Flow analysis of working fluid in micro electrical discharge drilling process

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Abstract

In this study, several types of tool electrodes with different grooves on the cylindrical surface were proposed, in order to effectively remove debris and realize deeper hole drilling with electrical discharge machining (EDM). Simulation was carried out with a general-purpose FEM software, COMSOL Multiphysics. The analysis results showed that the working fluid flows much more fluently and the debris is removed from the machining area much more effectively with the proposed electrode.

1. Introduction

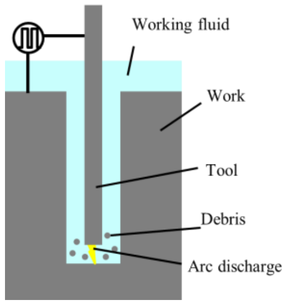


Fig.1 MEDD

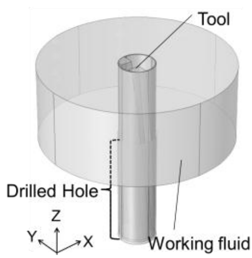


Fig.2 Schematic of model

Micro electrical discharge drilling (MEDD) is a thermal process that melts and evaporates the workpiece material by means of discharges occurring between the tool and workpiece separated by a narrow gap filled with insulating working fluid. When a deep micro hole is drilled, by-products, such as debris and bubbles, become difficult to be removed from the gap area, which causes short-circuits and abnormal discharges [1]. One solution for this problem is to use a tool with grooves on the cylindrical surface, with the expectation that the working fluid containing debris could easily flow through the grooves and remove debris effectively [2]. To remove debris more effectively and realize deeper hole drilling, it is important to find out the relation between the tool shape and the flow characteristics of working fluid. In this paper, working fluid in the gap area was modelled and the flow of working fluid was simulated by using a general-purpose FEM software, COMSOL Multiphysics.

2. Flow analysis of working fluid

The analysis target of MEDD is shown in Fig.1. The hole is processed by feeding the tool in the axial direction while rotating. Modelling and simulation was done by COMSOL Multiyphysics Ver4.3b. The schematics of analysis model and dimension are shown in Fig.2 and Fig.3. Z direction is the axial direction and the origin is set at the hole bottom. X-Y plane is the surface perpendicular to axial direction and the origin of X-Y plane is set at the tool centre. Deionized water was used as the working fluid and modelled as an incompressible fluid. The atmospheric pressure was applied to the surface of working fluid. Non-slip boundary condition, which means the velocity at the surface is zero, was applied to the boundary of the tool, the workpiece and the working fluid. The side gap distance was 5 μm, and the bottom gap distance was 10 μm. The rotating speed of the tool was 2000 rpm. Since the aim of this research is to simulate the flow of working fluid with a rotating tool, debris was not considered for simplicity. Tools with different shapes are shown in Fig.4. The conventional cylindrical tool without grooves is shown in Fig.4(a). The tool with two vertical grooves is shown in Fig.4(b). The tool with two crossing grooves, 5 degree tilted in different directions, is shown in Fig.4(c), while the tool with two parallel grooves, 5 degree tilted in the same direction, is shown in Fig.4(d). The width of the groove is 35 μm, the depth of that is 30 μm.

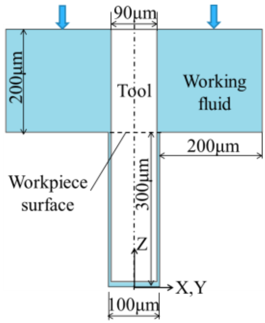
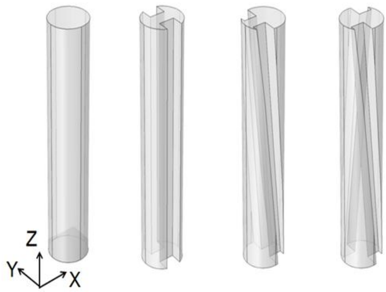


Fig.3 Dimension of model



(a) Cylindrical (b) Vertical (c) Crossing (d) Parallel
Fig.4 Tool shapes with different grooves

