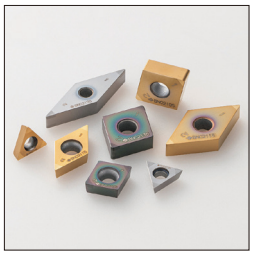


New Coated SUMIBORON BNC2100 series for High-Efficiency Machining of Hardened Steel

Yuki TSUTSUMIUCHI*, Yoshiki ASAKAWA, Ryosuke SAKON, Hironari MOROGUCHI, Yusuke MATSUDA, and Satoru KUKINO

SUMIBORON is a cutting tool that utilizes cubic boron nitride (CBN) sintered bodies formed from cBN particles and ceramic or metal bonding materials. Specifically, coated SUMIBORON has an expanded application range as a cutting tool for hardened steel in automotive parts. Recently, manufacturing sites have become aware of variable-volume production due to the diversification of parts and the importance of environmental considerations. Two trends have emerged: reducing CO_2 emissions by lowering equipment power consumption and establishing automated product lines to address price competition. Cutting tools require higher efficiency and longer tool life. To meet customer requests, we developed four new grades in the BNC2100 series: BNC2105, BNC2115, BNC2125, and BNC2135.

Keywords: CBN, PVD coating, hardened steel, high-efficiency

1. Introduction

Cubic boron nitride (CBN*[1]) exhibits the second highest hardness and thermal conductivity after diamond and has low reactivity with ferrous metals. We were the first company in the world to develop CBN sintered bodies by bonding cBN and ceramic binder, and in 1977 we commercialized SUMIBORON as a cutting tool for machining hardened steel. In 2000, we commercialized coated SUMIBORON, which features a ceramic coating with high heat resistance applied using PVD*[2] coating technology, significantly improving wear resistance. In cutting processes of hardened steel by using CBN tools, there has high flexibility and efficiency of machining compared to grinding processes. It has been reported that there has formed a few processing altered layer (white layer) compared to ceramic tools. Griding process has been changed to cutting process with CBN tool in sliding and rolling surfaces of automotive joint parts and bearing parts. Coated SUMIBORON achieves higher precision and efficiency than SUMIBORON, and has greatly encouraged the use of cutting, contributing to improved productivity and cost reduction.

Manufacturing industry recently has been focusing on green transformation (GX) to achieve carbon neutrality. The automotive industry which uses many hardened steel parts, shifts from internal combustion engine (ICE) vehicles to electric vehicles acceleratingly. The electric power industry shifts rapidly from dependence on fossil fuels to renewable energy sources such as windmill power generation. These changing of the markets are influences changing the requirements for hardened steel machining. In the automotive industry, manufacturing layouts are being revised one after another, and the production of parts for conventional ICE vehicles is being consolidated and new production lines are being set up to produce parts for electric vehicles. Although the demand of ICE vehicles is decreasing, it needs to produce various types and high production capacity. So customers request more short time to machine parts. On the other hand, electric vehicles are facing intensifying cost competition, which requires the production of fewer components at lower cost than ICE vehicles. The automotive industry is considering process consolidation and automation in order to reduce equipment investment and tooling costs.

In the windmill industry, because of the large size of the parts, the main request is to improve productivity by reducing the machining time for a single part. In addition, machining alteration layers and compressive stresses on the sliding surfaces of parts are related to the reliability of windmill turbine generator operation, so it needs to maintain stabilized cutting edge until tool life.

From the viewpoint of achieving carbon neutrality, the reduction of CO_2 emissions during parts production is a common issue at any kinds of production sites, and there is a demand to reduce power consumption of production equipment.

We developed four CBN grades of coated SUMIBORON BNC2100 series—BNC2105, BNC2115, BNC2125, and BNC2135—which realize significantly higher efficiency and longer stable tool life than the conventional coated SUMIBORON series to respond to customer requests.

2. Issues of Hardened Steel Machining

As shown in Fig. 1, coated CBN tool is made by applying a ceramic coating with excellent heat resistance and oxidation resistance to a CBN sintered body with excellent hardness and fracture toughness. So coated CBN tool achieves longer tool life even if machined parts are hardened steel with high cutting temperature. On the other hand, ceramic coating is occurred mechanical wear and peeling when subjected to mechanical loads because of lower hardness and fracture toughness than CBN sintered body.

