Mechanical and electrolytic hybrid grinding of metal ceramic composites using coarse diamond grinding wheel

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Abstract. The application and development of metal ceramic composites have been restricting due to its low grinding efficiency and ground quality. In this paper, the hybrid machining technology combined mechanical with electrolytic grinding based on dressed coarse diamond grinding wheel is proposed to perform efficient and precise grinding of metal ceramic composites. First, the dry electrical discharge dressing technology was used to dress coarse diamond grinding wheel to obtain high grain protrusion and sharp micro-grain cutting edges. Next, the mechanical and electrolytic hybrid grinding process using dressed coarse diamond wheel was developed to grind metal ceramic. Finally, the effects of different process parameters on ground surface topographies and surface roughness were investigated. It is shown that the proposed hybrid grinding method was feasible and can effectively improve the ground surface quality. The experimental results show that the optimal process parameters including the depth of cut, open-circuit voltage and impulse width were 5 µm, 20 V and 400 ns, respectively. Compared with traditional mechanical grinding, the ground surface roughness by the proposed hybrid machining method was improved by about 25%.

1. Introduction

Metal ceramic is a kind of heterogeneous composite material composed of ceramic phase and metal phase. It not only has high hardness, high temperature resistance, corrosion resistance and good biocompatibility, but also has certain metal plasticity, toughness and electrical conductivity. Therefore, it has been widely used in aerospace, machining tools, biomedical and other fields [1]. However, as a typical hard and brittle material, the internal metal phase and ceramic phase of metal ceramic is very different, making it very difficult to conduct secondary precision processing [2]. At present, grinding with diamond wheel is the most common precision machining method of metal ceramic [3]. Fine-grained diamond wheels were generally used in the grinding process of metal ceramic, and can obtain good surface quality [4]. However, the wear of the fine-grained diamond grinding wheel was very fast in the process of grinding. In order to ensure the processing quality, it is necessary to frequently dress and true the fine-grained diamond grinding wheel, leading to low grinding efficiency. Therefore,
taking advantage of the excellent wear resistance and large grain protrusion of coarse diamond grinding wheel, the processing technology using metal-bonded coarse diamond grinding wheel was proposed to grind metal ceramic to realize the high efficiency and precision grinding.

For coarse diamond grinding wheel, the obtained grain protrusion height was low and the dressing efficiency was also extremely low using the traditional mechanical dressing method. Therefore, the dry electrical discharge dressing method was used to dress the coarse diamond grinding wheel to rapidly obtain sharp grain cutting edges [5].

In this paper, a coarse diamond grinding wheel after dry electrical discharge dressing was used to conduct an electrolytic composite axial grinding experiment on metal ceramic composites. The effects of process parameters including cutting depth, open-circuit voltage and impulse width on the ground surface quality of metal ceramic composites were investigated. The relationship between process parameters and ground surface quality of electrolytic composite axial grinding was revealed and the process conditions of electrolytic composite axial grinding were optimized.

2. Experiments and methods

Figure 1 shows the schematic diagram and photo of the mechanical and electrolytic hybrid grinding of metal ceramic composites using coarse diamond grinding wheel. Firstly, the SD46 diamond grains derived from metal bonded were dressed by the dry electrical discharge dressing technology. Then, the mechanical and electrolytic hybrid grinding experiments of metal ceramic composites using coarse diamond grinding wheel were conducted to study the influences of discharge parameters (open-circuit voltage and impulse width) and depth of cut on the ground surface qualities of metal ceramic composites. The detailed machining conditions of the mechanical and electrolytic hybrid grinding of metal ceramic composites are shown in Table 1.

Figure 2 shows the schematic diagram of microscopic removal of mechanical and electrolytic hybrid grinding of metal ceramic using coarse diamond grinding wheel: (a) Photo; (b) Schematic diagram.

