International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

Optimization of Machining Parameters for Turning of ASTM A387 Alloy Steel on CNC Lathe Machine

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***Abstract*----Quality is inversely proportion to variability. In the other words as variability reduces, Quality improves. This approach has been used in this work. In the present work variability in the dimension of the manufactured part has been reduced. Reduction in the surface roughness as well as tolerance is the basic aim of this work. The optimization of input parameter has been done for improvement of quality of the product in turning operation on CNC machine. Feed Rate, Spindle speed & Depth of cut are taken as the input variables and the dimensional tolerances and the surface roughness are taken as quality output. In the present work Taguchi L9 Array has been used for design of experiment for optimization of input parameters in turning of ASTM A387 Alloy Steel. It was found that the spindle speed is key factor for minimizing the dimensional variation and feed rate is most effective input parameter for minimizing the surface roughness.**

***Keywords*- Taguchi, Feed Rate, Spindle speed, Depth of cut, surface roughness**

I. INTRODUCTION

CNC turning is one of the most popular and efficient machining operations, with which, the high surfaces finish & dimensional accuracy of work piece can be easily obtained. Surface roughness is an essential requirement in determining the surface quality of a product. Surface roughness is a measure of the irregularities on the surface of a component resulting from machining operations. The dimensional accuracy is also an essential requirement because it decides the quality of fitment of two matching parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as cutting speed, feed rate, depth of cut and cutting tool wears. Optimization refers to the art and science of allocating scarce resources to the best possible effect. Optimization techniques are called into play every day in question of industrial planning, allocation, scheduling, decision-making, etc.

Recent studies that explore the effect of setup and input parameters on surface finish all find that there is a direct effect in feed rate, that spindle speed's effect is generally nonlinear and often interactive with other parameters, and that depth of cut can have some effect due to heat generation or chatter [1, 2, 3,4].Several studies exist which explore the effect of feed rate, spindle speed, and depth of cut on surface finish [5, 2, 3, 6]. These studies all supported the idea that feed rate has a strong influence on surface finish. Spindle speed and depth of cut were found to have differing levels of effect in each study, often playing a stronger role as part of an interaction.

Tzeng Yih-Fang [7] has taken a set of optimal turning parameters for producing high dimensional precision and accuracy in the computerized numerical control turning process was developed. Taguchi dynamic approach coupled with a proposed ideal function model was applied to optimize eight control factors for common tool steels SKD-11 and SKD-61. Shoukry [8] has also performed an experiment to evaluate the effects of speed, feed and depth of cut on the dimensional accuracy of aluminum bars turned on a lathe. The optimum values of the dimensional accuracy with respect to speed, feed and depth of cut were determined.

II. EXPERIMENTATION

The experiment was conducted to manufacture a 9.665 mm cylindrical pin of ASTM A387 Alloy Steel with the tolerances limit 20 micron. While the surface finish was so required that the surface roughness should remain less than 2 micron.
The three parameters were taken under study namely feed rate, spindle speed and depth of cut which were taken on the bases of past study found. The levels of all three input parameters decided by doing pilot experiments are given in table 1

Table 1: levels of input parameters

Parameters	Designation of parameter	Level 1	Level2	Level3
Spindle Speed (RPM)	A	1600	1300	1000
Feed Rate(mm/rev)	B	0.4	0.3	0.2
Depth of Cut (mm)	C	0.35	0.30	0.25

The turning of the steel pin was carried out on the Strom A 50 CNC lathe by carbide tool shown in figure1.

Figure 1: Strom A50 CNC lathe machine with automatic tool changer

The Taguchi L9 orthogonal array was used design of experiments the experiments the schematic scheme of experiments is given in table 2. The experiment was conducted and the deviation of pin diameter from its nominal value was recorded for each sample. The surface roughness in terms of Ra value was also recorded by surface roughness tester. The mean value of dimensional deviation and roughness (Ra) value are given in table 2. The deviation of pin diameter from its nominal size was obtained by Air Gauge and The Surface roughness values were obtained using the RA values obtained from in talysurf surface roughness tester according to standrad: IS-3073-1967. The sample size for measuring both the output response was 100 pieces.