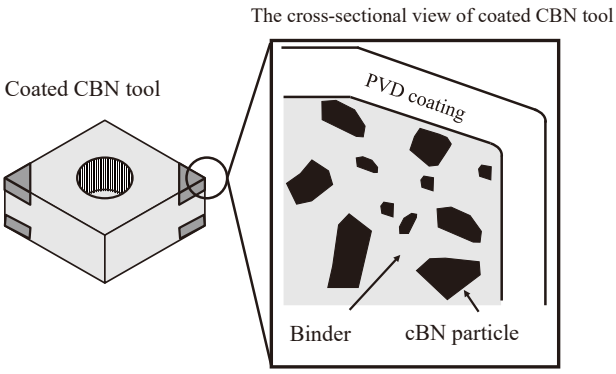


Fig. 1. Structure of coated CBN tool

Parts of hardened steel are given shape and durability by pre-formed machining and heat-treated, but they sometimes include some kinds of variation (shape, hardness, microstructure, stress, etc.) between and within manufacturing lots. In some cases, rigidity of tooling such as lathes, holders, and chucks is not enough for machining. The load on the cutting edge is higher as machining efficiency becomes high. Cutting edge is occurred breakage suddenly and tool life is unstable because the influence of aforementioned effects increases. As a result, we have to change to new tool at irregular intervals, and we have to consider manual machining or set short tool life limits to mitigate the risk of breakage. This situation leads to poor productivity and increased costs of parts.

Figure 2 shows the main types of tool damage and our recommended grades in the ratio of intermittence of parts and machining efficiency of hardened steel machining. BNC2105 demonstrates effectiveness against tool flank wear that occurs in continuous machining with low feed and high-speed conditions. BNC2115 shows crater wear resistance and front notch wear resistance in continuous and intermittent machining with low feed or high-speed conditions. BNC2125 is suitable for suppression of breakage by crater wear and lateral notch wear in continuous and intermittent machining with high feed or high speed. BNC2135 is effective against for breakage of front notch wear in heavy interrupted machining.

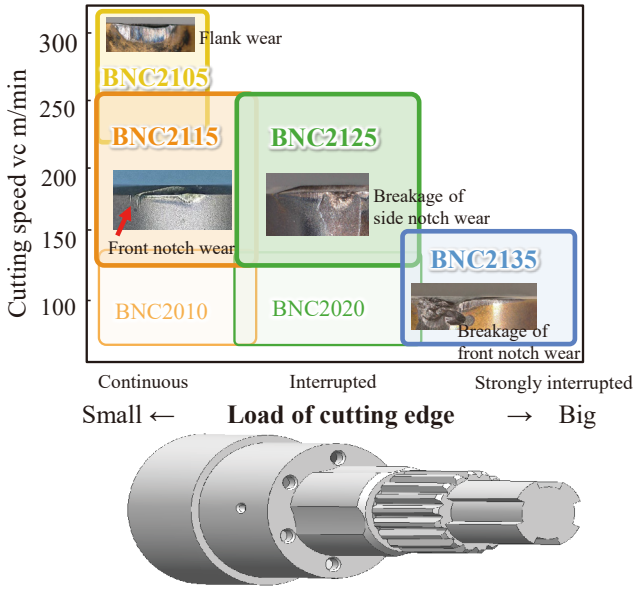


Fig. 2. The main types of tool damage in hardened steel machining

3. Features and Cutting Performance of the BNC2100 Series

Four kinds of the BNC2100 series are all new CBN sintered bodies and PVD coatings optimized for each type of tool damage in hardened steel machining. Table 1 shows the specifications of the BNC2100 series.

Table 1. Specifications of the BNC2100 series

Grades	CBN sintered body			PVD coating	
	cBN content (%)	Grain size of main cBN particles (μm)	Binder	component	Thickness (μm)
BNC2105	45-50	3	TiCN	TiAlBN ultra-multilayer	3
BNC2115	60-65	3	TiN	TiAlSiN ultra-multilayer	3
BNC2010	50-55	2	TiCN	TiCN multilayer	2
BNC2125	65-70	4	TiN	TiAlBN ultra-multilayer	3
BNC2020	70-75	5	TiN	TiAlN multilayer	2
BNC2135	60-65	1	TiN	TiAlN/AlCrN	1
BNC300	60-65	1	TiN	TiAlN	1

