Coated SUMIBORON BNC2010/BNC2020 for Hardened Steel Machining Realizing Long and Stable Tool Life

Yusuke MATSUDA*, Hironari MOROGUCHI, Nozomi TSUKIHARA, Katsumi OKAMURA, Makoto SETOYAMA and Tomohiro FUKAYA

In the automotive industry, a trend is seen that in line with the acceleration of automakers' transferring production to developing countries, an increasing number of production lines are unmanned, or operated by a small number of people. For that reason, there are strong demands for cutting tools having long and stable tool life. To satisfy such demands, we have developed Coated SUMIBORON BNC2010/BNC2020. Compared with conventional cutting tools, Coated SUMIBORON BNC2010 has improved in notch-wear resistance and achieves longer tool life, even in high-precision cutting of strict surface roughness criteria. BNC2020 has improved in breakage resistance and peeling resistance of the coating layer and achieves longer and more stable tool life in continuous and interrupted machining. This report describes the advantages and cutting performance of BNC2010/BNC2020.

Keywords: PCBN, hardened steel, high precision cutting, interrupted cutting, PVD coating

1. Introduction

Cubic boron nitride (CBN)*[1] has hardness and thermal conductivity second only to diamond, and has low reactivity with ferrous metals. Sumitomo Electric Hardmetal Corporation succeeded in developing the world's first CBN tool for the machining of hardened steel parts by sintering a mixture of CBN particles and a special ceramic binder, and launched it on the market in 1977 under the trade name SUMIBORON. Since the release in 2000 of Coated SUMIBORON, which features higher wear resistance by ceramic coating on the CBN sintered body with PVD*[2] technology, higher-precision and higher-efficiency machining have been realized. The shift from grinding to cutting, has contributed to productivity improvement and cost reduction, mainly in the automotive industry.

In the automotive industry, a trend is seen that, in line with the acceleration of automakers' transferring production to developing countries, an increasing number of production lines are unmanned, or operated by a small number of people. For that reason, customers' demands for cutting tools have shifted from "high-efficiency cutting" to "long and stable tool life." Furthermore, the requirement for high-precision cutting has become stronger against the background of an increase of high-functional automotive parts. To satisfy such demands, we have developed Coated SUMIBORON BNC2010 and BNC2020, which achieve considerably longer and more stable tool life than the conventional Coated SUMIBORON series. The advantages and cutting performance of BNC2010 and BNC2020 are described below.

2. Issues in Hard Turning

A coated CBN tool has a hard and tough CBN sintered body covered with a ceramic coating having excellent heat and oxidation resistance, as shown in **Fig. 1**. As the result, it can achieve longer tool life, even in hard turning where the cutting edge is subjected to high load and heat during the cutting. However, the hardness and toughness of a ceramic coating is lower than a CBN sintered body, abrasive wear and coating peelings occur in the case when the mechanical load is added at the cutting edge. On the other hand, desired shape and mechanical strength are given to the hardened steel workpieces by applying appropriate forming, forging and thermal treatments. However, surface integrity, such as hardness, microstructure and stress state, may vary among different lots and within the same lot, too. Moreover, an overall tooling system, composed of a lathe, a chuck and a holder, may not always has enough rigidity to cut hardened steel. As the result, above abrasive wear or coating peeling may occur due to discontinuous load, and often cause shorter or more unstable tool life.

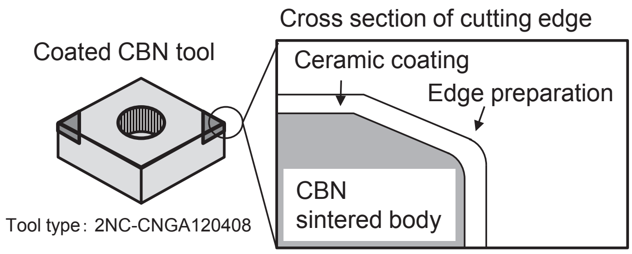

Fig. 1. Structure of Coated CBN tool

Figure 2 shows classification of the failure mode in hard turning. In the case of high-precision cutting with the required surface roughness of less than Rz 3.2*[3], the feed rate is often set low for the superior theoretical surface roughness. As a result, the notch wear is increased by the focused mechanical load on the end-cutting edge of the notch where the thickness of the chip becomes thin. In such high-precision cutting, suppression of the notch wear is most important because it is transcribed on the machined surface and it becomes a deciding factor of the surface roughness, as shown in **Fig. 3**. In the case of general purpose, breakage from crater wear and chippings from coating peeling become the main failure mode because of the high feed rate, high depth of cut, or interruptions.

