

Methods for electrode effective size monitoring in EDM

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Abstract

The on-line determination of the effective size of the electrode is very important for a proper process control. An overview of known methods for on-line determination of the electrode effective size is given in the present paper. Further on a new method is presented based on evaluation of the electric current signal in the gap. The results show that the ratio between the applied discharge energy and the electrode effective size can be significantly detected by the applied method.

Keywords: Spark erosion, electrical discharge machining, monitoring, electrode area

1 Introduction

Manufacturers of EDM machines are trying to achieve higher automation of the machining process. *Setup parameters*, such as peak current i_e , free voltage u_i and pulse duration t_i determine discharge energy A_e and consequently the machining regime (rough, fine). *Control parameters* are used to control the machining process. The setup parameters are mostly constant during the machining whereas the control parameters are changing to achieve good machining quality. In some cases, e.g. machining conical shapes (Figure 1) where the electrode effective size is varying during the machining or machining with CNC controlled EDM machines (orbital machining), the discharge energy has to be adapted to the electrode effective size to achieve optimal current density in the gap, which is necessary for stable machining and low electrode wear. It was shown that stable process can not be achieved if current density exceeds certain value [1].

The setup parameters influence electric current $I(t)$ and voltage $U(t)$ signal in the gap and (if isofrequent generator is used) also discharge duration t_e . Discharge energy A_e is determined by these parameters according to the following equation:

$$A_e = \int U(t) \cdot I(t) \cdot dt$$

Larger eroding surface allows higher discharge energies [2] and rough machining should be performed with the highest possible discharge energy. Thus there exists an optimal discharge energy according to the electrode effective size.

The methods of determination of the electrode effective size can be realized in very different ways. From the physical structure of the working gap, there are only three basic variants of the size detection [1]:

- via the capacity of the eroding gap [3,4],
- via the gap impedance [5] and
- via the technological removal rate parameters [1,6].

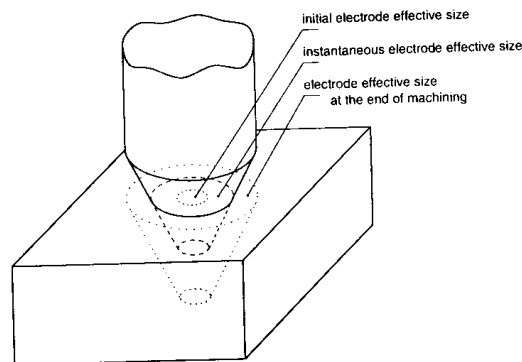


Figure 1: Variations of the electrode effective size during conical shape machining.

2 Drawbacks of the effective size detection methods

The measured capacity on a machine C consists of the capacitive parts of the frontal gap C_f , of the lateral gap C_l and the machine inner part C_i

$$C = C_f + C_l + C_i$$

Drawbacks of the capacity method for effective size detection [1]:

- The aim is to detect the projected, effective size of the electrode, which dependence on measured capacity varies according to the shape of the electrode (C_f , C_l).
- Practical measurement at industrial EDM machines showed that the machine capacity C_i (10..20 nF) is much larger than the gap capacity (100..200 pF). Therefore, measuring systems with a very high gauge accuracy must be used, because the relevant capacity changes are only of 10..20 % of the measured capacity.
- The lateral working gap falsifies the searched projected face, because the lateral working gap is only involved in a conditional manner in the removal process.

The method of effective size detection via determination of the **gap impedance** has the same problems as the capacitive method. Partly the measurement errors are even higher because the partial conductivity in the working gap changes in several orders of magnitude. The measured impedances are also falsified by pollution (removal particles) and local overheating of the dielectric.

Schulze et.al. [1,6,7] measured the electrode effective size by use of **a model of the material removal per pulse**. Demands for the method are:

- high repeat-ability of the pulse parameters,
- very precise model of removal for workpiece and tool and
- sufficing period for calculation (millisecond) of the instantaneous effective size.

These are also drawbacks of the method since it is very difficult to satisfy the given demands.

3 Monitoring the electrode effective size through the electric current signal in the gap

When machining large surfaces the discharge energy is difficult to control. The electric current $I(t)$ measured in the gap is higher than the peak current on the machine i_r , because of

the electrode capacitance [8,9]. This leads us to the idea that also in the case of small eroding surfaces electric signal in the gap could depend on the electrode effective size.

The approach of checking the suitability of the discharge energy according to the electrode effective size by attributes on electric current signal $I(t)$ during the discharge was investigated [10]. Two electrode effective sizes and one set of setup parameters were used in experiments. In the first experiment (No. 0) the current density exceeded the critical value and in the second experiment (No. 1) the current density was under critical value (Figure 2).

