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Original Research Article

Controlled surface engineering of AA6062 aluminum via reverse polarity electrical discharge coating

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ABSTRACT

Electrical Discharge Coating (EDC) leverages reverse polarity to deposit electrode materials like Titanium (Ti) and Copper (Cu) onto AA6062 aluminum, offering a versatile solution for micro fluidic biochips and heat exchangers. Using a Face-Centered Central Composite Design, this study found that increasing peak current and pulse-on time significantly boosts both Deposition Rate (DR) and Micro-hardness (MH). Interestingly, while a longer pulse-off time improves the DR, it simultaneously reduces the MH of the resulting layer. SEM analyses confirmed successful elemental diffusion into the substrate, validating EDC as an effective surface modification technique. By fine-tuning these electrical parameters, the process allows for precise control over the aluminum's surface characteristics, successfully bridging the gap between standard machining and advanced functional coating.

1. Introduction

Electrical Discharge Machining (EDM) is a machining process of hard, conductor metallic materials that involves intense electric sparks up to 12,000 o with a temperature of 12,000°C, but it tends to leave the surface of the material with a weak recast layer, which is a problem of its own compared to the problems of direct cutting tools [1]. In response, Electro Discharge Coating (EDC) is used to deposit tough materials and carbides by reversing the polarity to greatly improve surface behavior such as hardness [2, 3]. The particular study employs EDC to lightweight and strong materials (Aluminum alloys) in automotive and aerospace components that otherwise have low high-temperature wear and corrosion resistance [4, 5]. Although numerous standard and advanced surface modification methods are available to enhance wear and hardness like Chemical Vapor Deposition (CVD), Plasma Enhanced CVD (PECVD), Physical Vapor Deposition (PVD), Thermal Spraying, High-Velocity Oxygen Fuel (HVOF) spraying, Electro less Plating, Plasma Immersion Ion Implantation, and Laser Cladding such EDC, by contrast, provides a more straightforward, direct alternative which can be studied down to the level of single sparks [6]. Previous research has shown that EDC is an effective method to enhance the Material Transfer Rate (MMR), layer thickness (LT), and Micro Hardness (MH), with higher currents and pulse-on times positively affecting the growth of the coating, but the addition of solid lubricants, such as Titanium (Ti) or post-processing of the layers, can influence the overall hardness and finish [7, 8]. This notwithstanding, and the established performance of other EDC cermet coating in wear [9] there is a significant gap in research. In particular, the literature confirms the efficacy of EDC however, does not include extensive investigation and multi-attributes decision-making on altering the surfaces with the use of a combined Titanium-Copper (Ti-Cu) powder metallurgy tool or green compact electrode to establish the best process parameters [10].

2. Methodology and experimental design

Aluminum alloy 6062 (AA6062) was used as the major substrate in the current study. The Titanium (Ti) and Copper (Cu) fine powders were mixed in fine proportions (60:40) to come up with a self-lubricating composite electrode to enhance the wear resistance of the compound. When the powdered elements had homogenously mixed, the mixture was pressed using a high compaction load of 10 tons in a punch and die apparatus to produce a dense green compact. A thermal process was then carried out to enhance good inter-particle cohesion and enhance structural integrity of the electrode. This was cured under a tube furnace which was filled with an inert atmosphere of argon and its temperature maintained at an approximate of 130°C and was maintained at that temperature for 20 minutes. The working surface of the fabricated electrode was properly ground and polished on the active side, before the main experimental studies were commenced to get a smooth and flat surface all over.

