euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017
www.euspen.eu

Observation of phenomenon in gap area during micro hole drilling with micro EDM

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Abstract
In this paper, the phenomenon was investigated that machining speed decreases obviously after a certain depth in the micro hole drilling by micro EDM with high aspect ratio and observed by the high-speed camera. The experiments in the stainless steel SUS304 and SiC were done to observe the movement and deformation of bubble in the final stage. Based on the observation, the reason of decrease of machining speed was discussed.

Electrical discharge machining, micro hole, aspect ratio, high speed camera

1. Introduction

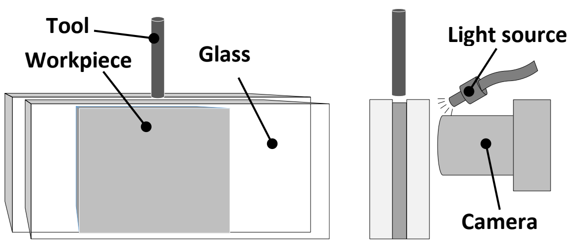
It is well-known that the machining speed decreases at a certain depth in the electrical discharge drilling of a micro hole with high aspect ratio [1]. Although there are many researches have been carried out to find the reason [2], there is no direct observation of the phenomenon in the gap area during machining. In this study, a high-speed camera was used to observe the gap area in micro EDM. The observation was realized by clamping a thin film workpiece with two pieces of glass, which simulates the drilling of the blind hole. Based on the observation, the influence of the movement and deformation of bubbles in the discharge gap was discussed.

2. Experiment method and condition

2.1. The hold for the foil workpiece

It is difficult to observe the gap area in the micro EDM because most metal workpieces are not transparent, and the surface of the conductive transparent material such as SiC (single crystal silicon carbide) becomes black after heated, which make it impossible to observe the gap area directly.

A method was put forward to hold the workpiece as the Figure 1 showed. The workpiece was clamped tightly by two pieces of glass. A high-speed video camera (VW-9000, Keyence) was used to record the phenomenon in the gap area.



(a) The front view (b) The side view

Figure 1. The hold of workpiece

The aim of the holder is to make sure the discharge gap can be observed directly by the high-speed camera. In the process, the tool diameter is the same as the thickness of the foil workpiece. Because of the discharge, all the material in the discharge gap will be removed so that part of gap area near the tool can be observed directly. Moreover, the width of observation area D can be predicted and shown in Figure 2.

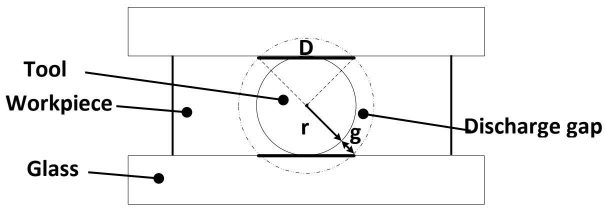
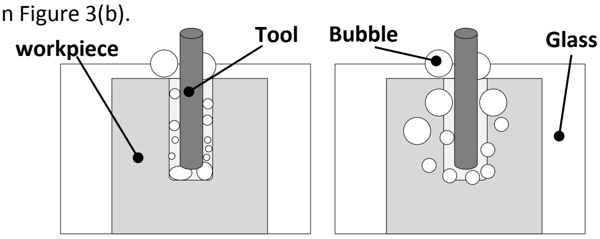


Figure 2. The width of observation area

Although the holder is designed to simulate the process of drilling micro hole, it is different from the true environment of drilling blind micro hole. Therefore, according to experimental conditions, there are two situations for the simulation as the Figure 3 shows. The first situation is that the glass plates fit the foil workpiece perfectly so that no bubbles overflow through the clearance and all bubbles only exist in the discharge gap; The second situation is that the glass plates do not fit the workpiece perfectly, in which bubbles can not only overflow from the discharge gap, but also from the clearance as shown in Figure 3(b).



(a) Success (b) Failure

Figure 3. The schematic of simulation for drilling blind micro hole

2.2. Experimental design and conditions

The experiments were designed to investigate the drilling micro hole by micro EDM. The first sample was to drill the blind hole to confirm whether the machining speed will decrease when a Φ250μm tool was used to drill holes in stainless steel SUS304 with thickness of 5mm. The second sample was to drill the micro holes by clamping the 250μm thick foil SUS304 workpiece with glass plates to investigate the machining speed for the success simulation with a Φ250μm tool. The third sample was to drill micro holes using the holder to clamp a 300μm thick SiC foil workpiece with the Φ300μm tool and observe the discharge gap by the high-speed camera. Experimental parameters are showed in Table 1.

Table 1 Machining conditions

Workpiece	250μm and 5mm thick stainless steel SUS304, 300μm thickness SiC
Tool electrode	Tungsten carbide
The length of tool	3.2mm
The feed amount of tool	3mm
The feed rate of tool	5μm/s
The open voltage	100V
Capacitance	1000pf
Dielectric	Deionized water

3. Results and discussions

In the experiment, the position of the micro tool was recorded by the displacement transducer fixed in the Z axis. The feed depth of three samples were shown in Figure 4. The videos in the red points were recorded by the high speed camera. In the first sample, the result showed that the machining speed decreased obviously at the depth of around 1.1mm. The tool position kept in the state that fluctuated around 0.9mm and couldn't continue to feed obviously as shown in Figure 4. Meanwhile, the tool could not be fed at the depth of 0.9mm in the second sample. Since there is clearance in nano-scale between the workpiece with glasses, the debris could be washed out of the discharge gap by the bubbles, decreasing the accumulation of debris. Therefore, the tool will continue to feed in as the curve showed in red rectangular.

