Development of Sumiboron BNC100 for High-Speed Cutting and Sumiboron BNC160 for High-Precision Cutting of Hardened Steel

Minori TERAMOTO*, Katsumi OKAMURA, Satoru KUKINO and Tomohiro FUKAYA

Cubic boron nitride (cBN) shows high levels of hardness and thermal conductivity second only to diamond and has a low affinity to ferrous metals. Cutting by polycrystalline cBN(PCBN) tool "SUMIBORON", which is produced by binding cBN particles with a special ceramic binder, has many advantages over conventional grinding process. Recently, the increasing global awareness of environmental issues has induced demands for high-speed and high-precision cutting. In order to satisfy such demands, new PCBN grades BNC100 and BNC160 have been developed. High-speed cutting at 250 m/min or higher and high-precision cutting with a surface roughness (Rz) of 1.6 μm and the tolerance grade IT6 can be achieved using BNC100 and BNC160. The features and cutting performances of these new grades are described in this report.

1. Introduction

Cubic boron nitride (cBN) shows high levels of hardness and thermal conductivity second only to diamond, and has a low affinity to ferrous metals. "Sumiboron" polycrystaline cBN (PCBN) tools fabricated by sintering cBN particles with special ceramics binder can be used for cutting high hardness materials such as hardened steel, which had conventionally been machined only by grinding (1). Recently, the growing global awareness of environmental issues has induced demands for high-speed cutting that consumes low electric power and high-precision cutting that does not produce industrial wastes like grinding sludge.

In order to satisfy such demands, Sumiboron BNC100 and BNC160 grades have been developed. Sumiboron BNC100 grade for high-speed cutting of hardened steel has excellent wear resistance even at a cutting speed of 300 m/min, and Sumiboron BNC160 grade for high-precision cutting of hardened steel provides satisfaction of a surface roughness requirement of Rz = 1.6 μm and the tolerance grade IT 6. The features and cutting performances of BNC100 and BNC160 are described in subsequent sections.

2. Features and geometries of BNC100 and BNC160

2-1 Structural and material features of BNC100 and BNC160

Figure 1 shows the outside appearances of non-coated and coated Sumiboron inserts and the cross-sectional views of cutting edges. Sumiboron PCBN insert is made by brazing PCBN onto cemented carbide and has chamfered cutting edges. In recent years, high performance PCBN inserts coated with ceramics has become mainstream (2), (3). As shown in **Fig. 1**, coated Sumiboron PCBN insert is available in two cutting edge structures. One is structure (b) that has PCBN with carbide back metal brazed onto a carbide substrate, and the other is structure (c) that has PCBN brazed directly onto a carbide substrate. BNC100 has structure (b) and BNC160 has structure (c).

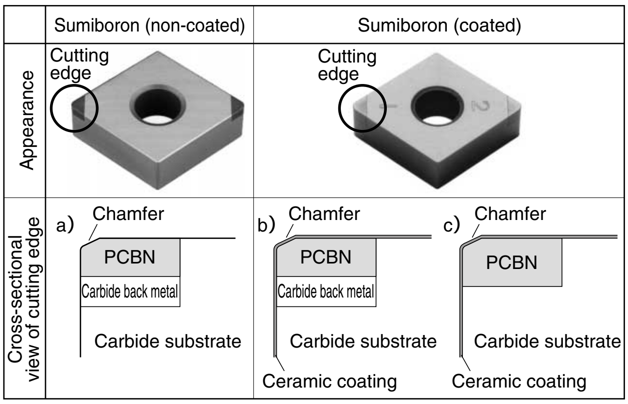


Fig. 1. Outer appearances and cutting-edge cross-sections of Sumiboron inserts

Table 1 shows the grade specifications of BNC100, BNC160, and conventional grades. **Table 2** shows their physical properties. The conventional grades BNC150 (coated insert) and BNX10 (non-coated insert) are for high-speed cutting, and BNC80 (coated insert) is for high-precision cutting.

BNC100 grade for high-speed cutting has a TiAlN/TiCN-based special ceramic coating on a newly developed special PCBN substrate. BNC100 offers a cBN content of about 40 vol% and the average cBN particle size is about 1 μm. This grade shows excellent wear resistance particularly in cutting at high speeds ranging from 200 to 300 m/min.

