Experimental analysis of the EDM process of dissimilar materials

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Abstract. The aim of the present study is to investigate the surface roughness of Electrical Discharged Machined (EDM) samples with Electrode Tool (ET) materials. For the experiments, three different types of ETs were considered which are made of different materials viz. composite, copper, and graphite. Aluminium, low alloy 35GS steel and OT4 titanium alloy were selected as the workpiece materials. Machining parameters used were: current (I) 8 A, voltage (U) 100 V, and pulse duration (Ton) as 150 μs. It was found that the ET made of composite material performs best in EDM of 35GS steel and OT4 titanium alloy. Specifically it was concluded that in the first case, the performance of composite ET is higher than graphite ET by 59 %. Similarly, in the second case, its productivity was found to be 74% and 95% higher when machined with graphite and copper ET respectively. Moreover, the surface roughness values of 35GS steel machined with composite ET was found to be 15% higher when machined with copper and graphite ET. While processing titanium alloy with composite ET, surface roughness values were observed as high as 44% and 25% when machined with copper and graphite ET respectively.

1. Introduction.
Metals and their alloys with different physical and mechanical properties are widely used in manufacturing a wide range of components. To enhance the properties of components manufactured for aviation, and space technologies, continuous improvement is required in design, materials, and the manufacturing techniques. With the advancement of the technology, the shapes of the components become more complicated to manufacture with the conventional techniques. Materials like titanium and its alloys are widely used in avionic industry due to the properties high strength, light weight, and corrosion resistant to the extreme environments. In such domains, mass and reliability of the material play a vital role. However, titanium alloys are difficult to machine effectively due to the generation of high temperatures in the cutting zones. This high temperature affects the machining efficiency, increase wear rate of the tool and enhance the risk of thermal hardening of the surface of workpiece. Thus, the cutting tools for machining complex geometries of such materials has to be decided on the amount of cutting force being generated. This high bearing capacity of thrust force is difficult to achieve by the conventional machining tools and processes [1, 2].
The solution of this problem can be hybrid machining e.g., electro-physical machining. One of such method is electrical discharge machining (EDM). In today’s manufacturing practice, electric discharge machining (EDM) has become the famous, non-traditional, material removal process. That's because of a variety of reasons. EDM allows the machining of extremely hard materials and it is possible to produce complex shapes with high precision. Another feature that meets the expectations of modern manufacturing is its inherent automation capability [3-6]. In EDM, copper and graphite are widely as ET material. Due to the high wear and low productivity achieved by these materials makes EDM process impractical to use for batch manufacturing of aerospace components. A number of wear resistant composite materials have been developed of properties similar to the traditionally used ET materials for machining such components. One of the promising materials for the ET is a composite material: pseudo-alloy (copper colloidal graphite systems with graphite content of less than 2%).

The influence of the ET material on the surface roughness of the machined surfaces and performance of EDM has not been investigated. Also, Composite material as ET has not been studied completely. Thus, the aim of the study is to investigate the achieved surface roughness and the performance of the EDM of materials with different physical and mechanical properties by using different ETs.

2. Materials and methods
Experiments were conducted on EDM machine, Electronica Smart CNC. The materials selected are mentioned in Table 1. For the experiment, electrodes tool (ET) used were made of different materials: Graphite; Composite Material (Pseudo alloy of the copper + colloidal graphite (CuC) system); Copper (M1 grade). Transformer oil (GOST 982-80) was used as the working fluid. Experiments were performed at a current (I) = 8A, voltage (U) = 100V, and pulse duration Ton = 150μs. Measurements of machining productivity Q(mm/h) were carried out on a coordinate measuring machine (make :Carl Zeiss Contura G2). Surface roughness parameter Ra (μm) was obtained using Mahr Perthometer S2 profilometer as per GOST 2789-73. Surface images were obtained with a microscope (make: Olympus GX51) at a magnification of 100 ×.

Table 1. Different types of workpiece material used in this study.

| S.No. | Workpiece material | Specification | Standard        |
|-------|--------------------|---------------|-----------------|
| 1     | Aluminium          | AD1           | GOST 4784-97    |
| 2     | Low alloy steel    | 35 GS         | GOST 5781 - 82  |
| 3     | Titanium alloy     | OT4           | GOST 19807 - 91 |

3. Results
The experimental results are presented in Figure 1. Surface roughness achieved by the composite ET is higher than copper and graphite by 59%. While productivity achieved by composite ET was 74% higher than that of a graphite ET, and 95% higher than that of copper ET. However, surface roughness values of 35GS steel machined with composite ET was found to be 15% higher when machined with copper and graphite ET respectively. While machining of titanium alloy with composite ET resulted in low surface roughness values as compared to when machined with copper and graphite ET. When processing aluminum AD1, the composite electrode showed the lowest productivity, as well as the worst roughness of the treated surface. Graphite ET showed the lowest roughness values during the processing of aluminum AD1 and steel 35GS. In addition, when processing aluminum, the graphite electrode exhibits the greatest productivity. Copper ET showed the least surface roughness values for OT4 alloy, but at the same time its productivity is 5 times lower than the graphite electrode and 20 times lower than the performance of composite ET (Figure 2).
Figure 1. Dependency of the surface roughness parameter (Ra) on ET material.

The study of the surface topography after EDM showed that the surface acquires a specific roughness due to the formation of micro-wells on the surface. Processing with a copper electrode results in a surface with a distinct shape of the micro-wells (Figure 3 (a)). When machined with graphite and composite ETs, the micro-wells combine with each other and form large depressions, which lead to an increase in surface roughness (Figure 3 (a), (b)).

Figure 2. Relationship between productivity (Q) on ET material.
Figure 3. Surface topography of steel 35GS after processing with three types of electrodes, (a) copper ET; (b) graphite ET; (c) composite ET; 100 ×

4. Conclusions
Based on the results of the experiment and analysis of the data obtained, we can draw the following conclusions:

1. The electrodes made of composite material of copper-colloidal graphite system is advantageous to use for EDM of titanium alloys and low alloy steels to achieve very high surface finish.
2. Graphite ET is suitable for the moderate finishing of low alloy steels, titanium alloys, and aluminum.
3. It is advisable to use copper ET to achieve better finishing in EDM of steels.

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