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Effect of Machining Parameters in Milling Aluminum Alloy 7075-T6 under MQL Condition

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Abstract: ***Minimum quantity lubrication (MQL) is an eco-friendly method, where a small amount of fluid was sprayed to cutting edge in mist form with the aid of the air. The foregoing studies revealed that inappropriate machining parameters without the assistance of the cutting fluid methods became a major challenge in milling aluminum alloy 7075-T6. The paper presents the findings of the experimental work to assess the effect of machining parameters towards cutting tool life and machined surface roughness in milling aluminum alloy 7075-T6 at high cutting speed under MQL condition. An eight-run experiment was designed according to full factorial design based upon two levels of cutting speed (500 m/min, 600 m/min), feed rate (0.12 mm/tooth, 0.15 mm/tooth), and axial depth of cut (1.40 mm, 1.70 mm) and then analyzed employed ANOVA to determine the significant machining parameters. The cutting tool life and machined surface roughness were assigned by the rejection criterion of tool flank wear in the milling operation. The optical microscope and portable surface roughness tester were applied to analyze tool wear and average surface roughness value. Cutting speed and feed rate were significantly contributing to the tool life and surface roughness. The longest tool lifespan of 20.14 minutes and lowest surface roughness value of 0.569 µm were obtained at a speed of 500 and 600 m/min, respectively, with a low combination of the rest of parameter which are 0.12 mm/tooth and 1.40 mm.***

Keywords: Minimum Quantity Lubrication, Machining Parameters, Aluminum Alloy 7075-T6, Tool Life, Surface Roughness.

I. INTRODUCTION

Over the year the machining industries has become more and more stringent on the usage of machining fluid or lubrication due to the rise of concern on how it effects their worker and especially the general environment as a whole while abiding to the international standard 14001 which is to protect the environment from industrial waste [1]. In the machining process, the uses of the coolant are to take away the heat generated by the material removal process and the heat arise at the cutting edge as it will affect the final work piece quality and many researchers have shown that the cooling method used while machining the work piece will have an impact on determining the quality of the surface roughness of the finished product [2]. Cutting fluid have been used in many machining process to cool down the tool and the cutting zone of the machined work piece. However, it is expensive and bring negative impact on the environment [3]. Hannu et al. [4] found out that respiratory and skin symptoms was reported as common diseases occurred in metal working machinist who kept regular contact with metal cutting fluid. One of the solution for this problem is using an alternative way to cool down the workpiece during machining process. Joshua et al [5] suggested the uses of minimum quantity lubrication (MQL), a method where a very minimum amount of fluid in range of 5 to 100 mL/h is sprayed to cutting edge in the mist form during the machining process and has proven to benefit environment. This however introduce a new parameter in the machining process and different machining parameter will produce different results, an analysis of the surface topography of aluminum 7075 showed that the surface roughness was sensitive to changes in cutting parameters [6]. This interaction of cutting speed, feed rate, depth of cut and lubrication method have to be researched properly first before any machining process is to be taken on in order to obtain the optimum result such as good surface roughness, longer tool life, chip breakage, reducing cutting temperature, reducing cutting force and various others outcomes [7]. This paper presents the impact of involved machining parameters in milling towards the tool life and surface roughness of aluminum alloy 7075-T6 at high speed cutting under MQL condition.

II. METHODOLOGY

Aluminum alloy 7075-T6 along with a length of 300 mm, a width of 150 mm and a thickness of 40 mm was milled DECKEL MAHO DMU 50 eVolution CNC five axes milling machine using uncoated carbide insert. Machine tool equipped with functional capabilities of spindle speed and feed, which are 16000 rpm and 20000 mm/min, respectively. The composition of work piece material was Al of 90.3%, Zn of 5.6%, Mg of 2.5%, and Cu of 1.6% as provided by the manufacturer.

