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Super long life mirror grinding using ultrafine-crystalline cBN abrasive grit

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Abstract
This paper deals with the grinding performance for mirror finishing of a polycrystalline cBN (UcBN) abrasive grit developed from hBN of high purity by direct conversion sintering at high temperature and high pressure. A series of cylindrical plunge grinding experiments for producing mirror surface in a high efficiency were conducted using this UcBN wheel and a typical conventional monocrystalline cBN wheel prepared by means of the micro dressing method with a fine grained diamond dresser. The result showed that UcBN wheel was able to produce a mirror surface with a higher quality in a higher efficiency than the conventional monocrystalline cBN wheel. Moreover, it was confirmed that the grinding wheel life for creating mirror surface using UcBN wheel was about 3 times longer than that using the conventional monocrystalline cBN wheel.

Keywords: ultrafine-crystalline cBN abrasive grit, mirror grinding, grinding wheel life, mirror finished surface, cutting edge wear, micro dressing

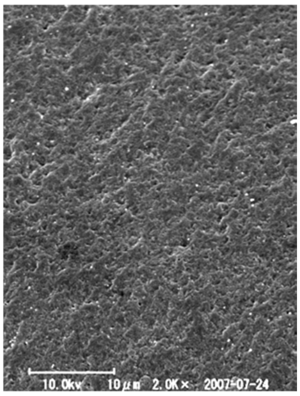
1. Introduction

To enhance the grinding performance of cBN wheels, we have developed a new type of polycrystalline cBN abrasive grit by direct transformation from hexagonal boron nitride, which was produced by a chemical vapor deposition process [1]. This cBN abrasive grit possesses an ultrafine crystal structure composed of submicron-sized primary crystal grains. Therefore, we call this new abrasive 'ultrafine-crystalline cBN' (UcBN or cBN-U for short) grit. The cBN-U abrasive grit is expected to be used for a wide range of applications from high-efficiency grinding to high-quality grinding, because its wear resistance is superior to those of conventional monocrystalline and poly-crystalline cBN abrasive grits. On the other hand, we have proposed a grinding method that can create a high-quality mirror surface at a high-efficiency using the coarse grit cBN wheel prepared by a micro dressing method [2].

This paper presents the mirror grinding of high chromium roll steel using a metal bonded coarse grit UcBN wheel prepared by this micro dressing method. A series of cylindrical plunge grinding experiments with this wheel working surface were conducted to clarify the possibility of creating mirror surface. Especially, the grinding time for creating mirror surface, that is, the grinding wheel life is discussed from the viewpoint of the wear behavior of grit cutting edges.

2. Experimental procedure

cBN-U grit have an ultrafine polycrystalline structure composed of primary crystal grains with a grain size smaller than 500 nm, as shown in **Figures 1** and **2**. The tensile fracture strength of cBN-U grit is about 3.5 times higher than that of representative conventional monocrystalline cBN-B grit. Prior to grinding experiments, the micro dressing of cBN wheel was precisely carried out using a rotary dressing device equipped with a fine grain diamond dresser of mesh size #1200, under the following conditions: peripheral dresser speed v_d = 0.6m/s, speed ratio v_d/v_s = 0.01, dresser depth of cut a_d = 2μmx2, and dressing lead l_d = 0.05 mm/rev.



10μm

Figure 1 SEM image of fracture surface of cBN-U grit

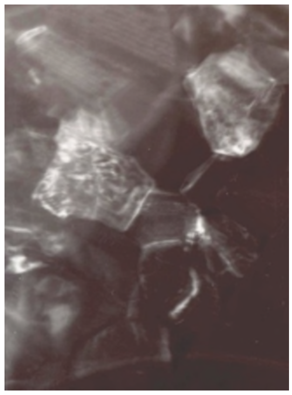
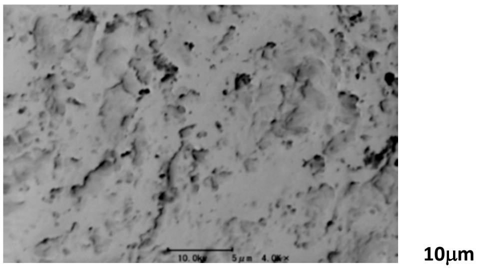

500 nm

Figure 2 TEM image of crystal structure of cBN-U grit

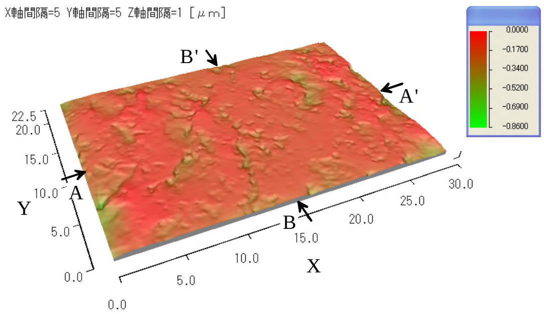
To clarify the possibility of creating the mirror surface, cylindrical grinding experiments were carried out using an ultraprecision universal grinding machine (TOYODA-GU/25/63), equipped with a hydrostatic bearing spindle, under the grinding conditions listed in **Table 1**.

