International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 3 Issue 8 ǁ August 2014 ǁ PP.54-58

"The Effect of Process Parameters on Surface Roughness in Face Milling"

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ABSTRACT : *The purpose of this study is to investigate effect of process parameters on surface roughness on SAE 1541 material by carbide tools in face milling. In this study, parameters like cutting speed, feed, depth of cut and coolant flow rate considered. Series of experiments were studied by Design of Experiments (DOE). L9 Orthogonal array is selected and experiments were taken by the use of Taguchi method. Experimental Analysis is done by ANOVA and results were drawn out on the basis of analysis. It is investigated that cutting speed, feed and depth of cut are the influencing factors.*

KEYWORDS: *Face Milling, Surface Roughness, Taguchi Method, L9 Orthogonal Array, ANOVA*

I. INTRODUCTION

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. There have been many research developments in modelling surface roughness and optimization of the controlling parameters to obtain a surface finish of desired level since only proper selection of cutting parameters can produce a better surface finish. In the manufacturing industries, various machining processes are adapted for removing the material from the work-piece for a better product. Out of these, end milling process is one of the most vital and common metal cutting operations used for machining parts because of its ability to remove materials faster with a reasonably good surface quality. In recent times, computer numerically controlled machine tools have been implemented to utilize full automation in milling since they provide greater improvements in productivity, increase the quality of the machined parts and require less operator input.[1] Face milling is an operation for producing plane or flat surfaces using face milling cutters. Surface roughness is one of the most important parameter to determine the quality of product. Several factors like cutting speed, feed, depth of cut, type of coolant, coolant pressure, tool geometry, work piece material influence surface roughness[2].

Surface Roughness : The surface parameter used to evaluate surface roughness in this study is the roughness average (Ra). The roughness average is the area between the roughness profile and its central line, or the integral of the absolute value of the roughness profile height over the evaluation length [3]. Ra is defined as the arithmetic value of the departure of the profile from the centerline along sampling length. It can be expressed by the following mathematical relationships.

$$Ra = \frac{1}{L}\int_0^l |Y(x)|\,dx(l) \qquad \textbf{…(i)}$$

where
Ra=the arithmetic average deviation from the mean line, and
Y =the ordinate of the profile curve.

II. EXPERIMENTAL SET-UP

In this work, Taguchi method used for Design of experiments (DOE).Analysis of Variance is adapted for performance analysis. Finally, with the use of Regression Analysis, mathematical model for Ra is generated and it is validated.

a) Workpiece Material : *In this study,workpiece material is SAE 1541,a type of low alloy steel. It is also called as medium carbon steels is type of Mn alloy [8]. Percentage of each element is given below:*

Table 1: Chemical composition of work-piece component

C	Mn	Si	Cr	Al	Cu	HRC
0.399	1.52	0.205	0.103	0.25	0.15	52-59

b) Working Machine : *For the experiments, Hyundai WIA F500DI model Vertical Machining Centre (VMC) is used .For this experiments, IPOL cut 140AS this metal cutting fluid is used whose density is 0.88 (g/cm3) at 15°C,viscosity is 25 (mm^2/sec) at 40°C.Mititoyo surface tester of model SJ-400 is used to measure surface roughness in experimental work. The roughness tester having measuring force 075mN-4mN and Diamond tip 5µm stylus having accuracy ±0.03µm.The probe comes in and out holes while traveling on the surface. The probe is made up of diamond nip which very high in cost*

III. EXPERIMENTAL DETAILS

A series of experiments were carried out on Hyundai WIA F500DI (VMC) (Sanjeev Auto). From OVAT analysis four input controlling parameters selected having three levels.

Table 2:Summary details of parameters and their levels

Sr.No	Process Parameters	Level –I	Level-II	Level-III
1	Cutting Speed (rpm)	1200	1400	1600
2	Feed (mm/min)	150	180	210
3	Depth of cut (mm)	0.2	0.3	0.4
4	Coolant Flow Rate (lit/min)	20	40	60

