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Dry electrical discharge dressing and truing of diamond grinding wheel V-tip for micro-grinding

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Abstract: The dry electrical discharge dressing and truing technology was proposed to realize the high efficient and precise truing of diamond grinding wheel in this paper. Firstly, the V-shape tip of diamond grinding wheel was formed using dry electro-contact discharge (ECD) truing along setting crossed V-shape interpolation path. Secondly, the influence of different pulse discharge parameters on V-tip angle and V-tip radius was investigated, respectively. Finally, the trued V-tip diamond wheel was employed to fabricate micro-groove and micro-pyramid array structures on the surfaces of two hard and brittle materials by micro-grinding machining. The results indicated that the optimal pulse discharge parameters were open-circuit voltage E of 5V, pulse frequency f of 4000Hz and duty cycle d_c of 50%. The least V-tip angle error and radius of trued SD600 V-tip diamond grinding wheel was 1.1° and 33 μm, respectively. The micro-groove and micro-pyramid structures with regular shape and smooth surface can was effectively machined on the surfaces of difficult-to-cut materials.

Keywords: electrical discharge, dressing and truing, diamond grinding wheel, micro-grinding.

1. Introduction

The regular micro array structure at micron scale was machined on the surface of hard and brittle materials, which may produce new functional performance [1]. However, the micro-structured surface machining of difficult-to-machine materials was very difficult. It is known that precision grinding based on diamond grinding wheel is the most effective micro machining method [2].

However, the dressing and truing of diamond grinding wheel is the critical problem. The truing efficiency and precision have been technology bottleneck in industrialization. It had been confirmed that the dry electro-contact discharge (ECD) dressing and truing could vastly improve the truing efficiency [3]. Therefore, the dry ECD truing was developed to realize high efficient and precise V-tip truing of diamond grinding wheel.

The shape accuracy of machined micro-structures on material surface depends on form accuracy of diamond grinding wheel micro tip [4]. Therefore, the investigation on V-tip truing accuracy is very significant. The V-tip angle and radius were analyzed under different pulse discharge parameters to obtain the highest truing accuracy. In order to test the effectiveness of V-tip truing, two hard and brittle materials were used to conduct the micro-grinding experiments. The ground surface topographies were observed to verify the grinding performance of trued V-tip diamond grinding wheel.

2. Experimental setup of dry ECD

Fig. 1 shows the dry electro-contact discharge (ECD) truing and micro-grinding of V-tip diamond grinding wheel. The pulse power supply was connected between hybrid electrode (Cu and SiC) and metal-bonded diamond grinding wheel (see Fig. 1a). The electric spark was produced between metal bond from grinding wheel and rolled Cu chip when the rotary diamond wheel cut the conductive electrode. The diamond grinding wheel was driven along setting V-shape truing path. Gradually, the V-tip profile of diamond wheel was formed. The detail ECD truing conditions of SD600 diamond grinding wheel V-tip were shown in Table 1. The trued V-tip diamond wheel was employed to grind microcrystallite glass ceramics and SiC reinforced Al (Al/SiC_p) composites. The micro-groove array structures and micro-pyramid array structures were fabricated on those three material surfaces by micro-grinding machining technology, respectively. The micro-grinding photo of trued SD600 V-tip diamond wheel was shown in Fig. 1b. The machined V-groove depth and space was 500 µm and 570 µm, respectively. The detail micro-grinding machining conditions of SD600 diamond grinding wheel were shown in Table 2.

