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Optimization of Cutting Parameters in Boring Operation

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ABSTRACT : *In the present work an attempt is made to select the combination of optimum cutting parameters which will result in better surface finish. Machining with optimum cutting parameters will result in minimum machining time and hence increasing the productivity. Four parameters viz. spindle speed, feed, depth of cut and length to diameter (L/D) ratio of boring bar has been taken as control factors. The cutting trials were performed as per Taguchi* 3^4 (L_9) *orthogonal array method to deal with the response from multi-variables. AISI 1041 (EN9) carbon steel was used as a job material which was cut by using standard boring bars of various sizes each having a tungsten carbide inserts of same insert radius. The Analysis of Variance (ANOVA) was carried out to find the significant factors and their individual contribution in the response function i.e. surface roughness.*

Keywords - *Taguchi parameter design, Boring process, Surface roughness, Analysis of variance.*

I. INTRODUCTION

Boring is one of the important machining operation used to enlarge the pre-drilled or cast holes. Surface roughness is an important quality parameter of bored surface. Selection of correct combination of cutting parameters will help the machinist to complete the operation in minimum possible time maintaining the required value of surface roughness. This knowledge can be drawn after long period of experience. The basic objective of the work presented here is to find the optimized combination of cutting parameters to achieve the minimum value of surface roughness. The experimentation was carried out with the help of an ordinary lathe machine available in workshop. Three machining parameters such as spindle speed, feed and depth of cut were taken as control factors. During the machining, the boring bar is subjected vibrations in different directions. The first and the direct impact of these vibrations is the surface roughness which is an important quality parameter of the bored surface. In order to control the surface roughness it is important to control the boring bar vibrations.The vibrations generated in bar is the function of cutting parameters. The boring bar is generally a slender bar clamped at one end and subjected to cutting forces at other end. The literature available on boring bar vibrations shows that increase in the overhang length of the bar causes the bar vibrate more which results in poor surface finish. Hence the selection of boring bar length for a specific diameter can also help to achieve the better surface roughness. Hence the forth control factor considered here is the length to diameter (L/D) ratio of the boring bar which can be achieved either by varying the overhang length of single boring bar or keeping the length constant and changing the boring bar. Surface finish in boring is the function of the various factors such as speed, feed, depth of cut, work piece material, tool geometry, work hardness, tool nose radius, stability of machine tools, cutting fluids and many more. Many researchers have studied the effect of these parameters on the surface finish. Albrecht [2] has investigated the effect of speed, feed, depth of cut and tool nose radius on the surface finish of the steel components. Ansell and Taylor [3] have investigated the effect of tool material on the surface finish of the cast iron components. The effect of varying cutting speed on the surface finish due to formation of the built-up edge is investigated by Cook and Chandiramani [4]. Lambert [5] have studied the effect of speed, feed, depth of cut, cutting time and tool coating and used multiple regression technique to develop mathematical model. A number of experimental and analytical studies have done regarding tool vibrations in turning. The effect of machining parameters like speed , feed, tool nose radius and depth of cut on surface finish has been studied by Takeyama and Ono [6] and concluded that the speed is prominent than other parameters and have mixed effect on surface finish. The higher values of the speed gives better surface finish for the other parameters to be constant has proved through the experiments by Nassirpour and Wu [7]. Sundaram et.al. [8] have studied the effect of speed, feed, depth of cut, cutting time and tool coating and used multiple regression technique to develop mathematical model. Similar kind of study has been carried out by Mital and Mehta [9] in which they developed the surface finish prediction model as a function of cutting parameters for each individual metal. They have generated the surface finish data for aluminum alloy 390, ductile cast iron, medium carbon leaded steel 4130 and Inconel 718 alloy for a wide range of machining conditions. Several efforts have been made to measure the surface finish obtained in different machining processes by using various techniques. Azouzi and Guillot [10] utilized a neural network to construct an on-line prediction model for surface roughness based on the feed force and vibration feedback. The effects of tool wear, relative vibration between tool and work piece as well as changing nose radius were considered by Yan [11] who presented an on-line approach for predicting the maximum peak-to-valley surface roughness produced during finish turning. Computer Vision technique to sense the surface roughness of the machined part wherein the image of the machined surface is captured in digital camera and relationship is established between the features of the image and the actually measured roughness value is introduced recently by Lee and Tarng [12]. Abouelatta and Madl [13] used tool vibration data and predicted surface roughness using multiple regression. P.M. Noaker [14] has discussed the review of the surface roughness in respect to the cutting parameters. Beauchamp and others [15] have collected the surface roughness and tool vibrations data for mild steel for various set of speed, feed, depth of cut, tool nose radius, tool overhang and job length. The algorithm for correlation between surface roughness and cutting vibrations is developed by Jang et al. [16] in concern to flexible manufacturing system. The effect of tool wear on the surface finish through vibrations in turning is studied by Mer and Diniz [17] under the effect of variable cutting parameters. Risbood, Dixit, Sahasrabudhe [18] Predicted of surface roughness and dimensional deviation by measuring cutting forces and vibrations in turning process. To select the cutting parameters properly, several mathematical models based on statistical regression or neural network techniques have been constructed to establish the relationship between the cutting performance and cutting parameters. In the present work, an alternative approach based on the Taguchi method is proposed to determine the optimum combination of cutting parameters which will result in better surface finish with minimum machining cycle time.

