Development of New Grade “SUMIBORON BN7000” for Cast Iron and Ferrous Powder Metal Machining

Yusuke MATSUDA*, Katsumi OKAMURA, Shinya UESAKA and Tomohiro FUKAYA

“SUMIBORON” PCBN (polycrystalline cubic boron nitride) tools are widely used in the cutting of hard-to-cut ferrous materials, such as hardened steel, cast iron and ferrous powder metal (PM), and contribute to productivity growth and cost reduction for metalworking. In the recent growing automotive industry, the machining of cast iron and ferrous PM parts has been increasingly required. However, the machinability of these parts has been degraded because of their high functionality. Therefore, the demand has increased for PCBN cutting tools that enable efficient machining over an extended duration. The authors have developed SUMIBORON BN7000, which has the highest CBN contents among the present production line and excellent binding force between CBN particles. BN7000 ensures higher efficiency and longer tool life in cast iron and ferrous PM machining than any other conventional PCBN grades. This paper describes the development process and performance of BN7000.

Keywords: cast iron, powder metal, CBN, PCBN, cutting tool

1. Introduction

Cubic boron nitride (CBN) has the highest hardness and thermal conductivity among all materials except for diamond, and also has low reactivity with ferrous materials. Sumitomo Electric Hardmetal. Corp. (SHM) developed polycrystalline cubic boron nitride (PCBN) by sintering CBN with ceramic binding materials, and contributed to the shift in the machining method of hardened steels from grinding to cutting. Furthermore, we contributed to the productivity improvement and cost reduction in the finishing and semi-finishing of ferrous materials such as cast iron and ferrous powder metal (PM) with high content PCBN tools[(1)-(5)].

Carbide, ceramic and cermet cutting tools are mainly used for cast iron machining. On the other hand, in the high precision and high efficiency machining of cast iron, PCBN cutting tools are applied due to the high strength and high thermal conductivity. For example, the mating surface of an engine block or oil pump is often finished by milling with PCBN cutting tools for high efficiency and high precision machining.

Ferrous PM is applied to automotive function parts, such as transmissions, because it can be formed into complex and nearing-completion shapes with the progress of the near net shape technology. In addition, various metal characteristics can be designed by controlling the ratio and grain size of hard particles added to ferrous PM, sintering density and the method of hardening. In the machining of PM parts, high precision cutting is required for high quality automotive parts. However, the machinability of these parts has been degraded because of the increased hardness of their materials.

Therefore, the demand for PCBN cutting tools that enable high-efficiency machining and long tool life has increased. The authors have succeeded in developing “SUMIBORON BN7000.” This paper describes the development and performance of BN7000.

2. Features of BN7000

2-1 Characteristics of BN7000

CBN compact is divided into two types: one that has CBN particles bonded with a binder material, and the other one that is formed by binding CBN particles together using a small amount of a binder material. The former shows excellent wear resistance and is generally used for hardened steel cutting. On the other hand, the latter, which has high CBN content and features excellent thermal conductivity and toughness, can be used for the machining of cast iron, heat resistant alloys and PM parts. BN7000 is classified into the latter.

Table 1 shows the characteristics of BN7000 in comparison with SHM’s grade BN7500 for ferrous PM finishing and conventional CBN grade BN700. BN7000 realized excellent strength, toughness, high hardness and thermal conductivity by means of increasing the CBN content to a higher level than that of any other conventional grades. By using higher sintering pressure than conventional 5 GPa, the CBN content increased from 90 vol% to 93 vol% with an actual value.

Table 1. Characteristics of BN7000

Grade	CBN Content (vol%)	CBN Grain size (μm)	Hardness (GPa)	TRS (GPa)	K1c (Mpa·m$^{1/2}$)	Thermal conductivity (W/m·K)
BN7000	93	2	41-44	1.3-1.4	9-11	110-120
BN7500	91	1	41-44	1.4-1.5	7-9	100-110
BN700 (Conventional)	90	2	40-43	1.2-1.3	8-10	100-110

2-2 Structure of BN7000

Figure 1 shows the edge preparation of BN7000. BN7000 has three types of edge preparation: standard-type for general cutting, LF-type with a sharp cutting edge, and HS-type with a tough cutting edge. With this variation, BN7000 supports ferrous PM machining.

