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The machined surface of magnesium AZ31 after rotary turning at air cooling condition

G Akhyar [1*], B Purnomo [1], A Hamni [1], S Harun [1], Y Burhanuddin[1]
Department of Mechanical Engineering, Faculty of Engineering, University of Lampung. Jln. Prof.Sumantri Brojonegoro No.1 Gedung H FT Lt.2 Bandar Lampung

Email: gusri.akhyar@eng.unila.ac.id

Abstract. Magnesium is a lightweight metal that is widely used as an alternative to iron and steel. Magnesium has been applied in the automotive industry to reduce the weight of a component, but the machining process has the disadvantage that magnesium is highly flammable because it has a low flash point. High temperature can cause the cutting tool wear and contributes to the quality of the surface roughness. The purpose of this study is to obtain the value of surface roughness and implement methods of rotary cutting tool and air cooling output vortex tube cooler to minimize the surface roughness values. Machining parameters that is turning using rotary cutting tool at speed the workpiece of (Vw) 50, 120, 160 m/min, cutting speed of rotary tool of (Vt) 25, 50, 75 m/min, feed rate of (f) 0.1, 0.15, 0.2 mm/rev, and depth of cut of 0.3 mm. Type of tool used is a carbide tool diameter of 16 mm and air cooling pressure of 6 bar. The results show the average value of the lowest surface roughness on the speed the workpiece of 80 m/min, cutting speed of rotary tool of 50 m/min, feed rate of 0.2 mm/rev, and depth of cut of 0.3 mm. While the average value of the highest surface roughness on the speed the workpiece of 160 m/min, cutting speed of rotary tool of 50 m/min, feed rate of 0.2 mm/rev, and depth of cut of 0.3 mm. The influence of machining parameters concluded the higher the speed of the workpiece the surface roughness value higher. Otherwise the higher cutting speed of rotary tool then the lower the surface roughness value. The observation on the surface of the rotary tool, it was found that no uniform tool wear which causes non-uniform surface roughness. The use of rotary cutting tool contributing to lower surface roughness values generated.

1. Introduction

Magnesium is a lightweight metal and has characteristics similar to aluminum. Magnesium can be used as an alternative to iron and steel because magnesium is abundant elements and elements that make up the eighth most 2 % of the earth's crust, and is the third most element dissolved in seawater [1]. On development, magnesium or its alloys has been widely applied in the automotive industry among others to lose weight because of a component is a metal that is light [2]. Magnesium machining process is known to have excellent cutting characteristics because it has a low specific cutting force, furious chips are short, relatively low tool wear, high surface quality and can be cut at cutting speeds and feeds are high [3]. Although magnesium has many advantages, but has the disadvantage that magnesium is highly flammable because it has a low flash point. At such a low flash point will be burning furiously, where the cutting temperature exceeds the melting point of the material, namely (400° C - 600° C) [4].

In addressing these issues, numerous studies have been conducted to find an effective method to reduce the cutting temperature. As stated by previous researchers that a high cutting temperatures will produce a high surface roughness values [5]. Because the machining process with high temperature will cause occurrence of wear on the cutting tool so that it can degrade the quality of the workpiece surface roughness [6].

In the machining process, generally the method that is widely used to lower the temperature of cutting is to use liquid. But in its development began to minimized use this liquid because it is very dangerous for health and the environment [3]. In the study conducted by Doni [7] which aims to analyze the surface roughness value by lowering the temperature of the cutting. The chosen method is to use a rotating cutting tool on a lathe machining processes without coolant and use a rotary tool tilt angle of 0° with respect to the workpiece. Rotary tool method used successfully obtain minimum surface roughness value of 0.62 μm and a maximum surface roughness values of 2.86 μm. In his research, Doni [7] recommends using low feed rate , because the higher of feed rate will generate greater roughness values. Research on machining magnesium is also done by Andriyansyah [8] which aims to determine the effect of cutting parameters on surface roughness values of magnesium using air cooling of vortex tube cooler with a temperature of 15° C. Machining process used is a milling machining. Research results show that the value of the minimum surface roughness of 0.35 μm and maximum roughness value of 1.50 μm.

