A Study on Fracture Behavior of Brazed Multicrystalline CBN Abrasive Grains During Grinding

W. F. Ding, C. Y. Yang, J. H. Xu, Q. Miao, Z. W. Liu, J. He

***Abstract*— This paper analyses the fracture behavior of the brazed BCBN grain by comparison with brazed PCBN grain through grinding test of Nickel-based superalloy. The self-sharpening effect is created by timing micro-fracture behavior for BCBN abrasive grains, but by macro-fracture behavior for PCBN abrasive grains. During grinding with brazed BCBN abrasive grains, the material is removed together with the consumption of the CBN particle. While for PCBN ones, the fracture pattern consists of the intercrystalline fracture and the intergranular bond fracture. The service life of brazed BCBN grinding tool is around 1.67 times longer than that of PCBN one, furthermore the material removal of PCBN grinding tool is just about 73% of that of BCBN grinding tool in this investigation.**

***Index Terms*—multicrystalline CBN abrasive grain, brazing, fracture, wear behavior**

I. INTRODUCTION

CUBIC boron nitride (CBN) has a high level of hardness next to the diamond and superior thermo-chemical stability to the diamond. Therefore, CBN abrasive wheels have been widely used in various types of grinding operations, ranging from high-efficient grinding to high-quality grinding [1]-[2].

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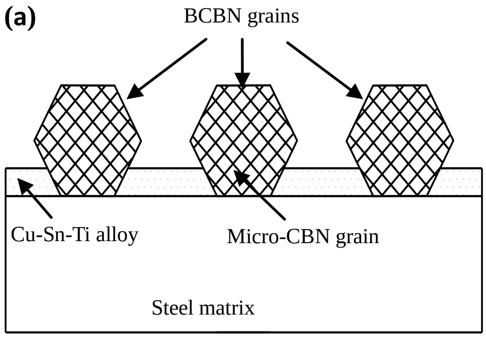
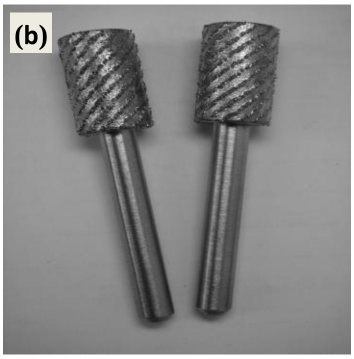
In recent years, due to the development of active brazing technology, to enhance the grinding performance of brazed cBN wheels, brazed multicrystalline CBN abrasive grains have attained more and more attention [3]. Generally, multicrystalline CBN abrasive grain consists of two types of CBN abrasive grain: conventional polycrystalline cBN grain (PCBN) which is synthesized by using the microcrystalline cBN particles and AlN ceramic binder material [4], and binderless polycrystalline cBN grains (BCBN) which is sintered by direct transformation from hexagonal boron nitride [5]. Until now, some studies on mechanical properties and grinding performance of multicrystalline CBN abrasive grains have been conducted [2]-[5]. However, the fracture behavior of multicrystalline CBN abrasive grains has not yet sufficiently elucidated. The purpose of this study is to detect the fracture behavior of the brazed BCBN grain by comparison with brazed PCBN grain in grinding of nickel-based superalloy, a typical difficult-to-cut material.

II. EXPERIMENTAL PROCEDURE

In this study, the size of abrasive grains was 300-450 μm. Then these grains and steel substrate were joined using the Cu-Sn-Ti alloy with the chemical content Cu 72 wt%, Sn 18 wt%, Ti 10 wt%. In particular, the Cu-Sn-Ti alloy has exhibited requisite wetting behavior and formed strong joints with CBN abrasive grains [6].The schematic diagram of the brazed BCBN specimen is displayed in Fig. 1(a). The brazing temperature was 900℃ with isothermally treating for 8 min. Grinding experiments were conducted with surface plunge grinding method. The experimental conditions are listed in table 1.



(a) schematic diagram



(b) morphology of brazed wheel heads

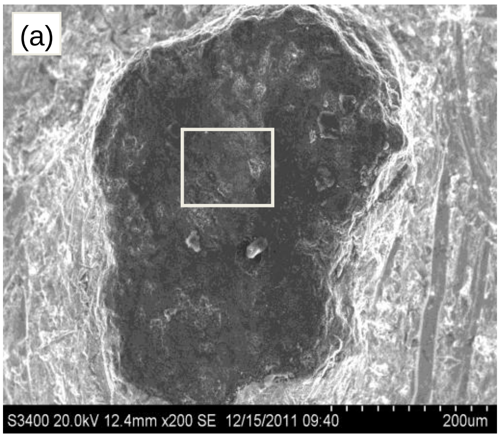
Fig. 1 Schematic diagram and morphology of brazed BCBN grains specimen

