Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:08:2021
DOI 10.17605/OSF.IO/EC9V6

PROCESS VARIABILITY REDUCTION THROUGH STATISTICAL PROCESS CONTROL FOR QUALITY IMPROVEMENT ON TURNING PROCESS

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Abstract

Quality has become one of the most important customer decision factors in the selection among the competing product and services. Consequently, understanding and improving quality is a key factor leading to University success, growth and an enhanced competitive position. Hence quality improvement program should be an integral part of the overall University strategy. According to total quality management, focused on process, rather than results as the results are driven by the processes. many techniques are available for quality improvement. Statistical Process Control (SPC) in one such total quality management technique which is widely accepted for analyzing quality problems and improving the performance of the production process. This research illustrates the step by step procedure adopted at a department of Industrial Engineering, Faculty of Engineering, Rajamangala University of Technology Lanna, Chiang Mai, Thailand to improve the quality by reducing process variability using Statistical Process Control by cause and effect diagram, and process capability analysis respectively.

Keywords: process, variable, reduction, statistical process control, turning process

INTRODUCTION

Statistical Process Control (SPC) tools can be used by operators to monitor their part of production or service process for the purpose of making improvements (Roberta Russell & Bernard W. Taylor., 2006). For more information on these charts, the interested reader is referred to AIAG and Montgomery Montgomery, D.C., 1991). Quality may be defined as that characteristic which renders a product or service as having “fitness for purpose or use”. There are different reasons why a product may have unsatisfactory quality. Statistical methods play a central role in Quality improvement efforts and recognized as an efficient and powerful tool in dealing with the process control aspects (Douglas C. Montgomery.,2003). A statistical rationale for adjusting estimates of process capability by including a shift in the average was provided by some researchers (Davis R Bothe., 2002). A method to detect all types of Shifts (large, moderate and small) by taking both large and small samples under suitable framework of sampling was given (Shivaswamy R, Santhakumaran A, C. Subramanian.,2000). Statistics is more applicable to measuring and controlling variation from common cause (random) than from special cause (SPC92b, file format: microsoft word., 2021).

Concept of Variation

Variation is part and work piece surface machined thickness of specimens. 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 turning process results because of two reasons namely, Chance cause and Assignable cause. A process that is operation with only chance causes of variation is said to be in a state of statistical control.

This means, chance causes results in only minor variation in the process. The major objective of 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.

Process Capability

The process capability studies are helpful in analyzing the quality and efficiency of the process. The process capability analysis has been widely adopted as the ultimate measure of performance to evaluate the ability of a process to satisfy the customers in the form of specification (English, J.R and Taylor G.D.,1993). Process capability acts as a TQM tool and is described as a strategic management technique that plays a vital role in the company’s operations management. The process capability study helps in designing the product, deciding the acceptance norms, process and operator’s selections in the operations management (Feigenbaum A.V., (1991). The evaluation of process capability is an important step in process quality improvement (Juran J.M. ,1991). There are several capability indices, including Cp,Cpu, Cpl and Cpk, that have been widely used in manufacturing industry to provide common quantitative measures of process potential and performance. Process capability induces are powerful means of studying the process ability for manufacturing a product that meets specifications (Ramakrishnan B, Sandborn P, Pecht M., 2001), (Montgomery DC., 2005). There is considerable theoretical and experimental research work on improving product quality and process efficiency using a process- capability analysis. (Kane,VE., 1986) 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 PA.,2000) discussed the cumulative distribution function of process-capability indices.

These defects indicated that there might be some assignable causes in the turning process. These causes are responsible for the needy quality of specimen. So, the objective of the study has been set to improve the quality by reducing the variability in the process through usefully quality control techniques by using cause and effect diagram, variable control chart and process capability analysis respectively.

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METHOD EXPERIMENTAL

Tools and Techniques Used in the Study

A detailed analysis was done for each production line. Data was collected at various stages of the turning process, keeping in mind the principles of rational sub grouping and the following tools and techniques were used.

1. Cause and effect diagram
2. Variable control chart ($\overline{X} - R\ chart$)
3. Process capability analysis

The actual root causes of the problem are further evaluated by cause and effect analysis using cause and effect diagrams on turning process can be presented Figure in 1 The real root of the problem among the potential causes.

