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Performance of Copper, Copper Tungsten, Graphite and Brass Electrode on MRR, EWR and SR of Aluminium LM6 in EDM Die Sinking

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Abstract – *This paper investigates the performance of copper, copper tungsten, graphite and brass electrode on machining characteristics of aluminium alloy LM6 (Al-Sil2) in the electrical discharge machine (EDM) die sinking. The relationship between the machining parameters such as peak current, voltage, pulse-on time, and pulse-off time on machining characteristics was studied. Design of experiment using orthogonal array of Taguchi technique is employed to design experimental matrix. The analysis was done by using the Minitab software version 16. From this study, it is found that graphite electrode produces the highest material removal rate (MRR) and low in surface roughness (SR) as compare to others electrode materials. Meanwhile, copper electrode has ability to generate highest Ra but low electrode wear rate (EWR). Copper tungsten electrode shows almost similar result with copper electrode however its hardness prevents from wear during machining process. Brass electrode shows low ability to withstand of spark energy that produces highest EWR. Thus, it shows that the objective of the experiment in terms of MRR, EWR and SR should be identified before specific electrode materials can be used for machining aluminium LM6 in EDM die sinking.*

Keywords: EDM Die Sinking, Eelectrode Performance, MRR, EWR, SR

1.0 INTRODUCTION

Electric Discharge Machining (EDM) die sinking is a non-conventional machining process, where electrical energy is used to generate electrical spark and removed the target area due to the high thermal energy of the spark generated causing melting and vaporising of workpiece material. Even tough, the electrode material is also melted and vaporised due to the high temperature of the spark [1][2][3]. Therefore, many experiments have been done using different types of electrode materials such as copper [4], copper tungsten [5], graphite [6] and brass [7] to improve the performance of EDM die sinking. Such type of electrode materials can give different result of machining characteristics such as high or low of material removal rate (MRR), electrode wear rate (EWR) and surface roughness (SR). Banker et al. studied the effect of different type of electrode materials such as aluminium, brass and copper on the MRR, EWR and SR of AISI 304L stainless steel. They revealed that copper has the highest ability to remove

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workpiece followed by aluminium and brass. Meanwhile the highest EWR on the electrode was brass followed by copper and aluminium. Further, many researchers used design of experimental models to investigate the relationship between input of machining EDM die sinking parameters such as current, voltage, pulse on time, pulse of time and the output of machining characteristics such as MRR, EWR and SR. Types of design of experimental models used between input of machining parameters and output of machining characteristics employed were full factorial design [8], response surface method [9], and Taguchi method [10]. In this study, design of experiment using orthogonal array of Taguchi technique is employed to design experimental matrix. As our mention in our previous studied that investigation of EDM die-sinking for aluminium composite (Al-Si2) where aluminium as matrix and silicon carbide as reinforcing agent is still inconsistent and yet need to be established and understood before it could be commercialized [11]. This is because of limitation machining processing of conventional machine such as milling and turning only dependent on the shape of diameter cutter design which is complicated geometrical shapes such as machining on sharp edge, pocketing area, deep slot and micro hole difficult to be done [12][13]. The alternative way to solve these problems is by using EDM Die-Sinking which is always offered a good method to solve the problems. Therefore, the aim of this study is to investigate the performance of copper, copper tungsten, graphite and brass electrode on machining characteristics of aluminium alloy LM6 (Al-Sil2) in the electrical discharge machine (EDM) die sinking.

2.0 EXPERIMENTAL

This project used EDM die-sinking machine Sodick AQ35L series and kerosene was used as dielectric fluid. The workpiece material used was aluminium composite which is known as aluminium alloy LM6 (Al-Sil2). Table 1 shows the physical properties of aluminium LM6.