Table 1. Grade specifications of BNC100 and BNC160

Application	Grade	Ceramic coating (PVD)		PCBN		
		Composition	Thickness [μm]	cBN content [vol%]	cBN particle size [μm]	Binder
High-speed cutting	BNC100	TiAlN+TiCN	2	40–45	1	TiN
	BNC150	TiCN	2	45–50	2	TiN
	BNX10	–	–	40–45	3	TiCN
High-precision cutting	BNC160	TiAlN+TiCN	2	60–65	3	TiN
	BNC80	TiN	2	60–65	3	TiN

Table 2. Physical properties of BNC100 and BNC160

	Hardness[GPa]	TRS[GPa]
BNC100	29–32	1.05–1.15
BNC150	29–32	1.00–1.10
BNX10	27–31	0.80–0.90
BNC160	31–33	1.10–1.20
BNC80	31–33	1.00–1.10

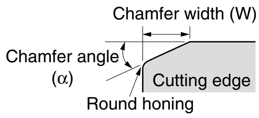
BNC160 grade for high-precision cutting also has a TiAlN/TiCN-based special ceramic coating on a special substrate. The cBN content of BNC160 is about 60 vol%, and the average cBN particle size is about 3 μm. Therefore, BNC160 grade shows a better chipping resistance than BNC80 and BNC100 and the equivalent wear resistance with BNC100 in middle- to high-speed cutting conditions.

2-2 Cutting edge specifications for BNC100 and BNC160

In general, PCBN tool cutting edges are chamfered so as to prevent chipping during cutting of high hardness work materials. There are three types of edge preparation: Standard type, LS type, and HS type. The specifications of these edge preparations are shown in **Table 3**. By applying suitable edge preparations, BNC100 and BNC160 grades provide best performance in various cutting applications. LS type edge preparation has a smaller chamfer angle compared with other edge preparations and its cutting edge surface is very smooth due to the use of a special treatment process, offering good cutting performance with small cutting force. HS type edge preparation has a larger chamfer angle and thus shows improved chipping resistance.

Table 3. Edge preparations of BNC100 and BNC160

Grade	Type	Chamfer angle (α) [°]	Chamfer width (W) [mm]	Round honing
BNC100	Standard	25	0.12	Adopted
	LS	15	0.17	Adopted
BNC160	Standard	25	0.12	Adopted
	LS	20	0.10	Adopted
	HS	30	0.17	Adopted

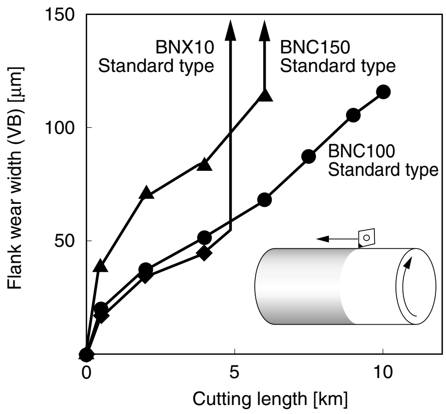


3. Cutting performance of BNC100 and BNC160

3-1 Cutting performance of BNC100 grade for high-speed machining

(1) Wear resistance evaluation

A comparative evaluation of wear resistance was made between BNC100, BNC150 and BNX10 grades. Outer diameter turning was conducted at a high speed of 250 m/min with JIS SCM415 carburized hardened steel (HRC58-62) that is equivalent to DIN 15CrMo5 as a work material. All three grades have the standard type cutting edge preparation with a chamfer angle of 25 degrees. **Figure 2** shows the flank wear width (VB) measurement results. The flank wear width of BNC100 is smaller by 40% compared with BNC150. This is because the percentage of the TiN-based binder having a low affinity for iron contained in BNC100 is higher than that in BNC150, and also because BNC100 has a newly developed special ceramic coating that exhibits excellent wear resistance.



Insert : 4NC-CNGA120408

Grade	Edge prep	Chamfer angle	Chamfer width	Round honing
BNC100	Standard type	25°	0.12mm	Adopted
BNC150	Standard type	25°	0.12mm	Adopted
BNX10	Standard type	25°	0.12mm	Not adopted

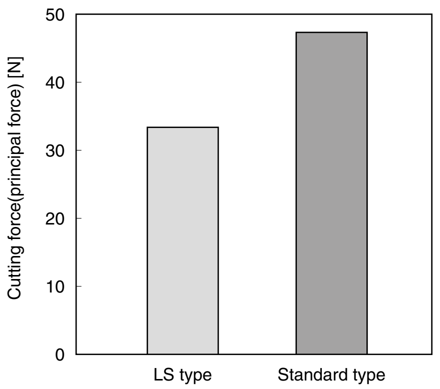
Work : JIS SCM415 (HRC58-62) Round bar [DIN 15CrMo5]
Conditions : V_c = 250 m/min, a_p = 0.1 mm, f = 0.1 mm/rev, dry

Fig. 2. Wear resistance of BNC100 in high-speed cutting

Moreover, the chipping resistance of BNC100 is improved by 30% or more compared with BNC150, and by 50% or more compared with BNX10. This is because BNC100 has a fine microstructure and the use of the new ceramics binder having a high interparticle binding force improves the strength of PCBN.

