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Study the effect of machining parameters on surface roughness in CNC Milling of AISI 316L

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Abstract

The present work focused on the influence of cutting speed, feed, depth of cut (doc) and type of coolant (dry and wet) on the surface roughness on AISI 316L stainless steel material during end milling. The experimental plan was based on Taguchi's technique L18 orthogonal array with four factors and three levels for each variables and studying the contribution of each factor on surface roughness. The ANOVA technique is employed to study the significance of each parameter.

Keywords: AISI 316L, Taguchi's technique, Surface Roughness, ANOVA technique.

Introduction

The success of any manufacturing organization depends mainly on two factors that are higher production rate and improved quality. The productivity is interpreted in terms of material removal rate in the production process. Quality represents product characteristics as desired by the customer. To improve these two factors, the engineers face two main practical problems in a manufacturing process. The first is to determine the values of process parameters that will yield the desired product quality (meet technical specifications) and the second is to maximize manufacturing system performance using the available resources. [1] Milling is one of the most widely used metal removing processes in industry. The surface generated during milling is affected by different factors such as vibration, spindle speed, tool geometry, feed, depth of cut. Many of the researcher investigated that the optimal machining parameter to reduce product cost and to maximize the gains from milling operation.

Singh et al. [2] investigated the influence of cutting parameters on surface roughness and material removal rate during milling of EN 24 steel. The control parameters such as speed, feed, and depth of cut were selected for the study. A total of 27 experimental runs were conducted using an orthogonal array, and ideal combination of controllable factor level was determined for the surface roughness and material removal rate. The result showed that feed rate is most affecting parameter in milling of EN 24 steel.

Thakre [3] investigated the effects of various cutting parameters such as spindle speed, feed rate, and depth of cut and coolant flow on surface roughness using L9 standard orthogonal array. The study was conducted on 1040 MS material in vertical milling using carbide inserts. The study indicated that coolant flow is the most significant parameter in controlling the surface roughness followed by spindle speed.

Maiyar et al. [4] investigated the parameter optimization of end milling operation for Inconel 718 super alloy with multi –response criteria based on the Taguchi orthogonal array with the gray relational analysis. They perform nine experimental runs based on an L9 orthogonal array of taguchi method. Cutting speed, feed rate and depth of cut are optimized with response parameters as surface roughness and material removal rate. The study reveals that gray relational analysis is an effective optimization tool for machining Inconel 718 alloy in end milling.

Yasir et al. [5] investigated effect of cutting parameters on the surface topography of AISI 316L stainless steel. End milling operation was performed on AISI 316L steel with tungsten carbide tool. The response surface methodology (RSM) technique was used for optimization. The input machining parameters like cutting speeds and feed rate were evaluated. Their study revealed that feed rate is most affecting parameters while milling of AISI 316L steel

Joshi and Kothiyal [6] investigated the impact of various parameters like spindle speed, depth of cut and feed rate on surface finish in end milling of aluminium cast heat-treatable alloy using Taguchi methodology. Experimental plan was performed by a Standard Orthogonal Array. Their results indicated that feed Rate is most influencing factor for modeling surface finish. Also the graph of S-N Ratio indicates the optimal setting of the machining parameter which gives the optimum value of surface finish.

Materials and Methods

The end milling was performed on VMC-BFW machine whose maximum spindle speed 6000 Rpm and power 7.5Kw. The machine set up was shown in Figure 1. Thefour flute carbide tool having Al, Ti coating having 10mm diameter was used in investigation. The rectangular plate of AISI 316Lstainless steel was used as workpiece. The size of workpiece material selected was 125mm×100mm×25mm. the chemical composition of 316L was 0.0203C, 0.21 Si, 1.88 Mn, 0.03P, 16.68Cr, 10.41Ni, 2.20Mo, 0.00266S, and balance Fe.

Figure 1: VMC-BFW Machine

Figure 2 shows surface roughness tester (Model - Mitutoyo SJ-210 ISO 1997) which is used for measurement of surface roughness. The cut off length for the measurement was set at 0.8 mm and total sampling length at 4 mm and traverse speed at 0.5 mm/s throughout the measurement of surface. Stylus traversed in horizontal direction on the surface of workpiece.

Figure 2: Surface roughness Tester

Experiments

Design of Experiments

For the experimental design, the Taguchi method has been used, in which the experiments are performed as per standard orthogonal array (OA). Based on review of literature, the selected input parameters to be investigated were four, namely the cutting speed, feed rate, depth of cut and type coolant. The levels and parameters are as shown in Table 1.The combinations of experiments for four factors and three levels as per Taguchi method is given in Table 2.

