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Analysis Of Effect Of Cutting Speed And Feed Rate On Surface Roughness During The Machining Of 6061 Aluminum Alloys

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ABSTRACT

This study investigated the effects of the machining parameters, cutting speed, feed rate on surface roughness of 6061 aluminum alloys. The research also examined the effect of cutting parameter, on surface roughness by the use of variance analysis (ANOVA). A confidence level of 95% was obtained between all the factors as presented according to the result of variance analysis. Feed rate with 48.14% significance contribution was found the most important factor affecting surface roughness. Aluminum Alloy 6061 was machined with tungsten carbide tool using all machining processes with a PATHER 1350 series, lathe machine. The surface roughness of the work piece materials was measured using MAHR-Perthometer M1 measuring equipment. Two factors were used at three levels (3^2). The factors are cutting speed and feed rate. The experimental design was done using (Design-Expert7 software) full factorial experimental design. The geometry of the cutting tool was 5° three different cutting speed 80m/min, 90m/min. 100m/min and feed rate 0.10mm/rev, 0.15mm/rev, 0.20mm/rev according to ISO 3685, and constant depth of cut 1.5 mm was selected as the machining parameters. Build – up edge in the cutting tool and work piece were formed most at cutting speed 80m/min and federate 0.10mm/rev. In order to measure surface roughness, cut – off length and sampling length were assumed to be 0.8mm and 5.6mm, respectively. The minimum surface roughness of 1.04µm was determined at cutting speed of 100m/min and 0.20mm/rev feed rate, while the maximum surface roughness of 2.03µm was obtained at cutting speed of 80m/min and feed rate of 0.1mm/rev. Each cutting experiment was repeated three times to ensure that the experimental results were repeatable

Keywords: cutting speed, feed rate, surface roughness, build – up edge, wearing, cutting fluid.

INTRODUCTION

In many industrial fields, Aluminum and its alloys are widely used as suitable materials for construction needed to be lighten. Aluminum, with over 100 possible alloying elements, even leaving out the elements that are very rare, millions of useful alloy combinations would seem possible. The possibilities are quite limited if small alloy variations are ignored (Enver *et al.*, 2015). It is commercially available as rough or cast in the form of ingots, bars, sheet, etc, it is a slivery while metal especially, noted for its density, about a third of steel. It has good electrical and thermal conductivities as well as good ductility and malleability. It can be surface finished within a wide range of values. It has the limitation of lower strength at elevate temperature, limited formability and relatively higher cost compared to steel (Aalco, (2010). It is widely used in the food industries, for structural applications, cryogenic applications, and extensively in transportation industry, Mathew (2010). According to Wilson (2016), 6061 aluminum alloy is an aluminum base alloy often used in the aerospace industries. It is among the strongest available aluminum alloy, as well as having high hardness. He further states that 6061 aluminum alloy is the second most popular of the 2000 series aluminum alloys after 6063 aluminum alloys. 6061 aluminum alloy is commonly extruded and forged (Polmear, 1995). Prior to the adoption of the aluminum association alloy designation in 1935, 6062 aluminum alloy was known by the industry conventional designation "61s". Talco, (2017), the composition of 6061 aluminum alloy include; Si, Mg, Cu, Mn, Ti, Zn, Fe. Talco, (2017)

On the other hand, Built-up edge effectively changes tools geometry and rake steepness. It also reduces the contact area between the chip and the cutting tool, leading to the reduction in the power demand of the cutting operation, slight increase in tool life; since the cutting is partly being done by built-up edge rather than the tools itself (Fang et al, (2005). According to Hassan and Taskesem (2008), the built-up edge and build up layer formation on the cutting tools is caused by tool-tool chip interface temperature and extreme pressure. The work piece material adheres to the rake face of the cutting tools in two different forms. The formation of built-up edge (BUE), have negative effects, on the quality of work piece, specifically;

a) Poor surface finish, since bits of the built-up edge (BUE) eventually break off and stick to the work piece. These bits tend to be problematic since due to the work hardening they underwent, they are very hard and so become abrasive.
b) Excessive work hardening at the surface of the work piece (Rao, 2009).

