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An Experimental Investigation of Machining Parameters on Aluminum Composites

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Abstract

The need for a material with good mechanical, thermal, and wear resistant properties is satisfied by aluminum composite. However, the biggest obstacle to substituting it with alternative materials is the machining challenges. For this kind of hard-to-cut material, electric discharge machining is a very efficient method. Thus, using a Taguchi-based method, an attempt has been made to determine the most advantageous amount of input parameters for EDM of Al composite. Taguchi's orthogonal array is used in the creation of the experimentation plan. The investigation takes into account several process characteristics, including voltage, peak current, and pulse on time. Due to their unique mechanical properties, metal-matrix composites (MMCs) and hybrid metal-matrix composites (HMMCs) are cutting edge materials that are ideal for industrial use. When comparing single-reinforced composites to hybrid composites containing two or more reinforcing materials, the latter offer improved mechanical and tribological properties. Due to the difficulty of machining hard materials using traditional methods, non-conventional machining processes have been introduced. Electric discharge machines is widely acknowledged and utilized as a non-traditional procedure, regardless of the material properties of the workpiece. The primary objectives of the current endeavor are to enhance material removal rate and determine the optimal combination of EDM parameters. Liquid stir casting is the technique employed in fabricating aluminum hybrid composites. An L27 orthogonal array is utilized in the present work, demonstrating the impact of multiple factors on the resulting reactions. The Taguchi method was employed in the current study to identify the optimal combination of parameters.

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INTRODUCTION

Metal-matrix composites (MMCs) and hybrid metal-matrix composites (HMMCs) can exhibit improved mechanical properties through compositional, processing, and manufacturing optimization. Though their processing and manufacture are difficult, MMCs and HMMCs have special mechanical qualities. Unfortunately, the current technologies for processing and manufacturing MMC and HMMC have high production costs and subpar mechanical properties. To increase their mechanical and frictional qualities, ceramic materials can be added to these materials in a variety of methods. While previous research about process parameters have looked at the process ability of different materials, not enough attention has been paid to HMMC as a working material. Moreover, little study has been done on optimizing various response characteristics. Complexity and volatility describe a series of notable shifts in the needs of the industrial sector. Properties like longevity, high strength, light weight, and low density are needed by industry today, and this has motivated researchers all over the world to concentrate on the study of materials and their uses. The researcher then focused on creating metal matrix composites as a result of this. The aluminum base composite has been in demand in the last few years for a wide range of technical applications, including aerospace, automotive, and piston applications. It also meets industrial needs. Different types of metal cutting operations can be used in machining operations, depending on the shape of the work piece. Industries are expanding, creating a greater demand for materials. To meet this demand, advanced materials such as hybrid composites are being used [1]. A study found that using a rotary EDM with a disk-like electrode resulted in a higher material removal rate (MRR) for the Al2O3/6061 Al composite, making it a viable option for machining [2]. Another analysis showed that the MRR for AlSiC composite EDM increased with higher discharge currents, regardless of the electrode's material, polarity, or SiC percentage [3]. Research indicates that increasing the percentage of SiCp reduces exposed electrical wear and increases the MRR [4]. Furthermore, the study of silicon carbide elements revealed a significant impact on the material removal rate. [5] The mechanical properties showed improvement when the reinforcing elements were evenly distributed. [6]

SV was a less significant factor compared to other work-related factors. [7] Hardness levels increase with the rise in silicon carbide composition. [8] It was observed that the surface roughness value was low under optimal conditions. [9] The study found that the values of hardness and density decrease with increasing graphite concentration. [10]An investigation into the impact of parameters such as gap voltage, pulse on time, pulse off time, wire feed, and percentage reinforcement on the responses MRR and SR was conducted during the machining of Al Alloy (A413)/fly ash/boron carbide hybrid composites using WEDM, as detailed.[11] The hybrid composites containing Al alloy (A413), fly ash, and boron carbide were fabricated.[12] In an examination of composites, the focus was on achieving uniform fiber distribution in the metal matrix to enhance their characteristics.[13] A new high-speed abrasive EDM technique was devised for machining particle-reinforced MMCs. [14] The research revealed that the high-speed abrasive EDM method surpassed the traditional EDM method in performance.[15] Comparison with previous single-reinforced composites indicated that the addition of graphene had a significant impact on mechanical performance, which was emphasized. [16] The liquid stir casting method was developed as an effective way to produce hybrid composites. [17]A study on the machining of aluminum hybrid composites with GRA involved the assessment of multi-response optimization of EDM process parameters. [18]

