Electrical discharge machining of polymer composite materials

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Abstract. Improving the technical capabilities of manufacturing processes and creating new parts that surpass existing quality benchmarks is a need of modern engineering. Polymer Composite Materials (PCM) are commonly used in the manufacturing of advanced aerospace components. The aim of this work is to study the process of Electrical Discharge Machining (EDM) of PCM VKU-29. To study the process performance, three different types of Electrode Tools (ET) of different materials were used. EDM was performed on three modes viz. maximum, medium, and minimum. The influence of process parameters and the electrode type on the formation of spark gap was investigated. The visual and the microscopic inspection revealed the absence of hairiness and traces of fiber rupture in case of composite ET. Thus, it can be concluded that the combination of smallest value of spark gap and the composite ET leads to the best quality of surface amongst all the other combinations. Moreover, while processing the PCM VKU-29 using composite ET, it is advisable to maintain a spark gap of 0.14 mm for the best results.

1. Introduction
Improving manufacturing capabilities and creating new components with their properties that are comparable or better to the existing is an imperative challenge for modern engineering. Polymer Composite Materials (PCM) are commonly used in the manufacturing of advanced aerospace components. PCMs are a kind of versatile and high performance material formed from a combination of two or more phases of materials [1]. Structural PCMs are currently being developed with high resistance to static and dynamic loads [2]. These materials have special properties, with a wide temperature range of operation. Due to the use of different binders, these materials are able to provide properties like heat resistance and strength. These properties ensure the machining of such structures [3, 4]. PCMs also have the ability to effectively damp the background noise associated with the operation of turbine blades used in aircrafts. Thus, noise absorption panels of aircrafts are usually made of these materials [5].
However, these materials have many advantages than the conventional materials but the processing of these materials is difficult. The manufacturing of components from this material has some limitations [6]. Yaroslavtsev et al. studied the PCM machining and concluded that on machining, the wear of the cutting tool increases which leads to the decrease in productivity [7]. Also, due to very low stiffness, it is difficult to machine these materials with multipoint cutting tools and abrasive blades.

During machining (drilling, turning, milling and surface machining) of PCM components, defects such as peeling and tearing of the fiber from the matrix arise. Surface defects such as low and uneven roughness, chips at the ends, cracks, and fiber delamination can be attributed to the cutting action of the tool on the two phased material [1, 2]. Thus, there is a demanding need of the research and development of such alternative machining processes which can machine materials like PCM with high accuracy [8-10]. An adequate solution to this can be the use of electrical discharge machining (EDM). Electrical discharge machining (EDM) is a non-conventional method of machining focused on removing material from a component through a sequence of periodic electrical discharges between electrodes, and the part being machined in the presence of a dielectric fluid [11]. The processes taking place during the electric discharge are presented in Figure 1.

![Figure 1. The basic physical processes during EDM.](image)

EDM of a variety of conductive materials have been investigated in the literature. But there is a dip in the literature for EDM of non-conducting materials. Specifically, EDM of PCM is not completely studied. Thus the aim of this current work is to study the process of EDM of PCM VKU-29.

2. Materials and Methods

For the current work, composite material- carbon fiber VKU-29 was selected. EDM of VKU-29 was carried out by three different Electrode Tools (ET). The details of the ET used have been given in the Table 1. The machining was carried out in three modes with a constant pulse duration (Ton) = 150 μs and open voltage (U) = 100 V. The value of current (I) was varied as 8A (maximum), 2A (medium), and 0.5 A (minimum). The machined surface and the ET after the machining were analyzed under Carl Zeiss CONTURA G2® coordinate measuring machine. An average of three readings were taken as the final value to eliminate any discrepancy during the analysis.

| S.No. | Electrode Tool | Standard       |
|-------|----------------|----------------|
| 1     | Graphite       | GOST 4426-80   |
Composite Material (Pseudo alloy of the copper + colloidal graphite (CuC) system) Powders PMS-1 (GOST 49-60-75) and dry colloidal graphite of the S-1 grade (TU 113-08-48)

Copper (M1 grade) GOST 1173–2006

3. Results and discussion

The burning of the samples has been observed during the maximum conditions (Maximum EDM mode). Figure 2 presents the values of the spark gap, measured as the difference between the width of the machined surface and the width of the ET before processing.

![Figure 2. The value of spark gap during EDM of VKU-29 with three different ETs.](image)

The results of the study show that it is difficult to machine the PCM with graphite ET in all modes. The value of spark gap during machining at maximum mode is the largest. Composite ET processing is characterized by the best quality of machined surface, and has a smaller value of the spark gap at all processing modes (Spark gap = 0.23-0.30 mm). When processing copper Electrode-tool in various modes, the spark gap is minimal (Spark gap = 0.23-0.32 mm), however, the surface of the VKU-29 thermoplastic was found to be fleecy. As a result of the experiments, it has been concluded that EDM of PCM by composite ET provides the best quality of surface (Figure 3).

![Figure 3. Surface characteristics of VKU-29 after EDM of (a) composite ET and (b) Copper ET.](image)

It was found that during EDM with composite ET, the treated surface has no traces of torn layers and hairiness, and subsequent finishing is not required. The effect of “sintering” of PCM fiber on the treated surface was observed. The machining process was accompanied by stable sparking without growths on the working surfaces of ET. In a similar study it has been shown that it is entirely feasible to machine carbon fibre composite materials by EDM process. The advantage of such a process with carbon fibre composite materials is the capability of producing irregular shaped holes with good surface finish and...
dimensional accuracy. Also, Copper electrodes prove to be better than graphite electrodes in terms of tool wear and surface finish [12].

4. Conclusions

The absence of hairiness and traces of fiber rupture on the machined surface concludes that it is possible to use EDM technology with composite ET for machining PCM VKU-29. It has been shown that while using composite ET for the EDM of VKU-29 material, it is necessary to maintain a spark gap of 0.14 mm for the best surface.

Acknowledgement

Financial support was provided by the Russian President in encouragement of young Russian scientists (grant MK-2072.2019.8).

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