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Masuzawa, T.; Heuvelman, C.J.

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A Self-Flushing Method with Spark-Erosion Machining

T. Masuzawa and C. J. Heuvelman (1)

It is one of the problems in EDM that in some cases it is difficult to avoid arcing, especially in machining where no flushing holes can be made in the electrode. In those cases a periodically lifting of the electrode is usually applied. However, since the lifting action does not make an effective use of the flow of the dielectric fluid, this way of machining can strongly decrease the average metal removal rate.

This paper describes the introduction of an pumping action of the dielectric fluid by means of a special electrode movement. With this way of machining no additional flushing is necessary.

A prototype of this self-flushing system is developed and tested on its effectiveness.

1. INTRODUCTION

It is well known that with EDM die-sinking the flushing is very important. A large extent of research has shown that the flow-rate of the dielectric fluid has a great influence on the machining characteristics [1,2,3,4]. Apart from the influence on the metal removal rate, the flushing influences the electrode wear, especially at sharp edges.

Other experiments showed that the contamination and the flow-rate also influence the average ignition delay and so indirectly the gap-size [5]. Severe local contamination of the dielectric fluid may cause short circuiting and arcing and thus a decrease of the metal removal rate combined with a serious increase of the electrode wear.

In order to have correct flushing characteristics during machining, the flow-rate in the gap must have well defined values. For that reason special measures are taken, such as the use of flushing bores through the electrode. However, holes are not always possible, so that means have to be used. Planetary movements can be very effective, especially with large-bottom holes.

When the local contamination is becoming too high so that arcing cannot be avoided, periodically lifting of the electrode may be applied. However, the flow is strongly influenced by the shape of the gap and is not very well controlled by a simple pull-up movement. There is even a tendency to allow dead points in the flow. Overmore, lifting needs an unnecessary long stroke to give enough disturbancy to the liquid for making the debris to diffuse and to leave the gap.

2. BASIC MECHANISM

The Self Flushing method (SF method) is realized by a special, fast additive movement of the electrode to the workpiece. The movement is arranged so that it causes a proper flow of the working fluid in the gap. The system uses a driving system which can activate the movement in at least 2 axes. During this movement the generator will be switched off.

One of the simplest movement is shown in Figure 1. The main flow of the flushing fluid is indicated in this figure.

The electrode moves in this example in a rectangular way. It makes the fluid comes in the gap at one side and goes out at the other side. Thus, the electrode and the workpiece construct a pump themselves. And so, the flow could be controlled better than in a simple lifting method. It is important to keep the ratio of the gap-distances at each side large during the movements c) and e). The lateral gaps at the other two sides are not changed by this planar movement. Although some leakage will occur through such side-gaps, the pumping effect still exists.

It could be more useful if the movement in another axis is available, because for many kind of electrodes it is necessary to have movements in more directions in order to obtain optimal results.

In some cases two-dimensional movement such as in

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Fig. 1. Basic movements of the self-flushing method.

3. EQUIPMENT

The prototype system consists of an EDM machine with a generator and a dielectric system, a gap analyzer and a controller. It can realize a two-axis SF operation.

The machine has a quill driven by a stepping-motor and a working table driven by a DC-servo-motor. The working tank can be moved vertically (z-axis). The maximum starting speed is about 2.5mm/sec. The displacement per step is 2.5um.

The workpiece is clamped in a working tank which is fixed to the table. It is driven horizontally (x-axis). A displacement of about 50um takes approximately 10ms.

Relative movement of the electrode and the workpiece in those two axes, x and z, forms the SF movement as explained above.

The tank is made of acrylic board, and its dimension is W140mmxL110mmxD80mm. It makes it easy to observe the debris which is coming out of the machining gap.

The generator is a transistor-switched square wave generator which generates pulses for discharge. The pulse duration can be set from 0.4us to 1.35ms. The rise- and fall times of the pulses are respectively 75ns and 230ns. The open-circuit voltage is 80V. The generator can be switched off by the controller.

