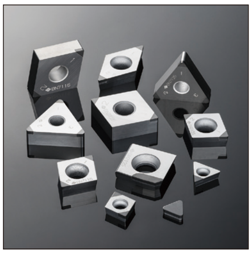


New series "SUMIBORON BN7115/BN7125 for Cast Iron and Sintered Alloy"

Yuta YOSHIOKA*, Yu ISHIDA, Yusuke MATSUDA, Satoru KUKINO, Yu KAWAMURA, and Akito ISHII

The cubic boron nitride (CBN) cutting tool "SUMIBORON" is made of sintered cBN particles, which have high hardness and thermal conductivity next to diamond and low reactivity with ferrous metals, bonded with a metal and/or ceramic binder. It has contributed to the improvement of machining efficiency and cost reduction in processing hard-to-cut hardened steel, and in machining of cast iron and sintered alloy where high-precision machining is required. In recent years, the machining of cast iron and sintered alloy parts—key components in automotive and construction machinery—has seen increasing demand for stability, long tool life, and high efficiency. In addition to high dimensional accuracy and surface quality, there is also a growing need for manpower savings in production lines and the manufacturing of high-precision parts. In response to the demand, we have developed CBN cutting tools SUMIBORON BN7115 and BN7125. BN7115 is designed for finishing, offering improved chipping resistance for stable, high-quality surface machining, while BN7125 is designed for general-purpose use, with enhanced breakage resistance for stable, long tool life even under heavy cutting loads. This report describes the features and performance of BN7115 and BN7125.

Keywords: PCBN, high precision and productivity, stable and long tool life, cast iron, sintered alloy

1. Introduction

Cubic boron nitride (cBN) has the highest hardness and thermal conductivity among all materials except for diamond, and has low reactivity with ferrous metals. We have promoted the development of polycrystalline cubic boron nitride (PCBN) "SUMIBORON" by sintering cBN with a special ceramic binder material, and contributed to the shift in the machining method of hardened steels from grinding to cutting. Furthermore, we contributed to improved productivity and cost reduction, mainly in semi-finishing and finishing of ferrous materials such as cast iron and sintered alloys with high content PCBN tools, which have over 90vol% cBN content.

Although Carbide, ceramics, and cermet are the main tools used in the cast iron machining, PCBN cutting tools with high strength and high-speed cutting capability are often used because high-precision and high-efficiency is required for machining the mating faces of engine blocks and oil pumps. In the case of high-speed milling at cutting speeds of around 1000 m/min, thermal cracks are likely to occur due to repeated thermal shock to the cutting edge. Particularly in processes where coolant from the previous process remains, the heat shock is intensified, leading to sudden fracture caused by thermal cracks.(1),(2)

Sintered alloys, which are manufactured by sintering metal powders, can be formed into complex and highly flexible shapes using near-net-shape technology*1 and can be freely designed by controlling metal powder composition, particle size, sintered density, and other material properties. It is widely used in highly efficient drive systems such as automotive transmission parts and electric variable valve timing (VVT) systems. In recent years, in order to suppress dimensional distortion during hardening, nickel and molybdenum are often added to these sintered alloys, but these additives worsen machinability and shorten tool life.

In order to meet the demands for high accuracy and stable long life against these problems, SUMIBORON BN7115 for finish machining and SUMIBORON BN7125 for general purpose machining of cast iron and sintered alloys have been developed. This paper introduces the features and cutting performance of BN7115 and BN7125.

2. Issues in Cast Iron Machining

During high-speed, high-efficiency cutting of cast iron, such as when machining FC300 (which consists of a pearlite-based structure*2) at speeds exceeding vc = 900 m/min, the temperature at the cutting edge can reach 1000°C or higher.(3) In milling or other intermittent machining, as shown in Fig. 1, when the tool surface is rapidly cooled during idling, the temperature drop inside the tool does not follow, resulting in a temperature difference between the surface and the interior, which generates tensile stress at the cutting edge due to thermal expansion and contraction. Repeated accumulation of such stress causes cracks (thermal cracks) at the cutting edge, as shown in Fig. 2, and eventually the cutting edge is lost, leading to the end of tool life. The higher the thermal conductivity of the CBN sintered material, the more heat is released from the cutting edge and the more the cutting edge temperature is suppressed. Therefore, it is required to improve the cBN content with high thermal conductivity and high high-temperature hardness to improve tool life.