Table 1: Physical properties of aluminium alloy LM6 [14]

Physical Properties	Value	Units
Coefficient of Thermal Expansion	0.00002	Per ^{o}C at 20-100^{o}C
Thermal conductivity	0.34	Cal/cm^2/cm/^{o}C/at 25^{o}C
Electrical conductivity	37	% copper standard at 20^{o}C
Solidification shrinkage	3.7	Approx. %
Specific Gravity	130	2.65
Freezing Range	575-565	Approx. ^{o}C
Pouring Temperature	725	Approx. ^{o}C

In this project, four input parameters with three levels were selected. This experimental design used the L_9 orthogonal arrays which were nine experimental runs with four factors and three levels. Four factors selected for this experiment were peak current, voltage, pulse on time and

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pulse off time. Table 2 shows the four factors and three levels used for machining aluminium LM6.

Table 2: Factors and levels selected for this experiment

Factors	Levels		
	Low (-1)	Medium (0)	High (+1)
Peak Current (A)	2	15	30
Voltage (V)	21	25	30
Pulse On Time (µs)	100	200	400
Pulse Off Time (µs)	1	5	9

3.0 RESULTS AND DISCUSSION

Result percentage contribution of peak current on the experimental material characteristics, i.e, MRR, EWR and SR, is shown in Figure 1. It is found that peak current shows the most significant contribution on the output responses as compared to the others input parameters such as voltage, pulse on time and pulse off time. For example, copper contributes 97.4% for the MRR and 75.23% for the EWR from peak current input. Meanwhile, percentage contribution from peak current for copper tungsten demonstrates dominance effect for SR which contributes 99.85%. Further, graphite and copper tungsten show similar percentage contribution in MRR and EWR. Then for SR, peak current shows dominance contribution from all of four electrode materials. Therefore, further discussion focuses on the result from input parameter of peak current on the material characteristics, i.e., MRR, EWR and SR.

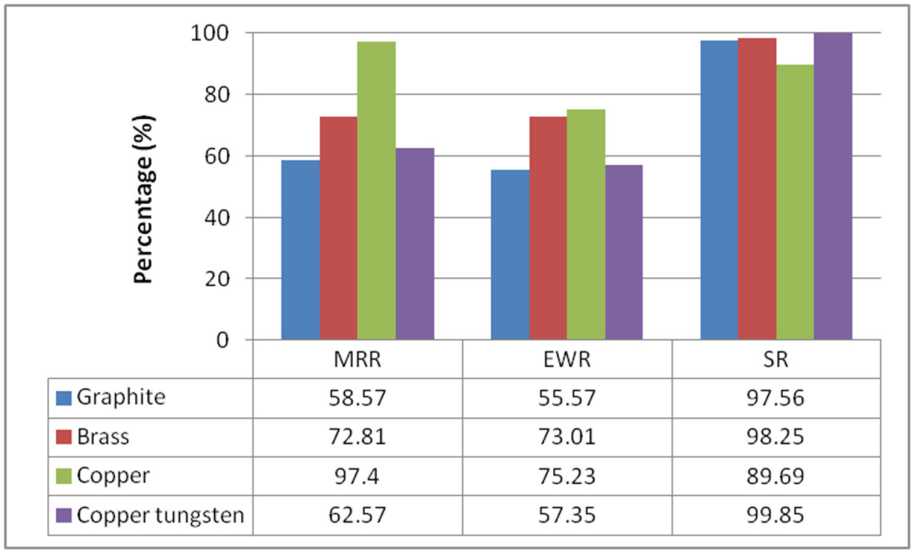

Figure 1: Percentage contribution of peak current for MRR, EWR and SR

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3.1 Material Removal Rate

Fig. 2 shows that material removal rate of the aluminium LM6 increases as the peak current increased. Some researchers agree that peak current influences MRR. When peak current increases, spark discharging increasing energy to facilitate the action of melting and vaporisation. Therefore, advancing the large impulsive force in the spark gap, in which increasing the MRR [5]. It well known that maximizing MRR is the important thing in the EDM process because it can save cost, how to increase the MRR will usually cause the workpiece surface will be roughed. Workpiece surface finish becomes rough from the outcome of fast removal rates. Even though, from this experimental result it shows that the electrode graphite promises high removal rate with better surface quality as shown in Figure 4. Result shows that graphite electrode produces the highest material removal rate meanwhile electrode of brass and copper show the material removal rate almost similar result followed by copper tungsten. Further, in Figure 4 the electrode copper produces the highest surface roughness followed by copper tungsten and brass.

