E-ISSN: 2707-8051
P-ISSN: 2707-8043
IJMTE 2020; 1(2): 01-05
Received: 01-05-2020
Accepted: 05-06-2020

Glenn Samuel D
Student of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India

Dr. Philip Selvaraj D
Associate Professor, Department of Mechanical Engineering, Karunya University, Coimbatore, Tamil Nadu, India

Dr. Devaarul S
Assistant Professor of Statistics, Government Arts College, Coimbatore, Tamil Nadu, India

Corresponding Author:
Glenn Samuel D
Student of Mechanical Engineering, Sri Krishna College of Engineering and Technology, Coimbatore, Tamil Nadu, India

A novel algorithm to monitor process mean and process capability index for a dynamic target

Glenn Samuel D, Dr. Philip Selvaraj D and Dr. Devaarul S

Abstract

In this article, a novel algorithm is introduced to monitor the process mean and a novel process capability index is developed for a normal production process. The new process capability index is able to deduct the capability of the process more accurately. An illustration is given for turning operations carried out in CNC machining centre. The work piece material used in the turning process is AISI 304 stainless steel. The process parameters used in the turning operations are 200 m/min cutting speed, 0.05 mm feed rate and 0.5 mm depth of cut. It is found that the new index is robust and can give warning if the spread is more in the process. It is found that when the mean is in the dynamic target, the process spread shows few warnings through the control charts. From the process capability analysis, it is found that the C_{pk} is less than one for the observed data. This shows that the process is not adequate of meeting the required dynamic target. Where as the newly developed algorithm is capable of meeting the required capability. Hence it is advisable to utilize C^T_{pk} to prevent future non-conformities.

Keywords: stainless steel, turning, process mean, monitor, capability index, dynamic target

Introduction

The process capability index gives the relationship of process specification and actual performance of the process. There are several process capability indices such as C_{pk}, C_r, C_p, C_{pm} etc. The process capability index is applicable to variable quality characteristics. It is a quantitative measure that reflects how well the process can produce components for the given standard or specification.

The process capability index is developed by Juran (1974) [6] and is defined as Cp = (U-L) /6σ, that does not depend on process mean. A new process capability index focused on the target value known to be C_{pm} is developed by Chan *et al.* (1988) [1]. Grant, E.L., and R.S. Leavenworth (1996) [3], have given the metrics for process capability indices. One can find a detailed study of process capability analysis in Montgomery, D.C (1996) [10]. Comparisons among various indices and its confidence intervals can be found in Mark L. Crossley (2010) [8]. Many authors have contributed to the development of process capability indices. The Cpk is introduced by Kane (1986) [7] to study the impact of process mean μ on the process capability indices. Hsiang and Taguchi (1985), considered the influence of the departure of the process mean (μ) from the target T. Yerriswamy Wooluru *et al.* (2014), have studied the process capability tools and techniques. Mohamed Boujelbene (2018) [9], has studied average roughness through process capability tools. Parvesh Kumar Rajvanshi and R.M. Belokar (2012) [11], have improved the boring operation through process capability tools. Gabriele Arcidiacono and Stefano Nuzzi (2017) [2] have reviewed the fundamentals of process capability ratio. Joseph KA (2017) [5], has studied process stability of the moulding machine.

The c_{pk} process capability index is the minimum of C_{pu}, C_{pl}. The International Standard of C_{pk} is 1.33. If the production process turns out more than 1.33 as C_{pk} value, then the process potential is upto International standard. In industries Shewhart Variable Control Chart is widely used to monitor the process mean. But due to several factors the target may be changed. Hence to incorporate the dynamic target appropriate algorithm is needed. However, there is a research gap in developing control charts and process capability indices for dynamic target. Hence a novel algorithm is developed in this article and accordingly the process capability index C_{pk} is modified.