The assessment focused on the parameters of the EDM process for hybrid metal matrix composites to achieve better results.[19] Mathematical modeling and EDM process parameter optimization were conducted on aluminum hybrid composite.[20] The study observed the influence of EDM control factors on aluminum hybrid composites. [21] The aforementioned study gap highlights the necessity of conducting experimental studies to investigate the effects of process parameters on different response characteristics of EDM and HMMC. Therefore, the main objective of this work is to increase the material removal rate and explore the optimal combination of EDM factors. A number of factors, including mechanical properties, material removal, tool wear, surface finish, integrity, precision, accuracy, process stability, process consistency, and cost-effectiveness, are affected by the process parameters in Electrical Discharge Machining for aged Metal Matrix Composites, making it critically important to optimize them. Because of the necessity to improve its mechanical qualities, aluminum alloy was selected as the matrix material for this investigation. Because of its better mechanical and lubrication qualities, silicon carbide and graphite particles were selected as the reinforcing material. For this reason, silicon carbide has the potential to enhance MMC's mechanical qualities. Because of the stir cast method's simplicity of construction, capacity to distribute reinforcements uniformly decreased vulnerability to oxidation and porosity, and other advantages. After being aged, this MMC was cooled in a furnace. By using a density test, the density of the aged and non-aged composites was ascertained.

The testing machine was used to determine the compressive and tensile strengths of both the aged and non-aged MMCs. The mechanical properties of the produced MMCs were used to find the best possible combination. MMC was shown to be the most efficient combination because it outperformed the other combinations in terms of hardness, tensile strength, compressive strength, and density. In order to improve the mechanical qualities without requiring more reinforcements, the aging process was implemented. To ascertain the weight percentage of the reinforcements and matrix as well as the presence of precipitates in the composites, a number of experiments were used. To confirm that silicon carbide was distributed uniformly across the matrix material, scanning electron microscopy equipment was used. Grey Relational Analysis based on Taguchi design was utilized to optimize the parameters of the EDM process for the aged composite. The percentage of reinforcement, the current, and the pulse-on time were the chosen input parameters for the optimization. The rate of material removal was selected as the response parameter for optimization. The proportion of reinforcement, current, pulse-on time, and optimal EDM process parameters for metal matrix composites are the order in which these factors influence EDM input parameters.

EXPERIMENTAL PERFORMANCE

By incorporating reinforcing components into a molten metal matrix, stir casting is a commonly used technique to create hybrid metal matrix composites. A mechanical stirrer was used to mix the reinforcing components into the molten metal. The resulting mixture was then poured into the desired shape and allowed to solidify. The fabrication of advanced material composites through the stir-casting process was undertaken. Figure 1 illustrates the incorporation of various SiC-Gr amounts (5-10-15 w%) with AC2B (95-90-85 wt%) as the matrix component in the specimen. The amount of each reinforcement (5-10-15 w%), the stir speed (450 rpm), the stir time (15 minutes), and the molten temperature (950 degrees Celsius) are the stir casting parameters. Aluminum hybrid composites were machined using electrical discharge machining to manipulate the input parameters and obtain the desired output response. An electric discharge machine, namely the Model ELECTRONICA-ELECTRAPULS PS 50ZNC (die-sinking type) with a constant gap servo head and positive polarity electrodes, is used for the entire experiment. The use of the Taguchi method aims to improve processing quality, minimize experimental trials, decrease processing variation, and maintain quality stability. The L27 Orthogonal array was utilized for the experimental trials.