(2) Edge preparation evaluation

High-speed continuous cutting was conducted using BNC100 standard type and LS type to evaluate the cutting force and wear resistance of BNC100 grade. **Figure 3** shows the result of cutting force measurement, and **Fig. 4** shows the result of flank wear width (VB) measurement. The cutting force of BNC100 LS type is lower than that of BNC100 standard type by 30%, and the flank wear width of BNC100 LS type is lower than that of BNC100 standard type by 20%. This is assumed to be because the load imposed on the cutting edge during cutting is lowered due to the low cutting force characteristics of BNC100 LS type.

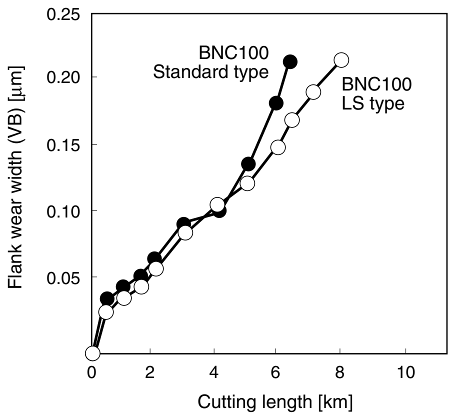


Insert : 3NC-TPGW110304

Type	Chamfer angle	Chamfer width	Round honing
LS type	15˚	0.17mm	Adopted
Standard type	25˚	0.12mm	Adopted

Work : JIS SCM420 (HRC55-57) [DIN 18CrMo4]
Conditions: V_c = 150 m/min, a_p = 0.08 mm, f = 0.07 mm/rev, dry

Fig. 3. Cutting force of BNC100 (Standard type and LS type)



Insert : 4NC-CNGA120408

Type	Chamfer angle	Chamfer width	Round honing
LS type	15˚	0.17mm	Adopted
Standard type	25˚	0.12mm	Adopted

Work : JIS SCM415 (HRC58-62) Round bar [DIN 15CrMo5]
Conditions : V_c = 200 m/min, a_p = 0.1 mm, f = 0.1 mm/rev, dry

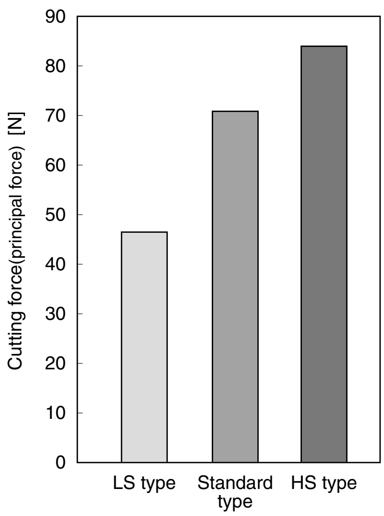
Fig. 4. Wear width of BNC100 (Standard type and LS type)

BNC100 LS type offers longer tool life while stably providing dimensional precision.

3-2 Cutting performance of BNC160 grade for high-precision cutting

(1) Edge preparation and cutting force

Figure 5 shows the results of cutting force measurement for BNC160 grade with different edge preparations. The cutting edges of BNC160 grade LS type are chamfered at a 20 degree angle. The cutting force of BNC160 LS type is the lowest among the three edge preparation types of BNC160 grade because BNC160 LS type has the smallest chamfer angle (20 degrees). BNC160 HS type has the largest chamfer angle of 30 degrees, which provides strength to the cutting edges. BNC160 standard type has a chamfer angle of 25 degrees and is superior in versatility.



Insert : 3NC-TPGW110304

Type	Chamfer angle	Chamfer width	Round honing
LS type	20˚	0.10mm	Adopted
Standard type	25˚	0.12mm	Adopted
HS type	30˚	0.17mm	Adopted

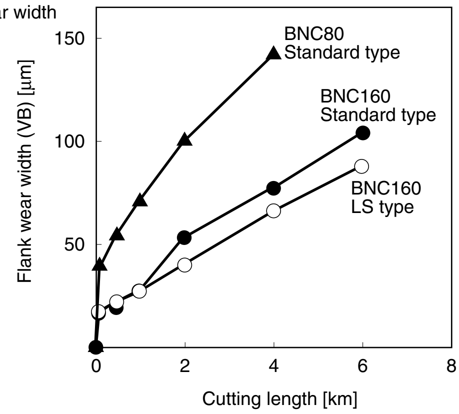
Work : JIS SCM420 (HRC58-62) [DIN 18CrMo4]
Conditions: V_c = 150 m/min, a_p = 0.08 mm, f = 0.07 mm/rev, dry

