EFFECT OF RESIN AND GRAPHITE OF THE BRONZE-BONDED DIAMOND COMPOSITE TOOLS ON THE DRY GRINDING BK7 GLASSES

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Abstract

The paper was to investigate the effect of graphite and resin added into the bronze-bonded diamond composite tools on grinding performance. These tools operated in the dry grinding BK7 glasses were used to evaluate the performance of grinding forces, the diamond wear, the material removal mechanisms and the surface roughness under four different conditions of the spindle speeds and table speeds.

The experimental results showed that the moderate combination of graphite and resin added into the bronze-bonded diamond tool during the dry grinding BK7 glass, which provides a multifunction of lubrication, heat dissipation and chip removal ability in the grinding zone, was employed, the resulting worn diamond at the end of life showed a flat with a slightly protrusion and the matrix displayed a slightly rough condition. This tool can obtain a better dry grinding performance. In addition, the low spindle speed adopted in the dry grinding can obtain a relatively better tool life. Furthermore, the material removal behavior of dry grinding BK7 glass without any aids of coolant mainly displayed a brittle fracture, and there are many residual chips adhered on the workpiece surface, which inhibits the diamond grits of the tool to perform a cutting action.

1 Introduction

The metal-bonded diamond composite tools [1-2] have been usually used for grinding various hard and brittle materials such as silicon, glass, alumina, stone, etc. Based on the environmental considerations, the dry condition will be sometimes employed to grind these materials. Zhang et al [3] indicated that in order to reduce the workpiece temperature during the grinding of ceramics, which avoids the wheel to produce glazing., the following methods can be adopted: (1) using a wheel of the coarser grit size, the softer grade, and the opener structure, (2) using a lower wheel speed, (3) reducing the depth of cut, (4) increasing a larger transverse rate, and (5) using a coolant. Namba et al [4] indicated that using grit size below 20 μm of resin-bonded diamond wheel during the grinding optical glass can obtain a ductile grinding of the workpiece surface. When the diamond grit size of 20-100μm for resin-bonded diamond wheel was employed during the grinding glass, the resulting material removal behavior was the coexistence of ductile grinding and brittle fracture. However, the poor machinability of ceramics causes difficulties in dry grinding. Hence, in this work the bronze-bonded composite tools containing graphite and resin fillers would be investigated to study the performance of dry grinding BK7 glasses.

2 The experimental method

2.1 Bronze-bonded diamond composite tools

Four different amounts of resin and graphite for the bronze-bonded diamond composite tools were fabricated for experimental studies. Table 1 gives the specifications of the bronze-bonded diamond composite tools used. Medium strength's diamond of 30-40 μm with 50 concentrations (12.5 Vol.%) was added into the metal bond. In order to regulate the properties of the diamond composite tools, graphite and resin were added into metal bond. The process of manufacturing these diamond composite tools used compression molding technique at 650°C. Diamond composite tools with diameter of 10mm were used in the test as shown in Fig.1. The typical microstructure on the fracture surface for diamond composite C as shown in Fig.2 displayed some pores on the matrix.

2.2 End grinding tests

End grinding tests of the bronze-bonded diamond composite tools were performed on a vertical CNC machining center, its engagement kinematics being shown in Fig.3. The grinding conditions in the tests are given in Table 2. The spindle speed/table speed used in the test was 1,000/15, 2,000/25, 3,000/35, and 4000/45 rpm/mm/min, and the depth of cut was fixed at 3 μm. Throughout the tests, dry grinding was employed. The workpiece material used was BK7 glass. For each tool the available grinding distance between two dressings and their responding grinding forces, and surface roughness were measured to evaluate the tool performance. For each test, normal, feed and lateral grinding force components were measured by means of a quartz piezoelectric type dynamometer (KISTLER type 9257B). Wear behaviors of the diamond particles and the bond and the appearance of the ground glass after grinding were examined using a SEM and a toolmaker's microscope. Besides, the surface roughness of the workpiece after grinding was examined using a profilometer.