Turning process details

The work piece material used in the turning process is AISI 304 stainless steel. The turning process is carried out in Batliboi make CNC machining centre. The diameter and length of the workpiece used in the turning operations are 40 mm and 100 mm, respectively. The process parameters used in the turning operations are 200 m/min cutting speed (v), 0.05 mm feed rate (f) and 0.5 mm depth of cut (d). The chemical composition of the AISI 304 stainless steel is shown in Table 1.

Table 1: Chemical composition of the AISI 304 stainless steel (weight %)

Element	C	Mn	Si	P	S	Cr	Mo	Ni	Fe
%	0.069	1.63	0.4090	0.0420	0.0110	18.5	0.29	8.02	70.1

Measures of Process Capability for a target mean

1. $C_{pu} = \frac{(USL-\bar{X})}{3\sigma}$
2. $C_{pl} = \frac{(\bar{X}-LSL)}{3\sigma}$
3. $C_{pk} = \min(C_{pu}, C_{pl})$.

Where, USL= Upper Specification Limit.
LSL=Lower Specification Limit.
σ= Process standard deviation.

A novel algorithm for $\bar{X}$ and R chart

Step 1: Draw a sample from the production process and arrange it in subgroups.
Step 2: Determine the median for each subgroups. This is the new dynamic target.
Step 3: Truncate left and right observations from the target median or smooth the data by replacing all the values that exceeds the new target by median value.
Step 4: Now find the sample mean $\bar{\bar{X}}$ and $\bar{R}$.
Step 5: Obtain Upper Control Limit and Lower Control Limit.
Step 6: Plot $\bar{X}$ and R chart and if any point falls beyond UCL or LCL, the process is said to be out of control. Otherwise the process is said to be in Statistical Quality Control.
Step 7: Determine Process Capability Index Cpk, if Cpk. 1.33, the process is capable of producing items according to international standard otherwise it shows incapable of the process. Hence remedial action is asked.

Measures of process capability indices for a dynamic target

The New Process Capability Indices based on dynamic target are given below:

1. $C^{T}_{pu} = \frac{(USL-\bar{X}_T)}{3\sigma}$
2. $C^{T}_{pl} = \frac{(\bar{X}_T-LSL)}{3\sigma}$
3. $C^{T}_{pk} = \min(C^{T}_{pu}, C^{T}_{pl})$.

Where, USL= Upper Specification Limit.
LSL=Lower Specification Limit.
σ= Standard deviation based on the target.
$\bar{X}_T$ = Dynamic target mean based on the target.
C^{T}_{pu}= Process capability index for the upper specification limit based on the target.
C^{T}_{pl}= Process capability index for the lower specification limit based on the target.

$C^{T}_{pk} = \min(C^{T}_{pu}, C^{T}_{pl})$.

Table 2: Observed data for turning operation of cylindrical components in a CNC Turning center (Diameters in Millimeters) Drawing Size = Diameter ⌀38 ± 0.02 mm

Exp. No.	X_1	X_2	X_3	X_4
1	38.00	38.01	38.01	38.00
2	38.00	38.00	37.99	37.99
3	38.00	37.99	38.00	37.99
4	38.01	38.00	38.00	38.01
5	38.01	38.01	38.00	38.00
6	38.01	38.00	38.00	38.01
7	38.00	37.99	37.99	38.00
8	38.01	38.01	38.00	38.00
9	37.99	37.99	38.00	38.01
10	38.01	38.01	38.00	37.99
11	38.01	38.00	38.01	38.00
12	37.99	38.00	38.00	37.99
13	37.99	37.99	37.99	38.00
14	38.00	38.00	38.00	37.99
15	38.01	38.00	38.00	37.99
16	37.99	38.00	38.01	37.99
17	38.00	37.99	38.00	38.00
18	38.00	38.01	38.00	37.99
19	38.01	38.00	38.00	38.01
20	38.00	37.99	37.99	38.00

