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ORIGINAL ARTICLE

Edge passivation and quality of carbide cutting inserts treated by wet micro-abrasive blasting

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Abstract
Micro-abrasive blasting was urged by compressed air to form the high-speed sprayed water beam and passivate the cutting edge of inserts. The cutting edge shape had been changed without any damages due to the micro-impacting action of the high speed abrasive, which improved the quality of the cutting edge. The generative mechanism of cutting edges during the micro-abrasive blasting was discussed, and then, the edge quality was evaluated. The orthogonal experiment was designed to optimize the micro-abrasive blasting parameters range, and the effects of micro-abrasive blasting parameters on the passivated edge quality were further investigated by full factors experiment. The edge passivation results indicated that the micro-abrasive blasting processing technology mainly relied on the micro-cutting action of abrasives which crashed the insert in the mixture to generate the rounded cutting edge. Moreover, the micro-abrasive blasting process could remove an amount of edge defects of inserts, such as cavities and cracks. After micro-abrasive blasting, the cutting experiment was used to assess the cutting performance of the passivated insert. And machining results showed that the insert treated by micro-abrasive blasting had a higher cutting life and stabler cutting force, which could improve the cutting performance of insert.

Keywords Micro-abrasive blasting · Cutting insert · Edge quality · Passivation · Damage

1 Introduction

The geometry and quality of the cutting edge have a great effect on the performance of cutting tools and cutting process [1, 2], such as the surface integrity [3], surface roughness [4], and chip formation [5]. And a reasonable shape of the cutting edge can reduce the cutting force and vibration and improve the cutting quality [6, 7]. The cutting edges of inserts must be passivated to protect the edge from tipping before use. Brushing passivation, grinding passivation, electrochemical passivation, and sandblasting passivation are common edge passivation methods [8, 9]. However, brushing and grinding are inefficient passivation methods, and electrochemical passivation is an unreliable method because of the instability of voltage. Compared to those methods, the wet micro-abrasive blasting should be a reliable and efficient passivation method. Now, micro-abrasive blasting technology is widely utilized in treating the surfaces, such as ornamentation, etching antiskid, metal peening, and so on [10]. Compared to the conventional sandblasting, micro-abrasive blasting is different because it is characterized by water jet using the smaller abrasive with an average particle size of 5~100 μm and a pressure of 0.05~0.9 MPa [11]. However, this conventional sandblasting is not appropriate for treating the cutting edge of inserts because it can provide an excessive impact force which can destroy the cutting edge or brought some surface damages to edge. Long et al. [12] sandblasted the parts surface using a pressure of 0.4~0.8 MPa and revealed that the rust removing mechanism was relying on the abrasive impact and friction. Zhou et al. [13] investigated the effect of process parameters on derusting efficiency using sandblasting technology and found that the optimum sandblasting angle was between 45° and 70°. Mohammadi et al. [14] used two grit materials and

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two types of blasting systems to investigate the influence of grit blasting parameters on the surface roughness of coated tools and found that the most significant grit blasting parameters were blasting system and grit size. Bouzakis et al. [15] applied the wet micro-blasting technology to deal with the coated tools and discussed the effects of wet micro-blasting pressure and time on coating properties, edge geometry, and tool life and found that wet micro-blasting technology could improve the cutting performance of tool. However, this study only focused on wet micro-blasting pressure and time and lacked a further investigation on the wet micro-blasting parameters and edge quality. After manufacturing the cutting insert, micro-abrasive blasting treatment can make the sharp edge become smooth transition and then strengthen the cutting edge of inserts. The feasibility of MAWJ (micro-abrasive water jet) to passivate insert was verified by Wan et al. [16]. In this study, the high pressure (80, 100, 120 MPa) and small diameter nozzle (0.5 mm) were adopted to sandblast, revealing the passivated mechanism of MAWJ to be that the high speed abrasive impacted the cutting edge and grinded the local area of edge to generate the arc edge. This study also pointed out that the abrasive water jet can make the defects such as burrs and cracks to weaken. However, this study still emphasized to investigate the abrasive water jet with a high pressure and small diameter nozzle, and it could not verify the feasibility of abrasive water jet to passivate the cutting edge of inserts under a lower pressure and bigger diameter nozzle.

Though the micro-abrasive blasting technology had a wide application in industry, few studies investigated the passivation effects of the cutting edge of insert within a wide range of process parameters through wet micro-abrasive blasting. The purpose of this study was to use the wet micro-abrasive blasting to scour the sharp cutting edge to make the edge be smooth and remove the edge defects such as micro-tipping and micro-cracks. The micro-abrasive blasting process was optimized, and its passivation mechanism was explored to analyze the edge quality after passivating. The effects of edge passivation on the cutting performance of inserts were also evaluated in machining of 17-4PH martensitic stainless steel.

2 Experimental

2.1 Experiment procedure

Most of carbide cutting tools have a chip breaker. The chip breaker can cause to the difficulty of edges observation after micro-abrasive blasting treatment. To avoid the influences of chip breaker, our investigated inserts have no chip breaker and their grade is a KT15 cemented carbide which is one of the most important tool materials. This material is made by Zhuzhou Jinxin Cemented Carbide Co. Ltd. Figure 1 shows the manufacturing process of inserts after micro-abrasive blasting passivation treatment. Firstly, a KT15 cemented carbide block of 100 mm × 30 mm × 20 mm was cut into the insert blanks of 12.8 mm × 12.8 mm × 4.8 mm by WEDM (wire cut electrical discharge machining). Secondly, the insert blanks were grinded by a manual operation. Thirdly, the nose radius of inserts was ground to 0.4 mm and the untreated cutting edge had a small radius with 6 μm before micro-abrasive blasting. Fourthly, the rake surface and major flank of cutting inserts were polished to Ra 0.1 μm. Finally, the finished insert was obtained after the cutting edges were passivated by micro-abrasive blasting.

