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Electrical Discharge Machining

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ABSTRACT

Tool electrode wear in sinking electrical discharge machining (EDM) is essential for a profitable output. The amount of tool electrodes needed for a particular machining process is determined by the tool electrode wear, which also has an impact on process efficiency. As a result, it is necessary to minimize relative tool wear, which is defined as the relationship between the volume of material removed between the tool and the workpiece electrode. The features of tool wear. The applied electrode materials and the parameters of the EDM processing have a significant impact on sinking EDM. A notable rise in relative tool wear is apparent, particularly in micro-EDM. Tungsten carbide-cobalt (WC-Co), due to its thermophysical characteristics, is a material that can be used as a sinking electrode for an EDM tool. In the current work, ZNC electrical discharge machining (EDM) is used to mill aluminum alloy 6061/10%SiC composite. Tungsten powder suspended dielectric fluid is investigated as a potential improvement in the material removal rate (MRR) in the EDM process. Process parameters such as peak current, pulse on time, pulse off time, and gap voltage are examined. A mathematical relationship is created using Response Surface Methodology (RSM) between process parameters and MRR. The outcomes are further contrasted with the MRR attained using basic EDM machining. The MRR increased by 48.43% when tungsten particles were present in the kerosene. SEM and EDS, or energy dispersive spectroscopy, are used to investigate the effects of tungsten powder mixed dielectric fluid on machined surfaces. Improvement in surface finish and decrease were shown by the results.

Keywords: Electrical discharge machining; EDM; Relative tool wear; Tungsten carbide-cobalt; : Dielectric; Discharge; EDM; PMEDM; MRR; RSM; Surface; Tungsten.

Introduction

The quick advancement of metallurgy contributed to the industries' quick adoption of metal matrix composites (MMC). The metal matrix phase of MMCs is typically composed of aluminum, magnesium, titanium, and reinforcing phases of silicon carbide (SiC), aluminum oxide (Al2O3), etc. in the form of fibers, whiskers, or particles [1,2]. Aluminum metal matrix composites are becoming more and more important in commercial applications including aerospace, automotive, and other industries where weight is a constraint because of their reduced weight and high specific strength. Because reinforcing ceramics like SiC or Al2O3 are brittle and abrasive, traditional machining frequently faces issues with excessive tool wear and poor surface finishing [3, 4]. In order to overcome these obstacles, non-traditional machining techniques like EDM have become the industry standard. In the EDM procedure, material is eliminated.Based on earlier studies, it is noted that the powder mixed electrical discharge machining technique is currently undergoing investigation into a variety of topics and industrial domains. PMEDM methodology is frequently employed to look at enhancement of machined surfaces' surface properties, primarily for non-composite materials. It is hardly ever utilized while investigating machinability performance, such as MRR, for composite materials, including metal matrix composite made of aluminum. An important consideration when assessing an industry's productivity and production costs is the machinability of the material.

The majority of research has attempted to incorporate additives like Al, Cu, Si, and Ti in either pure or carbide form in the dielectric fluid used in the EDM process. Tungsten powder is utilized in the dielectric fluid of the current investigation.One of the most significant methods for cutting intricate, three-dimensional features with great precision in difficult-to-cut materials is sinking electrical discharge machining (EDM). In order to machine intricate structures using sinking EDM, it is necessary to create a negative of the corresponding geometry in a number of tool electrodes. The production chain's most time- and money-consuming phase, the creation of tool electrodes for sinking EDM, primarily dictates the overall cost of a part made with sinking EDM. Tool wear volume (VE) is the term used to describe the material loss on the tool electrode caused by the electrical discharges between the tool electrode and the workpiece electrode.The machining of miniature dies and molds, where the aforementioned low discharge energies are necessary, is one area where EDM is being used more frequently . The difficulties with tool wear that have been mentioned encourage the adoption of materials with greater corrosion strength cm, a term that can also be used to characterize a tool electrode material's wear resistance.High specific heat capacity cp, high melting temperature, and high thermal conductivity λ are all present in materials with high erosion strength cm. These properties are very helpful for fragile structures, such as edges, which exhibit high wear phenomena because to the properties of the EDM process .The tungsten carbide-cobalt (WC-Co) material satisfies the aforementioned specifications. Owing to its restricted machinability through previous cutting operations, WC-Co has not been thoroughly examined for use as a tool electrode material in sinking EDM. Despite being used as a tool electrode material for EDM drilling, there is a lack of fundamental study on the composition of WC-Co and how it affects the outcomes of EDM processes .Previous studies have suggested a relationship between relative tool wear (ϑ) and cobalt concentration.Using the EDM method, Seo et al. examined the machining properties of functionally graded Al359/15-35% vol SiC composite. Peak current, pulse on time, and SiC % in Al alloy were all shown to improve MRR. The machinability of aluminum reinforced with different volume fractions of SiC in metal matrix composite, ranging from 5% to 25%, was examined by Habib SS [10]. Peak current and pulse on time increases were accompanied by an increase in MRR. MRR showed a lowering tendency up to 15% as SiC particles increased in the aluminum matrix phase, and then a reversing trend as the proportion of reinforcement increased. Agrawal and Yadava used a hybrid method of surface electrical discharge diamond grinding to assess MRR and surface roughness for machining of AA6025 with 10wt% SiC and 10wt% Al2O3.

