

Structure and Properties of Diamond Grits Coated with Corundum Micron Powders

Y. H. Wang, Y. C. Zhao, M. Z. Wang and J. B. Zang

Key Laboratory of Metastable Materials Science and Technology, College of Material Science and Engineering, Yanshan University, Qinhuangdao, P.R. China

Keywords: Diamond, Corundum coating, Resin bond, Tool

Abstract. Diamond is widely applied in cutting and grinding tools as the hardest and anti-wear material. Coating diamond surface with suitable materials is an effective method to improve the adhesion between diamond and matrix. Corundum-coated diamond, a new kind of diamond abrasive is developed for resin bond grinding applications. Diamond grits are coated with the corundum micron powders by the binding of a kind of vitreous material. The very rough and spiny morphology of the coated grit gives outstanding bond retention in resin matrix and avoids the premature loss of diamond from tools. The strength and oxidation resistance of diamond grits improve due to the coating protection effect. Industrial test results show that the grinding efficiency with an abrasive wheel made with corundum-coated diamond grits increases by more than 30% and the life of the wheel increases by 30~35%.

Introduction

Diamond grits give superior cutting performance for machining of rock and other nonferrous materials. The great attentions have been focused on the wear of diamond-segmented tools and the choice of bond type [1-4]. However, the waste of expensive grits associated with premature loss from tools is unexpected for toolmakers and users. One effective way to improve the adhesion between diamond and matrix is to coat diamond surface with suitable materials.

Two types metals are usually selected as coating materials. One is carbide-forming metal as titanium, tungsten etc, which can form chemical bond between diamond and metal matrix [5-9]. Diamond grits coated with above materials have been developed for metal bond tools. The other is the metal such as nickel or copper. The thick coating layer of the metal assists the retention of diamond grits by keying into the bond. Cu, Ni-coated diamond grits are suitable for resin bond application.

The metal coating, like Cu or Ni, can mechanically grip the friable grit to reduce its pullout and improve the adhesive strength between the grit and resin bond, thereby increasing the tool life greatly. However, designed for resin bond grinding wheels, the irregular friable grit is necessary for self-sharpening ability, which ensures the presence of new sharp cutting edges and keeps free cutting. The thick tough coating lowers the grit friability and cutting efficiency. The aim of this paper is to seek a suitable coating material that possesses the advantages of Cu or Ni coating and has no hurts to self-sharpening property. A new method has been developed to coat diamond with corundum micron powders, which are of low toughness and high strength. It is hoped that the new coating can meet all above-mentioned requirements. The coating process and the properties of corundum-coated diamond are introduced in this paper.

Experimental

Coating Process. Diamond grits were mixed with fine borosilicate glass powders; a thin layer of glass powders homogeneously bound on diamond surface, and then covered with corundum micro-powders. Various sizes of corundum micro-powders were selected to determine the effect of corundum particles on the coating properties. Table 1 shows the range of glass compositions. The

covered diamond grits were sintered at 800°C for 1h, then the corundum-coated diamond was obtained.

The phase composition of corundum-coated diamond was investigated by D/max-rB diffractometer using CuK α radiation. The compressive strength of the grits was measured by a single grit method. Thermogravimetry analysis (TGA) was used to measure the temperature under which oxidation took place on the coated grits.

Table 1 The composite scope of vitreous bond [wt%]

SiO ₂	B ₂ O ₃	Al ₂ O ₃	Li ₂ O	Na ₂ O	K ₂ O	MgO	CaO	ZnO
48~100	5~45	1~15	0~18	0~18	0~20	0~12	0~16	0~18

Results and Discussion

Morphology and Phase Composition of Corundum-Coated Diamond. The morphology of coated diamond grits is shown in Fig.1. The original shape and surface texture of diamond grits can not be seen due to the corundum coating, and the very rough, spiny and nodular surface presents. Therefore, when the grits with the corundum coating are used in resin bond tools, excellent bond retention and long tool life may be expected.

