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An Analysis of Machining Parameters for Metal Matrix Composite

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Abstract

The electro-discharge machining analysis of hybrid Composite is presented in this work. Variables are chosen for the input process parameters. The material removal rate is acknowledged as an output parameter, together with the current, graphite and silicon carbide percentage and pulse on time. We used the Taguchi Method to conduct our experiments. To create the theoretical model and look into how process parameters affect the rate at which material is removed from hybrid Composite pieces, analysis of variance was used. The outcomes showed that the material removal rate accuracy of hybrid Composite is highly influenced by current, silicon carbide percentage, and graphite content. Additionally, the machining theoretical model is constructed and shows the effectiveness within the allowable range. The model is a great tool for accurately estimating the correction factors needed to machine complexly shaped hybrid Composite parts, it is concluded at the end. Aluminum and its alloys are widely employed in a wide range of technical applications due to their excellent mechanical qualities. However, strong reinforcement has been added to further increase its tribological properties. This strong aluminum metal matrix composite was complicated to manufacture and machine at the same time. The most common modern solution for overcoming this was the Electrical Discharge Machine. Nevertheless, in theory or experiment, there is insufficient data to machine it at the ideal parameter. These were designed to concentrate on assessing and enhancing the EDM process parameters.

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INTRODUCTION AND LITERATURE SURVEY

Recently, it has been thought that substituting hybrid Composite for metallic machine parts could be a viable solution to a number of problems, such as expensive metal, rusting, and component weight. hybrid Composite materials that have mechanical and physical qualities that are comparable to or better than those of metals are highly valued in the contemporary machining industry. It is known that hybrid Composite is a class of materials that are challenging to process. Adding different reinforcements, like silicon carbide, alumina, graphite, etc., can significantly improve the mechanical and tribological properties of metal matrix hybrid Composite s hybrid Composite s [1]. By using unconventional machining techniques, particularly electrical discharge machining, cutting hard materials like ceramics and metal matrix hybrid Composite s hybrid Composite s might be less challenging [2]. The researchers discovered that when they machined aluminum hybrid Composite s, control parameters affected the machining properties [3]. In order to improve MRR and reduce electrode wear, the authors looked at the parametric combination of control parameters [4].