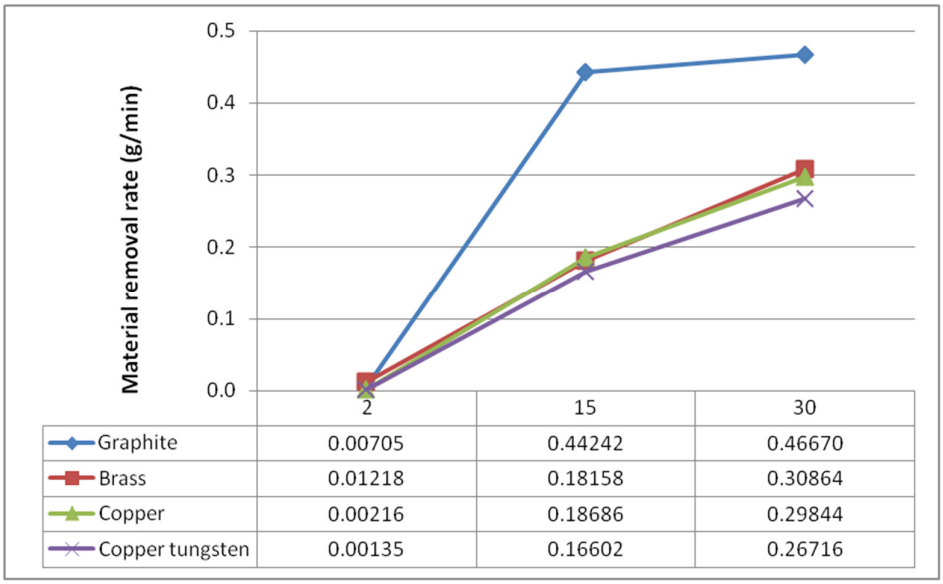

Figure 2: Material removal rate plotted against the peak current

3.2 Electrode Wear Rate

The electrode wear rate of the aluminium LM6 increases as the peak current increased which can be seen clearly in Figure 3. According to the result of electrode wear rate in figure, it indicates that brass has highest electrode wear rate due to the stable sparking conditions. Therefore, electrode brass always uses for application of drilling small holes where the high electrode wear is acceptable [2]. Meanwhile, copper tungsten resist wear better than copper and brass. It have been stated before that copper have higher wear rate than graphite due to having higher melting point [6].

3.3 Surface Roughness

The surface roughness increases when the peak current increased as shown in Figure 4. It well known that peak current shows the most influence factor to surface roughness. When the value of peak current increases, it leads to higher surface roughness due to increase in discharge heat