of the research that has been described above concludes that the value of the surface roughness of magnesium in addition influenced by cutting parameters, including feed rate and the cutting speed, also influenced by the temperature of the cutting. Therefore in this study will be analyzed on a surface roughness values lathe machining process using a rotary cutting tool with a tilt angle of 10 °. In a previous study of this corner enabled to reduce power by 30% of the total power use and reduce the amount of cutting force [9] [10]. The cutting process will be given air cooling output of vortex tube cooler constant. By using cold air is expected to reduce the temperature of the cutting so as to reduce the rate of tool wear and improve tool life [11] [12]. So this method is expected to produce a better roughness values and can be used as a substitute for innovation in the machining process fluid.
The purpose of this study is to obtain the value of surface roughness and implement methods of cutting tool rotary tool and air cooling output of vortex tube cooler to minimize the surface roughness values.

2. Research Methodology

Laboratory of Manufacturing, Mechanical Engineering, Lampung University. Materials used in the study are magnesium alloy AZ31 (Al of 3% and Zinc of 1%). Here is an AZ31 magnesium physical table property.

Table 1. Physical properties of magnesium AZ31

Density [kg/mm^3]	1,77 x 10^{-6}
Young’s Modulus [kN/mm^2]	45,000
Possion’s ratio	0.35
Melting temperature [K]	891
Thermal Conductivity [w/(mK)]	77 + 0.096T
Heat specific capacity [J/(kgK)]	1000 + 0.666T
Heat coefficient [K^{-1}]	2.48 x 10^{-5}

The machining is done on conventional lathes brands PINACHO type S-90/200. By using a rotary cutting tool system as shown in Figure 1. The material of tool used is a carbide, diameter of 16 mm and the air cooling pressure of 6 bar. Here are the figure and specifications of the tool cutting system spins and vortex tube :

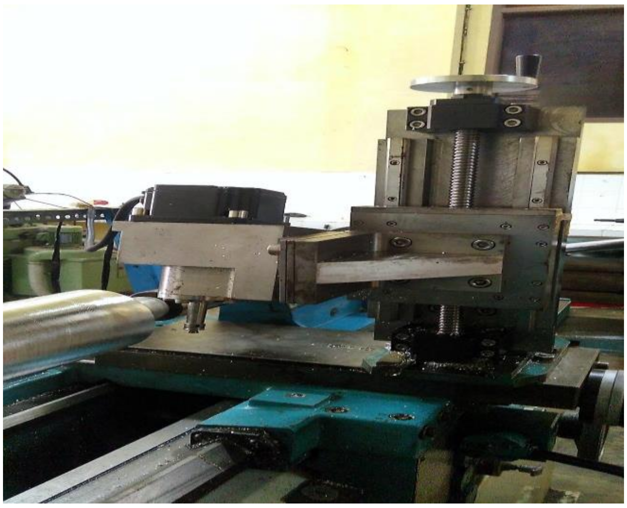

Figure 1. Rotary cutting tool system

Table 2. Specifications of rotary tool

Merk	AXUM590-A
Tool type	*Insert-Propeller*
Tool rotation speed	0-2000 rpm
Speed direction	CW/CCW
Diameter of insert	16 mm

Figure 2. Vortex tube used to produce air cooling.

Machining parameters that is turning using rotary cutting tool at speed the workpiece of (Vw), cutting speed of rotary tool of (Vt), feed rate (f), depth of cut (d). Can be seen in Table 3.

Table 3. Cutting parameters selected in turning process.

Speed of workpiece Vw, m/min			Feed rate *f*, mm/ref			Depth of cut d, mm	Speed of rotary tool, Vt m/menit			Temperatur e
80	120	160	0,10	0,15	0,20	0,3	25	50	75	0 °C. 6 Bar

Data collection roughness on every parameter done four times. This is done to get the maximum results. Measurement values using a surface roughness tester with an accuracy of 0.01 μm and surface profile of picture a using USB camera with a magnification of 600 x.