EXPERIMENTAL OBSERVATION

It can be seen from the primary effect plot that the parameters have a steep slope. As a result, these parameters had a greater influence than the parameter. The relationship between the response variables and the input parameters or the categorical factorial is displayed in the interaction plot. The interaction plot shows a different line for each of the other factors and the means for levels of one component on the horizontal axis. The interaction effect between the factor and the response variable is shown by the

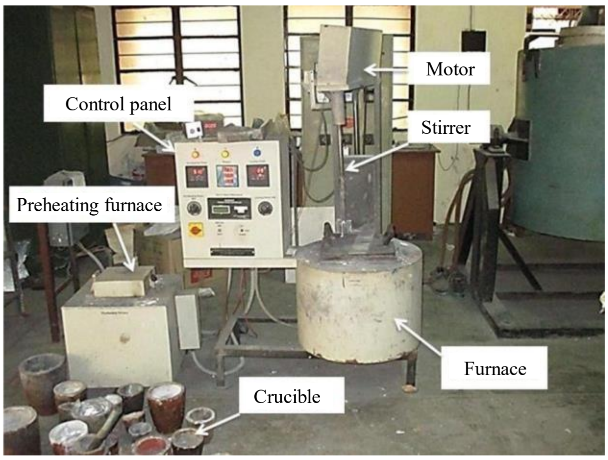

Figure 1. Experimental equipment [11].

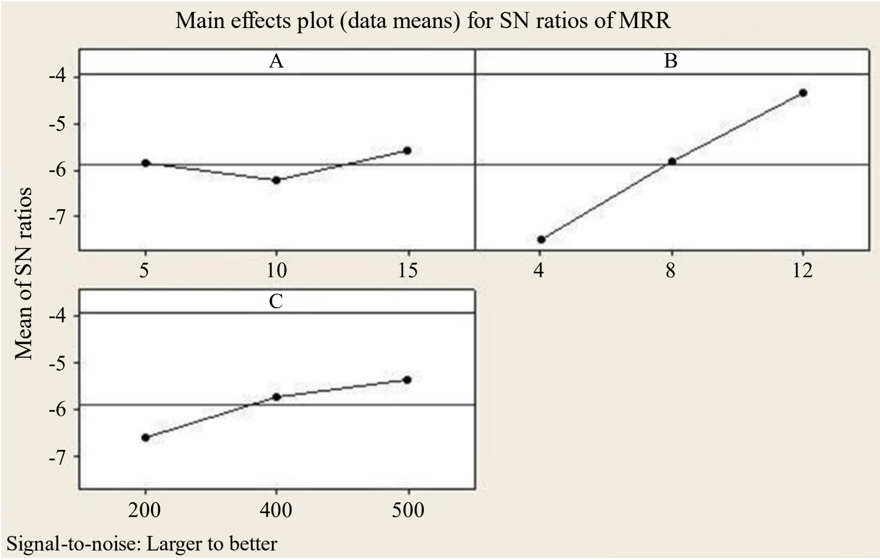

Figure 2. Signal to Noise ratio aligns with a greater material removal rate.

lines. The nonparallel lines exhibit the interaction effect, whereas the parallel lines indicate no interaction. The interaction is larger the more nonparallel lines. The major effect chart for the Signal to Noise ratio revealed the optimal input parameters. Figure 2 illustrates that the highest Signal to Noise ratio aligns with a greater material removal rate. Therefore, the ideal set of factors for achieving a higher material removal rate consists of 15% for factor A, 12 Amp for factor B, and 500 µs for factor C. These values are recommended as the ideal parameters for the study. The examination of the experiments revealed that Material Removal Rate was notably affected by two input parameters: current and other factors as shown in Figure 3. Among pulse on time and combined equal weight percentage of SiC-Gr, current is the most significant parameter for achieving the best material removal rate. Validation of the results concludes with confirmation testing, which is the final step.

