Advantage of Flange Type Electrode in Deep-Hole EDM

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Abstract:

In EDM of deep hole, the machined hole generally becomes concave shape by the occurrence of secondary discharges in the side gap. By using flange type electrode, the occurrence of secondary discharge could be reduced. In this report, the effects of the shape of flange type electrode on the machined result were investigated. Experimental results clarified that a straight deep hole could be attained by using flange type electrode with sufficiently large step, and the diameter of machined hole decreased with an increase of the step difference. Also, EDM performance became better, even if a EDM machine with ball screw drive was used.

Keywords: EDM, flange type electrode, debris, secondary discharge

1. Introduction

In deep-hole electrical discharge machining (EDM), the side wall of the machined hole generally becomes concave. Our previous reports showed that the electrode jump action and the movement of the debris inside the machining gap affected the concavity of the machined holes [1-3]. The concavity decreased with an increase of electrode jump height, which leads to improvement of the straightness of machined hole, however it takes time. The concavity of machined deep hole was mainly caused by the secondary discharges in the side gap due to the stagnation of debris, and the concavity becomes larger with an increase of the depth of machined hole because of the difficulty of the debris exclusion from the gap.

In this report, a flange type electrode with large side gap distance is proposed for improving the straightness of machined hole, and the machining characteristics were investigated comparing with those using a straight electrode.

2. Shape of electrode and EDM conditions

A normal cylindrical electrode and a flange type electrode are used in this study. Figure 1 shows the shape of flange type electrode with step. In the figure, a is defined as the step height and b is the step difference. The machining characteristics are evaluated with varying the step height and the step difference. Table 1 shows the dimension of electrode.

Figure 2 shows the electrode jump motion during EDM. Electrode moves up and down repeatedly, in order to exclude the debris from the gap. Electrode jump height H_j , jump time t_j , and others are defined as shown in the figure. In general, frequent electrode jumping is effective to exclude the debris from the gap and to keep a stable discharge performance, but it leads to long machining time because the material removal is not done during electrode jumping duration. Machining conditions are

listed in Table 2. Metal mold steel SKD61 in JIS specifications is used as a workpiece material.

3. Machined hole shapes

Figure 3 shows the wall profiles of the machined hole using flange type electrode and a normal straight electrode. Machined hole depth is 50mm. The jump height and the real machining time are set to 2.4mm

Table 1: Dimension of electrode

a(mm)	b(mm)
2.0	2.5, 2.0, 1.5, 1.0, 0.5, 0.25, 0.1
2.0, 5.0, 10.0, 15.0, 20.0	2.5

Figure 1: Shape of flange type electrode

Table 2: Machining conditions

Electrode	Cu (ϕ 10.0mm) Polarity: Electrode(+)
Discharge current i_e	24A
Pulse duration t_e	200 μ s
Pulse interval time t_o	90 μ s
Jump height H_j	38mm(t_j =500ms) 2.4mm(t_j =160ms)
Real machining time t_{rm}	600ms
Jump speed J_s	36m/min

Figure 2: Definition of electrode jumping

and 0.6s respectively in this case. The wall concavity defined as the difference between the maximum and the average minimum radial gaps. From the figure, the wall shape machined using a straight electrode becomes concave, and the concavity is as large as $50\mu\text{m}$. On the other hand, a straight deep hole can be obtained by using flange type electrode with large step. Therefore, it was made clear that the main factor causing the concavity in deep-hole EDM is secondary discharges at the side gap, and a straight deep hole can be attained by using flange type electrode.

Then, the effects of the step height and the step difference on the machined hole shape are investigated. Figure 4 shows the profiles of machined hole using flange type electrodes with various step height, the step difference is fixed 2.5mm. When the step height is more than 5.0mm, the side gap distance becomes very large. And, when flange type electrode with step height is 15, 20mm, the machined hole seems to become a little concave. Therefore, the secondary discharges and concavity of the machined hole can be prevented by using flange type electrode with short step height.