The EDM of the Al-Mg2-Si hybrid Composite was analyzed by the authors using RSM. [5] They found that the machining settings have a big impact on the microstructure and profile of machined surfaces. [6] The authors demonstrated that utilizing powder in addition to standard EDM produced superior experimental outcomes. [7] The authors demonstrated that whereas SiC weight fraction increases had a favorable effect on TWR and SR, they had a detrimental effect on MRR. [8] The authors used a Taguchi-based gray relational technique to determine the optimal parametric combination of machining settings.[9] Compared to the traditional EDM method, the authors' high abrasive EDM approach helped to improve efficiency and surface polish. [10] The author successfully machined an Al-SiC hybrid Composite after analyzing the effects of the input settings and obtaining better results than a stationary electrode. [11] By comparing microwave heat treatment to traditional heat treatment, the author demonstrated the effectiveness of microwave heat treatment. [12] For the purpose of determining the ideal parametric combination of control elements, the author used the Taguchi DOE technique. [13] On time settings, more current and pulse were shown to yield a larger MRR compared to surface quality, radial overcut, and taper city. [14] The current study's goal is to evaluate how control variables affect the machining parameters for metal matrix hybrid Composite s hybrid Composite s [15] The development of lightweight hybrid Composite materials is important for many important industrial applications as well as aviation. These materials lower the load of CO2 emissions and are economically efficient.[16] Due to their strong construction and resistance to heat, the binders employed in CM have a high elastic strength and stable operation. [17] On the other hand, the ductile matrix phase in the CM is what transmits the external load stress to the filler phase. A CM's mechanical attributes, such as strength, stiffness, and deformability, are determined by the filler or reinforcement that is utilized in it. [18] Ceramic or carbon fibers could be the filler. Both their mechanical and physical qualities are good in these fibers. Weaving is the process that turns these fibers into cloth. [19] Due of a mismatch in characteristics between the filler and matrix phases, CMs have numerous constraints while machining. Because of their high filler material hardness, poor binder flexibility, stacking, and structural variability, CMs are prone to delaminate over machining. [20] In addition, pulling out of fibers and other negative effects occur in the machined zone when PCMs are machined due to strong cutting forces and vibrations. [21] It is possible to see pull-out and delamination of the fibers, which lowers the constructed feature's quality. [22] In addition, excessive tool wear rates during CM machining raise manufacturing costs and reduce productivity. Different non-conventional machining techniques have been developed for these materials in order to avoid such issues.[23] Environmental risks arise from non-conventional processes like chemical and electrochemical processing, even though they offer numerous benefits over traditional machining techniques.[24] However, only in situations where accuracy is not the main priority are methods like water jet treatment, ultrasonic treatment, electron beam treatment, plasma treatment, and laser treatment deemed beneficial.[25] Furthermore, the applicability of these machining techniques for small-scale component machining is limited due to their drawbacks, which include lack of precision and thermal damage of the matrix phase.[26] Electrical discharge machining has shown to be a viable option among the different non-conventional machining techniques for accurately preparing tiny components [27]. This procedure involves the conversion of electrical energy into heat energy that melts the target zone through the use of thermal-electrical energy, and it may produce an exact curved profile on both metallic and hybrid Composite materials [28]. Using a computer numerical control program, the electrode travels vertically across sapphire or diamond guides during this operation. The workpiece and electrode are cooled, dirt is flushed away, and a constant stream of deionized water or another fluid is utilized as a dielectric medium. [29-30] A spark is created between the electrode tool and the workpiece electrode when the dielectric fluid becomes ionized. [31] A number of variables, including the working fluid's characteristics, the electrodes' material, the level of erosion-related pollution, and the dielectric flow pressure, affect dielectric fluid ionize. [32] The process variables and thermo physical characteristics determine unevenly the material is removed. Electrode erosion is controllable precisely by adjusting these parameters. [33] The working fluid condition, voltage, pulse creation time, and inter electrode gap size all affect the spark energy within the electrodes.[34] The size of the inter-electrode gap, thus, affects the precision of the CMs. [35] The working fluid's characteristics and the inhomogeneity of the structures/properties both affect the inter-electrode gap error.[36] On the surface of the workpiece, CMs cause craters and dimples of various sizes to appear. This random formation of craters and dimples makes it more difficult to forecast the inter-electrode spacing. [37] A number of researchers have looked into the use of on CMs. On the other hand, it is well known that CMs have a restricted conductivity. As a result, the CM's resin was destroyed along the holes' edges during the process. [38] This resulted from the machining zone's high temperatures and inadequate cooling. [39] The authors examined how unidirectional carbon fiber reinforced polymer hybrid Composite s' material removal rate, top and bottom cut-widths, and workpiece edge damage were affected by gap voltage, current, pulse-on time, and pulse-off time.[40] The single component influencing cut-width on the top surface was determined to be current, and pulse-off time was shown to be the statistically significant parameter in terms of MRR.[41] Authors recently looked into a modified version of that helps the electrodes spark an electrical spark during hybrid Composite cutting. [42] Incomplete cuts and machining direction variations during hybrid Composite s were managed with the use of metal plates as supporting electrodes. [43] The findings demonstrated that, while all other parameters were unchanged, cutting time was shortened by raising the current. [44] Similarly, by adding a conductive layer on top of the non-conductive CM, it was found in related investigations pertaining to CMs that the quality and precision of holes in a low-conductive material could be controlled. [45] Additionally, CMs' theoretical model creation offers a roadmap for achieving the process's necessary precision.

