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Experimental Investigation of Machining Parameters for Surface Roughness in High speed CNC Milling of Mild Steel Using DOE

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ABSTRACT: *As a basic machining process, End-milling is one of the most widely used metal removal processes in industry and milled surfaces are largely used to mate with other parts in die, aerospace, automotive, and machinery design as well as in manufacturing industries. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing costs. The effects of various parameters of the end milling process like spindle speed, depth of cut, feed rate have been investigated to reveal their Impact on surface finish using multiple regression prediction. The results of the analysis of variance (ANOVA) indicate that the depth of cut and spindle speed is the most influencing factor for modeling surface finish.*

KEYWORDS *; surface roughness, ANOVA, regression.*

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I. INTRODUCTION

As a basic machining process, milling is one of the most widely used metal removal processes in industry and milled surfaces are largely used to mate with other parts in die, aerospace, automotive, and machinery design as well as in manufacturing industries [1]. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing costs. The mechanism behind the formation of surface roughness is very dynamic, complicated, and process -dependent; it is very difficult to calculate its value through theoretical analysis [2]. Therefore, machine operators usually use "trial and error" approaches to set up milling machine cutting conditions in order to achieve the desired surface roughness. Obviously, the "trial and error" method is not effective and efficient and the achievement of the desired value is a repetitive and empirical process that can be very time- consuming. The dynamic nature and widespread usage of milling operations in practice have raised a need for seeking a systematic approach that can help to set up milling operations in a timely manner and also to help achieve the desired surface roughness quality [3].

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production costs [4]. Surface roughness has an impact on mechanical properties like fatigue behavior, corrosion resistance, creep life, etc [5]. It also affects other functional attributes of parts like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc. Sometimes, various catastrophic failures causing high costs have been attributed to the surface finish of the components in question [6]. As a result, there have been a great many research developments in modeling surface roughness and optimization of the controlling parameters to obtain a surface finish of the desired level since only proper selection of cutting parameters can produce a better surface finish.

II. MAREIALS AND METHODS

The Workpiece material is mild steel. The cutting tool is 4 edges HSS end mill with a 12mm diameter. Workpiece and tool- cutting levels are specified in table 1 and the experimental plan is illustrated in table 2.

Table1. Machining Parameters

	low	Center	High
	-1	0	1
Spindle Speed	600	800	1000
Feed Rate	0.3	0.45	0.6
Depth of Cut	0.1	0.15	0.2

Table2. Experimental Plan`

No.	Feed rate (A)	Spindle speed (B)	Depth of cut (C)	Surface roughness
1	0.3	600	0.1	2.18
2	0.3	600	0.1	2
3	0.45	800	0.15	2.5
4	0.6	600	0.1	2.2
5	0.6	600	0.1	2
6	0.3	1000	0.1	1.6
7	0.45	800	0.15	2.7
8	0.3	1000	0.1	1.7
9	0.6	1000	0.1	0.9
10	0.6	1000	0.1	1
11	0.3	600	0.2	3
12	0.3	600	0.2	3.2
13	0.6	600	0.2	3.4
14	0.6	600	0.2	4
15	0.3	1000	0.2	2.5
16	0.3	1000	0.2	2.1
17	0.6	1000	0.2	2.8
18	0.45	800	0.15	2.2
19	0.45	800	0.15	2.6
20	0.6	1000	0.2	2.9

Workpieces are 10 pieces of mild steel plate (100*70*12mm) that cut through row material. To achieve flat and uniform thickness both sides of the plates are machined with a face mill. 2 slots are machined on each workpiece by using HSS end mill of 12mm. each slot is one run with different cutting parameters. The surface roughness is measured in each slot. Each measurement needs to measure surface roughness 2 times and the average is set to analyses. After finishing the experiment data is analyzed by Design of Expert software.

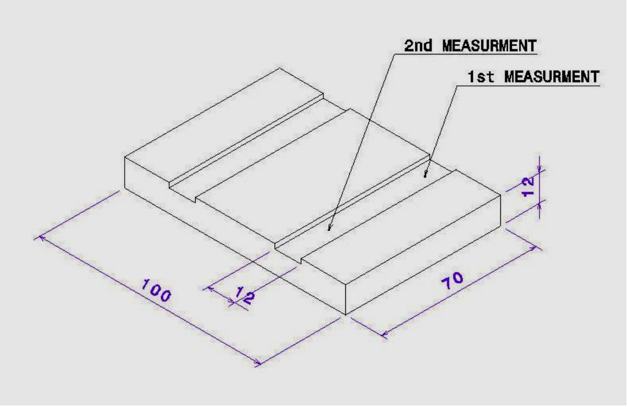

Fig.1. Measurement System

III. RESULTS AND DISCUSSIONS

According to Figure 2, there are two main effects significant (A and B) and also one interaction exists between A and c. the main factor A was chosen to follow the hierarchy principle. Figure 4.2 shows the Pareto chart for the effects of this model.