IV. RESULTS AND ANALYSIS

Table 3: Summary Report for different trial conducted during Experimentation

Exp No	Speed (rpm)	Feed (mm/min)	DOC (mm)	CF (lit/min)	Ra (µm)	Ra mean	S/N Ratio
1	1200	150	0.2	20	0.69	0.785	3.223
2	1200	180	0.3	40	1.07	1.065	-0.5876
3	1200	210	0.4	60	1.48	1.475	-3.4052
4	1400	150	0.3	60	0.75	0.795	2.4987
5	1400	180	0.4	20	1.01	0.935	-0.0864
6	1400	210	0.2	40	1.14	1.075	-1.138
7	1600	150	0.4	40	0.61	0.600	4.2934
8	1600	180	0.2	60	0.63	0.620	4.0131
9	1600	210	0.3	20	0.88	0.895	1.1103
10	1200	150	0.2	20	0.88	0.785	1.1103
11	1200	180	0.3	40	1.06	1.065	-0.5061
12	1200	210	0.4	60	1.47	1.475	-3.3463
13	1400	150	0.3	60	0.84	0.795	1.5144
14	1400	180	0.4	20	0.86	0.935	1.31
15	1400	210	0.2	40	1.01	1.075	-0.0864
16	1600	150	0.4	40	0.59	0.600	4.5829
17	1600	180	0.2	60	0.61	0.620	4.2934
18	1600	210	0.3	20	0.91	0.895	0.8191

a) S/N Ratio Analysis-

Table 4: Response Table for S/N Ratios
Smaller is better (Ra)

Level	Speed	Feed	DOC	CF
1	-0.6278	2.8180	1.8488	1.1859
2	0.6302	1.3866	0.7980	1.0816
3	3.1830	-1.0192	0.5386	0.9180
Delta	3.8109	3.8372	1.3102	0.2679
Rank	**2**	**1**	**3**	**4**

Table 5: Response Tables for Means

Level	Speed	Feed	DOC	CF
1	1.1083	0.7267	0.8267	0.8717
2	0.9350	0.8733	0.9183	0.9133
3	0.7050	1.1483	1.0033	0.9633
Delta	0.4033	0.4217	0.1767	0.0917
Rank	**2**	**1**	**3**	**4**

The level of a factor with the highest S/N ratio was the optimum level for responses measured. From the Table 7 and Figure 4 it is clear that, the better surface finish (Ra) can be obtained at cutting speed (1600 rpm), feed (150 mm/min),depth of cut (0.2mm) and coolant flow rate (20 lit/min). The response table includes ranks based on Delta statistics, which compare the relative magnitude of effects. The Delta statistic is the highest minus the lowest average for each factor. Minitab assigns ranks based on Delta values[9]; rank one to the highest Delta value, rank two to the Second highest, and so on[10].

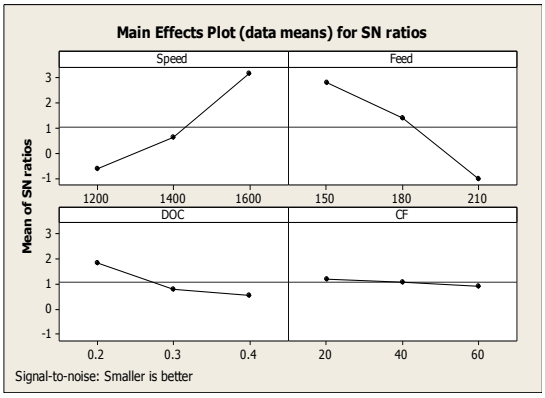

Fig 1. Effects of process parameters

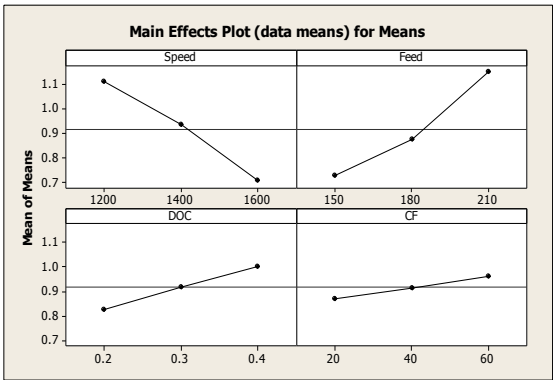

Fig2.Effects of process parameters on means on S/N Ratios

From main effect plot in figure 1.It has been shown that the value of a S/N ratio is maximum at speed of 1600 rpm and minimum at 1200 rpm, further it has been shown that the value of S/N ratio is increasing initially but it decreases further with the increasing in feed rate, and also as depth of cut increases, surface roughness also increases from 0.2 mm to 0.4 mm. Surface roughness value increases from 20 lit/min to 40 lit/min of coolant flow rate.

