

Simplified Technology Development for Electrical-Discharge Machining using Arc Information*

Arno Behrens; Jens Ginzel

Abstract:

For combining high performance and security during Electrical-Discharge machining (EDM) extensive technological experiments must be carried out in order to find secure working parameters which combine reduced arcing and acceptable removal rates. Ignitions with a tendency towards arcing are dangerous for the ongoing of the ED-process, because they can lead to a destruction of the workpiece surface due to overheating. Therefore a new methodology for detecting arcs has been developed, which increases process stability by switching off dangerous ignitions. This arc detection facility can also be used for a simplified development of technological data, by deriving secure working parameters from a statistical analysis of the data delivered by the arc detection facility.

Keywords: Production Process, Electro-Discharge Machining, Arcing

Introduction

Electro-discharge machining (EDM) uses the removal phenomenon of electrical discharges in a dielectric fluid. Two conductive electrodes, one being the tool of a predetermined shape and the other the workpiece, are immersed in a liquid dielectric. A series of voltage pulses, usually of rectangular form, are applied between the electrodes, which are separated by a small gap. A localised breakdown of the dielectric occurs and sparks are generated across the inter-electrode gap, usually at regions where the local electric field strength is highest. Each spark erodes a small amount of metal from the surface of both electrodes. The repetitive impulse together with the feed movement (by means of a servo mechanism) of the tool electrode towards the workpiece enables metal removal along the entire surface of the electrodes [1].

Besides the ignitions with contribution to material removal, arcing pulses can happen and a dangerous situation for the process stability can occur. Arcs are successive discharges which ignite concentrated in a small area of the workpiece. The effect of this discharge concentration is an overheating of workpiece and electrode. Instead of removing material, carbon is brought up by the arcs and finally the erosion process must be aborted. Therefore most modern ED- machines provide a facility for detecting arcs. Additionally, the machining parameters which are supplied by the manufacturer of the ED-machine are the result of extensive technological experiments. These experiments are carried out in order to provide working parameters combining high performance without the risk of arcing.

Methods for Arc Detection

The ignitions during ED-processing show various characteristics depending on the materials used for workpiece and electrode, the working current and the ignition voltage. This variety makes it hard to define a universal criterion for arcs and is responsible for the big number of different methods of arc detection.

The most popular arc detection methods are:

- ignition delay time (t_d) [2], [3]
- gradient of falling edge of the ignition voltage [4]
- level of the ignition voltage [5], [6], [7]
- frequency spectrum of burning voltage [8], [9], [10]

Many methods for arc detection are not applicable when using generators, designed as an active current source [11]. For example the gradient of falling edge of the ignition voltage can not be used as an arcing criterion when the generator is working as an active current source, because it is equivalent to the gradient of the raising edge of current, which is actively controlled by the generator. A validation of other arcing criterions can be found in [12]. This shows the need for the development of an arc detection method which is more suitable to the employed generator technology. The basic for this development is a model that represents the dynamic electrical behavior of the EDM system at pulse-start and -end time with the effect of applying a step function to an electrical system being terminated by a variable capacity/ resistor.

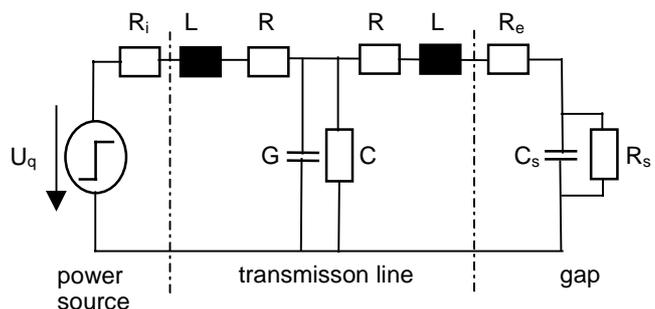


Fig. 1: Discrete model of EDM system at pulse-start and -end time

The gap is represented as an „imperfect“ capacity, whose capacitive part C_s is determined by the electrode surface and the geometrical distance. Of major importance for impulse analysis is the resistor part R_s , which is representing the varying pollution of the dielectric fluid in the gap region. The resistor R_e represents the loss caused by the electrodes.

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The model from fig. 1 is now transferred to the burning phase. In this case the resistor R_S is of major interest. With R_S it is possible to characterize the state of the dielectric fluid inside the gap (tab. 1).

