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Coating on MS with Reversible Experimental Technique on EDM

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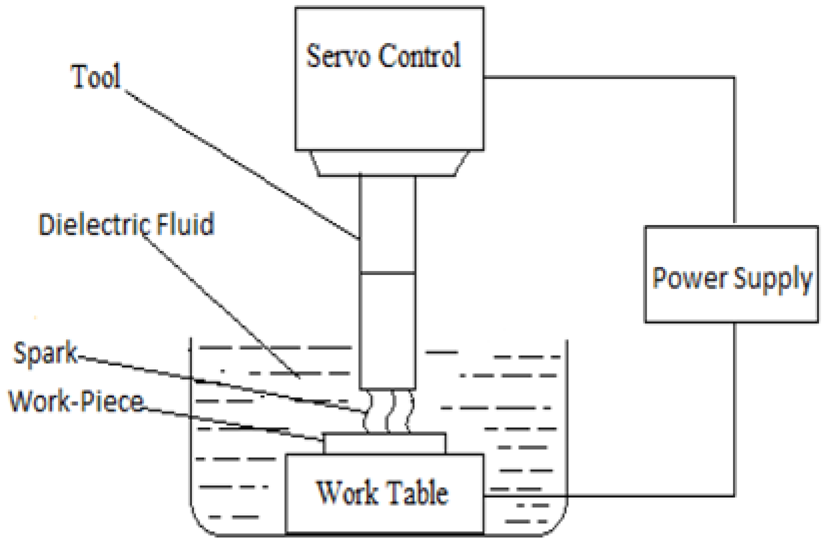
Abstract: ***This study investigates a novel micromachining method for fabricating micro - metal structures utilizing micro - reversible electrical discharge machining (EDM). The approach combines the deposition and selective removal processes within a micro - EDM system, enabling the ability to deposit or remove metal material using the same machining setup. The research begins by analyzing the process conditions for micro - EDM deposition based on the discharge mechanism. Experimental investigations were conducted using brass and steel materials as tool electrodes, resulting in the successful deposition of micro - cylinders with a diameter of 200µm and a height - to - diameter ratio exceeding 5 on a high - speed steel surface. The process was easily transformed from deposition to selective removal by adjusting the process conditions. Various removal strategies, including micro - EDM drilling and micro - EDM milling, were employed during the machining procedure. Successful drilling of micro - holes with an 80µm diameter in the radial direction of the deposited micro - steel cylinder was achieved. Additionally, micro - EDM milling was employed to fabricate a brass square column measuring 70µm on each side and 750µm in height, as well as a micro - cylinder with a diameter of 135µm and a height of 1445µm. Subsequently, the characteristics of the deposited material were analyzed. Results indicate that the material composition of the deposited micro - cylinder closely resembles that of the tool electrode, with a formed metallurgical bonding at the interface. Moreover, the steel deposited material exhibited a Vickers - hardness of 454Hv, surpassing the hardness of the raw steel electrode at 200Hv. The proposed micro - reversible electrical discharge machining method demonstrates promising capabilities for precise fabrication of micro - metal structures, offering both deposition and selective removal functionalities in a single machining system.***

Keywords: Coating, EDM

1. Introduction

Surface coating plays a crucial role in enhancing the performance and durability of engineering components by modifying their surface properties. Through this process, various desirable characteristics such as high hardness, wear resistance, high - temperature resistance, and corrosion resistance can be achieved without significantly altering the bulk properties of the underlying structure. During electrical discharge machining (EDM), the tool electrode undergoes wear and material removal from its surface. Interestingly, this removed material can be deposited onto the work - piece surface, effectively transforming the machining process into a coating technique. In this scenario, the tool electrode, typically manufactured using powder metallurgy (P/M) techniques, is connected as the anode, while the workpiece serves as the cathode in the electro discharge machine (EDC).

In this study, we explore the potential of EDC as a surface coating process, focusing on its unique ability to reverse the material removal process observed in EDM. By utilizing the tool electrode as the source of coating material and employing the EDC setup, we aim to investigate the feasibility of achieving enhanced surface properties without compromising the overall structural integrity of the components.



