Surface Integrity of magnesium alloy AZ91D at high speed milling

Mohd Shahfizal Ruslan[1], Jaharah A Ghani[1,*], Afifah Juri[1], Mohd Shahir Kasim[3], Che Hassan Che Haron[1], Kamal Othman[1,2]

[1)] Department of Mechanical and Material Engineering, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
[2)] German Malaysia Institute, Jalan Ilmiah, Taman Universiti, 43000 Kajang, Selangor, Malaysia.
[3)] Fakulti Kejuruteraan Pembuatan, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.

[*]Corresponding e-mail: jaharahaghani@ukm.edu.my

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ABSTRACT – Magnesium alloy AZ91D is used extensively in automotive industry because of its high strength to weight ratio properties. The experimental work involved the use of uncoated carbide end mill cutting tool, with the utilization of full factorial (L16) design of experiment at cutting speed of 900 and 1300 m/min, feed rate of 0.02 and 0.05 mm/tooth, axial depth of cut of 0.2 and 0.3 mm and radial depth of cut of 10 and 40 mm in both dry and cryogenic for high speed milling operation. For this range of cutting conditions, a mirror like surface roughness in the range of 0.05- 0.27 μm were achieved. Furthermore, there were no microstructure changes observed beneath the machine surface for this range of cutting conditions. In comparison to dry machining, the utilization of cryogenic cooling improves the surface roughness by to 47% compared to dry machining.

1. INTRODUCTION

Magnesium alloy are known for its excellency in physical and mechanical properties such as low density, very high strength to weight ratio, high stiffness and mechanical cast ability. They are more preferred than aluminium or steel alloy in automotive industry due to its promising high strength to weight ratio characteristic [1]. Unfortunately, owing to the poor corrosion resistance characteristic of magnesium alloy, it has limited their practical applications. Nevertheless, it is largely utilized in automotive industry because of its advantage in term of energy and environmental concerns. Recently, leading car manufacturers, for instance Ford have investigated the replacement of steel with lighter material such as magnesium to achieve lightweight construction (for car seat frame construction) without compensating on rigidity. Consequently, can lead to greenhouse gas reductions and limiting the amount of exhaust emissions to satisfy legislative and consumers' requirements for safer, cleaner vehicles [2].

Pu et al. [3], investigated the effect of machining AZ31B Magnesium alloy in dry and cryogenic by using different cutting-edge radius tool on surface integrity. It was found that with the utilization of cryogenic coolant (liquid nitrogen) and by using a large edge radius tool has improved surface roughness by about 20% compared to dry machining.

2. METHODOLOGY

The dry and cryogenic machining experiments were conducted on a CNC milling machine (SPINNER VC450) which capable achieving of achieving maximum speed of 15,000 rpm. The workpiece material is Magnesium Alloy AZ91D with dimension of 150 x 150 x 50 mm. The chemical composition of AZ91D as shown in Table 1. Table 2 shows the machining parameters employed in this study. Based from the factors and level shown in Table 2, a total of 16 experiments was developed using full factorial design of experiment. The cryogenic condition was employed by using liquid nitrogen and was delivered directly to the cutting zone during machining process via nozzle, as shown in Figure 1.

Table 1 AZ91D composition.

Chemical Composition (%)							
Al	Zn	Mn	Cu	Ni	Si	Fe	Mg
8.73	0.69	0.2	0.0017	0.00081	0.017	0.001	Balance

Table 2 Factors and levels used for the experiments.

Factor	Level	
	0	1
Cutting speed, Vc	900 m/min	1300 m/min
Feed rate, fz	0.02mm/tooth	0.05 mm/tooth
Axial depth of cut, Ap	0.2 mm	0.3 mm
Radial depth of cut, Ae	10 mm	40 mm

Figure 1 Delivery of liquid nitrogen during the high-speed milling process.

The measurement of surface roughness value was conducted using Mitutotyo portable surface roughness model SJ-310. The equipment is used to measure the arithmetic value of Ra. The measurement process is according to ISO 4288: 1996. Total measurement length and cut off length is 4 mm and 0.8 mm respectively.

3. RESULTS AND DISCUSSION

3.1 Surface roughness

The measured surface roughness (Ra) value at beginning of cut in dry and cryogenic conditions are shown in Figure 2. Based from the graph, it can be seen that in dry machining lowest Ra value is 0.068 µmm at experiment trial 1 while for cryogenic machining 0.055 at experiment trial 10. Machining using cryogenic coolant has improved surface finish by up to 19%. The surface roughness readings are unstable and it might be due to chips sticking to the rake face or build up edge occurred. From the dry tool wear result, experiment trial 6 was the optimum parameter, and the surface roughness achieved is 0.082 µmm. compared to experiment trial 1, which the surface finish is better. However, the tool life achieved is around 260 min. Thus, it can be stated that good surface finish can be achieved, with longer tool life duration, hence less cost can be realized.

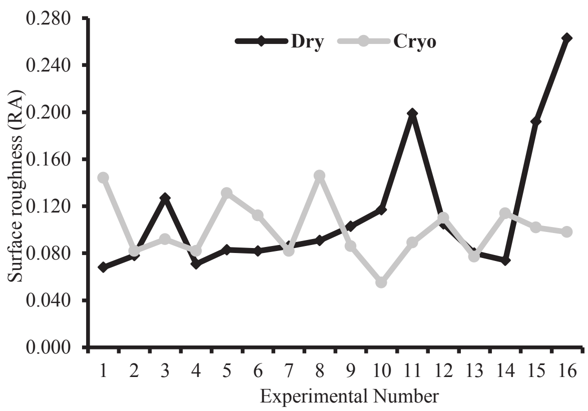

Figure 2 Surface roughness (Ra) for dry and cryogenic conditions.

3.2 Micro structure beneath the machined surface

Machining process generates thermal effect at cutting zone and it lead to changes of the microstructure in terms of reshaping and resizing of the grains or even phase transformation in near surface. The changes in microstructure depends on the selection of cutting parameter and cutting condition. Figure 3 shows the subsurface optical micrographs for experiment trial at beginning of cut and at flank wear land. VB =0.2 mm for both dry and cryogenic condition at Vc: 900m/min, Fz: 0.02 mm/tooth, Ap: 0.3mm, and Ae: 40mm.

4. CONCLUSION

From the results obtained, it can be concluded that the feed rate has the significant influence on the surface roughness. Furthermore, the utilization of cryogenic cooling proved to be more effective for improving the surface roughness of the machined surface.

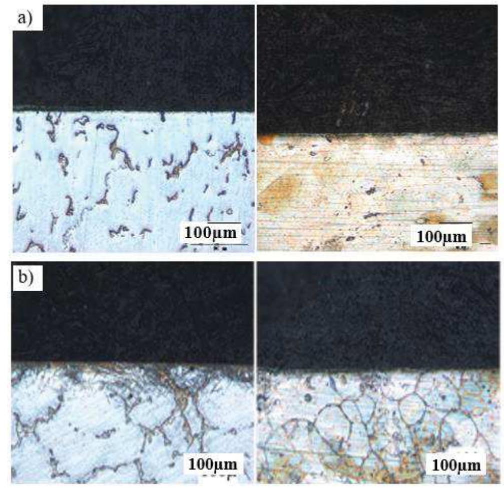

Figure 3 (a) dry cutting condition, (b) cryogenic condition *(need to zoom out the area of comparison)*

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