3.3 The gap analyzer

The gap analyzer supplies the gap informations to the controller and to the operator. The block-diagram is given in Fig. 2. It outputs four status values in percentage, which are erosion (E), arcing B, open-circuit (O) and short-circuit (K). These data are derived from the gap voltage.

The gap analyzer consists of a pulse conditioner, a EBOK-discriminator, a unit which derives the servo-control voltage from the ignition delay (td), a unit which calculates the data necessary for the computer (E-B-K comparator) and a visual display of the gap condition.

The pulse conditioner delivers two signals H and L, derived from the comparison of the gap voltage with a high level (approx. 50V) and a low level (approx. 15V).

![Diagram of the gap analyzer](image-url)

Fig. 2. Block-diagram of the gap analyzer.
The E-B-K comparator supplies a signal to the controller, when the number of B-pulses is larger then the number of E-pulses, averaged over 50 ms. A similar signal is derived for E>K.

The feedback signal to the amplifier for the x-axis is set to zero. It is the same movement as a conventional electrode-lifting.

In 'SF' both x- and z-axis are driven accordingly to the request of the program. Three programs, SF1, SF2 and SF3, are developed.

SF1 gives the fundamental SF movement.

SF2 includes a function, which remembers the deepest position of the electrode during the sparking period and re-set the electrode at this position just before the movement of the electrode begins.

SF3 is arranged so that the movement of the electrode occurs only when the output B>E from the gap analyser is true. The other functions are the same as in SF2.

SF1 is used for 'z-only' because it gives a similar movement of the electrode as of conventional electrode-lifting when the value of the x-axis amplitude is set to zero. With the experiments only the programs SF2 and SF3 are used.

The conditions of the spark pulses are constant in all tests, i.e. \(i_e=5A\) and \(t_{i}=40\mu s\), which are selected to represent the conditions in which it is rather difficult to machine without flushing. Furthermore are these settings normally for finishing operations with low electrode wear. The machined surface roughness with this condition is about 1.5µm CCA.

The workpiece is made of tool-steel 210Cr12 which had been hardened and tempered. The electrodes are made of copper and machined into three different shapes as shown in Fig.5.

Fig.6 shows the relation between machining time and depth.

The metal removal rates with the three methods, 'normal', 'z-only' and 'SF' (by the program SF2), are measured and compared. For these experiments the rectangular electrode (Fig. 5a) is used. The machining depth is measured as a function of the machining time.

The machining characteristics are compared under three conditions:

- Normal machining, with no additional electrode movement (hereafter 'normal'),
- Machining with electrode-lifting ('z-only'), and
- Machining with self-flushing, z- and x-movement ('SF').

In 'normal' no flushing is applied. The z-axis motor is driven by the usual servo circuit for gap-control.

In 'z-only', a program for the SF movement is used and the data for the x-axis amplitude is set to

\(U_h = 0\)

\(U_l = 50-400\) ns

\(U_{gen} = 50-400\) ns

\(f_p = 50-400\) ns

\(f_g = 50-400\) ns

\(f_s = 50-400\) ns

Fig.3. Simplified circuit-diagram of the EBOK discriminator.

In Fig. 3 the simplified circuit-diagram of the EBOK discriminator is given. The output signals are proportional to the percentages of E-, B-, O- or K-pulses. This drawback of this discriminator is that the average value of the output voltages are influenced by the change of the duty cycle of the generator pulses. In that case the full-scale output values of the visual display have to be retuned. The outputs of the E-B-K comparator are not influenced by the change of the duty cycle.

3.4 The controller

The controller consists of two blocks, a controller block and a driving block. (See Fig. 4.)

The controller includes the usual servo system which works during the normal machining (sparking) period. The input signal for the x-axis amplifier is given from this servo circuit and from a circuit which works during the SF machining (non-sparking). These signals are sent to the driving block.

The control block has a microcomputer board in it and generates the signals for the x- and z-axes movements. These signals are sent to the driving block, which consists of two amplifiers for driving both motors. The control block also controls the pulse generator as mentioned before.