Table 1 Grinding conditions and parameters

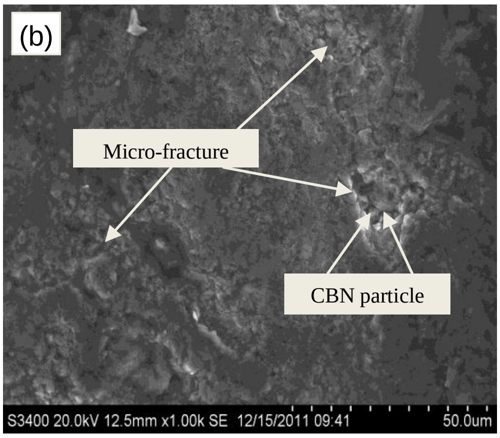
Types	Contents
Grinding machine	Precise horizontal spindle grinding machine modeled HZ-Y150
Brazed abrasive tool	Brazed PCBN and BCBN grinding wheel heads
Grinding fluid	Water-based emulsion
Workpiece	Nickel superalloy GH4169 Dimensions: 45^l mm $\times 8^w$ mm $\times 30^h$ mm
Peripheral wheel speed v_s	10 m/s
Work speed v_w	2 m/min
Wheel depth of cut a_p	10 μm

III. Wear Topography of Brazed Abrasive Grains

The surface topography of a grinding tool is strongly influenced by the grinding condition and the correspondent tool wear. Multicrystalline CBN grain is sintered using microcrystalline CBN particles under high temperature and high pressure [3]-[4], whose fracture exhibits special characteristic. Accordingly, Fig. 2 (a) and (b) show the typical wear morphology of a brazed BCBN grain. Obviously, there are many microcrystalline CBN particles on the fracture surface. During grinding, the internal new CBN particles in the BCBN grain sequentially come into being to participate in the material removal process. The appearance of micro-fracture exhibits an excellent self-sharpening behavior in the grinding process. In Fig. 3 (a) and (b), the typical wear morphology of a brazed PCBN grain is displayed. On one hand, vast of micro-fractures appear on surface of PCBN grain due to self-sharpening effect. Therefore, the brazed PCBN grinding tool could be conducive to the maintenance of sharp cutting edges and well resistant to the attrition wear during grinding.

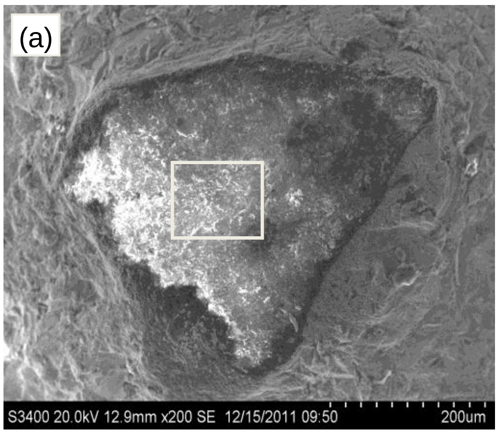


(a) Whole



(b) Regional

Fig.2 The typical wear topography of BCBN grain



(a) Whole and

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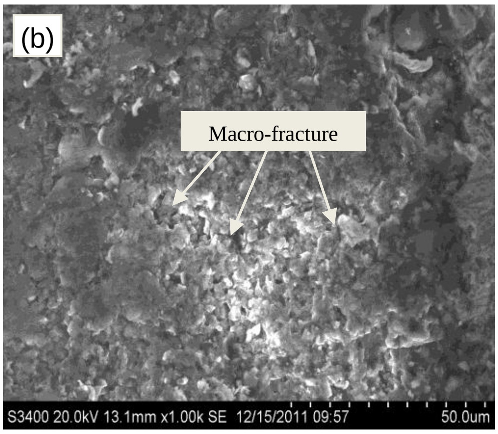

(b) Regional
Fig.3 The typical wear topography of PCBN grain

On the other hand, the continuous severe macro-fracture can necessarily have a negative effect on the tool life. Though newly sharp cutting edges are perhaps created through the grain fracture, almost the cutting zone of the grain is put away.

IV. FRACTURE MECHANISM OF BRAZED ABRASIVE GRAINS

Fig.4 shows the micro-fracture topography in grinding with brazed BCBN tool. The adhered deposit material suggests that the abrasive grain is perhaps near the final wear state. Nevertheless, there are still many CBN particles which have protruded on the top fracture surface. Note that, abrasive grain crack or pullout is not observed yet from the working surface. As mentioned above, the cutting edges of BCBN grains continue to refreshing properly due to excellent self-sharpening effect in the grinding process. Therefore, the material is removed together with the consumption of the CBN particle.