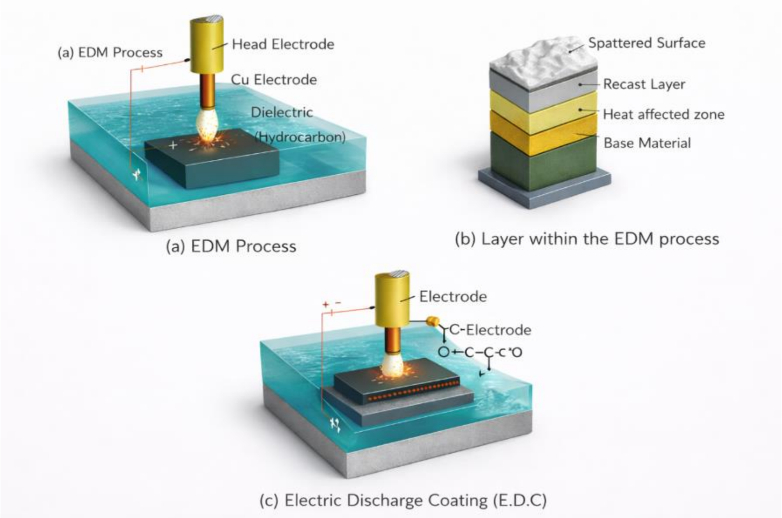

Figure 1: Schematic representation of the Electro Discharge Coating (EDC) process.

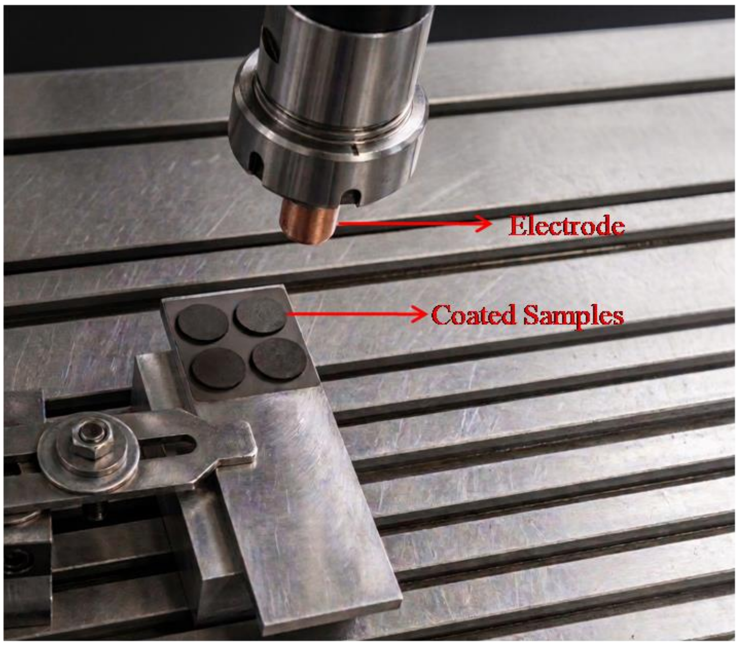

Figure 2: Schematic representation of the coating on the Al-6062 substrate.

3. Result and discussion

3.1 Effect of machining parameters on deposition rate (DR)

The analysis and research showed that the Deposition Rate (DR) rises linearly with the current between 2A and 3A, which overcomes the initially inadequate discharge energy, which otherwise leads to shallow craters and low deposition. Adding more current to make it 4A creates a lot of thermal energy that not only pushes off more electrode powder, but also leads to rapid cooling and differentiated thermal contraction, making the coating full of micro-cracks. In pulse timing, the shorter pulse on-times result in a higher DR due to formation of a high intensity and localized plasma channel, which facilitates a rapid and uniform material deposition. On the other hand, as the pulse on-time is increased to 70-90 micro-seconds the DR will drop due to long-term arcing resulting in the missed pulses, arc stagnation and transition to vaporization rather than material deposition. This long period results in the presence of different-sized globules on the surface (Figure 3) because of the partial evaporation and re-condensation and the net decrease in DR is further enhanced by the reduction of the thermal energy supplied over time and the constant flushing of debris during the longer off-period.

3.2 Effects of EDC parameters on MH

Micro Hardness (MH) of the surface being coated, measured by a Vickers hardness tester, is an important performance parameter that improves with an increase in electrical current between 2A and 3A. This is because at the highest current settings (3A to 4A) the MH peaks since more electrode material is transferred and that carbon is lost in the dielectric fluid in the process of the sparking. An increase in the pulse-on time is also very effective in increasing the MH since the long period of sparking provides a lot of thermal energy and a very strong explosion force that creates large amounts of molten metal. Since this prolonged period does not allow the molten material to fully leave the machining area, it solidifies, sticks and re-hardens into a hard layer that mechanically bonds with the workpiece. On the other hand, the lowest pulse-on times are used, which does not give sufficient energy to achieve proper sparking, leading to poor melting and solidification of the electrode material, which eventually reduces the MH. Lastly, comparing the pulse off-time, the data indicated that initially, MH declined; a reduced off-time was unable to provide adequate energy to create a strong metallurgical bond, and thus, the overall hardness decreased.

