for designing and manufacturing of bath fitting products. In this case study we are discussing Bib Cock where we have applied Process Capability Analysis for the betterment. The work piece was cast, using investment casting and machined using an industrial type lathe machine. The work pieces were machined under dry conditions. The case study shows the importance of statistical process control (SPC) for monitoring and ensuring the product produced is able to satisfy customers' needs and requirements. A detailed study of manufacturing process was carried out for the elimination of the quality characteristic problem during boring operation. The quality characteristic considered is shown in Figure - 1.

The focus of the study was to investigate the process capability of the ongoing process so as to decide upon the suitability of the machine to hold particular tolerance. In this study, in order to demonstrate the applicability of the proposed method and to make a clear decision about the capability of the machining process, the sample size was determined and a sufficient number of sample parts were inspected. A single sampling plan was implemented by using the lot-acceptance sampling plan. Samples were chosen randomly during the boring process. The data for the investigated characteristic was collected for 30 days in the company, determined for 100 samples (Observation Table). Control charts and histograms were prepared and statistical parameters were calculated using the measured values taken from the work pieces that represent the whole process. To receive a numerical measure of the capability, the so-called process-capability indices were calculated.

Machine used: Capstan Lathe
Material of tool: Mild Steel
Material of work piece: Brass

Sub-group	Sample Size				\bar{X}	Range
	1	2	3	4		
1	13.02	12.95	12.92	12.99	12.97	0.10
2	13.02	13.10	12.96	12.96	13.01	0.14
3	13.04	13.08	13.05	13.10	13.07	0.06
4	13.04	12.96	12.96	12.97	12.98	0.08
5	12.96	12.97	12.90	13.05	12.97	0.15
6	12.90	12.88	13.00	13.05	12.96	0.17
7	12.97	12.96	12.96	12.99	12.97	0.03
8	13.04	13.02	13.05	12.97	13.02	0.08
9	13.05	13.10	12.98	12.96	13.02	0.14
10	12.96	13.00	12.96	12.99	12.98	0.04
11	12.90	13.05	12.98	12.88	12.95	0.17
12	12.96	12.98	12.97	13.02	12.98	0.06
13	13.00	12.96	12.99	12.90	12.96	0.10
14	12.88	12.94	13.05	13.00	12.97	0.17
15	12.96	12.96	13.04	12.98	12.99	0.08
16	12.99	12.94	13.00	13.05	13.00	0.11
17	13.05	13.02	12.88	12.96	12.98	0.17
18	13.08	13.06	13.10	13.05	13.07	0.05
19	13.02	13.05	13.04	12.97	13.02	0.08
20	12.96	12.90	12.97	13.05	12.97	0.15
21	12.98	12.99	12.96	13.00	12.98	0.04
22	12.97	13.02	12.96	12.99	12.99	0.06
23	13.04	13.00	12.98	13.10	13.03	0.12
24	13.02	12.90	13.05	12.97	12.99	0.15
25	12.93	12.88	12.91	12.90	12.91	0.05
Average					12.989	0.102

OBSERVATION TABLE

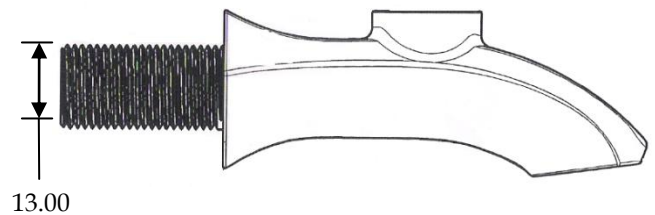


Figure (1) Diameter at Bottom Side

Operation: Boring
 Nominal value: 11.00 mm
 USL: 11.20 mm
 LSL: 10.80 mm
 Total no. of Subgroup (N): 25
 Subgroup Size (n): 4

4.1 Calculations of Control Limits

From the data taken, the control limits are calculated by

calculating Average (\bar{X}), Ranges (\bar{R}) and Standard Deviation (σ). Computation for control limits are as follows:

$$\text{Average } (\bar{X}) = \frac{\sum \bar{X}}{N} = 12.989$$

$$\text{Range } (\bar{R}) = \frac{\sum R}{N} = 0.102$$

$$\text{Standard Deviation } (\sigma) = \frac{\bar{R}}{d_2} = 0.049$$

For \bar{X} - Chart

$$\text{Upper Control Limit (UCLX)} = \bar{X} + A_2 \bar{R} = 13.06$$

$$\text{Lower Control Limit (LCLX)} = \bar{X} - A_2 \bar{R} = 12.91$$

For R - Chart

$$\text{Upper Control Limit (UCLR)} = D_4 \bar{R} = 0.23$$

$$\text{Lower Control Limit (LCLR)} = D_3 \bar{R} = 0$$

$d_2 = 2.06$, $A_2 = 0.73$, $D_4 = 2.28$, $D_3 = 0$

d_2 , A_2 , D_4 , D_3 = Depends on no. of samples taken in one subgroup.