Materials and Method

The chosen process parameters were pulse duration, graphite and silicon carbide proportion, and current. The orthogonal array was used to conduct the experimental runs. Mini Tab software was utilized to assist in obtaining the design matrix for the investigation. A hybrid Composite utilized in the aviation sector was selected for this investigation. Instead of submerging the CMs in a water bath, which would have caused flaws including swelling and water filling, distilled water was sprayed on the electrode as a dielectric medium. Metal matrix hybrid Composites are made by liquid stir casting and contain reinforcement made of 5–15% silicon carbide and 5–15% graphite. They weigh between 70 and 90 percent aluminum alloy. The reinforcing components are separated from the molten metal matrix material by heating them separately in a graphite crucible. The mixture is made homogeneous by using a mechanical stirrer the entire volume of silicon carbide and graphite, which equals %, along with the three levels of low, medium, and high pulse duration is regarded as control parameters. By examining the rate at which material is removed, one may evaluate the machining quality. The ratio of the pre- and post-machining weight differential of the material to the machining time is used to calculate the rates of material removal. EDM, a non-traditional machining technique, is used to carry out the experimental trials. Excellent mechanical and electrical properties characterize copper, the material used to make electrodes. It is the suitable material for a tool to machine metal matrix hybrid Composite s hybrid Composite s. The machining setup and the Taguchi method are used in the experiments. The weights of the electrode and work piece are used to compute the rates of material removal, and the orthogonal array L27 is used to set up the experimental trials. Averaging values are analyzed and all experiments are run twice for better results.

Experimental Test

This study employs the Taguchi approach, which works incredibly well for handling answers that are impacted by multiple variables. This strategy offers a straightforward, effective, and methodical way to identify the ideal machining parameters and is a potent Design of Experiments tool. The number of experiments needed to model the response functions is significantly reduced with this strategy as opposed to the traditional approach to experimentation. One variable at a time experiments, in which all other variables are kept constant, are a feature of traditional experimentation. The primary drawback of this approach is that it ignores any potential interactions between the parameters. Failure of one component to have the same influence on the response at varying levels of another factor is called an interaction. Furthermore, it is not feasible to investigate every element and identify its primary effects that is, its individual effects in a single experiment. The Taguchi approach gets around all of these problems. The response function's average value at a specific parameter level is the principal consequence. A factor level's effect is the departure it makes from the mean reaction as a whole. The Taguchi technique was developed to optimize processes and find the best combinations of elements for certain responses.

a. Identifying the response functions and the process parameters to be assessed is the first stage.
b. Find out how many layers the process parameters have and whether they interact.
c. Decide on a suitable orthogonal array, set up the process settings for it, and carries out the related experiments.
d. Evaluate the experimental findings and decide on the ideal set of process parameters.
e. Use a confirmation experiment to validate that the process parameters are ideal.

Response functions include material removal rate, tool removal rate, and surface roughness, while process parameters including current, pulse time, and SiC-Gr % were selected for the studies. The selection of the parameters' range and number of levels is based on a review of the literature, taking into account the capabilities of the commercial EDM machine that is currently in use as well as basic guidelines for machining conditions for composites. Choosing a suitable orthogonal array for the experiments requires calculating the total number of degrees of freedom. The definition of degrees of freedom is the number of comparisons required to establish which level is superior. One degree of freedom, for instance, is present in a two-level parameter. The levels of the machining parameters and their interactions with one another are not included in the current analysis. The selection of the parameters' range and number of levels is based on a review of the literature, taking into account the capabilities of the commercial EDM machine that is currently in use as well as basic guidelines for machining conditions for composites. Choosing a suitable orthogonal array for the experiments requires calculating the total number of degrees of freedom. The definition of degrees of freedom is the number of comparisons required to establish which level is superior. One degree of freedom, for instance, is present in a two-level parameter. The levels of the machining parameters and their interactions with one another are not included in the current analysis. Table 1 depicts an experimental configuration with an L27 orthogonal array.

RESULTS AND DISCUSSION

A statistical method that is frequently used to assess a model's significance and the impact of individual process parameters on the experimental response is analysis of variance. The process factors, namely current, percentage of graphite and silicon carbide, and pulse duration, have a significant impact on the measured response Material Removal Rate, according to a statistical analysis of the experimental data. The suggested model satisfies the requirements for a sufficient model and does not violate the assumptions of independent or constant variance. The effects of current, pulse length, and equal weight percentages of graphite and silicon carbide on the material removal rate of the metal matrix hybrid Composite s are shown in Figures 1, 2, and 3. The hybrid Composite s' metal removal rate grows linearly as the current value increases. The increased energy of the spark discharge allows the strong impulsive force in the spark gap to travel forward more easily and melt more quickly, increasing the rate at which metal is eliminated. High current level causes the work piece and tool electrode to experience increased heat stress, which results in an increased rate of metal loss. It has been demonstrated that when current increases, the rate rises.