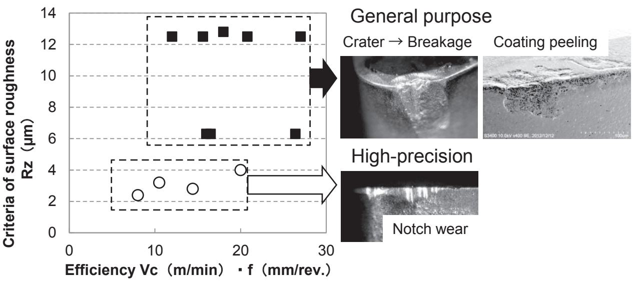

Fig. 2. Failure mode for hard turning

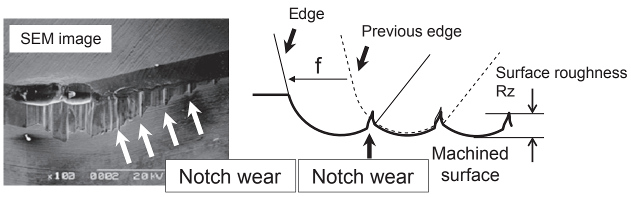

Fig. 3. Relationship between notch wear and surface roughness

BNC2010 for high-precision cutting is able to maintain superior surface finish by suppressing notch wear. BNC2020 has improved in breakage resistance and peeling resistance of the coating layer, achieving a longer and more stable tool life under various cutting conditions. As a result, BNC2010 and BNC2020 eliminate tool change at irregular intervals, making unmanned operations possible over a longer time, and realizing significant progress in both productivity improvement and machining cost reduction.

3. Features of BNC2010 and BNC2020

3-1 Characteristics of BNC2010 and BNC2020

Table 1 shows the specifications of BNC2010, BNC2020 and conventional grades. **Table 2** shows the physical properties of these grades. The CBN content, particle size, and binding material are optimized and controlled, depending on the applications, to provide the CBN sintered body with the desired breakage and wear resistances.

Table 1. Specifications of BNC2010 and BNC2020

Application	Grade	CBN sintered body			Ceramic coating	
		CBN content (%)	CBN grain size (μm)	Binder	Composition	Tickness (μm)
High precision	**BNC2010**	**50-55**	**2**	**TiCN**	**TiCN+Unique multi layer**	**1.5**
	BNC100	40-45	1	TiN	TiAlN+TiCN	2
	BNC160	60-65	3	TiN	TiAlN+TiCN	2
General	**BNC2020**	**70-75**	**5**	**TiN**	**TiAlN+Unique adhesion layer**	**1.5**
	BNC200	65-70	4	TiN	TiAlN	2

Table 2. Physical properties of BNC2010 and BNC2020

Application	Grade	Hardness HV (GPa)	Strength TRS (GPa)	Toughness K1C (MPa・m$^{1/2}$)	Thermal conductivity (W/m・K)
High precision	**BNC2010**	**30-32**	**1.10-1.20**	**5.5-6.0**	**40-60**
	BNC100	29-32	1.05-1.15	5.0-5.5	40-60
	BNC160	31-33	1.10-1.20	6.0-6.5	55-75
General	**BNC2020**	**34-36**	**1.20-1.30**	**7.0-7.5**	**65-85**
	BNC200	33-35	1.15-1.25	6.5-7.0	60-80

Figure 4 shows the micro structure of the CBN sintered body of BNC2010 and BNC2020. Both have improved in wear and breakage resistances by extremely decreasing impurities which causes wear and cracks. Furthermore, BNC2010 shows high wear resistance in the cutting from high-speed to light interruption by applying a high-purity titanium carbonitride (TiCN) binder with excellent heat resistance. BNC2020 has improved in thermal conductivity and toughness by applying a larger size of CBN particles than conventional CBN grades and a high-purity titanium nitride (TiN) binder.