Fig 1(A): Machined work piece **(B)** Diameter measurement using micrometer

Table 3: Descriptive Statistics for the known variables before smoothing

Sample	N	Mean	SE Mean	TrMean	StDev	Minimum	Q1	Median
X1	20	38.002	0.00172	38.002	0.00768	37.990	38.000	38.000
X2	20	37.999	0.00170	37.999	0.00759	37.990	37.990	38.000
X3	20	37.999	0.00135	37.999	0.00605	37.990	38.000	38.000
X4	20	37.998	0.00172	37.998	0.00768	37.990	37.990	38.000

Table 3 shows the descriptive statistics for the experimental data before smoothing. Table 4 shows the descriptive statistics for the smoothed data by using new algorithm.

Table 4: Descriptive Statistics for the known variable X by using new algorithm

Sample	N	Mean	SE Mean	TrMean	StDev	Minimum	Q1	Median
X1	20	37.998	0.000918	37.998	0.00410	37.990	38.000	38.000
X2	20	37.997	0.00105	37.997	0.00470	37.990	37.990	38.000
X3	20	37.998	0.000918	37.998	0.00410	37.990	38.000	38.000
X4	20	37.996	0.00112	37.996	0.00503	37.990	37.990	38.000

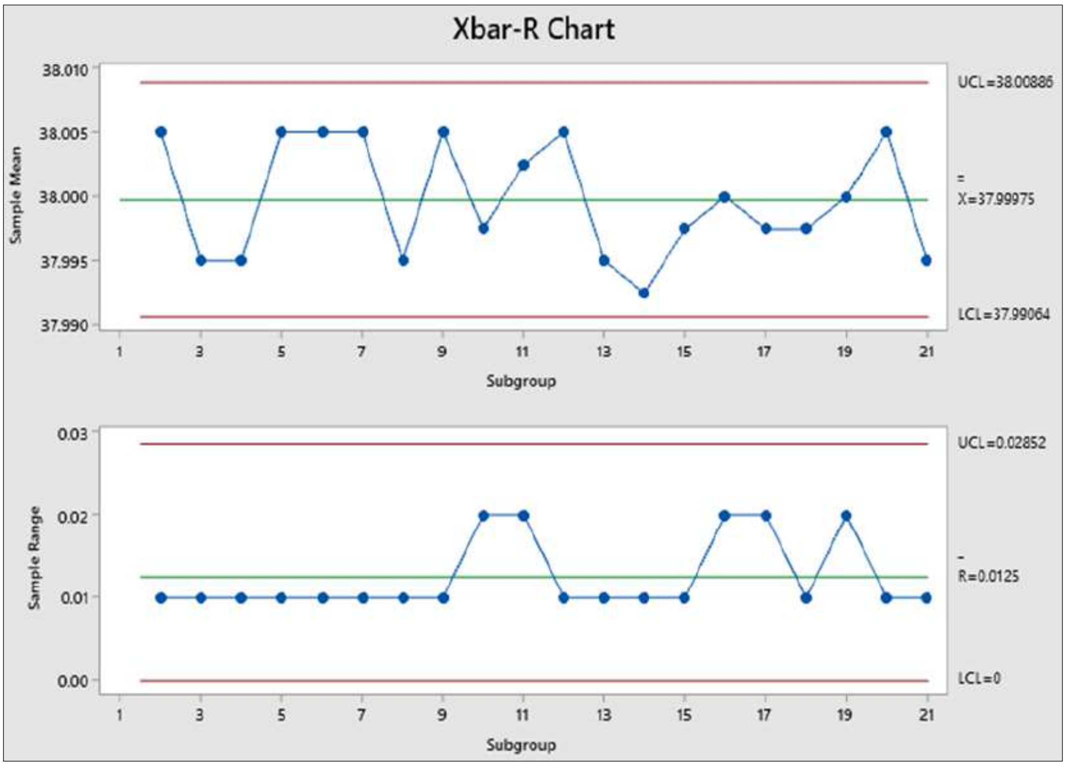


Fig 2: $\bar{X}$ and R chart for the observed sample data using Shewhart algorithm