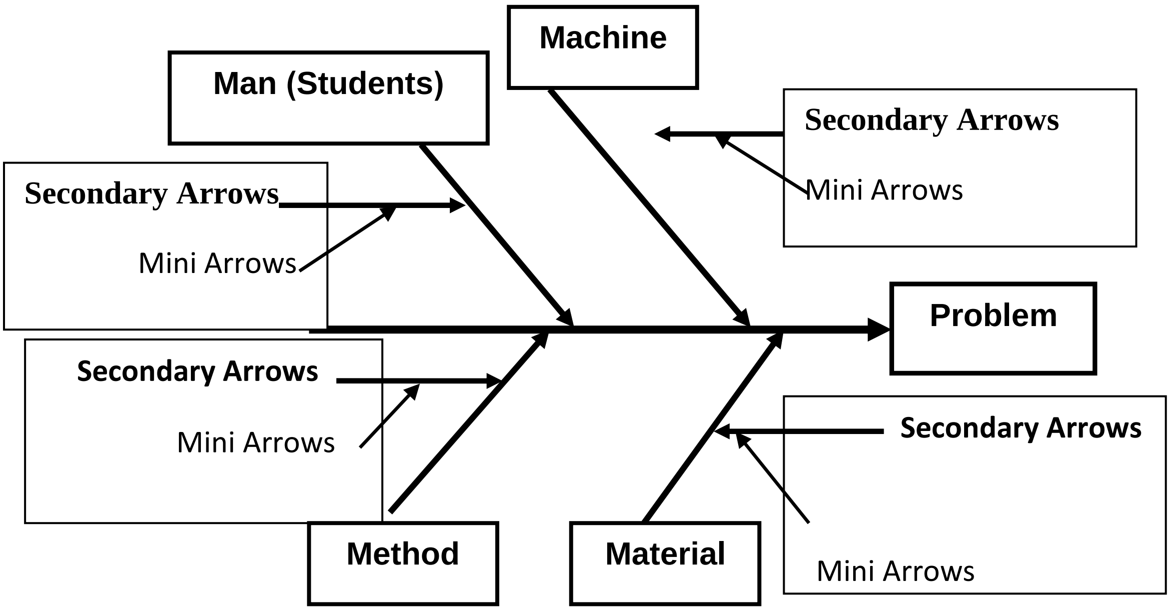

Figure 1 the real root of the problem among the potential causes.

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 (Gopala Raju, V. Durga Prasada Rao, Ranga Raju.,2005). This research has carried out a case study in department of Industrial Technology Education of turning process. Using the cause and effect diagrams, that identified problems and possible recommendations. Brainstorm the major categories of causes of the problem.

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Control Charts

Control charts are also known as Shewhart charts of process- behavior charts. Variable control charts are used study a process when characteristics is a measurement, for example, cycle time, processing time, waiting time, highest, area, temperature, cost or revenue (Rami Hikmat Fouad, Adnan Mukattas., 2010).

Process Capability Analysis

Process capability analysis using control chart the Normal Distribution. One should note that there are an infinite number of distributions which may show the familiar bell-shaped curve, but there are not normally distributed. This is particularly important to remember when performing capability analysis. Therefore, these need to determine whether the underlying distribution can indeed be modeled well by a normal distribution. If the Normal distribution assumption is not appropriate, yet capability indices are recorded, one may seriously misrepresent the true capability of a process. Consider the following simulation. Suppose the USL = thickness 20.05 and LSL = thickness 19.95 millimeters, and our target for this process is midway between analysis of the 100 observations. Firstly, considering the Equation (1), this see that the distribution is stable over the period of study. To illustrate the use of a process capability to estimate process capability, consider as in Figure 2, which presents a process capability of the samples data of 20 sample. The samples data shown Table 1 the 95 % confidence interval on Cp and Cpk.