Table2: Experimental scheme as per Taguchi L9 array

Exp. Run	A	B	C	Mean deviation of dimension (μm)	Mean Surface roughness Ra (μm)
	Speed (r.p.m.)	Feed rate(mm/rev)	Depth of cut (mm)		
1	1600	0.04	0.35	1.1922	1.6
2	1600	0.03	0.3	1.311	1.74
3	1600	0.02	0.25	1.157	1.66
4	1300	0.04	0.25	1.564	1.38
5	1300	0.03	0.35	1.72	1.7
6	1300	0.02	0.3	2.1086	1.33
7	1000	0.04	0.3	1.2856	1.43
8	1000	0.03	0.25	1.3048	1.75
9	1000	0.02	0.35	1.85	1.35

III. RESULTS AND DISCUSSION

As both the output responses are smaller the better type so the signal to noise ratio S/N was calculated as per equation1.

$$S/N = -10 \left(\log \sum_{i=1}^{n} \frac{y_i^2}{n} \right) \text{ (dB)} \quad (1)$$

The value of S/N ratio for dimensional deviation and surface roughness are given in table 3

Table3: S/N ratio of dimensional deviation and surface roughness

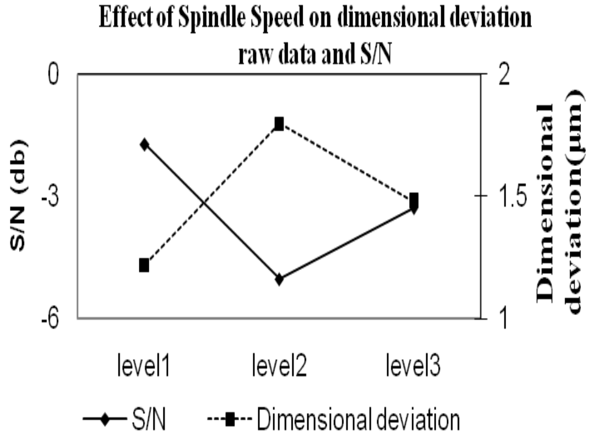
Exp. Run	A	B	C	S/N deviation of dimension (db)	S/N Surface roughness Ra (db)
	Speed (r.p.m.)	Feed rate(mm/rev)	Depth of cut (mm)		
1	1600	0.04	0.35	-1.53	-4.08
2	1600	0.03	0.3	-2.35	-4.81
3	1600	0.02	0.25	-1.27	-4.40
4	1300	0.04	0.25	-3.88	-2.80
5	1300	0.03	0.35	-4.71	-4.61
6	1300	0.02	0.3	-6.48	-2.48
7	1000	0.04	0.3	-2.18	-3.11
8	1000	0.03	0.25	-2.31	-4.86
9	1000	0.02	0.35	-5.34	-2.61

The average values of dimensional deviation and surface roughness of turnned ASTM A387 Alloy Steel pin for each parameter at levels 1, 2 and 3 for S/N ratio and raw data are given in the tables 4 and tables 5 respectively.

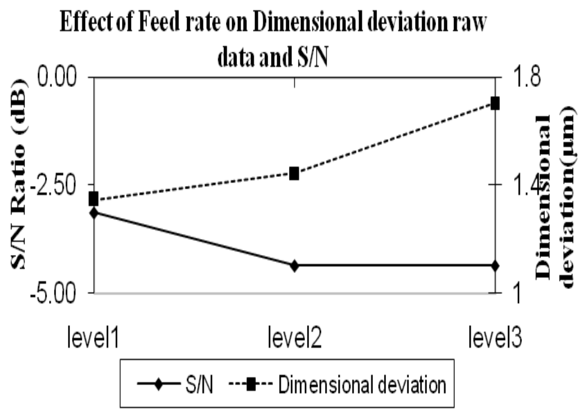
Table 4: Response Table for dimensional deviation raw data and S/N

	Spindle Speed		Feed rate		Depth of cut	
	Raw Data	S/N ratio	Raw Data	S/N ratio	Raw Data	S/N ratio
Level 1	1.22	-1.72	1.35	-3.12	1.54	-3.44
Level 2	1.80	-5.03	1.45	-4.36	1.58	-3.86
Level 3	1.48	-3.28	1.71	-4.36	1.39	-2.72
Delta	0.58	3.31	0.36	1.24	0.19	1.14
Rank	1	1	2	2	3	3

The main effect plot for S/N ratio and raw a data of dimensional deviation for each parameter are shown in Figures 2



(a)



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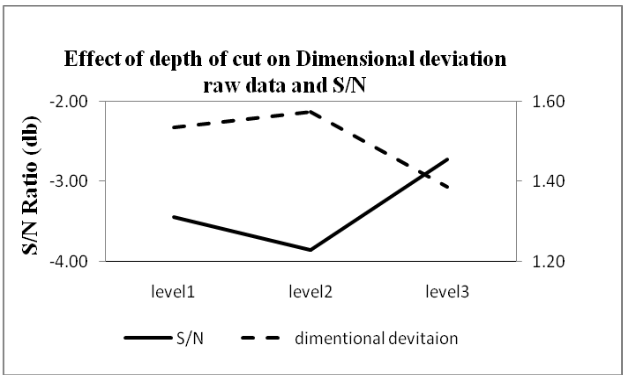