The self-developed micro-abrasive blasting machine is shown in Fig. 2 and it mainly includes the air compressor, abrasive pump, abrasive box, cutting tool fixture, and nozzle. The compressed air source can provide a pressure with a range of 0.2 to 0.7 MPa through a pneumatic valve. The diameter of injecting nozzle is about 8 mm. The cutting inserts were fixed horizontally on the fixture, and the micro-abrasive blasting distance between nozzle and cutting edge was set as 75 mm. The injection angle between nozzle and cutting edge was chosen to be 45° in order to guarantee the symmetry and uniformity of edge during passivating. The investigated micro-abrasive blasting parameters include the injection pressure and sandblasting time, and abrasive concentration and size. The micro-topography of white corundum abrasives was observed using a scanning electron microscopy (SEM, SUPRA55, Germany) and depicted in Fig. 3. These white corundum abrasives exhibit a polyhedron shape with sharp edges, which can take an action of micro-removal with a minor damage on the cutting edge during passivating insert. After micro-abrasive blasting, the microstructure and topography of cutting edge were observed using a SEM and laser scanning microscope (LSM, VKX200K, Keyence, Japan). The passivation process for cutting edges of inserts was carried out by four steps. Firstly, the water and the white corundum abrasives were mixed in an abrasive box and stirred uniformly by manipulator to guarantee the uniformity of the micro-abrasive blasting. Secondly, the fluid mixture was speeded up by the high-pressure pump and erupted from the nozzle directly to crash to the cutting edge of inserts at a high speed. Thirdly, an amount of abrasive uninterruptedly abraded the sharp edge to reach the passivation effect with almost no damage. Finally, the abrasive particles accompanying with fluid went back to the abrasive box after collision and continued a new micro-abrasive blasting cycle. In conclusion, our self-developed micro-abrasive blasting machine is characterized by a simple structure, convenient operation, low energy consumption, security, and high sandblasting efficiency.

2.2 Experimental design

The cutting edge radius is usually with a range of several tens of microns. The larger edge radius can weaken the

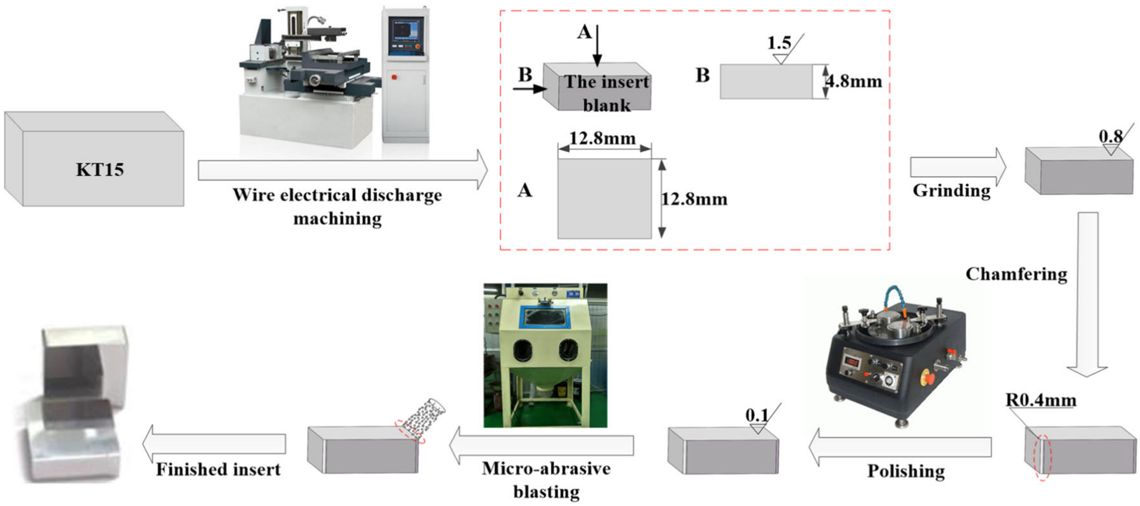

Fig. 1 The manufacturing process of inserts including grinding, chamfering, polishing, and micro-abrasive blasting passivating

sharpness of inserts and cause the increase of the cutting force and temperature, which reduce the cutting performance. The smaller edge radius also can weaken the robustness of inserts, which leads to the very easy chipping. The existed damages on the cutting edge, such as micro-indention, micro-cracks, and micro-poles caused by manufacturing the inserts, are very destructive to tool life because they can bring the unexpected tool failure. The edge quality can be evaluated by measuring the line roughness of edge. Therefore, the radius and line roughness of cutting edge are taken as the two main optimization objectives in our work. Two experimental methods were designed to evaluate the effects of micro-abrasive blasting process on the edge passivation. An orthogonal experiment was firstly designed in Table 1 to investigate the appropriate range of micro-abrasive blasting process parameters. A full factors experiment was then designed in Table 2, based on the optimized process parameters determined by orthogonal experiment, to find the optimum micro-abrasive blasting parameters and obtain the best edge quality and radius. The chosen experimental factors included the abrasive size and concentration, injection pressure and sandblasting time. In the orthogonal experimental analysis, the used abrasive particle sizes were 180 mesh, 240 mesh, 280 mesh, and 320 mesh, respectively. The abrasive concentration was defined by the percentage of weight ratio of abrasive to fluid mixture, which were 15, 20, 25, and 30%, respectively. The injection pressures were chosen as 0.3, 0.4, 0.5, and 0.6 MPa, and the sandblasting times were 40, 80, 120, and 160 s, respectively. After analyzing the orthogonal experimental results, the appropriate parameter ranges of edge passivation were obtained, and the optimum micro-abrasive blasting process, passivation mechanism, and damage were further investigated according to a full factors experimental.

To verify the cutting performance of passivated inserts by the micro-abrasive blasting process, three micro-abrasive blasting inserts were compared with no micro-abrasive blasting inserts by cutting experiment. A 17-4PH stainless steel was selected as the workpiece, and the cutting speed, cutting depth, and feed were set as 80 m/min, 0.15 mm, and 0.1 mm/r, respectively. The tool flank wear of inserts was measured at a distance of 90 mm using a tool microscope (Dino capture 2.0, China). It was considered that the insert had reached the normal tool life if the flank wear of 0.3 mm