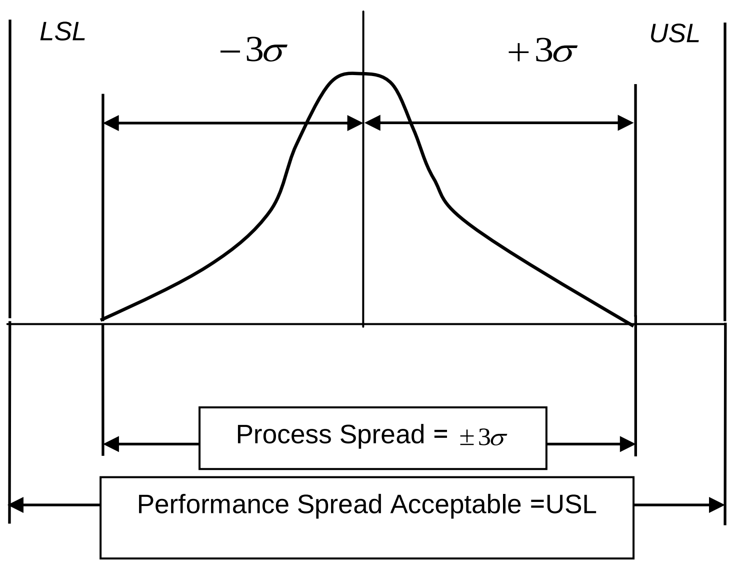

Figure 2 Process capability

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Table 1 Thickness for 201 sample data (millimeters ±0.05).

No.	X1	X2	X3	X4	X5	Sum	$\overline{X}$	R
1	20.01	20.02	20.01	20.00	20.02	100.06	-	-
2	20.02	20.01	20.02	20.00	20.00	100.05	-	-
3	20.00	20.00	20.03	19.99	20.01	100.03	-	-
4	19.99	19.99	20.00	20.01	20.02	100.01	-	-
5	20.00	20.01	20.02	20.01	20.02	100.06	-	-
6	19.99	19.99	20.02	20.01	20.03	100.04	-	-
7	20.00	20.04	20.02	20.03	20.01	100.10	-	-
8	20.01	20.02	20.02	20.03	20.02	100.10	-	-
9	20.00	20.01	20.00	20.01	19.99	100.01	-	-
10	20.00	20.02	20.00	20.00	20.00	100.02	-	-
11	20.00	20.00	20.01	20.01	20.00	100.02	-	-
12	19.99	19.99	20.01	20.00	20.01	100.00	-	-
13	20.00	20.01	20.00	20.00	19.99	100.00	-	-
14	20.00	20.01	20.02	20.02	20.01	100.06	-	-
15	20.02	20.01	20.02	20.01	20.01	100.07	-	-
16	20.01	20.02	20.00	20.02	20.01	100.06	-	-
17	20.01	20.00	20.01	20.02	20.02	100.06	-	-
18	20.02	20.02	20.02	20.01	20.03	100.10	-	-
19	20.01	20.01	20.00	20.01	20.02	100.05	-	-
20	20.00	20.00	20.01	20.02	20.03	100.06	-	-

Experimental Procedures

Process capability index relates the engineering specification (usually determined by the customer) to the observed behavior of the process. The capability of a process is defined as the ratio of the distance from the process center to the nearest specification limit divided by a measure of the process variability. Some basic capability indices that have been widely used in the manufacturing industry include Cp, and Cpk, explicitly defined as follows: (Automotive Industry Action Group AIAG., 1995).

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$$UCL_{\bar{X}} = \bar{\bar{X}} + A_2\bar{R}$$
$$CL_{\bar{X}} = \bar{\bar{X}}$$
$$LCL_{\bar{X}} = \bar{\bar{X}} - A_2\bar{R}$$
$$UCL_R = D_4\bar{R}$$
$$CL_R = \bar{R} \quad (1)$$
$$LCL_R = D_3\bar{R}$$

$$C_p = \frac{USL - LSL}{6\sigma} \quad (2)$$

where

UCL is the upper control limit

LSL is the lower control limit

$\bar{\bar{X}}$ is the average for each subgroup

$\bar{R}$ is the average of the ranges for all subgroups

A2,D3,D4 from table of SPC constants, for N = 5

Cp is the process capability

USL is the upper specification limit

LSL is the lower specification limit

σ is the standard deviation

Let, CPU and CPL are upper and lower process. Often the process data is collected in subgroups. Let Xij, i=1,…, m and j = 1,…, n represent the process data collected from the jth unit in the ith subgroup. Here, m equals the total number of subgroups, and n equals the subgroup sample size. The two most widely used capability indices are defined as:

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

$$C_{pm} = \frac{USL - LSL}{6t} \quad (4)$$

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Where $$t = \sqrt{\sigma^2 + (\overline{\overline{X}} - T)^2}$$

$$\hat{C}_{pk} = \pm z\sqrt{\frac{1}{9n} + \frac{\hat{C}^2{}_{pk}}{2n-2}} \qquad (5)$$

Where Cpm is the indicates how well the system can produce within specifications. Its calculation is similar to Cp

Cpk is the Process Capability Index. Adjustment of Cp for the effect of non-centered distribution

T is the mid-point of the specification interval between USL and LSL

n is the total number of subgroups

Were $\overline{\overline{X}}$, the overall average, is used to estimate the process mean μ , $\hat{\sigma}_s$, and $\hat{\sigma}_{\overline{R}/d_2}$ are different estimates of the process deviation.

