A self-flushing method with spark-erosion machining

Masuzawa, T.; Heuvelman, C.J.

Published in:
CIRP annals

Published: 01/01/1983

Document Version
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

• A submitted manuscript is the author’s version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
• The final author version and the galley proof are versions of the publication after peer review.
• The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

Citation for published version (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

• Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
• You may not further distribute the material or use it for any profit-making activity or commercial gain
• You may freely distribute the URL identifying the publication in the public portal

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 27. Dec. 2018
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. Moreover, lifting needs an unnecessary long stroke to give enough disturbanit 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. 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.

![Fig.1. Basic movements of the self-flushing method.](image)

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 know that 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 horizontal 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

![Fig.1. Block-diagram of the gap analyzer.](image)

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. 3.1 The machine

The machine has a quill driven by a stepping-motor and a working table driven by a DC-motor. It can be moved vertically (z-axis) and can be moved horizontally (x-axis). The maximum starting speed is about 2.8mm/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 50 um takes approximately 10 ms.

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 W140mm x H170mm x D80mm. 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 80 V. The generator can be switched off by the controller.

The pulse conditioner delivers two signals H and L, derived from the comparison of the gap voltage with the open-circuit (0) and short-circuit (K) levels. These data are derived from the gap voltage.

The gap analyzer consists of a pulse conditioner, an EBOK-discriminator, a unit which derives the gap condition data and compares these data with the target values for the EDM machine. A visual display shows 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).

Annals of the CIRP Vol. 32/1/1983 109
The E-B-K comparator supplies a signal to the controller, when the number of B-pulses is larger than
the number of E-pulses, averaged over 50 ms. A
similar signal is derived for E>K.

The number of E-pulses, averaged over 50 ms. A
controller, when the number of B-pulses is larger then
110

motor is driven by the usual servo circuit for
machining with self-flushing, z- and x-movement
machining with electrode-lifting ('z-only'),
movement (hereafter 'normal'),
normal machining, with no additional electrode
three conditions:

- during the normal machining (sparking)
- using a normal CRT terminal with a keyboard.

However, the average value of these signals are
proportional to the percentages of E-,B-,O- or K-
pulses. The 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 control
block and a driving block. (See Fig. 4.)
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.

The controller includes the usual servo system which
works during the normal machining (sparking)
period. The input signal for the z-axis amplifier is
given from this servo circuit and from a circuit which
generates the signal for the z-axis movement. They are
switched as programmed.

The feedback signal to the amplifier for the x
servo-motor is derived from a displacement transducer,
which is mounted on the working table.

4. EXPERIMENTAL DETAILS
The machining characteristics are compared under
three conditions:
- normal machining, with no additional electrode
  movement (hereafter 'normal'),
- machining with electrode-lifting ('z-only'),
- 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
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
analyzer 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 z-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. \( t_{E} = 5A \) and \( t_{L} = 40us \), 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 1.5um
CLA.

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.

![Fig.5. Shapes of the used electrodes.](image)

Fig.5 shows the relation between machining time and depth.

![Fig.6. Relation between machining time and depth.](image)

During the 'z-only' and 'SF' movements, the
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 effectiveness of the SF method on the electrode wear has been tested.

Fig.7 shows the result of the test similar to Fig.6, using the electrode of Fig.5b. Except for two conditions only the arcing points are shown. The result also supports the superiority of the 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.

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.8 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 electrode, the effectiveness on removing the debris is found somewhat lower less when it is placed parallel to x-axis.

Fig.9 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.

5.5 Other results

The effectiveness of the SF method is significant, either with a rectangular electrode or with a triangular electrode. But, concerning the triangular electrode, the effectiveness on 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. 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.6a. 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 range 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.