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Research on shape generation of tungsten carbide alloy by electrolyte jet with bipolar pulse

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Abstract
In this research, the WC alloy rod was machined by using the electrolyte jet machining with a cylindrical nozzle. In order to reduce the adhesion of the by-product WO_3 on the surface with $NaNO_3$ solution, a bipolar current pulse was used in the experiments. The nozzle wear caused by the bipolar pulse was successfully prevented by a new feeding method of controlling current flow with a sacrifice plate and a diode. After investigating the influence of the machining conditions, a complicated shape of WC alloy was generated by scanning the nozzle in the axial direction and superimposing simple grooves.

ECM, electrolyte jet, tungsten carbide alloy, bipolar pulse, shape generation

1. Introduction

Electrolyte jet machining is carried out by jetting the electrolyte from a nozzle toward the workpiece, while applying the machining current between the nozzle and the workpiece [1]. Since the jetted electrolyte dissolves metallic materials regardless of their hardness, difficult-to-cut materials like tungsten carbide (WC) alloy can be machined efficiently if the proper electrolyte and power supply are used. In this research, a rotated WC alloy with a 5.0 mm diameter is machined. When a complicated shape is generated by superimposing simple grooves with electrolyte jet machining, the removal amount distribution for the simple groove is independent to each other [2]. However, in the case of machining of WC alloy, by-products like tungsten trioxide WO_3 adheres on the processed surface and makes the further dissolution difficult. Thus, when a complicated shape is processed with the superimposing method, it is considered that the removal amount distribution for the following groove may be influenced by the by-products on the surface.

In this research, in order to avoid the adhesion of by-products on the machined surface with a bipolar current pulse and a neutral electrolyte $NaNO_3$ solution, a new feeding method of controlling current flow with a sacrifice plate and a diode was proposed. The effect was experimentally investigated. After that, a complicated shape of WC alloy was generated by scanning the nozzle under the calculated speed in the axial direction.

2. Process principle and experimental method

2.1. Schematic of experimental equipment and nozzle shape

Figure 1 shows a schematic of the experimental equipment. The workpiece is mounted in a rotating spindle whose position is controlled in the Z direction by a CNC unit. The nozzle is mounted in a stage whose position is controlled in the X, Y directions. The electrolyte is jetted from the nozzle due to the pressure produced by an air compressor. The position of nozzle in X direction was so set that the extended central axis of the nozzle touches the workpiece side surface (Figure 2). Because of the large electric resistance of the electrolyte jet, which is determined by the cross-sectional area of the electrolyte jet and the distance between the nozzle and the workpiece, a special nozzle shown in Figure 2 was designed for experiments in order to shorten the distance.

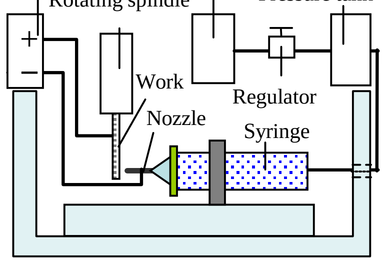


Figure 1. Schematic of experimental equipment.

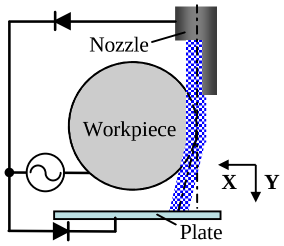


Figure 2. Feeding method with sacrifice plate.

2.2. Principle of ECM of WC alloy with bipolar pulse

Tungsten carbide alloy is composed of WC grains and cobalt which works as the binder. In ECM, WC alloy can be machined by using a mixed electrolyte solution NaOH and NaCl [3]. In this case, the tungsten carbide reacts with hydroxyl ion and form the WO_3 on the workpiece surface. Then, WO_3 reacts with NaOH to form the Na_2NO_4 which is water-soluble, and thus ECM of WC alloy is carried out. On the other hand, in the case of using a bipolar current pulse with $NaNO_3$ electrolyte, sodium hydroxide NaOH is generated during the half cycle when the WC alloy becomes the cathode [4]. With this reaction, the main by-product WO_3 is dissolved and does not adhere on the surface of WC alloy. One example waveform of the bipolar current pulse used in experiments is shown in Figure 3. In this research, the electrolyte jet machining is carried out by using this bipolar current pulse with $NaNO_3$, since the neutral electrolyte is safe to handle.

Meanwhile, when the bipolar current pulse is applied, the nozzle wear occurs during a half cycle since the nozzle becomes the anode. In order to prevent the nozzle wear, a metal plate which works as a sacrifice electrode, is mounted in the jet path (Figure 2). During the negative cycle, since the current flows between the sacrifice plate and the workpiece due to the diode, the wear will occur on the sacrifice plate, instead of the nozzle.

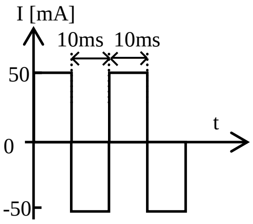


Figure 3. Bipolar pulse.