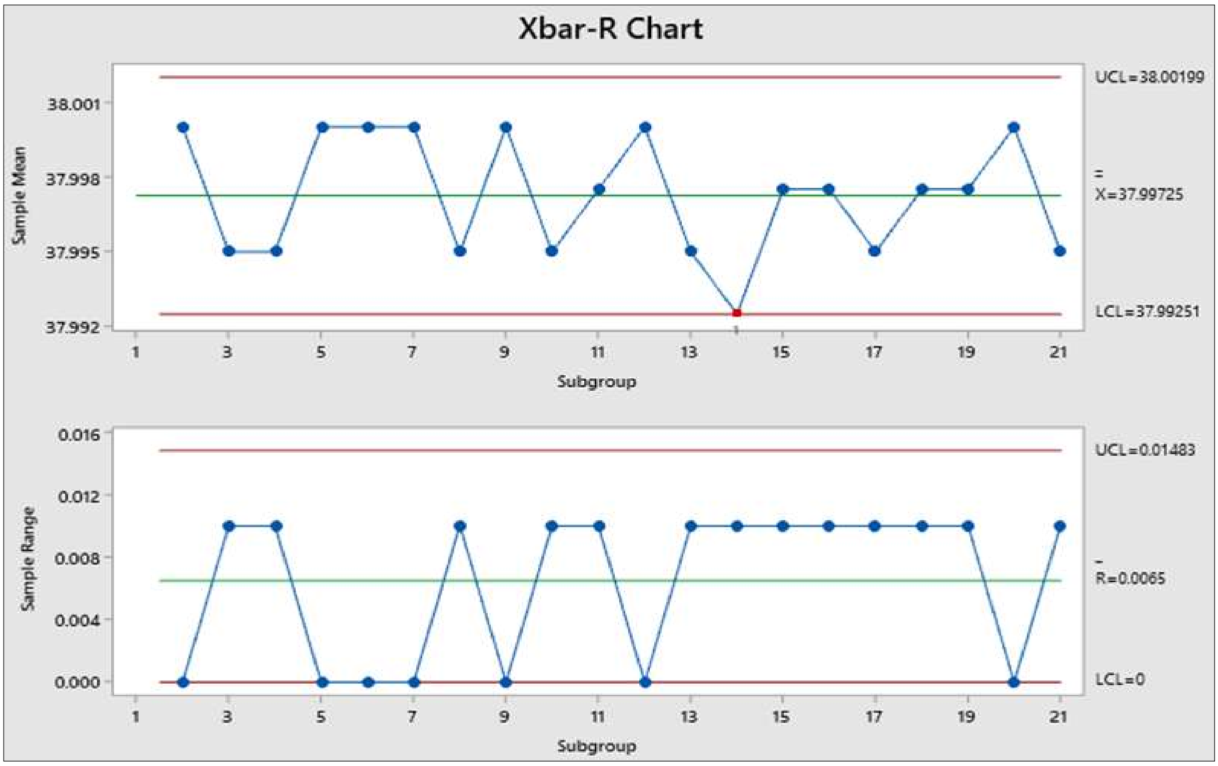