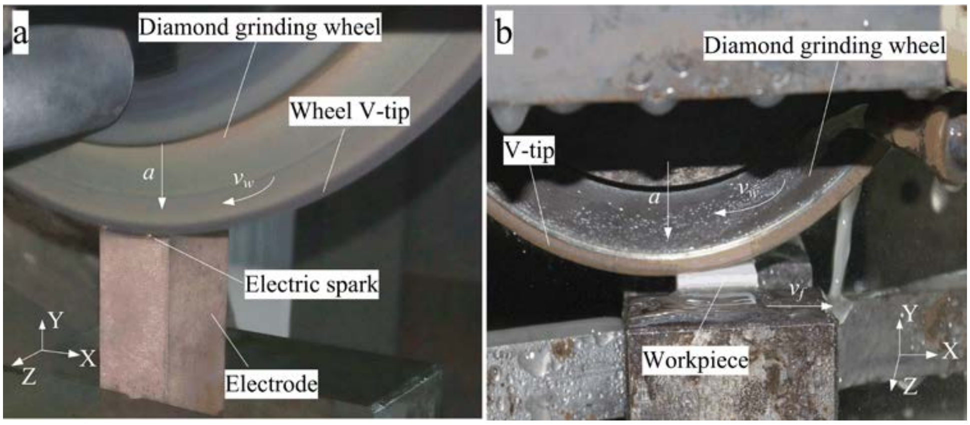


Fig. 1 Dry electro-contact discharge (ECD) truing and micro-grinding of V-tip diamond grinding wheel: (a) photo of V-tip truing and (b) micro-grinding photo of trued V-tip diamond wheel.

Table 1 The ECD truing conditions of SD600 diamond grinding wheel V-tip

CNC grinder	SMART B818
Diamond grinding wheel	SD600, metal bond, diameter D=160 mm, width B=2 mm
Tool truing path	Crossed V-shape interpolation path
Truing electrode	Hybrid electrode of Cu and SiC (#600); Size: 20×50×15 mm
Discharge parameters	Pulse power supply, open-circuit voltage E=10~25V, pulse frequency f=1000~5000Hz, duty cycle d_c=10~50%
Truing parameters	Wheel speed v_w=12.6~20.9 m/s, feed speed v_f=200~500 mm/min, depth of cut a=1~10 μm, cumulative feed depth Σa = 0.05~0.1 mm
Coolant	No

Table 2 Micro-grinding machining conditions of SD600 diamond grinding wheel

CNC grinder	SMART B818
Diamond grinding wheel	SD600, metal bond, diameter D=160 mm, width B=2 mm, wheel speed v_w=25.1 m/s
Tool path	Horizontal reciprocating and crossed interpolation path
Rough machining	Feed speed v_f=600 mm/min, depth of cut a=10 μm, cumulative feed depth Σa = 490 μm
Finish machining	Feed speed v_f=300 mm/min, depth of cut a=2 μm, cumulative feed depth Σa = 10 μm
Workpieces	Microcrystallite glass ceramics (30×15 mm); SiC reinforced Al (Al/SiC_p) composites (10×10 mm)
Coolant	Water

3. Results and discussions

Fig. 2 shows the V-shape tip and its grain protrusion topographies of SD600 diamond wheel after dry ECD truing. It is seen that the micro grain protrusion status of V-shape side of diamond wheel was very well. However, micro tip of grinding wheel became dull. This is because the ECD truing time of diamond wheel was too long. There were many protrusive diamond grains on the metal bond surface. Therefore, V-shape tip of diamond grinding wheel can be formed by ECD truing. The sharp micro grain cutting edge on the wheel surface was produced along V-shape cutting direction. The trued V-tip diamond wheel can be used in precise micro-grinding machining of hard and brittle materials.

