Development of SUMIBORON NEW BNC200 for High-Efficiency Machining of Hardened Steel Parts

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Recently increasing global awareness on environmental issues has induced demands for high-efficiency machining that improves productivity and cut capital spending. In order to satisfy such demands, SUMIBORON NEW BNC200 has been developed. NEW BNC200 provides longer tool life and higher machining efficiency by over 50% compared to the conventional BNC200 grade by drastically improving breakage resistance while at the same time maintaining high wear resistance. In addition to the standard edge preparation with broad general versatility, LS type with good sharpness and HS type with high toughness have been developed in order to achieve longer tool life and higher machining efficiency in machining of various hardened steel parts. The features and cutting performance of NEW BNC200 are described in this report.

1. Introduction

Cubic boron nitride (cBN) has hardness and thermal conductivity next to diamond, and has low reactivity with ferrous metals. Sumitomo Electric Hardmetal Corporation succeeded in developing the world's first cBN tool for machining of hardened steel parts by sintering a mixture of cBN particles and special ceramic binder, and launched it on the market in 1977 under the trade name SUMIBORON.[1] In these days, cutting by cBN tools has been accepted as one of the standard methods for machining hardened steels because it provides greater machining efficiency and flexibility than grinding. Since the release in 2000 of coated SUMIBORON BNC200 that features higher machining efficiency and longer tool life,[2] the BNC series has evolved to be used in various applications and contributed to productivity improvement and cost reduction.[3]-[5]

Because of growing public concern about environmental issues in recent years, environmental responsiveness is requested within manufacturing industries such as automobile. As a result, manufacturing companies are attempting to take various environmental measures like industrial waste reduction efforts and CO_2 emissions cut by power consumption reduction. To respond to the needs for environmental responsiveness, Sumitomo Electric Hardmetal has developed new BNC200, a coated SUMIBORON grade that has realized significantly higher machining efficiency and longer tool life compared to conventional BNC200. This paper reports on the features and cutting performance of this new grade.

2. Problems in high-efficiency cutting of hardened steels

Desired mechanical strength can be given to the specific portion of hardened steel by applying appropriate surface thermal treatment, such as carburizing, induction hardening, and nitriding, and controlling the hardness distribution in the depth direction of the hardened steel. However, in the cases of hardened steel parts, surface conditions such as hardness, microstructure and stress state may vary among different lots or even within the same lot. Moreover, overall tooling system composed of a lathe, a chuck and a holder not always has enough rigidity to cut hardened steel. Because stress applied to the cutting edge in high efficiency machining is larger than that in normal machining, variations in surface conditions and insufficient rigidity of tooling system may be amplified, thus causing unexpected tool breakage and shortening tool life. If tool life is unstable, cutting edge needs to be changed at irregular intervals and requires either manned operation or more frequent tool replacement, leading to poor productivity and difficulty in reducing machining cost.

By using coated SUMIBORON new BNC200, the occurrence of unexpected breakages can be reduced even in the high-efficiency cutting conditions. New BNC200 eliminates tool replacement at irregular intervals, allows unmanned operations possible over a long time, and realizes significant progress in both productivity improvement and machining cost reduction.

3. Features of new BNC200

Table 1 shows the specifications of new BNC200 and conventional BNC200. The cBN content, particle size, and binding material are optimized and controlled depending on the cutting applications to provide cBN sintered body with desired breakage resistance and wear resistance. Although there is generally a trade-off between breakage resistance and wear resistance, the development goal for new BNC200 was to improve breakage resistance while maintaining wear resistance. CBN sintered body is made by sintering cBN particles mixed with a composite ceramic binding material containing TiN and Al. Compared to cBN particles, composite ceramics have higher heat resistance but less mechanical strength. Unexpected breakages

Table 1. Specifications of new BNC200

Grade	Coating (Thickness)	cBN sintered body		
		cBN content (vol%)	cBN grain size (μm)	Binder
New BNC200	TiAlN (2μm)	65 to 70	4	TiN
Conventional BNC200	TiAlN (2μm)	65 to 70	4	TiN

in sintered body usually occur as micro-cracks generated in the low mechanical strength portions at bonded phases and then propagated. One of the best ways to improve sintered body's mechanical strength is to increase its cBN content. In this case, however, wear resistance reduces due to the decrease of the amount of ceramics in the sintered body. New BNC200 succeeded in greatly improving its breakage resistance by increasing the mechanical strength and toughness of binding ceramics and maintaining wear resistance by not changing the cBN content.

4. Cutting performance of new BNC200

4-1 Transverse rupture strength (TRS) evaluation

Transverse rupture strength (TRS) was measured for a total of 40 times (N = 40) to evaluate the breakage resistance of new BNC200. In order to investigate variations in breakage resistance, the Weibull plot, which can be used for the statistical analysis of strength for brittle fracture, is shown in **Fig. 1**. The average TRS value of New BNC200 is 17% higher than that of conventional BNC200. Moreover, the Weibull modulus (m) of new BNC200 is higher than that of conventional BNC200, indicating that new BNC200 has less variation in the TRS value than conventional BNC200. Therefore, new BNC200 is expected to have improved breakage resistance reliability for use in cutting tool applications.