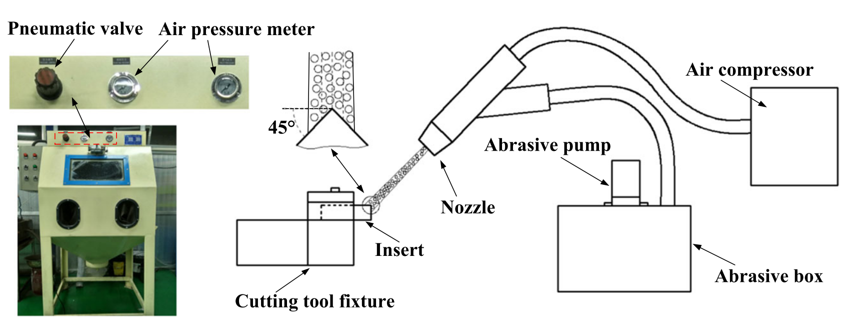

Fig. 2 The structure of micro-abrasive blasting equipment

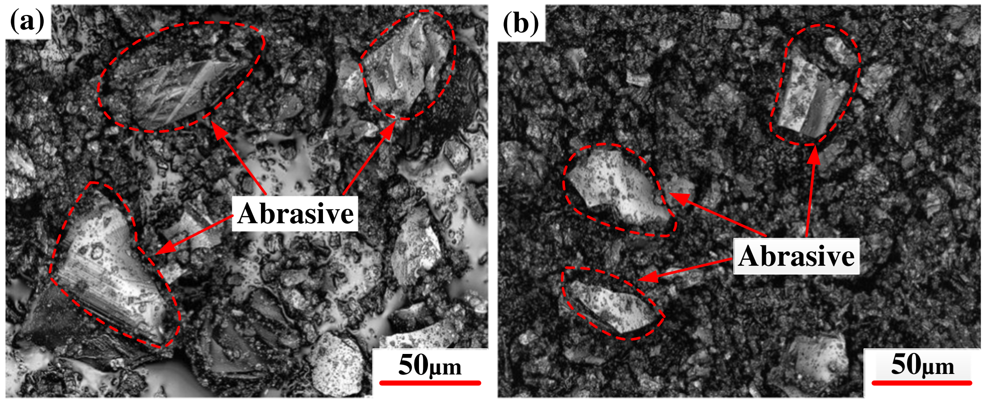

Fig. 3 SEM micrographs of white corundum abrasives with different meshes: **a** 280 mesh and **b** 320 mesh

was achieved, and the cutting performance of the passivated insert was evaluated by comparing the tool life and cutting force of the insert.

3 Results and discussion

3.1 Micro-abrasive blasting parameters

The results of the orthogonal experiment are shown in Table 3. The mean value of each parameter corresponding to the edge radius and roughness can be calculated by Table 3 to draw the Figs. 4 and 5 for further analysis.

Figures 4 and 5 show the effects of micro-abrasive blasting parameters on the edge roughness and radius, respectively, according to the analysis of orthogonal experiment. The cutting edge trended to the poor quality with the increase of sandblasting time, and the low and high abrasive concentrations were beneficial to the edge quality. The qualitative relationships of edge quality with injection pressure and abrasive size were not clearly understood. However, the low injection pressure and large abrasive mesh could passivate the cutting edge to have a good quality. The variation regulations of edge radius with parameters were different from the edge quality. The edge radius increased as the injection pressure or sandblasting time increased and decreased with the increase of abrasive mesh. The increase of abrasive concentration made the edge radius firstly increased then decreased. For the cutting edge, the lower the roughness value, the better the edge quality. The edge radius of inserts could neither be too big or too small and edge radius was usually with a range of several tens of microns. The big edge radius could weaken the sharpness of cutting edges and the small one could reduce the robustness of cutting edges. So, the lower roughness value and edge radius were considered, caused by micro-abrasive blasting parameters according to the orthogonal experiment. As can be seen from the orthogonal experiment results, the edge roughness and radius must be lower when the size of abrasive was set as 320 mesh. And lower edge roughness meant that inserts had smaller damage and better edge quality. So, 320 mesh abrasive was chosen to carry out a full factors experiment. The suitable parameters range is shown in Table 2.

Figure 6 shows that the relationship between abrasive concentration and cutting edge radius. The cutting edge radius firstly increased and then decreased with the increase of abrasive concentration under the injection pressures of 0.2 and 0.25 MPa, while the cutting edge radius had always increase trends with the increase of abrasive concentration under the injection pressures of 0.3 and 0.35 MPa. For the low injection pressure (0.2, 0.25 MPa), the speed of single abrasive particle was relatively slow, with the increase of abrasive concentration, the change of the speed in single abrasive particle was not obvious in the initial stage, and the main factor which affected the passivation capacity should be abrasive

Table 1 Design of the orthogonal experiment

Test number	Injection pressure (MPa)	Abrasive size (mesh)	Abrasive concentration (%)	Sandblasting time (s)
1	0.3	180	30	40
2	0.3	240	25	80
3	0.3	280	20	120
4	0.3	320	15	160
5	0.4	180	25	120
6	0.4	240	30	160
7	0.4	280	15	40
8	0.4	320	20	80
9	0.5	180	20	160
10	0.5	240	15	120
11	0.5	280	30	80
12	0.5	320	25	40
13	0.6	180	15	80
14	0.6	240	20	40
15	0.6	280	25	160
16	0.6	320	30	120

Table 2 Design of the full factors experiment

Test number	Abrasive concentration (%)	Injection pressure (MPa)	Sandblasting time (s)	Test number	Abrasive concentration (%)	Injection pressure (MPa)	Sandblasting time (s)
1	10	0.2	20	33	20	0.2	20
2	10	0.2	30	34	20	0.2	30
3	10	0.2	40	35	20	0.2	40
4	10	0.2	50	36	20	0.2	50
5	10	0.25	20	37	20	0.25	20
6	10	0.25	30	38	20	0.25	30
7	10	0.25	40	39	20	0.25	40
8	10	0.25	50	40	20	0.25	50
9	10	0.3	20	41	20	0.3	20
10	10	0.3	30	42	20	0.3	30
11	10	0.3	40	43	20	0.3	40
12	10	0.3	50	44	20	0.3	50
13	10	0.35	20	45	20	0.35	20
14	10	0.35	30	46	20	0.35	30
15	10	0.35	40	47	20	0.35	40
16	10	0.35	50	48	20	0.35	50
17	15	0.2	20	49	25	0.2	20
18	15	0.2	30	50	25	0.2	30
19	15	0.2	40	51	25	0.2	40
20	15	0.2	50	52	25	0.2	50
21	15	0.25	20	53	25	0.25	20
22	15	0.25	30	54	25	0.25	30
23	15	0.25	40	55	25	0.25	40
24	15	0.25	50	56	25	0.25	50
25	15	0.3	20	57	25	0.3	20
26	15	0.3	30	58	25	0.3	30
27	15	0.3	40	59	25	0.3	40
28	15	0.3	50	60	25	0.3	50
29	15	0.35	20	61	25	0.35	20
30	15	0.35	30	62	25	0.35	30
31	15	0.35	40	63	25	0.35	40
32	15	0.35	50	64	25	0.35	50

concentration. And the impacting frequencies of abrasive particle on the cutting edge were increased with the increase of abrasive concentration, as the result that the passivation capacity was strengthened. According to the law of conservation of energy, the speed of abrasive particle will lost a lot if the abrasive concentration is too great. However, the most key factor affecting the passivation capacity of micro-abrasive blasting for cutting edge was the impacting speed. The decrease of the impacting speed of abrasive particle would weaken the passivation capacity, which resulted in this relationship between edge radius and abrasive concentration. Under the condition of great abrasive concentration, the change of the speed in single abrasive particles was always not obvious even though the micro-abrasive blasting pressure rose to 0.3 or 0.35 MPa. The strengthened trends of passivation capacity owing to the increase of abrasive concentration were greater than the weak trends of passivation capacity due to the decrease of impacting speed. Therefore, the passivation capacity was strengthened in relatively higher injection pressure. On a whole, the higher injection pressure could bring about a stronger passivation capability to cutting edge.