Fig. 5. Cutting force for BNC160 (3 types of edge preparation)

(2) Evaluation of high-precision cutting

Among the three edge preparations of BNC160 grade, BNC160 LS type shows the highest cutting performance in high-precision cutting. **Figure 6** shows the comparison results of wear resistance and surface roughness among BNC160 LS type, BNC160 standard type and BNC80. Outer diameter turning was conducted at a cutting speed of 200 m/min with SCM415 carburized hardened steel (HRC58-62) as a work material. Compared with BNC80, BNC160 LS type showed a flank

i) Flank wear width



Insert : 4NC-CNGA120408

Grade	Edge prep	Chamfer angle	Chamfer width	Round honing
BNC160	Standard type	25˚	0.12mm	Adopted
BNC160	LS type	20˚	0.10mm	Adopted
BNC80	Standard type	20˚	0.10mm	Adopted

Work : JIS SCM415 (HRC58-62) Round bar [DIN 15CrMo5]
Conditions : V_c = 200 m/min, a_p = 0.1 mm, f = 0.1 mm/rev, dry

ii) Surface roughness

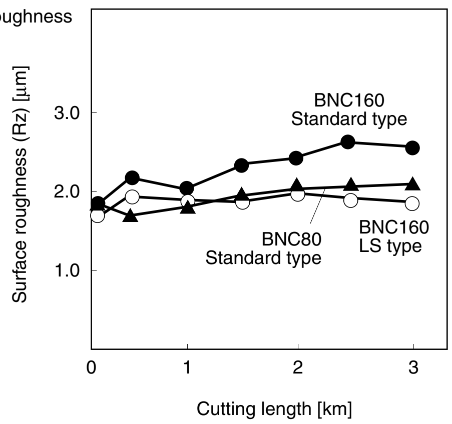
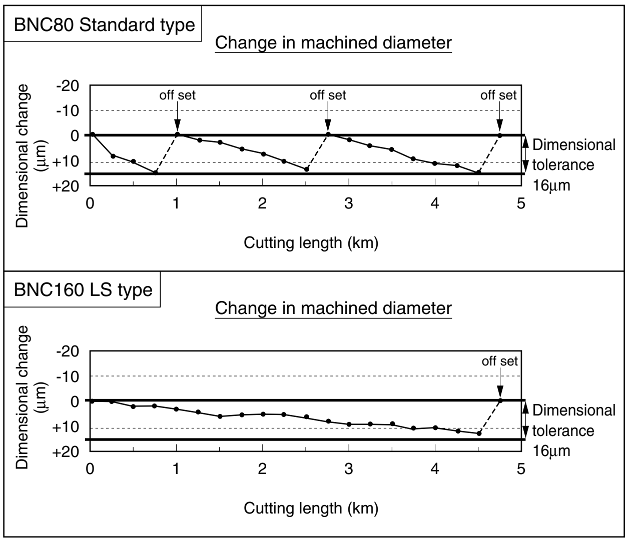


Fig. 6. Wear resistance and surface roughness of BNC160

wear width smaller by 52% and provided equivalent or better surface roughness stability. This is because the newly developed special ceramic coating smooths the developed notch wear and improves surface roughness in the same way as the special TiN coating applied onto BNC80 and has a higher wear resistance than the special TiN coating.

Figure 7 shows the results of evaluation on the dimensional stability (diametrical accuracy) obtained by machining using BNC160 LS type and BNC80. Because BNC160 grade shows excellent wear resistance, the amount of retrogradation of cutting edge is small and the cutting force is low. Hence, BNC160 can reduce the dimensional change in work diameters. When using BNC160 in machining with the tolerance grade IT6, the frequency of dimensional corrections is small and dimensional stability is obtained.

As shown in **Fig. 6**, BNC160 standard type can also stably provide excellent surface roughness, and has excellent wear resistance. The cutting edge chipping



Insert : 4NC-CNGA120408

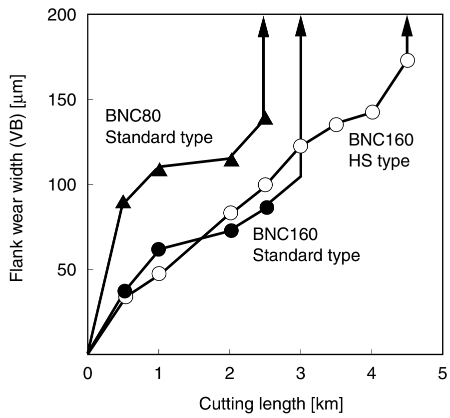
Grade	Edge prep	Chamfer angle	Chamfer width	Round honing
BNC160	LS type	20˚	0.10mm	Adopted
BNC80	Standard type	20˚	0.10mm	Adopted

Work : JIS SCM415 (HRC58-62) Round bar [DIN 15CrMo5]
Conditions : V_c = 200 m/min, a_p = 0.1 mm, f = 0.1 mm/rev, dry

Fig. 7. Change in machined diameter by BNC160 LS type

resistance of BNC160 standard type is higher than that of BNC160 LS type, so BNC160 standard type achieves excellent performance in general finish machining at which high machining efficiency and surface roughness of about Rz = 3.2 µm are required.