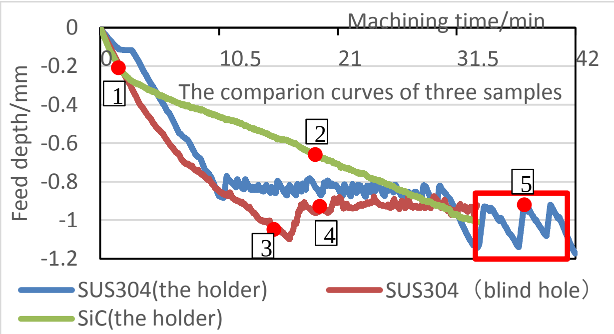
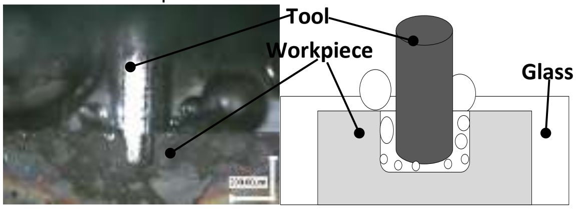


Figure 4. The comparison curves of three samples

In the third sample, the holder was used to fix a 300μm thick SiC workpiece and the high-speed camera was used to observe the bubbles in the discharge gap. Compared to the second sample, the machining speed decreased obviously after the depth of 0.3mm and kept at the lower speed until the end of machining, which may depend on the material property of SiC.

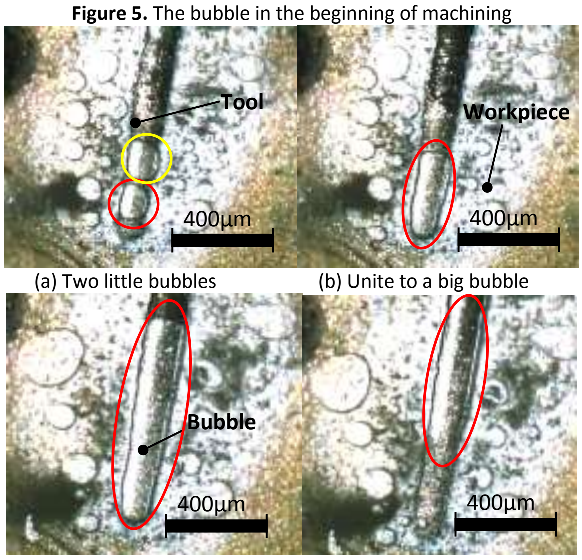
The result showed that bubbles not only generated in the discharge area but also in the surrounding area heated by the discharge energy once the discharge happens. In the beginning of machining, bubbles flowed out of the discharge gap easily and immediately as the Figure 5 (a) and schematic (b) showed from the video in red point 1. In the last stage of machining, bubbles couldn't overflow out of gap immediately, they grew up slowly, accumulated and united together to become a big bubble(see Figure 6 from point 2). Then the big bubble moved and deformed with the rotation of the micro tool and finally the last part of the micro tool was covered by the big bubble, which seems to have an air film coat.

According to the observation for the SUS304 as the Figure 7 showed, it indicated in Figure 7 (a) from point 3, the tool can reach the bottom of gap area. But in Figure 7 (b) and (c) respectively from point 4 and 5, the tool cannot reach the bottom of gap area. The bottom of gap area was full of the mixture of debris and dielectric. According to the Figure 7 (d), the discharge spark can be observed clearly, it can be found that in the last of the machining, when the bottom of gap area was full of the mixture of debris and dielectric, the discharge will happen between the tool and mixture, leading to the material in the workpiece cannot be removed.



(a) The observation figure (b) The schematic figure

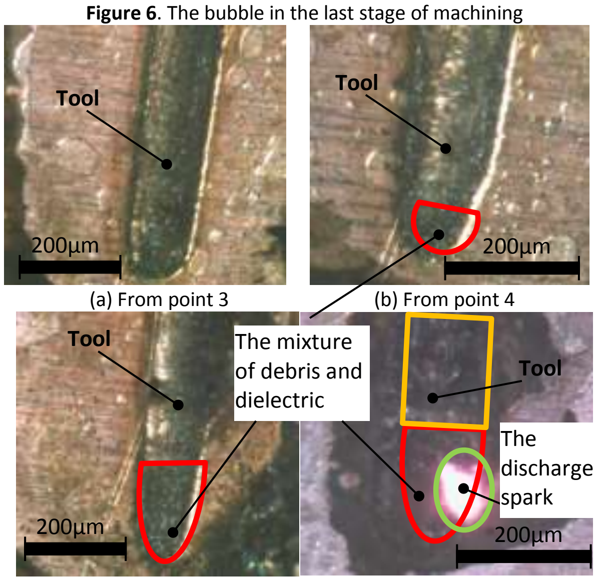
Figure 5. The bubble in the beginning of machining



(a) Two little bubbles (b) Unite to a big bubble

(c) The big bubble grew up (d) Overflow out of gap

Figure 6. The bubble in the last stage of machining



(a) From point 3 (b) From point 4

(c) From point 5 (d) The discharge spark

Figure 7. The figure of video from SUS304

4. Conclusion

In this paper, the discharge gap in drilling micro hole was observed by the high-speed camera and the movement and deformation of bubble have been explored. The results show that the accumulation of debris may lead to the decrease of machining speed.

References

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