Conference Paper

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Economic and energy efficiencies in meso-micro EDM

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Abstract

Economy and energy efficiency in die-sinking EDM are mainly defined by the number of electrodes required to reach the desired accuracy, form of the machined cavity and surface quality, where the recent trend of zero electrode wear in roughing operation has considerably reduced the required resources. In this work, using a novel low wear technology and spark location adaptive process control, electrode requirement is reduced by more than 25% for precision EDM and meso-micro EDM.

1 Introduction

Die-sinking EDM is a key technology in high precision die and mould machining, where electrode wear during erosion necessitates multiple electrodes to machine a cavity. Reduction in the number of electrodes required to machine complex shapes delivers obvious benefits of lower material costs, electrode preparation time, tool costs and energy requirements; prompting the development of low wear technologies, electrode re-use strategies and combination electrodes consisting of macro to micro scale features (see fig. 4). However, different process parameters required for macro scale and meso-micro scale erosion limits the use of combination electrodes. Hence, using the knowledge derived from EDM process analysis [1], an adaptive control is conceptualised to change the technology parameters based on the spark location.

2 Experimental setup

Combination graphite electrodes (Poco EDM-3 grade) consisting of macro to micro scale features are mill machined using a 5 axis high precision machining centre, W518MT from Willemin-Macodel SA. Machining time for micro scale electrodes is

40 min and for combination electrode 20 min. The erosion experiments are performed on Form 1000 from Agie Charmilles SA using IME110 dielectric oil from Oelheld SA and 1.2343 steel is chosen as workpiece material.

Low wear strategy for micro erosion and adaptive control algorithms are programmed using field-programmable gate array (FPGA). For low wear strategy, wear neutral pulse packets are generated consisting of a long duration pulse causing carbonaceous build-up on the electrode followed by short duration pulses causing wear of the generated build-up, as shown in fig. 1 (left). In addition, an adaptive control is conceptualised to change parameters of each spark depending on its location, deduced from its discharge voltage (see fig. 1 right). For measured voltage below Ref 2, described low wear technology for micro scale features is applied, whereas for the sparks with discharge voltage between Ref 1 and Ref 2, standard low wear technology is continued. Discharges with measured voltage above Ref 1 are considered lateral sparks and terminated within a few micro seconds after breakdown.

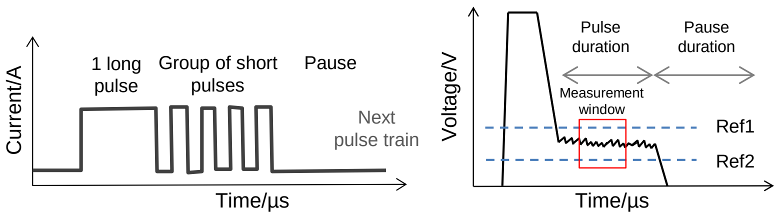

Figure 1: Left: low wear strategy for micro erosion; Right: Process parameter adaptation based on measured discharge voltage of each spark.

3 Results

3.1 Low electrode wear in meso-micro EDM

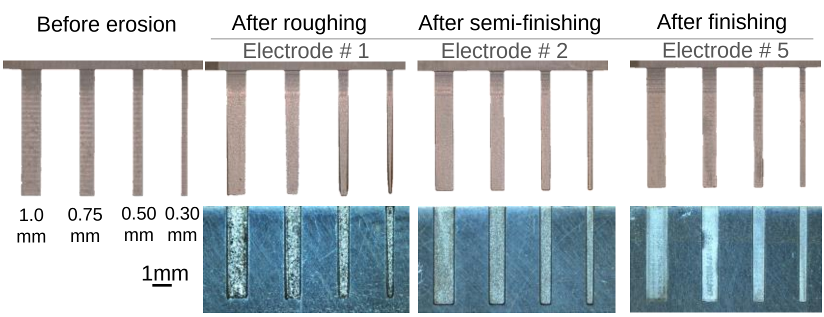

Figure 2: Low electrode wear achieved for micro scale erosion and machined cavities.

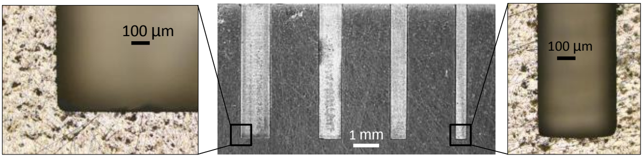

Figure 3: Inner corner radius and form of the cavities after using five electrodes.