BNC160 HS type achieves the highest performance in high-efficiency cutting among the three. **Figure 8**



Insert : 4NC-CNGA120408

Grade	Edge prep	Chamfer angle	Chamfer width	Round honing
BNC160	Standard type	25˚	0.12mm	Adopted
BNC160	HS type	30˚	0.17mm	Adopted
BNC80	Standard type	20˚	0.12mm	Adopted

Work : JIS SCM415 (HRC58-62) Round bar [DIN 15CrMo5]
Conditions : V_c = 150 m/min, a_p = 0.25 mm, f = 0.15 mm/rev, dry

Fig. 8. Cutting performance of BNC160 HS type in high-efficiency cutting

shows the evaluation results of wear resistance and chipping resistance in high-efficiency cutting using BNC160 HS type, BNC160 standard type and BNC80. The flank wear width of BNC160 HS type is lower than that of BNC80 by 30%. The chipping resistance of BNC160 HS type is 80% higher than that of BNC80 and 50% higher than that of BNC160 standard type. The strength of cutting edge of BNC160 HS type is much higher than that of BNC160 standard type, so BNC160 HS type exerts excellent performance in high-efficiency cutting at high feed rate and large depth of cut, such as removal of carburized layers.

4. Application areas

The application areas of Sumiboron in continuous, interrupted, and high-precision machining of hardened steel are shown in **Fig. 9**. BNC100 is applicable in the ranges of feed rate 0.03 to 0.20 mm, depth of cut 0.03 to 0.30 mm and cutting speed 120 to 300 m/min, and gives excellent performance in high-speed finish cutting. On the other hand, BNC160 is applicable in the ranges of feed rate 0.03 to 0.20 mm, depth of cut 0.03 to 0.35 mm and cutting speed 120 to 250 m/min. BNC160 LS type gives excellent performance in medium-speed finish cutting where high precision is required on surface roughness and dimensions. BNC160 standard type and BNC160 HS type are highly versatile and can be used in cutting under high load conditions with large depth of cut and high feed rate. In the case of continuous cutting, dry or wet can be accept. On the other hand, in the case of interrupt cutting, dry is recommended.

