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Taguchi Method Approach on Effect of Lubrication Condition on Surface Roughness in Milling Operation

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Abstract

This paper presents an investigation into Minimum Quantity Lubricant (MQL) and wet machining in milling processes of AISI 1060 Aluminum work material with the main objective is to determine the effect of lubrication conditions on the surface roughness. Three other parameters were also consider in this study; feed rate (FR), depth of cut (DOC) and cutting speed(CS).The levels each parameter had been selected is four levels. The ranges of feed rate 0.05mm/min,0.15mm/min,0.20mm/min and 0.25mm/min depth of cut used were 0.2mm,0.4mm,0.6mm and 0.8mm whereby the cutting speed values were 600mm/min,800mm/min,100mm/min and 1200mm/min. The surface roughness was evaluated using surface roughness tester Mitutoyo. The Taguchi method was used to predict the surface roughness. Finally, the experimental result showed good agreement with the estimated result. It was found that, MQL produced better surface finish as compared to wet machining. The result can significantly reduce cost and environmental pollution.

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Keywords: Milling machine,Lubricant condition,Taguchi method,surface roughness,regression analysis and ANOVA.

1. Introduction

Milling is a widely employed material removal processes for different materials. Milling process leads to high friction between tool and workpiece, and can result high friction between tool and workpiece, and can result high temperatures, impairing the dimensional accuracy and surface quality of product. The cutting fluid are used in machining processes reduce friction at tool, and remove chip. (Reddy and Rao, 2005).

Surface roughness is a commonly encountered problem in machined surfaces. It is defined as the finer irregularities of surface texture, which result from inherent action of the production process. Consequently, surface roughness has agreat influence on product quality. Furthermore a good-quality machined surface significantly improves fatigue strength, corrosion resistance, and creep life (Dhar *et al*., 2005).

The quality of the surface plays a very important role in the performance of milling as a good quality milled surface significantly improves fatigue strength, corrosion resistance, or creep life. Surface roughness also affect several functional attributes of parts, such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating, or resistance fatigue.(Lou et al.,1998).

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2. Methodology

MQL and wet lubricants has been used in this experiment. Based on observation, figure 1 shown MQL machining using a very small amount compared to the wet lubricant using higher amount. Figure 2 shows the condition of wet machining. The ways to control the MQL and wet machining are adjust the valve to minimum.

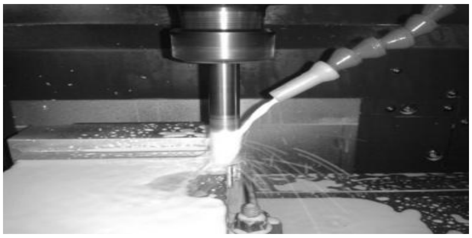

Fig. 1. MQL machining

Fig. 2. Wet machining

MQL) refers to the use of cutting fluids of only a minute amount—typically of a flow rate of 50–500 ml/h which is about three to four orders of magnitude lower than the amount commonly used in flood cooling condition. (MQL) in machining is an alternative to completely dry or flood lubricating system, which has been considered as one of the solutions for reducing the amount of lubricant to address the environmental, economical and mechanical process performance concerns. (Thakur *et al*., 2009).

Wet machining refers use a large quantities of lubricants. The wet machining can reduce the heat between the material surface and tools surface. In wet machining, the role of cutting fluids is transports the chips away from the cutting zone, at the same time cooling the chips and keeping dust and small particulates in liquids rather than in the air (Byers, 2006).

Taguchi Method was proposed by Genichi Taguchi, a Japanese quality management consultant. The method explores the concept of quadratic quality loss function and uses a statistical measure of performance called signal-to-noise (S/N) ratio, Antony, 2001). It is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized (Peace, 1993). The optimal setting is the parameter combination, which has the highest S/N ratio. Based on the signal-to-noise (S/N) analysis, the signal-to-noise (S/N) ratio for each level of process parameters are computed. Larger S/N ratio corresponds to better performance characteristics, regardless of their category of performance. It means that the level of process parameters with the highest S/N ratio corresponds to the optimum level of process parameters.

Taguchi method is usually used in an analysis that uses a lot of factor low than two will use the factorial design. When the total factors have been more than two, the number of experiment also will increase, and then the solution will be used Taguchi method. The flow of process when analysis by using Taguchi method.