Three representative passivated inserts with 16, 26, and 36 μm edge radiuses and one unpassivated inserts with 6 μm were utilized to carry out cutting experiment. Table 4 shows the cutting time for each insert when the flank wear was up to wear standard (0.3 mm). The tool lives of those

Table 3 Results of the orthogonal experiment

Test number	Edge radius (μm)	Edge roughness (μm)
1	213.1	0.485
2	126.9	0.485
3	132.3	0.499
4	93.9	0.470
5	493.9	1.232
6	267.3	0.550
7	95.9	0.574
8	124.3	0.432
9	509.2	1.018
10	209.4	0.450
11	176.3	0.564
12	134.9	0.475
13	255.8	0.799
14	157.9	0.673
15	353.7	1.058
16	267.9	0.502

passivated inserts were improved by 12, 20, and 37%, respectively, compared to the unpassivated insert.

Figure 7 compared the tool lives of passivated and unpassivated inserts in machining of a 17-4PH stainless steel. The Insert SA was treated by the micro-abrasive blasting and its cutting edge radius was about 36 μm. The Insert SB was untreated by the micro-abrasive blasting and its cutting edge radius was about 6 μm. It was seen that the tool life of the passivated insert treated by micro-abrasive blasting was improved by 37% than the unpassivated one when the flank wear was up to wear standard. Moreover, the former exhibited the smaller flank wear than the latter at the same machining time. Figures 8 and 9 show the cutting forces caused by Inserts SA and SB. The cutting forces caused by these two inserts increased gradually with the machining time because of tool wear. Before the machining of 30 min, the cutting forces caused by Insert SA were slightly higher than Insert SB because of the larger edge radius of Insert SA. After the machining of 30 min, Insert SB produced the rapidly increased cutting forces but the cutting forces of Insert SA still kept constant until 60 min. At 50 min, the cutting forces of Insert SB were more than twice as large as Insert SA. This demonstrated that Insert SB began to enter a severe wear stage at 30 min. The first wear stages (rapid wear) of Inserts SA and SB appeared at the initial 5 and 7 min, respectively, according to Fig.

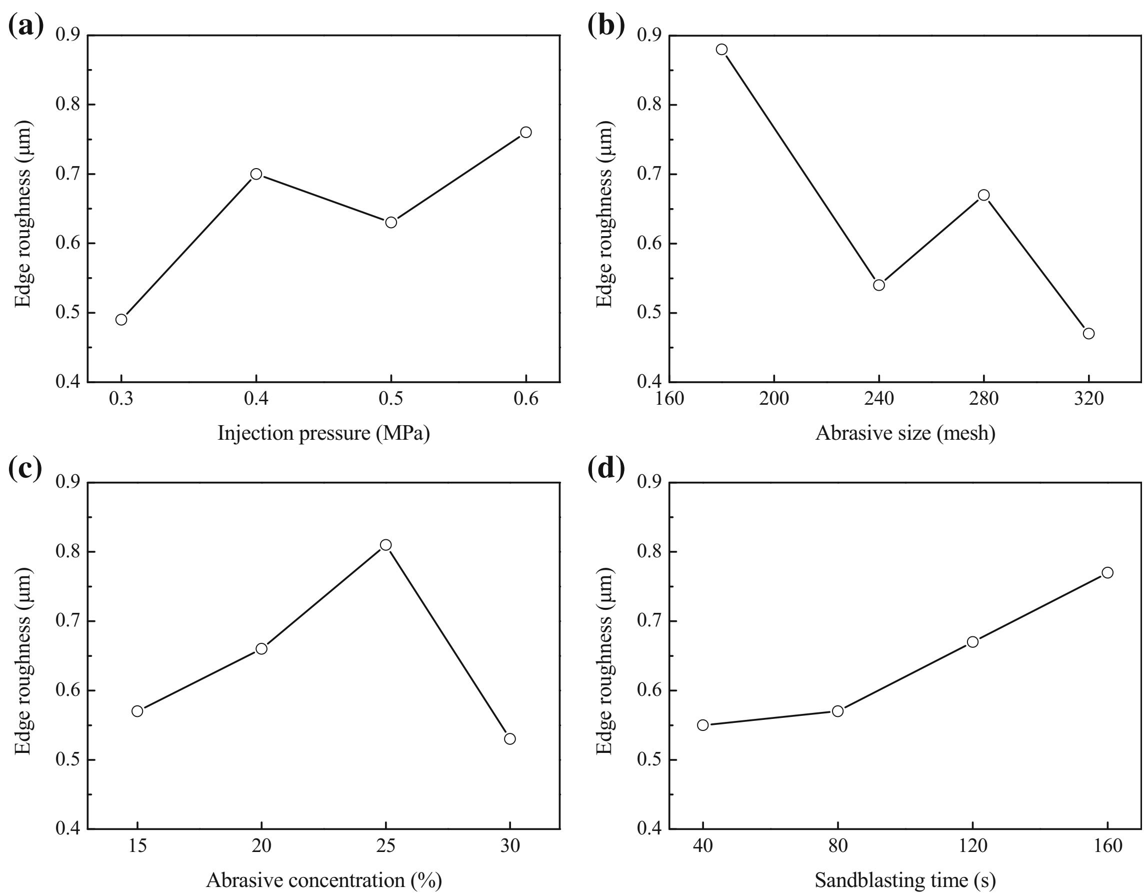

Fig. 4 Trends of the effects of micro-abrasive blasting parameters of **a** injection pressure (MPa), **b** abrasive size (mesh), **c** abrasive concentration (%), and **d** sandblasting time (s) on the edge roughness according to the orthogonal experiment