3. Results and Discussions

In Experimental trials of AZ31 magnesium alloys using conventional turning and rotary cutting tool system with air cooling. To determine the value of the surface roughness material magnesium alloy AZ31 has been carried out with a variety of machining parameters that is turning using rotary cutting tool at speed the workpiece of (Vw) 50, 120, 160 m/min, cutting speed of rotary tool of (Vt) 25, 50, 75 m/min, feed rate of (f) 0.1, 0.15, 0.2 mm/rev, and depth of cut of 0.3 mm. Here are the data obtained from the machining process with a variety of conditions, produces a variety of data as shown in Table 4-7:

Table 4. Measurement data value of roughness on speed the workpiece of 120 m/min, depth of cut of 0.3 mm, and cutting speed of rotary tool of 25 m/min.

No	Speed of workpiece (Vw) (m/min)	Feed rate (f) (mm/rev)	Depth of cut (d) (mm)	Speed of rotary tool (Vt) (m/min)	Surface roughness (μm) 1 *Ra*	2 *Ra*	3 *Ra*	Average (μm)	Time (t) (Minute)
1					1,22	1,32	1,27	**1,27**	05:28
2	120	0.1	0.3	25	1,37	1,28	1,14	**1,26**	10:53
3					1,24	1,09	1,24	**1,19**	16:20
4					1,24	1,02	1,02	**1,09**	21:47
1					0,89	1,15	0,78	**0,94**	02:43
2	120	0.2	0.3	25	1,29	0,82	0,9	**1,00**	05:27
3					1,22	1,32	1,27	**1,27**	05:28
4					1,37	1,28	1,14	**1,26**	10:53

Table 5. Measurement data value of roughness on speed the workpiece of 160 m/min, depth of cut of 0.3 mm, and cutting speed rotary tool of 50 m/min.

No	Speed of workpiece (Vw) (m/min)	Feed rate (f) (mm/rev)	Depth of cut (d) (mm)	Speed of rotary tool (Vt) (m/min)	Surface roughness (µm)			Average (µm)	Time (t) (Minute)
					1	2	3		
					Ra	*Ra*	*Ra*		
1	160	0.1	0.3	50	1,59	1,35	1,3	**1,41**	04:20
2					1,45	1,64	1,4	**1,50**	08:40
3					1,73	1,64	1,51	**1,63**	13:01
4					1,49	1,6	1,59	**1,56**	17:22
1	160	0.2	0.3	50	1,64	2,48	1,79	**1,97**	02:10
2					2,87	2,33	1,71	**2,30**	04:20
3					1,76	2,54	2,51	**2,27**	06:31
4					2,25	1,35	1,85	**1,82**	08:43

Table 6. Measurement data value of roughness on speed the workpiece of 80 m/min, feed rate of 0.15 mm/rev, and depth of cut 0.3 mm.

No	Speed of workpiece (Vw) (m/min)	Feed rate (f) (mm/rev)	Depth of cut (d) (mm)	Speed of rotary tool (Vt) (m/min)	Surface roughness (µm)			Average (µm)	Time (t) (Minute)
					1	2	3		
					Ra	*Ra*	*Ra*		
1	80	0.15	0.3	25	1,01	0,7	0,95	**0,89**	06:37
2					1,05	0,97	0,91	**0,98**	13:15
3					0,63	0,85	0,69	**0,72**	19:53
4					1,17	0,62	0,95	**0,91**	26:29
1	80	0.15	0.3	75	0,82	0,61	0,97	**0,80**	06:38
2					0,76	0,88	0,83	**0,82**	13:15
3					0,84	0,7	0,77	**0,77**	19:54
4					0,95	0,84	0,66	**0,82**	26:30

Table 7. Measurement data value raughness on the feed rate 0.15 mm/rev, depth of cut 0.3 mm, and cutting speed of rotary tool of 25 m/min