Table 1: Machining Parameters and their levels

Parameter	Levels		
	1	2	3
Environment (D/W)	Dry	Wet	--
Speed (RPM)	1600	1900	2100
Feed (mm/min)	0.12	0.15	0.18
DoC (mm)	0.1	0.3	0.5

Results

Table 2 shows the measured surface roughness values of machined samples along with combinations of experiment

Table 2: Experimental Results

Exp. No	Environment	Speed (RPM)	Feed (mm/min)	DoC (mm)	Surface Roughness (µm)
1	Dry	1600	0.12	0.1	0.097
2	Dry	1600	0.15	0.3	0.129
3	Dry	1600	0.18	0.5	0.124
4	Dry	1900	0.12	0.1	0.172
5	Dry	1900	0.15	0.3	0.137
6	Dry	1900	0.18	0.5	0.111
7	Dry	2100	0.12	0.3	0.179
8	Dry	2100	0.15	0.5	0.098
9	Dry	2100	0.18	0.1	0.161
10	Wet	1600	0.12	0.5	0.210
11	Wet	1600	0.15	0.1	0.219
12	Wet	1600	0.18	0.3	0.160
13	Wet	1900	0.12	0.3	0.144
14	Wet	1900	0.15	0.5	0.254
15	Wet	1900	0.18	0.1	0.169
16	Wet	2100	0.12	0.5	0.133
17	Wet	2100	0.15	0.1	0.154
18	Wet	2100	0.18	0.3	0.135

Analysis of Variance

ANOVA is performed in order to identify the significance and influence of process parameters on surface roughness and material removal rate. The analysis is carried out at 95% confidence level. ANOVA results for surface roughness are given in Table 3. Figure 4 shows the main effect plot for the surface roughness. The graph of main effect plot shows that environment is most influencing parameter for the surface roughness. A sudden increase in surface roughness observed when environment changes from dry to wet. Surface roughness increases when speed increases from 1600 to 1900 RPM and suddenly it shows decreasing tend with further increase in speed at 2100RPM.Same trend is recorded for feed also as feed increases from 0.1 to 0.15 surface increases but further increases in feed up to 0.2 mm/min shows decreasing trend. For depth of cut exactly opposite trend to that of speed and feed is observed for first increment of depth of i.e. from 0.1 to 0.3 surface roughness decreases and further increase in depth of cut shows decrease in surface roughness.

Table 3: Analysis of Variance (ANOVA) for Surface Roughness

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Environment (D/W)	1	0.007606	0.007606	4.11	0.07
Speed (RPM)	2	0.001371	0.000685	0.37	0.69
Feed (mm/min)	2	0.001440	0.000720	0.39	0.68
DoC (mm)	2	0.000646	0.000323	0.17	0.84
Error	10	0.018497	0.001850		
Total	17	0.029559			

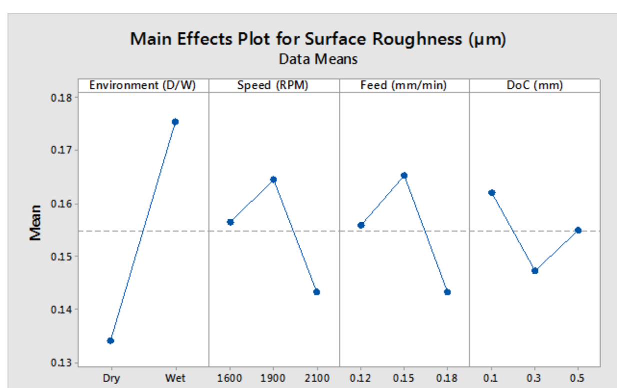

Figure 4: Main effect plot for surface roughness

Table 4: Response Table of Surface Roughness for Signal to Noise Ratios Smaller is better

Level	Environment	Speed	Feed	DoC
1	17.65	16.47	16.40	16.05
2	15.33	15.97	16.10	16.69
3		17.02	16.97	16.73
Delta	2.31	1.05	0.88	0.68
Rank	1	2	3	4

Conclusion

Taguchi design method is suitable to optimize the surface roughness in end milling AISI 316L. The most significant parameters amongst cutting speed, feed rate, depth of cut and type of coolant for surface roughness as response variable are type of coolant followed by cutting speed, feed rate and depth of cut respectively. The optimum values for the surface roughness, environment is dry, cutting speed is 1600 rpm, feed rate is 0.12 mm/min and depth of cut is 0.1mm.

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