Development of "SUMIBORON BN7500" for Ferrous Powder Metal Finishing

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"SUMIBORON" PCBN tools are widely used in the cutting of hard-to-cut ferrous materials, such as hardened steel, cast iron, and powder metal and contribute to productivity growth and cost reduction for metalworking. In recent automotive industry, powder metal consumption is increasing. The powder metal materials have more flexibility in design and can be sintered into complex shapes. However, these have the disadvantage of poor machinability. Therefore, the demand for PCBN cutting tools for higher precision performance and longer tool life has increased. "SUMIBORON BN7500," shows a higher precision and longer tool life in the finishing of powder metal parts than conventional PCBN grades by maintaining cutting edge sharpness. BN7500 has the highest cBN content among the present production line and excellent binding force between fine-grained cBN particles. The development and the performance of BN7500 are described in this report.

Keywords: powder metal, finishing, cBN, PCBN, cutting tool

1. Introduction

Cubic boron nitride (cBN) has the highest hardness and thermal conductivity among all the materials except for diamond, and also has a low affinity with ferrous materials. Sumitomo Electric Hardmetal, Corp. (SHM) developed polycrystalline boron nitride (PCBN) by sintering cBN with ceramic binding materials, and contributed to the shift of the machining method of hardened steel from grinding to cutting [(1)-(3)]. Furthermore, we contributed to the productivity improvement and cost reduction in finishing and semi-finishing of ferrous materials such as cast iron and powder metal (PM) with high content PCBN tools [(4)].

Recently the consumption of ferrous powder metal in automotive parts is increasing. Ferrous PM parts, requiring little machining, can be formed into complex from with the progress of near-net-shape technology, and lead to realization of cost reduction and energy saving. Ferrous PM also can be designed various material by control the ratio and grain size of added hard particles, sintering density and the method of hardening. However, machinability of ferrous PM parts decreases and conventional cutting tools cannot have enough machining accuracy and tool life. To respond to these needs, "SUMIBORON BN7500" for ferrous PM finishing was developed. This paper reports on the features and cutting performance of this new grade.

2. Subjects in Cutting of Ferrous PM

In case of ferrous PM cutting, conventional carbide or cermet cutting tools cannot have enough machining accuracy or cannot achieve enough tool life, therefore the application of PCBN cutting tool is increasing. In recent trends of automotive parts, ferrous PM has superior mechanical properties, and as the result, its machinability becomes poor. Therefore cutting tools are required to have superior wear resistance and breakage resistance.

Especially in finishing of ferrous PM, burr and chipping at workpiece's edge and white turbidity are main problems. To eliminate these problems at workpiece's edge, brush or barrel finishing is needed after cutting, and the omission or contraction of these process is required. To suppress burr and chipping at workpiece's edge and white turbidity, maintaining the sharpness of cutting edge is the most important.

Partially hardened ferrous PM for high mechanical strength, which has a high hardness, causes tools to wear quickly, and is prone to chipping and breakage at cutting edge by interrupted impacts in case of interrupted cutting. Therefore PCBN cutting tool, which has a high strength of cutting edge and stability of long tool life, is required.

3. Features of BN7500

3-1 Specifications of BN7500

Table 1 shows the specifications of BN7500 in comparison with SHM's conventional PCBN grade BN700. BN7500, which has the higher cBN content and finer-grained cBN particles than BN700, has an excellent strength and hardness. The higher cBN content suppresses the abrasive wear by the hard particles in the ferrous PM due to the decrease of the amount of binder in the sintered body. In addition, BN7500, which has the ex-

Table 1. Specifications of BN7500

Grade	cBN sintered body		Hardness Hv (GPa)	TRS* (GPa)	K1C (MPa·m$^{1/2}$)
	cBN content (vol%)	Grain size of cBN (μm)			
BN7500	90-95	1	41-44	1.4-1.5	7-9
BN700	90-95	2	40-43	1.2-1.3	8-10

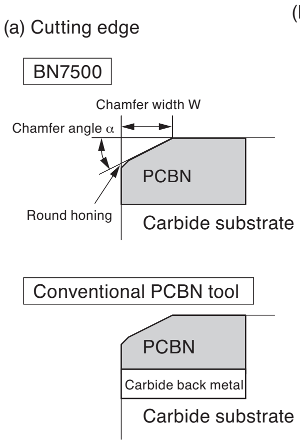
* Transverse rupture strength

cellent binding force between fine-grained cBN particles, can form a sharper cutting edge and maintain the sharpness of cutting edge during the machining.