3 Results and discussions

3.1. Grinding forces

The variations of the normal grinding forces during dry grinding BK7 glass with the available grinding distance between two dressings were shown in Fig.4 for the bronze-bonded diamond composite tools at the spindle speed of 2,000 rpm and the table speed of 25 mm/min. It can be seen that the tool C during the dry BK7 glass can maintain the relatively longest grinding distance of about 3200 mm between the adjacent two dressing, and its normal grinding force progressively increases like-sawtooth until the end of grinding. Causing this phenomenon may be the effect of the chip removal during the dry grinding without any aid. Finally, it can't work due to the high noise and chatter or burn as shown in Fig.5. For tool B, the available grinding distance can maintain to about 1900 mm during the dry grinding BK7, and its normal grinding force gradually increases like-sawtooth to about 26 N, which causes the tool high noise and chatter or burn. However, for tools A and D, the grinding distance only can maintain to about 500 mm, which causes the tools high noise and chatter, thereby can't work continuously. Although the grinding forces are relatively low. But, the chip removal during the dry grinding BK7 glass is poor. Causing the results of these diamond composite tools may be attributed to the difference of the amount of graphite and resin added into the bronze bond. Because they can provide lubrication, heat dissipation and chip removal ability in the grinding zone during the dry grinding. In the experimental observation the chip removal ability in the grinding zone is very important during the dry grinding BK7 glass.

Fig.6 showed the available grinding distance with four different grinding conditions for four diamond composite tools. It can be seen that the tool C is the relatively longest grinding distance obtained at the spindle speed of 2000 rpm and the table speed of 25 mm/min, next to at the spindle speed of 1000 rpm and the table speed of 15 mm/min. At the higher spindle speed of 3000 rpm and 4000 rpm, the available grinding distance during the dry grinding is relatively shorter. This may be due to the higher grinding temperature to cause the chip difficult to escape. In addition, the order of the available grinding distance obtained during the dry grinding BK7 glass from high to low was diamond tools C > B > D > A. It implies that the combination of graphite and resin added into the bronze bond can produce a better tool life of dry grinding performance, which provides a multifunction of lubrication, heat dissipation and chip removal ability in the grinding zone during the dry grinding BK7 glass. Furthermore, the low spindle speed adopted in the dry grinding can obtain a relatively better grinding life.

3.2 Wear behaviors of diamond composite tools

The worn behaviors of the medium zone of diamond composite tools A, B, C, and D after the end life of dry grinding BK7 glass at the spindle speed of 2000 rpm and the table speed of 15 mm/min were shown in Figs.7(a)-(d), respectively. For diamond tool A, most of diamond grits on the worn surface displayed the flatten appearance (Fig.7(a)) and the bond matrix produced a rubbing flat condition. For diamond tool D, the bond matrix showed a more amount of pores with a weak structure (Fig.7(d)) and a more amount of diamond grit pulled-out and flatten particles. Although the worn surfaces of tools showed a small number of chips, but there are many chips adhered on the workpiece surface. Causing tools A and D only maintains a short grinding distance to produce a high noise and chatter during the dry grinding BK7 glass. For the diamond tool B, the worn surface showed many of the flatten diamond particles (Fig.7(b)). For diamond tool C, the bond matrix in Fig.7(c) showed a rough appearance and the diamond grits displayed the flat conditions. In a situation, the resulting final grinding forces develop to a larger condition (refer to Fig.4), which causes the tool to can not work. Due to containing graphite and resin for tools B and C, the resulting tools have a better lubrication and chip removal ability. Hence, the tool C produces the relatively best grinding distance and grinding ratio among all tools.