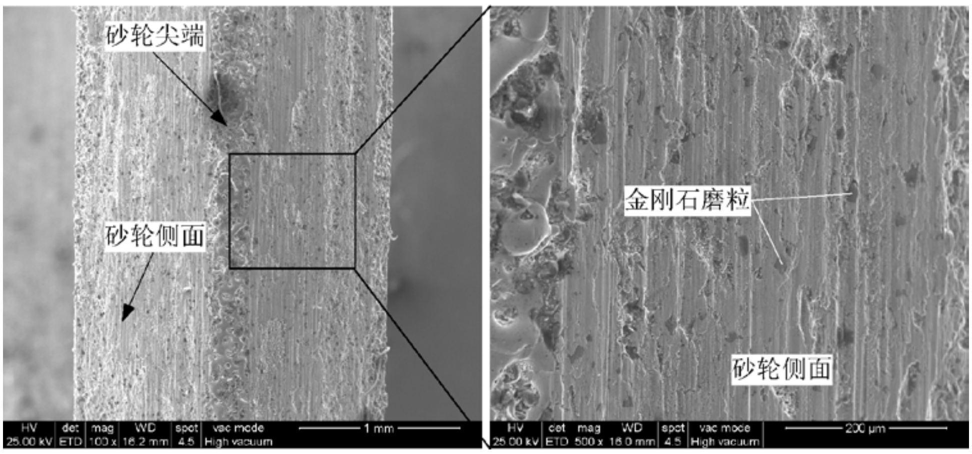


Fig. 2 V-shape tip and its protrusion topographies of SD600 diamond wheel after dry ECD truing.

Fig. 3 shows the influence of different pulse discharge parameters on V-tip angle φ of SD600 diamond grinding wheel. When the open-circuit voltage E was 5V and 25V, corresponding V-tip angle φ was 88.9º and 89.4º, respectively. Compared with the setting theoretical truing angle of 90º, the V-tip angle error was only 1.1º and 0.6º, respectively (see Fig. 3a). The V-tip angle φ first gradually decreased, then increased with the increase of pulse frequency f (see Fig. 3b). The reason is that the V-tip truing of diamond wheel was excessive due to the arc discharge. When the pulse frequency f was 4000~5000Hz and duty cycle d_c was 50%, the V-tip angle error reached minimum value of 0.6º (see Fig. 3c).

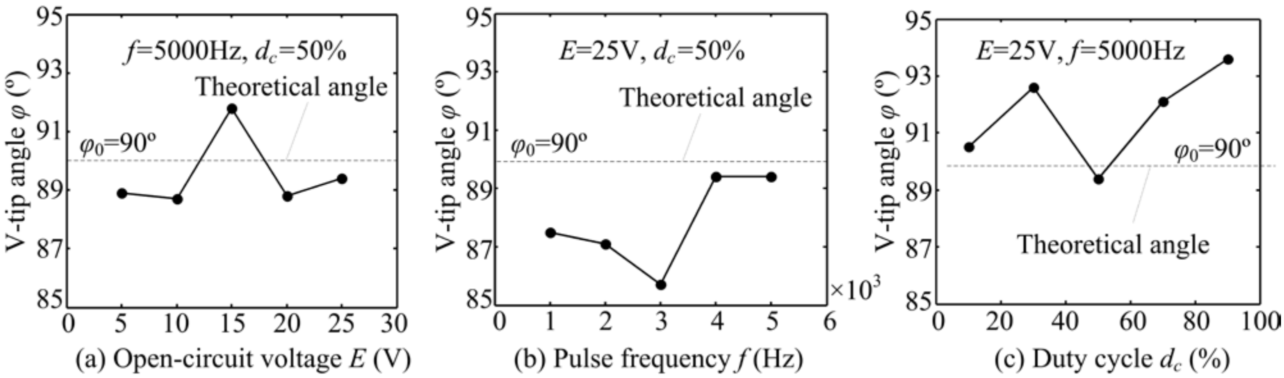


Fig. 3 shows the V-tip angles φ of SD600 diamond grinding wheel versus different pulse discharge parameters: (a) open-circuit voltage E, (b) pulse frequency f and (c) duty cycle d_c.