In addition, since thermal stress accumulates at the interface between cBN and the binder material, which have different coefficients of thermal expansion, it is considered important that the binder material has a coefficient of thermal expansion close to that of cBN and is uniformly distributed in the PCBN structure.

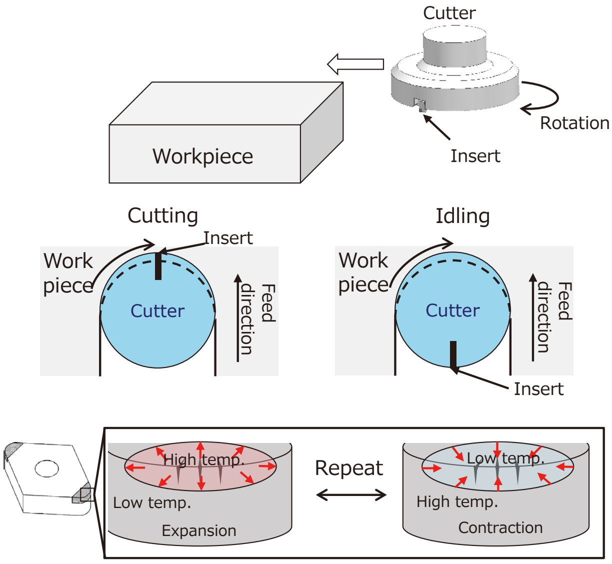


Fig. 1. Mechanism of thermal crack initiation during milling process

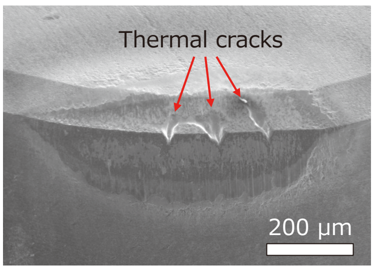


Fig. 2. Cutting edge after high-speed milling of cast iron

3. Issues of Sintered Alloy Machining

Figure 3 shows typical failure when sintered alloy is machined by PCBN cutting tool. Concavo-convex wear on the flank face is main failure and Fig. 4 shows the wear mechanism. First, the low-hardness bonding material is abraded by high-melting-point metals and carbides contained in the sintered alloy, and workpiece material components adhere to the abrasion area. The heat of processing diffuses and reacts with the bonding material, causing only the bonding material to dissolve, resulting in a state in which the cBN particles float to the surface, and wear is considered to progress when the cBN particles eventually drop out. Therefore, in order to suppress wear of the cutting edge in sintered alloy processing, it is required to improve the bonding strength between cBN particles to suppress cBN particle dropout.(4)