In order to determine the most important elements influencing the material removal rate and the percentage contribution of each parameter, a statistical study using Analyses of Variance with a 95% confidence interval has been conducted. The best process parameters will be determined using the "Higher-the-better" Signal to Noise ratio in order to achieve a greater material removal rate. A confirmation test will also be conducted in order to determine the percentage error that exists between the Taguchi method and the experiment. First, the parameters that significantly affected the material removal rate were identified and their impacts were analyzed using Analysis of Variance. The prediction and experimental error between the two approaches were calculated by comparing the values of the prediction equations that were developed with the data obtained from the experiment. Utilizing Taguchi analysis with Minitab software, the ideal set of process parameters was also determined to yield the maximum material removal rate utilizing the "Higher-the-better" Signal to Noise ratio. To match the ideal parameters discovered by the Taguchi approach with the results of the experimental testing, confirmation experiments were lastly carried out. One way to verify the ideal process parameters that were discovered through analysis is to conduct a confirmation test. A signal-to-noise ratio-based orthogonal array was used for optimization in this experimental inquiry. All cutting parameters were set to their optimal levels. Selecting a nominal level in the Taguchi technique involves picking each parameter's level so that it is extremely close to the signal to noise ratio's mean value. The Taguchi approach provides a superior combination of optimum cutting parameters for attaining a higher material removal rate in the machining of MMC, as confirmed by the comparison of nominal and optimum values. There has been a notable increase in the improvement %. The nominal and optimal circumstances were the subjects of the confirmation experiment. Whereas the observed values were obtained through validation tests, the anticipated values were calculated. The fact that the observed value is nearly in line with the projected value indicates that the Taguchi method's prediction of optimization is dependable.

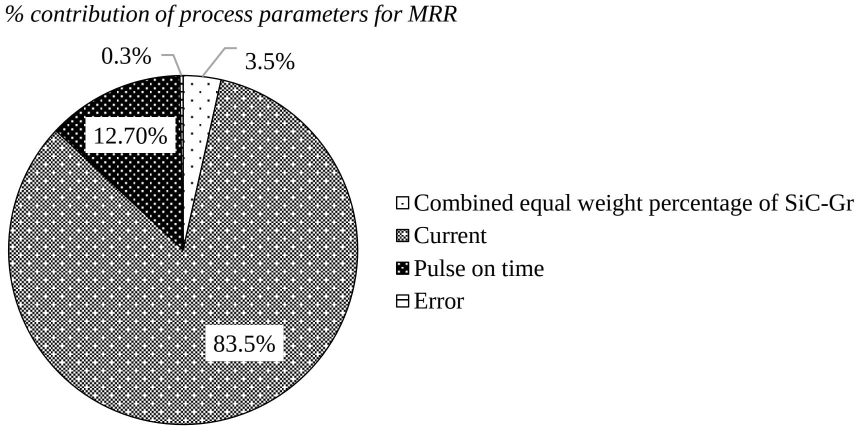

Figure 3. Contribution percentage of process parameters.

CONCLUSION

Furthermore, in order to identify the ideal set of process parameters, future study can investigate the application of sophisticated optimization techniques such genetic algorithms, artificial intelligence, and machine learning. This can help to increase the accuracy of the results and decrease the number of tests needed to find the ideal process parameters. Additionally, the effect of EDM on the HMMCs' mechanical characteristics was investigated. This can facilitate the creation of new materials with enhanced mechanical properties and help realize the full potential of EDM for the machining of HMMCs. The advanced composites were created using the liquid stir casting technique. Experimental trials were conducted using a Taguchi orthogonal array. Analysis of the trials showed that two input parameters, specifically current and other factors, had a notable impact on Material Removal Rate. The ideal set of factors for achieving a higher material removal rate consists of 15% each reinforcements, 12 Amp, and 500 µs as they result in a higher material removal rate. Among pulse on time and combined equal weight percentage of SiC-Gr, current is the most significant parameter for achieving the best material removal rate. Validation of the results concludes with confirmation testing, which is the final step.

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