Table 1. An experimental configuration with an L27 orthogonal array.

Experiment number	Parameter A	Parameter B	Parameter C
1	1	1	1
2	1	1	2
3	1	1	3
4	1	2	1
5	1	2	2
6	1	2	3
7	1	3	1
8	1	3	2
9	1	3	3
10	2	1	1
11	2	1	2
12	2	1	3
13	2	2	1
14	2	2	2
15	2	2	3
16	2	3	1
17	2	3	2
18	2	3	3
19	3	1	1
20	3	1	2
21	3	1	3
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23	3	2	2
24	3	2	3
25	3	3	1
26	3	3	2
27	3	3	3

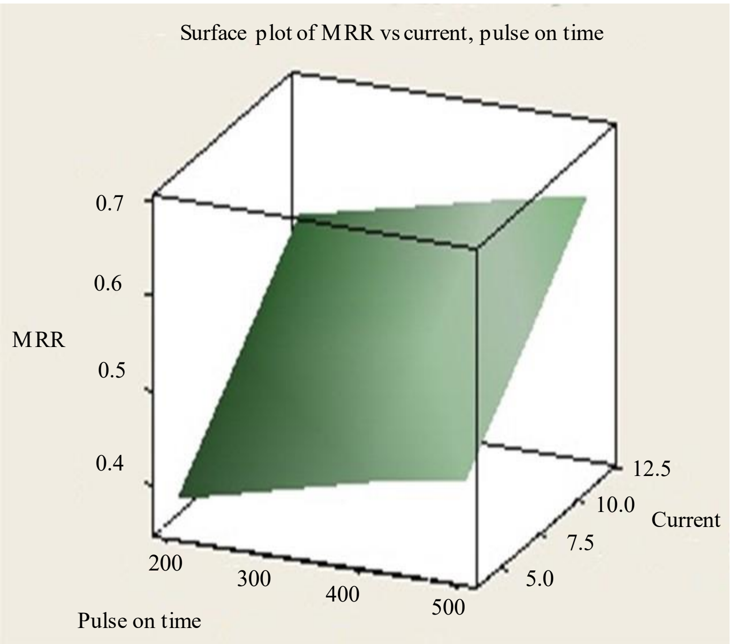

Figure 1. Comparing MRR with Current, the combined weight percentage of SiC-Gr.

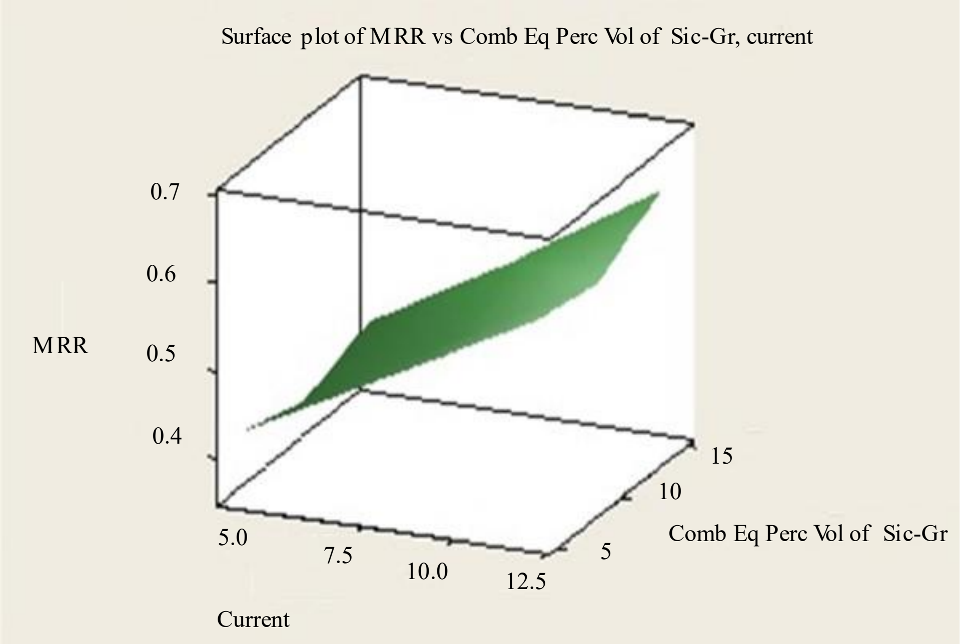

Figure 2. Comparing MRR and Pulse on Time, the combined weight percentage of SiC-Gr.