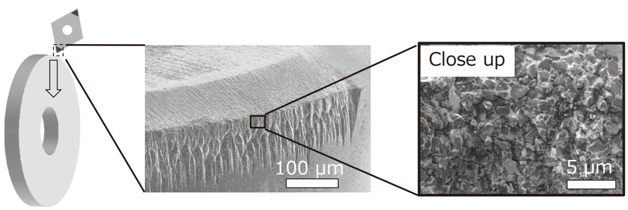


Fig. 3. Typical failure of cutting edge after sintered alloy machining

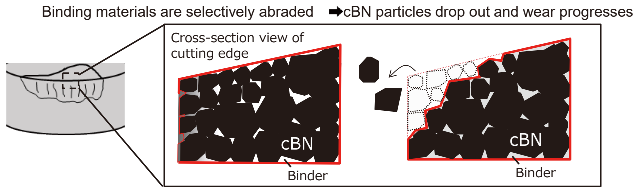


Fig. 4. Wear mechanism of sintered alloy machining

4. Features of BN7115 and BN7125

4-1 Material properties of BN7115 and BN7125

Table 1 shows the specifications and physical properties of BN7115 and BN7125 together with those of conventional grades BN7500 and BN7000. The particle size and binding material composition of BN7115 and BN7125 are designed as needed to achieve chipping and wear resistance, required for each application. BN7115 and BN7125 have improved strength, toughness, and thermal conductivity compared to the conventional grades by increasing the cBN content and the bonding strength between cBN particles using our new special binding material and ultra-high pressure and high temperature sintering technology. Figure 5 shows microstructures of conventional and BN7125 sintered bodies and their acid-treated microstructure in which only the binding material is removed and only cBN particles are present. Before acid treatment, the white areas are the bonding material and the black areas are the cBN particles. After acid treatment, the black areas are the voids where the binding material was leached out by acid treatment, and the gray areas are the cBN particles. Compared to the conventional material, BN7125 has fewer voids, and the bonded area between cBN particles has increased, indicating that the cBN content has improved. In addition, as

Table 1. Specifications and physical properties of BN7115/BN7125

Grade	cBN		Physical properties			
	Content (vol%)	Grain (µm)	Hardness (GPa)	Strength TRS (Gpa)	Toughness K1C (Mpa・$m^{1/2}$)	Thermal conductivity (W/m・K)
BN7500	90	1	41-44	2.0-2.1	7-9	100-110
BN7115	**91**	**1**	**41-44**	**2.2-2.3**	**10-11**	**110-120**
BN7000	92	2	41-44	1.8-1.9	9-11	110-120
BN7125	**94**	**2**	**41-44**	**1.9-2.0**	**12-13**	**120-130**

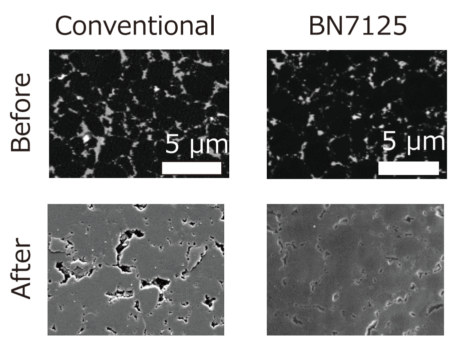


Fig. 5. PCBN structures of before and after acid treatment

shown in Fig. 6, the new binding material containing Cr has been designed to have a thermal expansion coefficient close to that of cBN, resulting in reduction of thermal stress and a significant improvement in thermal crack resistance.

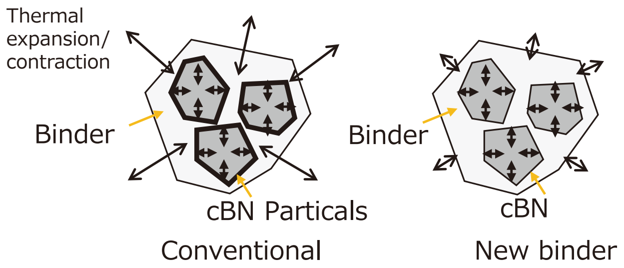


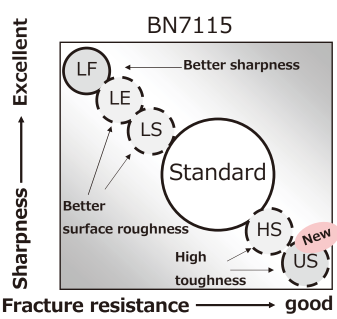
Fig. 6. Suppression of thermal stress by new binding material

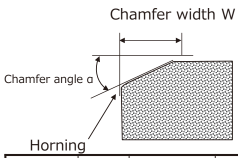
BN7115 applied fine cBN particles with an average particle size of 1 µm for high strength and excellent edge standing. On the other hand, BN7125 applied relatively coarse cBN particles with an average particle size of 2 µm for high toughness and high thermal conductivity, and is designed to emphasize fracture resistance.