The estimate

$$\hat{\sigma}_{within} \text{ is } S_r = \sum_i \frac{\left(\frac{f_i r_i}{d_2(n_i)}\right)}{\sum_i f_i} \qquad (6)$$

The estimate $\hat{\sigma}_{overall}$ is the sample standard deviation

$$S = \sqrt{\frac{\sum_i \sum_j (X_{ij} - \overline{X})^2}{(\sum n_i) - 1}} \qquad (7)$$

$\hat{\sigma}_{\overline{R}/d_2} = \overline{R}/d_2$ is an estimate derived using the subgroup ranges Ri, i=1,…,m

The parameter d2 is an adjustment factor needed to estimate the process standard deviation from the average sample range. Since d2 is also used in the derivation of control limits for. It is tabulated in standard references on statistical process control, such as the QS-9000 (Roberta Russell & Bernard W. Taylor., 2006), (Montgomery, D.C.,1991), (Kane,VE., 1986). Large values of Cpk and Cpm should correspond to a capable process that produces the vast majority of units within the specification limits. However, Equation (4),(5) is used when the mean of process data is departure from the median of specification limits and Equation (6) is actually, an upper limit can also be had by replacing the minus sign with a plus above use z=1.645 to be approximately 95% sure that the real Cpk is above the limit. where USL and LSL are the upper and the lower specification limits, respectively, is the process mean, and σ is the process

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standard deviation(overall process variation). The index Cp measures the magnitude of the process variation relative to the specification tolerance. and, Therefore, it only reflects process potential. The index Cpk takes into account process variation as well as the location of the process mean, which is designed to monitor the performance of near-normal processes with symmetric tolerances. The index Cp is defined as the following, where M or T is the mid-point of the specification interval. The calculation formulae presented in the Table 1 is right when the analyzed parameter is subject to a normal distribution or its distribution is close to the normal one. In such situations there is obligatory the rule of three standard deviations according to which within the range shown in Table 1 (i.e. within the range determined by a natural tolerance, as in Equation (1)) all possible realizations of the process should be contained in Figure 2. In this paper, we consider testing of the most popular capability analysis Cp, Cpm and Cpk using process capability. The index Cpk takes the mean of the process into consideration, but it can fail to distinguish between on-target processes and off-target processes, which is a yield-based index providing lower bounds on the process yield (Montgomery, D.C., 1996).

