Characterization of positive and negative pulses from a commerial RC based pulse generator in micro-EDM milling

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Abstract

Resistor-capacitor (RC) based pulse generators are commonly used in micro-EDM applications thanks to their ability to provide very low energy pulses to remove volume of material per spark. Tool wear however can still be significant, crucially affecting the machining accuracy. In this work, the characteristics of the discharging pulses with respect to a given set of machining conditions and pulse generator are studied. This research will enable the further development of tool wear control and prediction models.

1. Introduction

Micro-EDM milling is an electrical discharge machining (EDM) process, which is based on the common electro-thermal material removal mechanism but with much lower sparking energy by using relaxation (RC) type generators.

During micro-EDM machining, it has been observed that RC pulses often display a negative part of current flow at the end of the positive part, presumably due to the presence of a parasitic inductance in the discharge circuit, especially when working at high frequency. The negative pulse parts have been reported as leading to excessive electrode wear [1, 2]. However, there is still no detailed study on the characteristics of the negative pulse parts and their impact on tool wear. The discharge pulse characteristics are studied in this paper.

2. Discharge pulse acquistion

Experiments have been performed on a Sarix SX 100 micro-EDM milling machine, equipped with a RC based pulse generator. A tungsten carbide rod, with nominal diameter of 500 µm, was used as tool electrode while a block of martensitic stainless steel AISI 420 modified was used as workpiece. The machining setting has been chosen within the finishing regime. Accordingly, the energy index, *e*, (related to the generator capacitance) and the open voltage, u (volts), were the only varied machine parameters. Due to the stochastic nature of the sparking process, discharge pulses were statistically studied off-line using a large population of pulses. Fig. 1 shows a scheme of the setup used for pulse acquisition and monitoring. The acquired pulse data (voltage and current) are stored in an external file with maximum record length of 10 million points per channel for the off-line analysis.

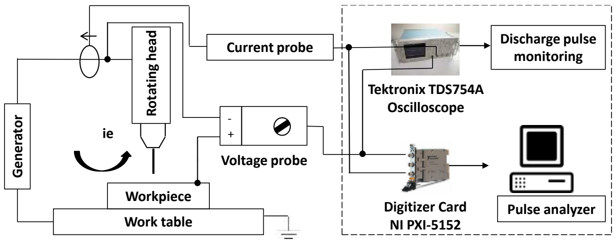
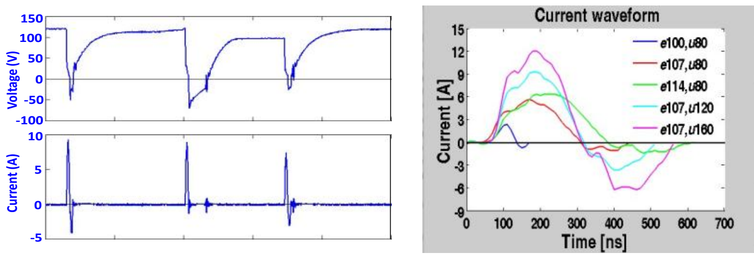


Figure 1: Experimental setup for discharge acquisition

3. Results

3.1 Characteristics of positive and negative pulse parts



a) at e107, u120 (V) b) varied e and u

Figure 2: Off-line reconstructed discharge pulses

Fig. 2a shows three discharge pulse patterns at the sparking regime machine settings e107, u120 (V): the first two patterns both discharge at the open voltage level, thus both have a large positive current peak while the second pattern has a negligible negative current peak; the third pattern discharges at a lower voltage level, both positive and negative current peak are smaller than for the first pattern. Fig. 2b shows that pulse current peak value and duration of both positive and negative part (the first pattern) all tend to increase along with e and u, except the duration of positive part with varying u, which confirms the RC type generator behaviour.

