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Study on Influence of Process Parameters on Surface Roughness in CNC Milling Operation

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Abstract

Machine tools are a vital element in engineering manufacturing environment. It assists in the supply of products and components that meet the highest possible standards. An experimental approach was administered to evaluate the factor affecting surface finish in milling operation performed on ferrous material under wet cutting condition. Laboratory inspection was initiated to assess the effect of process parameters on surface finish. Cost effective experimental trials combining speed, feed and depth of cut were formulated using Taguchi L9 orthogonal array. The significant factor influencing surface topography was analyzed using analysis of variance (ANOVA) tool. The examination divulges that the surface roughness was found to be maximum at the lower levels of process meters in the milling process on mild steel material. The ANOVA depicts the process parameter which is greatly contributing to the surface texture.

Keywords: *Analysis of Variance, Process Parameter, Surface Roughness, Taguchi, Wet Cutting Condition.*

1.0 Introduction

Manufacturing is a process which transforms the raw material into a useful part or product. It involves several phases starting from pre machining to finishing with intermediate qualifications tests. In the process of making the useful part from a raw material requires reliable resources such as machine tools and testing facilities. The validation of reliable resources will also be crucial decision of an engineering manufacturing sector. Several methodologies, techniques were developed over a period of time to support this decision making process. These techniques enable the user to answer the queries of flexible and dynamic market demand. An experimental work was evolved for predicting the effect of feed on surface finish in milling operation on titanium alloy using finite element method. The investigation revealed that finite element method is useful to predict the value of feed, which monitors the surface texture[1]. During end milling machining process on cast alloy based metal matrix composites, it was found that spindle speed found to have greater influence than feed rate[2]. In an operation of orthogonal turn milling of ASTM B139, it has found that the feed was the directly to related to the nature of surface roughness, whereas feed and depth of cut came out as most on cutting tool vibrations[3]. Taguchi design optimization technique for turning operation was inspected to reduce the cost and time of laboratory work[4]. Low feed and higher speed leads to good surface finish in lathe operation performed for carbon alloy steels[5]. In another case, feed and radial travel of the tool contributes more on material removal rate and surface texture[6]. Taguchi proves to be an efficient technique in determining optimal cutting parameters for surface finish and cutting force[7]. An Experimental work, explored the impact of machining variables on surface roughness. One of the variable, namely feed rate was found to be the crucial factor for surface

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finish. The result also indicated that higher value of spindle speed and lower feed rate decreases the surface roughness[8]. Surface topography on a milled work piece surface was greatly affected due to increase in feed than speed[9]. A study on Surface roughness in end milling of AlSi/AlN metal matrix composite with carbide cutting tool reveals that an uncoated cutting tool gives better results with respect to surface finish compared to a coated carbide tool[10]. Insert tool advance on the face of the work piece contribute more on surface finish[11]. Feed and speed were the main contributing factors on surface roughness in plane milling process[12]. In a laboratory analysis, the impact of process variables on cutting tool vibration were examined. Cutting depth was found to be remarkable variable on vibrations[13]. The research works, especially based on process parameters optimization during milling operation has a limited exposure on automated machine tools such Computerized Numerical Control (CNC). In this context, an effort has been made to explore the influence of process parameters on surface roughness during milling operation in a vertical CNC milling machine tool.

2.0 Experimental Setup

The exploratory work on the mild steel was carried on FANUC make CNC milling machine having model number as SPARK XL under wet cutting conditions. The wet machining condition environment was created with water and Best spin 12 coolant combination, prepared at 20:1 ratio. Optimum number of laboratory trials were generated through Taguchi technique using predefined levels of parameters as shown in Table 1.

Figure 1 illustrates the experimental set up. The experimental trails were planned and performed as per the Taguchi technique by using machining variables, mentioned in Table 2. Offline measurement of surface texture on the machined surface of the work piece performed at three different locations and average of these three readings were recorded and tabulated as shown in Table 2. The instrument used for offline measurement of surface roughness was Talysurf instrument of Mitutoyo make with model number as SJ-210 which has maximum resolution of 360 microns and a minimum resolution of 0.002 microns.

3.0 Results and Discussions

The surface roughness data for different cutting parameters was recorded by conducting milling operations as per the Table 1. For each operation, the surface roughness was recorded and documented as shown in Table 2. The data was examined to determine the impact of variables on surface finish. ANOVA is used to determine the most significant parameter on surface roughness.