No	Speed of workpiece (Vw) (m/min)	Feed rate (f) (mm/rev)	Depth of cut (d) (mm)	Speed of rotary tool (Vt) (m/min)	Surface roughness (µm)			Average (µm)	Time (t) (Minute)
					1 *Ra*	2 *Ra*	3 *Ra*		
1	80	0.15	0.3	25	1,01	0,7	0,95	**0,89**	06:37
2					1,05	0,97	0,91	**0,98**	13:15
3					0,73	0,85	0,89	**0,82**	19:53
4					1,17	0,62	0,95	**0,91**	26:29
1	160	0.15	0.3	25	1,81	0,7	1,6	**1,37**	02:53
2					1,64	1,6	1,49	**1,58**	04:46
3					2,06	1,44	1,38	**1,63**	07:39
4					1,19	1,74	1,53	**1,49**	10:32

3.1. Feed rate and surface roughness value

The following is a graph showing the comparison surface roughness values between feed rate 0.1 mm/rev and 0.2 mm/rev at the depth of cut (d) 0.3 mm.

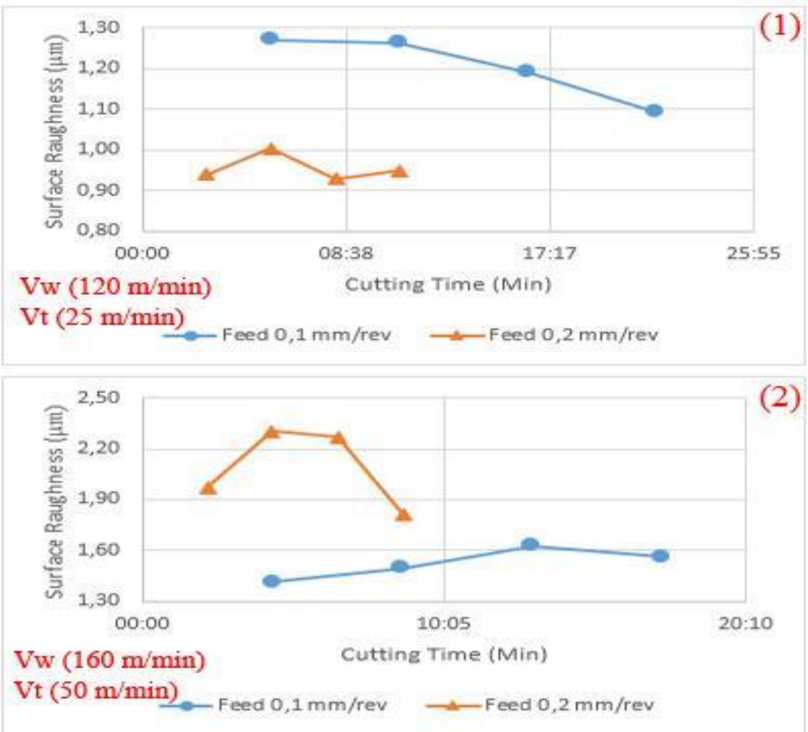

Figure 3. Comparison of surface roughness between feed rate 0.1 and 0.2 mm/rev.

Figure 3 is a comparison of the effect of feed rate on the value of surface roughness. Where in graph 1 surface roughness value was lower than in the feed rate of 0.2 mm/rev. It is inversely proportional to the statement earlier researchers [7]. Which states that the chip of feed is very influential on the surface roughness, where the greater the price of feed. the greater the level of coarseness. But in general, the value of the surface roughness is influenced by a variety of many factors. These factors include other parameters of the machining process, the condition of the tool, the workpiece and the cutting phenomenon [13] [14]. From the statement of course in this case the value of the feed is not completely affect the value of the resulting roughness.