The first step before using the technique Design of Experiment (DOE) knew how many factors and level. Table 1 shown the factor and level had been decided. Actually, method of Taguchi has been be used if the factor has more than two to be able to reduce the number of the experiment.

Table 1. Factor And Level

Factors	**Levels**			
	1	2	3	4
CS	600	800	1000	1200
DOC	0.05	0.15	0.20	0.25
FR	0.1	0.2	0.3	0.4

After identifying the number of factors and level, orthogonal array of methods used for the experiment to knew the total of experiment. The total should be known in two ways, namely using a table or MINITAB software. In this experiment L16 has been used after recommended by orthogonal array based on the three factors and four levels. Table 2 shown the total number experiment has been conducted.

Table 2: No Of Experiment Had Been Conducted

EXP	**MQL/Wet**		
	CS	DOC	FR
1	600	0.2	0.05
2	600	0.4	0.15
3	600	0.6	0.20
4	600	0.8	0.25
5	800	0.2	0.15
6	800	0.4	0.05
7	800	0.6	0.25
8	800	0.8	0.20
9	1000	0.2	0.20
10	1000	0.4	0.25
11	1000	0.6	0.05
12	1000	0.8	0.15
13	1200	0.2	0.25
14	1200	0.4	0.20
15	1200	0.6	0.15
16	1200	0.8	0.05

After the experiment knew the number required,experiment started on fixed recommendation.The vales of surface roughness has been taken into account after the experiment complete.

A multiple regression analysis was performed to demonstrate the fitness of the experimental measurement, as shown result and discussion.The used of MINITAB statistical software.

The flow of processes is, first a linear polynimial model was developed to control the roughness data.The fitness characteristic is shown by the following:

(1)

Where b1,b2 and b3 are estimate of the process parameters and In a multiple regression analysis,R2,which is called R-sq, is the correlation coeffcient and should fall between 0.8 and 0.1.

Taguchi recommends the use of the S/N ratio for the determination of the quality characteristics implemented in engeenering design problems.The S/N ratio characteristics can be devided into three stages:smaller the better,nominal the best and larger the better, signed-target type (Phadke,1989).Since the purpose of this study is to minimize surface roughness within the optimal levels of process parameters, the smaller the better quality characteristic is selected.

In addition to the S/N ratio, a statistical analysis of variance (ANOVA) ca be emplyoed to indicate the impact of process parmeters on surface roughness.In this way, the optimal levels of process parameters can be estimated.The result of the for mentioned subjects are given in the following sections.

3. Result and Discussion

The result will be expressed in tables and graphs to provide the reader with a clearer view. The experimental result will then be analyzed and compared using MINITAB software. Table 3 shows the result for the surface roughness and S/N ratio. *Ra* value will get from surface roughness tester (Mitutoyo).Each Ra value was repeated at least five times. S/N ratio gets from MINITAB software.

Table 3: Result *Ra* Value And S/N Ratio

EXP	MQL		Wet	
	Ra Value	S/N ratio	*Ra* Value	S/N ratio
1	0.365	12.8033	0.399	7.98054
2	0.814	1.78751	0.844	1.47315
3	1.789	-5.05221	1.885	-5.50623
4	2.267	-7.10903	2.514	-8.00731
5	0.581	4.71648	0.640	-3.87640
6	0.255	13.1911	0.372	-8.00234
7	2.269	-7.11669	2.394	-7.58248
8	1.442	-3.17931	1.679	-4.50101
9	1.162	-1.30412	1.220	-1.72720
10	1.917	-5.65244	1.982	-5.94207
11	0.358	8.92234	0.414	7.65999
12	0.559	5.05176	0.722	4.70154
13	1.777	-4.99375	1.808	-5.14397
14	0.972	0.246675	0.987	0.11366
15	0.464	6.66964	0.474	6.48443
16	0.318	9.95146	0.440	7.13095

3.1.Regression Analysis

A multiple regression analysis was performed to demonstrate the fitness of the experimental measurements. The regression was simulated using MINITAB software.

In a multiple regression analysis, R^2, Which is called R-sq, is the correlation coefficient and should fall between 0.8 and 1.In this study, equation 2 shows the R^2 for wet machining is 0.958.Then equation 1 show the R^2 for wet machining is 0.947.As such, the multiple regression models for surface roughness matches very well with the experimental data

3.2.Analysis of Variance (ANOVA)

In this study, the ANOVA will examine the influence of cutting parameters to the quality of surface roughness. Table 4 shows the ANOVA get from MINITAB software. The result show the feed rate is more significant parameter which is the value of F-ratio is 169.89 more higher than cutting speed and depth of cut.