Using the low wear strategy consisting of wear neutral pulse packets as described above, near zero wear is achieved for erosion using electrodes consisting of different micro scale features as shown in fig. 2. Inner corner radius of about 150 µm is obtained using only two electrodes, whereas one achieves inner corner radius of 45 µm ± 5 µm after five electrodes (see fig. 3). Oversize of the cavities is 150 µm ± 5 µm and depth of the eroded cavities is 4990 µm ± 10 µm, with final surface roughness R_a~ 0.3 µm. Roughing step performed to erode 4.8 mm deep cavity using 5.4 A results in frontal build-up/wear within ± 40 µm. For subsequent semi-finishing and finishing steps to reach 5 mm depth, frontal wear was within 10 µm. Required roughing time is 370 min, semi-finishing time is 110 min and finishing time 90 min.

3.2 Precision machining in macro-micro scale

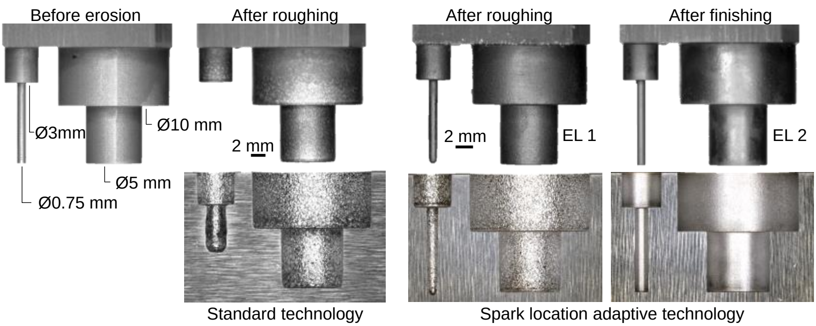

Figure 4: Comparison of standard technology and spark location adaptive technology for erosion using combination electrode consisting of macro to micro scale features.

Table1: Measured frontal wear and erosion times for adaptive control technology.

EL #	Machining step	Frontal wear (mm)		Erosion time (min)
		Micro	Macro	
1	Roughing	-0.274	-0.026	163
1	Semi-finishing	0.002	0.013	85
2	Finishing	-0.003	0	130

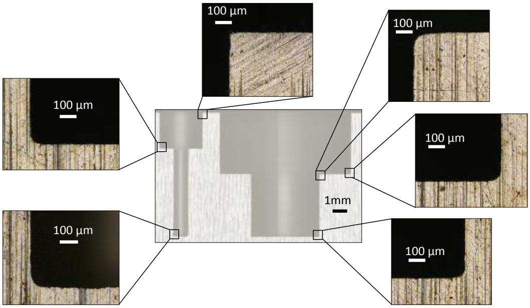

Figure 5: Form precision of the machined cavity using two combination electrodes.

A combination electrode having macro to micro scale features as shown in fig. 4 is used for erosion using standard low wear technology. It is seen that while near zero frontal wear is achieved on macro and meso scale features, the micro scale feature is broken during the erosion due to high average current. On the other hand, using spark location adaptive control, wear neutral pulse packets are applied when the sparks are determined to be occurring on the micro scale features, corners or edges in order to reduce average current and obtain low wear during roughing with 20 A. High form conformity after just one electrode results in near zero wear for finishing operation using the second electrode to reach surface roughness R_a~ 0.25 µm. After using two electrodes, inner corner radius of 140 µm ± 5 µm is achieved for 10 mm erosion depth and 0.4 mm oversize of the cavity. Total erosion time of 383 min is required to machine the final cavity, where 163 min required for roughing using adaptive control is 30 min less than erosion using standard low wear technology.

4 Conclusions

Using the low wear technology for micro features and spark location adaptive control, precision macro to micro scale cavities are produced using just two electrodes. Thus, machining time for each electrode along with the material costs and about 7.5 kW·h machine energy consumption is directly saved. Faster erosion speeds further reduce energy consumption by EDM machines of about 2.5 kW·h, thus providing economic and energy efficient high precision and meso-micro scale machining process.

References:

[1] Maradia U. et al., EDM process analysis using high-speed imaging, Proceedings of the 13th euspen International Conference, Berlin, 2013, V2 pg.39-42.