Whereas in Figure 2 the surface roughness value was lowest in the feed rate 0.1 mm/rev. In both cases carried out observations of the surface profile, wherein the surface profile measurements to feed mark the resulting on cutting scars. Here is a comparison of the measured surface profile of the workpiece :

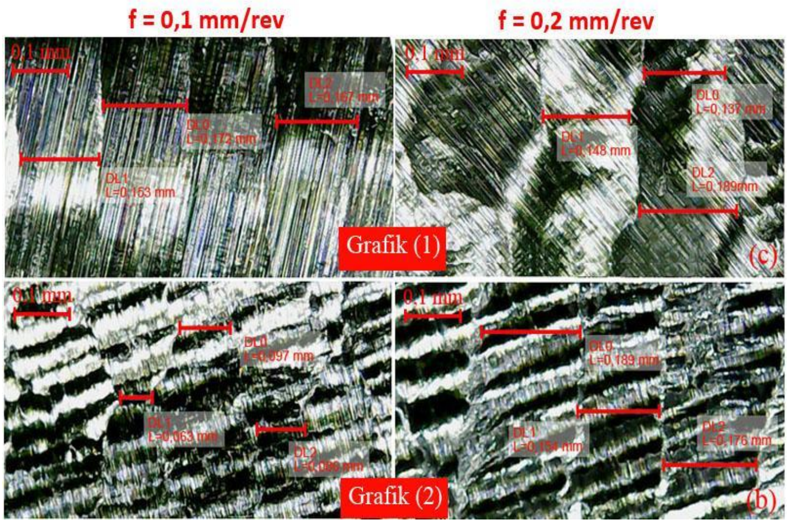

Figure 4. Comparison between profiles of feed rate (f) 0.1 and 0.2 mm/rev.

In Figure 4 obtained value feed mark on the first surface profile of feed rate 0.1 mm/rev of 0.164 mm and feed rate 0.2 mm/rev of 0.158 mm. While the second profile feed rate 0.1 mm/rev produce value feed mark of 0.082 mm and feed rate 0.2 mm/rev of 0.173 mm.

3.2. Cutting speed Rotary and surface roughness value

The following is a graph showing the comparison between the surface roughness value of the cutting speed of rotary tool of 25 m/min and 75 m/min with the depth of cut (d) 0.3 mm :

Figure 5 . Graph comparison of cutting speed of rotary tool (Vt) of the surface roughness values.

Figure 5 is a comparison of the effect of cutting speed rotary tool against the surface roughness values. Where is concluded that the value of the surface roughness was lowest in the cutting speed of rotary tool (Vt) 75 m/min and the surface roughness values were highest in cutting speed of rotary tool (Vt) 25 m/min. As already stated by Doni [7], the greater the cutting speed of the rotary cutting tool resulting roughness value would be lower. For a comparison of the surface profile can be seen in Figure 6.

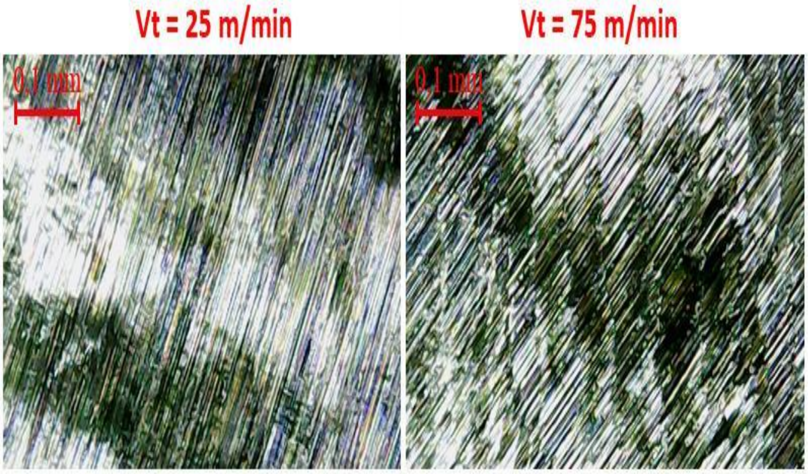

Figure 6. Comparison between the profile cutting speed of rotary tool 25 and 75 m/min.

