Managing the Process Variability of CNC Turning Operation Using Quality Control Tools

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Abstract: **Variation is present everywhere in our lives. It is assumed that as variation is reduced, quality is improved. In current scenario, specifications for products have been tightened due to performance competition in market. Statistical tools like control charts, process capability analysis and cause and effect diagram ensure that processes are fit for company specifications while reduce the process variation and important in achieving product quality characteristic. Process capability indices (PCIs) are used in the manufacturing industry to provide numerical measures on whether a process is capable of producing items within the predetermined specification limits. This study focuses on process capability analysis turning operation. For the analysis purpose MINITAB 16.0 is used and is found that the process is placed exactly at the centre of the control limits. Analysis also shows that process is not adequate. The cause and effect diagram is prepared to found out the root cause of variation in diameter of work.**

Keywords: **Cause and Effect Diagram, CNC Turning Center, Control Charts, Process Capability, Process Capability Indices (Cp and Cpk), Standard Deviation, Variability.**

Nomenclature :

CL	Center line
C_p, C_{pk}, C_{pl}, C_{pu} and C_{pm}	Notations for process capability indices
LCL	Lower control limit
LSL	Lower specification limit
PCIs	Process capability indices
PCS	Process capability study
PPM	Parts per million
R	Range
UCL	Upper control Limit
USL	Upper specification Limit
$\overline{\overline{X}}$	Mean of sample means
$\overline{X}$	Sample mean
μ	Process mean
σ	Standard deviation

1. INTRODUCTION

The concept of process capability was given by J. M. Juran, a famous Quality Guru in early 1970 with the introduction of 'capability ratio' [1]. Juran introduced the ratio of specification range (UCL-LCL) to the process variation (6σ) and is known as "capability ratio" (C_p). After that many indices such as C_p, C_{pk} and C_{pm} are developed to measure process performance. In mass production large a number of products are manufactured by duplicating the products designed by R & D department. Also manufacturing processes are never stable enough for every product to be an ideal replica of the desired product. Therefore, different indices are utilized to measure the variation. Process capability indices (PCIs) are used in the manufacturing industry to provide numerical measures on whether a process is capable of producing items within the predetermined specification limits. The modern high-volume industry has been forced to develop its process capability to ever higher levels to meet the high-level demands set for the products. As a consequence process deviation is narrow in capable processes. In this study the process-capability analysis was carried out in laboratory for the identification of the variability among products.

The paper also shows cause and effect diagram for variability which is one of the simplest and cheapest tools for identifying the root cause of variation so that further improvements can be done accordingly [2].

2. PROCESS CAPABILITY

Process capability study (PCS) is recognized and recommended as able aid for process improvement. By PCS it is possible to establish quality standard for the process and thus further improvement can be made [3].

The process capability study is a long-term study that is conducted over an extended operating time and includes sources of variation external to a machine. These sources can be categorized under the headings of Man, Machine, Material, Method and Environment [4].

2.1. Process capability indices

Process capability indices (PCIs) are used in the manufacturing industry to provide numerical measures on whether a process is capable of producing items within the control limits. The modern high-volume industry has been forced to develop its process capability to ever higher levels to meet the high-level demands set for the products. As a consequence process deviation is narrow in capable processes [3].

There are many Process Capability Indices (PCIs) developed so far for measuring process capability. However, the most common PCIs include C_p and C_{pk} [5].

$$C_p = \frac{UCL - LCL}{6\sigma}$$

$$C_{pk} = \frac{\min\{UCL - \mu, \mu - LCL\}}{3\sigma}$$

Where μ is the process mean (expected dimension), UCL is the upper control limit, LCL is the lower control limit and σ is the process standard deviation.

The data used for calculating C_p and C_{pk} are based on samples. So, the values of μ and σ in a process are approximate values. Relatively a large number of samples are required to give a reliable measure of C_p and C_{pk}.

Control limits for $\overline{X}$ and R charts can be calculated using the following formulae [6].

$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2 R$$

$$UCL_R = D_4 \bar{R}$$

$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2 R$$

$$LCL_R = D_3 \bar{R}$$

The values of constants

A_2 = 0.58 for subgroup size 5

D_4 = 2.11

D_3 = 0

Table 1 shows that how the estimation can be made according to the calculated values of PCIs C_p and $C_{PK.}$

Table 1: Process Estimation Based on PCIs [7]

Capability index	Estimation of process
$C_p = C_{pk}$	Process is placed exactly at the centre of the control limits
$C_p < 1$	Process is not adequate
$1 \leqslant C_p < 1.33$	Process is adequate
$1.33 \leqslant C_p < 1.50$	Process is satisfactory
$1.50 \leqslant C_p < 2.00$	Process is excellent
$C_p \neq C_{pk}$	Process is not adequate

3. METHODOLOGY

To analyze the process capability of CNC Turning centre CLT-100 manufactured by HYTECH, Pune in CAM Laboratory at SKIT, Jaipur 95 work pieces were turned for 20 mm diameter. For the process capability analysis MINITAB 16.0 is used.