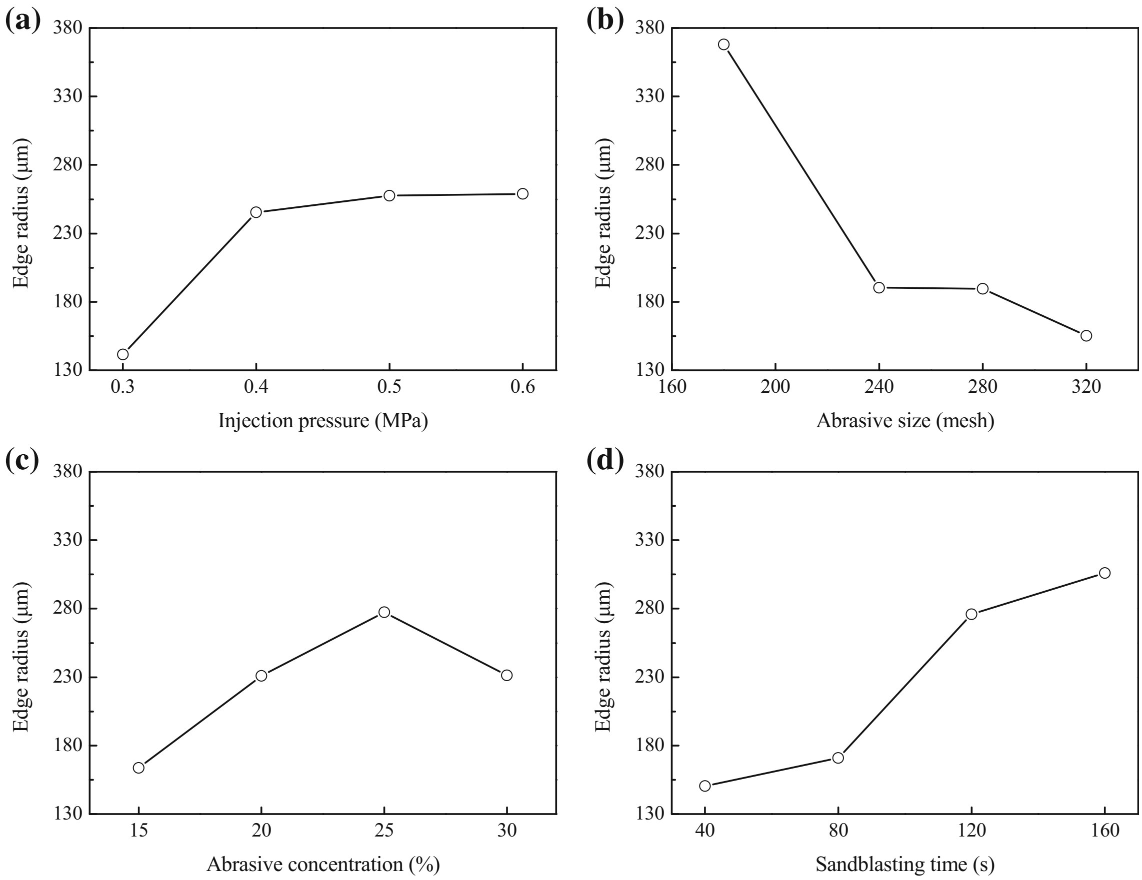

Fig. 5 Trends of the effects of micro-abrasive blasting parameters of **a** injection pressure (MPa), **b** abrasive size (mesh), **c** abrasive concentration (%), and **d** sandblasting time (s) on the edge radius according to the orthogonal experiment

7. At the initial second wear stage (normal wear), Insert SA had a stronger resistance to wear than Insert SB even if it produced the slightly higher cutting forces, while the worn edge of Insert SB further could give a rise to the higher cutting forces at the later second wear stage, which induced the shorter tool life. Therefore, the insert passivated by micro-abrasive blasting was beneficial to reduce the cutting force and prolong the tool life, which meant that it was feasible to improve the cutting edge quality and cutting performance using micro-abrasive blasting technology.

3.2 Microstructure and passivation mechanism

To explain the actions of micro-sands and water on edge passivation, a water jet without micro-abrasive was utilized to spray the cutting edge, under a pressure of 0.35 MPa in 50 s. Figure 10 shows the LSM patterns before and after the micro-abrasive blasting treatment and pure water jet treatment. The cross-sections I, II, and III of cutting edge were set to observe edge topography, and the lines l_1, l_2, and l_3 on cutting edge were selected to measure line roughness of edge. The topography and radius of the cutting edge passivated by micro-abrasive blasting had changed significantly, and the cutting edge pattern was nearly unchanged only by water power. Besides, the better edge quality of insert was obtained due to the decrease of edge roughness after micro-abrasive blasting treatment. Although the cutting edge pattern and roughness were nearly unchanged after pure water jet, the water also played an important role in wet micro-abrasive blasting. Firstly, the kinetic energy of water could wash away the materials that had been removed on the insert surface. On the other hand, the crack could be expanded by water wedge, which could accelerate the material removal to passivate the sharp edge.

Cemented carbide belongs to a brittle material. The mechanisms of precision finishing brittle materials were summarized as grain removal, material peeling, brittle fracture, and micro-crushing grain boundary [17, 18]. Figure 11 shows the SEM micrographs of the cutting edge before micro-abrasive blasting treatment and the passivated cutting edge using the optimum micro-abrasive blasting parameters (injection pressure 0.35 MPa, abrasive size 320 mesh, sandblasting time 50 s, and abrasive concentration 20%). The passivated cutting edge of inserts exhibited an arc shape, which could provide a smooth transition between the rake face and flank face of inserts. The micro-topography of the cutting edge could be

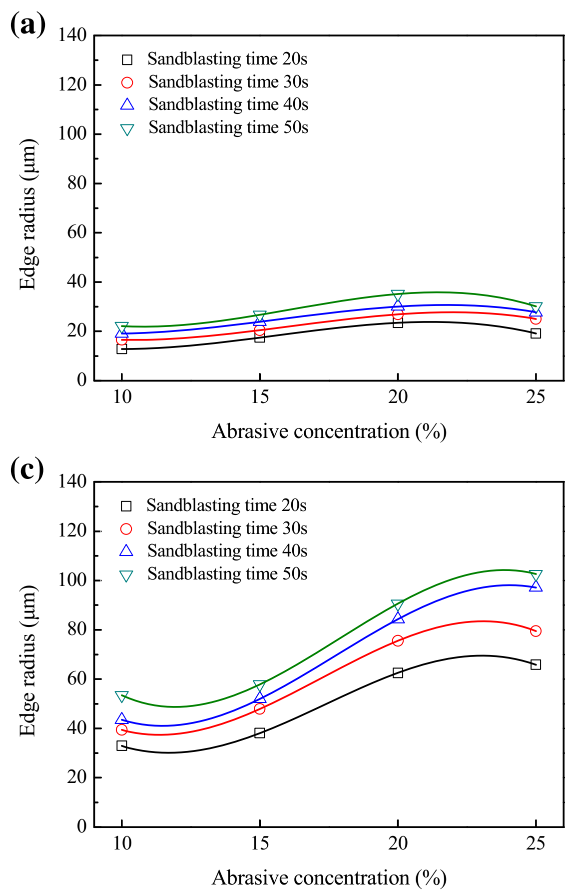

Fig. 6 The relationships of abrasive concentration with edge radius under different injection pressures of **a** 0.2 MPa, **b** 0.25 MPa, **c** 0.3 MPa, and **d** 0.35 MPa

observed by enlarging the cutting edge area. It can be seen that there were some defects on the cutting edge before micro-abrasive blasting, such as cavities, cracks, scratches, and broken grains. After micro-abrasive blasting, the edge was smoother and had a better edge quality, and it was more important that the originally existed defects almost had been removed to form a cutting edge with no damage. It was known that the KT15 cemented carbide was composed of WC, solid solution, and binder phases. As a matter of fact, the removal process of these phases by the impaction of abrasives on the grains of cutting edges should be definitely different because of their different properties. There were some clear scratches on the arc edge, revealing that the movement of white corundum abrasives scraped the microstructure of KT15 carbide mainly due to the micro-cutting implanted by the sharp edges of many abrasives (seen in Fig. 11d). Furthermore, the scratches mainly existed in binder phases because the binder

