ANALYSIS OF SURFACE INTEGRITY AND FORMATION OF MATERIAL SIDE FLOW IN DRY AND WET MACHINING OF ALUMINUM ALLOY

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ABSTRACT: This paper presents the surface integrity of aluminum alloy under dry and wet conditions. Bars of aluminum alloy with consistent size have been machined at different cutting speeds and feed rates at very short cutting time. The comparison between dry and wet cutting have been assessed based on the surface integrity, determined by the surface roughness value and observation of surface profiles. The result shows that machining in dry condition produces better surface finish where the coolants did not give a big impact on the surface roughness especially at the higher cutting speed. Further observation at the surface profile of dry cutting shows that more formation of material side flow appeared on the machined surface that could decreased the surface roughness value. Surface generated under bot dry and wet conditions appeared with well-defined and free from other damage such as cracking or tearing.

KEYWORDS: *Machining; Material Side Flow; Surface Integrity; Surface Roughness*

1.0 INTRODUCTION

Aluminum is a material that widely used in manufacturing industries, especially in automotive and aeronautics sectors. In many applications, aluminum replaces steels due to its high corrosion resistance, lightweight and easy to be fabricated [1]. When alloyed, the properties of aluminum can be improved in terms of strength, hardenability, weldability and machinability, make it versatile in many applications [2]. Aluminum alloy normally supplied in cast or wrought conditions before processed by secondary actions to prepare the materials into intended functions.

In order to produce precise aluminum components, machining process often used to shear the material according to required shape. During machining, surface integrity plays an important role as it influences the quality of surface profile, surface appearance, dimensional accuracy, tolerance as well as fatigue strength of the components. The surface integrity depended on many factors such as cutting parameters, the properties of workpiece material and the properties of cutting tool [3]. Nevertheless, cutting conditions such as dry or wet machining also significantly influence the surface integrity of machined component [4].

Aluminum can be machined either in dry or wet conditions depended on the application or functionability of the components. The literature however presents contradictory findings about machining in dry and wet conditions [5-7]. It has been established that the machining in wet conditions should produce longer tool life due to low friction and temperature [8]. However, due to strict environmental regulations, coolants are the major source of pollution, which hindered the use of wet cutting in some practices. On the other hand, the use of dry cutting is preferable as the machining process can be operated in cleaner condition and lower cost. However, dry cutting accelerated wear to the cutting tool which increased the usage of cutting tool and time consuming to insert the tool [9]. Therefore, more machining trials is required to further explain and observe the comparison between dry and wet cutting especially at the cutting area where the coolant penetrate into the cutting zone.

This paper presents the analysis and observation of surface integrity when machining commercial aluminum alloy under dry and wet conditions. Main purpose of this paper is to explore the characteristics of machined surface for common industrial material at very short machining time. Several bars of aluminum alloy with same dimension were machined with different cutting speeds and feed rates and comparison were made according to the trend of surface roughness plotted. This study also try to propose some explanations to differentiate the characteristics of machined surface for both conditions.

2.0 METHODOLOGY

The focus of this experiment is to differentiate the surface integrity under dry and wet conditions. 12 bars of commercial aluminum alloy with consistent diameter of 20 mm and length of 150 mm were prepared. For each bar, machining tests were held at both dry and wet conditions according to the cutting parameters as given in Table 1. The experiments were carried out on a manual lathe machine. Since the machine that used in this study was conventional lathe machine, the cutting speed and feed rate were varied according to the machine set up. The cutting tools used were Canela insert grade PM25 carbide cutting tools, clamped on PSBNR16-4R174.3-2525-12 tool holder. Mineral oil was used as the coolant for wet condition. Surface roughness and surface profiles for the machined surface have been evaluated by using Surface Roughness Tester and Scanning Electron Microscope. For surface roughness analysis, the measurements were made at two areas, at starting area, around 5 mm from the starting point of cutting length, and at the end area, around 5 mm at the end of cutting length. Figure 1 shows the area of measurement in this study.

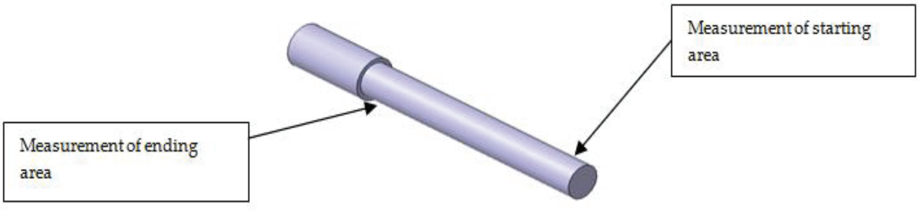


Figure 1: Measurement area of machined surface

Table 1: The value of cutting speed and feed rate

No.	Spindle Speed (mm/min)	Feed Rate (mm/min)
1	10,000	45.72
2	15,000	66.04
3	22,000	96.52
4	32,000	142.24
5	47,000	210.82
6	71,000	307.34

