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The effect of unilateral side flushing on the integrity of the workpiece under different machining conditions

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Abstract

Electrical Discharge Machining (EDM) removes material by melting and vaporization as consequence of high temperatures generated by high-frequency electrical discharges. This result changes the material integrity, due to the production of an affected layer and micro-cracks. In this study, the integrity generated by the use of unilateral side flushing in EDM was evaluated. The experiment consisted of machining square cavities with different parameters. Analysis of texture, roughness, affected layer and micro-hardness were investigated. The results show variations in the thickness of the affected layer at different positions of the machined cavity and showed changes with machining conditions along the flushing path.

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*Keywords:*Electrical Discharge Machining (EDM); Surface analysis; Affected layer

1. Introduction

Electrical discharge machining (EDM) is a nontraditional machining process used to manufacture hard and brittle materials and complex geometries with high accuracy. It is frequently used in mold and die making [1]. The removal of material occurs due to the conversion of electrical energy into thermal energy through a series of discrete electrical discharges between the electrode and workpiece which are immersed in a dielectric fluid [2]. It results in significant surface change, in the form of a recast layer that results in the formation of cracks, high tensile residual stress and a rough morphology [3].

The objective of this paper is to study the impact of machining a hollow cavity by EDM using different roughing parameters and unilateral side flushing. Surface quality, affected layer and micro-hardness were evaluated. All data was subjected to an analysis of variance (ANOVA) with 5% significance.

2. Methodology

All the samples were obtained using an EDM Engemaq machine, model EDM 440 NC. The electrodes used were made of C11000 Electrolytic Tough Pitch (ETP) Copper. The workpiece material was AISI P20 steel, with hardness between 350 and 380 HV. The dielectric fluid was a mineral oil Microcorte 102-A. The workpiece was completely submersed in dielectric fluid, and was flushed with one external nozzle at a pressure of 0.5 MPa. The nozzle opening was rectangular (25 mm x 1 mm), positioned with a 30° inclination from the workpiece surface. Roughing conditions used are given in Tab. 1. An automatic gap and positive polarity was used. The electrode was set for a 2 mm retreat between cycles. A square cavity was open with a copper electrode with 14 mm x 14 mm dimension and 8 mm depth. After that, the cavity was extended using a copper or graphite electrode to a 15 mm x 15 mm hole with 9 mm depth. Four different machining conditions were used. A replica was made for all conditions. Surface characterization was conducted

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through SEM texture image analysis using a MIRA3 TESCAN FEG-SEM. Surface roughness evaluation was conducted using a Mitutoyo SJ-301 surface roughness tester. The parameters analyzed were: arithmetic average roughness (Ra), average peak to valley height (Rz (med)) and maximum height of profile (Rz). The parameters were obtained according to the ISO 4287:1997 standard. The analyzed locations were the flushing entrance wall (EnW), the exit wall (ExW), the bottom side of the flushing entrance (EnB) and the exit (ExB). Six measurements were made.

Table 1. Machining conditions

Condition	Current Density (A)	Off Time (μs)	Erosion Time (s)	Number of cycles before a full retreat
Starter hole	18	100	1	10
Cond. 1 (C1)	12	90	0.5	5
Cond. 2 (C2)	12	90	1	5
Cond. 3 (C3)	12	90	0.5	10
Cond. 4 (C4)	12	90	1	10

The affected layer thickness was measured in four different cavity locations. Six measurements were made in each analyzed spot at 500 times magnification. The samples were etched with Nital 2% solution. The analyzed positions were showed in Fig. 1: the flushing entrance wall, near the workpiece surface (EnW1) and near the cavity bottom (EnW2), and the flushing exit wall, near the workpiece surface (ExW1) and near the cavity bottom (ExW2). Hardness measurements were performed with Vickers microindenter Shimadzu Mitutoyo, using a 0.025kg load, following the ASTM International Designation E384 – 11. The hardness measures were performed 20, 40, 60 and 80 μm from the surface. All roughness, affected layer thickness and hardness data were subjected to an ANOVA analysis with 5% significance.