Table 4 Tool lives of inserts with different edge radiuses at 0.3 mm of flank wear

Edge radius (μm)	Flank wear (mm)	Cutting time (s)
6	0.3	2992
16	0.3	3350
26	0.3	3586
36	0.3	4068

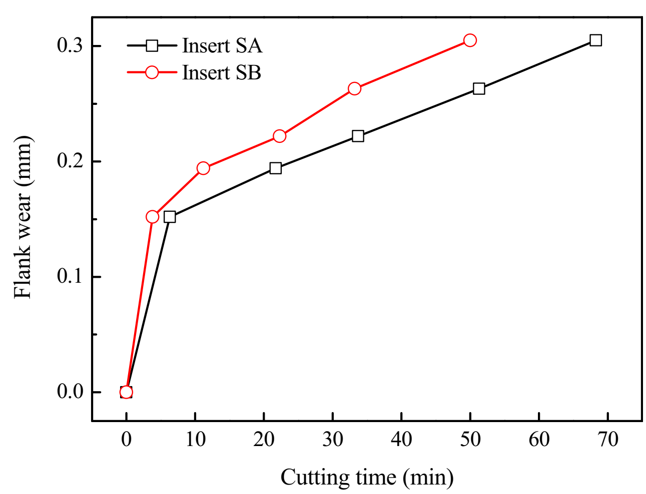

Fig. 7 The change chart of the flank wear changed with cutting time

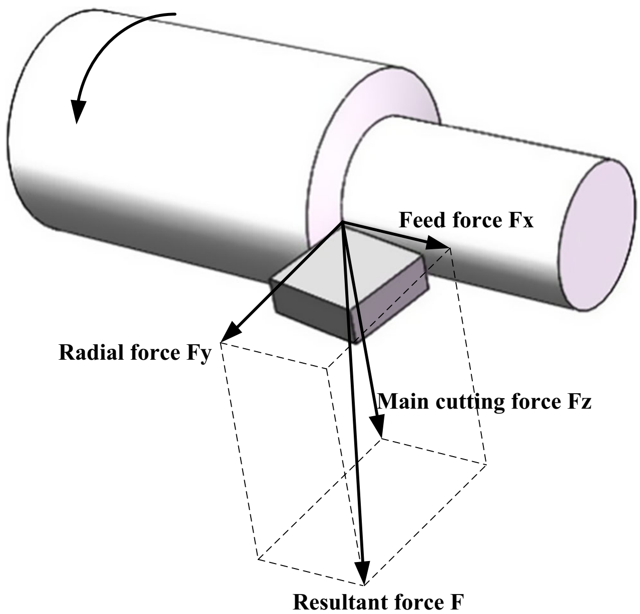

Fig. 8 The diagrammatic sketch of the cutting force

phases were soft relative to hard phases. On the contrary, some removal of the hard phases in the cemented carbide of inserts could be ascribed to crack propagation caused by brittle fracture under the impact of abrasives. Abrasive particles with sharp edges made the hard phases-generated radial and lateral cracks, and the high frequency impact of abrasives caused the expansion of the lateral cracks, and then formed a mesh crack to complete the material removal [19]. The material removal of cutting edge in micro-abrasive blasting treatment mainly included the removal of hard phases and binder phases. Compared to hard phases of inserts, the binder phase seemed to be removed easily and it was more obviously observed in Fig. 11d. Generally, the cement carbide was characterized by a skeleton microstructure, in which the binder phase filled in the microstructure to bond all of hard phases including WC and solid solution grains. The binder and hard phases had a good strength and ductile, and the hard phases had a good red hardness and wear resistance. The combination of these properties of binder and hard phases ensured the KT15 cemented carbide to become a candidate as tool material.

It was undoubted that the passivation of cutting edge of inserts could improve the cutting performance and tool life, and it could remove many existing defects of cutting edge after manufacturing to take account of sharpness and robustness of inserts. Though the passivated area was extremely small for the cutting edge, the abrasives had to be interacted simultaneously with several phases with different properties,