3.0 RESULT AND DISCUSSION

Figure 2 shows the plot of the surface roughness, Ra (μm) versus cutting speed for both dry and wet cutting conditions at the starting area. Referring to Figure 2, dry cutting demonstrated lower surface roughness as compared to wet cutting. At the early machining stage, the surface roughness increased tremendously when the cutting speed increased from 10000 mm/min to 22000 mm/min. The surface roughness then decreasing steadily when the cutting speed increased from 22000 mm/min to 71000 mm/min. Figure 3 shows the plot of the surface roughness, Ra (μm) versus cutting speed for both and wet dry cutting conditions at the ending area. Similar trend as compared to Figure 2, the plot indicates that dry cutting provides better surface finish than wet cutting. At the early machining stage, the surface roughness increased slightly when the cutting speed increased from 10000 mm/min to 15000 mm/min. The surface roughness then decreased gradually when the cutting speed increased from 15000 mm/min to 71000 mm/min. The result from both plots in Figure 2 and Figure 3 indicate that cutting fluid did not show a significant effect to the surface finish at the very short machining time. The use of cutting fluid indeed benefitted the machining performance in terms of chip removal and to avoid them entangled with the cutting tool. This results is consistent with Yahya [5] that also found that the cutting fluid (in certain conditions) did not give a big impact on surface roughness during the machining trial of AISI 1050 steel with coated carbides tool.

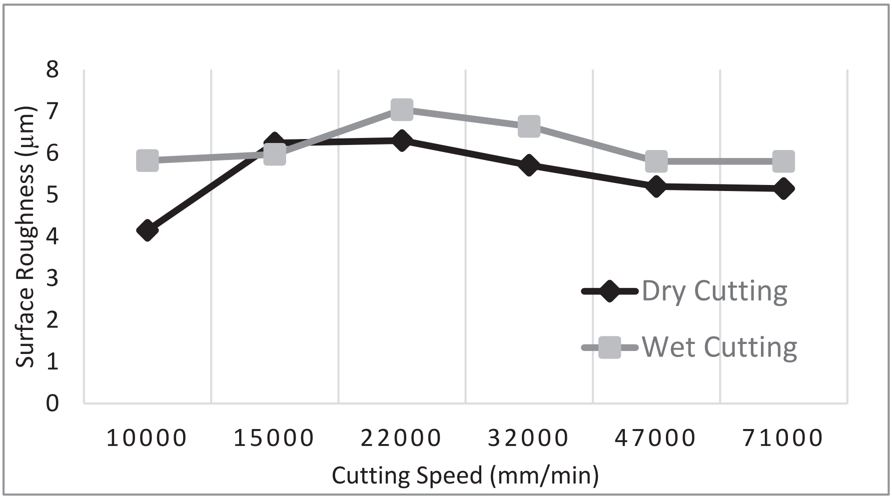


Figure 2: Graph comparison of surface roughness, Ra vs cutting speed (at start point)

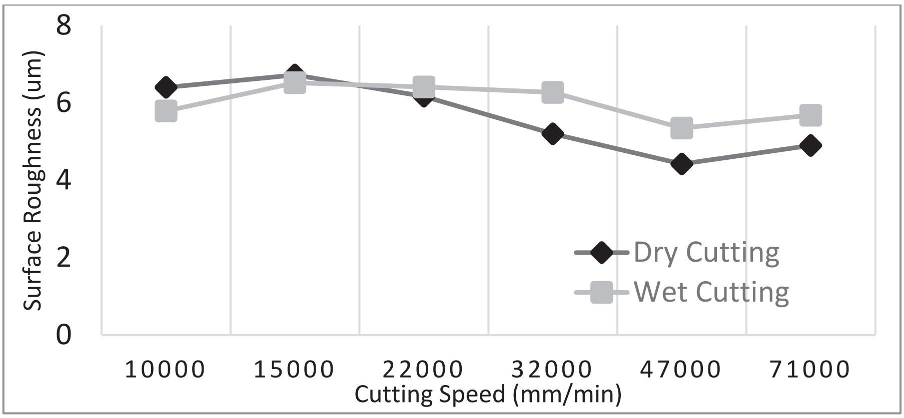


Figure 3: Graph comparison of surface roughness, Ra vs cutting speed (at end point)

Figure 4 shows edge of tools used for both machining trials. Images that generated in Figure 4 demonstrated that the possible explanations to propose why the surface roughness of dry cutting is lower as compared to wet cutting. During machining in wet cutting, the use of cutting fluids resulting cooling and lubrication at the cutting zone. As a result, the tool can maintain its nose radius shape in a longer time [10]. As the cutting tool trimmed the workpiece, the good shape tool nose radius produced larger gap between the peak and valley profile along the machined surface [11]. This resulting higher surface roughness value when measured from Centre Line Average (CLA), as shown in Figure 4(a). On the other hand, during machining in dry condition, high temperature generation may resulting early tool wear and development of built up edge at the tool nose radius [12]. Worn cutting tool sometimes produce a lower surface roughness value due to smaller crescent shape formed between peak and valley profiles. This is also shown in Figure 4(b) where the distance of peak and valley measure from CLA is lower as compared to Figure 4(a).