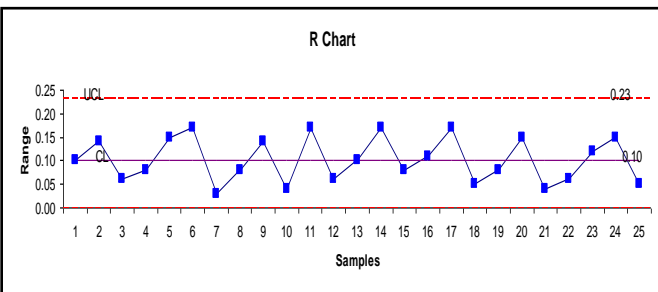
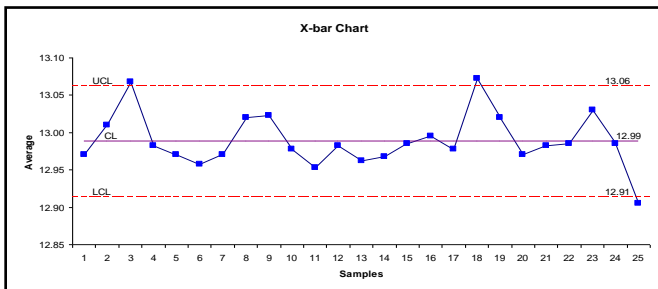


Figure (2) \bar{X} & R Chart for Bottom Side (Iteration-1)

4.2 Interpretation of Control Chart (Figure - 2)

After calculating control limits, the control chart for ranges is drawn and it is found that all points are within the control limits. Then \bar{X} chart is analyzed and it is found that point 3 & 18 are above UCL and point 25 is below LCL. Thus the process is out of control. The control limits are, therefore, recalculated.

4.3 Revision of Control Limits

The points are going out of control limits in \bar{X} and R chart, so it is re-evaluated. The computations for control limits are as follows:

$$\text{Average } (\bar{X}) = \frac{\sum \bar{X}}{N} = 12.985$$

$$\text{Range } (\bar{R}) = \frac{\sum R}{N} = 0.155$$

$$\text{Standard Deviation } (\sigma) = \frac{\bar{R}}{d_2} = 0.075$$

For \bar{X} - Chart

$$\text{Upper Control Limit (UCLX)} = \bar{X} + A_2 \bar{R} = 13.06$$

$$\text{Lower Control Limit (LCLX)} = \bar{X} - A_2 \bar{R} = 12.91$$

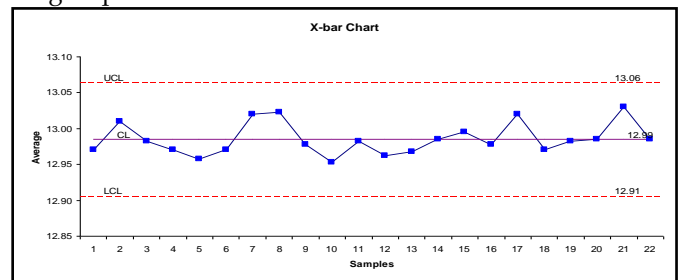
For R - Chart

$$\text{Upper Control Limit (UCLR)} = D_4 \bar{R} = 0.25$$

$$\text{Lower Control Limit (LCLR)} = D_3 \bar{R} = 0$$

$d_2 = 2.06$, $A_2 = 0.73$, $D_4 = 2.28$, $D_3 = 0$

d_2 , A_2 , D_4 , D_3 = Depends on no. of samples taken in one subgroup.