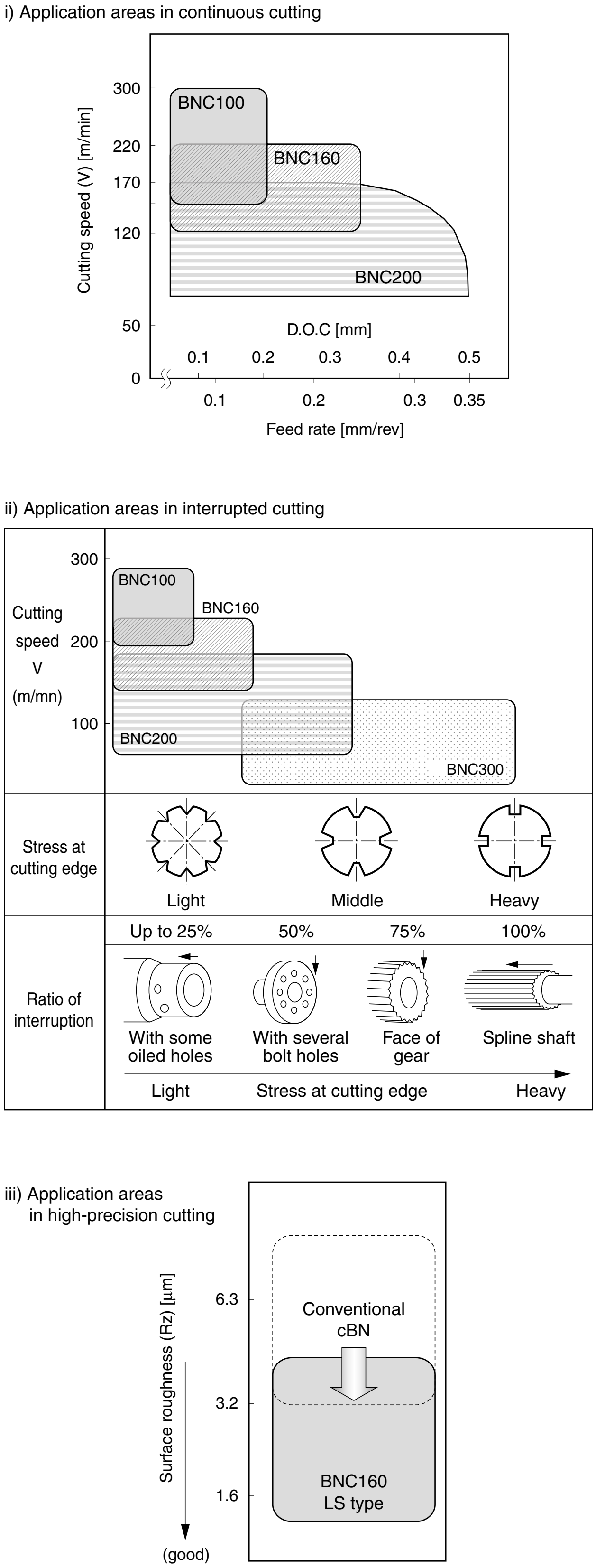


Fig. 9. Application areas of coated Sumiboron

5. Application examples

Figure 10 shows the application examples of BNC100. Example 1 is inner diameter turning of planetary gears machined under a high-speed cutting condition of Vc = 250 m/min. BNC100 standard type has achieved a 1.4 times longer life than the competitor's grade. Example 2 is outer diameter turning of shaft parts. BNC100 standard type enables high-speed cutting and improves the machining efficiency to 1.5 times that of ceramic tools, and also has a tool life 10 times longer. Example 3 is outer diameter turning of shaft parts with a dimensional tolerance of 13 µm. By using BNC100 LS type in achieving the required precision, stable machining was observed and a long life 1.5 times that of BNC150 was obtained. Example 4 is outer diameter turning of the end-faces of pinion gear parts with a surface roughness requirement of Rz = 1.6µm. The conventional BNC150 grade wiper insert achieved a tool life of 400 pieces, but the surface roughness it provided was not so stable. By using a BNC100 grade wiper insert, high-efficiency, high-stability cutting can be performed, and a long life 1.25 times that of the BNC150 grade wiper insert can be achieved.

Figure 11 shows the application examples of BNC160. Example 5 is outer diameter turning of input

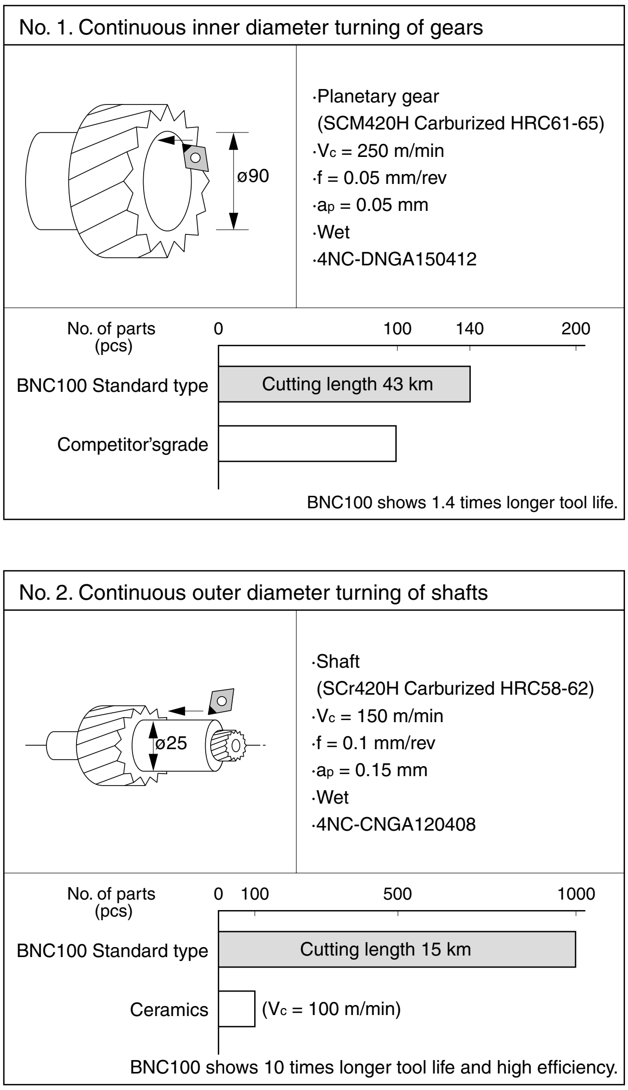


Fig. 10. Application examples of BNC100(1)