The standard-type, which has an appropriate balance between breakage resistance and sharpness, is primarily recommended for general ferrous PM finishing. The LF-type, equipped with sharp cutting edges for ferrous PM machining, can ensure smooth surface roughness by suppressing burr formation and white turbidity. The HS-type, which has a large chamfer angle and round horning, can suppress chippings and breakage at cutting edges even in the interrupt cutting of hardened ferrous PM (more than HRC50), and achieves a long tool life.

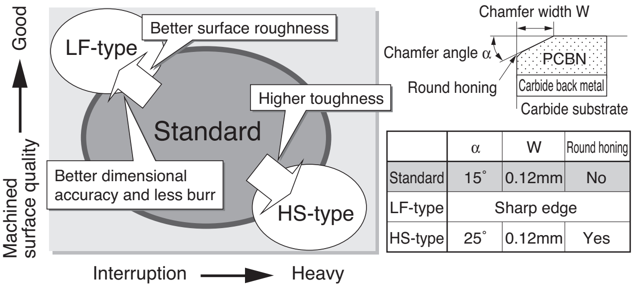

Fig. 1. Edge preparation of BN7000

3. Cutting Performance of BN7000 for Ferrous PM

3-1 Issues in ferrous PM cutting

Figure 2 shows a main tool failure, concavo-convex wear, in ferrous PM cutting by PCBN cutting tools. The analysis of worn parts with a scanning electron microscope (SEM) revealed the following mechanism of the tool failure in ferrous PM cutting. First, the binder is scratched by hard particles like high melting point metal or carbide in a workpiece, and then CBN particles are embossed and drop out. By repeating this process, wear progresses in ferrous PM cutting.

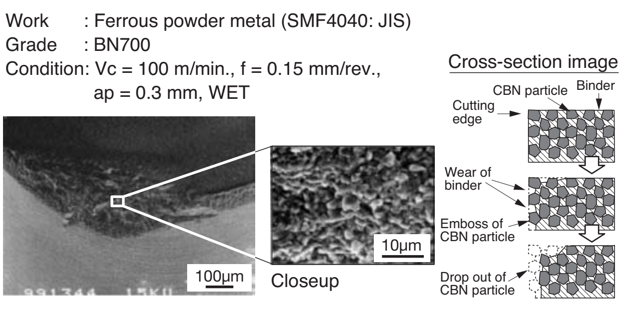

Fig. 2. Tool failures in ferrous PM machining

Therefore, preventing CBN particles to drop out is important for the improvement of tool life.

3-2 Ferrous PM cutting by BN7000

(1) Features of BN7000

The amount of binder in BN7000 is reduced by 30% compared with that in the conventional grade in order to suppress the abrasive wear of the binder. Furthermore, the binding force between CBN particles has become stronger than that of the conventional grade by improving the binder composition and accelerating the reaction between CBN particles during the sintering process.

In order to confirm the effect of the improvement on BN7000 and the conventional grade, their micro structures were observed by using their samples (3 mm in length, 3 mm width and 1 mm in height, surface polish with 3 μm diamond loose grains, acid treatment with nitric-hydrofluoric acid under 180 degrees Celsius for 12 hours).