Table 1. Conditions of electrolytic composite axial grinding

| CNC Grinder   | SMART B818 III |
|---------------|----------------|
| Diamond grinding wheel | SD400, resin bond, diameter \( D = 150 \text{mm} \), width \( B = 4 \text{mm} \), Wheel speed \( N = 3000 \text{ r/min} \) |
| Workpiece     | Metal ceramic (TN60, Kyocera) |
| Machining parameters | Feed speed \( v_f = 10 \text{ mm/min} \); depth of cut \( a = 1-20 \mu \text{m} \), \( \Sigma a = 50 \mu \text{m} \) |
| Coolant       | Water-soluble electrolyte (Water soluble solution: Water=1:20) |

Figure 2 shows the schematic diagram of microscopic removal of mechanical and electrolytic hybrid grinding of metal ceramic. In this experiment, the coarse diamond grinding wheel was first dressed by electrical discharge. The positive pole of the power supply with nanosecond pulse width was connected to the workpiece, and the negative pole was connected to the grinding wheel. During
the grinding process, the workpiece was fixed on the worktable, and the grinding wheel was driven along the spindle direction relative to the worktable. At the same time, the generated chip was electrolyzed as an anode and washed away by electrolyte. The type of metal ceramic material used is TN60 (Kyocera, Japan). The electrolyte was mixed by water-soluble emulsion and water at a certain proportion (1:20). In this paper, the influences of three grinding process parameters including depth of cut, pulse voltage and pulse duration on the machining qualities of metal ceramic composites were investigated. When the open-circuit voltage was 60 V, there were obvious holes on the surface of metal ceramic composites, which affected the surface quality. The open-circuit voltage, impulse width and depth of cut were set as 0~60 V, 0~1600 ns and 1~20 \( \mu \text{m} \), respectively. In order to evaluate the ground surface quality of metal ceramic, 3D laser scanning microscope (VK-250, Keyence) and scanning electron microscope (FEI Quanta 450FEG) were used to detect the 3D and surface topographies.

3. Results and discussions

The surface topographies of ground metal ceramic were observed and analyzed under different grinding and discharge parameters. Figure 3 shows the SEM photos of mechanical and electrolytic hybrid ground surfaces of metal ceramic. Compared with traditional mechanical grinding, it is found that the surface roughness \( R_a \) of ground metal ceramic surface using mechanical and electrolytic hybrid grinding method was reduced by 25%. This is because in the process of mechanical and electrolytic hybrid grinding, the generated chip was electrolyzed and quickly washed away by the electrolyte, thus reducing the damage in ground surface. In addition, it would also remove the metal bond on the surface of coarse diamond grinding wheel, so as to realize self-dressing of the grinding wheel. Compared with traditional mechanical grinding, the proposed mechanical and electrolytic hybrid grinding can obtain better surface quality.
Figure 4(a) shows the influences of different depth of cut $a_p$ on ground surface roughness $R_a$ of metal ceramic. It can be seen that the surface roughness basically increased with the increase of the depth of cut $a_p$. When the depth of cut was 5 µm, the surface roughness $R_a$ reached a minimum value of 0.124 µm. As shown in Figure 4(b), the surface roughness first decreased and then increased with the increase of open-circuit voltage $E$. When the open-circuit voltage was 20 V, the surface roughness $R_a$ reached the minimum value of 0.124 µm. With the increase of the open-circuit voltage, the electrolytic reaction can be fully carried out, thus improving the ground surface quality of workpiece. Therefore, the suitable open-circuit voltage was 20 V in the grinding of metal ceramic using mechanical and electrolytic hybrid grinding.

As shown in Figure 4(c), the surface roughness first decreased and then increased with the increase of impulse width $T_{on}$. When the impulse width was 400 ns, the surface roughness $R_a$ reached the minimum value of 0.124 µm. The reason for this phenomenon was similar to the variation of the open-circuit voltage. The larger the impulse width is, the greater the pulse discharge energy is, resulting in deterioration in ground surface quality of workpiece. Therefore, the appropriate impulse width was selected as 400 ns in the mechanical and electrolytic hybrid grinding process of metal ceramic.

Figure 4. Effects of different process parameters on surface roughness $R_a$ of metal ceramic: (a) depth of cut $a_p$, (b) open-circuit voltage $E$ and (c) impulse width $T_{on}$.

4. Conclusions
In this paper, the mechanical and electrolytic hybrid grinding method based on the dressed coarse diamond grinding wheel is proposed to grind metal ceramic material to obtain high surface quality. It provides a feasible scheme for high efficiency and precision machining of conductive metal ceramic materials. The optimal process parameters including the depth of cut, open-circuit voltage and impulse width were 5 µm, 20 V and 400 ns, respectively. Compared with traditional mechanical grinding, the ground surface roughness can be improved by about 25% using the proposed hybrid machining method.

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