Journal of Solid and Fluid Mechanics (JSFM), 13(4): 1-3, 2023

Journal of Solid and Fluid Mechanics (JSFM)

DOI: 10.22044/JSFM.2023.12837.3711

Investigating factors affecting electrode wear rate in electrical discharge machining of AZ91 magnesium alloy metal matrix composite reinforced with silicon carbide microparticles

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Received: 03/14/2023 Revised: 08/23/2023 Accepted: 10/01/2023

Abstract

Metal matrix composites have attracted a lot of attention for application in the aerospace, defense, and automotive industries. Machining these materials with traditional machining methods is very difficult due to the presence of abrasive particles. Electrical Discharge Machining (EDM) is one of the most widely used advanced machining methods and seems to be a good method for machining metal matrix composites. Tool wear occurs during the process and cannot be reduced to zero, but it can be reduced as much as possible. In this research, the effect of discharge peak current, pulse on time, and pulse off time on the workpiece made of AZ91 magnesium alloy, reinforced with 5% of powdered silicon carbide particles has been investigated. The effect of these parameters on the wear rate of copper electrode is studied. The tests of this process have been modeled using the response surface methodology. 17 experiments have been done to reach the results. Discharge peak current, pulse on time, the interaction effect of discharge peak current and pulse on time, and the interaction effect of pulse off time and discharge peak current are effective factors on electrode wear rate. The lowest electrode wear rate is on the 300 microseconds pulse on time, 11.69amp discharge peak current, and pulse off time of 20 microseconds.

Keywords: electrical discharge machining, magnesium matrix composite, electrode wear rate, Response surface methodology.

1. Introduction

Extensive research is being done in the field of materials science towards the introduction and development of light engineering materials. Advanced automotive and aerospace technologies need such characteristics for their used materials to increase production efficiency. These features cannot be achieved with titanium, aluminum, and magnesium alloys. As a result, designers have introduced new types of composites called metal matrix composites (MMCs). MMC is a composite material with at least two constituent parts, one is the base metal and the other is reinforcing particles that may be of a different metal or another material such as a ceramic or organic compound. The base metal is a monolithic material in which reinforcing particles are embedded and are completely continuous. A lighter metal such as aluminum, magnesium, or titanium is usually used as the substrate, providing a conformal support for the reinforcing particles [1].

Electric discharge machining is one of the advanced machining methods that is used in the industry for high-precision machining of all kinds of conductive materials, alloys, and even ceramic materials of any hardness and shape that are difficult to manufacture with traditional machining. Among many machining techniques, EDM has proven to be effective in machining composite materials. Various researchers have conducted many tests on different composites [2].

In this research, for the first time, a detailed and methodical experimental study was carried out to investigate the effect of parameters of discharge peak current (I), pulse on time (Ton), and pulse off time (Toff) in the machining process of electric discharge machining of AZ91 magnesium alloy metal matrix composite reinforced with 5% of powdered silicon carbide particles has been done. The electrode wear rate (EWR) response is studied. To model the experiments, the response surface methodology (RSM) has been used, and second-order linear regression equations have been presented to predict the behavior of the parameters.

2. Materials and methods

The current magnesium matrix composite is produced by the stir-casting method. Silicon carbide particles with a grain size of 45 microns and a mesh of 320 were used to make the metal matrix composite of the present study. To make the test sample, the base alloy mixture with reinforcing particles was heated in the furnace to a temperature above 700 degrees Celsius to melt all the metal points, and a mechanical and magnetic stirrer was used during melting. Finally, the metal matrix composite of AZ91 alloy was made with 5% powdered silicon carbide reinforcing particles. The schematic image of the furnace used and the method of making the prototype is shown in “Figure 1”. The image of the scanning electron microscope (SEM) and X-ray energy diffraction spectroscopy (EDS) analysis of the workpiece used in the current research is also given in “Figure 2”.