II. EXPERIMENTAL SET-UP AND PROCEDURE

Four parameters i.e. spindle speed, feed, depth of cut and length to diameter (L/D) ratio of boring bar has been taken as control factors. Table 1 shows the levels of control factors used. The 34 orthogonal array (L9) was chosen as there are four control parameters with each having three levels. Table 2 shows the orthogonal array chosen. Total nine runs were conducted during one trial. Trials were repeated to check the consistency in the output. Cutting trials were conducted on Kirloskar make (Enterprise-500) center lathe machine. AISI 1041 carbon steel cylinders with 100 mm outside diameter, 85 mm inside diameter and 75 mm length were used as work pieces. The tested mechanical and chemical properties of AISI 1041 carbon steel are given in Table 3 and 4 respectively.

Table 1 Control factors and their levels

Control variables		Level-1	Level-2	Level-3
A	Spindle Speed (RPM)	54	140	224
B	Feed (mm/rev)	0.045	0.36	0.676
C	Depth of Cut (mm)	0.5	0.75	1
D*	L/D ratio for Boring Bar	4	5	6.25
		L=100, D=25	L=100, D=20	L=100, D=16

(* L & D is expressesed in mm.)

Table 2 The basic Taguchi L_9 (3^4) orthogonal array

Run	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Standard boring bars with Widax tool holder S25TPCLNR12F3, S20SSCLCR09T3 and S16QSCLCR09T3 along with cemented carbide inserts having radius 1.2mm were used for metal cutting. Surface finish was measured offline by using HOMMELWERKE TURBO RAUHEIT V 6.14, Swiss make surface recorder having 0.8 mm cut-off and 4.8 mm sample length.

Table 3 Mechanical properties of AISI 1041 Carbon Steel

Hardness (BHN)	Tensile strength (MPa)	UTS (MPa)
207	510	660

Table 4 Chemical properties of AISI 1041 carbon steel

% C	% Mn	% Si	% P	% S
0.42	0.72	0.72	0.017	0.008

III. RESULTS AND DISCUSSIONS

The averages of surface roughness values obtained during each trial (Ra1 and Ra2) are given in Table 5. Based on the average values of surface roughness (Ra) the Signal-to-Noise (S/N) ratio can be calculated for the criteria of lower-the-better. The Table 6 shows the values of S/N ratio calculated.

Table 5 Experimental results for surface roughness

Run	A	B	C	D	Ra_1	Ra_2	Ra
1	1	1	1	1	3.57	3.69	3.63
2	1	2	2	2	12.30	10.29	11.30
3	1	3	3	3	13.81	13.59	13.70
4	2	1	2	3	6.24	5.69	5.97
5	2	2	3	1	6.90	6.74	6.82
6	2	3	1	2	10.18	10.22	10.20
7	3	1	3	2	5.22	3.95	4.59
8	3	2	1	3	8.52	6.79	7.66
9	3	3	2	1	2.87	3.11	2.99

Table 6 Calculated S/N ratios for surface roughness

Run	A	B	C	D	Ra	S/N ratios
1	54	0.045	0.5	4	3.63	-11.1981
2	54	0.36	0.75	5	11.30	-21.0616
3	54	0.676	1	6.25	13.70	-22.7344
4	140	0.045	0.75	6.25	5.97	-15.5195
5	140	0.36	1	4	6.82	-16.6757
6	140	0.676	0.5	5	10.20	-20.1720
7	224	0.045	1	5	4.59	-13.2363
8	224	0.36	0.5	6.25	7.66	-17.6846
9	224	0.676	0.75	4	2.99	-9.5134

In addition, the total mean S/N ratio for the nine experiments was also calculated and listed in Table 7.