R_S	state of dielectric fluid inside the gap	conclusion
medium R_S	only slightly polluted dielectric fluid inside the gap. Good working conditions	the actual ignition is <u>not</u> an arc
small R_S	strong polluted dielectric fluid inside the gap. Poor working conditions.	the actual ignition <u>is</u> an arc

Tab. 1: Classification of ignitions by gap-resistor

The gap-resistor R_S varies during the burning phase. The measurement of R_S is possible by using the burning voltage. A drop of R_S is interpreted as a turning of the ignition into an arc. This can easily be measured by comparing the burning voltage to a reference value B_S .

Fig. 2 shows an example of a discharge classified as an arc. It can be seen, that in this case the drop of the burning voltage below the reference value takes place immediately after the ignition phase.

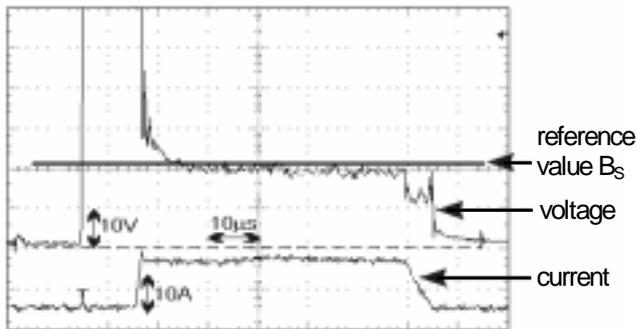


Fig. 2: Burning voltage of an arc

In Fig. 3 the burning voltage is above the reference value until the end of the pulse. So this ignition will not be classified as an arc.

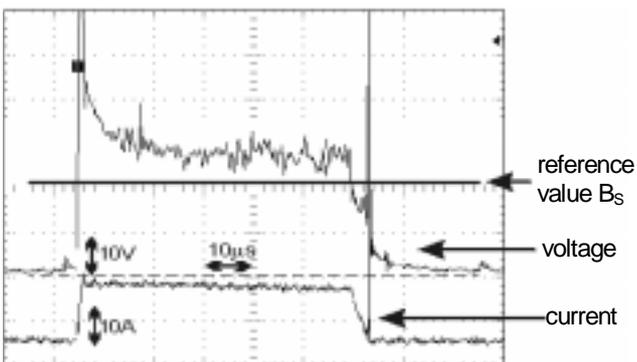


Fig. 3: Burning voltage recorded from a normal discharge

Effectiveness of the Developed Arc Detection Method

Many experiments have been carried out to study the effectiveness of the developed arc detection method. The value of the reference voltage (B_S), which is used to classify an arc is of high importance for the efficiency of the arc detection facility.

B_S depends on the materials used for workpiece and electrode as well as on the working current. The sensibility of the arc detection module is defined by the reference voltage.

If the reference voltage is too low, arcs will be detected too late or even not at all. If this happens the surface of the electrodes can be affected. Often black spots are visible on the workpiece. If the reference voltage B_S is adjusted too high, the removal rate goes down and the electrode wear is increased. In case of an increased B_S many normal discharges that would have contributed to material removal are classified as arcs and switched off. Therefore removal rate decreases. The increased electrode wear is caused by the fact that material removal on the electrode normally (in case the electrode has positive polarity) happens during ignition phase. Therefore, all ignitions classified as arcs and switched off still contribute to electrode wear.

The following figures show the effect of varying the reference voltage B_S on removal rate (fig. 4) and relative electrode wear (fig. 5) during a roughing operation (parameters: Cu (+) /X210Cr12 (-); I_e 40A; U_0 160V; t_c 200µs; t_0 20µs).