RESULTS AND DISCUSSION

Cause and Effect Diagram

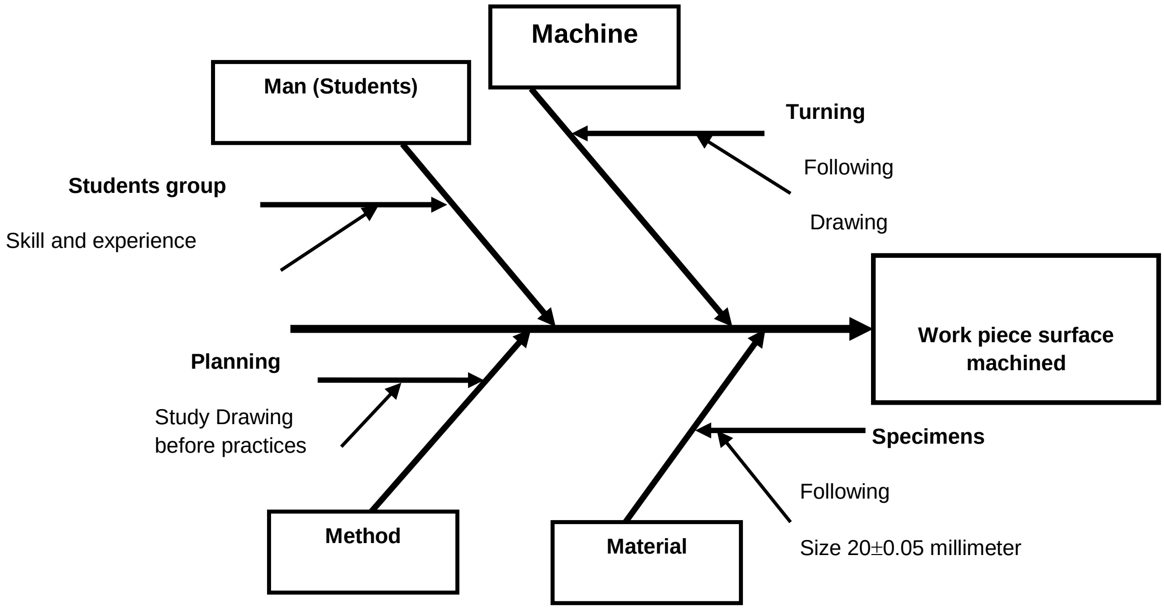

Figure 3 Cause and effect diagrams for work piece surface machined problem

After using cause and effect diagrams is Figure 3 shown for work piece surface machined, this research can the variation in the average of 50 percent reduced.

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Especially, specimen thickness from 0.10 to 0.50 millimeter. And student's skill and experience as well increase.

Sample Size

Because process capability indices are determined from estimates of standard deviation, they are affected by sample size (degrees of freedom). As expected, the stability of estimates of the standard deviation increases with sample size (n) of 5 provide a very stable estimate of process capability. Even when n is 20 and m is 100 there is still substantial uncertainty in the estimator of Cpk. Tables 1 provide estimates of 95% Confidence Bounds for Cpk (lower bound) and Ppk (two-sided interval), assuming normality. The data was classified into 20 subgroups of five observation each by measuring the thickness of in each batch units. Table 2 shown the 100 recorded data observations.

This type of capability study usually measures product functional performance, not the process itself. When the engineer can directly observe the process and can control the data collection methods this study is a "true process capability study" (Montgomery, D.C., 1996). When the historical data is used and direct observation of the process is not possible, Montgomery refers to this as a product characterization study. "In a product characterization study that we can only estimate the distribution of the product quality characteristics; we can say nothing about the statistical stability of the process." Histograms require at 20 observations. If the data sequence is preserved, Mean Square of Successive Differences (MSSD) can be used to estimate the short-term Standard Deviation (STSD). Or, an estimate of process standard deviation can be obtained from

.

THE RESULTS

The results of the preliminary analysis the values of size parameters i.e. thickness shown in Table 2, the empirical distribution is shown in Figure 4 and especially the graphical test of normality is Figure 4 shows indicate that the analyzed parameter is not subject to a normal distribution. In connection with it Cpk capability analysis have been determined. Figure 4 shows the corresponding chart and all points under control limits. Analysis: Here in the above observation record, we have a number of variable measurement outcomes for the number of specimens on a Turning Machine. To analyze the process capability, the statistical quality control chart techniques can be implemented in the following way:

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Table 2 the results $\bar{X}$ - R chart 20 samples thickness.

No.	X_1	X_2	X_3	X_4	X_5	Sum	$\bar{X}$	R
1	20.01	20.02	20.01	20.00	20.02	100.06	20.01	0.02
2	20.02	20.01	20.02	20.00	20.00	100.05	20.02	0.02
3	20.00	20.00	20.03	19.99	20.01	100.03	20.00	0.04
4	19.99	19.99	20.00	20.01	20.02	100.01	19.99	0.03
5	20.00	20.01	20.02	20.01	20.02	100.06	20.00	0.02
6	19.99	19.99	20.02	20.01	20.03	100.04	19.99	0.04
7	20.00	20.04	20.02	20.03	20.01	100.10	20.00	0.04
8	20.01	20.02	20.02	20.03	20.02	100.10	20.01	0.02
9	20.00	20.01	20.00	20.01	19.99	100.01	20.00	0.02
10	20.00	20.02	20.00	20.00	20.00	100.02	20.00	0.02
11	20.00	20.00	20.01	20.01	20.00	100.02	20.00	0.01
12	19.99	19.99	20.01	20.00	20.01	100.00	19.99	0.02
13	20.00	20.01	20.00	20.00	19.99	100.00	20.00	0.02
14	20.00	20.01	20.02	20.02	20.01	100.06	20.00	0.02
15	20.02	20.01	20.02	20.01	20.01	100.07	20.02	0.01
16	20.01	20.02	20.00	20.02	20.01	100.06	20.01	0.02
17	20.01	20.00	20.01	20.02	20.02	100.06	20.01	0.02
18	20.02	20.02	20.02	20.01	20.03	100.10	20.02	0.02
19	20.01	20.01	20.00	20.01	20.02	100.05	20.01	0.02
20	20.00	20.00	20.01	20.02	20.03	100.06	20.00	0.03
						Sum	400.192	0.46
						Mean	20.0096	0.023

