Compound Conductors in Electric Release Machining: An Evaluation

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Abstract: The review begins with an overview of EDM's significance in modern manufacturing and the pivotal role electrodes play in shaping its efficiency and precision.

The advantages of both electrode types are examined, ranging from heightened material removal rates and superior surface finishes to reduced tool wear and enhanced machining precision. Challenges specific to each electrode type, such as complex fabrication and stability during machining, are critically assessed alongside potential solutions proposed by researchers and practitioners manufacturing, and micromachining.

In conclusion, this review paper encapsulates the current state of research and development in the field of EDM using carbonbased and graphite-based composite electrodes. By providing insights into their advantages, challenges, and practical implementations, this review serves as a comprehensive guide for researchers and engineers aiming to harness the potential of these composite.

Keywords : EDM, Composite Electrode, Process parameter, MRR, TWR.

INTRODUCTION

In the realm of modern manufacturing, precision and efficiency are paramount, leading to the continuous exploration of advanced machining techniques. Electric Discharge Machining (EDM) stands as a pivotal non-conventional method that utilizes controlled electrical discharges to shape complex geometries with high precision. The effectiveness of EDM, however, is intricately tied to the choice of electrode material – a factor that has spurred ongoing research into enhancing the process through the integration of composite electrodes(Jain, 2009).

Composite electrodes, developed by combining multiple materials, offer a new dimension to EDM. Among these, carbonbased and graphite-based composite electrodes have emerged as particularly promising candidates. Their unique properties, stemming from the incorporation of carbon-rich materials, hold the potential to redefine EDM's capabilities.

Carbon-based composite electrodes encompass an array of materials, including diamond, carbon nanotubes, and graphene, each possessing remarkable attributes such as exceptional hardness, thermal conductivity, and wear resistance(Lau et al., 1990). These properties present the opportunity to overcome traditional limitations in material removal rates, surface finishes, and tool wear associated with conventional EDM electrodes.

On the other hand, graphite-based composite electrodes integrate graphite with various additives to enhance electrical conductivity and tailor the electrode's response to different EDM conditions. The versatility of graphite-based composites makes them adaptable to a wide range of machining requirements, thereby influencing EDM precision and material removal rates.

This review delves into the intricate interplay between composite electrode materials and EDM processes, with a specific focus on the effects of carbon-based and graphite-based composites. By examining the underlying principles, fabrication techniques, and resultant properties, this review aims to provide a comprehensive understanding of how these electrodes contribute to advancing EDM. Furthermore, the review explores the contrasting impacts of these two composite electrode categories on EDM performance, including factors like material removal rates, surface finish quality, and electrode stability.

CARBON BASED COMPOSITES

Carbon-based composite electrodes have emerged as a revolutionary addition to Electric Discharge Machining (EDM), offering enhanced performance and versatility. These composite electrodes incorporate materials like diamond particles, carbon nanotubes, or graphene into their structure. The unique properties of these carbon-rich materials significantly influence EDM processes.

Carbon nanotube/carbon fibre (CNT/CF) reinforced composites, which (Hassan et al., 2016) researched, have several potential uses in the aviation industry due to its high strength and lightweight design. This work includes an analysis of machinability to determine the impact of pulse duration, pulse peak current, duty factor, and gap voltage on the mechanism for removing material in Therefore, the factor that had the biggest influence on this investigation's results was found to be gap voltage. This machinability study presents a significant chance to boost output and dimensional precision for aerospace applications. Electrical discharge machining (EDM) study was conducted by (Guu et al., 2001) on carbon fibre reinforced carbon composite material. They considered the machining settings in light of the traits of composites produced by EDM machining. A composites empirical model was also proposed based on the experimental findings. The workpiece's surface and the resolidified layers were examined using scanning electron microscopy (SEM). Surface roughness was also measured using a surface profilometer. According to experimental results, power input is inversely related to surface roughness, recast layer thickness, and degree of delamination. The EDM process effectively produces composites with exceptional surface characteristics and high-quality holes in low discharge energy conditions. An experimental research on the electric-discharge machining (EDM) of VKU-29 composite material was carried out by (Ablyaz et al., 2017). The lateral electrode gap, which is determined by the machining settings, is the distance between the width of the tool electrode and the width of the slot produced by EDM in the polymer composite. latter type creates the best surface quality.