3-1 BNC2105

Application area of BNC2105 is finish machining, main cutting condition is low-feed and up to high-speed to get high-efficiency. As the result, the finished dimensions after machining many parts are getting worse because flank wear of tool become large and cutting force is high to increase contact area with parts by high cutting temperature while machining long cutting distances. Figure 3 shows the cross-sectional view of the BNC2105 cutting edge. The CBN sintered body combines TiCN binder with excellent heat resistance and large cBN particles with high thermal conductivity. The coating has a TiAlBN ultra-multilayer structure with excellent heat resistance and nano size

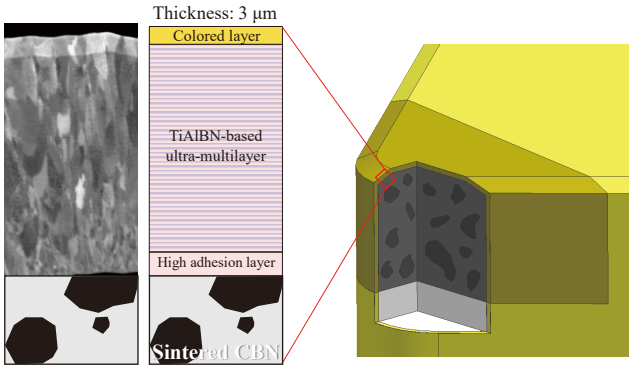


Fig. 3. Cross-sectional view of BNC2105 cutting edge

crystal grains. Then BNC2105 can machine stable dimensions by excellent flank wear resistance in long time and chipping resistance in the early stages of machining. Figure 4 shows the tested results of continuous machining of carburized hardened steel SCM415H (HRC58-61). BNC2105 can maintain abrasion of flank wear as same as conventional coated CBN grade even if cutting speed is 1.6 times faster (vc = 250 m/min) than conventional.

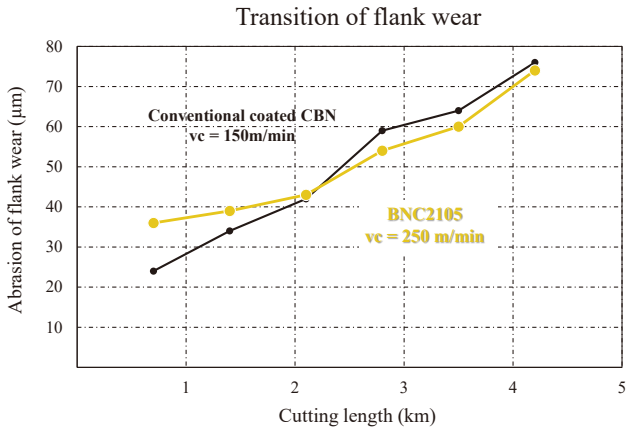


Fig. 4. Tested results of continuous machining of carburized hardened steel by using BNC2105

3-2 BNC2115

Against the parts requiring high surface quality (surface roughness Rz*3 under 3.2 μm) in high-precision machining area, BNC2115 is recommended. As shown in Fig. 5, notch wear is transferred to the surface of parts in the turning process, it is important to suppress notch wear to get long tool life. notch wear has two types of damage modes: mechanical abrasion wear that occurs when machining hardened parts, and crater wear caused by thermal reactive wear that connects with the notch wear. And both types of damage must be suppressed. Figure 6 shows a cross-sectional view of the BNC2115 cutting edge. The CBN sintered body has high strength TiN binder which suppress mechanical abrasion wear. The coating combines some high heat resistant TiCN suppress crater wear and high strength TiAlSiN ultra-multilayers suppress notch wear. BNC2115 can maintain excellent surface roughness of parts for long time.

Figure 7 shows the tested results of continuous machining of carburized carburized hardened steel