Photo 1 shows the observed microstructure. BN7000

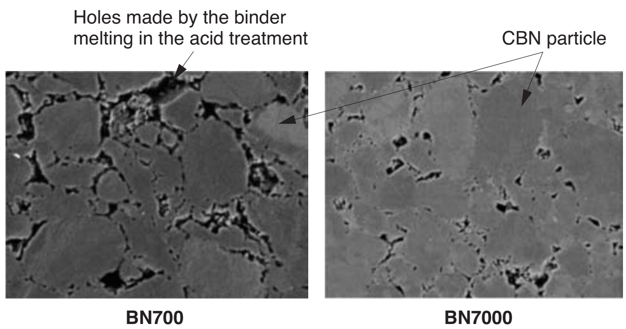

Photo 1. Microstructure of CBN compact after acid treatment

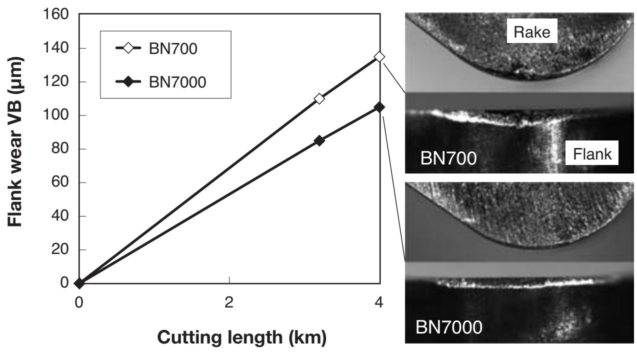

Fig. 3. Result of cutting test of ferrous PM

has fewer holes made by binder melting during the acid treatment than the conventional grade, and there is little interface between CBN particles due to an increase in the contact area between CBN particles resulting from the high CBN content.

(2) Cutting performance of BN7000

In order to compare wear resistance between BN7000 and the conventional grade, a machining test was carried out using cutting tools of 2NU-CNGA120408 with honing, ferrous PM hollow cylinder (outer diameter: 65 mm, inner diameter: 27 mm, length: 41 mm, hardness: HRB70), parts of SMF4040 (JIS), in the cutting condition of Vc = 100 m/min., f = 0.15 mm/rev., and ap = 0.3 mm with a coolant.

Figure 3 shows the result of the evaluation for wear resistance of BN7000 in the machining of ferrous PM. BN7000 shows 20% less wear than the conventional grade.

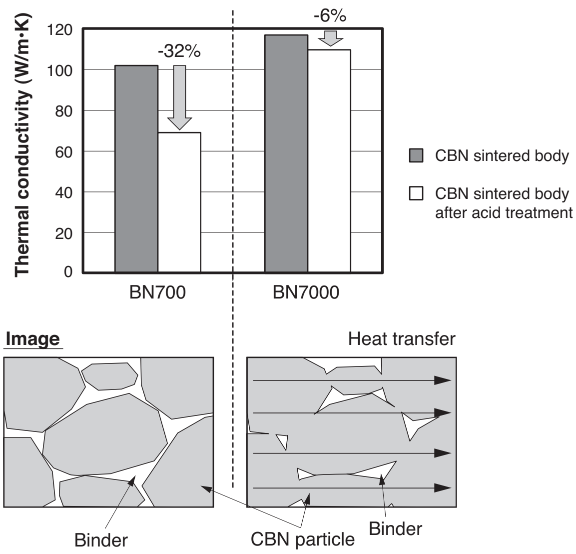

Fig. 5. Thermal conductivity of CBN compact

4. Cutting Performance of BN7000 for Cast Iron

4-1 Issues in cast iron cutting

The temperature of cutting edge becomes up to 1000 degrees Celsius in high speed cast iron machining at Vc = 700 m/min.[6]. In interrupted cutting like face milling, the main criteria is the prevention of thermal cracks which occur at cutting edges due to the tensile stress caused by the cycle of expansion and shrink of the edges due to the temperature changes in the tools and their surface associated with the cycle of cutting and idling. In order to suppress the thermal cracks, cutting tools which have high toughness and thermal conductivity are required.

4-2 Cast iron cutting by BN7000

(1) Features of BN7000

BN7000 has a higher CBN content and better binding force between CBN particles than the conventional grade as mentioned in 3-2.

In order to confirm the strength of the connection between CBN particles in BN7000 and the conventional grade, their thermal conductivity was measured by using their samples (Diameter: 6 mm and height: 1 mm) before and after acid treatment with nitric-hydrofluoric acid at 180 degrees Celsius for 12 hours. **Figure 4** illustrates the measurement test by Xe laser flash method. **Figure 5** shows the thermal conductivity of BN7000 and the conventional grade. BN7000 has 10% higher thermal conductivity than that of the conventional grade. Furthermore, the decrease of thermal conductivity of BN7000 after acid treatment is smaller than that of the conventional grade, which means there are stronger connections between CBN particles in BN7000 than in the conventional grade. Heat generated at the cutting edge of BN7000 during the machining is emitted efficiently through the connected CBN particles.

(2) Cutting performance of BN7000

In order to compare the thermal crack resistance between BN7000 and the conventional grade, milling tests were carried out using milling cutter FMU4100R and cutting tools SNEW1203ADTR for cast iron plates of FC250 (JIS) (150 mm in length, 100 mm in width and 25 mm in height, hardness = HB200-230) as shown in **Fig. 6**. The cutting conditions were Vc = 1500 m/min., f = 0.2 mm/rev., ap = 0.3 mm without coolant.