4-2 Shapes of BN7115 and BN7125

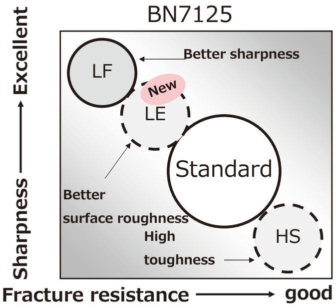
The BN7100 series further demonstrates its performance by combining the aforementioned sintered PCBN materials and optimized cutting edge specification. Figure 7 shows the cross-section view and edge specifications of the BN7115 and BN7125.

BN7115 has six types of edge preparations: the highly versatile "standard type," the "LF type," which emphasizes sharpness, the "LE and LS types," which emphasize surface roughness, and the "HS and US types," which emphasize chipping and breakage suppression. BN7125 has four types edge preparations: the highly versatile "standard type," the "LF type," which emphasizes sharpness, the "LE type," which emphasizes surface roughness, and the "HS type," which emphasizes chipping and breakage suppression. Edge preparations of BN7100 series have expanded from conventional grades to handle cast iron and sintered alloy machining with a wide range of machinability and part geometries.





	α	W	Round horning
standard	15°	0.12 mm	No
LF type	α = 0° Sharp edge		No
LE Type	α = 0° Only horning		Yes
LS Type	15°	0.07 mm	Yes
HS Type	25°	0.05 mm	Yes
US Type	25°	0.12 mm	Yes



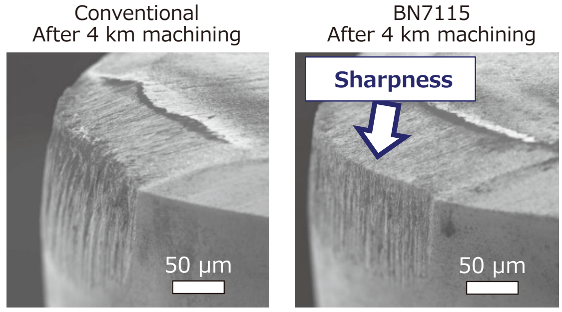
	α	W	Round horning
Standard	15°	0.12 mm	No
LF Type	α = 0° Sharpedge		No
LE Type	α = 0° Onlyhorning		Yes
HS Type	25°	0.12 mm	Yes

Fig. 7. Edge specifications of BN7115/BN7125

5. Cutting Performance of BN7115 and BN7125

5-1 Evaluation of high-precision finish machining of sintered alloy (BN7115)

Figure 8 shows the cutting edges of the conventional grade and BN7115 after continuous face machining of sintered alloy. BN7115 shows better resistance of cBN particle drop out and maintains sharpness of cutting edge compared to conventional grade due to improved bonding strength between cBN particles. Figure 9 shows a comparison of wear resistance (VBmax) and the roughness of the machined surface (Ra) of BN7115 with those of the conventional grade. BN7115 shows 1.5 times longer tool life when the flank wear criteria are set to 100 µm and 1.4 times longer tool life when the surface roughness criteria is set to Ra 0.7 µm compared to conventional grade.



Workpiece: SMF4040
Cutting conditions: vc = 200 m/min, f = 0.1 mm/rev, ap = 0.2 mm, WET

Fig. 8. Cutting edge of conventional grade and BN7115 after sintered alloy machining

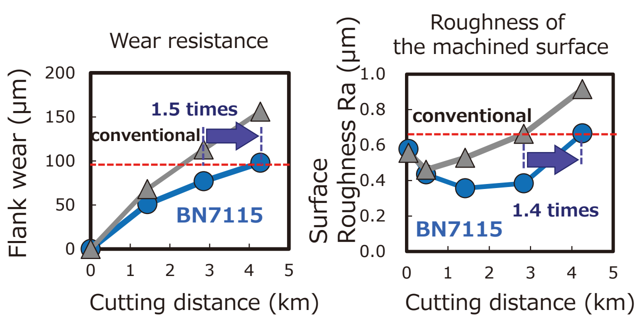


Fig. 9. Sintered alloy machining performance of BN7115

5-2 Evaluation of high-speed milling of cast iron (BN7125)

Figure 10 shows the thermal conductivity (room temperature) and Vickers hardness (high temperature) measured by the Xe laser flash method*3 of the conventional grade and BN7125 PCBN materials. BN7125 improved 10% thermal conductivity and 6% hardness at 1000°C compared to conventional grade. These result indicate that the content of cBN with high thermal conductivity and high-temperature hardness has increased and the bonding strength between cBN particles have been enhanced.