In addition, the worn surface obtained by tool A at the spindle speed of 4000 rpm and the table speed of 45mm/min displayed a flat appearance and a flat diamond on the matrix as shown in Fig.8. Oppositely, at a relatively lower spindle speed of 1000 rpm and 2000 rpm the worn surface shows a relatively rough appearance, but the diamond grits also produce a flat state. It implies that using a relatively low spindle speed during the dry grinding BK7 glass has a better diamond cutting ability, thereby causing a better tool performance.

3.3 Material removal mechanism and surface roughness of Bk7 glass

The surfaces on the trace of BK7 glass workpiece after dry grinding by diamond tool C at four different grinding conditions were shown in Figs.9(a)-(d), respectively. From the Fig.9(a), it can be seen that there were many chips adhered on the ground surface of glass to form a plastic sliding appearance at the spindle speed of 1000 rpm. At the spindle speed of 2000 rpm, the workpiece surface has many residual chips (Fig.9(b)) on the trace and the medial cracks and lateral cracks formed. At the spindle speed of 3000 rpm, the workpiece surface has a relatively less amount of residual chips (Fig.9(c)) on the the trace, and the medial cracks and lateral cracks are produced. At the spindle speed of 4000 rpm, the workpiece surface on the center of the trace has a less amount of residual chips (Fig.9(d)) due to a better chip removal of a higher centrifugal action, and the medial cracks and lateral cracks formed. In summary, the material removal behavior of dry grinding BK7 glass without any aids mainly displays a brittle fracture, and there are many residual chips adhered on the workpiece surface, which inhibits the diamond grits of the tool to perform a cutting action. Although the graphite and resin added into the metal bond diamond tool can aid the action of lubrication, heat dissipation and chip removal and the depth of cut is only 3 μm during the dry grinding, the workpiece surface of BK7 glass ground still produces most of brittle fracture, not ductile grinding.

Fig.10 showed the average surface roughness of the workpiece before the near end of dry grinding for four diamond tools at four different grinding conditions. It can be seen that the workpiece surface ground by diamond tool D during the dry grindingBK7 glass displays a relatively best roughness, next to the tool C, and the worst roughness of the workpiece is produced by the tool A. It implies that the more amount of resin added into the bronze bond can produce the better surface roughness during the dry grinding BK7 glass. This may be due to heat dissipation and chip removal ability in the grinding zone during the dry grinding BK7 glass. But, the difference of the roughness produced by four tools is not too large due to the same diamond size of 30-40 μm used.

4 Conclusions

Based on the results of this work, the following conclusions can be drawn:

(1) The worn diamonds of a tool containing the more amounts of graphite and no resin, which displays a relatively stronger structure, at the end of life for dry grinding BK7 glass showed mainly the flat appearance with a smoother matrix. The resulting tool life is relatively lower. When the tool containing the less amount of graphite and the more amount of resin was employed, the worn diamond at the end of life showed a flat with a slightly protrusion and the matrix displayed a slightly rough condition, which has a relatively better tool life. When a tool containing no graphite and the more amount of resin, which causes a weaker and looser structure, was employed, the resulting worn surface showed a relatively more amount of diamond pulled-out and a flat diamond appearance at the end of tool life, which causes a relatively shorter tool life.

(2)When the tool during the dry grinding BK7 glass was operated at a higher spindle speed, the worn surface displayed a severer glazing appearance and many flat diamond particles on the matrix. Oppositely, at a relatively lower spindle speed operated the worn surface showed a relatively rough appearance, but the diamond grits produced a flat state as well. Hence, using a relatively low spindle speed during the dry grinding BK7 glass has a better diamond cutting ability, thereby causing a relatively better tool life.

(3) The material removal behavior of dry grinding BK7 glass without any aids of coolant mainly displays a brittle fracture, and there are many

residual chips adhered on the workpiece surface, which inhibits the diamond grits of the tool to perform a cutting action. In addition, the workpiece ground by the tool containing a more amount of resin added into the bronze bond can produce the better surface roughness during the dry grinding BK7 glass.