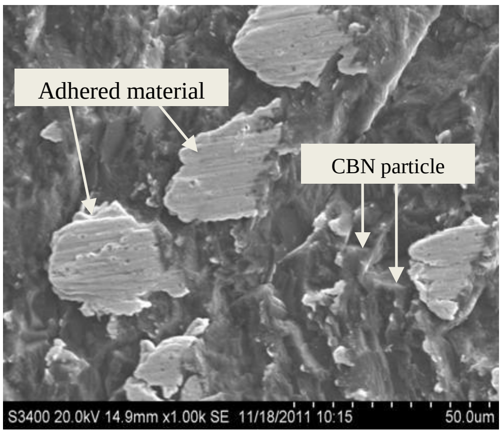

Fig. 4 Micro-fracture topography of BCBN grain

Fig.5 displays the micro-crack path of brazed PCBN abrasive grain during grinding. According to the literature [7], the fracture behavior of PCBN grains is dominated by the joining effect of the AlN binder among the adjacent microcrystalline CBN grains, as illustrated in Fig.5. The self-sharpening effect of PCBN grains by means of the micro-fracture behavior is mainly dependent on the level of thermal-mechanical loads during grinding [7]. Moreover, due to the formation of the bridging sites and certain residual thermal stresses, this bond system makes it possible to create the propagation of brittle micro-crack. As a result, the micro-crack and micro-fracture of PCBN grain contributes each other to occur. The fracture pattern of PCBN grains consists of the intercrystalline fracture and the intergranular bond fracture.

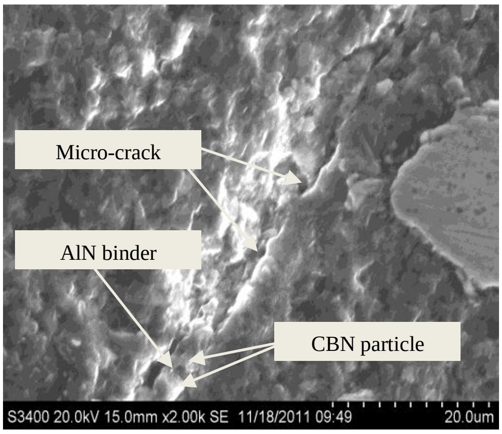

Fig. 5 Micro-crack path of PCBN grain

Respecting the strength and resistance to dynamic loads of the multicrystalline CBN grains on a local scale, the formation of cracks can be significantly limited. Yoshio. I etc. have revealed that the BCBN grain possess a higher fracture strength than PCBN grain [5]. Furthermore, in case of the sintered microcrystalline CBN particles in BCBN grains, the fractures run along the particle boundaries. This wear mechanism guarantees not only the ability of BCBN grain with a higher wear resistance but also the prolongation of working life of the active grains.

V. GRINDING PERFORMANCE OF BRAZED GRINDING TOOLS

In this investigation, the measurements were taken every 20 grinding passes until the failure of the grinding tool occurred. After 20 grinding passes at the initial state, the BCBN grain had experienced a few of fractures while the macro-fracture began to occur on surface of PCBN grain. At this very moment, the sound from the grinding process was regular.

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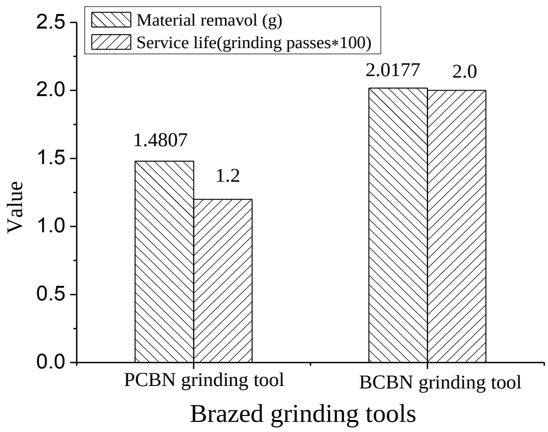

Fig. 6 The comparison of grinding performance of BCBN and PCBN grinding tools

In the steady grinding state, there appeared lots of fragments beside the grains gradually. The sound changed significantly during 100-120 grinding passes for PCBN grinding tool and 180-200 grinding passes for BCBN one. In the final grinding state, there was appearance of corrosion spots and stripes on surface of the workpiece. Thus the failure of the grinding tool was decided in accordance with the harsh voice during grinding. The brazed PCBN grinding tool ended the service life within 120 grinding passes, while for BCBN one, it ended within nearly 200 passes.

A comparison in material removal and service life of the grinding tools is displayed in Fig.6. It is obvious that the brazed BCBN grinding tool takes a much higher value in wear resistance, tool efficiency and service life than the PCBN one. The service life of brazed BCBN grinding tool is around 1.67 times longer than that of PCBN one, furthermore the material removal of PCBN grinding tool is just about 73% of that of BCBN grinding tool. This indicates that the brazed BCBN abrasive grains have a great advantage over PCBN ones in grinding performance.

VI. CONCLUSIONS

(1) The self-sharpening effect is created by timing micro-fracture behavior for BCBN abrasive grains, but by macro-fracture behavior for PCBN abrasive grains.

(2) During grinding with brazed BCBN abrasive grains, the material is removed together with the consumption of the CBN particle. While for PCBN ones, the fracture pattern consists of the intercrystalline fracture and the intergranular bond fracture.

(3) The service life of brazed BCBN grinding tool is around 1.67 times longer than that of PCBN one, furthermore the material removal of PCBN grinding tool is just about 73% of that of BCBN grinding tool in this investigation.

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