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A thickness of the work piece surface almost 1 to 2 mm was skimmed off in order to eliminate any surface flaws that can influence the machining result. The controlled machining parameters includes cutting speed (vc) of 500 and 600 m/min, feed rate (fz) of 0.12 and 0.15 mm/tooth, and axial depth of cut (ap) of 1.40

III. RESULTS AND DISCUSSION

Table 1 shows the results of the cutting tool life and machined surface roughness with the full factorial design. The results obtained from eight experiment runs.

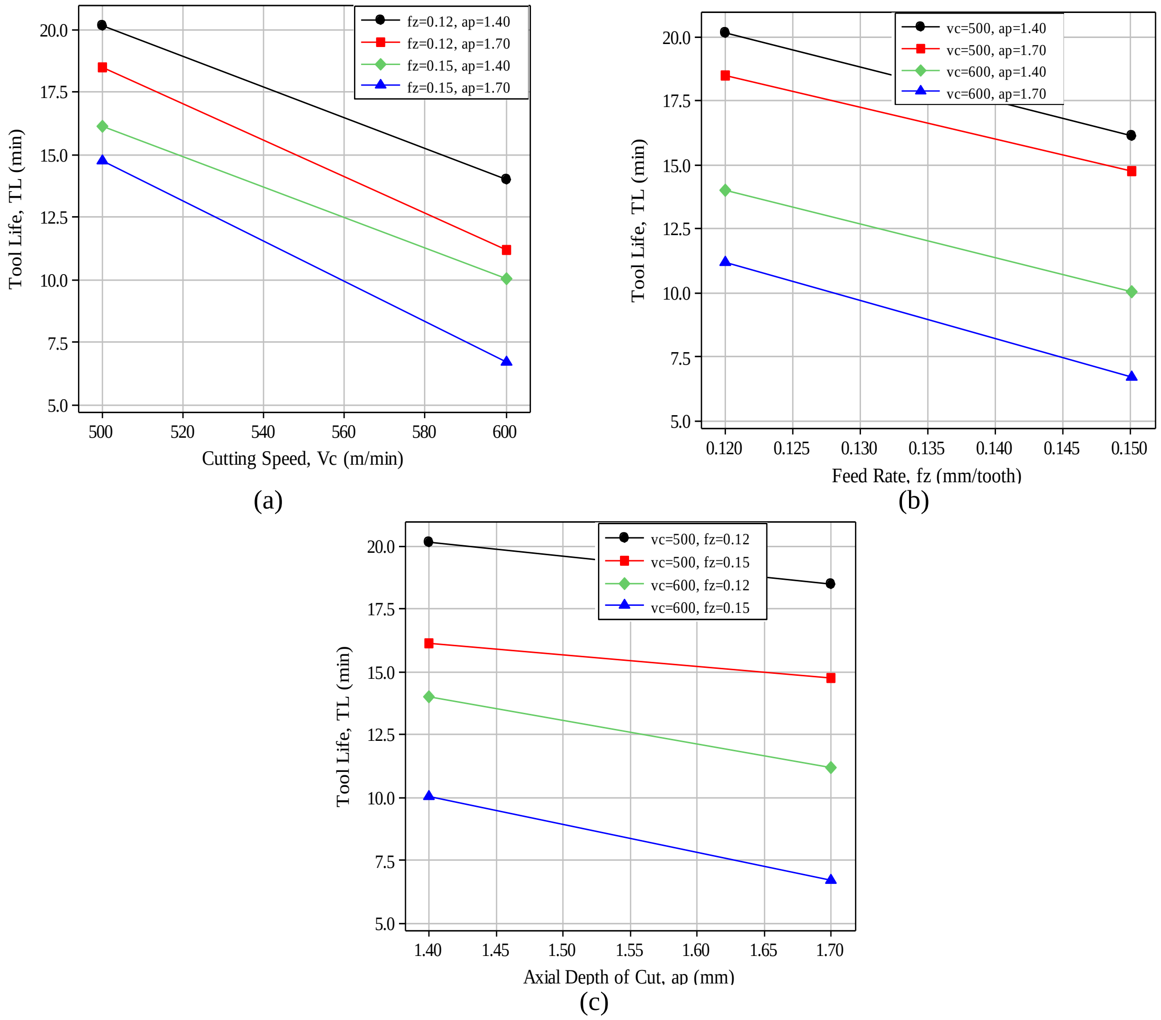


Fig. 1. Effect of machining parameter on tool life (a) cutting speed (b) feed rate (c) axial depth of cut

