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Experimental investigation of wear resistance of copper coated electrode-tool during electrical discharge machining

T Ablyaz [1], K Muratov[1], S B Preetkanwal[2], S S Sarabjeet[2]
[1] Perm National Research Polytechnic University, Perm-614000, Russian Federation
[2] Mechanical Engineering Department, Beant College of Engineering & Technology, Gurdaspur-143521, India

[*]E-mail: lowrider11-13-11@mail.ru

Abstract. In this study, electrode-tools with excellent electrical and thermal properties were manufactured for use in die-sinker Electrical Discharge Machining. The most common materials, nowadays, for the manufacture of electrode tools are copper and graphite. The traditional method of obtaining complex profile electrodes tools is multi-axis metal cutting blade processing. The low utilization rate of the tool material during the shaping of complex-profile electrodes significantly affects the cost of a suitable product. The paper proposed a method of fabricating electrodes obtained by casting methods with the subsequent application of electro-erosion resistant coatings. The study of the investigating the durability of the coated electrode during the processing of 34CrNiMo6 steel has been carried out. It has been established that to obtain a uniform copper coating with a thickness of 300 μm, it is necessary to use a current density in the course of galvanic deposition of 1.3 A / mm² at an exposure of 5 hours. An experimental study of the durability of the coating during the die-sinker Electrical Discharge Machining of 34CrNiMo6 steel showed that with an increase in the current intensity above 8A, the copper coating burns out. Based on the research, it was found that the processing of 34CrNiMo6 steel with electrode having copper coating on aluminum alloy AK12 as a base metal showcased superior processing capacity. The economic efficiency of using coated electrodes was enhanced by 35% as compared to the technology for obtaining a tool from a solid copper billet.

1. Introduction

The technology of die-sinker electrical discharge machining (EDM) allows manufacturing complex shape parts made of materials with enhanced physiomechanical properties [1-5]. The main limiting factor in the use of die-sinker EDM machines is the limited technological capabilities in manufacturing complex profile electrode tools (ET) [2]. A majority of the total time in process of manufacturing parts by the EDM method is consumed while fabrication of desired ETs. The EDM utilizes ETs made up of materials with high thermo-electric and erosion resistant properties. Amongst these materials, copper and graphite are the first choice for ET fabrication.

Electrodes tools (ET) are fabricated in various ways; the most common methods are casting, turning, pressing, and processing by the method of selective laser melting and sintering (SLM). In EDM two types of ETs are categorized: profiled and non-profiled. The Profile tools are applicable in the die-sinker EDM wherein, the shape of the finished part corresponds to the tool profile. Aluminum, copper, and bronze are the most common electrodes used therein. Non-profiled tools are employed in wire-cut EDM equipment. Brass or copper wire is the tool that performs cutting on the end surfaces.

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In the traditional manufacturing of ET having complex profile, its shape is divided into basic areas, and each section is fabricated separately. The individual elements of the electrode are then coupled in one tool. At present, metal-cutting techniques for producing ET of a complex profile are widely used. However, the final complex profile electrodes, thus produced, lack the accuracy while used in machining. As the cost of manufacturing a complex profile electrode depends on the complexity of the tool profile, often the processing of promising parts such an electrode becomes economically unprofitable [2, 3].

One of the ways to reduce the cost of manufacturing ET is to obtain complex ET with erosion-resistant coatings (cortical electrodes) [5]. Both metallic and polymeric materials can be used as a base for coating. The metal or polymer can be used as base material for manufacturing the complex ET employing Casting techniques and rapid prototyping technologies.

A similar research work [6] has highlighted the effective use of complex aluminum ET with copper coating for EDM of alloyed steel (figure 1).

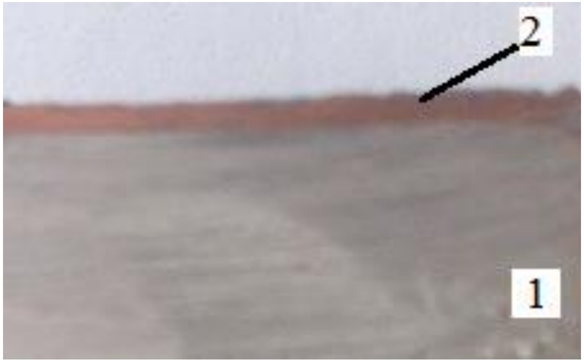

Figure 1. Aluminum ET with copper coating:
1-aluminum base; 2-copper coating

It was found that the amount of wear of the complex ET from aluminum with copper coated is comparable to the copper electrode. Comparison of the performance of copper and complex electrode-tools, showed a difference of not more than 4% percent.