3-2 Structure of BN7500

Figure 1 shows the cross section of cutting edge and edge preparation. The conventional PCBN tool is bonded on the carbide substrate over the carbide back metal, however, the sintered body of BN7500 is bonded on the carbide substrate directly (**Fig. 1(a)**). BN7500 has a thicker PCBN sintered body and can be applied for cutting with large wear. Furthermore, for the decrease of interface between the PCBN sintered body and the carbide substrate, reliability against tool failure is improved. BN7500 has three types of edge preparation: standard-type for general cutting, LF-type with sharp cutting edge and HS-type with tough cutting edge (**Fig. 1(b)**). Each edge preparation supports various ferrous PM machining.

The standard-type, which has an appropriate balance between breakage resistance and sharpness, is the primary recommendation for general ferrous PM finishing. The LF-type is equipped with sharp cutting edges for ferrous PM machining, and can maintain exellent surface integrity by the suppression of burr and white turbidity. The HS-type, which has a large chamfer angle and round honing, can suppress the chipping and breakage at cutting edge in the interrupted cutting of hardened ferrous PM (more than HRC50), and achieves a long tool life.



(b) Edge preparation

	α	W	Round honing
Standard-type	15°	0.12mm	No
LF-type	0°	–	No
HS-type	25°	0.05mm	Yes

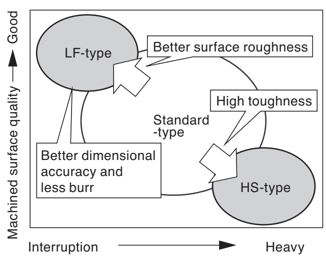


Fig. 1. Structure of the cutting edge of BN7500

4. Cutting Performance of BN7500

4-1 Cutting on standard ferrous PM

Figure 2 shows the results of the evaluation for cutting force, surface roughness and burr in standard ferrous PM finishing. The workpieces used were SMF4040 which have holes on the end face (**Fig. 2(a)**). The LF-type, equipped with sharp cutting edge with no chamfer, shows the smallest cutting force. HS-type, equipped with the larger chamfer angle and round honing, shows the largest cutting force especially back force. The standard-type equipped with the chamfer angle only, shows the cutting force between the LF-type and the HS-type (**Fig. 2(b)**). The surface roughness is improved, as the cutting speed becomes