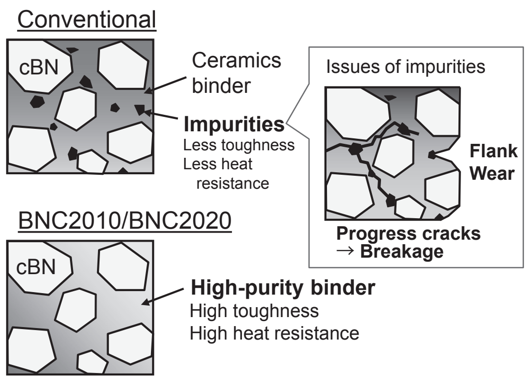

Fig. 4. CBN sintered body of BNC2010 and BNC2020

Ceramic coating can add various functions to the cutting tool by design of its composition, thickness and structure of coating layer. **Figure 5** shows the cross section view of BNC2010 and BNC2020 coatings. BNC2010 has a trilaminar structure of a TiCN layer and unique multi-layer that shows excellent notch wear resistance. BNC2020 has a titanium aluminum nitride (TiAlN) layer and unique adhesion layer that shows

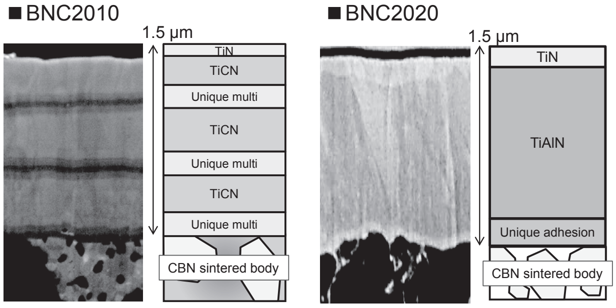

Fig. 5. Coating structure of BNC2010 and BNC2020

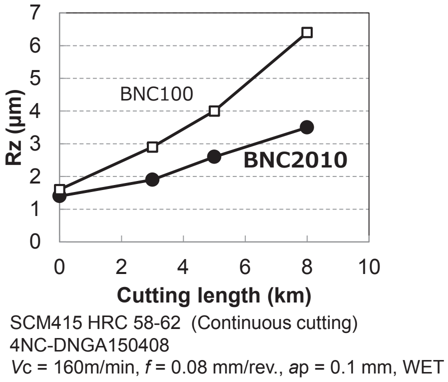

Fig. 7. High-precision cutting evaluation results of BNC2010

excellent wear and coating peeling resistances, and realized stable coating during cutting.

3-2 Edge preparation of BNC2010 and BNC2020

BNC2010 and BNC2020 have two types of edge preparations as shown in **Fig. 6**. "Standard" is for general purpose and "HS" is a stronger type. By using appropriate edge preparation for each application, BNC2010 and BNC2020 can be used for various hard turning, which covers a wide range of machinability and shape of workpiece. "Standard", with a good balance between sharpness and breakage resistance, is the first recommendation for general cutting. By using "HS", the breakage in interrupted cutting could be suppressed by larger chamfer angle and width.

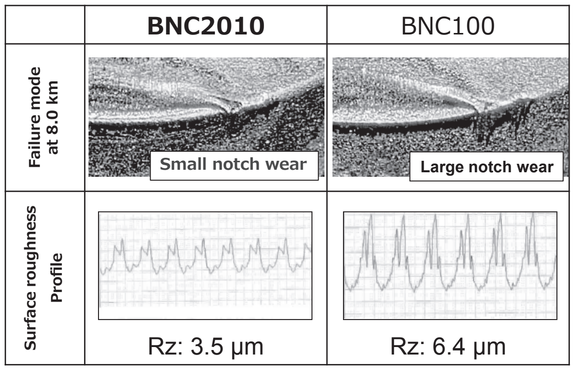

Fig. 8. Comparison of BNC2010 with conventional CBN

		α	W	Honing
BNC2010	Standard	25	0.12	Yes
	HS	30	0.17	Yes
BNC2020	Standard	25	0.12	Yes
	HS	35	0.27	Yes