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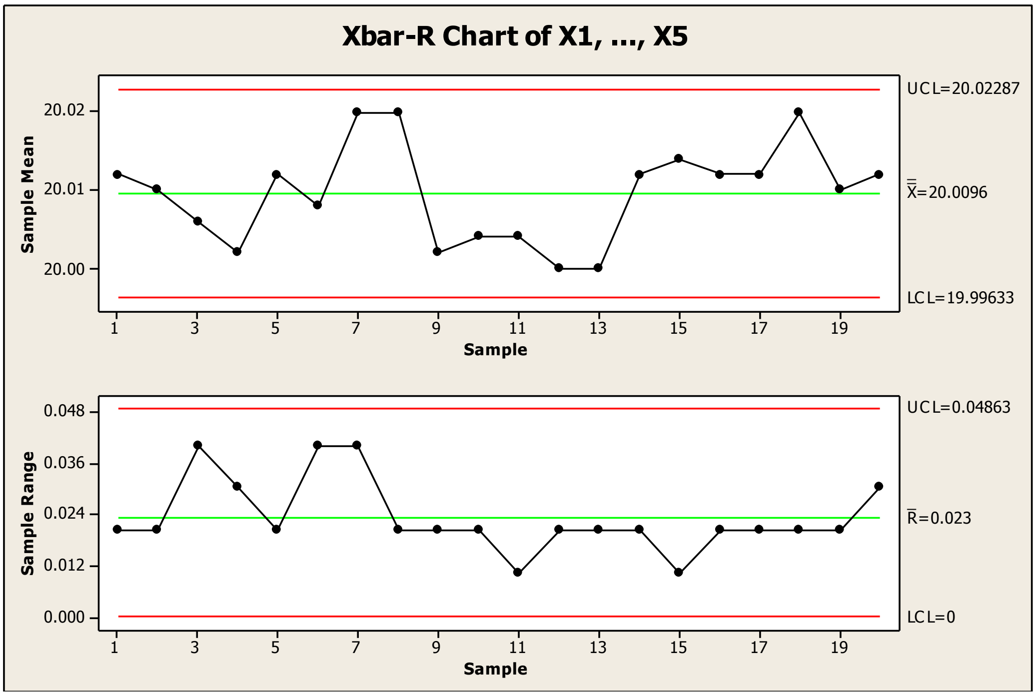

Figure 4 $\overline{X}$ - R chart for specimen thickness

As the $\overline{X}$ - R charts indicate stability, even using all of the Western Electric rules (Western Electric., 1965). We have some justification to use estimates of the overall process mean (σ) and the within subgroup (short-term) standard deviation (σ_{within}) from this course of study. Many practitioners mistrust the estimate of the overall standard deviation (σ_{overall}) as their question whether this window of inspection could truly estimate all of the possible realizations of special causes in the long term (Keith M. Bower, M.S., 2001).

As we can observe from the $\overline{X}$ - R charts, the thickness of all the components are out of the control limits, this means that process is capable of producing the thickness within specification limits. It is concluded that the process is now under control and capable of meeting the specific demand thickness of tolerances ($\pm$0.05 millimeters).

The capability analysis is shown in Figure 4 that with the USL = 20.05 and LSL = 19.95 millimeters, long-term performances are also indicated, namely that approximately 0.00 parts per million (ppm) for within performance would be nonconforming if only common causes of variability were present in the system, and approximately 0.00 ppm in the long-term.