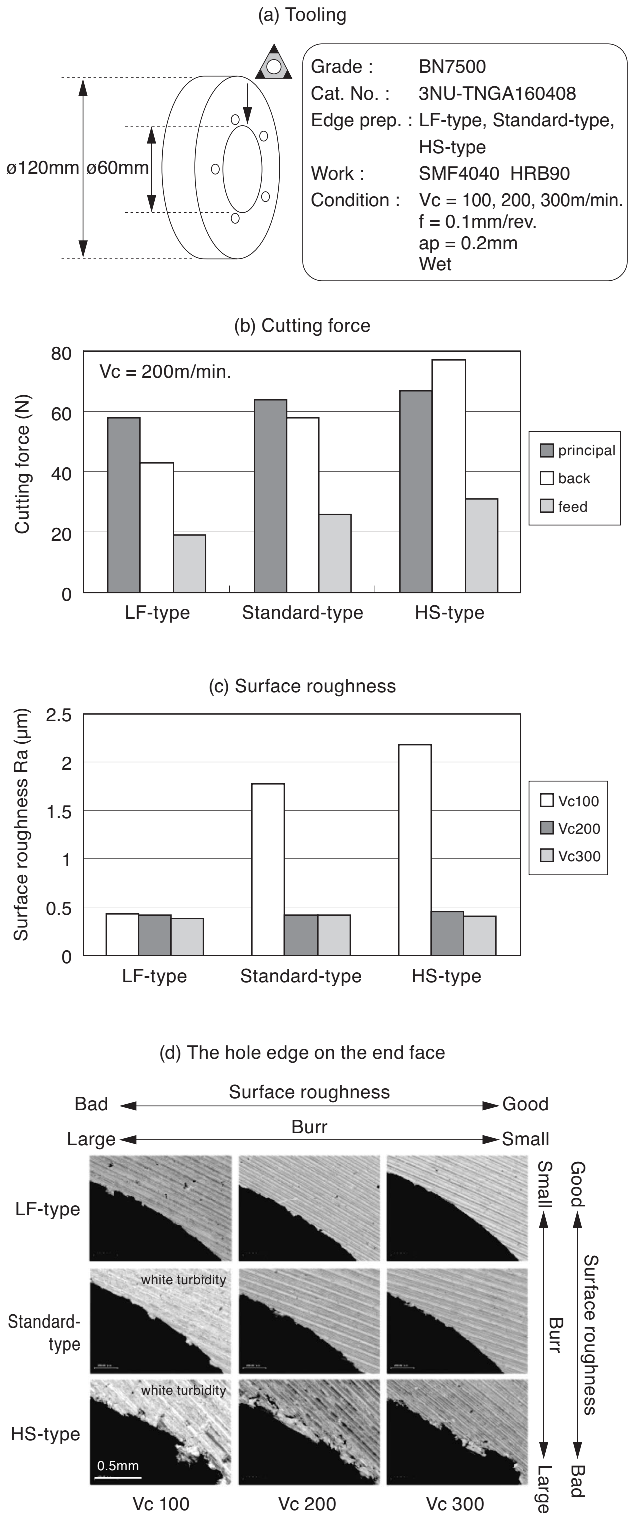


Fig. 2. Results of cutting test on standard ferrous PM

higher, and the machined surface looks shiny. The surface roughness machined by each edge preparation is improved in the cutting speed of more than 200 m/min. In cutting speed of 100 m/min., the machined surface by the standard-type and HS-type edges have white turbidity caused by high surface roughness, however, the machined surface by the LF-type edge is excellent (**Fig. 2(c)**). Furthermore, burr at the edge of the hole on the end face shows the same tendency with surface roughness, burr becomes smaller by using the cutting edge with a smaller chamfer angle or increasing the cutting speed (**Fig. 2(d)**).

In case of standard ferrous PM, standard-type for general use is the primary recommendation, and cutting speed more than 200m/min. is recommended to suppress the white turbidity. If the cutting speed cannot be high due to the size of workpieces, or tool life is not enough by surface roughness or burr, the LF-type with sharp cutting edge is recommended.

4-2 Cutting on hardened ferrous PM

Figure 3 shows the results of the evaluation for chipping resistance in the machining of hardened PM gear parts (HRC60). The HS-type has an excellent strength of cutting edge due to the large chamfer angle of 25 degrees and round honing, and realizes stable and long tool life in the interrupt cutting of hardened ferrous PM.

Also in case of hardened ferrous PM, the standard-type for general use is the primary recommendation. If tool life is not enough by chipping or breakage at cutting edge, the HS-type with tough cutting edge is recommended.

4-3 Countermeasure against white turbidity on ferrous PM

The mechanism of white turbidity on the machined surface of ferrous PM is not resolved completely, however, it is empirically known that it's suppressed by using a sharper cutting edge or increasing the cutting speed as described in this report 4-1. **Figure 4** shows the results of the evaluation about the white turbidity of ferrous PM in the perspective of the sharpness of cutting edge. The workpieces used were SMF4040 (HRB70) machined by BN7500 and the conventional PCBN (**Fig. 4(a)**). **Figure 4(b)** shows the SEM photograph of damaged cutting edges with the same flank wear width (VB = 0.05 mm). In the conventional PCBN's cutting edge, the ridge line is rounded because of the dropout of coarse-grained cBN particles. In the BN7500's cutting edge, the ridge line maintains sharpness. By the comparison of the machined surface by each damaged cutting edge, the machined surface by conventional PCBN had tear, however, the machined surface by BN7500 did not (**Fig. 4(c)**). It is presumed that the white turbidity by tear occurred for the reduction of cutting edge's sharpness by the rounded ridge line of cutting edge, where the negative rake angle becomes large (**Fig. 4(d)**).