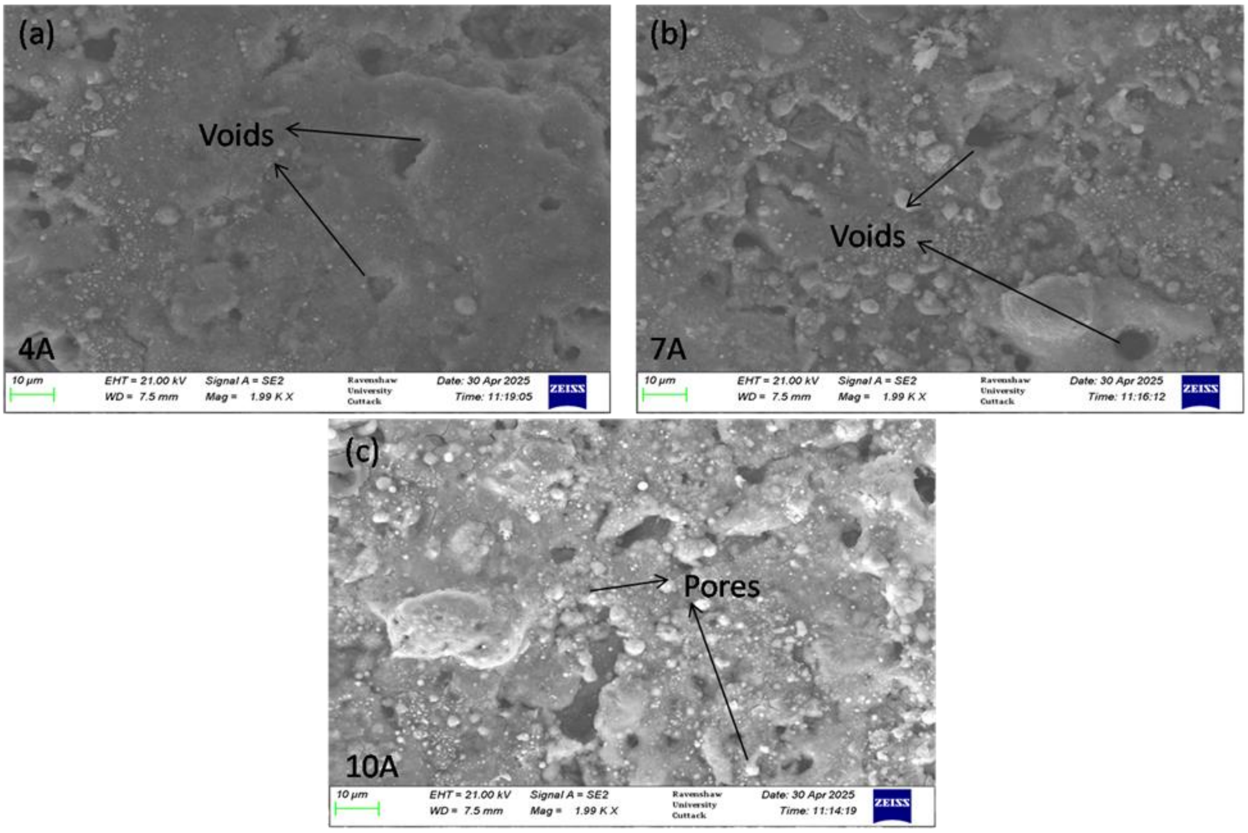

Figure 3: Structural defects overview.