BASIC MECHANISM OF EDC

2. Methodology

- Selection of Materials and Powders: - Careful consideration was given to selecting suitable materials for both the tool electrode and the workpiece. Various powders were evaluated to determine their compatibility and effectiveness in the coating process.
- Selection of Parameters for Preliminary Experiments: - A range of parameters, such as voltage, current, pulse duration, and electrode gap, were identified for initial exploratory experiments. These parameters were chosen to provide a baseline understanding of the EDC process and to assess its feasibility.
- Performing Preliminary Experiments: - The identified parameters were implemented in a controlled EDC setup. Preliminary experiments were conducted, coating the workpiece surface with the material removed from the tool electrode during EDM. The coating process was carefully monitored and recorded for subsequent analysis.
- Examination of Preliminarily Experimented Workpiece: The workpiece that underwent the preliminary experiments was carefully examined and evaluated. The coated surface was analyzed to assess the coating quality, adhesion, and overall effectiveness. Further analysis, including microscopic examination and material characterization techniques, such as scanning electron microscopy (SEM), X - ray diffraction (XRD), and Vickers' hardness testing, was conducted to gather comprehensive data.
- Selection of Fixed Parameters for EDC Process: Based on the results and analysis from the preliminary experiments, a set of optimized parameters was identified. These fixed parameters provided a consistent and controlled environment for the subsequent final experiments.
- Selection of Variable Parameters for Final Experiments: In addition to the fixed parameters, specific variables were chosen to explore their impact on the coating process. Variables such as powder composition, particle size, feed rate, and coating thickness were systematically varied to assess their influence on the final coating results.
- Performing the Final Experiments: The final experiments were conducted using the selected fixed parameters and varied variables. Multiple coating samples were produced to ensure reliable and statistically significant results. Each experiment was meticulously documented to facilitate accurate analysis and comparison.
- Analyses of the Coated Surface: The coated surfaces obtained from the final experiments were subjected to in - depth analysis. Scanning electron microscopy (SEM) was employed to examine the morphology, microstructure, and coating thickness. X - ray diffraction (XRD) was utilized to identify the crystalline phases and structural changes in the coating. Vickers' hardness testing was performed to evaluate the mechanical properties and hardness of the coated surface.

3. Selection of Components

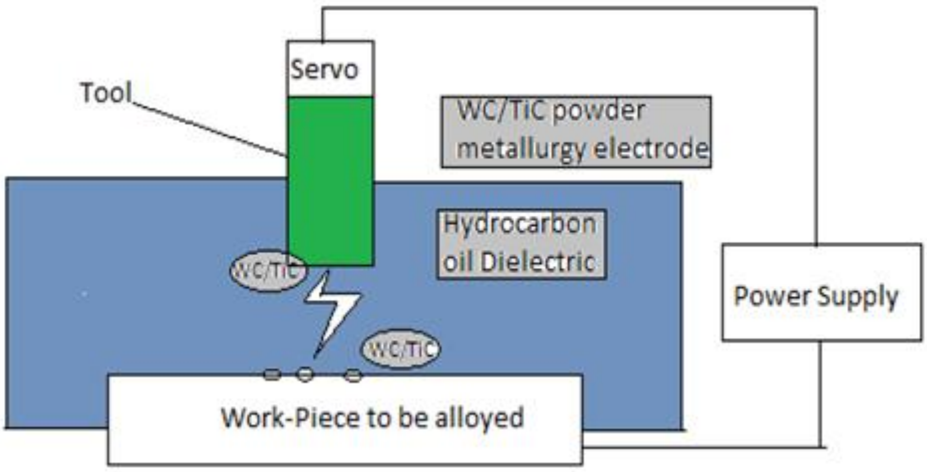
In the context of P/M (powder metallurgy) green compact EDC (electro discharge coating), careful consideration was given to the selection of components to ensure optimal performance and compatibility within the process. The following choices were made:

- **Tool Electrode Materials**

Two materials, namely tungsten (W) and copper (Cu) powders, were elected as suitable candidates for the tool electrode. Tungsten offers high melting point and excellent hardness, making it suitable for withstanding the rigors of the EDC process. Copper, on the other hand, provides good electrical conductivity and thermal properties, contributing to efficient energy transfer during the coating process.