However, in order to fully understand the operational characteristics of the coated electrodes, this work is aimed to study the durability of the coated ET while ED machining of 34CrNiMo6 steel.

2. Materials and Methods

34CrNiMo6 steel was chosen as workpiece for carrying out the EDM experiments and Electronica make Smart CNC EDM machine was utilized for this purpose incorporating dielectric oil as working fluid.

Table 1. Materials for the preparation of galvanic solution

Materials	**Concentration (g/l)**
Sulphuric acid	30
Alcohol	5
Distilled water	1 l
Copper sulfate	200

This study was conducted on three cylindrical samples of aluminum AL1 (figure 2).

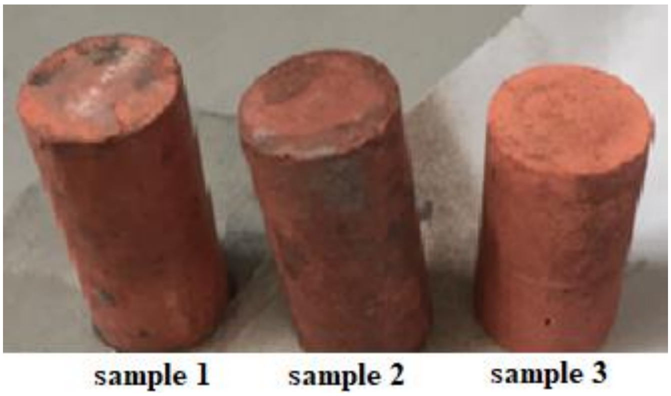

Figure 2. Copper-coated EI samples

The exposure time of each sample was 1 hour (table 2).

Table 2. Time and current strength in the experiment

Sample	Current, A	Holding time, h	Current density, A/mm²
1	3	1	0.95
2	4	1	1.27
3	2	1	0.63

After each exposure, the thickness of the coating was measured using an Infinity microscope at 100x magnification. After coating the samples, experimental studies of the electrical discharge machining of a billet of steel 34CrNiMo6 were carried out to measure the amount of wear for the applied cortical coating. Processing modes are presented in table 3. Each experiment was repeated three times.

Table 3. Processing parameters on the copy-piercing equipment

Mode	Current, A	Ton, MKS	Voltage, V
Max	8	150	100
Min	2	150	100
EDM time - 20 minutes			

3. Results and discussion

The results of the thickness of the copper coating as per the parameters (table 2) of galvanic deposition are presented in table 4.

Table 4. Formation of the thickness of the coating samples after an hour of exposure

Sample	Current, A	Coating thickness, micron
1	3	76.98
2	4	112.12
3	2	42.23

The results of the study showed that aluminum samples 1 and 3 with an exposure of 1 hour (table 2) have a small coating thickness, which will certainly lead to its burning out upon contact with workpiece while EDM. Sample 2 of aluminum (figure 3) witnessed the highest coating thickness among all samples after copper plating and holding for 1 hour.

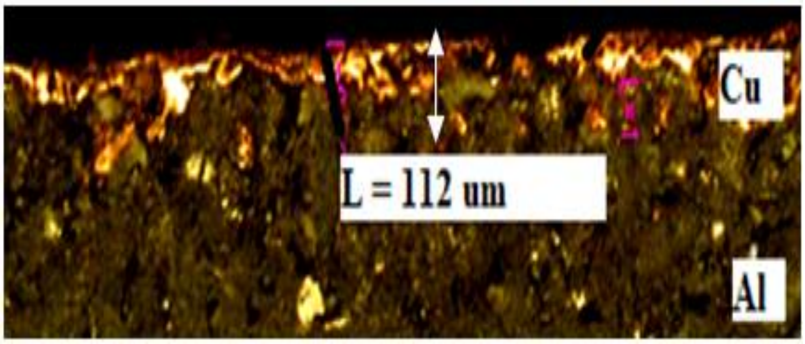

Figure 3. The thickness of the copper coating sample 2

After obtaining the suitable parameters for galvanic deposition by current values, the effect of exposure time on the formation of the coating thickness with a step of 1 hour was studied. It has been established that to obtain a uniform copper coating with a thickness of 300 μm, it is necessary to use a current density in the course of galvanic deposition of 1.3 A / mm² at an exposure of 5 hours. The subsequent increase in the exposure time did not lead to a significant increase in the thickness of the coating.

