Conference Paper

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EDM process analysis using high-speed imaging

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Abstract

In order to gain new insights in electrical discharge machining process (die sinking EDM, wire EDM, EDM drilling variants), especially in meso-micro scale sinking EDM (area: 10mm^2 - 0.1mm^2), high-speed imaging (up to 500’000fps) of the process is combined with electrical process signals in a time synchronised manner, for quasi-real erosion conditions. The process understanding derived by correlating the visual and electrical information of the sparks and gap region along with the discharge craters enable next level of adaptive process control in high precision EDM.

1 Introduction

EDM is a widely used precision machining process, where millions of sparks erode the material to produce a desired geometry and surface finish. However, multi-physics nature of the EDM gap phenomena occurring at multi-time scales hinders the deeper insight into the process to exploit its capabilities. A recent method from Kunieda [1] uses transparent electrode for gap phenomena observation, but lacks the conventional electrode materials and steady-state process. In current work, a method is devised to concurrently integrate visual and electrical information of the gap phenomena in quasi-real steady-state erosion conditions, demonstrated through meso-micro scale sinking EDM.

2 Experimental setup

The experiments are performed on Form 1000 from Agie Charmilles SA. A Phantom v12.1 high-speed camera (up to 1M frames per second) from Vision Research with a telecentric lens (1x) is used for imaging through the glass windows of an erosion chamber. Lecroy 44Mxi is used for electrical signal measurements, as shown in fig. 1.

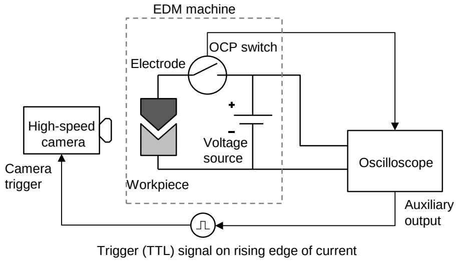

Figure 1: Schematics of the experimental setup.

The large amount of data (8GB per test) generated through photography is processed using MATLAB image processing tool with the help of electrical signals measured using oscilloscope. Statistical analysis is then performed on the images and measured voltage-current signals to infer the relevant information about process or discharges.

2.1 Quasi-real erosion condition

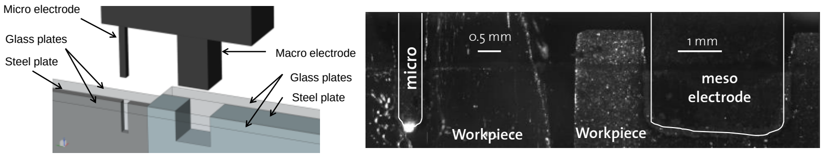

Figure 2: Left: Quasi-real erosion condition; Right: Image of the actual erosion setup.

Two of the four walls of a machined cavity are replaced by tightly placed glass to visually observe the process, thus emulating the real erosion conditions as shown in fig. 2. The glass plates allow observation of the gas bubble dynamics and other gap phenomena in quasi-real erosion conditions with limited dielectric fluid in the cavity.

2.2 Time-synchronised visual and electrical information

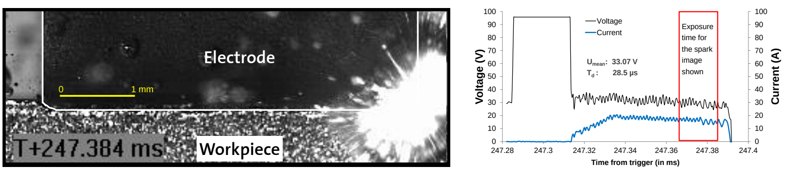

Figure 3: Time synchronised visual and electrical information of the EDM spark.

To correlate the electrical information of the sparks with their photographs, time synchronisation is performed through oscilloscope auxiliary output, triggered based on current channel, where steady-state or any chosen part of the process is acquired.