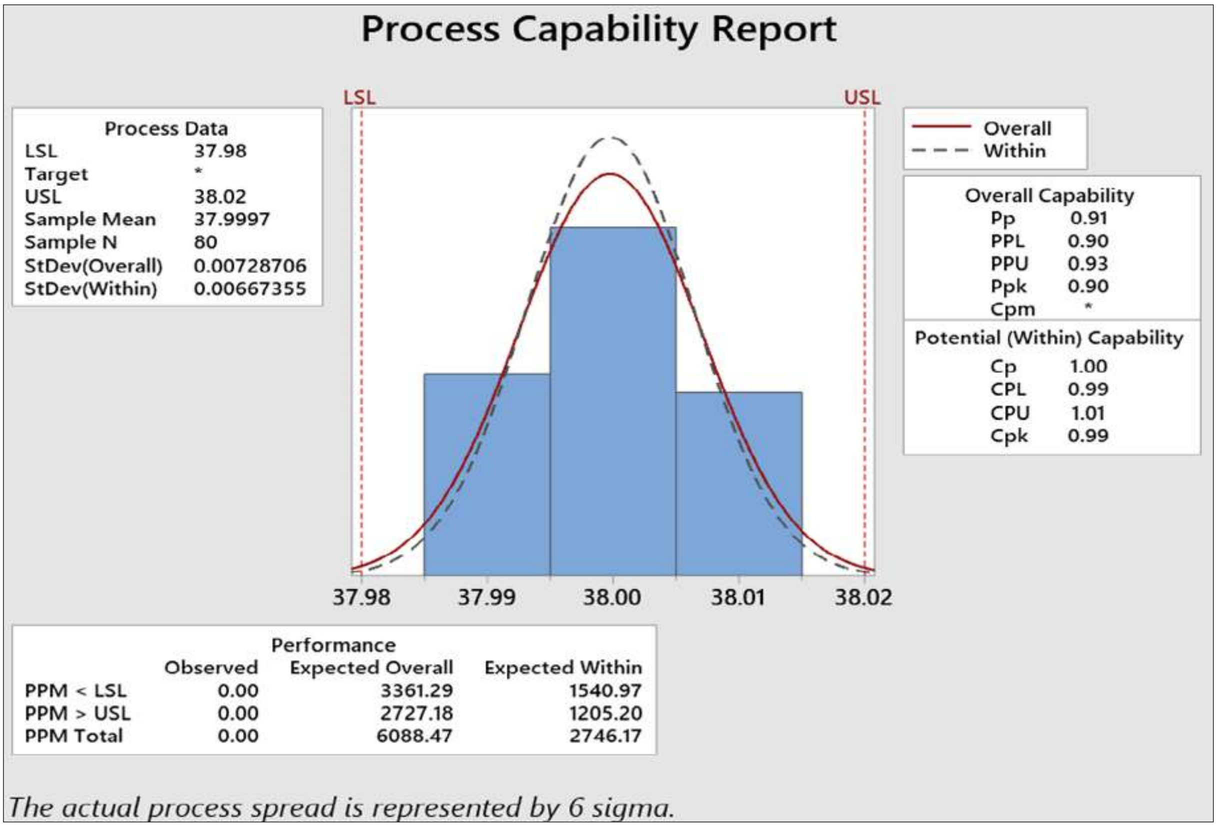