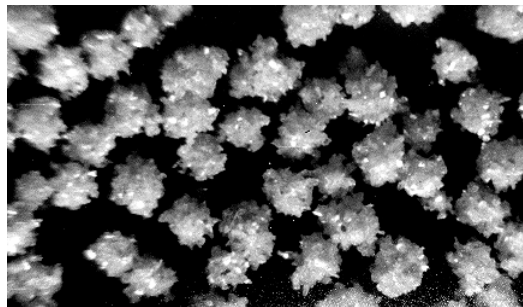


Fig.1 The morphology of corundum-coated diamond

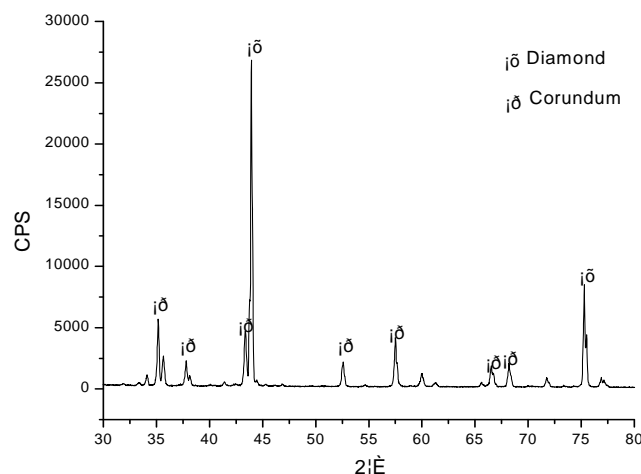


Fig.2 XRD pattern of corundum-coated diamond

Fig.2 shows the results of XRD analysis on the corundum-coated diamond. The crystal phases are diamond and corundum. The result shows that vitreous powders melted and consolidated during sintering process and formed a continuous bond layer. The corundum particles are firmly bound with diamond grit through this layer. The adhesive strength between the coating and the grit lies on the properties of the bond. The vitreous bond with high strength and low melting point is expected to

achieve strong bond. Table 2 gives the optimum composites of the vitreous bond that may meet above demands.

Table 2 The optimum composite of vitreous bond [wt%]

SiO ₂	B ₂ O ₃	Al ₂ O ₃	Li ₂ O	Na ₂ O	K ₂ O	MgO	CaO	ZnO
66.5	23.0	3.0	-	3.7	3.8	-	-	-

The Choice of Corundum Particle. The corundum particles with suitable size are selected to form a rough spiny coating in which corundum particles densely distribute on the diamond surface. This is described by the granularity ratio of diamond to corundum. Assuming diamond and corundum particles to be spheric, their radius ratio (R_1/R_2) equals to the granularity ratio (see Fig.3). The number of corundum particles needed for one densely covered corundum layer on a grit can be proximately described as $N=4F(R_1+R_2)^2/R_2^2$ (F is the filling coefficient and equals to $3/4$). Table 3 shows the calculated value of N corresponding to different radius ratios. When relatively coarse corundum particles are chosen, the ratio is low and N is small. The bond layer has to be thick enough for strong adhesion. However, in this case, the brittle vitreous layer easily cracks and leads to drops of corundum particles from diamond surface. High ratio needs more corundum particles in the coating when particles are fine, but the roughness of coating surface lowers. A series of industrial test results prove that the expected morphology of coated diamond can be achieved when the ratio of R_1/R_2 is between 4 to 8. According to this principle, the radius ratio of diamond to corundum chosen in this paper are shown in Table 4 which can be used as a reference for the choice of corundum powders.

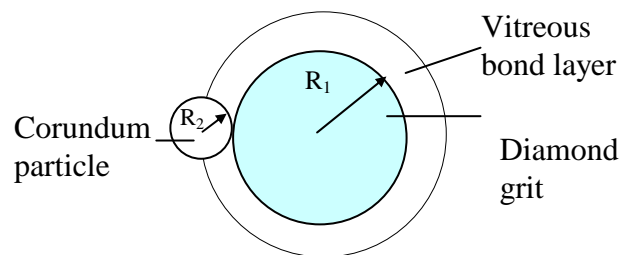


Fig.3 The diagram of the coating structure

Table 3 The value of N in different ratio

R_1/R_2	1	2	3	4	5	8	10	15	20
N	12	27	48	75	108	243	363	768	1323

Table 4 The radius ratio of diamond particle to corundum particle

Diamond particle R_1 [μm]	Corundum particle R_2 [μm]	R_1/R_2
425	63	6.7
300	50	6.0
212	40	5.3
180	28	6.4
150	28	5.4
125	28	4.5
106	28	3.8
90	20	4.5
75	20	3.8

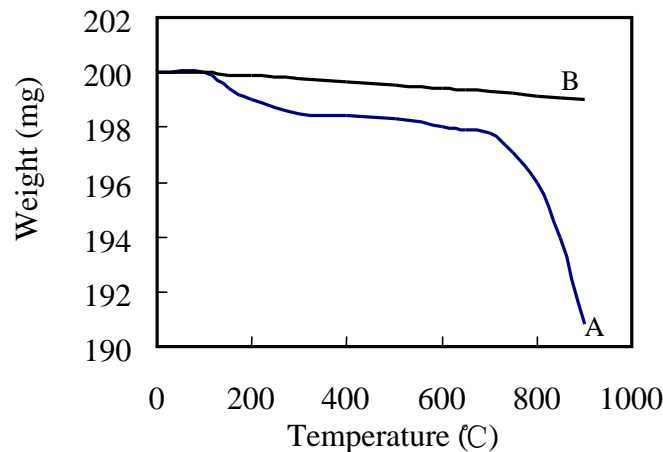
Coating Thickness and Weight Increment of Coated Grit. The corundum powders with various sizes were chosen for coating diamond grits, thereby resulting in different coating thickness and weight increment of the coated grits. The coating thickness may be at the range of 10~150 μ m, and the weight may increase by 8~200wt%. The expected values for specific application can be obtained by adjusting the thickness of the vitreous bond layer. According to industrial application results, the coated grits with 43% weight increment give optimum grinding performance.