MATERIAL AND METHODS

The materials used for this research work were 6061 aluminum alloy, tungsten carbide and cutting fluid. 6061 aluminum alloy was selected due to the fact that it has a wide range of application in the construction and aerospace industries, etc. it was cut and casted into 80mm diameter and 500mm length according to American Society for Testing Materials (ASTM A751) standard, the specimen was machined according to the experimental design (3^2) two factors randomized complete block design. The machining process was done with PANTHER 1350 series industrial type lathe machine with tungsten carbide, insert to the tool holder. Surface roughness of the work piece was measured using MAHR – perthometer MI measuring equipment. The geometry of the cutting tool was 5^0, the cutting speed were varied from 80 to 100m/min, feed rate was within 0.10, 0.15 and 0.20mm/rev according to ISO 3685, and 1.5mm constant depth of cut used for the entire experiments. In order to measure surface roughness, cut – off length and sampling length were assumed to be 0.8mm and 5.6mm, respectively. Each cutting experiment was repeated three times to ensure that the experimental result was repeatable.

RESULT AND DISCUSSIONS

Design summary, selection of factors and levels for cutting speed and feed rate are presented in table 1 and 2 respectively. The effects of cutting speed and feed rate on the surface roughness were determined by applying analysis of multiple variances on the determined data. Significant changes with a confidence level of 95% were determined between all the factors according to the result of the analysis of variance. The analysis of variance implemented to determine the effect of cutting speed and feed rate on surface roughness is presented in table 4 and 5. P – Values presented in table 4 and 5 are the realized significance levels, associated with the F – tests for each source of variation. The sources, with a P-value less than 0.10 are considered to have a statistically significant contribution to the performance measures. The last column of table 4 and 5 shows that the percent contribution of each source to the total variation indicating the degree of influence on the result. Table 6 shows that the only significant factor for the surface roughness is feed rate which has 48.14% of the total variation, cutting speed with 45.85% significant level has less contribution on surface roughness.

According to the test results on fig 3 and 4 maximum surface roughness of (2.03μ m) was obtained at 80m/min cutting speed and feed rate of 0.10mm/rev while minimum surface roughness of (1.04) was obtained at 100m/min cutting speed and 0.20mm/rev feed rate.

CONCLUSION

The effect of machining parameters namely, cutting speed and feed rate on surface roughness was both experimentally and statistically investigated. It was observed from the test result that the most important parameter affecting surface roughness is feed rate, and significance level for these effects was 48.14% for surface roughness. It was found that build – up edge formation on tool surface at the cutting speed of 80m/min was larger than those of 90 and 100 m/min. hence cutting speed must be selected above 80 – 90m/min in order to prevent build – up edge formation.

Table 1: Selection of factors and levels for cutting speed and feed rate

Factors	Level		
	I	II	III
Cutting Speed (m/min)	80	90	100
Feed rate (mm/rev)	0.1	0.15	0.2

Table 2: Machining conditions for full factorial design of experiments

Number	Runs	Block	Cutting speed (m/min)	feed rate (mm/rev)
1	1	Block 1	80	0.1
2	4	Block 1	90	0.1
3	7	Block 1	100	0.1
4	2	Block 1	80	0.15
5	5	Block 1	90	0.15
6	8	Block 1	100	0.15
7	3	Block 1	80	0.2
8	6	Block 1	90	0.2
9	9	Block 1	100	0.2