Literature Review

1.Dielectric liquids and materials for electrodes:

Dielectric fluids have the following functions: they cool the electrode, transport the removed particles from the machining zone, increase energy density, stabilize dielectric strength, and behave as electrically non-conducting materials until breakdown voltage is reached. Furthermore, the dielectric fluid functions as an insulator between the cavity and electrode. The ability of a fluid to act as an insulator determines its dielectric fluid performance. Moreover, the characteristics of the dielectric fluid affect the machining components' performance (MRR, TWR, and SR). Kerosene oil's low viscosity improves flushing properties, but it has significant disadvantages in the form of high volatility, low flash point, odor, and skin response.

2.MRR in the EDM :

Distilled water machining produces better MRR and lower TWR, however at a high energy pulse rate, the machining precision is poor.On machined work samples, the performance of three different electrode materials is investigated. Electrical conductivity, wear rate, melting point, and electrical resistance of the electrode material are the main factors influencing the performance of the work material. An electrode material with a 20 mm diameter was employed for investigation and optimization.Because the workpiece electrode is attached as an anode, electrochemical dissolution can be used to remove some of the material. especially considering that the process liquid's normal conductivity ranges from 3 to 5 mS/cm. Additionally, rather than the electric field discharges that are typical of standard wire EDM, it is believed that this will result in thermal breakdown discharges.

The wire electrode often requires over 10 hours of machining before rupturing; this low wear rate may possibly be attributed to the distinct discharge creation.The examination of pulses that occur in the HSWEDM process is the focus of this paper. The various pulse types are recognized, and the ratios of each under various parameter configurations are noted. A deeper comprehension of the various pulse types and how they affect the cutting rate is gained from the examination of these data.

3.Fabrication of materials on EDM :

The primary cause of the variance in the Sic material characteristics obtained after HP and RHP is the variation in the heating and holding periods during the sintering process. In conventional HP, convection and radiation from the heating source indirectly heat the graphite dies and the powders. On the other hand, in RHP, the graphite die (as well as Sic powders) gets direct current. This led to the production of in-situ graphite.In the current work, the Sic's made using the RHP sintering approach were machined using WEDM (Accutex-300i, Taiwan). The thermal diffusivity and electrical conductivity were found to have direction-dependent (anisotropic) material properties, as was previously described.A variation of this kind impacts the overall machinability. As a result, the pressing direction and the machining processes were carried out in simultaneously.The Sic samples were first chopped and ground with an optical profile grinder before being machined.

Methodology

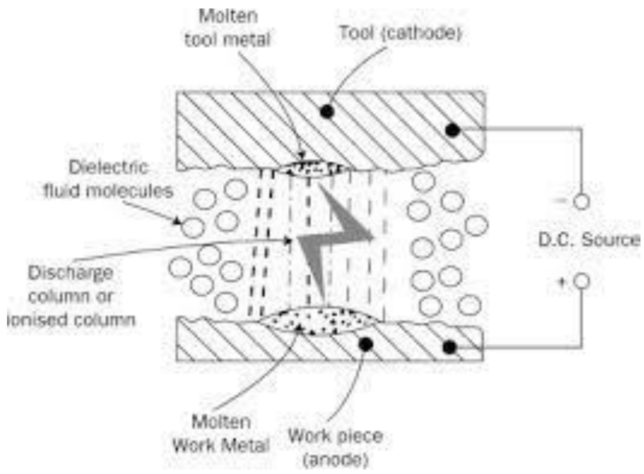
The RSM technique is applied to problem modeling and analysis. The relationship between the replies and the input parameters is correlated using this method. This is also employed in parameter optimization. The quadratic model interprets the behavior of the problem.