- **Substrate Material**

The substrate material chosen for the EDC process is AISI 1020 medium carbon steel (M. S). AISI 1020 M. S. is widely used in engineering applications due to its good machinability, weldability, and cost - effectiveness. The selection of AISI 1020 M. S. as the substrate provides a suitable base material for the coating process, allowing for the evaluation of coating characteristics and properties on a common engineering - grade material. By opting for tungsten and copper as the tool electrode materials and AISI 1020 M. S. as the substrate material, the selected components offer a balance of mechanical, electrical, and thermal properties necessary for successful EDC coatings. This combination enables the achievement of desired coating characteristics and facilitates subsequent analysis and evaluation of the coated surfaces.



4. Advantages And Disadvantages

4.1 Advantages

Electro discharge coating (EDC) offers several advantages, making it an attractive method for creating ceramic layers on work pieces:

Simplicity and Equipment Requirements: EDC eliminates the need for complex equipment such as vacuum apparatus. It can be easily performed using a standard EDM machine tool, making it accessible and cost - effective.

Flexibility in Coating Placement and Speed: EDC enables the creation of ceramic layers at different locations on the work piece with varying areas. This flexibility allows for tailored coating placement based on specific requirements. Additionally, the coating speed achieved through EDC is rapid, facilitating efficient production processes.

Controlled Ceramic Layer Thickness: EDC provides excellent control over the thickness of the ceramic layer. This precision ensures consistent coating thickness, critical for achieving desired functional properties.

Wide Range of Materials: The EDC method supports a broad range of materials for coating applications. This versatility allows for the deposition of various ceramic materials onto workpieces, expanding the potential applications of EDC. Furthermore, the simplicity of the operation makes it a promising method for diverse coating needs.

4.2 Disadvantages

While EDC offers several advantages, it is important to consider the limitations associated with the process:

Slow Metal Removal Rate: One limitation of EDC is its relatively slow metal removal rate compared to traditional machining methods. This slower rate can increase the processing time required for achieving desired coating thickness or removing unwanted material.

Tool Wear: EDC can lead to increased tool wear due to the erosive nature of the process. The constant exposure to electrical discharges and material deposition can degrade the tool electrode over time, necessitating periodic replacement or maintenance.

High Specific Power Consumption: EDC can consume a significant amount of power during the coating process. The intense electrical discharges required for material deposition contribute to higher energy consumption, which may have cost implications.

Complex Contour Machining Limitation: EDC is less suitable for machining complex contours on workpieces. The process is better suited for simpler geometries and achieving intricate profiles or complex surface features may be challenging or impractical.

5. Conclusion

This study focuses on the experimental investigation of electro discharge coating (EDC) by considering various variable parameters. The objective is to explore the effects of parameters such as current, voltage, composition of the tool electrode, compaction pressure, polarity, duty factor, pulse on time, and pulse off time on the EDC process. The key goals of this investigation are to determine the material deposition rate for different composition combinations, assess the surface hardness, measure the material removal rate (MRR), and conduct a microstructure study of the coated MS steel substrate.

By systematically varying these parameters and conducting comprehensive experiments, valuable insights can be gained regarding the influence of each parameter on the EDC process and its resulting characteristics. The study aims to provide a deeper understanding of the EDC process and its potential for achieving desired material deposition rates, surface hardness, and microstructural properties.

The outcomes of this investigation will contribute to advancing the knowledge and application of EDC for surface coating purposes. The findings can assist in optimizing the EDC process by identifying the most favorable parameter combinations for specific coating requirements. Furthermore, the microstructure study will offer insights into the structural integrity and properties of the coated MS steel substrate, shedding light on the suitability of EDC for enhancing surface characteristics.

Overall, the experimental investigation conducted in this work is anticipated to provide valuable information for researchers, engineers, and industries seeking to utilize EDC as a coating technique. The findings will pave the way for further advancements and applications in the field of electro discharge coating, enabling the development of tailored surface properties for improved performance and durability of engineered components.