The flow diagram as shown in Figure1 explains the methodology to be used to calculate process capability of CNC turning center. Certain points should keep in mind while conducting study- (i) Process should be in statistical control (ii) Independent data should be collected to make control charts.

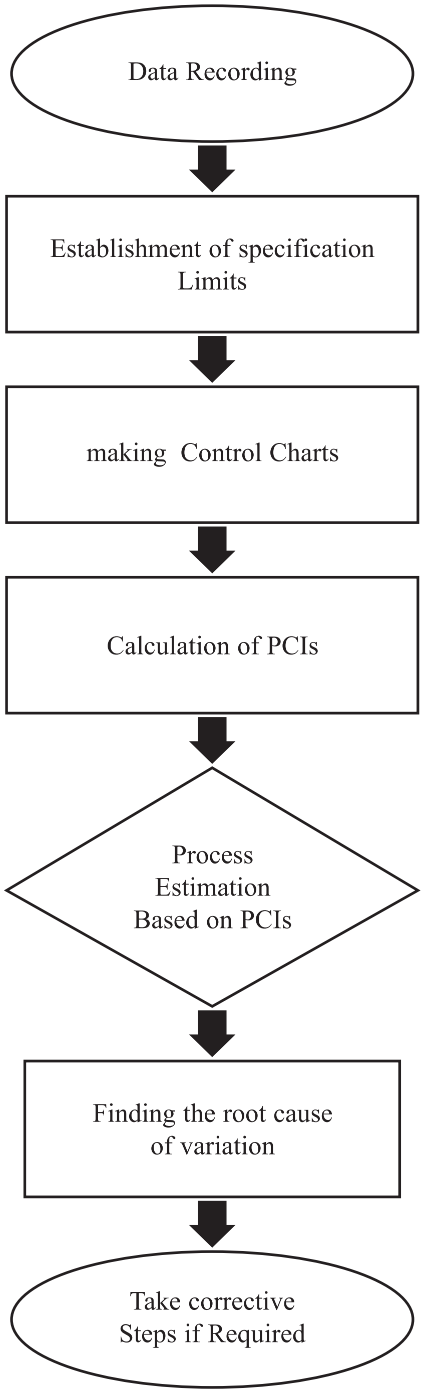

Fig 1: Steps of work

4. OBSERVATIONS AND CALCULATIONS

Diameters of 95 work pieces turned on CLT-100 were recorded which are as shown in Table 2.

Table 2: Recorded Data for 95 works in mm

Sample Number	X(Diameter in mm)				
1	20.1	20.16	19.8	19.9	20.12
2	20.14	20.08	19.8	19.9	19.92
3	20.16	20.06	19.94	19.9	20.1
4	20.02	20.08	20.08	19.9	19.8
5	20.1	20.16	19.8	19.9	20.12
6	19.9	19.92	20.16	20.06	19.94
7	20.16	19.8	19.9	20.12	20.1
8	20.16	19.8	19.9	20.12	20.1
9	20.16	19.8	19.9	20.12	20.1
10	20.16	19.8	19.9	20.12	20.1
11	19.8	19.9	19.92	20.16	20.06
12	19.94	19.9	20.1	20.02	20.08
13	20.08	19.9	19.8	20.1	20.16
14	19.8	19.9	20.12	20.1	19.9
15	19.92	20.16	20.06	19.94	20.16
16	19.9	20.12	20.1	20.16	19.8
17	19.9	20.12	20.1	20.16	19.8
18	19.9	20.12	20.1	20.16	19.8
19	19.9	20.12	20.1	19.8	19.9

5. PROCESS CAPABILITY ANALYSIS

The control chart for sample mean and ranges with their control limits are shown in Figure 2. Control charts show that all points are within the control limits, so the process seems to be under control and stable. The control limits are as follows:

$UCL_{\overline{X}} = 20.1953$

$LCL_{\overline{X}} = 19.8127$

$CL_{\overline{X}} = 20.0040 = \text{sample mean}$

$UCL_R = 0.7011$

$LCL_R = 0.0000$

$CL_R = 0.3316$

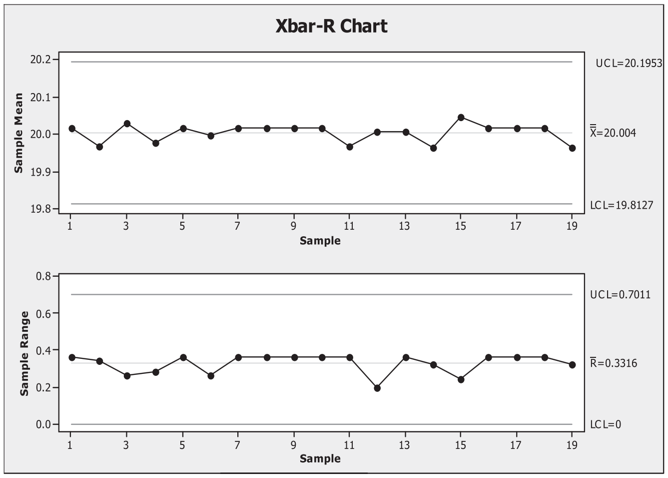

Fig 2: $\overline{X}$ and R Chart

The process capability indices and process data are summarizes in Figure 3. The indices Cp and C_{pk} have same value which is 0.45. Number of non-conforming parts out of the LSL is 89800.98 PPM and the out of USL is also 89800.98 PPM in a short period of time. The number of non-conforming parts out of the LSL is 70515.20 PPM and the out of USL is also 70515.20 PPM in a long period of time.

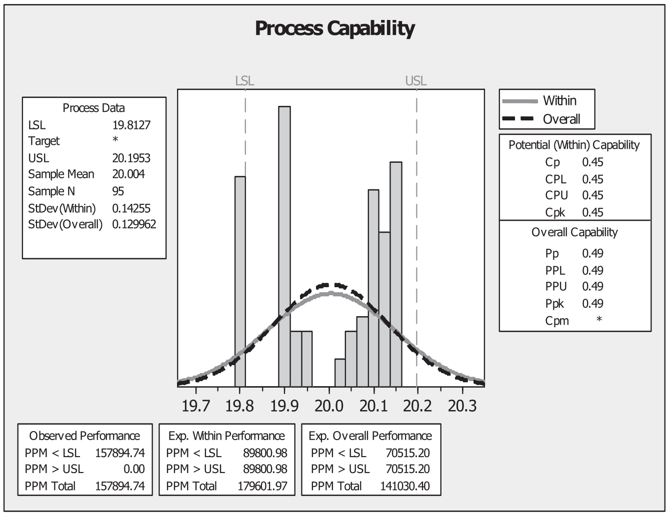

Fig 3: Process capability analysis summary

6. FINDING THE ROOT CAUSES FOR THE VARIATION

To find out the root cause, cause and effect diagram was drawn which is shown in Figure 4.

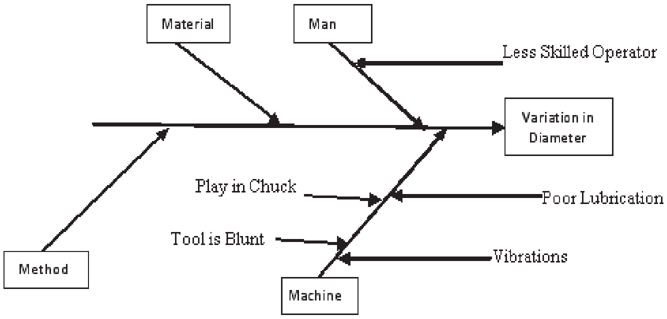

Fig 4: Cause and effect diagram

possible causes of variation in diameter of the work are mostly due to machine causes and man causes. The variations can be minimized by removing these causes.

7. CONCLUSION

As the value of $C_p = C_{pk}$, the process mean is centered on the process width, and the process mean is near to the target value. But as the calculated Cp value is less than 1, the process does not meet the capability requirement. These product items do not conform to the established specifications and are not considered as reliable products. It is also clear from the analysis that the number of non-conforming parts out of the LSL is 70515.20 PPM and the out of USL is also 70515.20 PPM in a long period of time. Cause and effect diagram shows the possible causes of variation in diameter of the work and these are mostly due to machine and operator. The variations can be minimized by removing these causes. In this study the process-capability analysis was carried out in laboratory for the identification of the variability in the process and root causes of variability. This framework can be used in any production company and the losses due to poor-quality production can be reduced in the particular company.

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