Table 7 Calculated Mean S/N ratios

Level	A	B	C	D
1	-18.33	-13.32	-16.35	-12.46
2	-17.46	-18.47	-15.36	-18.16
3	-13.48	-17.47	-17.55	-18.65
Delta	4.85	5.16	2.18	6.18
Higher S/N ratio	3	1	2	1

Total mean of S/N ratios = -16.4233

Figure 4 shows the mean S/N ratio graph for surface roughness. The S/N ratio corresponds to the smaller variance of the output characteristics around the desired value.

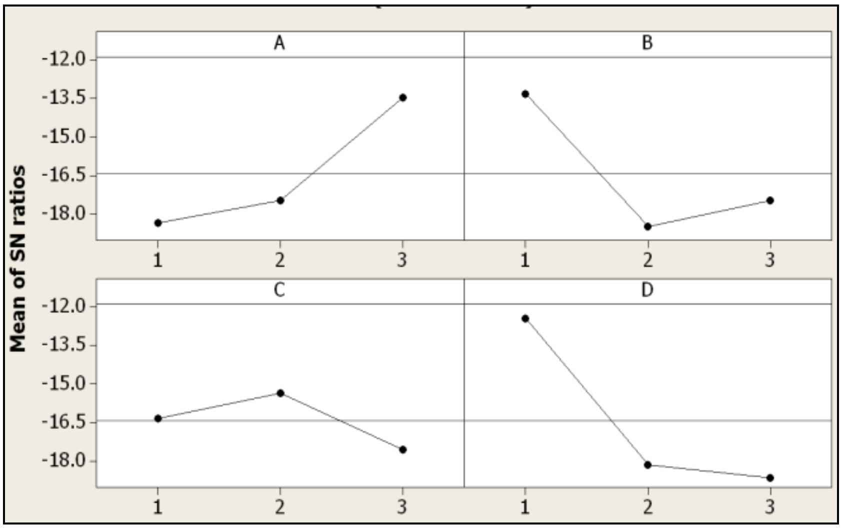

Fig. 4 Plots for mean S/N ratios for A, B, C, D

The optimal values of control factors A, B, C and D can be obtained from the plots. Table 7 shows that the S/N ratio for spindle speed is higher at level 3, similarly for others the values are feed 1, depth of cut 2 and L/D ratio 1. Hence the optimal combination of control factors can be given as 3-1-2-1. Analysis of Variance (ANOVA) is carried out to check the significant contribution of each control factor in response function. Table 8 shows the results of the ANOVA for surface roughness.

Table 8 Results of the ANOVA for surface roughness

Source of Variation	Degree of freedom	Sum of Squares	Mean Square	F-ratio	Contribution (%)
Sp. Speed (A)	2	60.30	30.15	59.66	27.65
Feed rate (B)	2	66.02	33.01	65.33	30.28
Depth of cut (C)	2	8.48	4.24	8.39	3.89
L/D ratio (D)	2	78.65	39.32	77.82	36.07
e	9				

It can be noted from the ANOVA Table that the parameters A, B and D are having significant contribution of 28%, 30% and 36% respectively in the response function (Ra) whereas the parameter C has relatively less contribution and thus is of less importance. The confirmation test with the combination of parameters as shown in Table 9 was carried out.

Table 9 Optimal parameters and their values

Cutting Parameters	Optimal Level	Optimal Value
A: Spindle speed	3	224
B: Feed rate	1	0.045
C: Depth of cut	2	0.75
D: L/D ratio	1	4

The surface roughness was evaluated at three different locations. The results of the conformation test are shown in Table 10. The average surface roughness during confirmation test was found less than any other value of Ra in L9 orthogonal array.

Table 10 Results of the confirmation run

Location	Ra	Average (Ra) value
1	0.35	1.46
2	1.88	
3	2.17	

IV. CONCLUSIONS

This study presents an efficient method for determining the optimal turning operation parameters for surface roughness under varying conditions through the use of the Taguchi parameter design process. The study shows that the control factors had varying effects on the response variable. The use of the Taguchi parameter design technique was considered successful as an efficient method to optimize machining parameters in a boring operation which will tend to reduce the machining time and enhance the productivity.

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