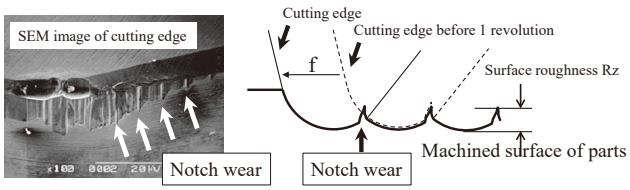


Fig. 5. Relationship between notch wear and surface roughness in turning

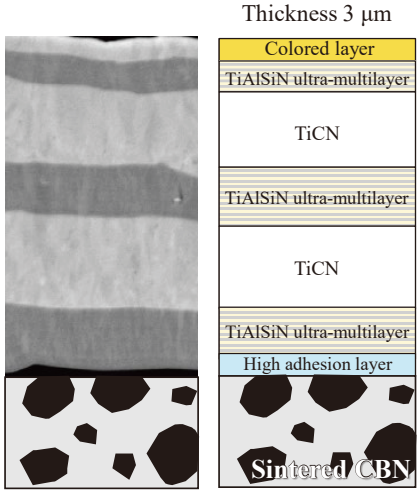


Fig. 6. Cross-sectional view of BNC2115 cutting edge

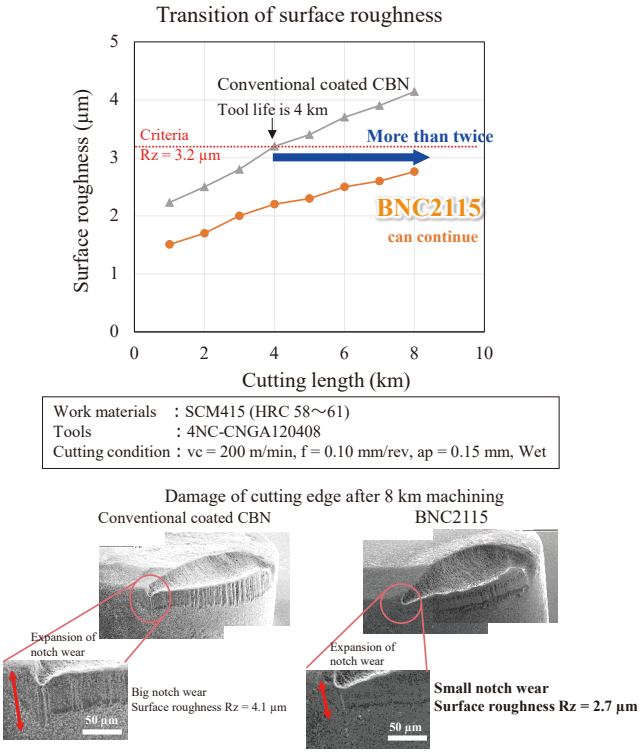


Fig. 7. Tested results of continuous machining of carburized hardened steel by using BNC2115

SCM415H (HRC58-61). BNC2115 achieves twice longer tool life under Rz = 3.2 μm than conventional coated CBN grade by suppressing notch wear

3-3 BNC2125

As a general-purpose application like a mixture of continuous and interrupted machining, BNC2125 can achieve stable and long life in higher efficiency cutting condition than conventional. Figure 8 shows a cross-sectional view of the BNC2125 cutting edge. For general-purpose application machining, high performance that suppresses suddenly breakage in high load is needed. The CBN sintered body combines high strength TiN binder and

mixed fine and coarse grain size cBN particles. The coating has TiAlBN ultra-multilayer with a fine structure to get excellent heat resistance and chipping resistance.

Figure 9 shows the tested results of continuous and high load machining of SUJ2 bearing steel (HRC58-61) that material is hard to be machined because of many thermal and mechanical wear in hardened steel. BNC2125 successfully suppressed flank wear compared to the conventional coated CBN grade, and get stable tool life even in high load machining.