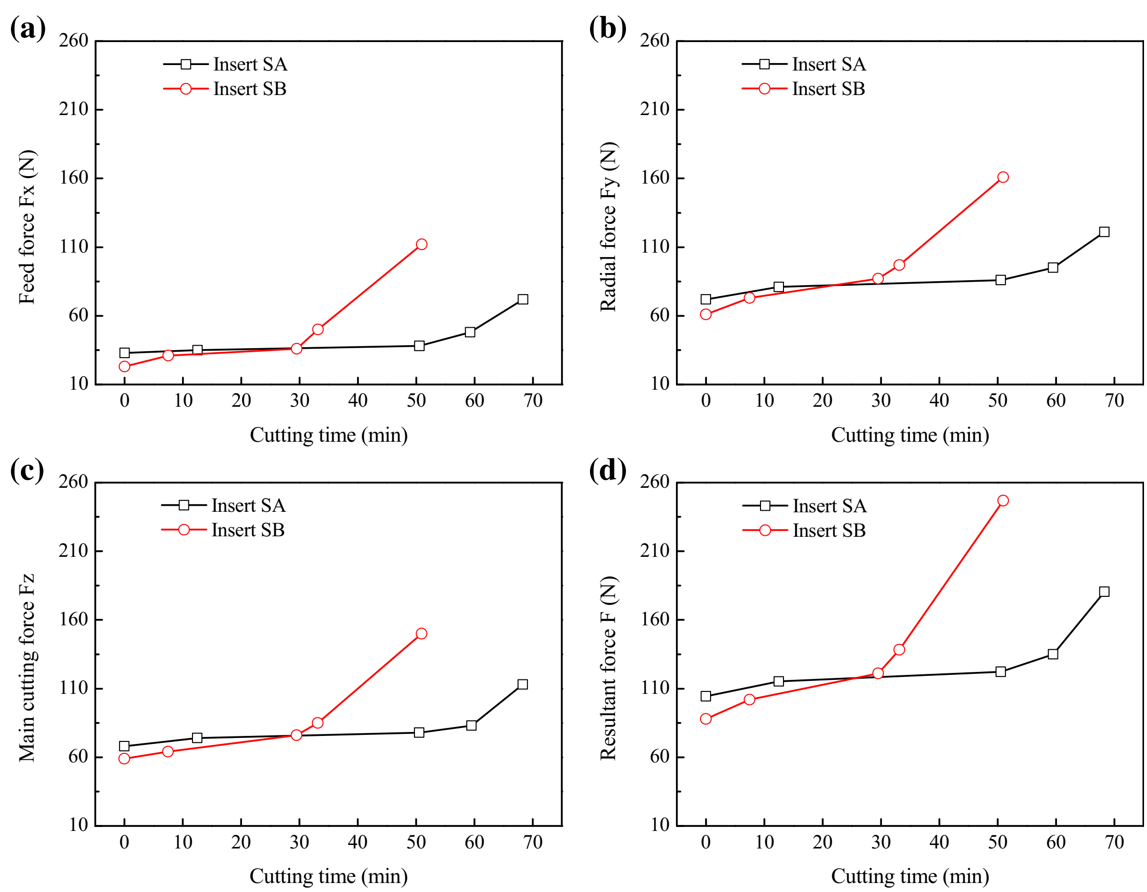

Fig. 9 The cutting forces caused by Inserts SA and SB in machining of 17-4PH stainless steel

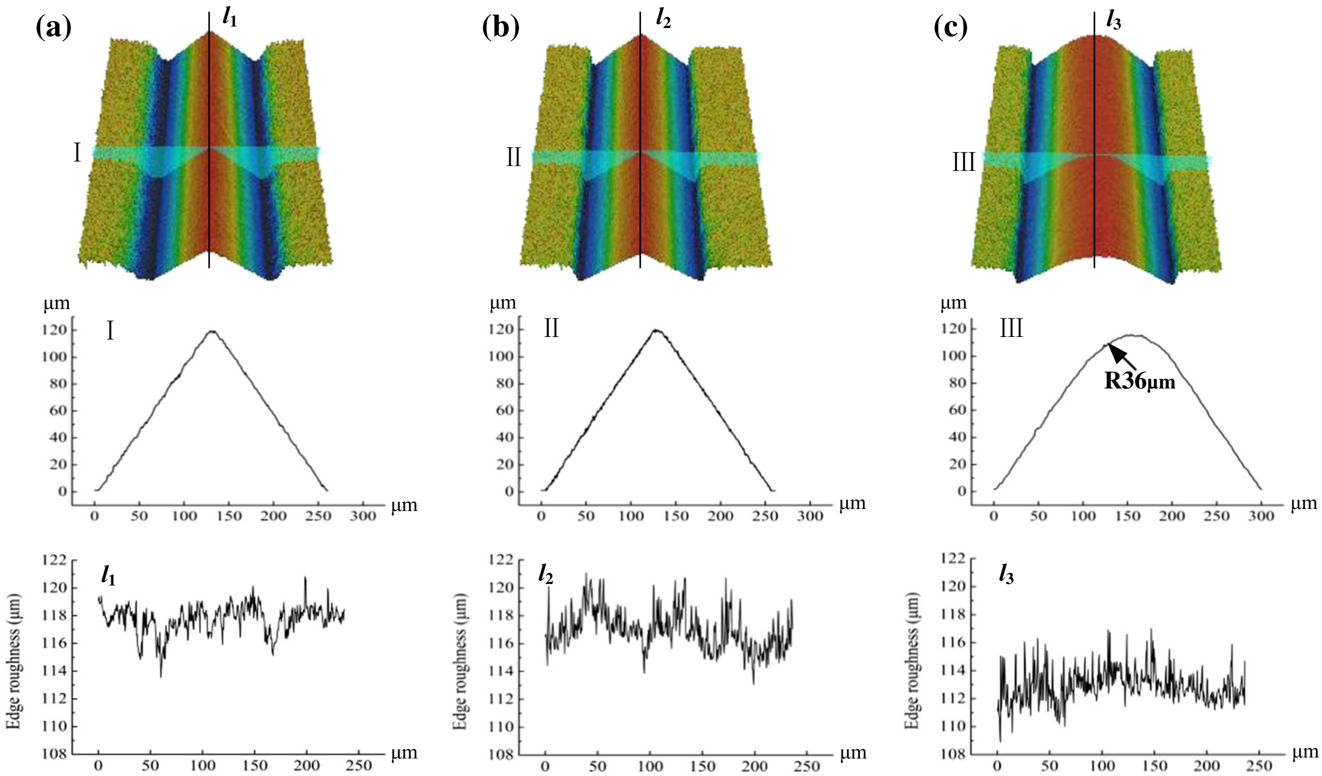

Fig. 10 LSM patterns of cutting edge. **a** Before micro-abrasive blasting treatment. **b** Pure water jet treatment. **c** After micro-abrasive blasting treatment