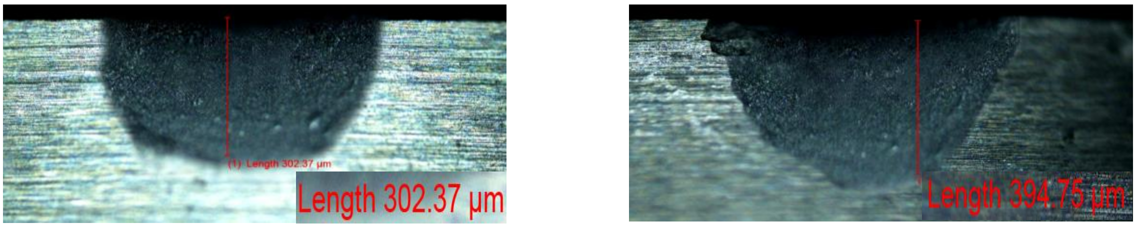
and 1.70 mm while the radial depth of cut (ae) restricted to 14 mm.

The tool life criterion was evaluated after achieving tool flank wear (vb) of 0.30 mm in accordance with ISO 8688-2-1989 [8]. Flank wear was examined and measured at every pass interval employed an optical microscope in which manufactured by Olympus BX53M. Furthermore, the measurements of surface roughness (Ra) were determined on the machined surface using Mitutoyo Surftest SJ-210 portable surface roughness tester and 0.80 mm was set as cutoff distance. The Ra values were measured at three different locations in the perpendicular direction to feed and subsequently, the Ra average was computed. A full factorial design was applied for the ease of designing the experiments carried out wherein a total of eight runs was developed that ensue from a merger of three controlled factors and two levels. Analysis of variance (ANOVA) was then employed to define the machining parameters most influence tool life and surface roughness.

Table 1: Result of tool life and surface roughness

No	vc, (m/min)	fz, (mm/tooth)	ap, (mm)	TL, (min)	Ra, (µm)
1	500	0.12	1.40	20.14	0.691
2	500	0.12	1.70	18.46	0.720
3	500	0.15	1.40	16.11	0.752
4	500	0.15	1.70	14.77	0.803
5	600	0.12	1.40	13.99	0.569
6	600	0.12	1.70	11.19	0.605
7	600	0.15	1.40	10.07	0.635
8	600	0.15	1.70	6.71	0.680

Tool life is denoted as TL where defined as the total cutting time when the tool has become worn. It was normally occurring due to the temperature produced in the cutting edge. From Table 1, the experimental results of the tool life show that the lifespan between 6.71 and 20.14 minutes was taken.



(a) (b)

Fig. 2. Tool flank wear at (a) longest tool life (b) shortest tool life

Maximum tool life of 20.14 minutes was attained at cutting speed of 500 m/min, the feed rate of 0.12 mm/tooth, and axial depth of cut of 1.40 mm after milling with the uncoated carbide. The shortest tool life of 6.71 minutes was obtained at an elevated merger of cutting speed, feed rate, and axial depth of cut, which are 600 m/min, 0.15 mm/tooth, and 1.70 mm, respectively.

Figure 1 illustrates the influence of machining parameters on tool life. Prolonged tool lifespan was obtained by a decrease in cutting speed and feed rate along with the axial depth of cut as depicted in Figure 1 (a). The shortest tool life was obtained by a heightened in the value in cutting speed, feed rate, and axial depth of cut. Similar results were revealed by Khorasani et al. [9] who study the correlation of machining parameters in the end milling of aluminum 7075-T6, mainly cutting speed, feed rate, and depth of cut on tool life employ Artificial Neural Networks (ANN). However, they found that the longest tool life was taken at the moderate value in cutting speed and the lowest value of feed rate. It seems that the contradicting machining parameters were suspected due to a small ability of machine tool in a tendency to achieve a longer tool life.