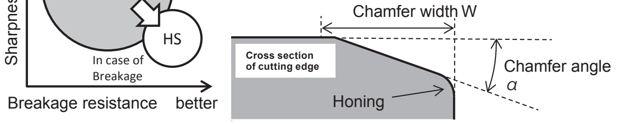

Fig. 6. Edge preparation of BNC2010 and BNC2020

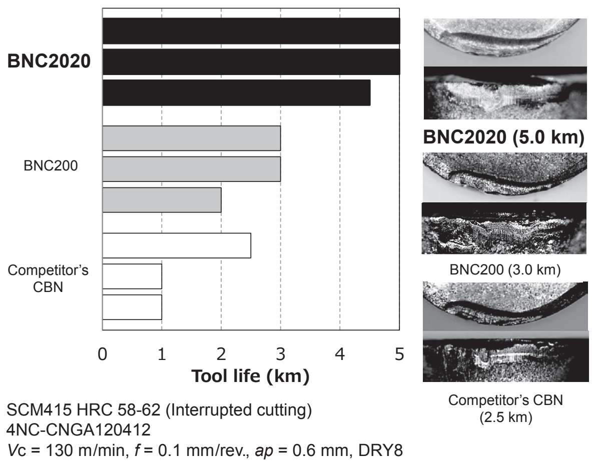

Fig. 9. Interrupted cutting evaluation results of BNC2020

4. Cutting Performance of BNC2010 and BNC2020

4-1 High-precision cutting evaluation of BNC2010

Figure 7 shows the results of a comparison of BNC2010 with conventional BNC100 in continuous cutting of case hardened steel. BNC2010 achieved a twice longer tool life by maintaining a lower surface roughness than BNC100 in the case of the required surface roughness of Rz 3.2. **Figure 8** shows the results of a comparison of the failure mode and machined surface after 8 km of cutting of these 2 grades. It seems that the notch wear of BNC2010 was smaller than that of BNC100 and the surface roughness became better.

4-2 Interrupted cutting evaluation of BNC2020

Figure 9 shows the results of a comparison of BNC2020 with conventional BNC200 and a competitor's CBN in interrupted cutting by using a case hardened steel workpiece with 5 V-shaped grooves. The criteria of tool life was the breakage size of 0.2 mm. BNC2020 achieved 1.8 times longer tool life than BNC200 and 3 times more than the competitor's CBN. It seems that BNC2020 achieved the longest tool life of the 3 grades because of its higher toughness.

4-3 Coating peeling evaluation of BNC2020

Figure 10 shows the result of a coating peeling evaluation of BNC2020, conventional BNC200 and a competitor's CBN in accelerated cutting condition in which the cutting edge was repeatedly contacted to the case hardened steel workpiece. Comparing the average of the peeling areas after 1,000-time contacts repeated 3-time tests for each grade, the peeling area of BNC2020 is one-third of BNC200 and one-sixth of the competitor's CBN. BNC2020 shows excellent coating peeling resistance due to the effect of its unique adhesion layer.

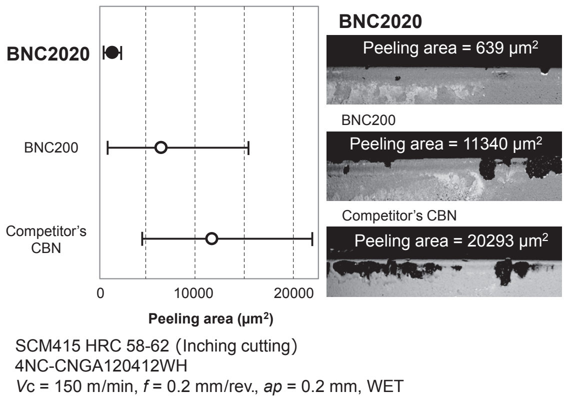

Fig. 10. Coating peeling evaluation results of BNC2020

4-4 Continuous cutting evaluation of BNC2020

Figure 11 shows the results of a comparison of BNC2020 with conventional BNC200 in continuous cutting of case hardened steel. BNC2020 achieved 1.5 times longer tool life than BNC200 in the case of the required surface roughness of Rz 3.2. Comparing these failure modes after 3-km cutting, BNC2020 had smaller notch wear than BNC200 and showed better surface roughness. It seems that the coating of BNC2020 at the notch was maintained by the effect of unique adhesion layer and worked to suppressing notch wear.

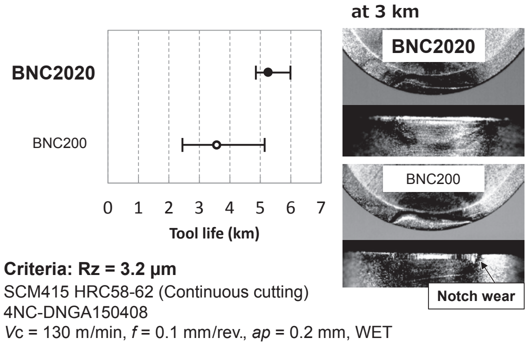

Fig. 11. Continuous cutting evaluation results of BNC2020

5. Application Range of BNC2010 and BNC2020

Figure 12 shows the application range of Coated CBN grades in hard turning. BNC2020 is a general purpose grade which can use in a wide range from continuous to medium interrupted cutting. In the case of heavy interrupted cutting, conventional BNC300 is the first recommendation. BNC2010 can be applied from continuous to light interrupted cutting, and especially shows excellent performance in high-precision cutting, such as a required surface roughness of less than Rz 3.2.