Fig 3: $\bar{X}$ and R chart for the Modified algorithm

Interpretation: Figure 2 shows the $\bar{X}$ and R chart for the observed sample data using Shewhart algorithm. From the figure 2, it is found that the production process is in Statistical Quality Control. It reveals that the process is governed only by the natural variances. Figure 2 shows the $\bar{X}$ and R chart for the Modified algorithm. However if the dynamic target changes then the control charts are changed as in figure 3, that reveals a warning. Hence appropriate action is sought. This may help the quality control practitioners to avoid future non-conformities.



Process Data	
LSL	37.98
Target	*
USL	38.02
Sample Mean	37.9997
Sample N	80
StDev(Overall)	0.00728706
StDev(Within)	0.00667355

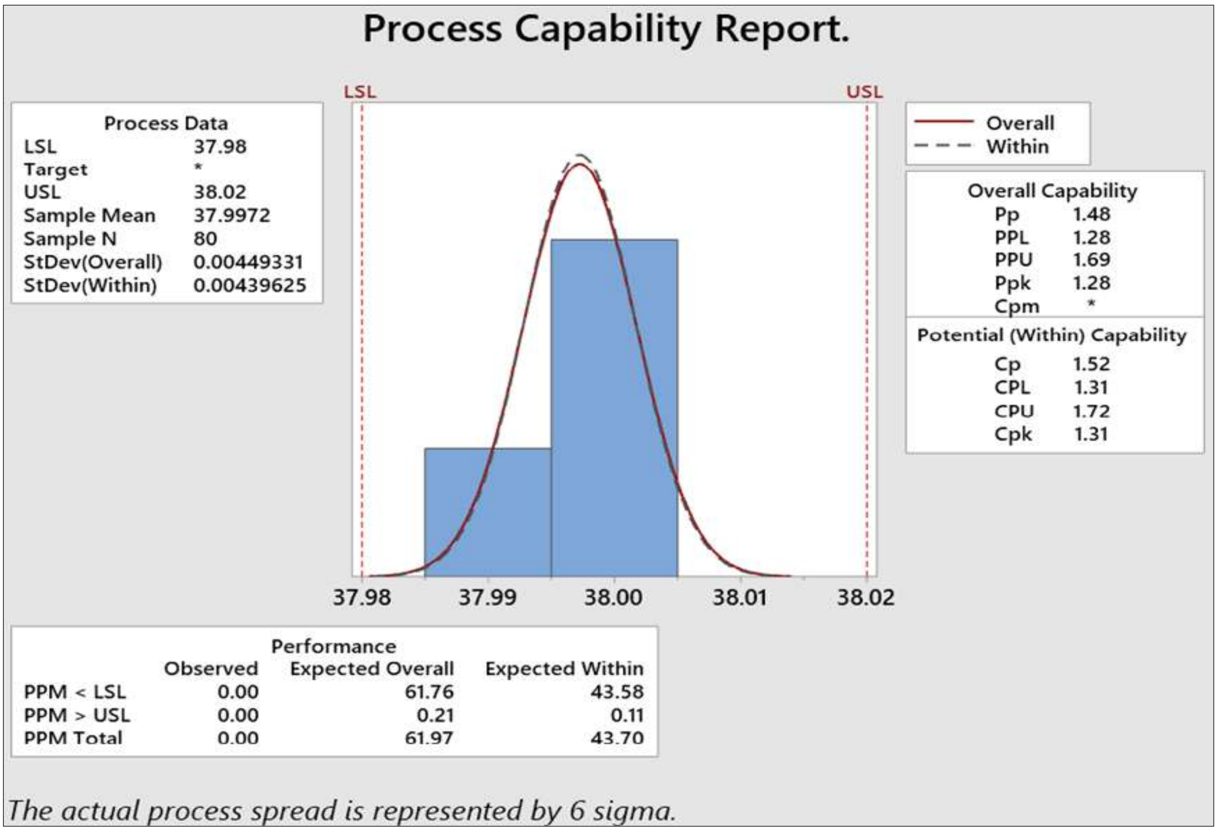
Overall Capability	
Pp	0.91
PPL	0.90
PPU	0.93
Ppk	0.90
Cpm	*

Potential (Within) Capability	
Cp	1.00
CPL	0.99
CPU	1.01
Cpk	0.99

Performance	Observed	Expected Overall	Expected Within
PPM < LSL	0.00	3361.29	1540.97
PPM > USL	0.00	2727.18	1205.20
PPM Total	0.00	6088.47	2746.17

The actual process spread is represented by 6 sigma.

Fig 4: Process capability values for the observed data



Process Data	
LSL	37.98
Target	*
USL	38.02
Sample Mean	37.9972
Sample N	80
StDev(Overall)	0.00449331
StDev(Within)	0.00439625

Overall Capability	
Pp	1.48
PPL	1.28
PPU	1.69
Ppk	1.28
Cpm	*

Potential (Within) Capability	
Cp	1.52
CPL	1.31
CPU	1.72
Cpk	1.31

Performance	Observed	Expected Overall	Expected Within
PPM < LSL	0.00	61.76	43.58
PPM > USL	0.00	0.21	0.11
PPM Total	0.00	61.97	43.70

The actual process spread is represented by 6 sigma.