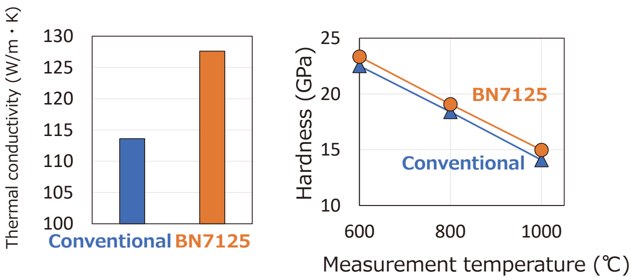


Fig. 10. Thermal conductivity and high temperature hardness of the conventional grade and BN7125

Figure 11 shows the results of milling of flat plate of FC250 (pearlite substrate) at a cutting speed of 1500 m/min, feed rate of 0.13 mm/t per blade, and depth of cut of 0.4 mm with coolant remaining on the workpiece surface. The thermal crack of BN7125 has suppressed and BN7125 achieved 3.7 times the fracture tool life compared to conventional grade, due to its improved thermal conductivity and high-temperature hardness.

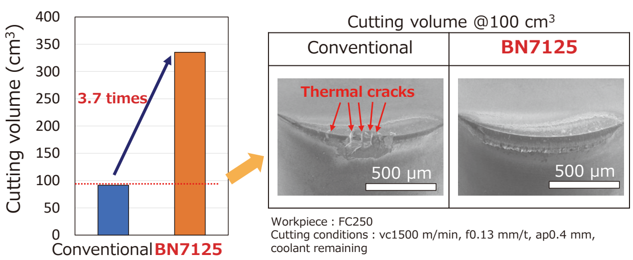


Fig. 11. Cast iron high-speed milling performance of BN7125

6. Application Areas of BN7115 and BN7125

Figure 12 shows the application areas for cast iron machining. BN7125, which has excellent wear resistance and thermal cracking resistance, is recommended for high-speed finishing. BNS8125, a solid CBN grade with a long cutting edge length, is recommended for rough machining with a depth of cut of 1 mm or more. Figure 13 shows the application areas for sintered alloy machining. For traverse machining of automotive VVT parts, oil pump rotor parts, and VSR (Valve Seat Ring), where surface quality is required, BN7115 is recommended first for finishing applications due to its excellent edge standing ability. On the other hand, BN7125 with excellent fracture resistance is recommended for high-load machining applications like plunge cutting and rough machining where the depth of cut exceeds 0.3 mm. By the way, in the continuous machining of hardened sintered alloys with hardness of around HRC60, PCBN grades for hardened steel are recommended because the wear progresses due mainly to the thermal reaction.

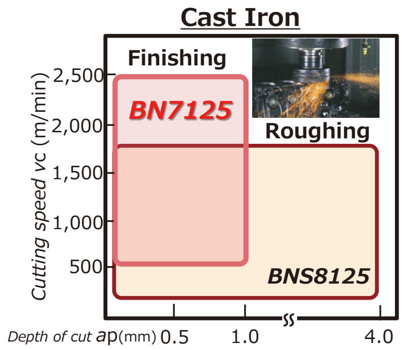


Fig. 12. Application areas of cast iron with CBN grade

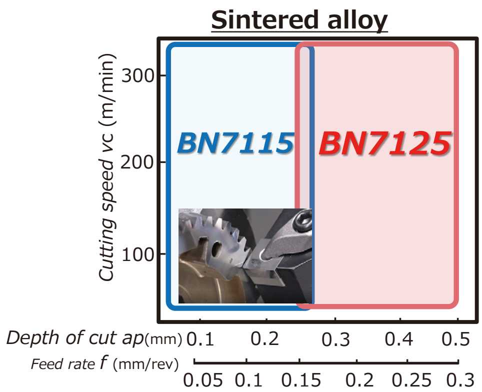


Fig. 13. Application areas of sintered alloy with CBN grade

7. Use Cases for BN7115 and BN7125

Figures 14 to 19 show the application examples of BN7115 and BN7125.