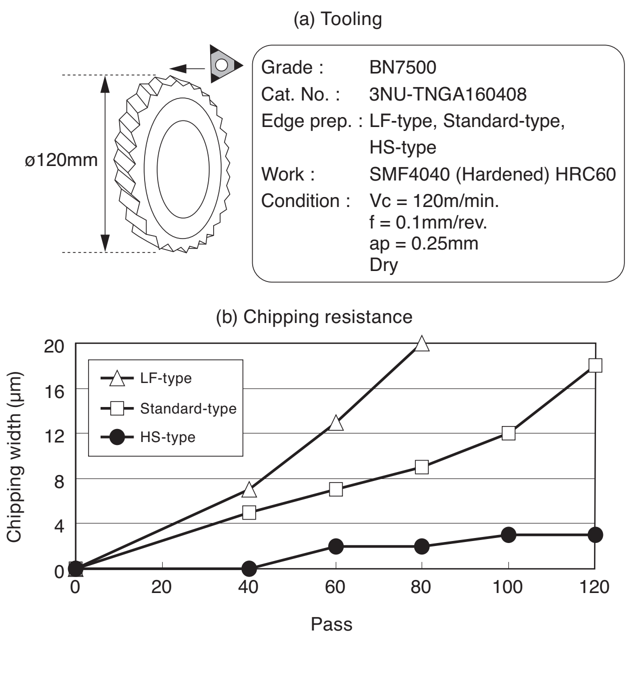


Fig. 3. Results of cutting test on hardened ferrous PM

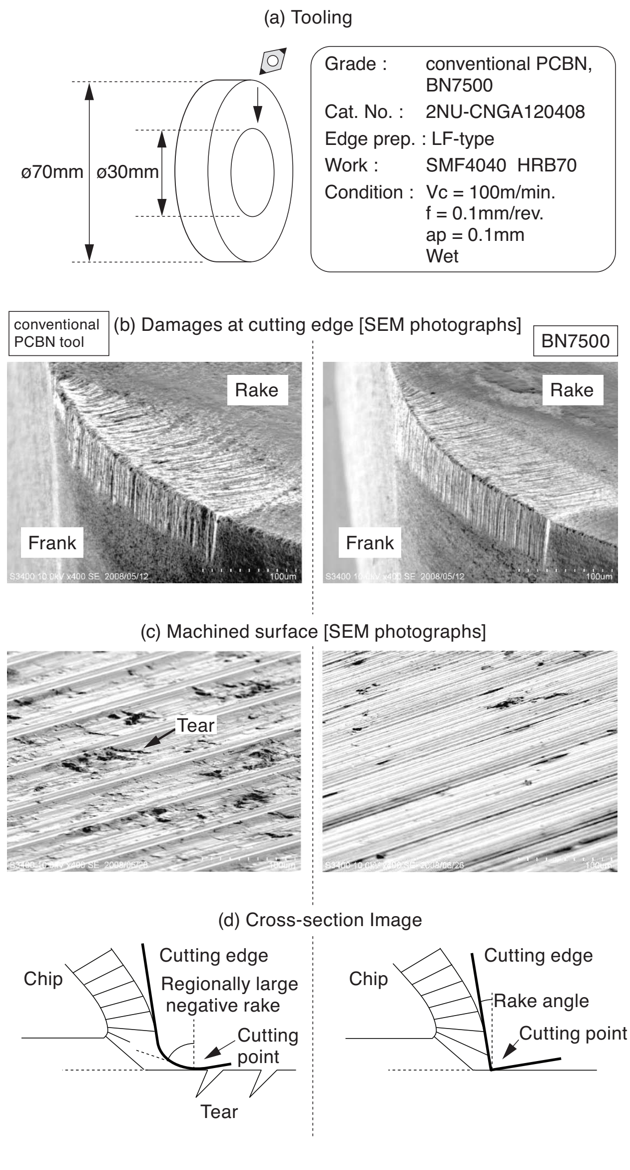


Fig. 4. Results of cutting test of white turbidity on ferrous PM

To suppress the white turbidity, it is important that the cutting edge is kept sharp. By using BN7500, which can suppress the dropout of cBN particles at cutting edge, the white turbidity is suppressed and high precision cutting and longer tool life can be achieved.

5. Application Area and Example of BN7500

Figure 5 shows the application areas in the machining of ferrous PM proposed by SHM. In case of ferrous PM roughing, stability of breakage resistance is important because the burr and chipping at workpiece's edge are eliminated at brush or barrel finishing after cutting. Therefore SHM recommends BN700, which has high fracture toughness properties due to the larger grained cBN particles, in roughing of ferrous PM. On the other hand, BN7500 is recommended in ferrous PM finishing, because it can maintain the sharpness of the cutting edge for a long time due to the excellent strength of cutting edge. BN7500 exhibited excellent properties, for example, in the machining of oil pump rotor, variable valve timing-intelligent system (VVT) and plunge finishing of valve sheet insert (VSI).

Figure 6 shows the examples of the use of BN7500. In case of standard ferrous PM finishing, BN7500 showed 1.5 to 2 times longer tool life than conventional PCBN cutting tool due to the suppression of the burr.