Table 1 Grinding conditions

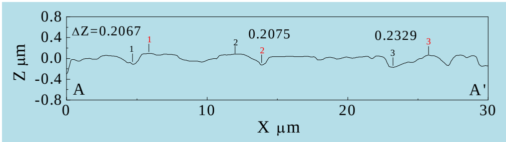
Grinding method		Cylindrical plunge grinding, Up-cut
Grinding wheel		CBN140N100M Dimensions: ϕ 305 × t16 mm
cBN grain		Ultrafine-crystalline cBN(cBN-U) Monocrystalline cBN (cBN-B)
Wheel speed	v_s	30 m/s
Workp speed	v_w	0.033-0.133 m/s
Wheel depth of cut	a	2 μm/rev
Stock removal rate	Z'	4-16 mm^3/mm・min
Spark out time		8 s
Grinding fluid		Emulsion-type, 2 % dilution
Workpiece		5%Cr roll steel (Hardness: HRC60) (ϕ 80 × t5 mm)



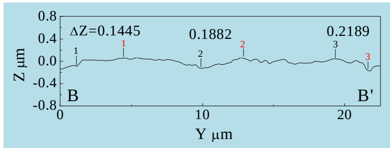
(a) Secondary electron image



(b) 3D image



(c) A-A' sectional profile



(d) B-B' sectional profile

Figure 3 A typical 3D-SEM imaging of grit cutting edge formed on the cBN-U wheel surface by micro dressing.

3. Results and discussion

Many cBN grits having a flat plane formed by the cutting edges on the diamond dresser are observed on the wheel surface after micro dressing. **Figure 3** shows a typical 3D-SEM image of grit cutting edges formed on the cBN-U wheel surface by micro dressing. The flat plane is composed of a brittle fractured surface and a ductile smooth surface. The roughness of the flat plane is 0.4-0.5 μm in *Rz*. These results show that the formation mechanism of the flat surface is based on a combination of ductile deformation and brittle fracture.

Using such a wheel working surface, mirror finish grinding experiments were conducted to investigate the grinding wheel life for creating mirror surface. **Figure 4** shows the changes of finished surface roughness with increasing the accumulated stock removal. In grinding with cBN-B wheel, surface roughness maintains a value lower than 0.2 μm in *Rz* until a stock removal of 4200 mm^3/mm. For instance, when the required threshold of finished surface roughness is 0.2 μm in *Rz*, the grinding time to maintain a value lower than the threshold, that is, the grinding wheel life T_l is about 550 min. In contrast, cBN-U wheel can maintain a lower value than 0.2 μm in *Rz* until a stock removal of 15000 mm^3/mm and its grinding wheel life T_l is about 1875 min. Thus, it was confirmed that the grinding wheel life for creating mirror surface using UcBN wheel was about 3 times longer than that using conventional monocrystal-line cBN-B wheel.

Figure 5 shows typical SEM images of grain cutting edges on the wheel working surfaces after dressing and grinding. A wear flat plane due to attrition wear is generated on the smooth plane of grain cutting edge formed by the micro dressing. The area of this wear flat expands gradually with stock removal. In grinding with cBN-B wheel, many streaks caused by the attrition wear are observed on the wear flat plane. These wear streaks develop with increasing the stock removal. However, in the case of cBN-U wheel, such wear streaks are not easily generated compared to the case of cBN-B wheel. The difference in wheel life between cBN-U and cBN-B wheels is mainly caused by a difference in such a microscopic behavior of cutting edge wear between both wheels.

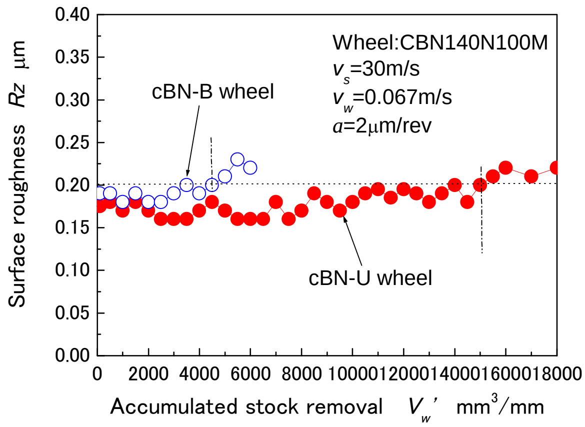


Figure 4 Changes of finished surface roughness with increasing accumulated stock removal

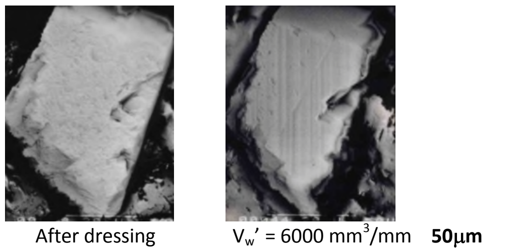
4. Conclusions

The main results are summarized as follows:

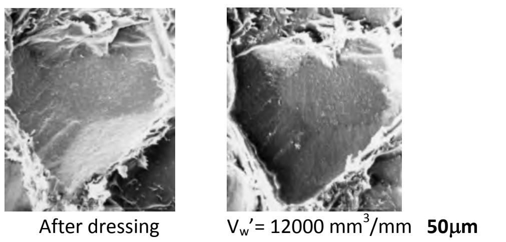
(1) The mirror surface with a roughness less than 0.2 μm in *Rz* (0.018 μm in *Ra*) can be efficiently formed using cBN wheel working surface prepared by the micro dressing method.

(2) cBN-U wheel can produce a mirror surface with a higher quality in a higher efficiency than conventional mono-crystalline cBN-B wheel.

(3) The grinding wheel life for creating mirror surface using cBN-U wheel is about 3 times longer than that using conventional cBN-B wheel.



(a) cBN-B wheel



(b) cBN-U wheel

Figure 5 Wear behavior of cBN grit cutting edge

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[2] Ichida Y: 2012, *Key Eng. Mater*., **523-524**, 137-142.