NON-CONVENTIONAL MACHINING OF ALUMINIUM METAL MATRIX COMPOSITE

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Abstract

Aluminium metal matrix composite is slowly making in roads into various engineering applications. Among the limitations of this material is its difficulty to machine due to its soft and particles tend to wrap around tool bit and break the tool. This material has yet to be tested using non-conventional machining techniques such as. This research explores the possibility of machining using Electro-discharge machining by varying various machining parameters. Results indicated that aluminium metal matrix composite can be effectively EDM machined at low peak current at certain ON-time and OFF-time.

Introduction

Application of aluminum metal matrix composite materials in various industrial and commercial applications such aviation, automotive and marine is expanding but has been limited due to difficulty of machining by conventional machines such milling and turning. Electro-Discharge machining (EDM), a non-conventional machining process for material removal, might be a feasible option which have yet to be tested on aluminium metal matrix composite material. This research is conducted to explore the possibility of EDM machining of aluminum metal matrix composite (A242.0/Al_2O_3) with copper electrodes . Various EDM machining parameters such as pulse current (Ip), ON-time pulse duration and OFF-time was varied to investigate their effects on the material. The characterization of the surface roughness and white layer was made using surface roughness tester, scanning electron microscopy (SEM) and energy dispersive microscopy (EDS). Result showed affects on surface roughness and crack formation size with increasing of EDM parameters.

Methodology

Electrolytic Copper with density 8.96 g/cm^3, melting point 1083^{0}C, Young Modulus 130 GPa and Hardness 100 HB (assumption) is machined to diameter Ø5.6mm electrode to EDM machined the aluminum metal matrix composite Al-A242 / 30% Al_2O_3. material. The composition by weight is Al 96.174% with constituents of O, Cr, Co, Cu, Fe, Mg, Ti, Zn, Mg and Ni. An EDM die-sinker was used to machine aluminum metal matrix composite (AMC) to investigate the machinability and identify the optimal machining parameters by varying these parameters and studying their effects on surface roughness (Ra) , surface morphology, MRR and TWR. Scanning electron microscopy (SEM) and Energy dispersive spectroscopy (EDS) are used to analyze formation of white layer and cracks on surface. Material removal rate and wear rate are also the performance to investigate by calculus??. The die-electric used is mineral oil with top directional flushing at a 0.05 kg/cm^3. The three critical machining parameters are peak current, ON-time and OFF-time was varied separately as shown in Table 1.0 to investigate their affect on machining and resulting properties. Ra was measured on four different locations around the circular solid sample and the average from the four measurements is recorded and analyzed for its variance.

Table 1: Machining parameters

Work material	Aluminum material matrix composite
Electrode	Copper
Dielectric fluid	Oil
Direction of fluid flushing	Top
Dielectric pressure	0.05kg/cm^3
Peak Current (A)	1.6, 2, 4, 6, 10, 12
ON-time (μs)	1.5, 2.5, 3.5, 4.5, 5.5, 6.5
OFF-time (μs)	1, 1.5, 2.5, 3.5, 4.5, 5.5

Result and Discussion

Analysis of surface roughness and surface topography was carried out on all samples. The effect of varying peak current, ON-time and OFF-time on the surface properties was recorded and presented in the following graphs. Figure 1, Figure 2 and Figure 3 shows the effects of EDM parameters on surface roughness. The result reaveled that the surface roughness increases when the current and ON-time increase. However, when OFF-time increases, the surface roughness decreases.