3 Results: Single and multiple discharges

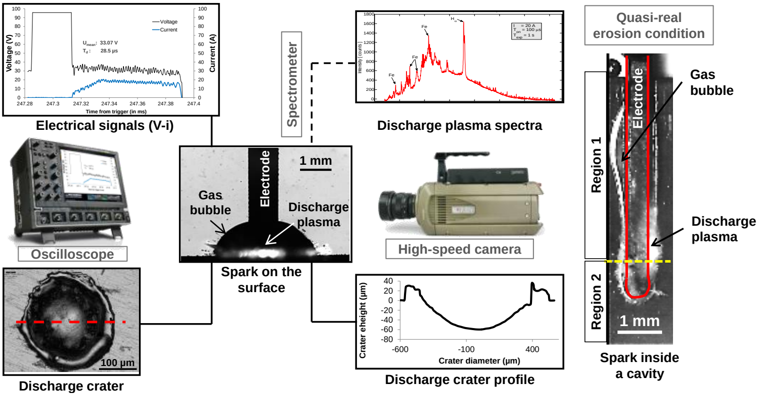

Figure 4: Concurrent visual, electrical, crater and plasma information of a discharge.

3.1 Gas bubble and plasma expansion

Using the formulated method, gas bubble expansion for micro and macro geometry is compared. Additionally, gas bubble expansion for micro electrode on surface and in quasi-real erosion setup has been analysed, shown in fig. 4. It is seen that during the actual erosion most of the micro cavity is filled with the gas bubble(s), causing the metallic phase discharges, if the pause duration between the two sparks is kept short.

3.2 Discharge characterisation

By correlating the electrical signal of the spark with discharge crater, different types of sparks and their effect on the workpiece are characterised. For example, short circuit sparks have been analysed, where it was seen that during the short condition, gas bubble and plasma generation takes place, leading to small material removal from the workpiece. Arcs and their effect on the workpiece are analysed. Including also the the information of plasma states using plasma spectroscopy as shown in fig. 4, an understanding of how the different plasma states affect the material can be gained.

3.3 Material removal mechanism

The material debris ejecting from the spark region during the discharge and due to the implosive forces during gas bubble collapse have been observed. However, for lateral sparks, the implosion does not occur on the spark location, instead the dielectric flows towards the low pressure region in the gap, resulting in a lower material removal.

3.4 Process instability

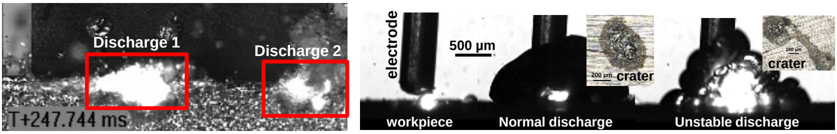

Figure 5: Left: Simultaneous discharges; Right: stable, unstable sparks and craters.

Simultaneous sparks have been observed (see fig.5 left) against the common belief that only one spark takes place at a time in EDM. Additionally, micro electrode vibration due to the discharge forces has been observed, indicating a strong need for avoiding the lateral sparks to achieve a stable process and reduce oversize of the machined cavity. Also, the sparks with discharge voltage > 30V have been observed which create a cathode spot at about 300-500µm lateral distance from the micro electrodes, causing an overcut in the machined cavity. The observations as inputs for the generator design and process control lead to low defect precision EDM process.

3.5 Spark location detection

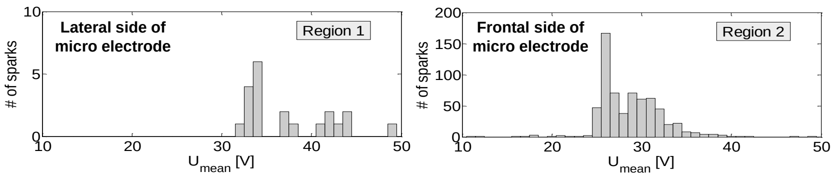

Figure 6: Spark distribution on different regions of a micro electrode (see fig. 4 right).

Using statistical analysis, dependence of the discharge voltage of each spark on its location on electrode has been found, enabling a surface area adaptive process control which also reduces corner and lateral spark growth to increase the precision in EDM.

5 Conclusions

Effect of different spark types on process outputs and their electrical signals provide informed input for the intelligent adaptive process control of high precision EDM.

References:

[1] T. Kitamura, M. Kunieda, K. Abe, High-Speed Imaging of EDM Gap Phenomena using Transparent Electrodes, Procedia CIRP, 6 (2013) 315-320.