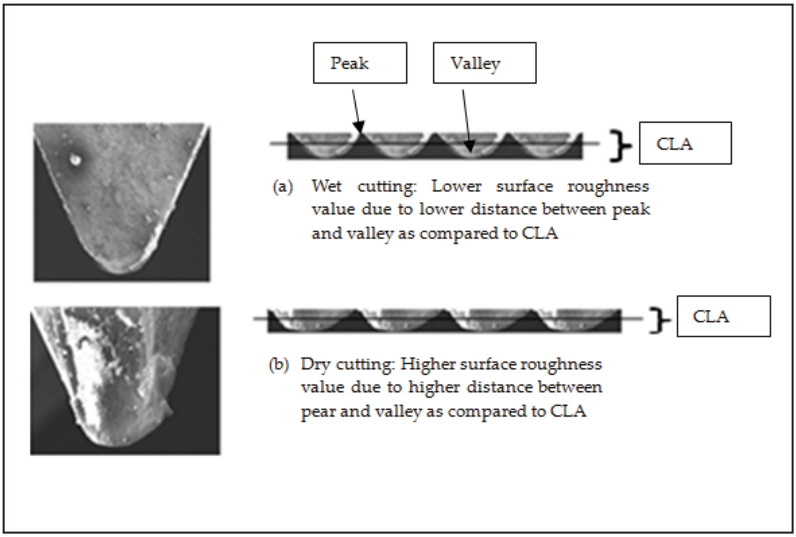
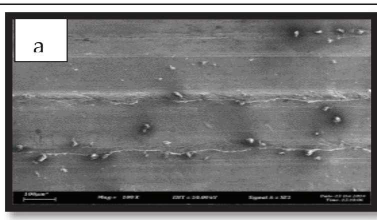
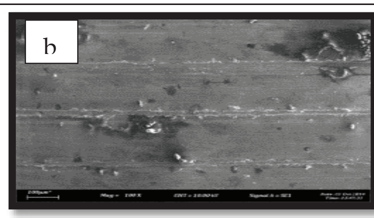
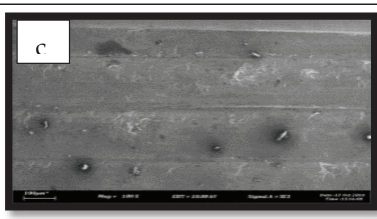
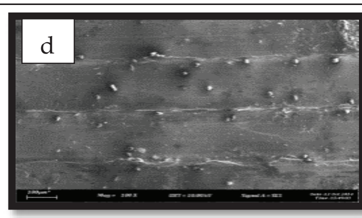
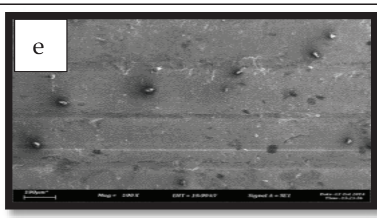
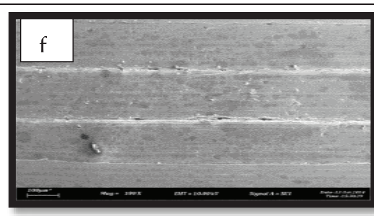


Figure 4: (a) wet cutting and (b) dry cutting conditions

Figures 5 ((a)-(l)) show the micrograph of surface under dry and wet cutting observed under scanning electron microscope (SEM). From these figures, the surfaces generated under the conditions investigated were well-defined and free from other damage such as cracking, tearing and rupture that are detrimental to machined components. There is an evidence of micropits that randomly distributed along the machined surface. The change of feed rate not obviously changed the size of feed marks along machined surface. At 10,000 rpm/min (Figures 5(a) and (b)), the surface roughness of dry machining shows a homogenous material slide flow as compared to the wet machining, while at 71,000 rpm/min (Figures 5(k) and (l)) the material slide flow is reduced. Based on the observation, it can be said that the higher cutting speed able to reduced the material slide flow thus give a good surface finish to the samples.