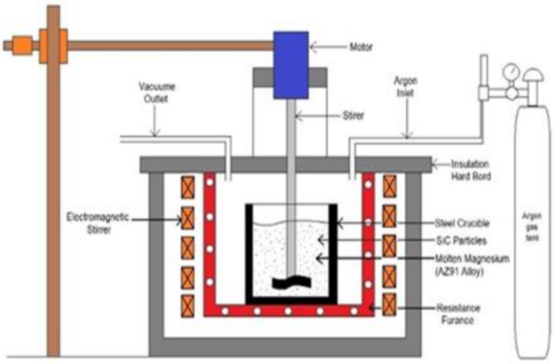

Figure 1. Schematic image of the manufacturing method of the material used

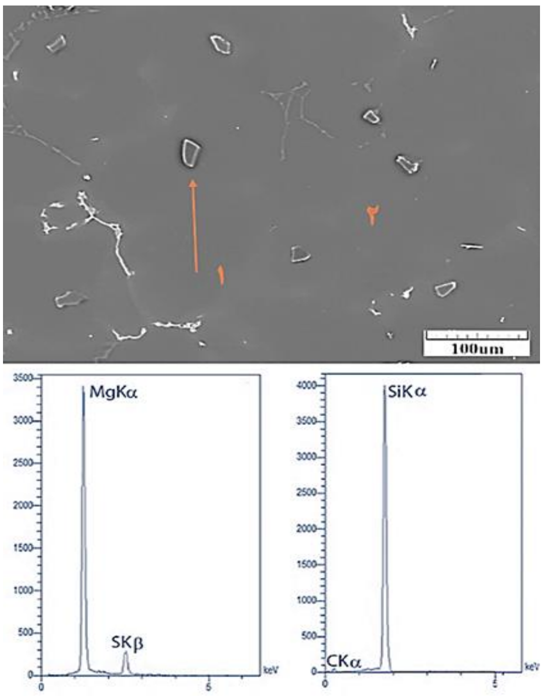

Figure 2. Scanning Electron Microscope (SEM) Image and X-ray Energy Diffraction Spectroscopy (EDS) Analysis

2.1. The design of experiments

In this research, the response surface methodology (RSM) and, composite design (CCD), were used to design the experiments. The levels of input parameters including discharge peak current, pulse on time and pulse off time are presented in “Table 1”. The value of α=1 is considered. According to the value of alpha, 3 levels are considered for each of the input parameters. The number of tests in this method, considering 3 repetitions for the central point, is 17 tests.

Table 1. Input parameters and their values

Factor	Name	Low	Center	High
A	pulse on time (µs)	100	200	300
B	peak current (A)	5	10	15
C	Pulse off time (µs)	20	30	40

3. Results and Discussion

Equation (1) is used to calculate the electrode wear rate.

$$EWR = \frac{W_b - W_a}{T_m} (g/min) \quad (1)$$

W_b = electrode weight before machining (g), W_a = electrode weight after machining (g), T_m = machining time (min).

3.1. Effect of input parameters on EWR

Among the parameters studied in this research, one of the most important parameters with the greatest effect is the discharge peak current “Figure 3 (a)”. The pulse on time “Figure 3 (b)” and the pulse off time “Figure 3 (c)” are the next parameters that have the greatest effect on the tool wear rate. The interaction effect of the discharge peak current and the pulse on time are the next influencing parameters on the electrode wear rate “Figure 3 (d)”.The interaction effect of pulse off time and the discharge peak current also affects electrode wear rate “Figure 3 (e)”.After melting the surface of the workpiece as a result of electric discharge, by continuing to apply the voltage and current, the ionization channel becomes wider and the surface of the melting point increases, but this voltage and current cannot be continued because with the continuation of the current, that point It gets hotter and the carbons get enough time to burn, and these carbons stick together due to the resulting pressure and because the ionization channel is wet, and instead of moving through the ionization channel, the electrons are transferred through this mass of carbon, and besides It does not help in melting more, but it increases the electrode wear and also causes a very bad complication called ARC or welding. With the lengthening of the pulse on time, the plasma channel expands its diameter increases, and part of the energy is transferred to the dielectric material, Material removal does not take place, therefore, the electrode wear is reduced compared to the machining time. The copper electrode is much softer than the silicon carbide particles in the magnesium matrix composite. When the pulse is off, due to the collisions between the silicon carbide particles and the electrode surface, the wear of the electrode increases. In the electric discharge machining process with positive electrode polarity, when the duration of the pulse on time is short, the dominant mechanism for material removal is the movement of electrons from the negative pole (workpiece) to the positive pole (electrode), which causes more corrosion of the electrode in this condition; With the increase of the light time of the pulse, due to the expansion of the radius of the plasma channel, the movement of positive ions from the side of the tool (positive pole) to the workpiece (negative pole) becomes easier and when the positive ions collide, it is the dominant mechanism of chip removal and This factor reduces the electrode wear rate [3]. The heat vaporizes the dielectric liquid and creates a pressure between the electrode and the workpiece, but this pressure is much smaller than that which can cause movement in the workpiece or the electrode, but this pressure is a very large value per unit area and causes electrode wear. As the removed material moves away from the workpiece surface, this material causes wear on the surface of the electrode, and at longer pulse off times, the wear created on the electrode surface will be greater.