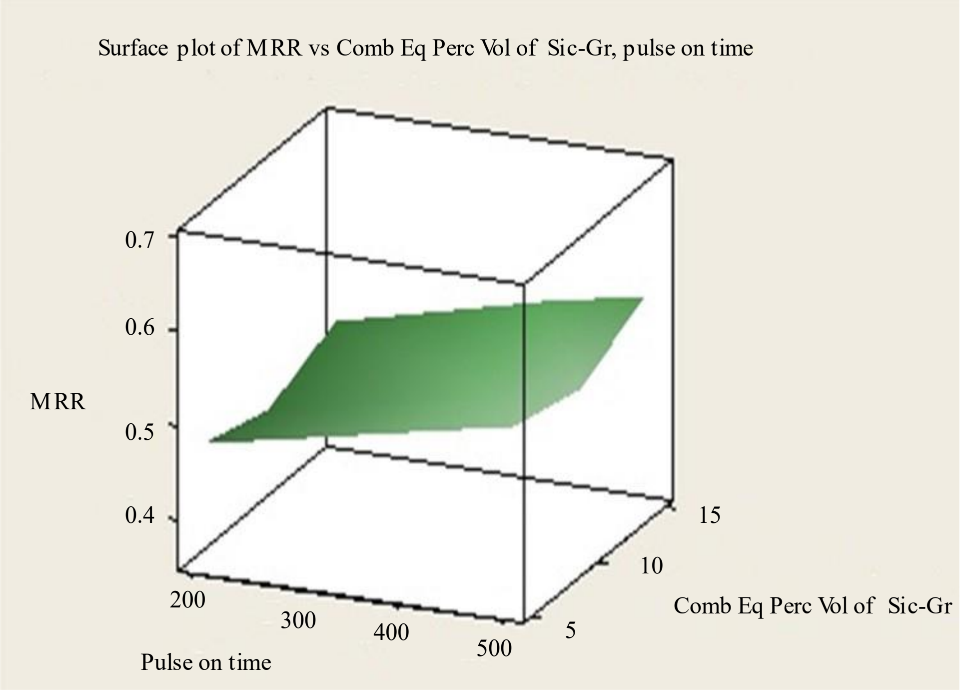

Figure 3. Comparing MRR with pulse on time and current.

CONCLUSIONS

The outcome of the experiment shows how processing parameters like current, the percentage of silicon carbide and graphite, pulse-on and pulse-off times, and others rely on the pace of material removal. The process parameters for milling the CM workpiece are found to be significantly influenced by the following factors: current, the percentage of silicon carbide and graphite, and their interaction. In addition, an interaction model that best fits the experimental values collected is built to estimate the material removal rate. A complex-shaped CM product could be accurately machined if the material removal rate correction factor for the electrode's trajectory was predicted using the established model. It is therefore recommended that the given model effectively enables accuracy predictions. Metal matrix hybrid Composite s hybrid Composites have several reinforcing. It has superior mechanical and tribological properties when compared to single reinforced hybrid Composite s. Because hard materials are challenging to deal with using regular machining processes, non-traditional machining methods must be developed. Regardless of the work piece's material properties, electric discharge machining is a widely used and acknowledged technology. To optimize material removal rate, the best combination of EDM parameters is searched for. The degree to which the three control variables influenced the machining characteristics considered in this study was examined. It is possible to attain the highest material removal rate by using the ideal values for the control parameters. The metal matrix hybrid Composite s aluminum alloy that has been added 15% graphite and 15% silicon carbide shows improved metal removal rate, reduced surface roughness, and reduced tool wear.

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