Acknowledgments

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Table 1 Specifications of the bronze-bonded diamond composite tools

Tool type	85/15 Bronze (Vol.%)	Graphite (Vol.%)	Resin (Vol.%)	SiC Filler		Diamond		
				Size (μm)	Amount (Vol.%)	Type	Size (μm)	Concentration
A	60	30	0	15	10	PK-7E	30-40	50
B	60	20	10	15	10	PK-7E	30-40	50
C	60	10	20	15	10	PK-7E	30-40	50
D	60	0	30	15	10	PK-7E	30-40	50

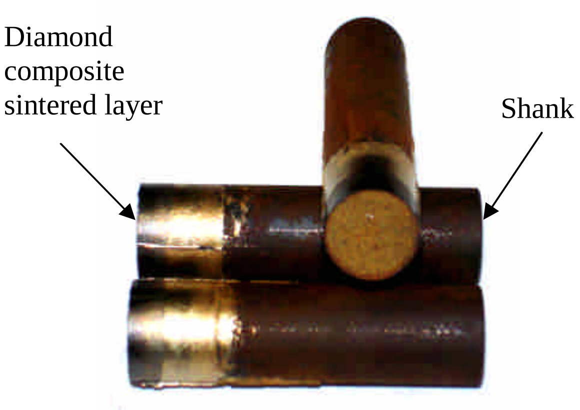


Fig.1. The bronze-bonded diamond composite tools

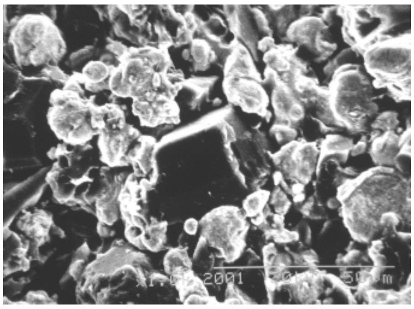


Fig.2. The microstructure on the fracture surface for diamond composite tool C.

Table 2 Grinding conditions

Tool size (mm)	ϕ10			
Spindle speed (rpm)	1000	2000	3000	4000
Table speed, *Vw* (mm/min)	15	25	35	45
Depth of cut, *d* (μm)	3			
Coolant	No (dry)			
Workpiece (size)	BK7 glass (75×75 mm)			

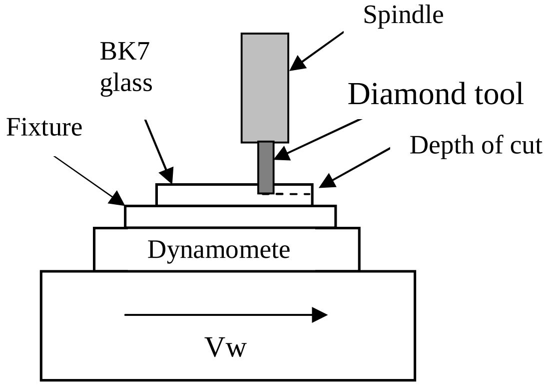


Fig.3 Geometry of the grinding kinematics for the bronze-bonded diamond composite tools.

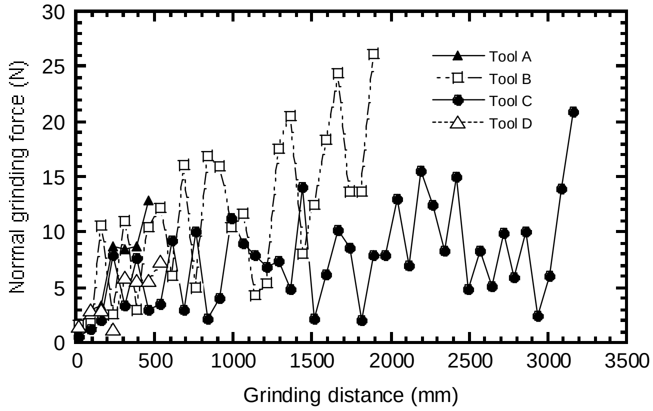


Fig.4. The variations of the normal grinding forces with the available grinding distance between two dressings during dry grinding BK7 glass at the spindle speed of 2,000 rpm and the table speed of 25 mm/min.