Table 3: Results of Surface Roughness at Varying Input Parameters

Std	Runs	Block	Factor 1: Cutting speed (m/min)	Factor 2: feed rate (mm/rev)	Response 2 Surface Roughness (µm)
1	1	Block 1	80	0.1	2.03
2	4	Block 1	90	0.1	1.31
3	7	Block 1	100	0.1	1.50
4	2	Block 1	80	0.15	1.80
5	5	Block 1	90	0.15	1.66
6	8	Block 1	100	0.15	1.25
7	3	Block 1	80	0.2	1.74
8	6	Block 1	90	0.2	1.81
9	9	Block 1	100	0.2	1.04

Table 4: Variance Analysis (ANOVA) Regarding the Surface Roughness (Ra)

	Sum of Square (SS)	Degree of Freedom (df)	Variance	F value	P value Prob > F	C (%)
Model	3.44	8	0.43	168.11	<0.0001	
Factor A: Cutting Speed	1.60	2	0.80	311.85	<0.0001	45.85%
Factor B: Feed rate	1.68	2	0.84	327.36	<0.0001	48.14%
A*B	0.17	4	0.042	16.61	<0.0001	4.87%
Error	0.046	18	2.559		0.0030	1.32%
Total	3.49	26				100%

SS: sum of squares, df: degree of freedom, C: percent contribution
Factor A; Cutting speed (80, 90, 100 m/min)
Factor B; Feed rate (0.1, 0.15, 0.20 mm/rev)

Fit Statistics

Std. Dev.	0.281	**R^2**	0.457
Mean	1.56	**Adjusted R^2**	0.412
C.V. %	17.9	**Predicted R^2**	0.313
		Adeq Precision	6.35

The **Predicted R^2** of 0.3126 is in reasonable agreement with the **Adjusted R^2** of 0.4116; i.e. the difference is less than 0.2.
Adeq Precision measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 6.354 indicates an adequate signal. This model can be used to navigate the design space.

Table 5: Process Parameters and their Experimental Actual Values and Predicted Values of Surface Roughness

Run	Cutting speed rpm	feed rate (mm/rev)	Predicted value Surface roughness (Ra)	Actual value Surface roughness (Ra)
1	80	0.1	2.01	2.03
4	90	0.1	1.26	1.31
7	100	0.1	1.45	1.50
2	80	0.15	1.71	1.80
5	90	0.15	1.60	1.66
8	100	0.15	1.20	1.25
3	80	0.2	1.65	1.74
6	90	0.2	1.75	1.81
9	100	0.2	1.02	1.04