3.3. Workpiece speed and surface roughness value

The following is a graph showing the comparison between the value of the surface roughness of the speed the workpiece of 80 m/min and 160 m/min with the depth of cut (d) 0.3 mm:

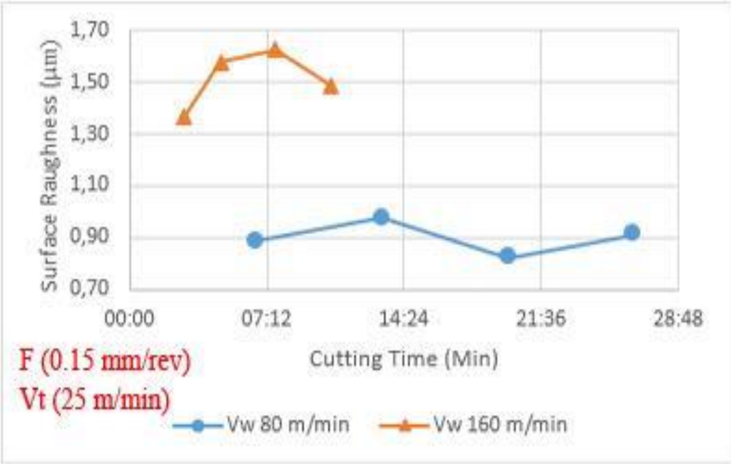

Figure 7. Graph speed the workpiece (Vw) of the surface roughness values.

Figure 7 is a comparison of the effect of speed of workpiece on the value of surface roughness. Where is concluded that the value of surface roughness was lowest in the speed of workpiece of 80 m/min and the highest surface roughness values occur at the speed of workpiece 160 m/min. As stated by Fariza [15] in his study, the greater the speed of workpiece then the resulting roughness value will be higher. For a comparison of the surface profile can be seen in Figure 8.

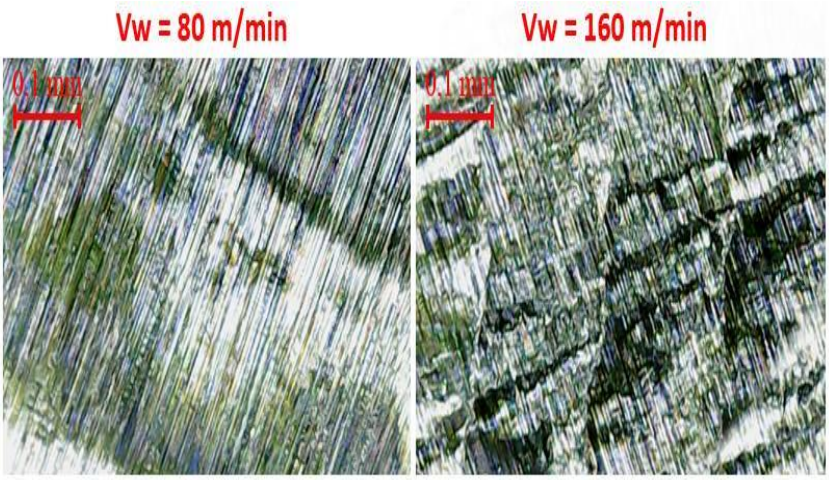

Figure 8. Comparison between the velocity profile speed of workpiece 80 and 160 m/min..

4. Conclusions

1. The average value of the lowest surface roughness obtained on the speed of the workpiece (VW) to 80 m/min, cutting speed of rotary tool (Vt) of 50 m/min with feed rate 0.2 mm/rev and depth of cut 0.3 mm. While the average value of the highest surface roughness obtained on the speed of the workpiece (Vw) of 160 mm/min, the cutting speed of rotary tool (Vt) of 50 m/min with feed rate 0.2 mm/rev and depth of cut 0.3 mm.

2. Values of surface roughness is not uniform throughout the machining process, this is due to tool wear is not uniform along the edge of the rotary cutting tool.
3. Values of surface roughness parameters are more influenced by the speed of the workpiece (Vw) and the cutting speed of rotary tool (Vt). Higher speed of the workpiece (Vw) then the surface roughness of the resulting higher. Instead higher cutting speed of rotary tool (Vt) then the value of the resulting surface roughness is lower.
4. Turning process using a rotary tool and air cooling can be implemented in a lathe machining process AZ31 magnesium material for producing a lower roughness values compared to using a silent tool.

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