The "Lack of Fit F-value" of 1.95 implies the Lack of Fit is not significant relative to the pure error. There is a 17.27% chance that a "Lack of Fit F-value" this large could occur due to noise. Non-significant lack of fit is good we want the model to fit.

The "Pred R-Squared" of 0.8678 is in reasonable agreement with the "Adj R-Squared" of 0.9072."Adeq Precision" measures the signal- to -noise ratio. A ratio greater than 4 is desirable. So, the ratio of 22.104 indicates an adequate signal. This model can be used to navigate the design space.

Sufface roughness model = 2.37400 + 0.057500 * A - 0.40500 * B + 0.64500 * C + 0.23000* A * C

Table 3. ANOVA Analysis

Source	Sum of Square	df	Mean Square	F value	P-vlaue
Model	10.18	4	2.55	47.44	< 0.0001 significant
Feed rate(A)	0.053	1	0.053	0.99	0.3365
Spindle speed(B)	2.62	1	2.62	48.92	< 0.0001
Depth of cut(C)	6.66	1	6.66	124.07	< 0.0001
AC	0.85	1	0.85	15.78	0.0012
Residual	0.8	15	0.054		
Lack of fit	0.33	4	0.083	1.95	0.1727 not significant
Core total	10.98	19			
R^2	0.9267	**Adj R^2**	0.9072	**Pred R^2**	0.8678

Confirmation Test

In order to verify the adequacy of the model developed, two confirmation run experiments were performed. At The optimal condition, the factors were at spindle speed (B) 1000 rpm, feed rate (A) 0.6 m/min, and depth of cut (C) 0.1 mm.

Table.4.Confirmation Experiments

No	Feed Rate	Spindle Speed	Depth of Cut	Surface Roughness			
				Actual Ra	Predicted Ra	Residual	Error (%)
1	0.6	1000	0.1	1.1	1.15	0.05	4.54%
2	0.6	800	0.15	2.3	2.4	0.1	4.35%
3	0.6	800	0.2	3.4	3.3	0.1	2.94%

From graph 2 we can see that the normality of residuals is satisfactory. As can be seen from figure 3, the residuals versus predicted values to check for constant error.

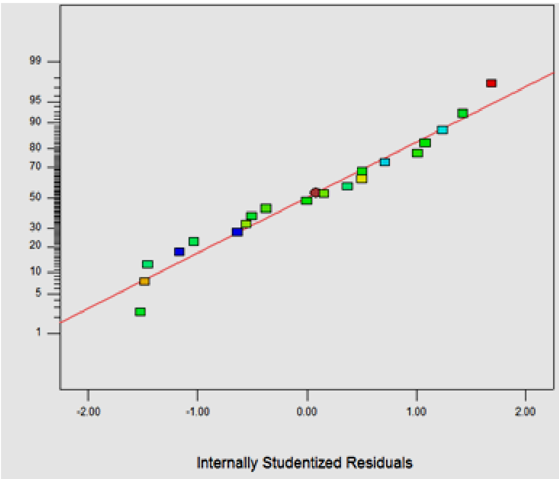

Fig.2. Normal Plot of Residuals

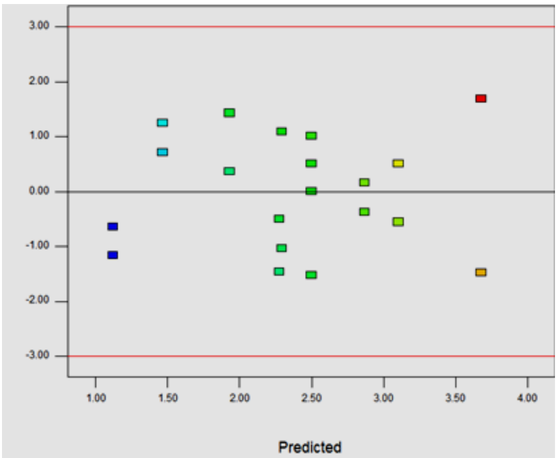

Fig.3. Residuals vs. Predicted

IV. CONCLUSION

In general, the regression model has been successfully built to predict the surface roughness (Ra) from the three input variables, which are spindle speed, feed rate, and depth of cut. Depth of cut was identified to be the most significant machining parameter and spindle speed was also significant. There was an interaction between the depth of cut and feed rate. These factors determine the surface roughness in the regression model. Finally, confirmation runs confirmed the result of this study

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