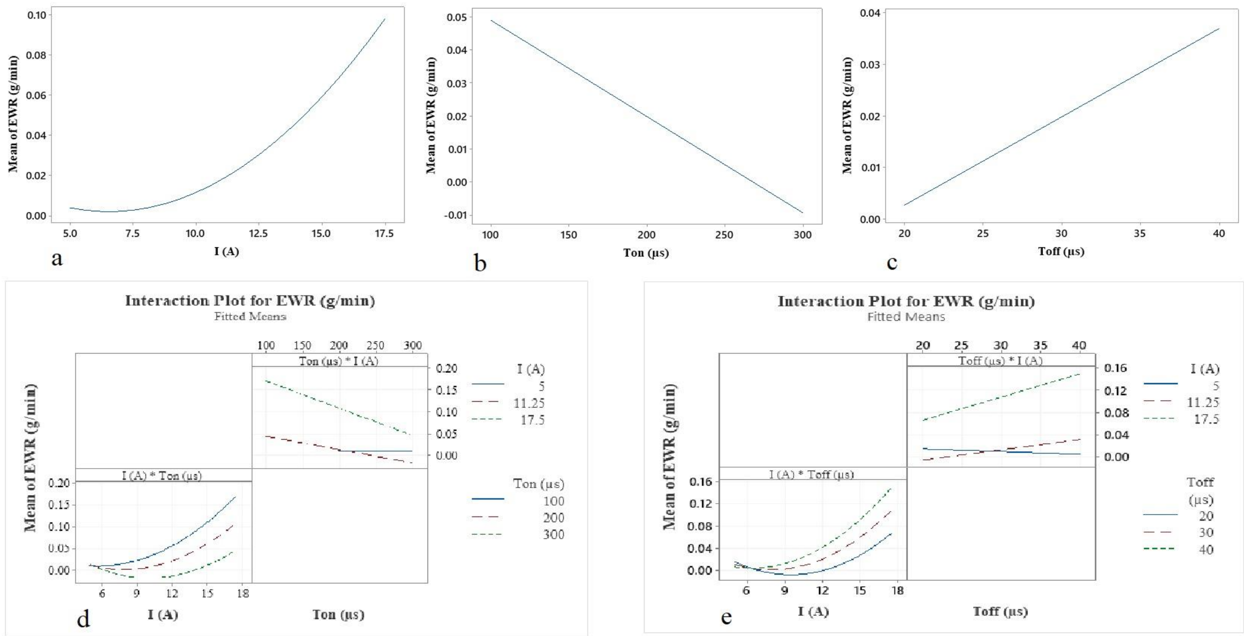

Figure 3. Diagrams of the effects of discharge peak current (a), pulse on time (b), pulse off time (c), interaction effect of pulse on time and discharge peak current (d), and interaction effect of discharge peak current and pulse off time (e) on the electrode wear rate

4. Conclusions

According to the results obtained from the present research and the examination of its charts and tables, the general results of this research can be stated as follows:

- Due to the presence of abrasive particles in metal matrix composites and the problems in their traditional machining, using the electrical discharge machining method can be appropriate.
- Among the parameters investigated in this research, the factors affecting the electrode wear rate are the discharge peak current, the pulse on time, the pulse off time, the interaction effect of the pulse on time and the discharge peak current, and the interaction effect of the discharge peak current and the pulse off time.
- By optimizing the process to achieve the lowest electrode wear rate, the input parameters have been obtained as pulse on time of 300 microseconds, discharge peak current of 11.69 amps and pulse off time of 20 microseconds.

5. References

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