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OPTIMIZATION OF CYLINDRICAL GRINDING PROCESS PARAMETERS OF SS316L AUSTENTIC STAINLESS STEEL BY TAGUCHI METHOD

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ABSTRACT

The main objective of this study is to optimize the cylindrical grinding parameters that can be utilized to predict optimal grinding parameters to achieve minimum surface roughness of a material. A SS 317L Austentic steel round rod of 80 mm x 168 mm was considered for cylindrical grinding in this study. Cutting speed, depth of cut and feed rate were chosen as input variables while Surface roughness (Ra) selected as output response. An L9 orthogonal array was selected for this study and S/N ratios were analyzed to study the surface roughness characteristics. Nine experiments were conducted in the surface grinding machine with different values of input parameters obtained from the orthogonal array. The surface roughness values were optimized in the optimization software (Minitab version 17) and the optimal solution was obtained for minimum response. Minimum surface roughness is achieved with 100 rpm cutting speed, 0.03 mm depth of cut and 1 mm/s feed rate. The confirmation experiments were conducted for the optimal solution obtained from Taguchi experiment and the results are verified.

Keywords: *Cylindrical Grinding, Optimization, Taguchi method, Minitab and Roughness.*

1. Introduction

Cylindrical grinding is an essential process for final machining of components requiring smooth surfaces and precise tolerances. As compared with other machining processes, cylindrical grinding is a costly operation that should be utilized under optimal conditions [1]. Many experimental investigations reveal that depth of cut, wheel speed, and work speed are the major influential parameters that affect the quality of the ground part. Determination of optimum parameters lies in the proper selection and introduction of suitable design of experiments (DOEs) at the earliest stage of the process and product development cycles [2]. Design of experiments is a powerful analysis tool for modeling and analyzing the influence of control factors on performance output. The traditional experimental design is difficult to be used especially when dealing with large number of experiments and when the number of machining parameter is increasing [3]. The most important stage in the design of experiment lies in the selection of the control factors [4]. Therefore, the Taguchi method, which is developed by Genichi Taguchi, is introduced as an experimental technique which provides the reduction of experimental number by using orthogonal arrays and minimizing the effects out of control factors [3]. Taguchi is a method which includes a plan of experiments with the objective of acquiring data in a controlled way, executing these experiments and analysis data in order to obtain the information about behavior of the given process [5, 6]. The Present work involves a L9 orthogonal array design of experiments to study the influence of the input parameters on the surface roughness of cylindrical grinding of SS 316L steel. In this work cutting speed, depth of cut and feed rate are taken as input variables and surface roughness is taken as output.

2. Experimental Work

Cylindrical grinding is used to grind the cylindrical surfaces and shoulders of the work piece. In this work, SS 316 L stainless steel of dimension ϕ80 mm x 168 mm is chosen as the work specimen. The chemical composition of the material is shown in Table 1 and the mechanical properties of the material are shown in Table 2. The present study employs a Taguchi L9 orthogonal array in the experiments on the cylindrical grinding process. Cutting speed (N), Depth of cut (D) and Feed rate (F) were chosen as input parameter and surface roughness (Ra) is chosen as response. The input parameters are optimized using Taguchi method in order to achieve minimum surface roughness value.

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Table 1 Chemical Composition of SS316L

Element	Content (%)
Chromium , Cr	18-20
Nickel , Ni	11-15
Molybdenum , Mo	3-4
Manganese, Mn	2
Silicon , Si	1
Phosphorus , P	0.045
Carbon , C	0.03
Iron , Fe	Balance

Table 2 Mechanical Properties of SS316L

Properties	value
Tensile strength	595 MPa
Yield strength	260 MPa
Modulus of elasticity	200 GPa
Hardness, Rockwell	85

Nine work pieces were prepared with dimensions 80 mm x 168 mm and the tests were carried out in HMT G17 800 cylindrical grinding machine. The cylindrical grinding machine used in this study is shown in Fig. 1. The surface roughness is measured by surface roughness tester Mitutoyo SURFTEST SJ-210.

Fig. 1 Cylindrical Grinding Machine HMT G17 800

Totally nine experiments were carried out in the cylindrical grinding machine with a repetition of two times and the surface roughness values are measured using surface roughness tester for three specimens of each experiment and the average value of the surface roughness is taken.

3. Design of Experiment

In this study L9 orthogonal array is selected for conducting design of experiment. The number of factors considered is three and the number of levels is three. Cutting Speed, Depth of Cut and the Feed rate were taken as the Input parameters. The values of the levels for conducting design of experiment are given in Table 3 and the corresponding design of experiment table is shown in Table 4 and Table 5.