Photo 2 shows the comparison of thermal cracks between BN7000 and the conventional grade after 45 passes machining. Thermal cracks observed at the cutting edge

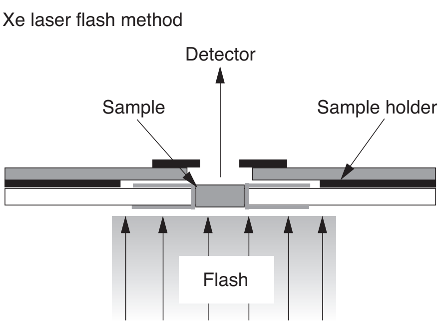

Fig. 4. Thermal conductivity measurement

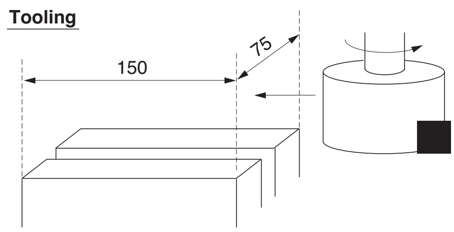

Fig. 6. Milling test of cast iron

of BN7000 are smaller than those observed at the conventional grade's, and thus the improvement of thermal crack resistance was confirmed.

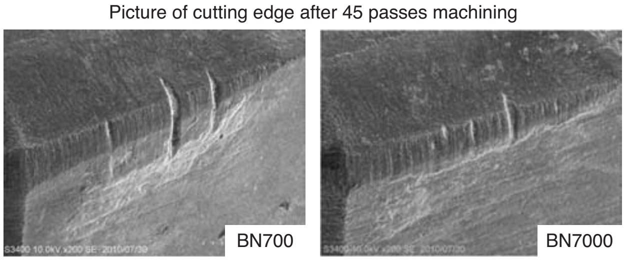

Photo 2. Comparison after the milling test on cast iron

5. Application Area and Example of BN7000

Figure 7 (a) shows the application area of BN7000 in cast iron machining based on the results of our evaluation tests and user examples. BN7000 shows excellent wear and thermal clack resistance in the high speed finishing of cast iron. When the cut depth is larger than 1 mm, BNS800, a solid CBN cutting tool, is recommended. **Figure 7 (b)** shows the application area of BN7000 in ferrous PM machining. BN7000 is the best recommendation for ferrous PM general machining. For finishing, however, BN7500 with fine-graded CBN particles is recommended as it can maintain the sharp cutting edge. In the continuous cutting of hardened ferrous PM (HRC60), CBN grades for hardened steel are recommended because the wear progresses due mainly to the thermal reaction.

Figure 8 shows the examples of the use of BN7000 cutting tools. In iron and ferrous PM machining, BN7000 showed 1.3 to 2 times longer tool life than a competitor's CBN cutting tool due to the excellent wear and breakage resistance.

BN7000 achieved 4 times longer tool life than the competitor's CBN cutting tool in VSI (valve sheet insert) machining, which is difficult because of carbide or other hard particles contained in the material. As mentioned above, BN7000 achieved high efficient cutting and long tool life in the cast iron and ferrous PM machining of various shapes and material types of parts.