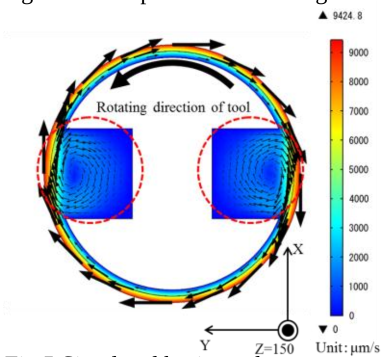
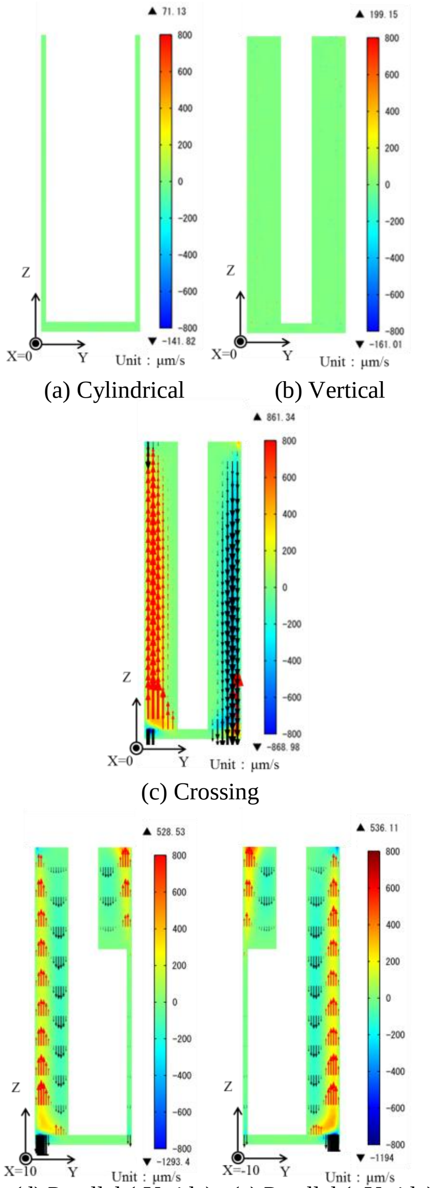


Fig.5 Simulated horizontal component of velocity of working fluid for the tool

Figure 5 shows the simulated horizontal component of the relative flow velocity of working fluid for the tool with vertical grooves. It is found that vortex occurs in this case. Vortex is also observed when using other tools with grooves. Figure 6 shows the simulated velocity of working fluid in the axial direction. In the case of the tool with crossing grooves, upward velocity occurs in one groove, while downward velocity occurs in the other groove. In the case of the tool with parallel grooves, there exist upward and downward velocities in each groove. Also, it is found that greater velocity of working fluid in the axial direction occurs when tools with angled grooves are used.

3. Flow rate at the workpiece surface

In this research, to reveal the role of the groove, the axial flow rate at the entrance of the machined hole was calculated in the groove area, and the area except the groove. Figure 7 shows the flow rate at each area. The flow rate at the grooves of crossing groove tool is quite larger than that of other tools. The flow that flowing out of the drilled hole occurs in one groove and the flow that flowing into the hole occurs in the other groove. From these results, it is expected that



(a) Cylindrical (b) Vertical

(c) Crossing

(d) Parallel (-Y side) (e) Parallel (+Y side)

Fig.6 Velocity in the axial direction

the flow from one groove to the other groove might exist at the bottom surface and efficient removal of debris from gap area may be realized.

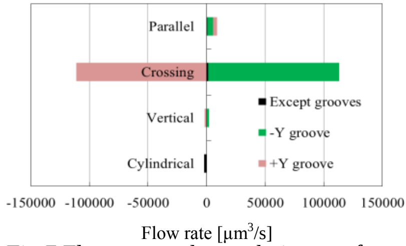


Fig.7 Flow rate at the workpiece surface

4. Behaviour of debris in the gap area

As described above, working fluid may flow from one groove to the other groove and remove debris from gap area when the tool with crossing grooves is used. Here, the behaviour of debris was simulated by putting a particle in the working fluid. The initial position of the particle was set in the groove where the fluid flowing into the hole occurs. The material of the particle is stainless and the diameter is 0.5 μm. The gravity force, the buoyancy and the force based on the Stokes's law was taken into consideration. Figure 8 shows the relative trace of the particle with respect to the tool. The x-mark in Fig.8 shows the initial position of the particle. The figure shows that the particle moves from one groove to the other through the bottom gap area and rises through the groove. From this result, it can be concluded that debris will be removed from the bottom gap area through the groove when the tool with crossing grooves is used.

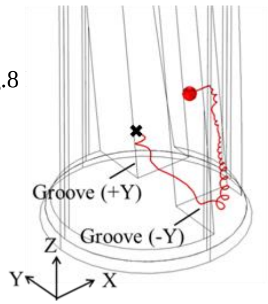


Fig.8 cle

5. Conclusions

In this study, working fluid in micro electrical discharge drilling was modelled and the flow of working fluid was simulated by FEM software. It was found that the flow out of the drilled hole in one groove and the flow into the hole in the other groove occur when the tool with crossing grooves tilted in the axial direction was used. Then, the debris behaviour was simulated. As the result, it was found that working fluid flows from one groove to the other through the bottom gap area and debris can be efficiently removed from the bottom gap area.

References:

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[2] Takumu MIYAMOTO, Tomohiko ICHIKAWA, Wataru NATSU : Influence of tool electrode shape on depth machining limit in micro EDM, Society for Precision Engineering Spring Conference Academic Conference Proceedings, (2013), pp.519-520.