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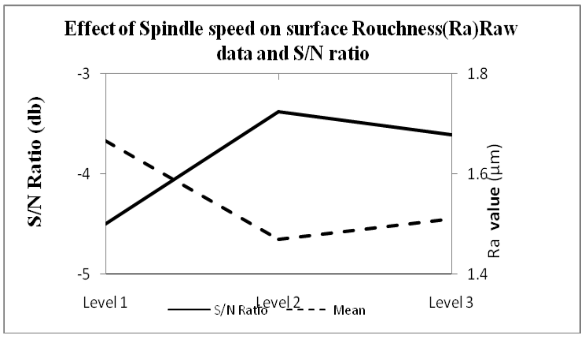
Figure2: Main effect plot Showing Effects of Process Parameters on Dimentional Deviation

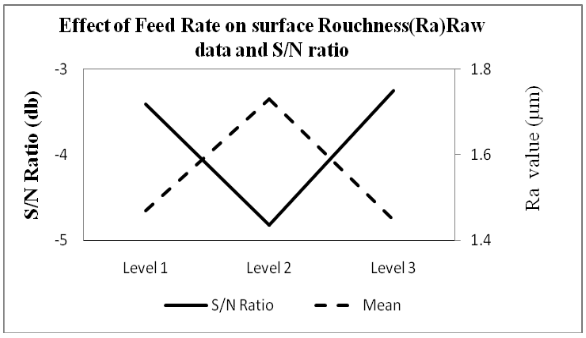
It can be seen from the figure 2 that as the spindle speed increases the dimensional deviation is decreases Similerly the deviation in dimention was also found increasing with the decrease in feed rate but the it decreasesing with the reduction in depth of cut.

Table 5: Response Table for Surface roughness raw data and S/N

	Spindle Speed		Feed rate		Depth of cut	
	Raw Data	S/N ratio	Raw Data	S/N ratio	Raw Data	S/N ratio
Level 1	1.67	-4.50	1.47	-3.41	1.56	-3.88
Level 2	1.47	-3.38	1.73	-4.82	1.49	-3.49
Level 3	1.51	-3.61	1.45	-3.25	1.60	-4.11
Delta	0.20	1.12	0.28	1.57	0.11	0.62
Rank	2	2	1	1	3	3



(a)



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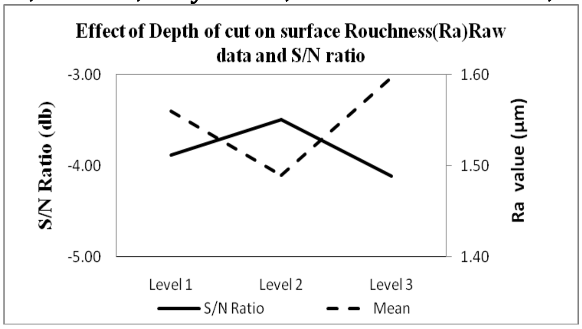

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Figure3: Main effect plot Showing Effects of Process Parameters on Surface Rougness(Ra)

The surface roughness was found lowest at the second level of spindle speed and it is highest at highest spindle speed and roughness increases again with further decreases of spindle speed.

The behavior of the roughness against feed rate was found just opposite to the spindle speed i.e. surface roughness lowest at first level of feed rate than it increases up to second level of feed rate and then again reduces to lowest value at third level of feed rate. The surface roughness varies against depth of cut just similar as it varies with spindle speed.

ANOVA of the S/N data and the raw data for dimensional deviation are given in Tables 5 and 6 respectively. From these tables, it is clear that spindle speed , Feed Rate , and depth of cut significantly affect both the mean and the variation in the Dimentional deviation values.

ANOVA of the S/N data and the raw data for dimensional deviation are given in Tables 6 and 7 respectively. From these tables, it is clear that spindle speed , Feed Rate , and depth of cut significantly affect both the mean and the variation in the dimentional deviation values because the F-ratio calculated from data is greater then F-Ratio table.The % contriibution of each factor was also claculated and shown in the tables.