Table 4. Anova Mql Machining

Source	DF	Seq SS	Adj SS	Adj Ms	F	P
CS	3	0.34143	0.34143	0.11381	7.68	0.018
DOC	3	0.21592	0.21592	0.07197	4.86	0.048
FR	3	7.55176	7.55176	2.51725	169.89	0.000
Error	6	0.08890	0.08890	0.01482		
Total	15	8.19801				

Table 5 shows the result of ANOVA for the Wet machining. The significant parameters almost same with the result for MQL machining. The feed rate shows the influence parameter more affect to the quality of surface roughness.It show the F-ratio for the feed rate is 234.78.

Table 5. Anova Wet Machining

Source	DF	Seq SS	Adj SS	Adj Ms	F	P
CS	3	0.34143	0.34143	0.11381	7.68	0.018
DOC	3	0.21592	0.21592	0.07197	4.86	0.048
FR	3	7.55176	7.55176	2.51725	169.89	0.000
Error	6	0.08890	0.08890	0.01482		
Total	15	8.19801				

3.3.Optimal Level Ra value

The Taguchi method will approve the optimal level for each level.The MINITAB software will be used to analyzed the data Ra value from experiment.Table 6 show the result from MINITAB software the more influence cutting parameter to the quality of surface roughness is feed rate.It can be judge the rank parameter on table is feed rate follow by cutting speed and depth of cut.

Table 6:Optimal Level Ra Value Mql

Level	CS	DOC	FR
1	1.2748	0.9372	0.9908
2	1.1375	0.9902	1.0045
3	0.9990	1.2200	1.3413
4	0.8827	1.1465	2.0575
Delta	0.3920	0.2828	1.0667
Rank	2	3	1

Table 7 shows the result optimal level Ra value for the wet machining.The result from MINITAB software shows the cutting parameter most significant almost same with the result from MOL machining feed rate.

Table 7: Optimal Level Ra Value WET

Level	CS	DOC	FR
1	1.4105	1.0168	1.2128
2	1.2778	1.0528	1.6350
3	1.0495	1.2918	1.4428
4	0.9272	1.3037	2.1745
Delta	0.4832	0.2870	0.7617
Rank	2	3	1

3.4.Calculated Ra Value

MQL machining:

The minimum surface roughness using Taguchi method will get from table 7, Ra response surface roughness.The optimal level will choose to know the calculated surface roughness.From that table the optimal level will be consider is, feed rate level 1, cutting speed level 4, and depth of cut level 1.

Cutting Speed(4) + Depth of Cut (1) + Feed Rate (1) – (Factor x Average Ra)
(4)

=0.8827 + 0.9372 + 0.9908 – (3x 1.021)

=0.2523 μm

Depending on these predictions, it can be inferred that calculated surface roughness is 0.2523 μm, which is smaller than 0.2546 μm from experiments.

Wet machining:

=0.9272 µm + 1.0168 µm + 1.2128 µm – (3 x 1.166 µm)

= 0.3412 µm.

Depending on these predictions, it can be inferred that calculated surface roughness is 0.3412 µm, which is smaller than 0.3412µm from experiments.

4. Conclusion

According to the experiment result, shows that lubrication condition is one of the factors affect the surface roughness. The effect of different lubrication condition, including MQL, Wet and dry cutting, on the surface roughness, Ra was analyzed in this study. The conclusions are MQL shows the better surface roughness compare with Wet machining. S/N noise ratio and Analysis of Variance (ANOVA) approve that parameter more significant affect the surface roughness is feed rate follow by cutting speed and depth of cut. Almost the correlation between dependent variable with independent variable very close and strong, which is approval by using multiple regression analysis. The value experiment with calculated almost closed. It means the Taguchi method have produced more accurate prediction value.

The result calculated for using MQL 0.2523 µm.Then the experiment result has shown 0.2546 µm..The percentage error occur between calculated and experiment is 0.9 %.The result for wet get 0.3412 µm..Then the experiment result has shown 0.3720 µm..The percentage error occur between calculated and experiment is 8.3 %.The percentage wet machining higher than percentage MQL machining.It can be conclude the some error more occurred during wet machining.The error perhaps occurred it vibration machine and etc.

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