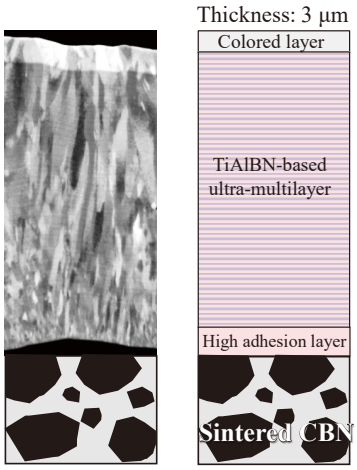


Fig. 8. Cross-sectional view of BNC2125 cutting edge

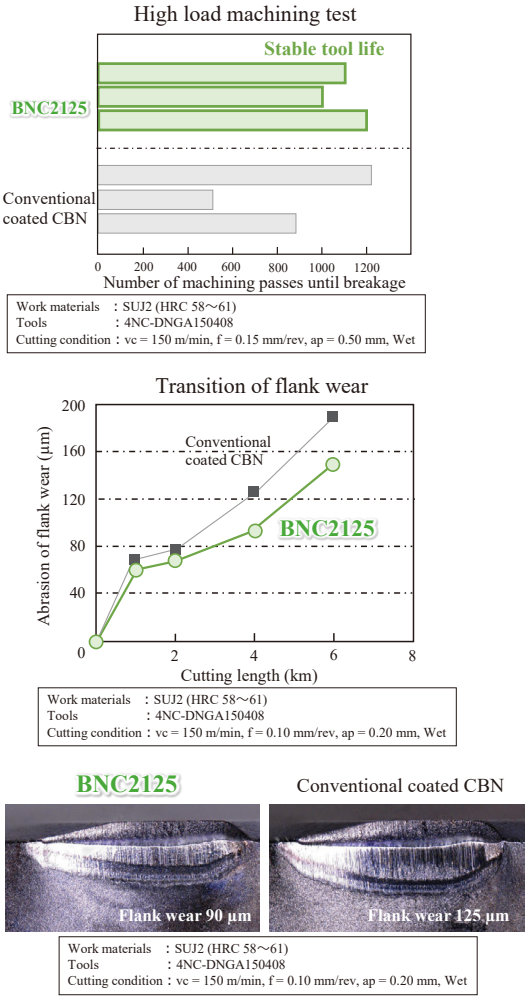


Fig. 9. Tested results of continuous machining of SUJ2 bearing steel by using BNC2125

3-4 BNC2135

BNC2135 was launched in January 2025 as an effective for parts with heavy interrupted. In heavy interrupted parts, many cracks occur to CBN sintered body and coating because the cutting edge repeatedly impacts hard parts. Figure 10 shows a cross-sectional view of the BNC2135 cutting edge. The CBN sintered body is made of well-dispersed fine TiN binder and cBN particles to get high strength and reduce initial crack points. The coating becomes combination of TiAlN and AlCrN with an excellent balance of wear and chipping resistance, and get smooth and fine crystalline structure by new coating technique. Then BNC2135 is an effective CBN grade for breakage with crack in heavy interrupted.

Figure 11 shows the tested results of heavy interrupted of carburized hardened steel SCM415H (HRC58-61). BNC2135 achieves 1.5 times longer and stable tool life compared to the conventional coated CBN grade.

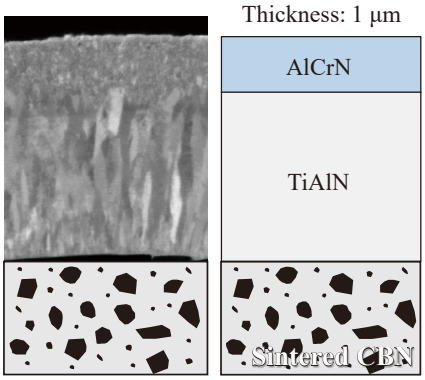


Fig. 10. Cross-sectional view of BNC2135 cutting edge

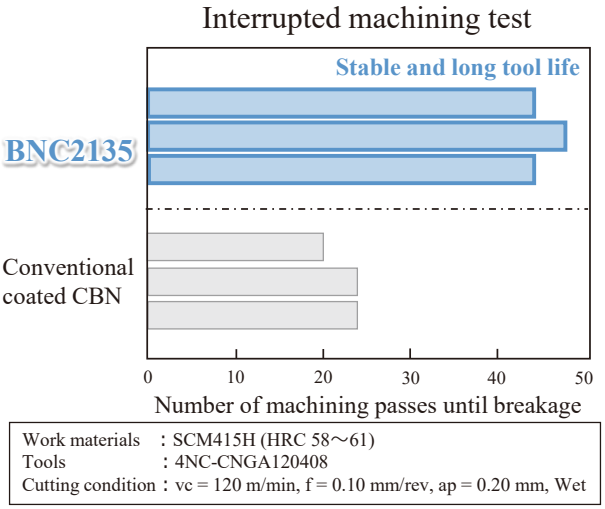


Fig. 11. Tested results of interrupted machining of carburized hardened steel by using BNC2135

4. Some cases of the BNC2100 Series

4-1 The cases of customer parts

Figures 12 to 15 show the application examples of the BNC2100 series.

Figure 12 shows an example of machining thin ring gear with BNC2105. Conventional coated CBN grade stopped to machine 200 parts because dimensional of parts is over due to large flank wear and chipping. BNC2105 achieved 400 parts twice as long as conventional.