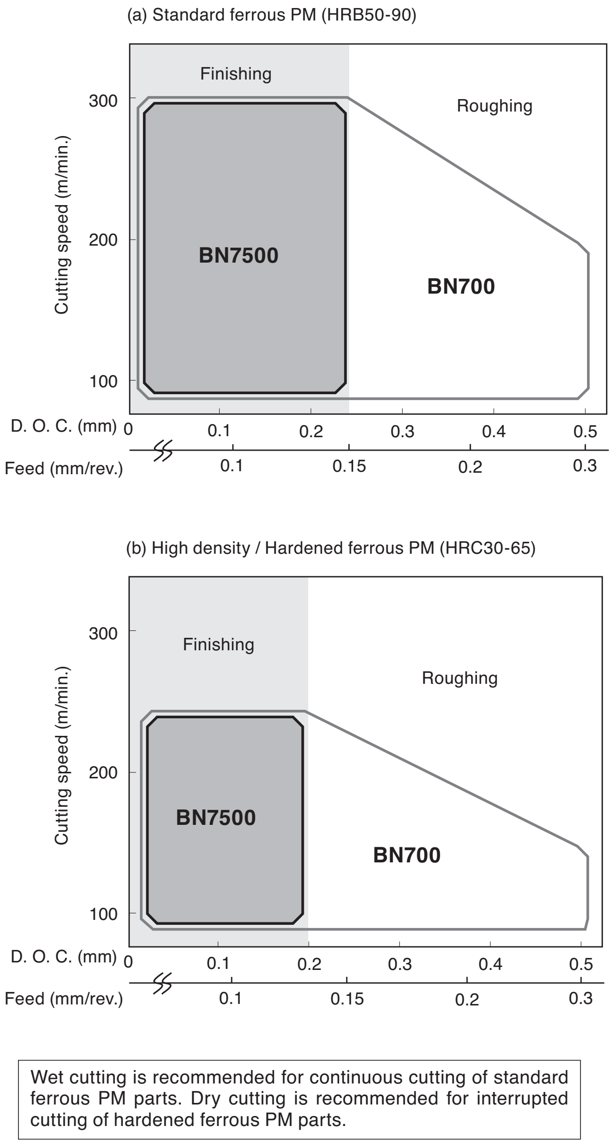


Fig. 5. Application areas for BN7500 in ferrous PM cutting

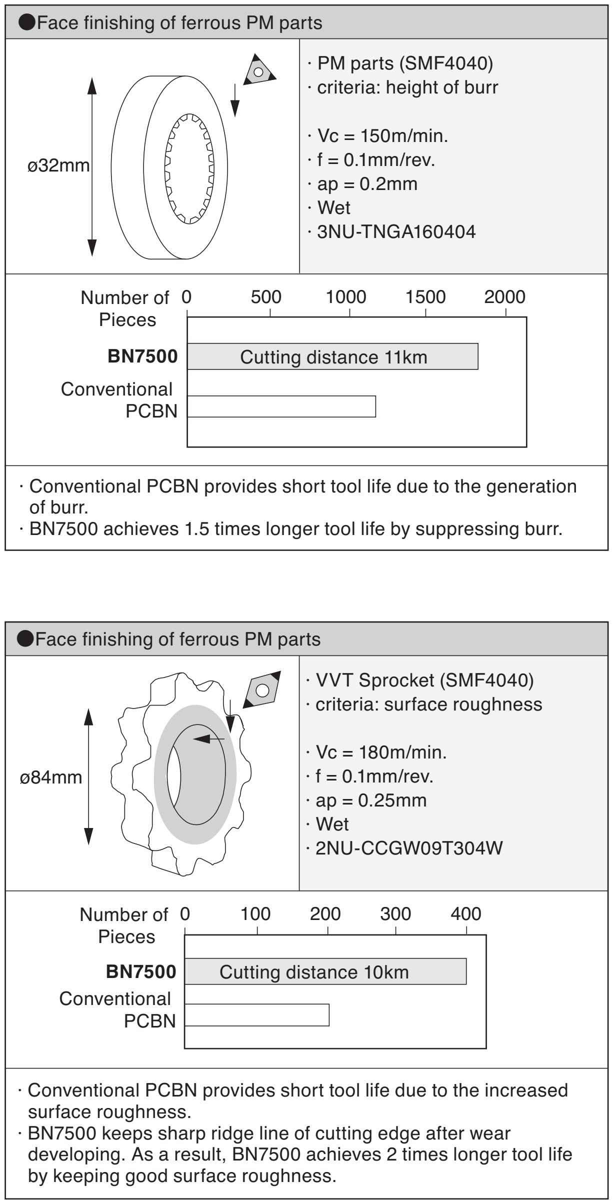


Fig. 6. Application examples of BN7500

6. Conclusion

By using “SUMIBORON BN7500” for ferrous PM finishing, burr and white turbidity are suppressed and a longer tool life can be achieved in the cutting of ferrous powder metal. BN7500 has the highest strength among “SUMIBORON” series, and it can be used not only for machining of ferrous PM but also for applications like high-speed cutting of cast iron, heavy-interrupted machining of hardened steel and hard milling, which need tools with a high strength, and the expansion of its application is expected.

* SUMIBORON is a trademark or a registered trademark of Sumitomo Electric Industries, Ltd.

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