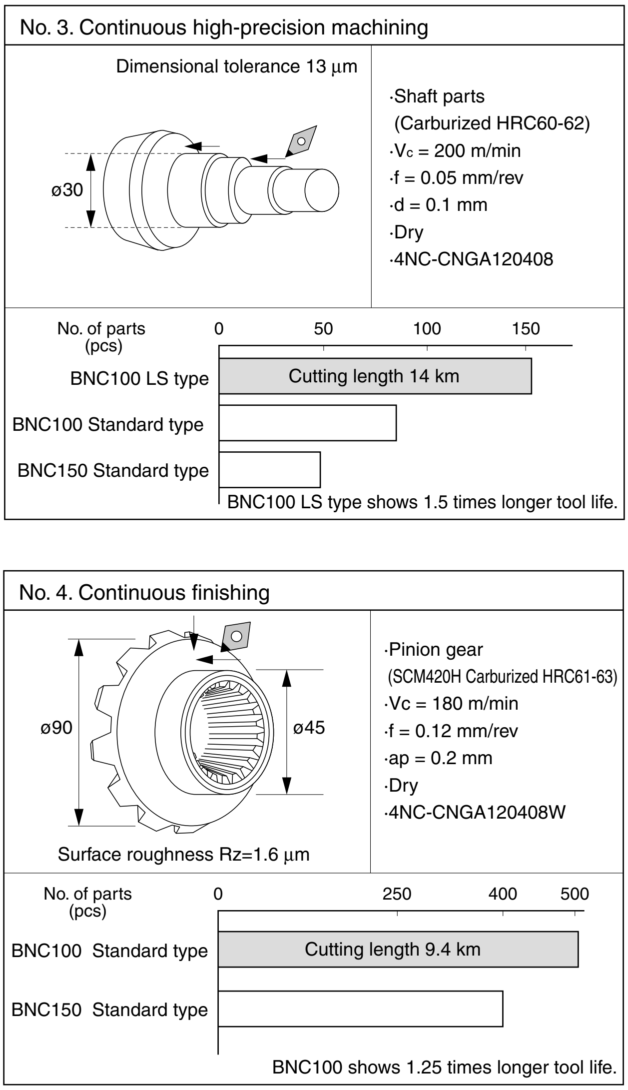


Fig. 10. Application examples of BNC100(2)

shaft parts with a surface roughness requirement of Rz = 1.6 µm and the tolerance grade IT6. BNC160 has achieved a long life 1.5 times that of the competitor's grade. Example 6 is outer diameter turning of sun gear parts with a surface roughness requirement of Rz = 2.0 µm. Chattering occurs when the conventional grade is used, but BNC160 has excellent wear resistance, and has achieved a long life twice that of the competitor's grade. Example 7 is machining of the end faces of shaft parts with a surface roughness requirement of Rz = 1.6 µm. BNC160 standard type has a longer tool life than BNC80 standard type because the wear resistance of BNC160 is superior to that of BNC80. Moreover, BNC160 LS type has achieved stable surface roughness and a long life 1.5 times that of BNC80. Example 8 is outer diameter turning of shaft parts that requires high-precision cutting at a feed rate of 0.05 mm/rev to achieve Rz = 1.6 µm as well as high-efficiency cutting at a feed rate of 0.13 mm/rev. cutting edge during high-efficiency cutting. When BNC160 standard type was used, although a long life 1.3 times that of BNC80 was achieved, minute chipping occurred at the cutting edge. When BNC160 HS type was used, the cutting edge had no chipping and the tool life was two times longer than that of BNC80.

6. Conclusion

BNC100 grade for high-speed cutting of hardened steel has achieved a long life 1.5 times that of the conventional grade in high-speed cutting at Vc = 250 m/min or higher.

BNC160 grade for high-precision cutting of hardened steel satisfies the surface roughness requirement of Rz = 1.6µm and the tolerance grade IT 6. Using BNC100/BNC160 may contribute in lowering electric power consumption, reducing environmental impact by