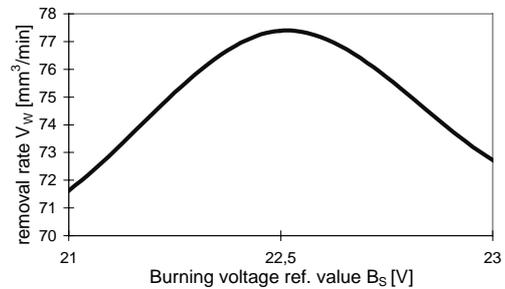


Fig. 4: Variation of reference voltage and removal rate

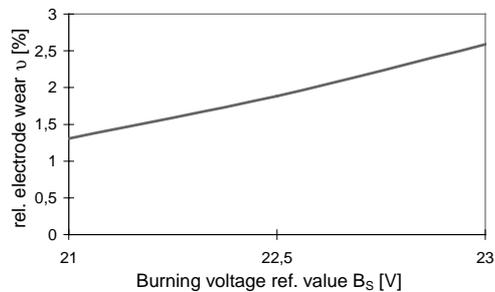


Fig. 5: Variation of reference voltage and electrode wear

From fig. 4 it can be seen that the removal rate shows a maximum when B_S has a value of 22.5 V. The reduced removal rate at low B_S -values indicates the effectiveness of the arc detection method, because when B_S is too low, arcs will be recognized too late or not at all. Therefore the reduction of the removal rate is caused by an increasing influence of not detected arcs on the removal process.

Simplified Technology Development using Arc Detection

By detecting arcs and switching off the current in case of arcing a damage of the electrodes can widely be avoided, but the reasons for arcing still exist.

One reason is the bad flushing condition inside the gap which can be improved by adding additional flushing movements into the erosion process in order to clean the gap. Another fundamental reason for arcing can be seen in the process parameters. To avoid arcing caused by improper process parameters many technological tests have been carried out by the manufacturer of EDM systems. But these basic technological data often does not fit to the actual application, therefore the user has to carry out additional tests [13].

The developed arc detection method provides a simplified approach for deriving secure and efficient process parameters. The basic question for this approach is:

What makes a discharge that starts normal turn into an arc?

In order to find a solution the exact point in time (t_{arc}) when a discharge „decides“ to become an arc was measured (fig. 6).

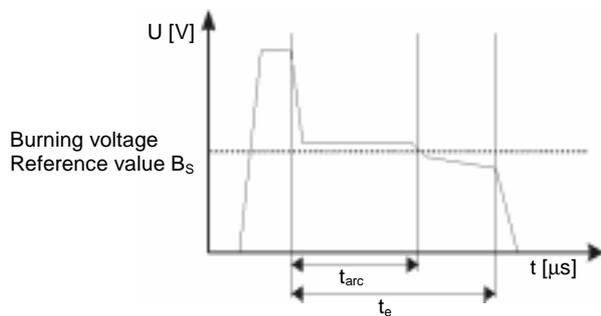


Fig. 6: Exact time when a discharge becomes an arc

By measuring t_{arc} for each arc out of a great number of discharges and by using various pulse times (t_e), it can be seen that nearly every discharge can turn into an arc, if the pulse time t_e is extended for too long.

Fig. 7 shows the histogram of t_{arc} made up from 32000 pulses recorded during a finishing application with a t_e of 10 μs . The process showed a stable behaviour during the inspected discharge duration (32000 pulses).

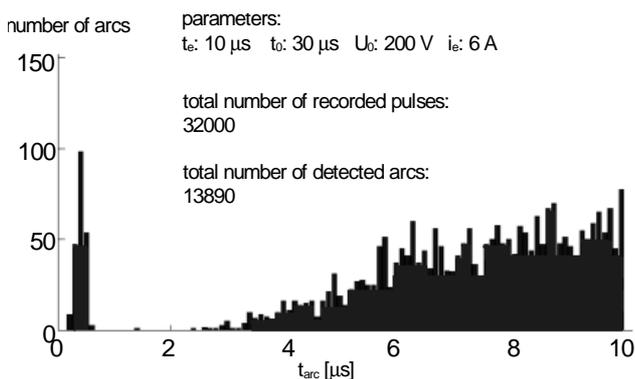


Fig. 7: Histogram of t_{arc} recorded during stable process conditions

The overall percentage of arcs can be regarded as low (9%). From the histogram of t_{arc} (fig. 7) it can be seen that some of the arcs happen immediately after ignition ($t_{arc} < 1 \mu s$). With growing t_{arc} an approximately linear growth of the number of arcs can be observed. This gives a first indication that the number of arcs is growing when burning-time t_e is extended.

In the next experiment the ED-process was first started with the parameters shown in fig. 7 providing a stable process behavior. During ED-processing the pulse time (t_e) has been extended abruptly to a much longer value (50 μs) just for recording another 32000 pulses and then the pulse time was set back to the previous value. The histogram of the arcing-time (t_{arc}) for those pulses showing extended t_e can be seen in fig. 8.