Surface Roughness

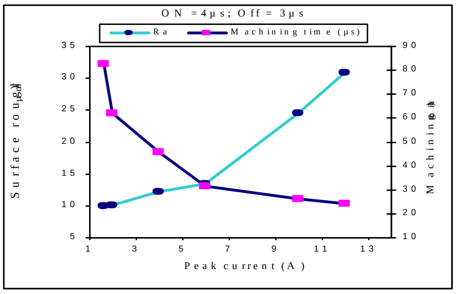

Figure 2: Effect of peak current on Ra

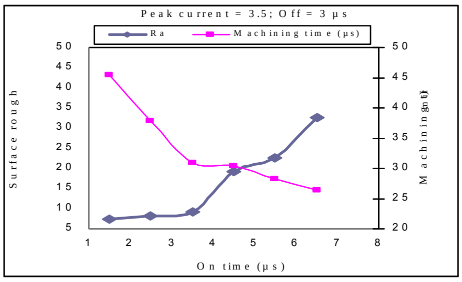

Figure 3: Effect of ON-time on Ra

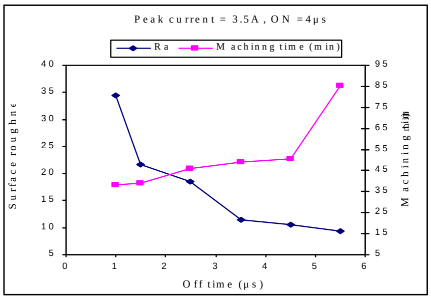

Figure 4: Effect of OFF-time on Ra

Analysis on Surface Roughness

A pertubation plot of Ra was conducted to identify which is the most significant factor affect the surface roughness. The intersection of the three lines was the reference point, and the actual condition factors are as indicated in the graph. The result shows that the factor A (current) has the most significant effects on surface roughness (Figure 15).

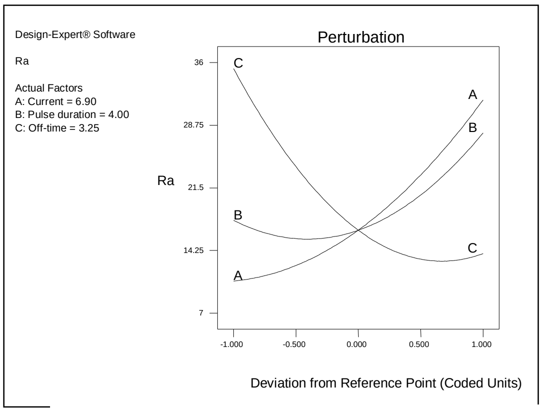

Figure 15: Perturbation plot of peak current, ON-time and OFF-time

Figure 5, Figure 6, and Figure 7 show the relationship between MRR and peak current and ON-time. MRR increases with increasing of current and ON-time.

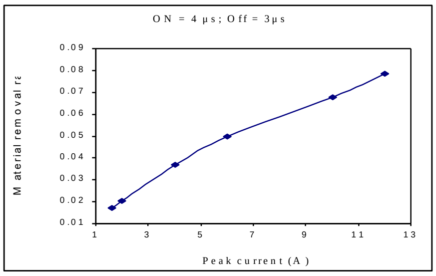

Figure 5: Relationship between MRR and peak current

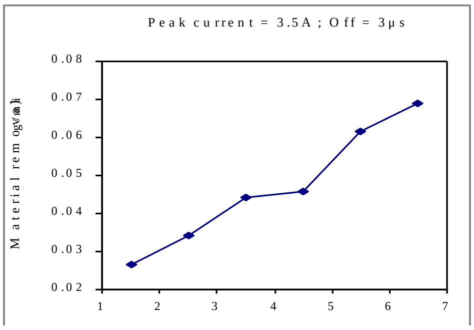

Figure 6: Relationship between MRR and ON-

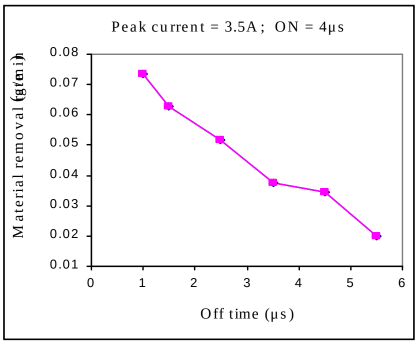

Figure 7: Relationship between MRR and OFF-time

Tool Wear Rate (TWR)

The tool wear rate is the rate at which the cutting edge of tool wears away during machining process (The change of shape of the tool from its original shape, resulting from the gradual loss of tool material). Figure 8, Figure 9 and Figure 10 show influence of machining parameters on TWR. It indicates that the variation of TWR is not uniform. Figure 8 indicates that current influenced more on tool wear rate. For the current bigger than 4.5A, TWR deceases and it justify that the tool wears less when current increases.