Figure 14 is continuous O.D. and face machining of sintered alloy. BN7115 achieves 1.6 times longer life in terms of surface roughness and burr compared to the conventional grade.

Figure 15 is continuous I.D. machining of a sintered alloy. BN7115 achieves a surface roughness life 1.5 times that of the conventional CBN grade.

Figure 16 is interrupted face machining of a sintered alloy where BN7115 achieves a stable surface roughness that is twice as long as that of the conventional CBN grade.

Figure 17 is face turning of cast iron, where BN7125 exhibits stable fracture resistance and achieves 1.7 times longer life compared to the conventional CBN grade.

Figure 18 is continuous face and I.D. machining of sintered alloy. BN7125 exhibits superior chipping and wear resistance compared to the conventional CBN grade and achieves 1.5 times longer tool life in terms of machined surface roughness.

Figure 19 is high-speed milling of cast iron, where BN7125 exhibits superior thermal crack resistance compared to the conventional CBN grade, realizes stable machined surface quality, and achieves more than 1.6 times longer life.

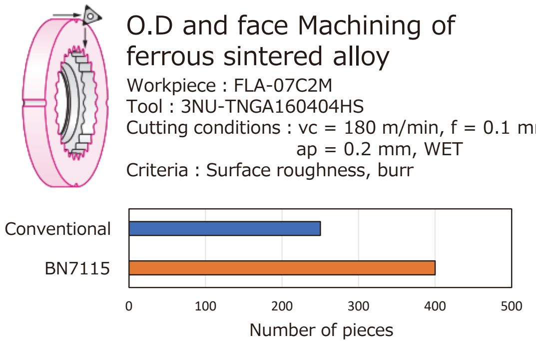


Fig. 14. Application example 1 of BN7115

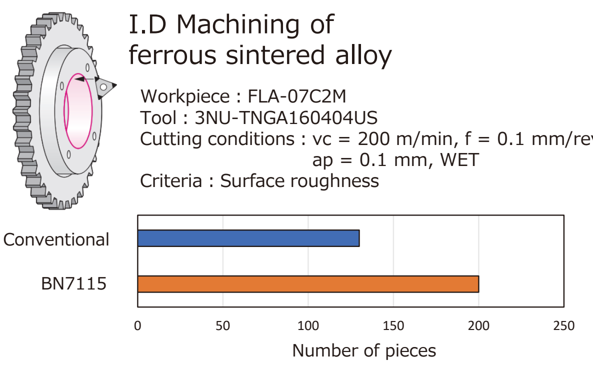


Fig. 15. Application example 2 of BN7115

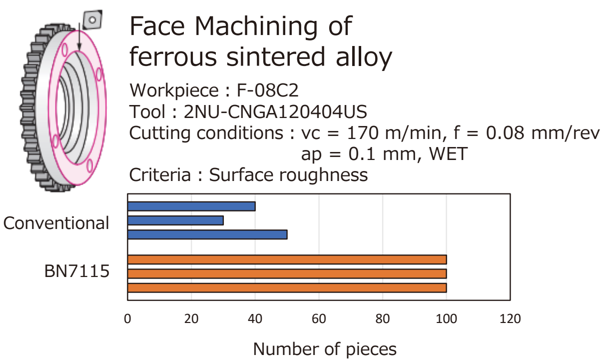


Fig. 16. Application example 3 of BN7115