Table 6 Analysis of Variance for dimensional deviation (S/N Data)

Source	SS	DOF	V	P	F-Ratio	F-Ratio Table
Spindle speed	16.45	2.00	8.22	60.90	71.51	19
Feed rate	5.24	2.00	2.62	19.41	22.79	19
Depth of cut	5.09	2.00	2.55	18.85	22.13	19
Error	0.23	2.00	0.12	0.85		
T	27.01	8.00		100.00		
DOF-degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, significance of a factor at 95% confidence level						

Table 7 Analysis of Variance for dimensional deviation (raw data)

Source	SS	DOF	V	P	F-Ratio	F-Ratio Table
Spindle speed	1.51	2.00	0.75	57.19	44.84	3.49
Feed rate	0.62	2.00	0.31	23.39	18.34	3.49
Depth of cut	0.18	2.00	0.09	6.67	5.23	3.49
Error	0.34	20.00	0.02	12.75		
T	2.63	26.00	*	100.00		
DOF-degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, significance of a factor at 95% confidence level						

The ANOVA was also carried out for surface roughness and it was found that all three parameter are significantly affect the surface roughness as the F-ratio calculated from data is greater than F-Ratio table. The results of ANOVA are given in table 8 and table 9 for S/N ratio and raw data along with the parameter contribution to the surface roughness.

Table 8 Analysis of Variance for surface roughness (S/N Data)

Source	SS	DOF	V	P	F-Ratio	F-Ratio Table
Spindle speed	3.75	2.00	1.88	49.31	125.00	19
Feed rate	3.21	2.00	1.61	42.21	107.00	19
Depth of cut	0.62	2.00	0.31	8.15	20.67	19
Error	0.03	2.00	0.02	0.39		
T	7.60	8.00		100.00		
DOF-degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, significance of a factor at 95% confidence level						

Table 9 Analysis of Variance for surface roughness (raw data)

Source	SS	DOF	V	P	F-Ratio	F-Ratio Table
Spindle speed	0.32	2.00	0.16	17.21	7.11	3.49
Feed rate	0.61	2.00	0.31	32.80	13.56	3.49
Depth of cut	0.48	2.00	0.24	25.81	10.67	3.49
Error	0.45	20.00	0.02	24.20		
T	1.86	26.00	*	100.02		
DOF-degrees of freedom, SS - sum of squares, MS - mean squares (Variance), F-ratio of variance of a source to variance of error, significance of a factor at 95% confidence level						

The optimum setting of turning parameters for turning ASTM A387 Alloy Steel pin are as given in table 6 on the bases of above analysis.

Table 6: Optimum setting of Input parameters

Response parmeter	Input parameter		
	Spindle speed	Feed Rate	Depth of cut
Dimensional Deviation	Level 1 (1600 rpm)	Level 1 (0.4mm/rev.)	Level 3 0.25 mm
Surface roughness	Level 2 (1300 rpm)	Level 3 (0.2mm/rev.)	Level 2 0.30 mm

IV. CONFIRMATION EXPERIMENTS

The results obtained were verified by running a separate experiment and manufacturing around 100 pieces of component.

The dimensional tolerance was found out by the Air Gauge in the company itself. The standard deviation for dimensional variation was found out to be 1.135 microns. [Using the Parameter combination A1B1C3]

These components were then sent to the Spectro Test Lab separately for surface roughness test. The RA for the component was found out to be 0.91 microns. [Using the Parameter combination A2B3C2] .

V. *CONCLUSION:*

It is found that the parameter design of the Taguchi method provides a simple, systematic and efficient methodology for the optimization of process parameters. The results obtained from the machining of ASTM A387 Alloy Steel pin on CNC lathe machine can be concluded:

a) The percentage contribution of cutting speed is 71.51%, feed rate is 22.79%, depth of cut was 22.13% and that of error is 6.7% for variation(S/N Ratio) of dimensional deviation.
b) The percentage contribution of the cutting speed is maximum i.e. 44.84, feed rate 18.34, and depth of cut was 5.23 % for raw data of dimensional deviation.
c) The optimum combination of the parameters and their levels for obtaining minimum dimensional variation is A1B1C3 (spindle speed = 1600, feed =0.4 mm/rev., depth of cut = .25 mm).
d) The percentage contribution of cutting speed was 49.31%, feed rate is 42.21 %, depth of cut is 8.51 % for variation(S/N Ratio) in surface roughness.
e) The percentage contribution of the cutting speed is maximum i.e. 17.21%, feed rate 32.80%, and depth of cut was 25.81 % for raw data of surface roughness.
f) The optimum combination of the parameters and their levels for obtaining minimum surface roughness is A2B3C2 (spindle speed =1300 , feed =0.2mm/rev , depth of cut =.3mm) .

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