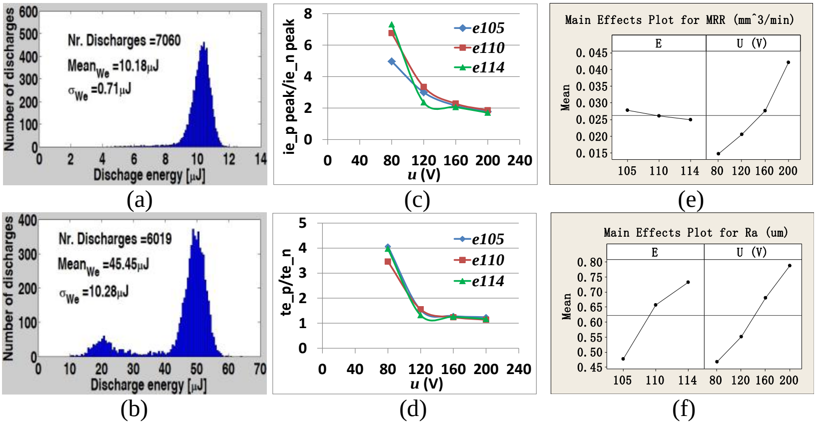


Figure 3: Discharge energy (summation of positive and negative pulse part) histogram at *e*105 and *u* of 80 V (a), 200 V (b); ratio of positve to negative part of discharge pulses on mean absolute pulse current peak value (c), pulse duration (d); main effects plot (by MINITAB®) of workpiece material removal rate (e) and surface roughness (f) with respect to *e* and *u*.

With the increasing of *u*, pulse energy of both positive and negative parts increase which will enhance the material removal rate (as well as the tool wear rate) but resulting a rougher machined surface as shown in fig. 3e,f; on the other hand, at higher *u*, the stochastic sparking behaviour is also promoted, resulting an increased percentage of low voltage or low energy discharges over the whole population as clearly shown in fig. 3a,b, which may introduce machining instability when gap voltage sensing based servo-control is applied. Therefore, low and medium *u* levels (80 V to 160 V) are chosen for further investigation.

When looking at pulse current peak value (in absolute) ratio and pulse duration ratio of the positive to the negative part (fig. 3c,d), both slowly saturate with increasing *u*, resulting a similar behaviour of the pulse energy ratio which is a function of both. It indicates that negative pulse part becomes comparable in amplitude and duration to the positive part starting from *u*120 (V), since then they have the same behaviour regardless of both *e* and *u*.

3.1 Discharge pulse discrimination

As a continuation of different pule patterns found in fig. 2a and current peak ratio behaviour in fig. 3c, the positive and negative pulse parts which are determining for tool wear can be further identified by a current threshold detection system. A current value of 10 A is chosen as the threshold level for the dominant positive pulse part at *e*107, *u*160 (V) from the analysis shown in fig. 4. The threshold level for the dominant negative pulse part can be analysed in a similar way, which in this case led to a choice for 4.5 A.

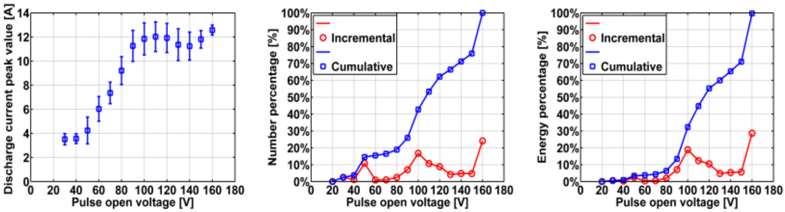


Figure 4: Discharge current peak value (left) and discharge number and energy percentage (middle, right) evolution with respect to maximum discharge voltage for positive pulse part at *e*107, *u*160 (V)

4. Conclusion

The characteristics of both positive and negative pulse parts in a micro-EDM milling process are studied using a discharge current threshold detection based pulse discrimination method. This allows to identify the dominant pulses contributing to the tool wear. This method will be further used as a tool wear prediction system.

Acknowledgement

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References

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