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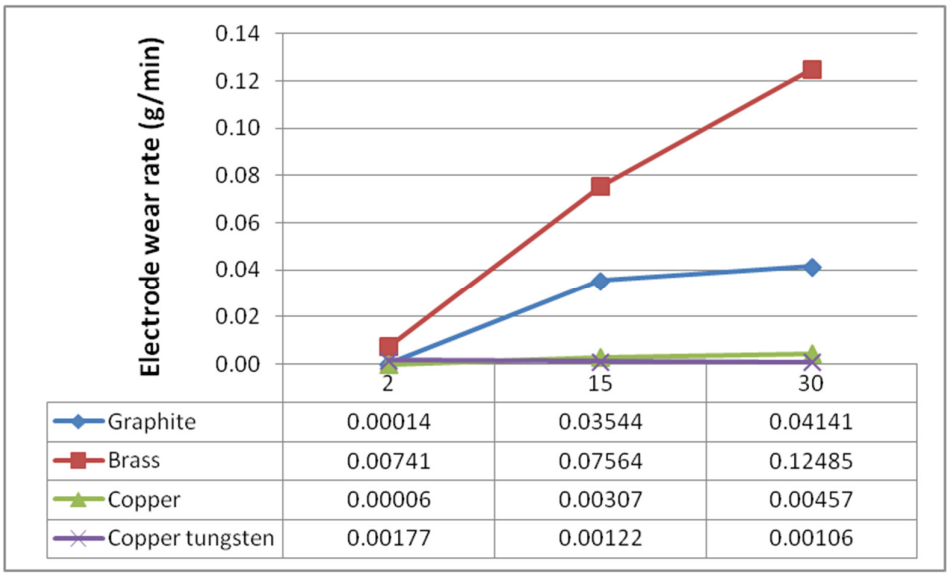
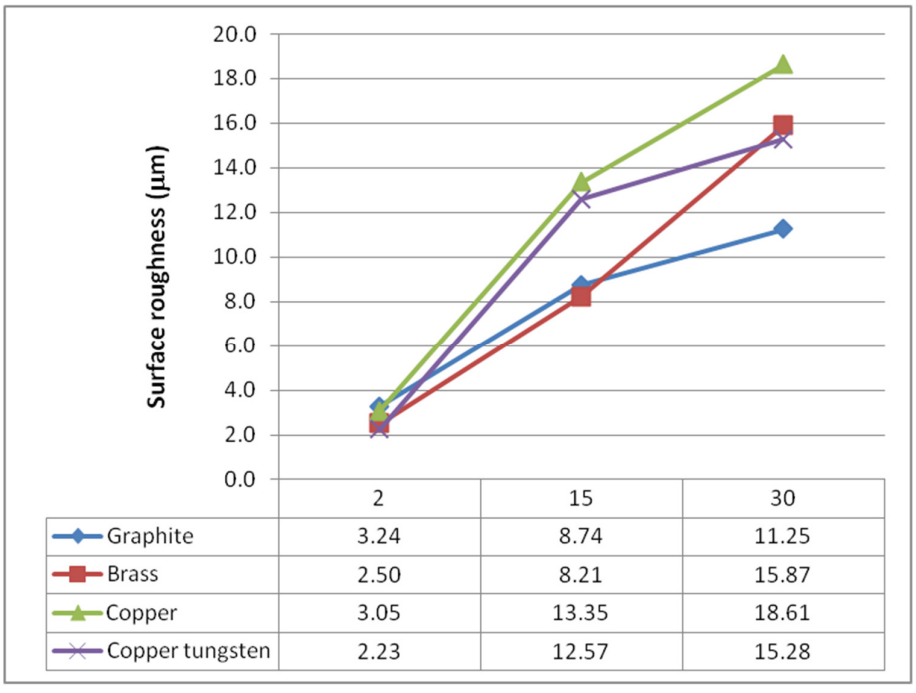
energy at the point where the discharge takes place. Formation of crater begins with the pool area of molten metal is formed after overheated is developed. Molten metal evaporates forming gas bubbles and taking molten metal material away when it overheated then after that it blow up when the discharge is ceased. Formation of crater becomes increased through succeed discharges. Different types of electrode materials produce different size of crater. Previous researcher has stated that graphite is better than electrode copper electrode in term of surface finish and materila removal rate [3].



	2	15	30
Graphite	0.00014	0.03544	0.04141
Brass	0.00741	0.07564	0.12485
Copper	0.00006	0.00307	0.00457
Copper tungsten	0.00177	0.00122	0.00106

Figure 3: Electrode wear rate plotted against the peak current



	2	15	30
Graphite	3.24	8.74	11.25
Brass	2.50	8.21	15.87
Copper	3.05	13.35	18.61
Copper tungsten	2.23	12.57	15.28

Figure 4: Surface roughness plotted against the peak current

4.0 CONCLUSSION

In this study, the performance of copper, copper tungsten, graphite and brass electrode on MRR, EWR and SR of aluminium LM6 in EDM die sinking is investigated. It can be concluded that high material removal rate with low surface roughness can be produced using electrode graphite as compare to others electrode materials. Meanwhile, copper generates high surface roughness and low electrode wear rate with copper tungsten due to its hardness prevent from wear during machining process. Brass electrode shows low ability to withstand of spark energy that produces highest EWR. Thus, it shows that thermal conductivity and melting point of electrode materials influence the output quality of material characteristics of workpiece.

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