In addition, Figure 1 (b) depicts the result of the feed rate effect on the tool life shows it decreases as the feed rate increases from 0.12 to 0.15 mm/tooth. The shortest tool life of 6.71 minutes occurs at a feed rate of 0.15 mm/tooth at a speed of 600 m/min. The longest tool lifespan of 20.14 minutes occurred at a feed rate of 0.12 mm/tooth at a speed of 500 m/min. It revealed that a low feed rate offers a longer tool lifespan. Apart from that, Figure 1 (c) exhibits the influence of axial depth of cut on tool life at each cutting speed and feed rate. It is evident that the tool life decreases when the axial depth of cut was increased from 1.40 to 1.70 mm. The longest and shortest lifespan, which is 20.14 and 6.71 minutes occurred in the axial depth of cut of 1.40 and 1.70 mm at a speed of 500 and 600 m/min, respectively. It reveals that longer tool life can be achieved with a low axial depth of cut.

Figure 2 (a) and (b) exhibits the tool flank wear on the uncoated carbide inserts under the near-dry machining at low combination of machining parameters and vice versa, respectively. It is noticed that a good wear pattern has appeared in the longest tool life of 20.14 minutes compared to shorter tool life caused by the capability of low values of machining parameter in decelerating the cutting temperature indirectly prevent the thermal shock on the cutting tool edge.

Table 2 presents the ANOVA results pertaining to the cutting tool life under MQL. It shows clearly that the cutting speed was most influence the tool life followed by feed rate due to the P-values are less than 0.05 at 95% confidence level. P-values of 0.021 and 0.036 were representing both significant factors. On the other hand, the other factors and interactions as stated in Table 2 are a negligible influence on tool life due to the fact the P-value is greater than 0.05.

Table 2. ANOVA for tool life

Factor	DF	SS	*F*	*P*
vc	1	94.669	935.00	0.021
fz	1	32.482	320.81	0.036
ap	1	10.534	104.04	0.062
vc*fz	1	0.058	0.57	0.588
vc*ap	1	1.232	12.17	0.178
fz*ap	1	0.006	0.06	0.847
Error	1	0.101		
Total	7	139.082		

The surface roughness (Ra) on the machined surface was influenced by the machining parameters and condition. In general, the lower value of Ra provides a promising effect on the surface of the machine. Figure 3 shows the results for surface roughness at varying machining parameter using uncoated carbide inserts. From Table 2, the results of the surface roughness show that the Ra values between about 0.569 and 0.803 µm was recorded. Lowest Ra value of 0.569 µm was obtained at cutting speed of 600 m/min, the feed rate of 0.12 mm/tooth, and axial depth of cut of 1.40 mm after milled with the uncoated carbide. Maximum Ra of 0.803 µm was obtained at cutting speed, feed rate, and axial depth of cut, which are 500 m/min, 0.15 mm/tooth and 1.70 mm, respectively.

Figure 3 illustrates the influence of machining parameters on surface roughness. Maximum Ra was obtained by an increase in the values of cutting speed, feed rate and the axial depth of cut as depicted in Figure 3 (a). The minimum Ra was obtained by a decrease in cutting speed and high combination feed rate of 0.15 mm/tooth and axial depth of cut of 1.70 mm. Obviously, this experiment affirms the fact that a high cutting speed with the low combination of feed rate and axial depth of cut has the potential to promote a favourable solution in the machining process [10]. Anwar et al. [11] have also reported similar results that the minimal Ra value was achieved at high cutting speed and low feed, which are 5000 rpm and 900 mm/min, respectively. Furthermore, Figure 3 (b) shows the result of the feed rate influence on the surface roughness. It increases with the feed rate from 0.12 to 0.15 mm/tooth. The lowest Ra value of 0.569 µm occurs at a feed rate of 0.12 mm/tooth at a speed of 600 m/min. Whilst, the highest Ra value of 0.803 µm occurred at a feed rate of 0.15 mm/tooth at a speed of 500 m/min. It revealed that a low feed rate offers a better

