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Multiple discharge phenomenon in micro-EDM with RC type generator

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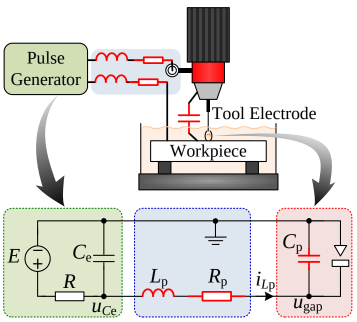
Abstract

In Micro electrical discharge machining (Micro-EDM) with a RC type generator, the normal discharge is often followed by alternating voltages and currents. In this paper, those voltages and currents are defined as a multi-discharge, and verified by electrical simulation and experimental tests. Then, the effects of the multi-discharge on manufacturing performance, such as the pulse frequency, material removal per discharge for the tool electrode and workpiece and tool wear ratio, are analysed. It is found that the multi-discharge phenomenon increases the material removal rate and reduces the tool wear ratio, so the servo feed rate, tool wear prediction, and compensation should be adjusted accordingly.

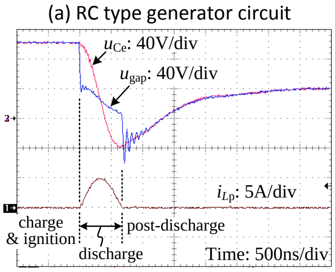
Key words: Micro electrical discharge machining (Micro-EDM) milling, RC type generator, multi-discharge, tool wear per discharge, material removal per discharge, tool wear ratio.

1. Introduction

In a micro Electro-discharge machining (EDM) system [1], the RC type (relaxation type) generator is still the priority option because of its very low energy per discharge [2]. A basic diagram of the connection of the generator and the two electrodes is shown in Fig. 1(a), with a simplified circuit using a RC type generator at the bottom side.



(a) RC type generator circuit



(b) normal discharge waveforms

Figure 1. Simplified micro-EDM electrical circuit with a RC type generator and the normal discharge waveforms.

The experimental waveforms of a normal discharge, including voltage across C_e, u_{Ce}, discharge current following through the cable, i_{Lp}, and discharge gap voltage, u_{gap}, is shown in Fig. 1(b). As seen, since L_p and C_e lead to resonance during the discharge phase, u_{Ce} reaches a negative value at the end of the discharge. Due to the voltage difference between u_{Ce} and u_{gap}, and C_p connect the resonant circuit in series, u_{gap} resonates to a large negative value at the beginning of post-discharge.

Since the high negative voltage applied on the gap, the partial debris, the poor flushing and the limited time to deionize the discharge gap, it is possible that another gap breakdown occurs in the negative polarity or even multiple discharges occur alternatively in both polarities, as shown in Fig. 2. Those alternating voltages and currents are defined as a multi-discharge in this paper. Bragancaet al. [3] also provides the multi-discharge waveforms in their RC type generator. Wang et al. [4] carried out some preliminary analysis on the multi-discharge effects on manufacturing, such as pulse number and tool electrode wear per discharge.

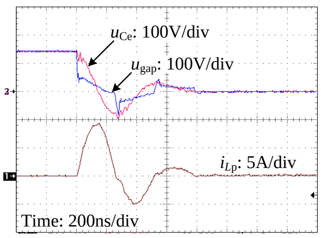
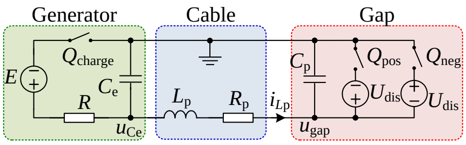


Figure 2. Multi-discharge phenomenon.

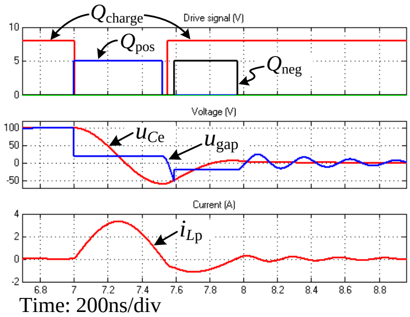
The objective of this paper is to investigate the multi-discharge phenomenon in micro-EDM with a RC type generator and its effects on manufacturing. Based on the electrical simulation (Section 2) and experimental verification (Section 3), it can be concluded that the multi-discharge is mainly caused by the cable inductance and large open voltage, and that it can increase the erosion efficiency. Hence, in order to achieve high speed and accurate manufacturing, this phenomenon should be considered in the servo feed rate control and tool wear prediction.