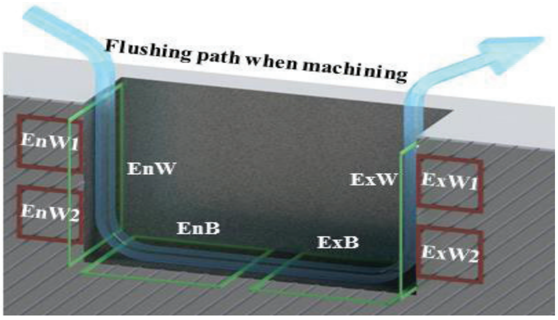

Figure 1. Analyzed spots along flushing path

3. Results and discussion

3.1 Surface Quality

The analyzed surfaces textures are shown in Fig. 2. The surface in the bottom of flushing entrance seems smoother and has less molten material at the crater borders. By comparison, the bottom of flushing exit is rougher. No microcracks were found. Surface machined by EDM seems to have a random pattern structure. The surface high peaks are formed adjacent to the melted valleys [4]. No qualitative differences were found in texture among the tested conditions.

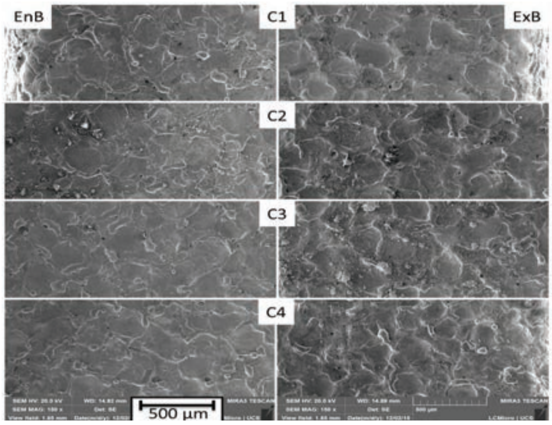

Figure 2. SEM Texture samples. Images of the bottom at the flushing entrance (EnB) and flushing exit ExB for all tested conditions.

Figures 3, 4 and 5 show the behavior of Ra, Rz (med) and Rz , at different analyzed positions within the cavity.

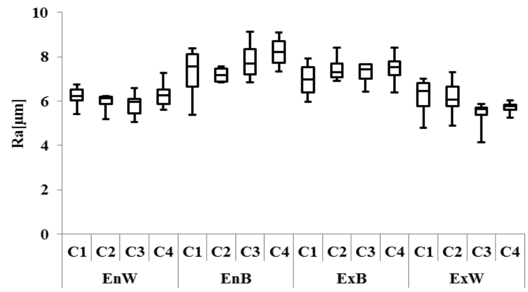

Figure 3. Arithmetic average roughness [Ra]

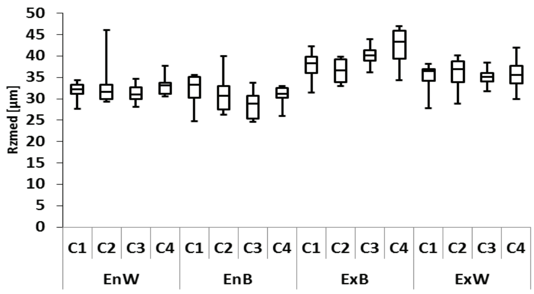

Figure 4. Average peak to valley height [Rz (med)]

The Fig. 3 shows that the Ra is bigger in the bottom than in the wall. In turn the results in figures 4 and 5 show a slight variation in surface roughness in the crater bottom with ExB slightly greater than EnB for Rz (med) and Rz.

The difference in Ra could be caused by the difficulty in remove debris from the bottom and a probable increase in electrode wear, both of them associated with increase of the machining depth. For Rz and Rz (med) the flushing can