Based on the data shown in Table 2 we calculate the following quantities $\overline{\overline{X}} = 20.0096$. , $\hat{\sigma}_{within} = 0.00620807$ *and* $\hat{\sigma}_{overall} = 0.00618241$ Since, in this example, the subgroup size equals five, d2 = 2.326. Using the definitions (2-8) yields Cp = 2.68, Cpl= 3.20, Cpu=2.17, Cpk=min{3.20,2.17}=2.17,Cpm=1.45,

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Pp=2.70,Ppl=3.20,Ppu=2.18,Ppk=min{3.20,2.18}=2.18. In this case, all the values are quite different, and, in fact, lie on different sides of the key cut off values 1.33 and 1.67 given in QS-9000. Which capability index is better in this example. As Equation (2),(8) the measures Cp, Cpk, Cpm and $\hat{C}_{pk}$ differ only in the estimate of the process standard deviation used in the denominator. As a result, to compare the seven capability measures we need to compare the two standard deviation estimates $\hat{\sigma}_{within}$ *and* $\hat{\sigma}_{overall}$. There is one important differences between $\hat{\sigma}_{within}$ *and* $\hat{\sigma}_{overall}$. Since the range-based estimate $\hat{\sigma}_{\bar{R}/d_2}$ is calculated based on subgroup ranges, it uses only the variability within each subgroup to estimate the process standard deviation. The sample standard deviation- based estimate $\hat{\sigma}_{within}$ *and* $\hat{\sigma}_{overall}$, on the other hand, combines all the data together, and thus used both the within and overall subgroup variability. The total variation in the turning process is the sum of the within and overall subgroup variability. As a result, estimate the total variation present in the process within estimates only the within and overall subgroup variation.

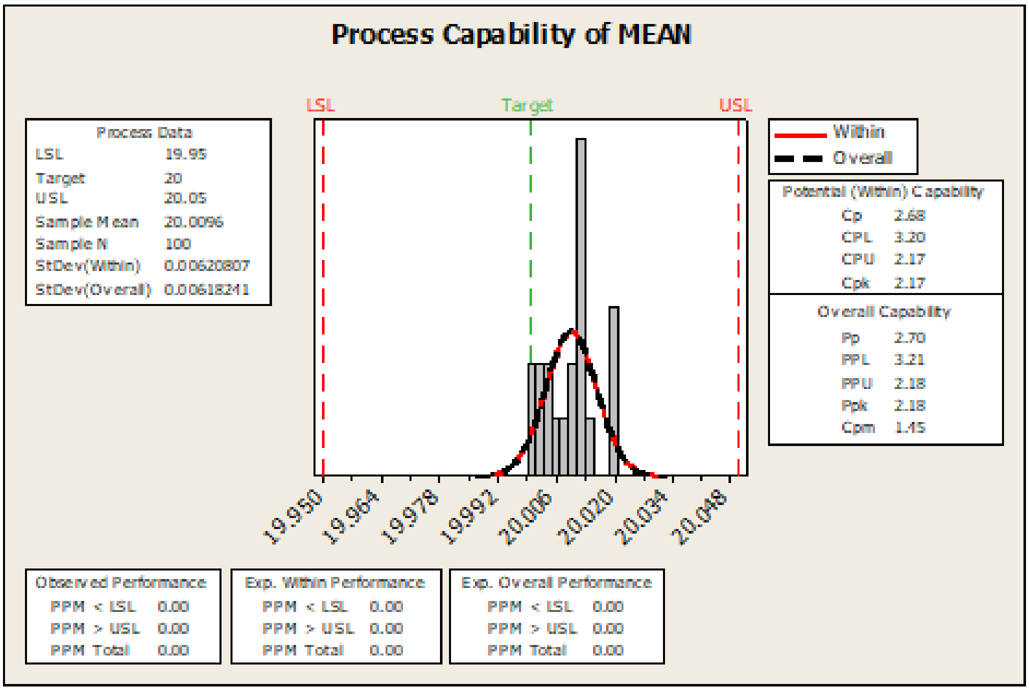

Figure 5 Graphical illustration of the specimen thickness

In connection with it Cp, Cpm, Cpk and $\hat{C}_{pk}$ capability analysis have been determined according to adequate expression presented as in Equation (1), (2) To determine the values $\overline{\overline{X}}, \overline{R}, \sigma_{within}, and\ \sigma_{overall}$ there are used eight the computable method basing on knowledge of density function. The results are shown in Table 3.

Estimation of $\hat{C}_{pk}$:

$$\hat{C}_{pk} = \min\left\{\frac{USL - \overline{\overline{X}}}{3S}, \frac{\overline{\overline{X}} - LSL}{3S}\right\}$$

$$= \min\left\{\frac{20.05 - 20.0096}{3(0.00620807)}, \frac{20.0096 - 19.95}{3(0.00620807)}\right\} = \min\{2.169,\ 3.200\}$$

$$\hat{C}_{pk} = \pm z\sqrt{\frac{1}{9n} + \frac{\hat{C}^2{}_{pk}}{2n-2}}$$

$$= 2.169 \pm 1.645\sqrt{\frac{1}{9(20)} + \frac{(2.169)^2}{2(20)-2}} = 2.169 \pm 0.529$$

Table 3 Summary of $\overline{X}$ process capability indices results.