2. Electrical Simulation

Fig. 3(a) is the schematic diagram of the electrical circuit with an RC type generator, where the discharge gap is modeled as a parasitic capacitor C_p and two constant voltage sources with opposite polarities in parallel. The two voltage sources are controlled by two power switches, Q_{pos} and Q_{neg}, respectively, to realize alternating discharges. Fig. 3(b) provides an example of the simulation waveforms of the drive signals of the three switches (top), u_{Ce} and u_{gap} (medium) and i_{Lp} (bottom), which is similar to that in Fig. 2.



(a) simulation electrical circuit



(b) simulation waveforms

Figure 3. Simulation circuit and waveforms.

3. Experimental Verification

In order to illustrate the multi-discharge effects obviously, a bench mark case, where a diode is inserted into the discharge loop to eliminate the multi-discharge phenomenon, is used for comparison. All the waveforms and data acquired from this case are hereinafter called the diode case.

Based on the experimental data acquired, Fig. 4 shows the pulse frequency (pulse per time unit) of the negative pulses and the positive pulses. Since the first negative current pulse and the first positive current pulse are counted to represent the number of total discharges and the number of multi-discharge case, their ratio can reflect the percentage of multi-discharge. The multi-discharge percentage increases with the increase of open voltage. Under a high open voltage, most normal breakdowns lead to multi-discharges, so most of the energy stored in the discharge capacitor is consumed by the gap discharge, and the erosion effects should be more obvious.

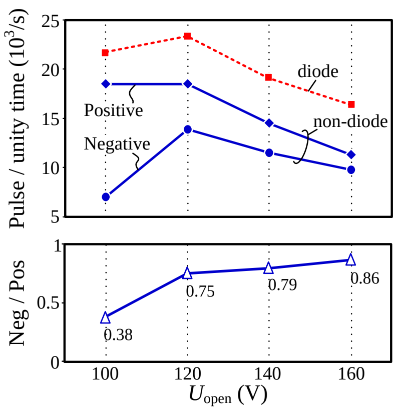


Figure 4. Pulse counting results that vary with U_{open} in diode and non-diode cases.

Since the material erosion results only from discharge, and the main difference between diode and non-diode case after the normal breakdown is only one positive discharge and a percentage of multi-discharge, the tool wear per discharge (TWD) and workpiece material removal per discharge (MRD) can be used to show the machining performance.

Fig. 5(a) shows the TWD, MRD and the tool wear ratio (TWR) for diode and non-diode case, respectively. For the diode case, since there is only one discharge for each normal breakdown and the energy consumed for one discharge is proportional with the open voltage, the erosion per discharge for both electrodes increases in a nearly linear manner. For the non-diode case, the TWD and MRD are larger than that of the diode case, and they are increased with the rise of open voltage. The TWR of the non-diode case is lower than that of the diode case. That means, in multi-discharge, beside the first normal discharge, the following discharges not only leads to additional tool wear, but also remove relatively large amount of workpiece material simultaneously, which increases the material removal efficiency.

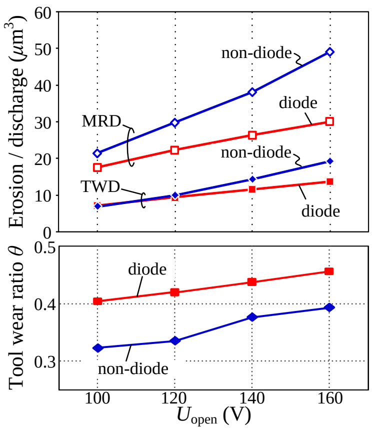


Figure 5. Material removals per discharge and tool wear ratio that varies with U_{open} in diode and non-diode cases.

4. Conclusions

The multi-discharge phenomenon in micro-EDM with a RC type generator is investigated by circuit simulations and experimental verifications. Since one normal breakdown in a multi discharge is followed by more than one discharge, most energy stored in the discharge capacitor is used in the gap discharge, and the material removal per discharge is increased while the tool wear ratio is decreased, which increase the manufacturing efficiency. Hence, for achieve high speed and accurate manufacture, this phenomenon should be considered.

Acknowledgement

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