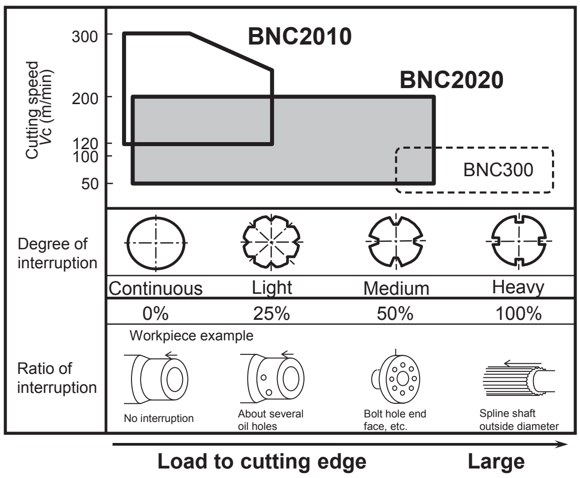

Fig. 12. Application range of Coated CBN

6. Cutting Example of BNC2010 and BNC2020

Figures 13–17 show the application example of BNC2010 and BNC2020.

Figure 13 is a high-precision cutting by BNC2010. It with WH-wiper achieved long and stable tool life, even in the case of a surface roughness requirement of Rz 1.6.

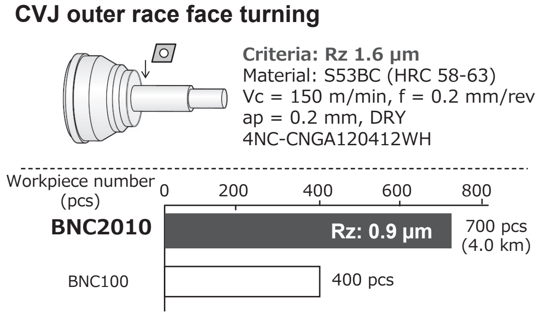

Fig. 13. Application example 1 of BNC2010

Figure 14 is a high-precision cutting by BNC2010 with a surface roughness requirement of Ra0.6, nearly equal to Rz 3.2. It maintained a low surface roughness and achieved more than twice a longer tool life than the conventional CBN grade.

Figure 15 is interrupted cutting by BNC2020. It achieved 1.5 times longer tool life than conventional CBN grade. Furthermore, BNC2020 with HS-type edge preparation showed greater breakage resistance and could continue to cutting over 300 pcs.

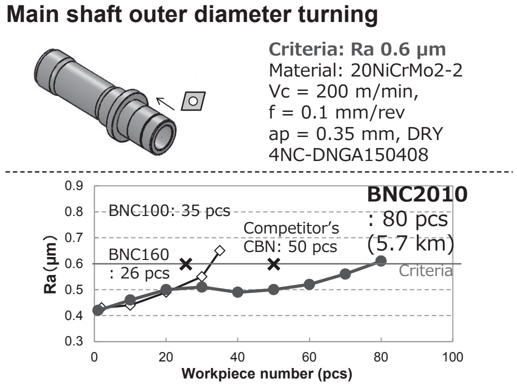

Fig. 14. Application example 2 of BNC2010

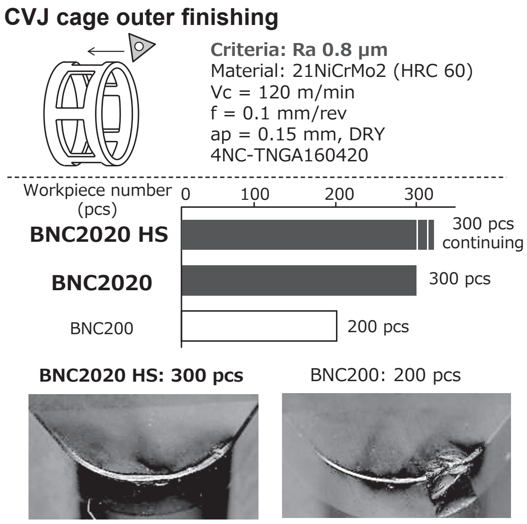

Fig. 15. Application example 1 of BNC2020

Figure 16 is a carburized layer removal machining by BNC2020, which was a very hard application because of the tough cutting conditions like 0.5 mm of ap (depth of cut) for eliminating the hardened layer. BNC2020 achieved 1.5 times longer tool life than the conventional CBN grade, and 3 times longer tool life than the competitor's CBN grade.

