A self-flushing method with spark-erosion machining

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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 borings through the electrode. However, holes are not always possible, so that means have to be used. Planetary movements can be very useful, 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 kind of 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 works well enough, depending upon the shape of the electrode.

3. EQUIPMENT

The prototype system consists of a 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 quill is fixed to the table. It is driven horizontally (x-axis) and vertically (z-axis). The maximum speed is about 2.5mm/sec. The displacement per step is 2.5um.

The workpiece is clamped in a working tank which is made of acrylic board, and its dimension is W1400mm x 1100mm x 800mm. 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.

3.1 The machine

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3.2 The generator

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 controller 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).
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.

A controller, when the number of B-pulses is larger than 110, generates the signal for SF movement. They are given from this servo circuit and from a circuit which generates the signal for SF movement during the normal machining (sparking). The conditions of the spark pulses are constant in all tests, i.e. \( i=5A \) and \( t_i=40\mu s \), which are selected to represent the conditions in which it is rather difficult to machine without flushing. Furthermore, these settings normally for finishing operations with low electrode wear. The machined surface roughness with this condition is about 1.5 \( \mu m \) CDA.

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.6 shows the relation between machining time and depth. At the flat points arcing occurs. After these points it becomes impossible to continue machining. With the method 'normal', the arcing occurred very early and machining is almost impossible. With 'z-only', the curves are different from one another, depending on the pull-up distance (value \( z \)). As it is obvious in this figure, the larger the distance, the longer the machining can be continued. But, it should be mentioned that the gradient of the depth is lower when a very large pull-up distance is applied. Furthermore, the x-displacement is quite effective for suppressing arcing. The metal removal rate when a small amount of x-displacement is applied. Overmore, the x-displacement is quite effective for suppressing arcing.

Fig.5 shows the shapes of the used electrodes.
generator is switched off. This means that during the actual machining periods the metal removal rate is higher then the value which can be calculated from the time-depth relation of Fig.6. The result of the calculation is shown in the table.

<table>
<thead>
<tr>
<th>machining condition</th>
<th>x=0</th>
<th>x=0</th>
<th>x=0</th>
<th>x=0</th>
<th>x=37</th>
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<tr>
<td></td>
<td>z=62</td>
<td>z=125</td>
<td>z=250</td>
<td>z=125</td>
<td></td>
</tr>
<tr>
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<td>1.3</td>
<td>1.3</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>metal removal rate</td>
<td>1.1</td>
<td>1.3</td>
<td>1.3</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>(cm/min)</td>
<td>1.7</td>
<td>2.2</td>
<td>2.4</td>
<td>2.6</td>
<td></td>
</tr>
</tbody>
</table>

Tabel of the obtained metal removal rates.

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.

5.2 Effect on the electrode wear

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

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.

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

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. The reason of this is explained by Fig.9. But, 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.5a. 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.

7. LITERATURE


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