$\sigma_{overall}$	σ_{within}	C_p	C_R	C_{pk}	C_{pm}	$\hat{C}_{pk}$
0.00618241	0.00620807	2.68	0.373	2.17	1.45	2.169±0.529

The specification limits. CR = 1/Cp x 100 = 37.313 % of the specification band is used by the process. After aggregating all the data obtained, it can be found that the system is operating under 3 sigma level. And also, since Cpk < Cp (2.17< 2.68), the process is off – centered and is towards the lower specification limit. No point is falling outside the upper specification limit. It clearly indicated that the variability in the process is very high.

The stability of the process refers to the ability of the process auditor to predict the process trends based on past experience. A process is said to be stable if all the variables used to measure the process performance have a consistent mean (within a specific range) and a consistent variance (within a specific range) over a sufficiently long period of time (Mohammed Raihan Chowdhury., 2013).

Conclusion

After a thorough analysis of the actual root causes for the defects, Students with more increased skilled and teamwork, discipline in the workplace. Known more empirically. And thus, the one most targeted average is 20.00 millimeter.

The estimation of process capability is one of the basic tasks of the statistical process control (SPC). The values of Cp, CR, Cpk, Ppk, and Cpm indices are very precise information on a process capability index. Correct determination of Cp, Cpk, Ppk, and Cpm indices values by counting requires identification of a distribution shape, at least as general settlement whether it is a normal distribution or not. If it is a normal distribution, for the estimation of Cp, CR, Cpk, Ppk, and Cpm we can use a simple counting classic approach that is based on the rule of 3 sigma. Statistical process control (SPC) and especially estimation of a process capability shows opportunities of practical application of statistics in aspect of the analysis of technological processes.

The control limits obtained after the remedial actions taken for the lathe are within specification limits and the thickness produced under the control limits. The thicknesses of all the specimens are located very close to the process mean. All these results are positive by which we conclude that the process is under control. The process capability (Cp) is 2.68 which show that implementation of SPC technique is proved and reduced variances to be successful in improving the performance of turning process thereby making it more capable of producing the products with right dimensions. Capability Ratio (CR) is 0.373 which means that the process spread now occupies 37 % of the tolerance (□0.05 millimeters). The lower is the CR the more is capable the process. Here, we got Cpk as 2.17 which is greater than 2 was required by the department of Industrial Technology Education, faculty of engineering, Rajamangala University of Technology Lanna, Chiang Mai, Campus, Chiang Mai, Thailand.

Using statistical quality control techniques to help reduce process variability, especially in turning processes. It can be of great help to the control to have confidence in the production system. In this research, fishbone charts were used to help analyze the cause of the process. Subsequently, process performance analysis techniques were used to determine the optimal CP value, and the resulting CP value was 2.68, a very high value was demonstrated. By analyzing the performance of the process with confidence. It can also be extended in related work in the future.

Acknowledgment

Financial support integrated Economic and Social Enhancement Project for Sub-District (1 Tambon 1 University) Rajamangala University of Technology Lanna area of responsibility Nong Phueng Sub-District, Saraphi District, Chiang Mai province name of project/activity in operation revitalizes the community economy in a new way with science. Technology and innovation in the case of Nong Phueng Sub-district, Saraphi District, Chiang Mai Province and support integrated Economic and Social Enhancement Project for Sub-District (1 Tambon 1 University) Chiang Mai Rajabhat University area of responsibility Muang Ngai Sub-District, Chiang Dao District, Chiang Mai province name of project/activity in operation Revitalizes the community economy in a new way with science. Technology and innovation in the case of Muang Ngai Sub-District, Chiang Dao District, Chiang Mai Province are gratefully acknowledged.

Tianjin Daxue Xuebao (Ziran Kexue yu Gongcheng Jishu Ban)/
Journal of Tianjin University Science and Technology
ISSN (Online): 0493-2137
E-Publication: Online Open Access
Vol:54 Issue:08:2021
DOI 10.17605/OSF.IO/EC9V6

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