Source	DF	Seq SS	Adj SS	F	P
Speed	2	44.248	44.248	45.54	0.000
Feed	2	46.023	46.023	47.36	0.000
DOC	2	6.136	6.136	6.31	0.019
CF	2	0.307	0.307	0.32	0.737
Error	9	4.373	4.373		
Total	17	101.087			

Table 6: Analysis of Variance for S/N Ratio
S = 0.697035 R-Sq = 95.67% R-Sq(adj) = 91.83%

Source	DF	Seq SS	Adj SS	F	P
Speed	2	0.49124	0.49124	51.71	0.000
Feed	2	0.54988	0.54988	57.88	0.000
DOC	2	0.09368	0.09368	9.86	0.005
CF	2	0.02528	0.02528	2.66	0.124
Error	9	0.04275	0.04275		
Total	17	1.20283			

Table 7: Analysis of Variance for Ra S = 0.0689202 R-Sq= 96.45% R-Sq(adj) = 93.29

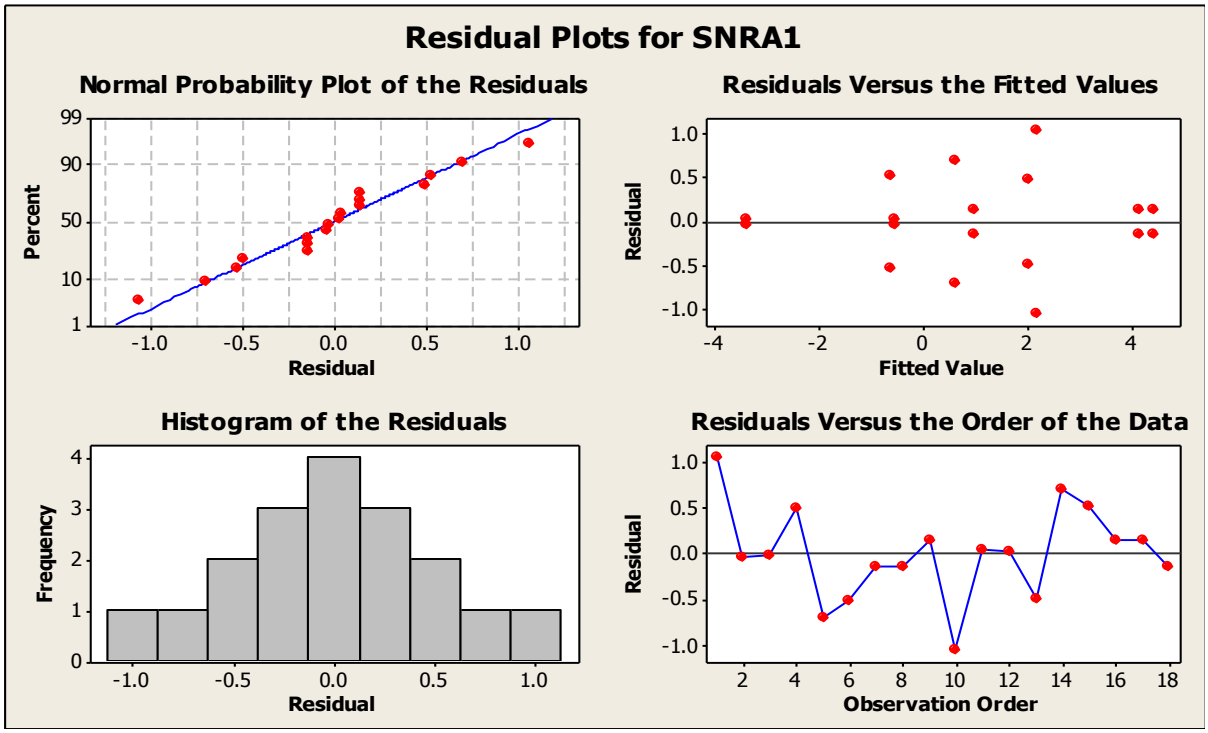

Fig 3.Residual plots for S/N ratio of Ra

Table 8: Comparison of Experimental Ra mean values and Predicted Ra mean values

Trial No	Predicated Ra mean value (µm)	Experimental Ra mean values (µm)	% Error
1	0.7709	0.785	1.79%
2	1.1159	1.065	-4.77%
3	1.4609	1.475	0.95%
4	0.7688	0.795	3.29%
5	0.9564	0.935	-2.28%
6	1.0365	1.075	3.58%
7	0.5893	0.600	1.78%
8	0.6394	0.620	-3.12%
9	0.877	0.895	2.01%

V. CONCLUSIONS

This study discussed the effects of face milling parameters on surface roughness of SAE 1541 by Taguchi method. From this research, following conclusions could be reached with a fair amount of confidence. Regardless of the category of the quality characteristics, the lower the better for surface roughness the lowest feed rate (B=150 mm/min),the highest cutting speed (A= 1600 rpm),lowest depth of cut (C=0.2 mm) and the lowest coolant flow (D=20 lit/min) lead to the lower surface roughness value In this study, feed and cutting speed are the most influencing factor compared to depth of cut. Coolant flow rate is the least significant factor for surface roughness.

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