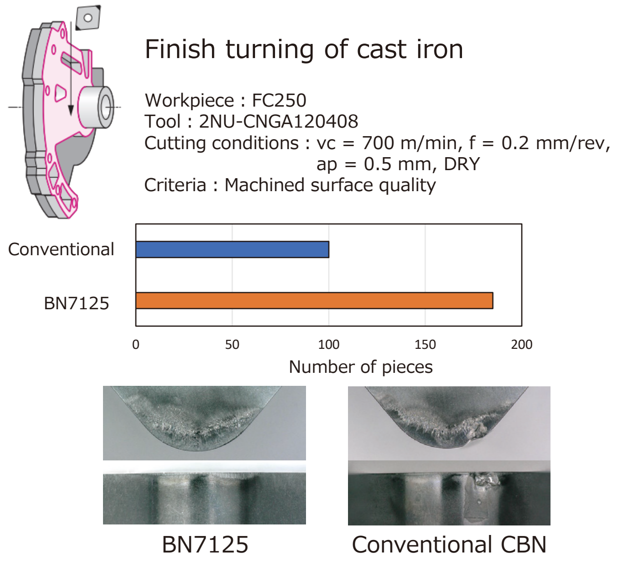


Fig. 17. Application example 1 of BN7125

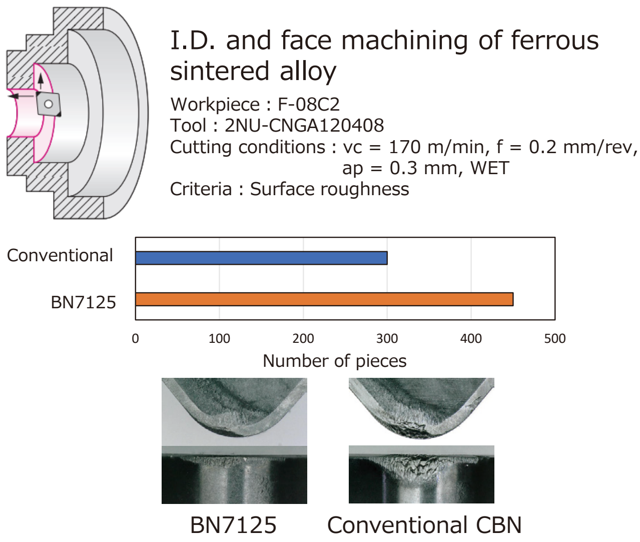


Fig. 18. Application example 2 of BN7125

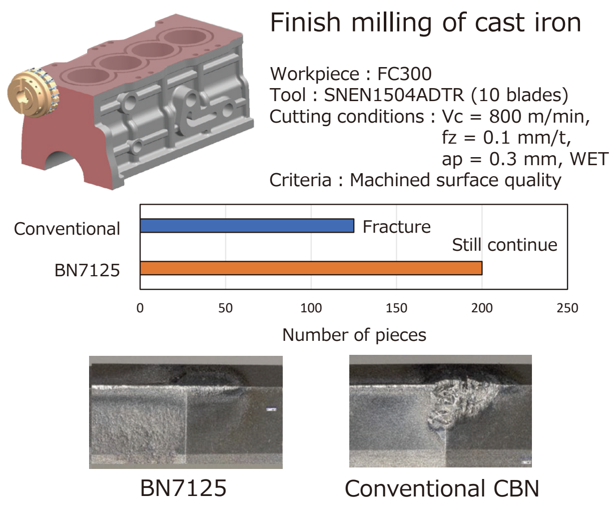


Fig. 19. Application example 3 of BN7125

8. Conclusion

SUMIBORON BN7115 and BN7125 provide improvement of machined surface quality, cutting efficiency and tool life in cast iron and sintered alloy machining. The BN7100 series' excellent physical properties allow it to be also used for hard-to-cut materials requiring tools with high strength. The BN7100 series is expected to contribute to improved productivity and reduced manufacturing costs in the future.

Technical Terms

*1 Near-net-shape technology: A molding method that aims to reduce the number of processes such as machining and electrical processing to obtain a shape close to the final product.

*2 pearlite-based structure: A type of steel microstructure in which 0.77 wt% carbon is eutectoid, which occurs when iron is slowly cooled from a high-temperature region to a temperature of 727 or below.

*3 Xe laser flash method: Thermal diffusivity is obtained by uniformly pulsing the surface of a flat sample placed in an adiabatic vacuum with an Xe laser and observing the thermal diffusion phenomenon from the surface to the back surface.

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