Compressive Fracture Strength (CFS) of Corundum-Coated Diamond. Compressive fracture strength (CFS) of diamond was measured by the single grit method. The results shown in Table 5 confirm that CFS increased by 12.30%~65.44% after being coated with corundum. The possible reason causing CFS improvement is the eliminating of the surface defects as micro-cracks and apertures due to the bond filling effect.

Table 5 CFS of diamond before and after coated

Original Grade and Size	Weight increment [wt%]	Original CFS [N]	CFS after Treatment [N]	CFS Increment [%]
RVD 100/120	38	19.89	30.30	52.33
RVD120/140	20	17.23	19.35	12.30
MBD 120/140	90	24.44	39.80	62.85
MBD 80/100	45	30.73	47.46	54.44

Oxidation Resistance of Corundum-Coated Diamond. Another important feature of the coating is that it can improve the oxidation resistance of diamond. Fig.4 shows the TGA curves of un-coated diamond and corundum-coated diamond when both are heated at the speed of 10 $^{\circ}$ C per minute in air. Curve A indicates significant weight loss of the uncoated diamond starting at around 700 $^{\circ}$ C due to oxidation. Little weight change of coated diamond until the temperature is as high as 900 $^{\circ}$ C, indicating that coating protects diamond from oxidation.



A. un-coated diamond, B. corundum-coated diamond

Fig.4 TGA curves of un-coated diamond and corundum-coated diamond

Industrial Application and Results. The resin bond diamond wheel was produced using corundum-coated diamond as abrasives and resin powder as bond matrix. The typical resin wheel prescription is shown in Table 6.

The diamond wheels are used for the grinding of cemented carbides. The diamond grits used in grinding wheels are coated to 46% by weight with corundum coating. The rough and spiny surface of the coating is helpful to the retention in the resin bond, and the pullout rate decreases greatly. The brittle coating including corundum particles and vitreous bond has no hurts on self-sharpening ability

of the friable diamond grits. Therefore, coated diamond grits exhibit good cutting performance for grinding cement carbide materials. The grinding results show that when wheels are produced with coated diamond, both wheel life and cutting efficiency improve. Compared to uncoated diamond, the lifetime of corundum-coated diamond wheels increases by 30~35% and the grinding efficiency increases by 30%.

Table 6 The prescription of diamond resin wheel

Diamond consistency [%]	75
Granularity [US mesh]	120~180
Resin powder [wt%]	19.9
Copper powder [wt%]	50.6
Cr ₂ O ₃ powder [wt%]	18.6
Diamond [wt%]	18.6
Molding density [g/cm ³]	3.54

Conclusions

Corundum micron powders are firstly selected to coat diamond grits. The strong adhesive between corundum particles and diamond grit is attributed to the binding of the vitreous bond. Corundum-coated diamond exhibits a very rough, spiny morphology that improves the bond retention in resin matrix, and prolongs life of resin bond grinding wheels. The brittleness of the coating, due to vitreous phase and corundum, can maintain the friable ability of diamond grit. High efficiency and long life can be realized in the wheel made by the coated diamond.

The vitreous bond composition and corundum particles with suitable size were chosen to form an expected surface morphology.

The coating can also protect diamond from oxidation and assist to improve the strength of the grits.

References

- [1] X.P. Xu: Tribology Letters Vol. 10 (2001), p. 245
- [2] X.P. Xu: Tribology International Vol. 34 (2001), p. 419
- [3] X.P. Xu: Transactions of the ASME: Journal of Manufacturing Science and Engineering Vol. 123 (2001), p. 13
- [4] X.P. Xu and J.Y. Shen: Key Engineering Materials Vols. 202-203 (2001), p. 67
- [5] D. Borse: European Patent Notification 0,254,940
- [6] E. Wilks and J. Wilks: *Properties and Application of Diamond* (Butterworth-heinemann, UK, 1991).
- [7] Y.H. Wang, et al: Journal of Inorganic Materials Vol. 10 (1995), p. 351
- [8] Y.H. Wang, et al: Key Engineering Materials Vols. 202-203 (2001), p. 147
- [9] Y.H. Wang, et al: Key Engineering Materials Vols. 202-203 (2001), p. 199