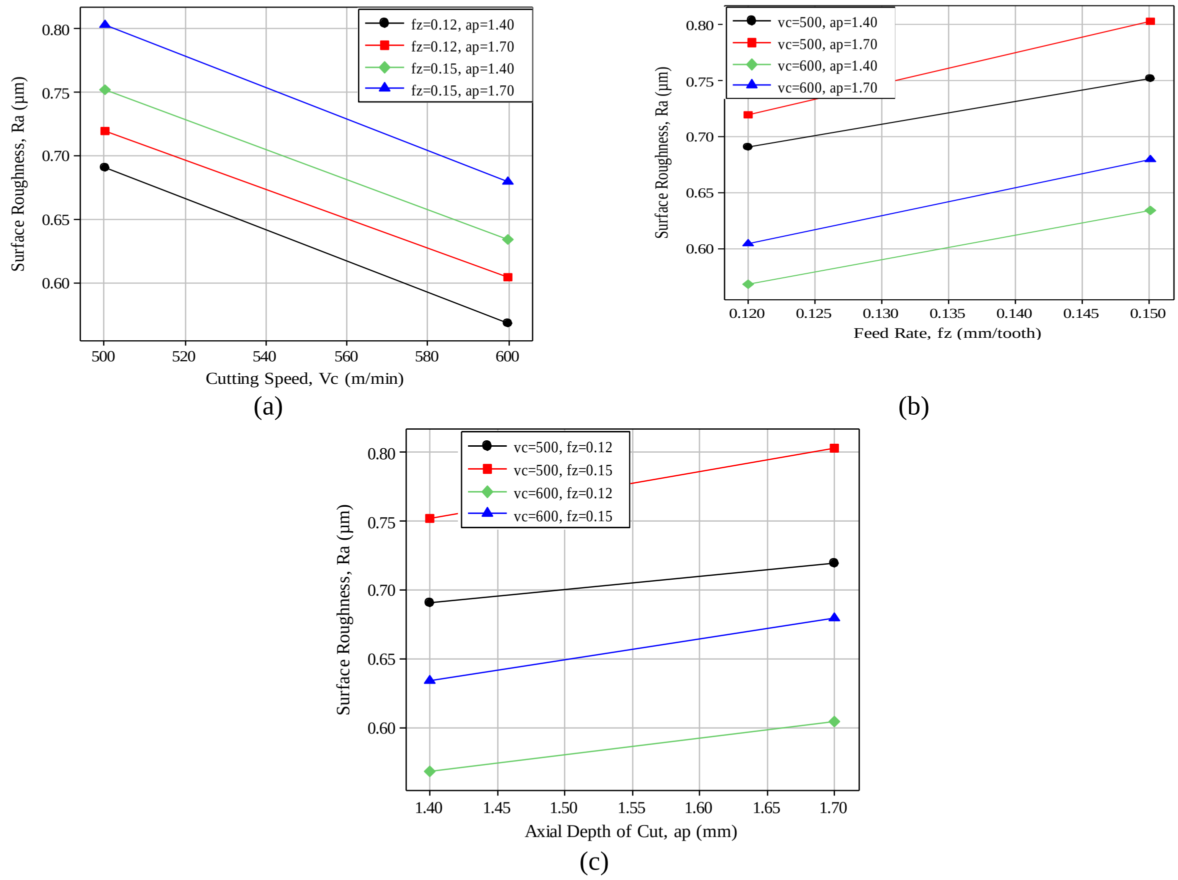


Fig. 3. Effect of machining parameter on tool life (a) cutting speed (b) feed rate (c) axial depth of cut

surface roughness. Besides that, Figure 3 (c) exhibits the influence of axial depth of cut on surface roughness at each cutting speed and feed rate. It is clear that the surface roughness increases when the axial depth of cut was increased from 1.40 to 1.70 mm. The low and high Ra value, namely 0.569 and 0.803 µm occurred in the axial depth of cut of 1.40 and 1.70 mm at a speed of 600 and 500 m/min, respectively. It seems that the lowest Ra value can be achieved with a low axial depth of cut.