1.Tugachi Method:

For statistical analysis and EDM trials, Taguchi orthogonal arrays were used. For analysis and optimization, the signal-to-noise (S/N) ratio suggested by Taguchi was employed. For a response function, the signal represents mean values, while the noise represents the standard deviation. The ideal situation for machining variables is considered to have a larger S/N ratio, which corresponds to three degrees of response. While the greatest values of MRR and minimum TWR are very desirable from an industrial standpoint in terms of inexpensive machining, the surface roughness of the machined item must be maintained at low values for good functioning during their service life . Consequently, lower-the-better response characteristics were used for SR and TWR, while the S/N ratio (ηij) of higher-the-better (HTB) response characteristics was used for MRR.

2.Utility concept

While lowering the machining cost can be achieved with lower TWR and greater MRR, in this study, enhancing the surface finish of the machined parts was considered a measure of product quality. A composite index known as the utility concept must be formed by combining the quality features of competing criteria in order to address the aforementioned challenge (finding a single optimal parameter setting for all outputs) [48]. Utility generally refers to how beneficial a process or product is in relation to the degree of expectations set by the customer through performance analysis based on multiple discrete objective functions. In order to enhance rational decision-making, various evaluative or quality factors are combined to create a composite index, or utility. The composite utility of each attribute is denoted by the total of its utilities.



Conclusion

The work's findings supported earlier research on this topic, which showed that when cobalt content increased, relative tool wear (ϑ) decreased. Furthermore, a small effect of the grain size dg on the relative tool wear ϑ and material removal rate V̇ W was observed. Additional investigation using a single WC-Co grade and several tool electrode geometries showed that, in comparison to the frequently used copper and graphite in macromachining, the process results for WC-Co tool electrodes were inappropriate. On the other hand, in micro-machining, WC-Co tool electrodes displayed a beneficial wear behavior. In this case, the relative tool wear ϑ was not significantly impacted by the discharge duration. This will be the main focus of further studies using relaxation discharges.

Analyzing the impact of process factors on the material removal rate of the AA6061/10%SiC composite has been done through experimental study. The machined surface is examined and contrasted with the outcomes of the fundamental EDM procedure. The current work leads to the following primary conclusions:

(i) Every process parameter that was chosen has a major impact on MRR in both basic EDM and PMEMDM.

(ii) Greater MRR can be attained by optimizing the gap voltage, pulse off time, current, and pulse on time.

(iii) Tungsten powder in PMEDM increased the MRR during the machining of AA6061/10%SiC composite by 48.43%.

(iv) Powder mixed EDM reduces the recast layer of the machined surface by 42.85% when compared to conventional EDM.

Result:

In terms of material removal rate V̇ W, the graphite and copper results are better than the WC-Co tool electrodes. Nevertheless, compared to \graphite = 10.6% and \copper = 14.6%, the relative tool wear for the WC-Co tool electrodes is \WC-Co = 5.3%. Although the low discharge durations (te = 11.0 µs) are not ideal for cutting small structures, they are necessary for copper and graphite. The 50% decrease in relative tool wear suggests that WC-Co could be used advantageously as the tool electrode material in micro-EDM.

The percent contribution of the error term is expressed as the ratio of its sum of squares (SS) to the entire sum of squares. The minuscule pure error magnitudes for PMEDM (0.5%) and basic EDM (2.24%) demonstrate how little the experimental results' error contributed to the variation. Consequently, the variance caused by the input parameters that were examined in the study outweighs the variation caused by errors.

When compared to the other characteristics, the electrode material is determined to be the most important factor for larger MRR, lower SR, and TWR.In comparison to brass and copper, graphite electrodes with distilled water as the dielectric fluid achieve higher MRR, lower SR, and TWR. enhanced HcHcr steel machinability, a graphite electrode with distilled -based fluid medium is recommended. Moreover, PCA has significant flaws in how the parameter weights are determined. Thus, Taguchi-CRITIC Utility approach hybrid methods can be used for multi-response optimization of another algorithm. Procedure for machining.

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