Figure 13 shows an example of machining side gear parts with a strict surface roughness. Tool life of conventional coated CBN grade is 200 parts because of worse surface roughness, BNC2115 got excellent surface roughness after 300 parts.

Figure 14 shows an example of machining CVJ parts with continuous in face and intermittent in outer diameter. BNC2125 achieved to machine same parts as conventional coated CBN grade even the cutting condition is twice higher than conventional.

Figure 15 shows an example of machining tool holder parts with intermittent grooves on both the end face and outer diameter. The situation of conventional coated CBN grade is unstable tool life because of sudden breakage after 30 parts. BNC2135 got stable long tool life with no breakage after 35 parts.

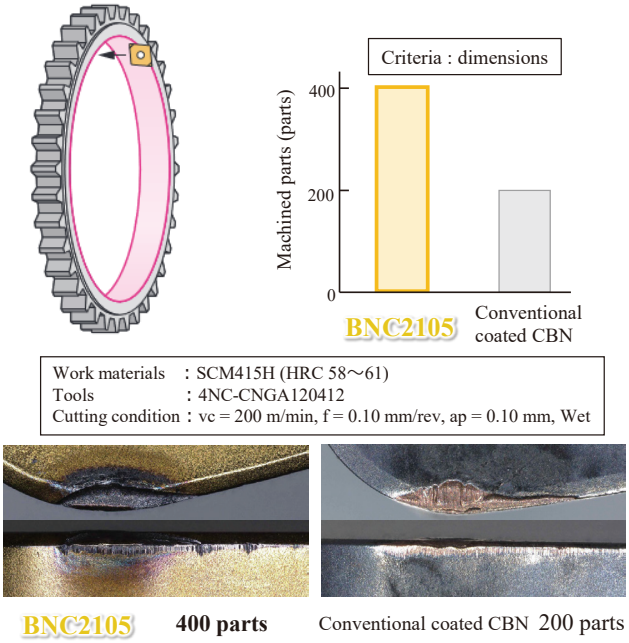


Fig. 12. Example of machining thin ring gear with BNC2105

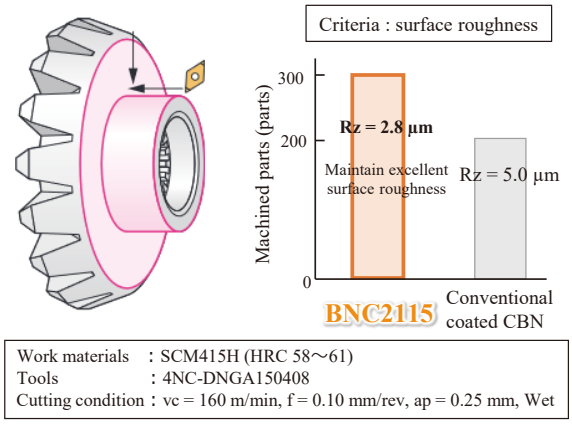


Fig. 13. Example of machining side gear parts with BNC2115

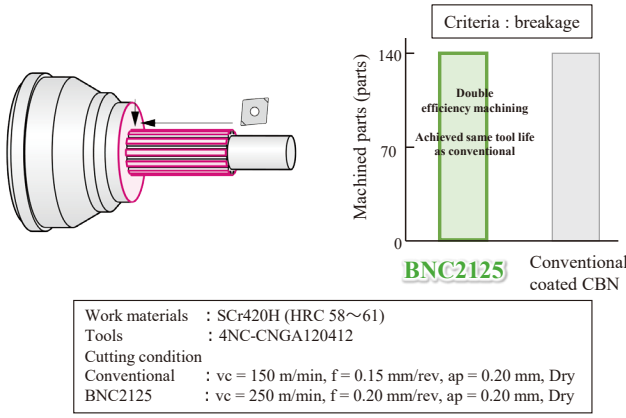


Fig. 14. Example of machining CVJ parts with BNC2125

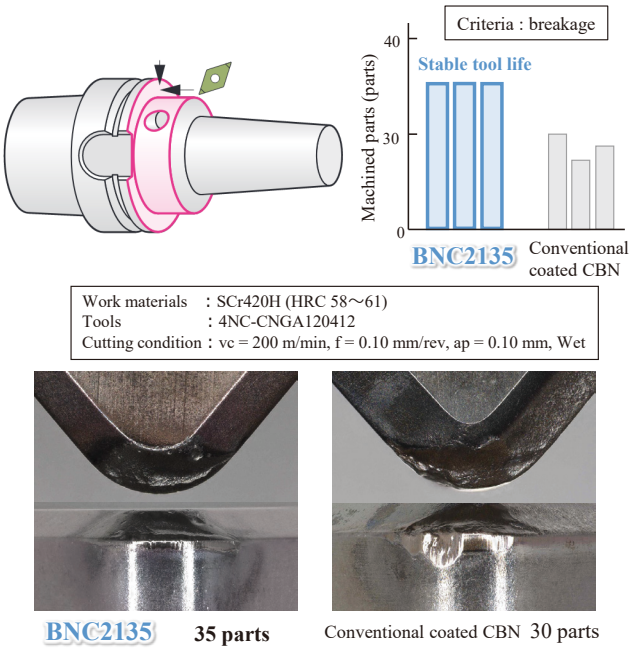


Fig. 15. Example of machining tool holder parts with BNC2135

4-2 The case of GX by high-efficiency machining

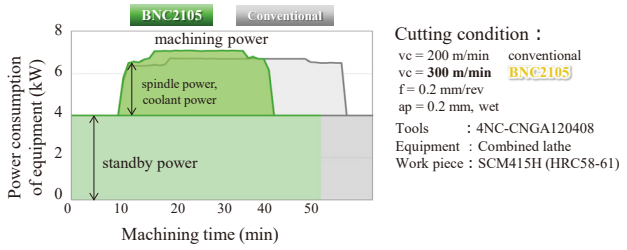
Figures 16 to 17 show the reduction in CO_2 emissions achieved by reducing power consumption of equipment through highly efficient machining using the BNC2100 series. Power consumption of equipment can be roughly classified into standby power, spindle power, coolant power, and machining power.

The machining power consumption of hardened steel is lower than other power consumptions, it is possible to reduce equipment power consumption by short machining

time with high-efficiency condition.

Figure 16 shows an example by using BNC2105 with higher speeds in carburized hardened steel SCM415H (HRC58-61).