Fig. 4 shows the influence of different pulse discharge parameters on V-tip radius r_v of SD600 diamond grinding wheel. The V-tip radius r_v increased with the increase of open-circuit voltage E (see Fig. 4a). When the open-circuit voltage E was 5V, the trued V-tip radius of diamond wheel reached minimum value of 33 µm. When the pulse frequency f was 4000 and 5000 Hz, corresponding V-tip radius r_v was 44 µm and 78 µm, respectively (see Fig. 4b). The V-tip radius r_v first gradually decreased, then increased with the increase of duty cycle d_c (see Fig. 4c). This is because large and little duty cycle may all cause inhomogenous electrical spark discharge. When the duty cycle d_c was 50%, the trued V-tip radius reached minimum value of 78 µm. As a result, under optimal pulse discharge parameters (E=5V, f=4000Hz and d_c=50%), the least V-tip angle error and radius of SD600 diamond grinding wheel after ECD truing was 1.1º and 33 µm, respectively.

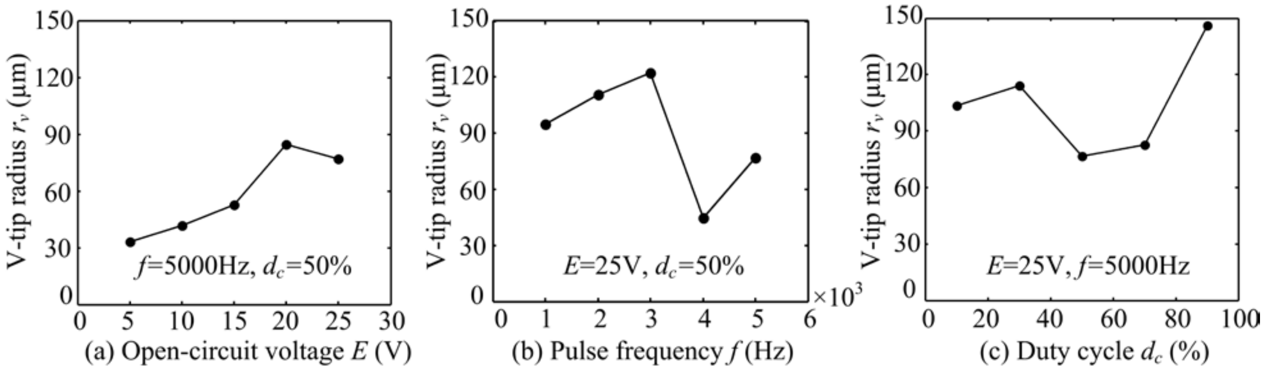
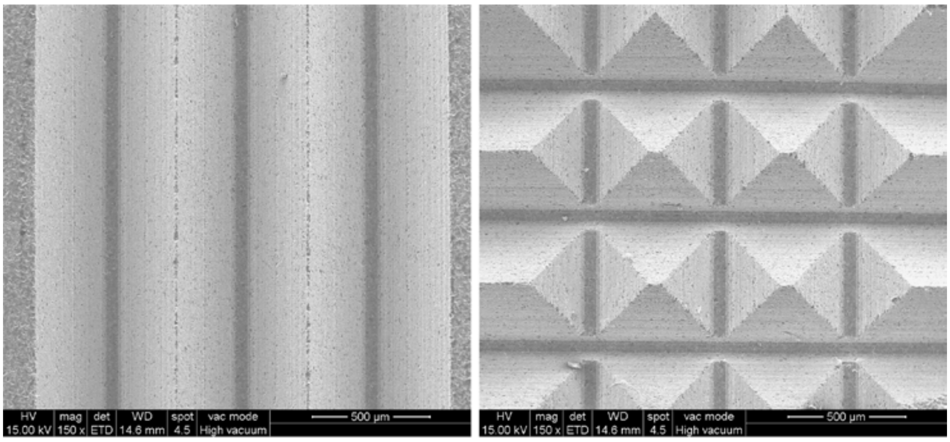