The microprocessor is an Intel 8085A-2. The program for SF method can be stored in an EPROM type 2716. It can also be stored in a random-access memory (RAM), which can be loaded from a host computer, so that the program easily can be modified. The data of the parameters for SF movement are input by hand, using a normal CRT terminal with a keyboard.

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The workpiece is made of tool-steel 210Cr12 which had been hardened and tempered. The electrodes are made of copper and machined into three different shapes as shown in Fig.5.

5. RESULTS AND DISCUSSION

5.1 Machinability

The metal removal rates with the three methods, 'normal', 'z-only' and 'SF' (by the program SF2), are measured and compared. For these experiments the rectangular electrode (Fig. 5a) is used. The machining depth is measured as a function of the machining time.

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Fig.6. Relation between machining time and depth.

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The workpiece is made of tool-steel 210Cr12 which had been hardened and tempered. The electrodes are made of copper and machined into three different shapes as shown in Fig.5.
The relative electrode wear with 'z-only' is about 0.7%. It increases to 0.8% when the SF method (x=50um, z=125um) is applied. Wear at the edge of the electrode is also tested, using a special electrode shown in Fig.5c, which has a sharp edge. Typical shapes of the edge before and after the machining are shown in Fig.8. As shown in the figure, the electrode wear at the edge increases by using the SF method. It is also apparent that the wear at the edge is larger when the electrode is placed parallel to x-axis.

5.2 Effect on the electrode wear

The effect of SF method on the electrode wear has been tested.

The conditions for 'z-only' (x=0), indicate that the metal removal condition in the gap becomes better when the lifting distance z increases. Application of a slight x-movement has a good effect on the average and on the corrected metal removal rate.

From the results discussed above, it can be concluded that SF method is effective to remove the debris from the gap, spending minimum time for the removing action. It is also confirmed by observation that the debris is coming out at the side which is expected.

In those tests the narrower side of the electrode was put parallel to the x-axis. An additional test was made to see the effect of orientation, rotating the electrode by 90 degrees. But, no significant difference was found during the test. Probably, the machined depth of 6mm was not deep enough to cause difficulties in both conditions.

Fig.7 shows the result of the test similar to Fig.6, using a thinner electrode (Fig.5b). Except for two conditions only the arcing points are shown. This result also supports the superiority of SF method. But, the difference between 'z-only' and 'SF' in the removal rate, or in the machining time, is not so much as with a thicker electrode. There may be a possibility for this electrode to have been bent elastically by the x-axis movement. If that happens, it may decrease the effectiveness of SF method.

5.3 Other results

The effectiveness of the SF method is significant, either with a rectangular electrode or with a triangular electrode. But, concerning the triangular electrodes, the effectiveness of the SF method in removing the debris is found somewhat lower less when it is placed parallel to x-axis. The reason of this is explained by Fig.9. As it is obvious from the illustration b, if the displacement in x-axis is constant, the ratio of the side-gaps in case when the electrode moves to the side of sharp edge is not large enough. Thus, the flushing effect is not as much as in the case of Fig.8a. From the discussion above it may be recommendable to select the orientation of the electrode carefully or to make the displacements of the both sides different from each other. It may also be effective to add some y-axis movement, which makes it possible to select the optimum direction of movement for all types of electrodes.

The program SF3 is also tested. But, this program shows no advantage comparing with 'normal' operation. This is probably caused by the fact that the percentage of arcing is already too high when this equals to the percentage of normal erosion pulses. It suggests that it is very difficult to recover the normal gap condition if the arcing has once occurred.

6. CONCLUSION

Self Flushing method is proposed for improving the productivity in EDM where a conventional flushing through the holes in the electrode cannot be applied. The machining characteristics in fine finishing ranges are tested and the superiority of this method to the usual 'electrode lifting' is confirmed. Although there is still some problems in the electrode wear, SF method will be a promising technique for conquering the arcing and its subsequent problems.

7. LITERATURE

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