Further observations throughout the machined surface demonstrated the evidence of material side flow, more frequently observed in dry condition. This is shown in Figure 6 where the formation of material side flow obviously appeared at the cutting speeds of 10000 mm/min (Figure 6(a)) and 71000 mm/min (Figure 6(b)). Material side flow defined as the displacement of a workpiece material in a direction opposite to the feed direction [13]. The appearance of material side flow can be represent by the formation of burrs that elongate at the side of feed marks ridge. During machining, the material side flow occurred when the sheared workpiece materials plasticised as the results of high cutting temperature and on the same time the cutting tool push aside that material to form a deformed layer [14]. It could be, the existence of material side flow could reduce the surface roughness of machined surface as the peaks between ridges were pushed aside, resulting lower peak crescents. Burrs that formed in material side flow may appeared in hard conditions, resulting tendency to abrade the cutting tool and accelerate wear at the tool edge [15].

Speed (mm/ min)	Surface Roughness (DRY)	Surface roughness (WET)
10k		
15k		
22k		

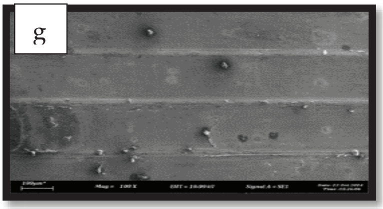
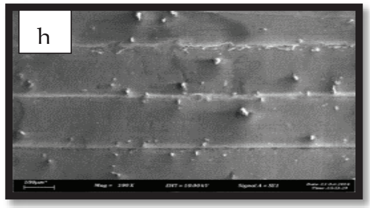
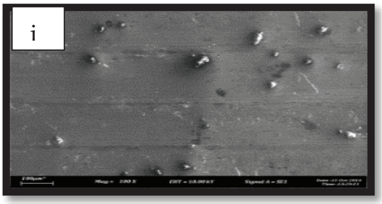
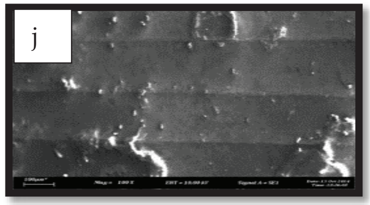
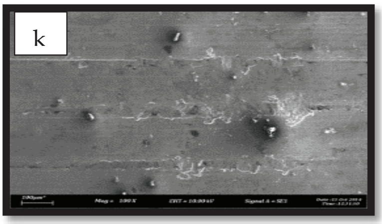
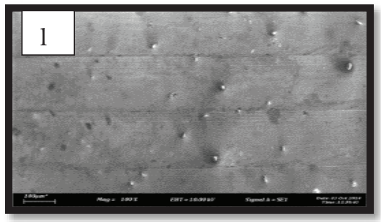
32k		
47k		
71k		

Figure 5: (a)-(l) micrographs of dry and wet conditions

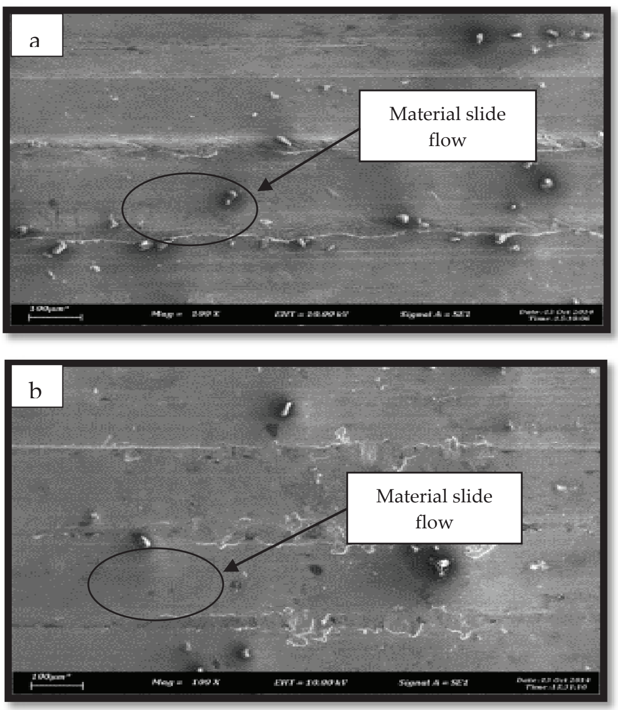


Figure 6: Formation of Material Side Flow at dry cutting at (a) 10000 mm/min and (b) 71000 mm/min cutting speed

4.0 CONCLUSION

From the experiment, the following findings have been determined:

i. For short machining time, machining in dry condition performed better as compared to wet condition in terms of surface roughness value.
ii. The cutting fluid did not give a big impact on the surface roughness during machining at shorter time as well as at higher cutting speed and feed rate.
iii. Machining in dry condition produces more material side flow that could reduce the surface roughness but detrimental to the fatigue life in a long term.
iv. The surfaces generated under the conditions investigated generally were well-defined and free from other damage such as cracking or tearing that detrimental to the machined components.

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