Table 3 Mechanical Properties of SS316L

Input parameters	Level 1	Level 2	Level 3
Cutting speed (rpm)	100	170	220
Depth of cut (mm)	0.01	0.03	0.05
Feed rate (mm/sec)	1	3	5

Table 4 L9 Orthogonal Array

Test No.	Cutting Speed	Depth of cut	Feed rate
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 5 Design of Experiments

Test No.	Cutting Speed (rpm)	Depth of cut (mm)	Feed rate (mm/s)
1	100	0.01	1
2	100	0.03	3
3	100	0.05	5
4	170	0.01	3
5	170	0.03	5
6	170	0.05	1
7	220	0.01	5
8	220	0.03	1
9	220	0.05	3

4. Results and Discussion

Table 6 gives the surface roughness results for the nine experiments and the main effect plot of SN ratio is shown in Fig.2

Table 6 Surface Roughness Results

Exp. No.	Cutting Speed (rpm)	Depth of cut (mm)	Feed rate (mm/s)	Surface roughness (Ra)
1	100	0.01	1	0.056
2	100	0.03	3	0.058
3	100	0.05	5	0.067
4	170	0.01	3	0.071
5	170	0.03	5	0.076
6	170	0.05	1	0.065
7	220	0.01	5	0.069
8	220	0.03	1	0.059
9	220	0.05	3	0.072

For optimization process Taguchi method uses the signal to noise (S/N) ratio instead of means. The S/N ratio of the surface roughness is calculated with smaller the better condition and the values of S/N ratio is shown in Table 7

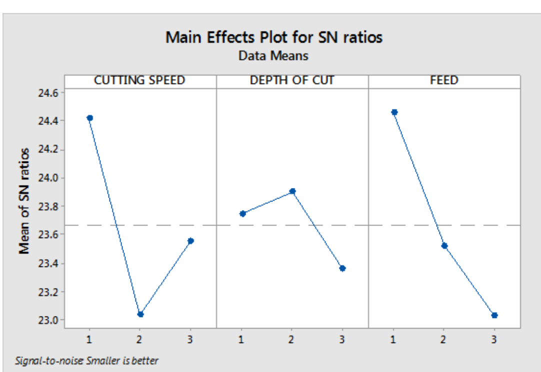

Fig. 2 Main effect plot for S/N ratio of Surface Roughness

The response table for S/N ratio is shown in Table 8 and it can be seen from the table the most effective parameter is Feed rate which is having the highest delta value of 1.43

Table 7 S/N Ratio

ExpNo.	Cutting Speed (rpm)	Depth of cut (mm)	Feed rate (mm/s)	Surface roughness (Ra)	S/N Ratio
1	100	0.01	1	0.056	25.03
2	100	0.03	3	0.058	24.73
3	100	0.05	5	0.067	23.47
4	170	0.01	3	0.071	22.97
5	170	0.03	5	0.076	22.38
6	170	0.05	1	0.065	23.74
7	220	0.01	5	0.069	23.22
8	220	0.03	1	0.059	24.58
9	220	0.05	3	0.072	22.85

The minimum surface roughness is achieved with a cutting speed of 100 rpm, depth of cut of 0.03 and feed rate of 1 mm/sec and the optimum condition is A1B2C1. The results of the ANOVA is tabulated in Table 9.

Table 8 Response table for S/N Ratio

Level	Cutting Speed	Depth of Cut	Feed rate
1	24.42	23.74	24.45
2	23.03	23.90	23.52
3	23.55	23.36	23.03
Delta	1.38	0.54	1.43
Rank	2	3	1

Table 9 ANOVA Results

Source	DF	Adjusted SS	Adjusted MS	F value	P value
Cutting speed	2	0.000163	0.000081	6.72	0.129
Depth of cut	2	0.000022	0.000011	0.89	0.529
Feed rate	2	0.000176	0.000088	7.28	0.121
Error	2	0.000024	0.000012		
Total	8	0.000385			

5. Conclusions

From this study, we can conclude that the optimum process parameter for cylindrical grinding of

SS 316L stainless steel occurs A1B2C1 viz. cutting speed of 100 rpm , depth of cut of 0.01 mm and a feed rate of 1 mm/sec. The Feed rate has dominant influence in attaining the minimum surface roughness followed by cutting speed and depth of cut. The optimum condition A1B2C1 is confirmed using confirmation experiment on the cylindrical grinding machine and a surface roughness of 0.055 is achieved.

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