Fig 5: Process capability indices values based on the novel algorithm

Interpretations

Fig 4, shows the process capability values for the observed data based on Shewhart algorithm. It is found that the process capability values are lower than one. Hence we conclude that the production process is not capable of producing items. Therefore, in order to achieve the capability of the process the dynamic target algorithm is recommended. Figure 5, shows the process capability indices values based on the novel algorithm Hence from figure 5, it is also found that the novel algorithm for $\bar{X}$ and R chart reveals the process is capable of producing according to International standard.

Confidence interval for the process capability index C_{pk}

Let

n = Sample size

C_{pk} = Process capability index

$Z_{\alpha/2}$ = Two- sided normal standardize value.

The upper tail confidence interval for C_{pk} is

$$C_{pk} + Z_{\alpha/2}\sqrt{\frac{1}{9n}+\frac{(Cpk)^2}{2n-2}}$$

The upper tail confidence interval for the dynamic target process capability index C^T_{pk} is

$$C^T_{pk} + Z_{\alpha/2}\sqrt{\frac{1}{9n}+\frac{(CTpk)^2}{2n-2}}$$

Table 5: Comparison of Confidence Intervals for C_{pk} and C^T_{pk}

	Value	Upper Limit
C_{pk}=	0.99	2.236788714
C^T_{pk}=	1.3	3.947411146

From table 5, it is found that the upper limit reaches nearly four in case of newly developed process capability index C^T_{pk}

Conclusion

The process capability studies in turning process of AISI 304 stainless steel is carried out sues fully. Due to several factors in the quality control environment, the target may be changed. Hence to incorporate the dynamic target appropriate algorithm is developed. The novel algorithm is capable of revealing the warnings in the control charts. The new algorithm is used to modify the process capability index C_{pk}. The newly introduced process capability index may be used in the industries for future purpose in order to achieve the international standard of the capability of the process.

References

1. Chan LK, Cheng SW, Spiring FA. A New Measure of Process Capability, Journal of Quality Technology 1988;20(3):162-175.
2. Gabriele Arcidiacono, Stefano Nuzzi. A Review of the Fundamentals on Process Capability, Process Performance, and Process Sigma, and an Introduction to Process Sigma Split, International Journal of Applied Engineering Research ISSN 0973-4562 2017;12(14):4556-4570.
3. Grant EL, Leavenworth RS. Statistical Quality Control, McGraw-Hill, New York 1996.
4. Gupta RC. Statistical Quality Control, Khanna publisher, Delhi 1993.
5. Joseph KA. Statistical Process Capability Design to Improve Process Stability of a Molding Machine, Journal of Applied & Computational Mathematics 2017;6(1):1-5. ISSN: 2168-9679.
6. Juran JM. Juran’s Quality Control Handbook, 3rd ed. McGraw-Hill, New York, USA 1974.
7. Kane VE. Process Capability Indices, Journal of Quality Technology 1986;18:41-52.
8. Mark Crossley L. Statistical Quality Methods, New Age International Publisher, India 2010.
9. Mohamed Boujelbene. Process Capability and Average Roughness in Abrasive Water Jet Cutting Process of Stainless Steel, Engineering, Technology & Applied Science Research 2018;8(3):2931-2936.
10. Montgomery DC. Introduction to Statistical Quality Control, John Wiley & Sons, New York 1996.
11. Parvesh Kumar Rajvanshi, Belokar RM. Improving the Process Capability of A Boring Operation by the Application of Statistical Techniques, International Journal of Scientific & Engineering Research Volume 2012, 3(5). ISSN 2229-5518.
12. Yerriswamy Wooluru, Swamy DR, Nagesh P. The Process Capability Analysis: A Tool for Process Performance Measures and Metrics: A Case Study, International Journal for Quality Research 8(3), 399-416. ISSN. 1800-6450.