An experimental study of the durability of the Cu coating ET during EDM of 34CrNiMo6 steel showed that the coating burns out with an increase in the current strength above 8A (max value of table 3) (figure 4a).

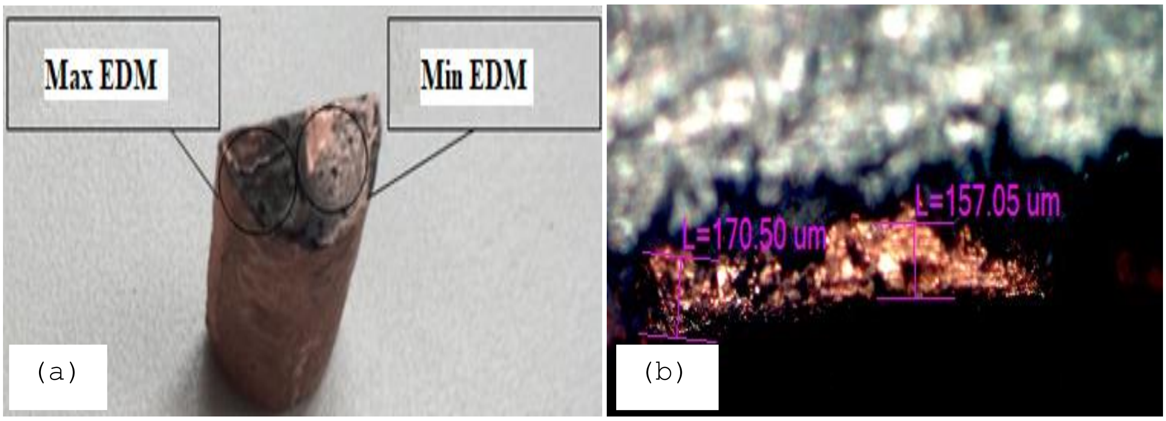

Figure 4. ET sample after EDM in a) max and min modes, b) the thickness of the coating after 2 hours of EDM at min mode

It was established that during EDM of workpiece with a current of 2A (min value), the coating burned out by 55% after 2 hours of processing (figure 2b). Complete burnout of the coating was witnessed after 5 hours of EDM.

On the basis of the experimental data, tests sample of cortical ET (figure 5) was fabricated and sent for production. This ET is intended for the manufacture of “Hook” type special engineering products.

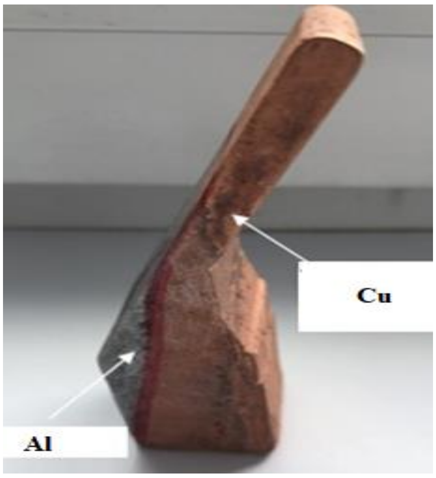

Figure 5. As fabricated Cortical ET

The resulting electrode was fully compliant with the EDM requirements but was prone to burning of the coating surface when used in rough machining conditions. Research on accuracy of processing would be carried out in the future.

4. Conclusions

The process of galvanic deposition of copper on the electrode surface has been carried out. The technology of investment casting, galvanic copper deposition and modeling has been studied. An electrode tool was fabricated to perform roughing operations on the die-sinker EDM equipment.

Based on the studies, it was found that ET coated on the aluminum alloy AK12 base allows to process 34CrNiMo6 steel, providing a given processing performance. The economic efficiency of using ET with coating was 35% in comparison with the technology for obtaining a tool from solid copper billet.

Acknowledgement
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