Table 1. Machining conditions.

Inside diameter [μm]	210
Gap length [mm]	1.0
Tank pressure [MPa]	0.45
Machining time [min]	DC 1 min, Pulse 30 s
Workpiece	5mm WC alloy
Revolution [rpm]	580

4. Effect of bipolar pulse on processed surface

The effect of current waveform on the processed surface was investigated. The current waveform affects the surface because the adhesion of by-products on the surface is quite different according to current waveform. One groove was machined with the bipolar current of ±50 mA as shown in Figure 3 and another groove was machined with a constant current of 50 mA under the machining conditions shown in Table 1. Figure 4 shows the surface profile measured at the centre of groove, and Figure 5 shows the SEM photo of the processed surface. Compared with the surface in the case of bipolar pulse, it is found that the surface is quite rough in the case of direct current (DC). The reason is considered that the distribution of the current density becomes unstable and thus causes the rough surface because of existence of by-products on the processed surface in the case of direct current. This result shows that bipolar pulse is an effective way to obtain smoother surface of WC alloy because of less by-product adhesion.

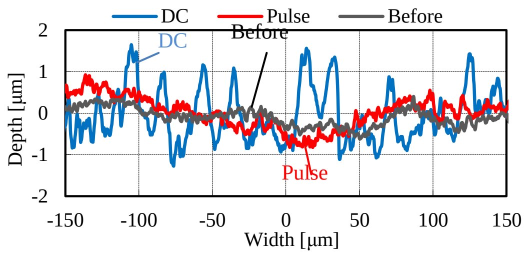
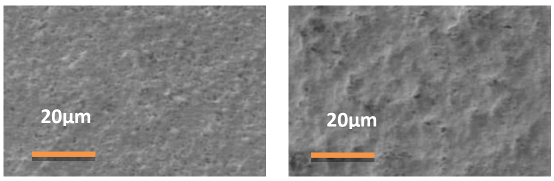


Figure 4. Profile of processed surface under bipolar pulse and DC.



(a) Bipolar (b) DC

Figure 5. SEM photo of processed surface under bipolar pulse and DC.

5. Generation of complicated shape of WC alloy

Since the by-products on the WC alloy surface were greatly reduced by using bipolar pulses, and the nozzle wear was prevented by the proposed new feeding method, a complicated shape of WC alloy was generated by superimposing simple grooves. The nozzle scanning speed to generate the target shape shown in Figure 6 with a dashed line was obtained through simulation (see Figure 7) and shown in Figure 8. The shape of WC alloy surface after scanning the nozzle along the axis direction under the calculated speed was measured and also shown in Figure 6 with the solid line. The result shows that the machined shape well meets the target one.

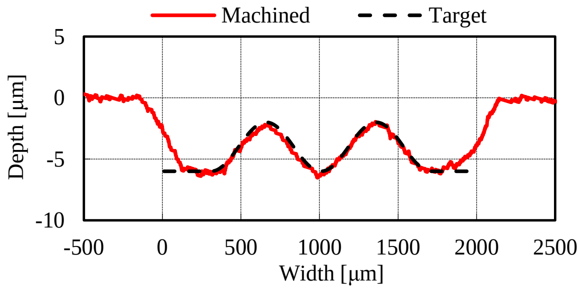


Figure 6. Target shape and generated one.

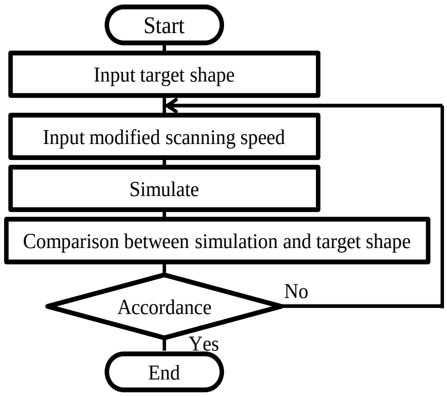


Figure 7. Flow chart to obtain scanning speed for machining.

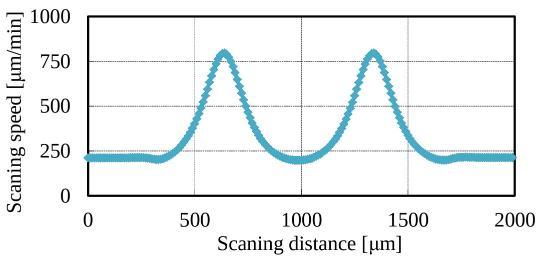


Figure 8. Scanning speed for shape generation.

6. Conclusions

A feeding method with the sacrifice plate and diode was proposed for generating complicated shape of WC alloy by electrolyte jet machining with bipolar current pulses. Experimental results show that by-products on the workpiece surface were greatly reduced and the generated shape coincides well with the target one.

References

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