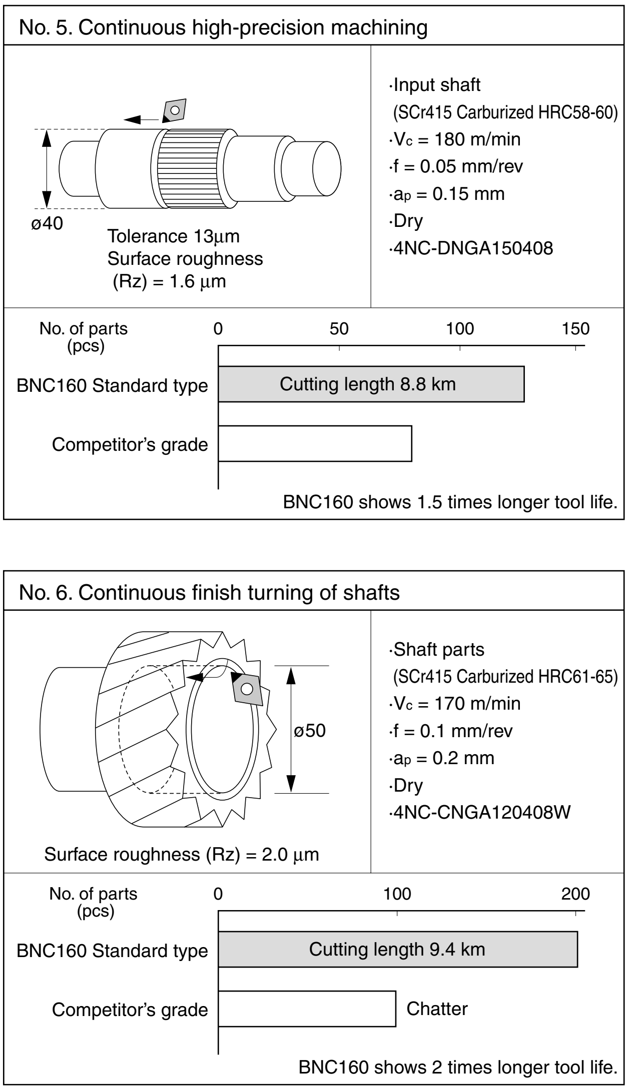


Fig. 11. Application examples of BNC160(1)

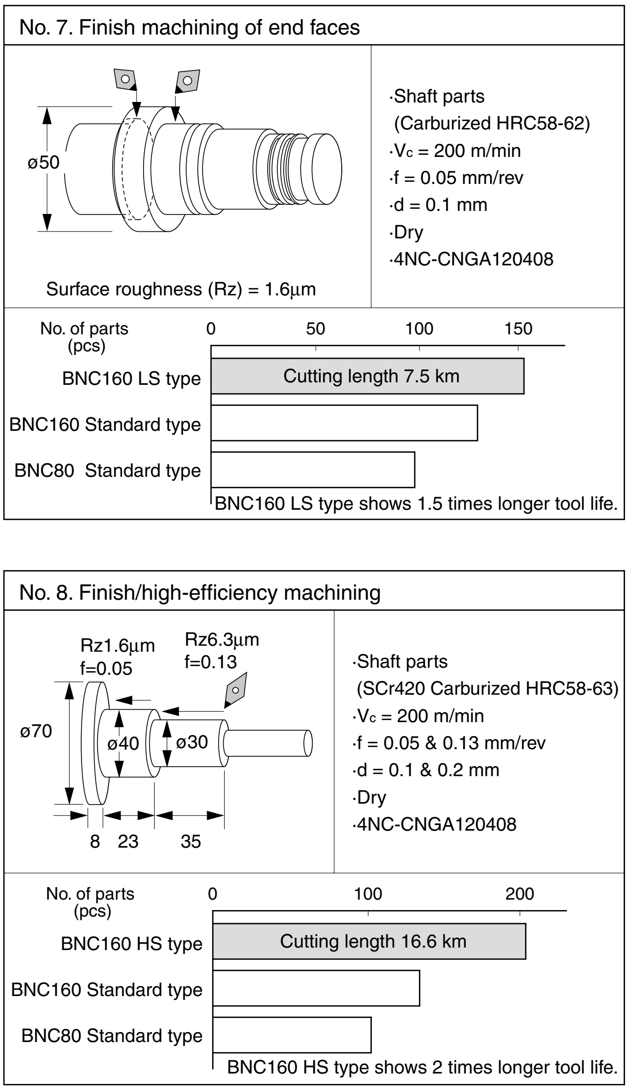


Fig. 11. Application examples of BNC160(2)

replacing grinding with cutting, and cutting down production cost.

References

(1) Hara, et al.: "Performance of SumiboronR BN200", Sumitomo Electric, No. 113, 161 (1978)
(2) Harada, et al.: "Development of coated cBN sintered material tool", SEI Technical Review, No. 158, 75 (2001)
(3) Okamura, et al.: "Development of SumiboronR BN350, BNC300 for interrupted machining of hardened steel", SEI Technical Review, No. 165, 87 (2004)

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

M. TERAMOTO*
- Super Hard Material Development Department, Sumitomo Electric Hardmetal Corporation

K. OKAMURA
- Super Hard Material Development Department, Sumitomo Electric Hardmetal Corporation

S. KUKINO
- Senior Manager, Super Hard Material Development Department, Sumitomo Electric Hardmetal Corporation

T. FUKAYA
- Manager, CBN-Diamond Products Group, Super Hard Material Development Department, Sumitomo Electric Hardmetal Corporation