Figure 4 illustrates a comparison of the effects of cutting speed of 500 and 600 m/min on the surface roughness at a feed rate of 0.12 mm/tooth and axial depth of cut of 1.40 mm. It is evident that the surface roughness at initial cutting for the speed of 600 m/min was lower than 500 m/min. The surface roughness values at a speed of 600 m/min were constantly lower than 500 m/min at every cutting time. However, the Ra value was found lower substantially in a minute of 8.42 throughout near-dry milling at a speed of 600 m/min. This occurs possibly due to a smoother cutting edge tends to the better roughness. Surface roughness at a speed of 500 m/min was found to be higher at the final of the tool lifespan from the initial cutting.

Table 3 exhibit the ANOVA results on the machined surface roughness under MQL. It is evident that the cutting speed has the most significant effects followed by feed rate on the surface roughness due to a smaller P-values of 0.05 at 95% confidence level. P-values for both significant factors were 0.017 and 0.029. Additionally, the other factors and interactions are a negligible effect because of the fact the P-value is greater than 0.05.

From Figure 1 and 3, the excellent results for tool life and surface roughness was reached at 600 and 500 m/min, respectively, with the feed rate of 0.12 mm/tooth and axial depth of cut of 1.40 mm. It occurs consequently the occurrence of low friction in the tool-work contact region in achieving the longest tool life and high shear pressure between the work piece and chips to obtain better surface roughness.

IV. CONCLUSION

The paper provides an experimental work towards the tool life and surface roughness of aluminum alloy 7075-T6 involving the key milling parameters under MQL condition using the uncoated carbide inserts. Raise and diminish in cutting speed and low of feed rate and axial depth of cut resulted in a promising performance of tool life and surface roughness, respectively. The cutting at speeds of 500 and 600 m/min at the feed rate of 0.12 mm/tooth and axial depth of cut of 1.40 has offered to extend the tool life and minimize surface roughness value, respectively. From ANOVA results, the cutting speed was found to be the most significant factor, followed by the feed rate that affects cutting tool life and machined surface roughness. The cutting temperature has an influence in achieving the prolonged tool lifespan that controls by a low combination of machining parameters to prevent the thermal shock on the tool edge.

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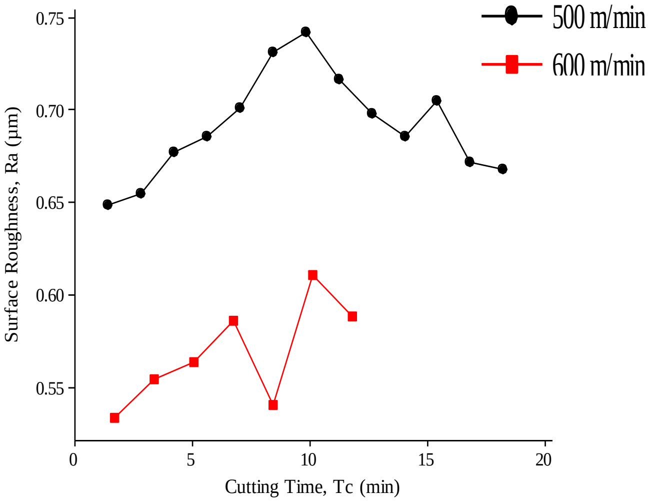

Fig. 4. Comparison of surface roughness trend at different cutting speed with feed rate of 0.12 mm/tooth and axial depth of cut of 1.40 mm

Table 3. ANOVA for surface roughness

Factor	DF	SS	*F*	*P*
vc	1	0.0284411	1346.33	0.017
fz	1	0.0101531	480.62	0.029
ap	1	0.0032401	153.38	0.051
vc*fz	1	0.0000011	0.05	0.856
vc*ap	1	0.0000001	0.01	0.951
fz*ap	1	0.0001201	5.69	0.253
Error	1	0.0000211		
Total	7	0.0419769		

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