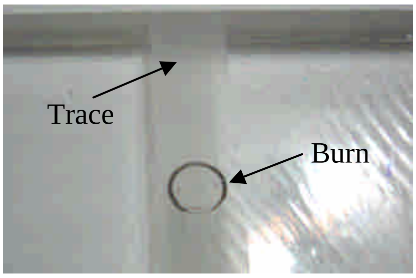


Fig.5. Burn appearance on the trace.

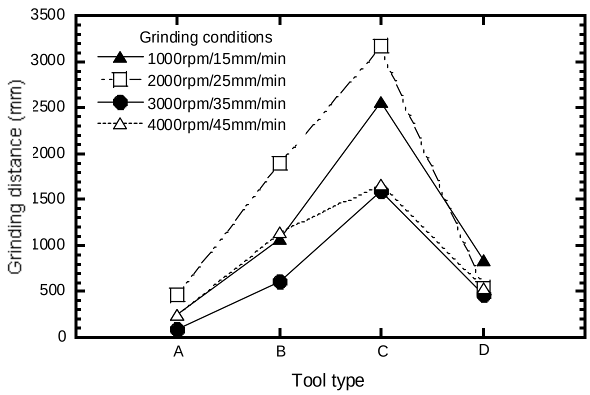
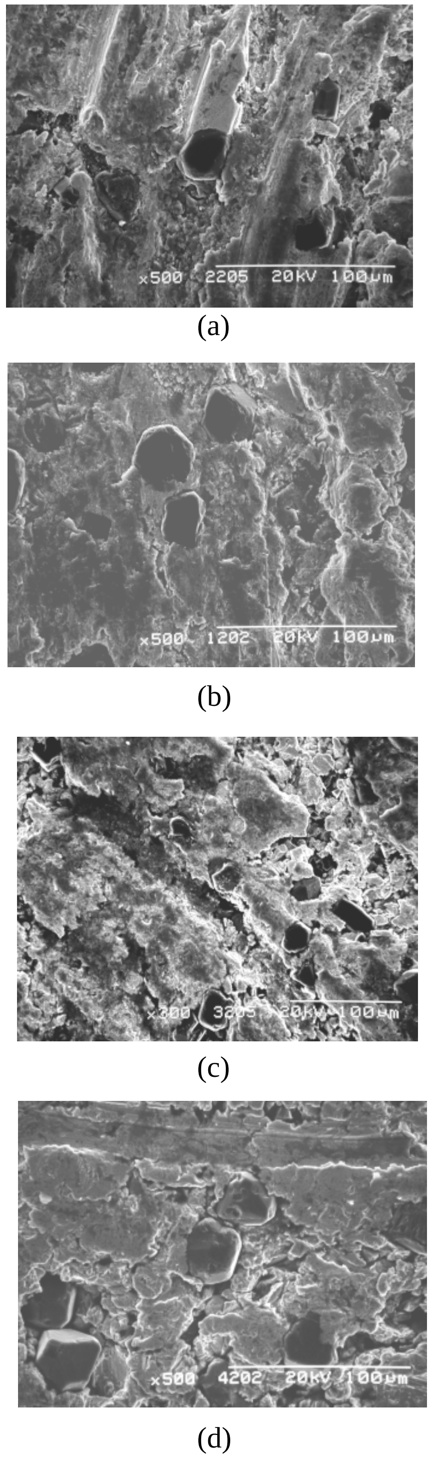


Fig.6. The available grinding distance with four different grinding conditions for four diamond composite tools.