The manufacturing of composite electrodes is a successful method for enhancing the efficiency of the Electric Discharge Machining (EDM) procedure. (Rajaguru et al., 2016) use the spark plasma sintering (SPS) technique to conduct an experiment on a new copper/carbon nanotube (Cu/CNT) metal matrix composite electrode at various volume fractions of CNT (0.35%, 0.70%, and 1.05%). By altering the EDM process parameters (discharge current, pulse-on time, and voltage), the real-time functional performance of the generated electrode during EDM machining is also investigated. The composite electrode characterization results showed that the density decreased and electrical resistance rose due to the rise in porosity as the percentage of CNT increased from 0.35 to 1.05 vol%. Due to increased discharge energy and an expansion in the spark gap, performance analysis of CNT-infused electrodes during EDM machining revealed a higher Material removal rate (MRR) and good surface smoothness than the Cu electrodes. Cu/CNT electrodes, however, wore down 90% more quickly than Cu electrodes, probably as a result of the decrease in heat conductivity brought on by porosity effects. (SUZUKI et al., 2015) investigated how carbon nanotubes (CNTs) were composited into the Cu matrix to improve the wear qualities of the Cu-based electrodes used in electrical discharge machining (EDM). In order to impregnate the liquid phase alloys among the CNTs and create dense composite materials, the CuCNT composite electrodes were sintered with 12 vol% of low melting point alloys, whose liquidus temperature is 780°C. In comparison to pure Cu electrodes, the wear ratios of sintered Cu-CNT electrodes with 30 vol% CNTs were reduced by 68%. The wear ratio of the electroplated Cu-CNT electrode, which had a measured volume fraction of CNTs of 11.1%, was roughly the same as that of the sintered Cu-CNT electrode.

The particular requirements of the EDM application determine the choice of composite electrode materials. The selection of composite materials is influenced by elements such material removal rate, wear resistance, surface finish, and workpiece material. To ensure optimum performance, it is crucial to take into account the characteristics of both the conductive matrix material and the reinforcing materials.

The aim is to develop composite electrodes with improved properties, such as higher conductivity, better wear resistance, and increased tool life, to meet the evolving demands of EDM applications.

Advantages of Carbon-Based Composite Electrodes:

A. High Hardness: Incorporating diamond particles, carbon nanotubes, or graphene imparts exceptional hardness to the composite electrodes, leading to reduced electrode wear during machining(Mantilla Gilart et al., 2012). B. Thermal Conductivity: Carbon-based composites exhibit high thermal conductivity, effectively dissipating heat generated during EDM processes. This minimizes the risk of electrode damage due to excessive heat. C. Enhanced Material Removal Rates: The superior hardness and thermal conductivity of carbon-based composite electrodes contribute to higher material removal rates, improving machining efficiency. D. Improved Surface Finish: Carbon-based composite electrodes can achieve finer surface finishes on machined workpieces due to the precision of EDM and the properties of the composite materials. E. Reduced Tool Wear: The durability of diamond-based electrodes and the self-lubricating properties of carbon nanotubes and graphene lead to reduced tool wear, increasing the electrode's lifespan.

Challenges of Carbon-Based Composite Electrodes:

A. Fabrication Complexity: Integrating advanced materials like diamond particles or carbon nanotubes into the electrode matrix can be technically challenging and may require specialized manufacturing techniques. B. Material Compatibility: Ensuring uniform dispersion of carbon materials within the matrix while maintaining compatibility can be demanding and impact the overall performance of the composite electrode(Borenstein et al., 2017). C. Cost: The incorporation of advanced carbon materials can increase the cost of electrode fabrication, affecting the economic viability of their widespread use.

GRAPHITE BASED COMPOSITES

The conductive matrix material graphite is also frequently used in EDM electrodes. It can be used with substances like silver or copper to create composite electrodes with improved characteristics. Composites made of graphite and copper (Gr-Cu) are suited for EDM operations because they have excellent electrical conductivity, thermal stability, and low wear rates.

A study on AA7050 hybrid composites reinforced with graphite and boron carbide was done by (Ranjith et al., 2017). Stir casting was used to create the composites, which contained 7.5 weight percent boron carbide and various amounts of graphite (2.5, 5, 7.5, and 10 weight percent). The bonding between the reinforcement and matrix was strengthened by the addition of potassium titanium fluoride (K_2TiF_6) flux. In this work, the impact of graphite particles on mechanical characteristics, wear resistance, sulphide stress corrosion cracking, and electric discharge machining was examined. With increasing graphite content, the hybrid composites' hardness, tensile strength, and wear resistance decreased. But the composites treated with graphite showed increased resistance to sulphide stress corrosion cracking. With more graphite present, the rate of material removal during electric discharge machining increased, but the surface finish suffered as a result of insufficient heat dissipation.