3.3 Variation of coating microstructure with respect to duty factor

The duty factor effect on the coating microstructure was scientifically measured between 30% and 90% on a TiCu (50:50) composition at a fixed peak current of 10 A. In EDC process, the duty factor determines the length of time and heat input of thermal energy at the electrode- workpiece interface. Low energy of discharge at low duty factors (30 and 50 percent) was not enough to maintain a stable plasma channel and resulted in incomplete melting of the copper matrix, limited dispersion of Ti particles, and weak interfacial bonding, which eventually led to a discontinuous and porous layer. On the other hand, a medium level of 70% duty factor allowed stable plasma conditions to be achieved, allowing uninterrupted melting and uniform transfer of the TiCu particles to form a dense, smooth and smooth coating with reduced porosity and good adhesion. But raising the duty factor further to 90 percent resulted in excessive sparking, overheating and arcing which resulted in molten debris accretion, uneven deposition and creation of larger voids. All in all, a 70% duty factor offers the best combination of thermal energy and deposition rate resulting in an exceptional composite microstructure and coating performance.

4. Conclusions

The electrode that was used in the EDC process to enhance the surface traits of AA6062 aluminum was Ti & Cu powder. Vickers micro-hardness, SEM, analysis showed uniform trends: Deposition Rate (DR) was sharply increased with current, as more sustained heat resulted in increased quantity of material melting and vaporizing. Moreover, this was assisted by a reduced pulse off time which produced a more energetic plasma channel. As far as hardness is concerned, both current and pulse on-time had to be raised and the MH value had to go up. It is because long pulse times imply more heat and explosive energy, resulting in a considerable amount of electrode material disintegrating on the surface during cooling producing a harder layer.

Authors' contributions

All authors contributed equally to the conception, design, experimental work, data analysis, interpretation of results, and preparation of the manuscript. All authors reviewed and approved the final version of the manuscript for publication.

Conflicts of interest

The author declares no conflict of interest.

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Data availability

No new data were created.

References

[1] A. Goto, Development of electrical discharge coating method, Proc. 13th Int. Symp. Electr. Mach. (ISEM-12),

Bilbao, Spain (2001).

[2] S. Chakraborty, S. Kar, V. Dey, S.K. Ghosh, The phenomenon of surface modification by electro-discharge coating process: A review, *Surf. Rev. Lett.* **25** (2018) 18300034.

[3] M. Okada, A. Yoshida, T. Furumoto, H. Watanabe, N. Asakawa, M. Otsu, Mechanisms and characteristics of direct cutting of tungsten carbide using a diamond-coated carbide end mill, *Int. J. Adv. Manuf. Technol*. **86** (2016) 1827–1839.

[4] A. Ahmed, Deposition and analysis of composite coating on aluminum using Ti–B4C powder metallurgy tools in EDM, *Mater. Manuf. Process*. (2015). https://doi.org/10.1080/10426914.2015.1025967.

[5] H.J. Chen, K.L. Wu, B.H. Yan, Dry electrical discharge coating process on aluminum by using titanium powder compact electrode, *Mater. Manuf. Process*. **28** (2013) 1286–1293.

[6] B. Thiyagarajan, V. Senthilkumar, Experimental studies on fly-ash erosion behavior of Ni-Cr based nanostructured thermal spray coating in boiler tubes, *Mater. Manuf. Process*. **32** (2017) 1209–1217.

[7] E.K. Mussada, P.K. Patowari, Post processing of the layer deposited by electric discharge coating, *Mater. Manuf. Process*. **32** (2017) 442–449.

[8] S.J. Algodi, J.W. Murray, P.D. Brown, A.T. Clare, Wear performance of TiC/Fe cermet electrical discharge coatings, *Wear* **15** (2018) 109–123.

[9] N. Beri, S. Maheshwari, C. Sharma, A. Kumar, Technological advancement in electrical discharge machining with powder metallurgy processed electrodes: A review, *Mater. Manuf. Process*. **25** (2010) 1186–1197.

[10] S. Chakraborty, S. Kar, V. Dey, S.K. Ghosh, Multi attribute decision making for determining optimum process parameter in EDC with Si and Cu mixed powder green compact electrodes, *J. Sci. Ind. Res.* **77** (2018) 229–236.