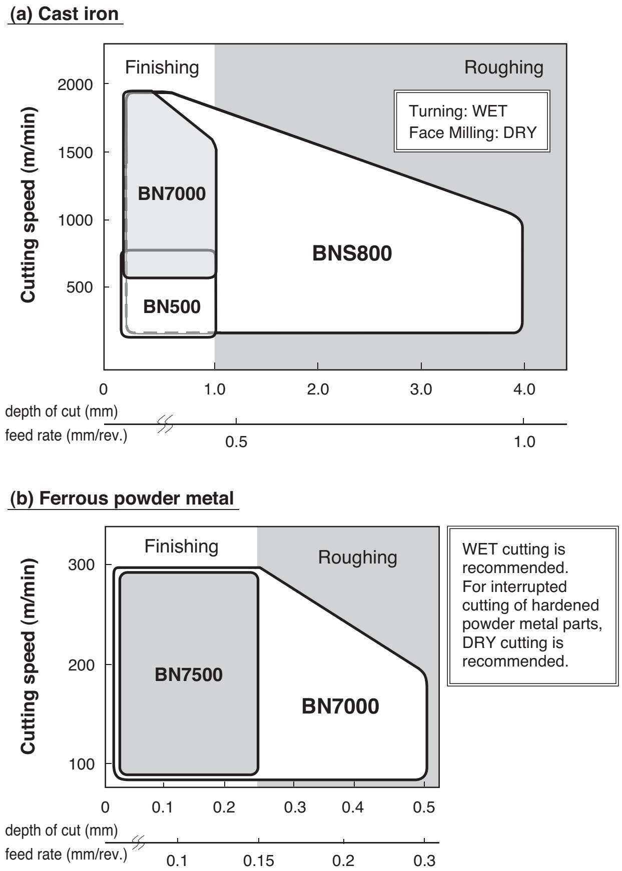

Fig. 7. Application area of BN7000

6. Conclusion

SUMIBORON BN7000 ensures high efficient cutting and long tool life in cast iron and ferrous PM machining. Featuring the highest CBN content, hardness, and thermal conductivity among SUMIBORON series, BN7000 can be used for machining difficult-to-cut materials, which requires tools with high strength. BN7000 is expected to contribute to the total cost reduction of cutting process as well as the improvement of product quality and precision.

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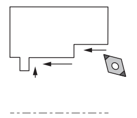
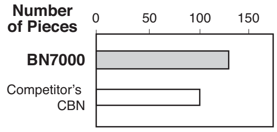
● Inner finishing of transfer part

Work: Ferrous PM (SMF4040: JIS)
Process: Inner boring



Criteria: Dimensions

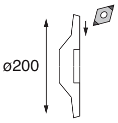
Grade	**BN7000**
Insert	2NU-CNGA120408
Vc m/min	120
f mm/rev	0.15
ap mm	0.3
Coolant	Wet



• BN7000 achieved 1.3 times longer tool life than competitor's CBN by excellent wear resistance.

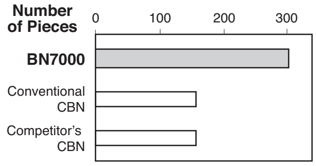
● Cutting of oil pump

Work: Gray cast iron (FC200: JIS)
Process: Finishing of face



Criteria: Surface roughness, Burr

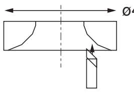
Grade	**BN7000**
Insert	2NU-CNGA120408
Vc m/min	300-1000
f mm/rev	0.12
ap mm	0.2
Coolant	Wet



• BN7000 with high wear resistance keeps a sharp edge for a long time and achieves 2 times longer tool life than conventional or competitor's CBN

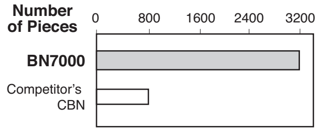
● Plunge cutting of VSI

Work: VSI (In)
Process: Finishing of 45 degree surface



Criteria: Surface roughness

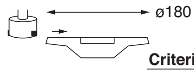
Grade	**BN7000**
Insert	Special Bite
Vc m/min	100
f mm/rev	0.08
ap mm	–
Coolant	Wet



• BN7000 with high wear resistance keeps a sharp edge for a long time and achieves 4 times longer tool life than competitor's CBN.

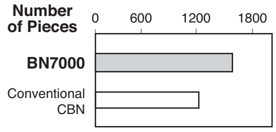
● Milling of oil pump

Work: Gray cast iron (FC250 : JIS)
Process: Finishing of face



Criteria: Surface roughness, Dimensional accuracy

Grade	**BN7000**
Insert	SNEW1203ADTR / FMU4100R
Vc m/min	1500
fz mm/rev	0.13
ap mm	0.3
Coolant	DRY



• BN7000 achieved 1.3 times longer tool life than competitor's CBN by excellent breakage resistance.

Fig. 8. Examples of machining by BN7000

Contributors (The lead author is indicated by an asterisk (*).)

Y. MATSUDA*

• Sumitomo Electric Hardmetal. Corp.
He is engaged in the development of PCBN tools.

K. OKAMURA

• Sumitomo Electric Hardmetal. Corp.

S. UESAKA

• Sumitomo Electric Hardmetal. Corp.

T. FUKAYA

• Sumitomo Electric Hardmetal. Corp.