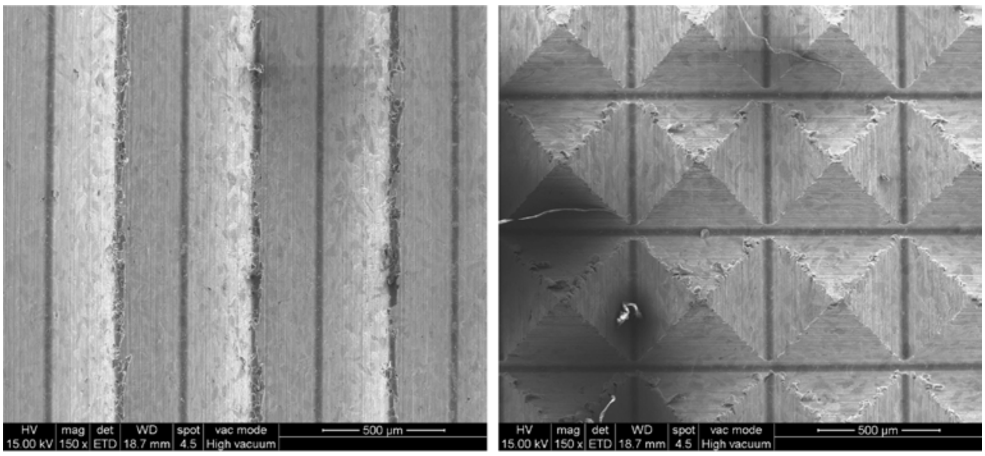
Fig. 4 shows the V-tip radius r_v of SD600 diamond grinding wheel versus different pulse discharge parameters: (a) open-circuit voltage E, (b) pulse frequency f and (c) duty cycle d_c.

Fig. 5 displays the ground surface topography of microcrystallite glass ceramics after micro-grinding using trued SD600 V-tip diamond grinding wheel. It is seen that the ground micro-groove and micro-pyramid structured surfaces were very smooth and the edges were not any damaged. Moreover, the V-tip shape of micro-grooves and micro-pyramids spire was also very complete. However, there were many micro holes on the surface of microcrystallite glass ceramics. This is becasue the brittleness of microcrystallite glass ceramics was considerable.



(a) Micro-groove array structure (b) Micro-pyramid array structure

Fig. 5. The ground surface topography of microcrystallite glass ceramics after micro-grinding: (a) micro-groove array structure and (b) micro-pyramid array structure.



(a) Micro-groove array structure (b) Micro-pyramid array structure

Fig. 6. The ground surface topography of SiC reinforced Al composites after micro-grinding: (a) micro-groove array structure and (b) micro-pyramid array structure.

Fig. 6 presents that the ground surface topography of SiC reinforced Al (Al/SiC_p) composites after micro-grinding using trued SD600 V-tip diamond grinding wheel. Compared with microcrystallite glass and reaction sintered SiC ceramics surfaces, the surface machining quality of SiC reinforced Al composites was worst. Besides, the breakage of micro-groove tip was very serious and there were many burrs at the edge of micro-pyramid. This is because the aluminum substrate contained SiC particles. The collision or brittle rupture extremely easily occurred in the grinding process of Al/SiC_p composites. Therefore, the machining of Al/SiC_p composites was very difficult.

4. Conclusions

The high efficient and precise V-tip truing of diamond grinding wheel was realized using dry ECD truing method. The pulse discharge parameters were optimized in the experiment of V-tip truing. The optimal pulse discharge parameters were open-circuit voltage E of 5V, pulse frequency f of 4000Hz and duty cycle d_c of 50%. The sharp micro grain cutting edge on the wheel surface was formed after ECD truing. The least V-tip angle error and radius of trued SD600 V-tip diamond grinding wheel was 1.1° and 33 μm, respectively. The trued V-tip diamond wheel can be employed to fabricate regular and smooth micro-groove and micro-pyramid array structures on the surfaces of hard and brittle materials such as microcrystallite glass ceramics and Al/SiC_p composites.

5. Acknowledgments

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