Table 1. Machining conditions

Variable	Details	
Machining Variables	Spindle speed (s) in rpm (3 levels)	600, 800, 1000
	Depth of cut (d) in mm (3 levels)	0.50, 0.75, 1.00
	Feed rate (f) in mm/min (3 levels)	40, 50, 60
Cutting tool	Solid carbide tool insert	
Work piece Material	Mild steel	
Cutting Condition	Wet	

Figure 1. Machining operation.

Figure 2. Measurement of surface roughness using Talysurf instrument.

3.1 Influence of Process Parameters on Surface Roughness

Surface roughness data is recorded under different cutting conditions. The interaction between machining parameters and surface roughness was established through a graphical plot as shown in Figure 3. The plots were generated by holding one process parameter and varying the other two parameters. The trend depicted in the plots reveals that there exists maximum surface roughness in the lower process parameters and reduces as the process parameters increases to mid-level. Further increase in the magnitude of process parameters indicates the considerable rise in surface roughness. However, the difference in magnitude of surface roughness at lower and higher level values parameters was found to be >10%. The reason for this variation could be higher frictional at cutting zone during lower values of process parameters.

Table 2. Data from laboratory trials

Inspection	s	d	f	Surface Roughness (Microns)
1	600	0.50	40	1.753
2	600	0.75	50	0.764
3	600	1.00	60	1.82
4	800	0.50	50	0.243
5	800	0.75	60	1.504
6	800	1.00	40	1.173
7	1000	0.50	60	0.783
8	1000	0.75	40	0.687
9	1000	1.00	50	1.475

3.2 Analysis of Variance (ANOVA)

Significant parameter on surface finish was decided using Analysis of Variance (ANOVA). This analysis was conducted using Design Expert software and the outcome is as shown in Table 3.

For any parameter to be considered as most significant in ANOVA, it must have the maximum F and minimum p value. Table 3 depicts the machining variables in the chronological order as most and least influencing parameter on surface finish during milling operation.

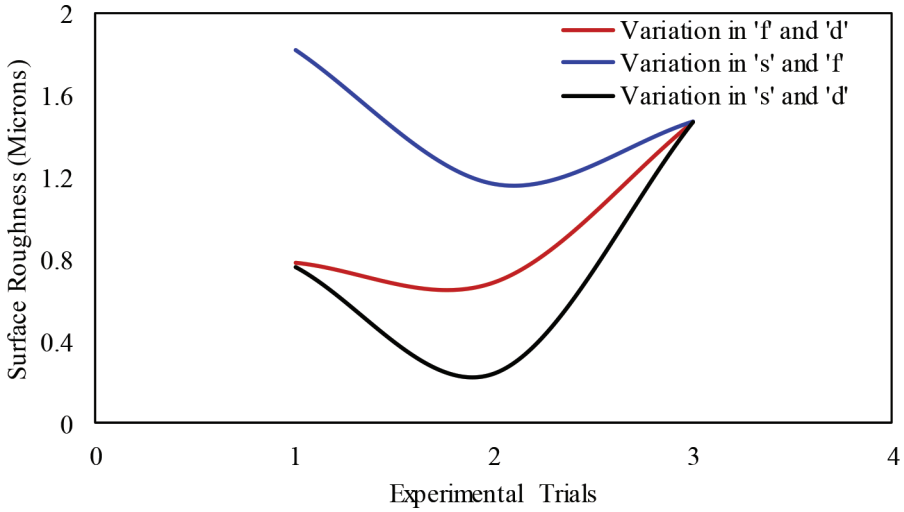

Figure 3. Influence of process parameters on surface roughness.

Table 3. Analysis of Variance (ANOVA)

Process Parameters	Sum of Squares	DoF	Mean Square	F Value	p value
s	1.802	2	0.901	3.662	0.214
d	0.008	2	0.004	0.017	0.983
f	0.058	2	0.029	0.119	0.893
Error	0.492	2	0.246		

4.0 Conclusions

The exploration determines the outcome of machining parameters on surface finish. Various efforts were undertaken with the combination of parameters, designed through Taguchi technique. An analysis was done using Analysis of variance (ANOVA), to evaluate the consequences of machining parameter on surface

finish. The recorded data was analysed graphically to explore the relationship between machining variables and surface finish during machining of ferrous metal. It has found that the lower levels of machining variables greatly influence the surface texture. The exploration yields out a conclusion to state, the most remarkable variable for surface finish as spindle speed.

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