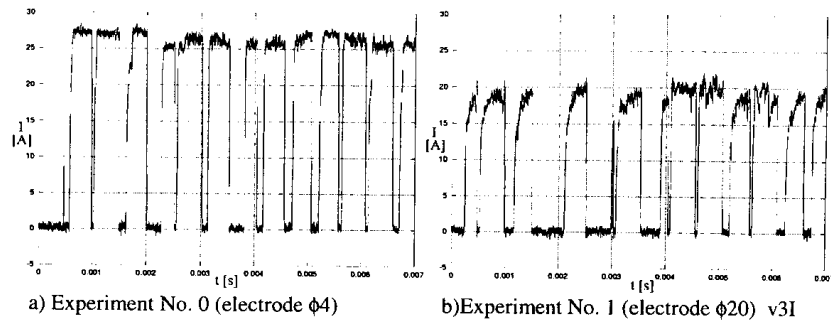


Figure 2: Electric current signals in the gap

For discharge evaluation by the modeler five attributes were defined on each discharge current signal. Modeling was done by a conditional average estimator (CAE), which is non-parametric regression method and it is described in literature [11,12].

It is to expect high rate of similarity between discharges of experiment No. 0 and experiment No. 1, because there are also other influences on discharges beside electric current density in the gap. The classification of discharges is shown in Figure 3, where first 160 discharges on the abscissa belong to the experiment No. 0 and last 160 discharges belong to the experiment No. 1. The ordinate shows the classification results: each discharge gets the value of the optimal predictor y in range between 0 and 1. The value y is in the figure presented with symbol *. Number closer to 0 indicates the discharge belongs to experiment No. 0 and number closer to 1 indicates the discharge belongs to experiment No. 1. Ideally discharges from $x=1$ to $x=160$ should have value $y=0$ and discharges from $x=161$ to $x=320$ should have value $y=1$.

Figure 4 can be interpreted as follows: Since it is known which discharges belongs to the same group - the same values of setup parameters, one can make a decision about the suitability of the discharge energy. Value $y=0.5$ could be treated as a threshold. In the group of first 160 discharges only 17 discharges have optimal predictor value bigger than 0.5 and in the group of last 160 discharges only 26 discharges have optimal predictor value smaller than 0.5. All together 10 % of discharges have wrong optimal predictor value.

According to these results it is possible to conclude that setup parameters in experiment No. 0 determine exaggerative discharge energy (y close to value 0) and the setup parameters in experiment No. 1 determine optimal discharge energy (y close to value 1) which is true for both experiments.

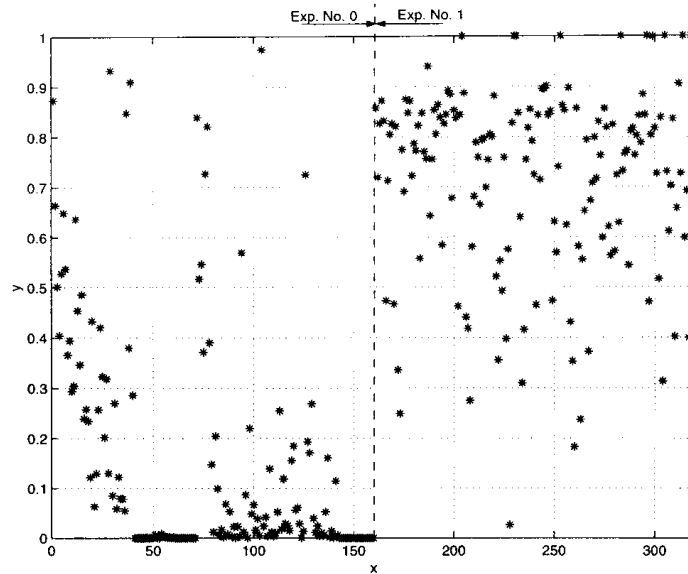


Figure 3: Graphical presentation of the optimal predictor value for each discharge.

4 Conclusion

In general the effective size of the electrode is not constant during the machining, specially in the case of NC controlled EDM machines, where electrode performs orbital movement during the machining and in the case of conical shapes machining (with or without orbital movement of the electrode).

Different approaches of monitoring of the effective size of the electrode have been presented in the past. Some of them are applied on industrial machines, but the search for better solutions haven't finished yet. Results of monitoring of the electrode effective size through the electric current signal in the gap are promising for further investigations, but there is one big disadvantage. Comparing characteristic of the generator on Ingersoll 80P machine with modern generators installed on new machines, one can find a difference in electric current signal in the gap during the discharge. Modern generators tend to keep the current during the discharge as constant as possible while the current signal on Ingersoll 80P machine is unbounded. Thus it is possible that such approach is not applicable on modern machines.

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