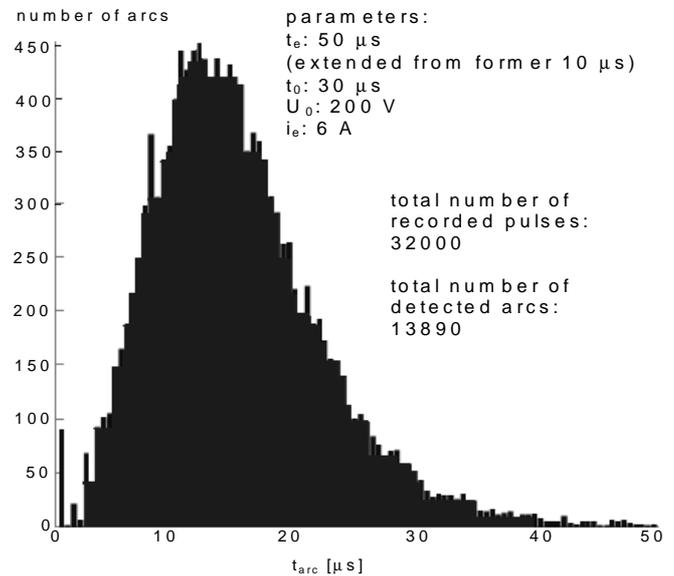


Fig. 8: Histogram of t_{arc} for pulses during extended pulse time

Comparing fig. 7 to fig. 8 the total number of arcs is about 5 times higher indicating a poor process stability. This behavior confirms the assumption that much more ignitions turn into arcs if pulse time t_e is extended too long.

The histogram of t_{arc} in fig. 8 shows a bell-shaped curve for the t_{arc} values between 1 μs and 50 μs with a maximum at 12 μs . The conclusion from fig. 8 is that most of the arcs can be avoided, if t_e is chosen smaller than 12 μs (as it is in fig. 7). On the one hand the removal rate is reduced, if t_e is assigned a small value, but on the other hand the process stability can be increased if arcing is avoided. It is normally the task of extensive technological tests to figure out an acceptable compromise between process parameters leading to a high removal rate and those leading to a secure process. The introduced arc detection facility can help to reduce these technological testing.

Of course it would be possible to run the ED-process with a longsome t_e and therefore an increasing number of arcs. Due to the arc detection module the risk of an electrode destruction is widely reduced, but there would be no improvement in removal rate, because many discharges get switched off because of their turning to arcs within the pulse duration time. As pointed out earlier, this will result in a raised electrode wear.

The process of obtaining secure working parameters which combine reduced arcing and acceptable removal rates is based on the measurement of the t_{arc} time and their analysis into histograms. The key part of this process is an abrupt and wide extension of t_e during a few pulses while recording t_{arc} . When analysing these data the ED-process „tells“ which maximum of burning time t_e is acceptable.

The procedure of deriving optimal t_e -values out of the process uses the new arc detection method and the t_{arc} -histogram. The procedure can be described as follows:

- Start the ED-process with a small t_e -value that provides stable process conditions and a low number of arcs (the pause-time t_0 must be chosen high enough to avoid arcing due to insufficient de-ionization).
- Based on stable process conditions provided by the small t_e and a sufficient t_0 the time of the burning phase t_e must be suddenly extended to a high t_e -value. This extended t_e should be kept only for a limited number of pulses in order to avoid process corruption.
- Recording the time t_{arc} for all of the arcs occurring during the extended t_e interval will provide the data for further statistical analysis.
- The histogram of the t_{arc} -values provides the information for the optimal t_e . The optimal t_e -value is identical to the t_{arc} -value just before reaching the maximum in the bell curve.

This experiment has to be repeated for different values of working current i_e and material combinations.

Conclusion

Based on a discrete model of the energy transfer from EDM source to EDM sink a new arc detection method has been developed and applied. This arc detection method is characterized by a simple measuring method and a high sensibility compared to other well known arc detection strategies.

By measuring the exact point in time when a discharge “decides” to become an arc, the foundations for a much more efficient way of acquiring secure machining parameters is built. With this method the optimum burning time t_e can be determined for a given working current i_e and material combination.

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