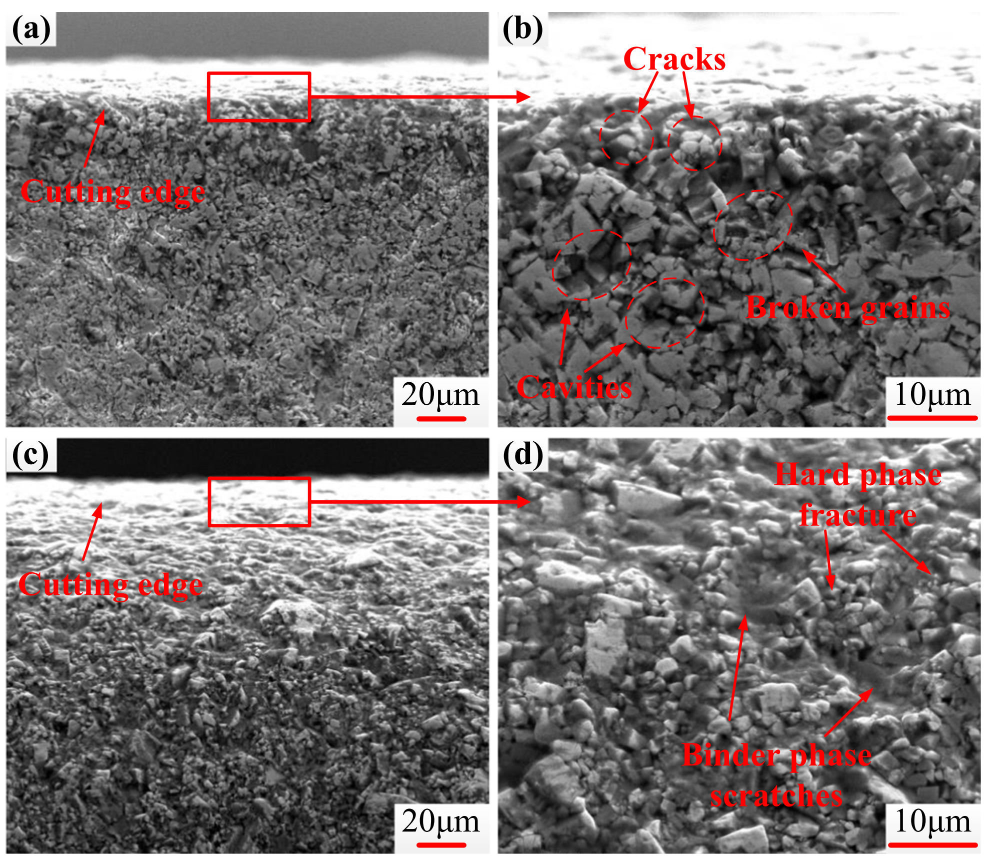

Fig. 11 SEM micrographs of the cutting edges. **a** Cutting edge untreated by micro-abrasive blasting. **c** Cutting edge treated by micro-abrasive blasting

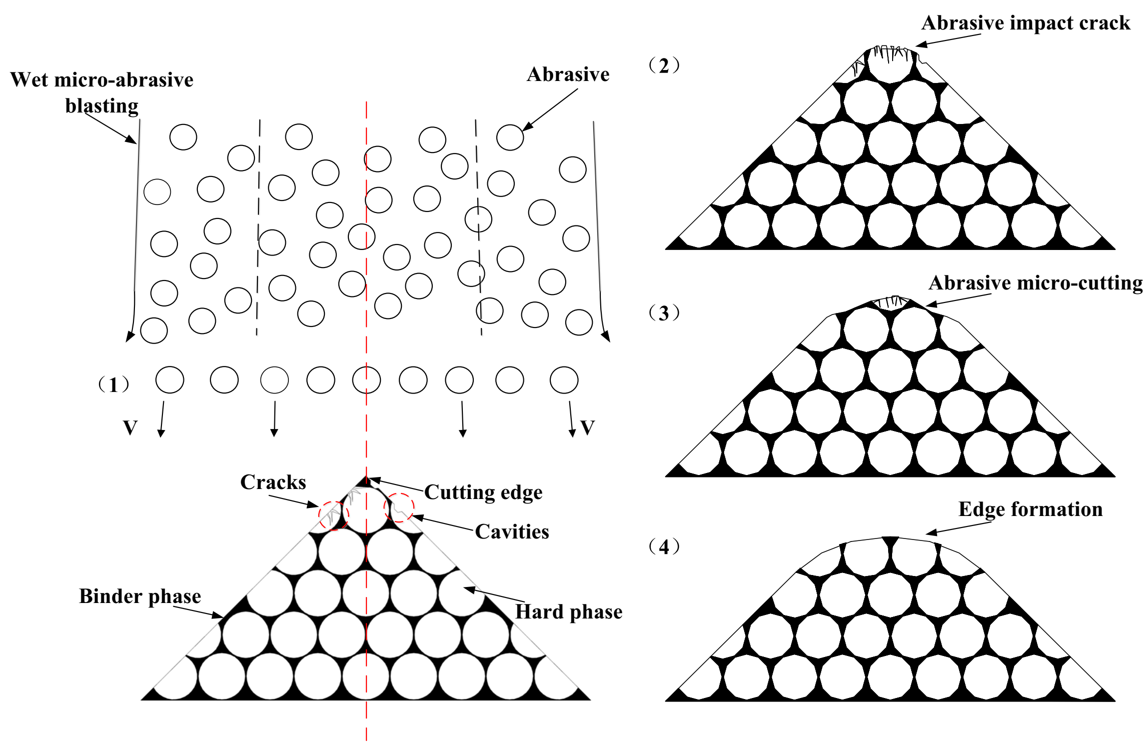

Fig. 12 The passivation mechanism of the sharp edge of inserts during micro-abrasive blasting

and thus, the different erosion processes and mechanisms must occurred during passivating. Figure 12 shows the passivation process of the cutting edge using micro-abrasive blasting treatment. Before micro-abrasive blasting, the unpassivated edge exhibited a sharp angle converged by the rake face and flank face of inserts, and there were some defects such as cracks, cavities, scratches, and broken grains on the cutting edge. Therefore, the edge passivation process could be described as follows: firstly, the abrasives driven by the water jet impact the grains on the cutting edge, and the softer binder phase was firstly removed due to the impact of the abrasives. Secondly, some cracks were initiated on some hard phase grains by the continuously impacting and water wedge, and then, hard phase grains would be removed due to the extension between lateral cracks. At the same time, edge defects also were removed with the removal of binder and hard phases. Thirdly, the residual hard phases and binder phases after rupturing and impacting would be removed by the effect of micro-cutting, and the cutting edges finally were trimmed to smooth under the influence of micro-cutting and water wedge.

4 Conclusion

(1) The micro-abrasive blasting could change the cutting edge geometry without bringing out any damages to passivate edge. The micro-abrasive blasting parameters could control the edge passivation effects, and parameters had a different influence on passivation effect. The higher injection pressure (0.35 MPa) and abrasive concentration (20~25%), longer sandblasting time (50s), and smaller abrasive size (320 mesh) were good processing parameters to provide a stronger passivation capability to cutting edge.

(2) For insert passivation of wet micro-abrasive blasting, it mainly depended on the impacting and micro-cutting action to complete edge passivation and remove defects. But water also played an important role in micro-abrasive blasting technology. Firstly, the kinetic energy and water wedge could accelerate the edge passivation. Secondly, water could suppress dust and improve micro-abrasive blasting environment, which was more environmental.

(3) The passivation mechanism of micro-abrasive blasting was that binder phases were firstly removed by micro-cutting, and cracks were generated in hard phases by the uninterrupted impact of abrasives, then the hard phases were fractured due to the crack extension. Also, the original defects on the cutting edge were removed due to the removal of edge materials.

(4) The insert treated by micro-abrasive blasting had a lower edge roughness and higher life and relatively stable cutting force, which could obviously improve the quality of cutting edge and eliminate the existing defects of inserts by the previous manufacturing process. Therefore, our

work fully demonstrated that it was feasible to passivate the cutting edge of inserts using the wet micro-abrasive blasting.

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