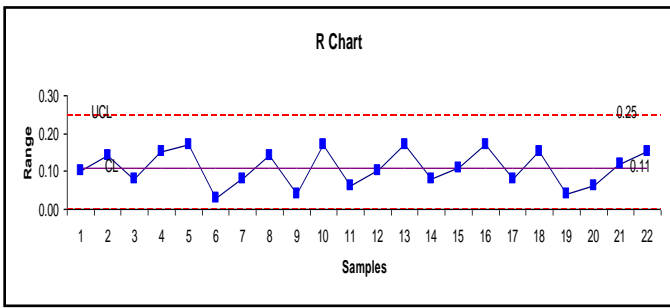


Figure (3) \bar{X} & R Chart for Bottom Side (Iteration-2)

4.4 Interpretation of Control Chart (Figure - 3)

The control chart for ranges is drawn and it is found that all points are within the upper & lower control limits. Then \bar{X} chart is analyzed and it is found that no point goes out of control so the process is under control and stable.

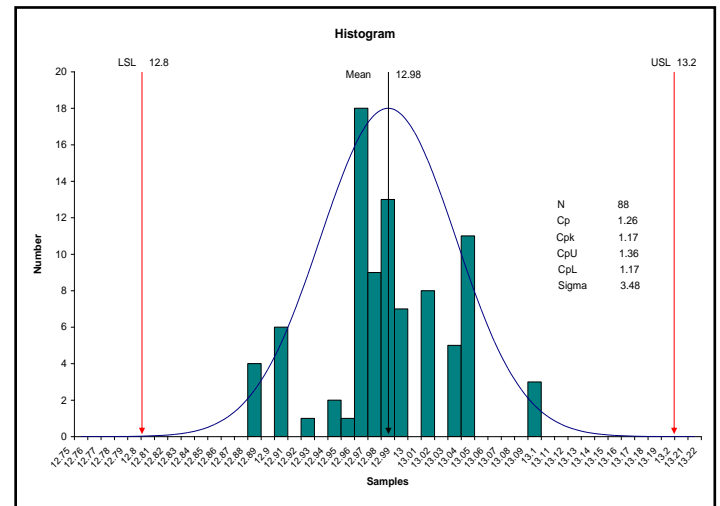


Figure (5) Process Capability Analysis for Bottom Side

5. CAUSE & EFFECT DIAGRAMS

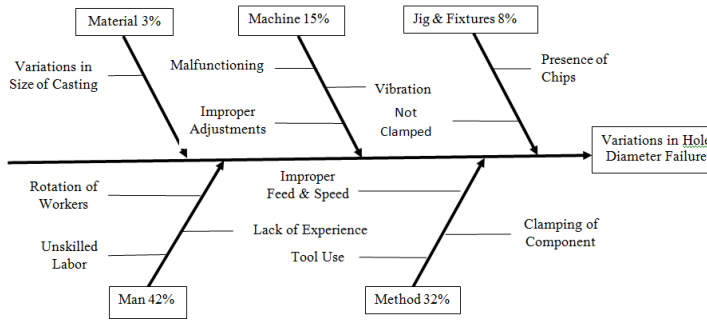


Figure (4) Cause & Effect Diagram for Variations in Hole Diameter in Bottom Side Failure

6. PROCESS CAPABILITY INDICES

Since process is under control and is stable, process capability indices are calculated to know whether process is capable or not.

$$C_p = \frac{USL - LSL}{6\sigma} = 1.26$$

So process is capable.

$$C_{pk} = \min \left[\frac{USL - \bar{X}}{3\sigma}, \frac{\bar{X} - LSL}{3\sigma} \right] = 1.17$$

7. CONCLUSION

In recent years, process-capability analysis has become an important integrated part in the applications of statistical techniques for quality assurance. Quality assurance in mass production is achieved using statistical process-control techniques. The process-capability analysis, which is a SPC technique, helps to determine the ability for manufacturing between tolerance limits and engineering specifications. The capability analysis gives information about the changes and tendencies of the systems during production.

In this study, Control charts for variables are implemented to achieve a good control over the process. SPC technique was used to evaluate machines' capability (C_p) and process centering (C_{pk}) of manufacturing process to find whether the process is capable or not. The number of non-conforming part was determined in observed values, in short and long periods of time. After monitoring the process a significant improvement has been experienced in terms of increase in process capability indices and reduction in defective parts per million (ppm). The Ishikawa Diagram for critical defeats is drawn, the root causes for each are identified and the suitable remedial measures are suggested. Faults regarding manufacturing out-of-tolerance limits were eliminated, the variability in the process and the cost due to low-quality production were reduced in the particular company.

In today's competitive market, SPC is not the most frequently used technique in small and medium-sized companies. The most important problems in Business is that there are no trained employees to apply it and there is insufficient investment. Consequently, SPC must be applied widely and continuously to achieve quality improvements.

8. REFERENCES

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