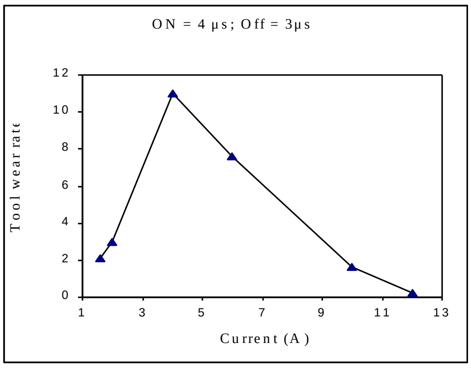

Figure 8: Relationship between TWR and peak current

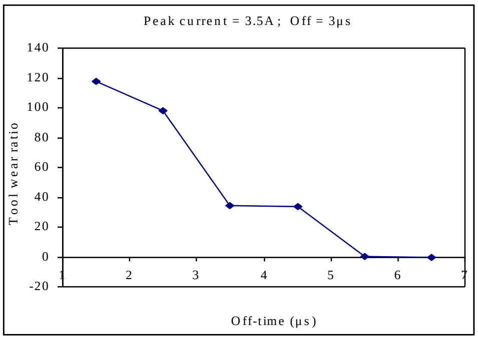

Figure 9: Relationship between TWR and ON-time

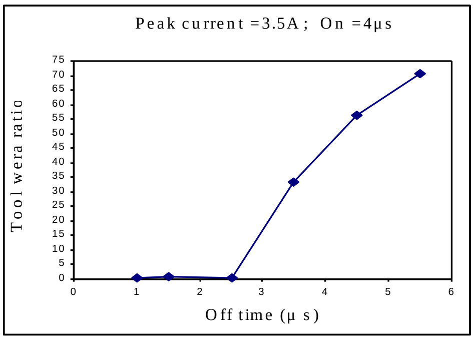

Figure 10: Relationship between TWR and OFF-time

Surface Morphology

SEM analysis indicate effects on the surface of aluminum metal matrix composite due to electro-discharge machining. Small craters and micro-cracks can be seen due to high energy released by discharge followed by rapid cooling. The crater and micro-cracks can be seen especially for samples machined at high peak current (Refer Figure 11).

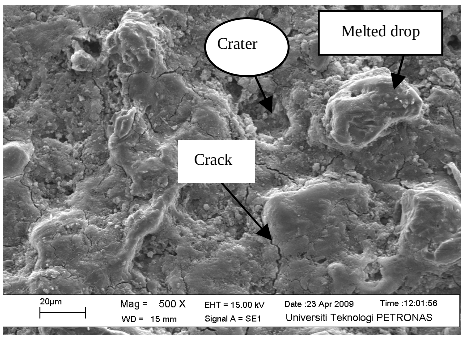

Figure 11: SEM micrograph of surface machined at high peak current (6 Amp)

Overcut (OC)

Over-cut is a normal consequence in EDM machining caused by sparking gap erosion and the known over-cut value can be used for determining the size of the electrode. Figure 13 provides the documented value of over-cut for the tested peak current.

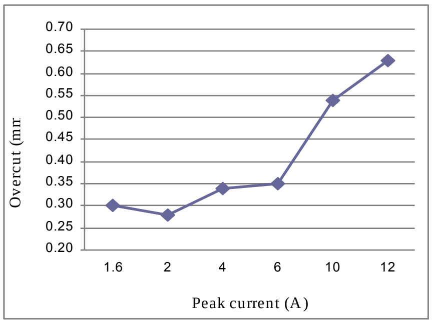

Figure 13: Overcut increases with increasing peak

Conclusion

Aluminum metal matrix composite Al-A242 / 30% Al_2O_3 material can be EDM machined using electrolyte copper to produce good result at low peak current. At high peak current white layer and micro-cracks tends to form on parts of the surface. Surface roughness and surface morphology deteriorates at high peak current. Documented value of over-cut for this material can be utilized to calculate the size of electrode required for EDM. Similarly documented value for MRR can be utilized to predict the machining time required.

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