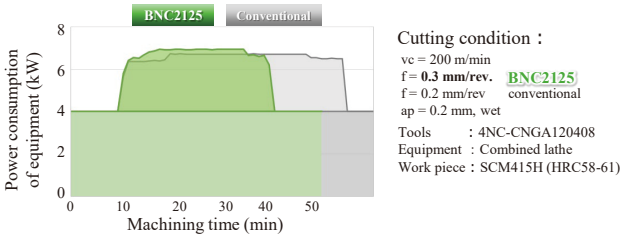
Figure 17 shows an example by using BNC2125 with high feed rate in carburized hardened steel SCM415H (HRC58-61).



Reduced Two-thirds of machining time by 1.5 times faster cutting condition.
Reduced approx. 30% Electricity consumption, and 2.1 kg CO_2 emissions

Powers measurements during production at our own facilities.
Emissions from cutting 200 parts.
Refer to the national average coefficient published by the Ministry of Economy, Trade and Industry for calculation. 0.000433 (t- CO_2 /kWh)

Fig. 16. Example by using BNC2105 with higher speeds in carburized hardened steel



Reduced Two-thirds of machining time by 1.5 times faster cutting condition.
Reduced approx. 40% Electricity consumption, and 2.8 kg CO_2 emissions

Fig. 17. Example by using BNC2125 with higher feed rate in carburized hardened steel

5. Conclusion

The BNC2100 series provides increased tool life and higher efficiency machining compared to traditional options through the application of new CBN sintered body and coatings. Additionally, the BNC2100 series can also reduce CO_2 emissions by minimizing machining power consumption under high-efficiency conditions. The expanded sales of these CBN grades are expected to contribute to further productivity improvement, manufacturing cost reduction, and the realization of carbon neutrality.

Technical Terms

∗1 CBN: Cubic boron nitride: an artificial material with the same crystal structure as diamond, cubic boron nitride exhibits hardness and thermal conductivity second only to diamond, and has low reactivity with ferrous metals.

∗2 PVD: Physical vapor deposition: a type of vapor deposition method that uses a physical reaction to form a thin film.

∗3 Rz: Ten-point average roughness. A type of surface roughness standard.

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