Figs.7. The worn appearances of the medium zone for diamond composite tools (a) A, (b) B, (c) C, and (d) D after the end life of dry grinding BK7 glass at the spindle speed of 2000 rpm and the table speed of 15 mm/min.

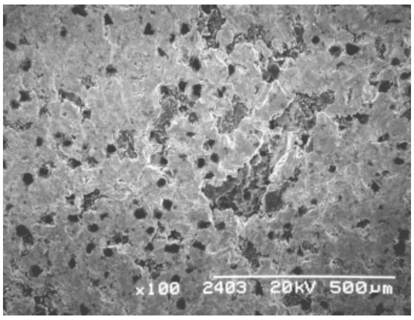
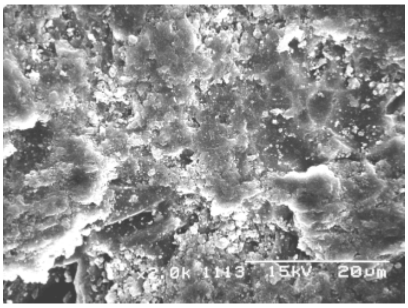
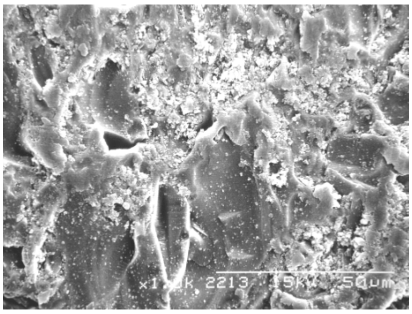


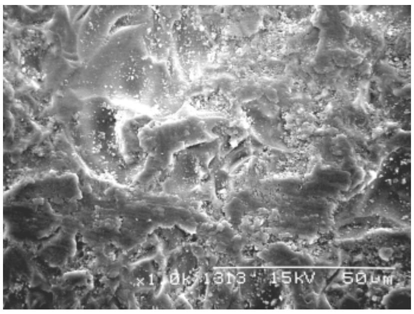
Fig.8. The worn flat appearance with many flat diamonds on the matrix produced for tool A at the spindle speed of 4000 rpm and the table speed of 45mm/min.



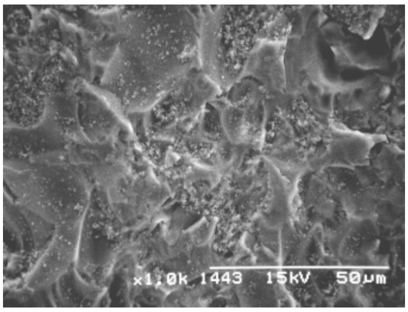
(a)



(b)



(c)



(d)

Figs.9. The surfaces on the trace of BK7 glass dry ground by diamond tool C at the spindle speed/table speed of (a) 1000rpm/15mm/min, (b) 2000rpm/25mm/min, (c) 3000rpm/35mm/min, (d) 4000rpm/45mm/min.

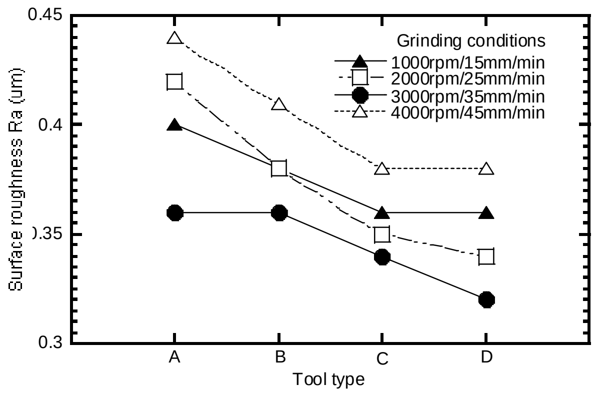


Fig.10. The average surface roughness of the workpiece before the near end of dry grinding for four diamond tools at four different grinding conditions.