Figure 17 is a continuous cutting by BNC2020. In this application, coating peelings were the main issue because of using a low rigidity lathe. BNC2020 achieved twice a longer tool life than the conventional CBN grade by suppressing coating peelings.

As described above, BNC2010 enables longer tool life in high-precision cutting by maintaining low surface roughness. BNC2020 realizes longer and more stable tool life with higher reliability against breakage and coating peeling in various cuttings, like interrupted or high-load cutting.

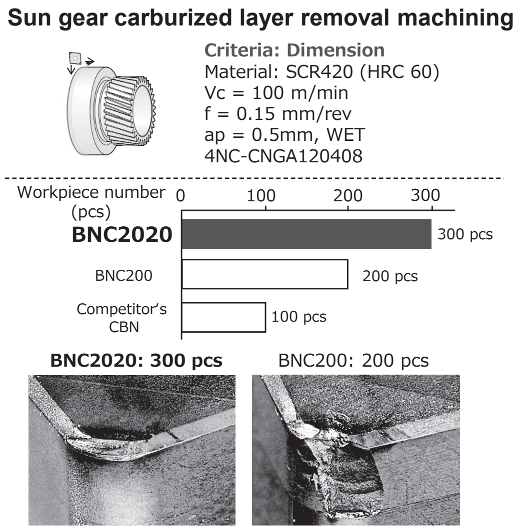

Fig. 16. Application example 2 of BNC2020

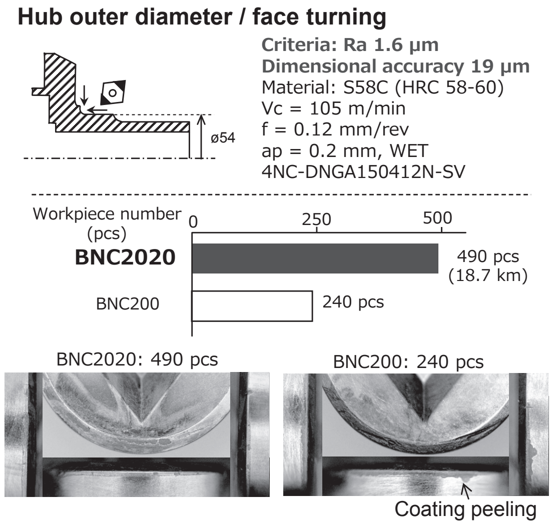

Fig. 17. Application example 3 of BNC2020

7. Conclusion

By using BNC2010 and BNC2020, longer and more stable tool life can be achieved in hard turning. It is expected that the use of BNC2010 and BNC2020 accelerates improvement in tool life making significant contributions to productivity improvement and cost reduction.

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

Technical Terms

∗1 CBN (cubic boron nitride): Has hardness and thermal conductivity second only to diamond, and has low reactivity with ferrous metals.

∗2 PVD (physical vapor deposition): A coating method using physical reaction

∗3 Rz (ten point average roughness): A criterion of surface roughness. Micrometer order.

References

(1) Harada et al., "Development of Coated cBN Sintered Tools," SEI Technical Review, No. 52, pp. 81–86 (2001)

(2) Teramoto et al., "Development of SUMIBORON BNC100 for High-Speed Cutting and SUMIBORON BNC160 for High-precision Cutting of Hardened Steel," SEI Technical Review, No. 66, pp. 93–100 (2008)

(3) Okamura et al., "Development of SUMIBORON NEW BNC200 for High-Efficiency Machining of Hardened Steel Parts," SEI Technical Review, No. 68, pp. 16–21 (2009)

(4) Harada et al., "Development of 'SUMIBORON' BN1000/BN2000 for Hard Turning" SEI Technical Review, No. 72, pp. 100–106 (2011)

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

Y. MATSUDA*

• Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.

H. MOROGUCHI

• Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.

N. TSUKIHARA

• Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.

K. OKAMURA

• Manager, Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.

M. SETOYAMA

• Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.

T. FUKAYA

• General Manager, Super Hard Materials Development Department, Sumitomo Electric Hardmetal Corp.