The work piece created by (Mausam, 2017), investigate is constructed of a 14-layered composite material reinforced with graphene, and the tool electrode is made of copper. The MRR has been demonstrated to be greatly increased by utilising copper nanoparticle-infused EDM oil rather than regular EDM oil. It has been demonstrated that using Copper mixed nanoparticles in EDM oil resulted in a lower TWR than using traditional EDM oil. (Piyar Uddin et al., 2016) report the work in an effort to assess the performance of Cu-Gr composite material as an EDM tool. Four different EDM tools with different copper-graphite compositions have been used to work AISI 1020 mild steel. Both MRR and TWR have been considered as EDM performance metrics. According to the results, adding more graphite to a Cu-Gr composite tool can lower both the TWR and MRR by up to 83%. (Ali et al., 2017), tested copper alloy composites (90% Cu and 10% Sn) with copper alloy + 4 wt% Gr, copper alloy + 4 wt% ZrO_2, and copper alloy + 4 wt% Gr + 4 wt% ZrO_2. Stir casting was used in the current experiment to create the CMC composite materials. Using a pin-on-disc apparatus, the wear behaviour was assessed for changing loads of 1, 2, and 3 kg at a constant speed of 300 rpm as well as for varying sliding speeds of 100, 200, and 300 rpm with a constant load of 3 kg. After testing on a wear machine, it was discovered that composites made of Cu alloy, graphite, and ZrO_2 show the best wear resistance under a variety of loads and operating conditions. (Rajkumar et al., 2014) compared research on EDM Machinability on the heat treated Al-B_4C (15vol%) graphite (5vol%) to EDM machined with conventionally heat treated composites.Microwave-heated composites demonstrated higher toughness as compared to traditional heat-treated composites. The most crucial MRR parameters were found to be nonlinear functions of the pulse on and off times for the composite's material removal rate (MRR).

(Alaneme & Sanusi, 2015) explored the microstructural properties, mechanical properties, and wear behavior of hybrid aluminium matrix composites supplemented with alumina, rice husk ash (RHA), and graphite. To create 10 weight percent hybrid reinforced Al-Mg-Si alloy based composites utilising two-step stir casting, alumina, RHA, and graphite were combined in various weight ratios. The generated composites were evaluated using wear tests, hardness, tensile characteristics, scanning electron microscopy, and other methods. The findings indicate that Hardness declines as RHA and graphite levels in composites increase, and that the effect of graphite on Hardness becomes less significant when RHA concentration increases to greater than 50%.

Advantages of Graphite-Based Composite Electrodes:

A. Electrical Conductivity: Graphite is intrinsically conductive, making graphite-based composite electrodes efficient in conducting electrical discharges during EDM processes. B. Adaptability: The properties of graphite-based composites can be tailored through additives, making them adaptable to different machining conditions and workpiece materials(Stankovich et al., 2006). C. Surface Finish Enhancement: Graphite-based composite electrodes contribute to improved surface finish quality on machined workpieces, essential in industries requiring smooth surface textures. D. Micro-Machining Capability: Fine granularity and precise material removal capabilities of graphite-based electrodes make them ideal for micro-machining applications.

Challenges of Graphite-Based Composite Electrodes:

A. Additive Selection: Choosing the right additives to achieve desired properties requires careful consideration and might involve trial and error. B. Precision Maintenance: The self-lubricating properties of graphite can occasionally lead to challenges in maintaining precision during electrode machining. C. Thermal Degradation: Excessive heat generated during EDM can lead to thermal degradation of the graphite matrix or additives, impacting electrode performance.

Balancing these advantages and challenges is crucial when designing and implementing carbon-based and graphite-based composite electrodes in EDM and other machining applications. This review paper can delve deeper into these aspects, providing valuable insights for researchers, engineers, and practitioners seeking to harness the potential of these electrodes.

CONCLUSION

In conclusion, the fusion of carbon-based and graphite-based composite electrodes with Electric Discharge Machining (EDM) has propelled the realm of precision manufacturing into a new era of possibilities. These advanced electrode materials, enriched with properties like exceptional hardness, thermal conductivity, and electrical resistance, have redefined machining efficiency, surface finish quality, and electrode longevity.

Carbon-based composite electrodes, enriched with diamond particles, carbon nanotubes, and graphene, have showcased unparalleled material removal rates and reduced tool wear. However, their realization requires overcoming fabrication complexities and ensuring stability during machining. On the other hand, graphite-based composite electrodes, rooted in adaptability and electrical conductivity, have found resonance in diverse applications, promising improved precision and enhanced surface finishes.

Industries spanning aerospace, automotive, and medical manufacturing have embraced these electrodes as instrumental tools in sculpting intricate geometries and impeccable surface textures. Looking forward, the horizon remains abundant with prospects, as ongoing research seeks to unlock the full potential of these electrodes through novel materials and advanced methodologies.

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