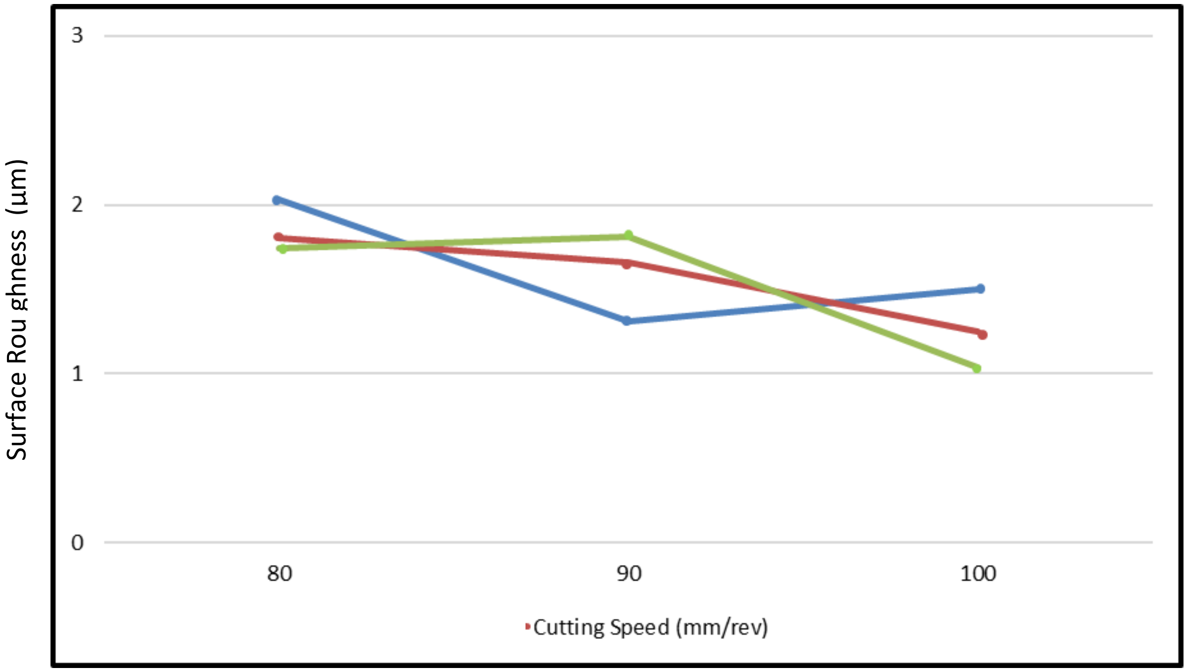

Fig 1: Average Surface roughness vs Cutting speed

Key: Blue – cutting speed at 80 m/mi

Red – cutting speed at 90 m/min

Green – cutting speed at 100 m/min

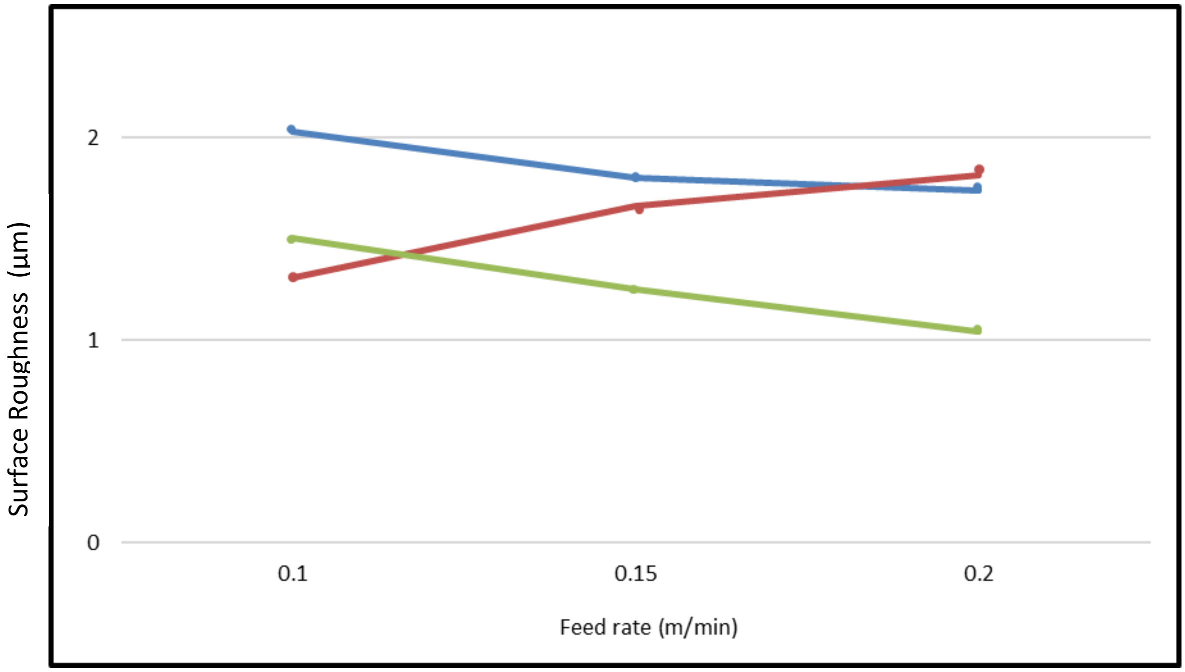

Fig 2: Average Surface roughness vs Feed rate

Key: Blue – feed rate at 80 m/mi
Red - feed rate at 90 m/min
Green – feed rate at 100 m/min

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