Figure 5 shows the profiles of the machined holes using flange type electrodes with various step difference, the step height is fixed 2.0mm. As can be seen from the figure, the concavity becomes small with an increase of the step difference. And the radius of the machined hole also becomes small. When the step difference is more than 0.5mm, the machined holes are almost straight. In particular, when the step difference is 2.5mm, the radius of machined hole is uniformly as small as 5.12mm. Therefore, by using a flange type electrode with sufficiently large step difference, the concavity of the machined hole can be well prevented.

4. Advantage of Flange Type Electrode

Figure 6 shows the variations of machining depth with machining time using EDM machine driven with ball screw system and EDM machine with linear motor drive. Electrode jump conditions of the EDM machine driven with ball screw system are as follows; the real machining time is 640ms, the electrode jump height is 2.5mm. These conditions are almost the same condition as linear motor driven EDM machine.

In the machining using EDM machine with linear motor drive, a straight deep hole could be obtained using a straight electrode, when the jump height is large.

Figure 3: Machined hole shapes with flange type electrode and a normal electrode

Figure 4: Effect of the step height on machined hole

Figure 5: Effect of the step difference on machined hole shape

Figure 6: Advantage of flange type electrode

Furthermore, the machining speed becomes constant. However, in the case of low jump height using a straight electrode in EDM machine of linear motor driven, machining deep hole was difficult, in which, the removal rate begins to decrease at the depth of 30mm. On the other hand, in the case of EDM machine driven by ball screw system, a deep hole with a constant removal rate can be machined by using the flange type electrode. Furthermore, the removal rate using the EDM machine driven by ball screw system with a flange type electrode is as same as that using EDM machine with linear motor drive.

From these results, it was clarified that EDM performance becomes better by using flange type electrode, even if a normal EDM machine with ball screw drive is used.

5. CFD analysis

In order to, explain the advantage of flange type electrode, it is necessary to understand flow field in the side gap during the electrode jump.

Figure 7 is one of CFD analysis results of flow field during electrode jump. Figure (a) shows the flow field when flange type electrode is going down. Figure (b) shows flow field when the electrode completes its jump. The electrode jump height is 2.4mm, and the jump time is 160ms. The arrows in the figure indicate the direction of the flow, and the length indicates the velocity. As shown in the figures, large vortex generates above the step of electrode during the electrode is going down. And it was confirmed that the size of the vortex becomes the largest at the end of electrode jump. Next, the observation and the visualization above the step of the flange gap were carried out by using high-speed video and PIV (Particle Image Velocimetry) analysis. Figure 8 shows the flow field pattern at the same time of Figure 7 (b). The velocity field pattern in this figure is quite similar to that of the CFD analysis in Figure 7 (b), which proves high reliability of the CFD analysis.

The debris particle motion during electrode jump is also simulated by using the flow pattern. Figure 9 shows the debris distribution for 0.131sec after jump starts in the bottom gap and the side gap. Even when the electrode

(a) Velocity pattern at 0.091sec after electrode jump starts

(b) Velocity pattern at 0.161 sec after electrode jump starts

Figure 7: Results of CFD analysis

Figure 8: Observation and flow field pattern above the step of flange type electrode

jump completes, most debris are left in the side gap and the bottom gap. However, there are not any high debris stagnation areas. From this analysis, it can be concluded that the most debris remains in the gap even after the electrode jump, but the density is almost uniform without high stagnation. Also, the side gap distance is large enough to prevent the secondary discharges. Consequently, the concavity in deep hole machining could be prevented by using the flange type electrode.

Figure 9: Debris distribution at 0.131sec after jump starts.

6. Conclusions

- (1) In EDM of deep hole, a straight deep hole can be attained by using flange type electrode with large side gap distance.
- (2) EDM performance becomes better by using flange type electrode, even if an EDM machine with ball screw drive is used.
- (3) CFD simulation of fluid flow in the side and the bottom gap during electrode jumping is quite similar to that of the high speed video observation.
- (4) Main factor causing the concavity in deep hole EDM is secondary discharges in the side gap.
- (5) CFD simulation also can show the debris particle motion during the electrode jump.
- (6) The most debris remains in the gap even after the electrode jump, but the density is almost uniform without high stagnation. Besides, when a flange type electrode is used, the side gap distance is large enough to prevent the secondary discharges.

References

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