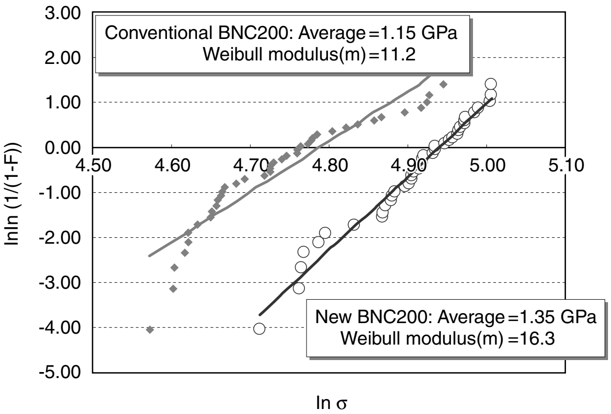


Fig. 1. Weibull plot of TRS

4-2 Methods for cutting performance evaluation

In the cutting performance evaluation of new BNC200, conventional BNC200 and a commercially-available general cBN grade were also evaluated for comparison purpose. The workpieces used were SCM415 whose surface was carburized to a hardness of 62 HRC and S55C whose surface was induction hardened to a hardness of 60 HRC. Wear resistance was evaluated in the general finishing condition, and breakage resistance was evaluated in the high-efficiency condition. In addition, breakage resistance in interrupted cutting was evaluated using V-grooved workpieces prepared from S55C. Furthermore, to investigate the advantage of new BNC200 in high-efficiency machining, interrupted cutting tests were performed using V-grooved workpieces prepared from SCM415 at a machining efficiency 2.25 times higher than that of a conventional non-coated cBN grade.

4-3 Cutting test results

Figure 2 shows the results of cutting tests performed under the finishing condition. Cutting performance was evaluated in terms of flank wear width and surface roughness. The results show that new BNC200 and con-

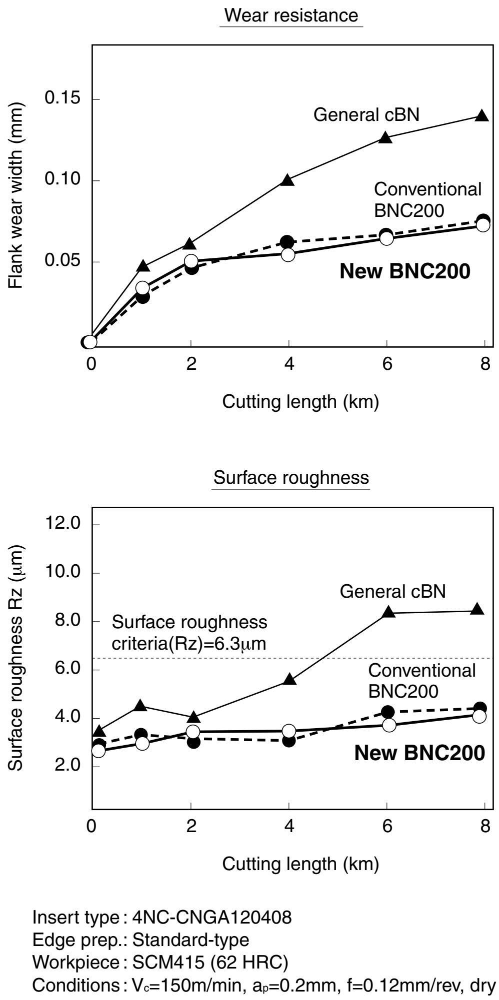
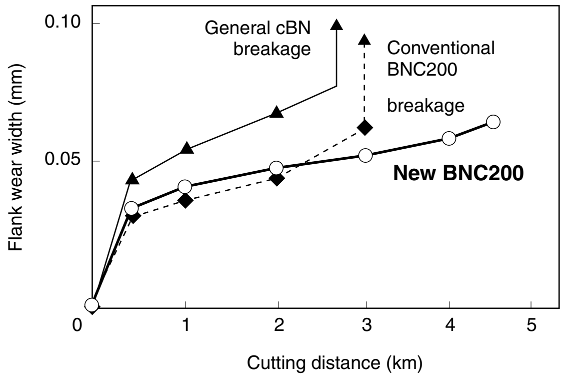


Fig. 2. Results of cutting tests under finishing conditions

ventional BNC200 demonstrate equivalent cutting performances.

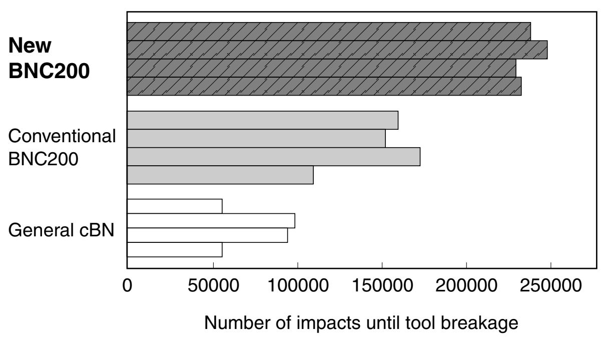
Figure 3 indicates the cutting test results under the high efficiency cutting condition. Cutting performance was evaluated in terms of flank wear width and end of tool life by breakage. New BNC200's tool life until breakage is 1.5 times longer than that of conventional BNC200, but wear resistance is similar between the two grades.



Insert type : 4NC-CNGA120408
Edge prep.: Standard-type
Workpiece : SCM415 (62 HRC)
Condition : V_c=150 m/min, a_p=0.4mm, f=0.2mm/rev, dry

Fig. 3. Results of cutting tests under high-efficiency cutting conditions

Figure 4 shows the results for the interrupted cutting tests (N = 4). Cutting performance was evaluated by the number of impacts at which the breakage occurred. New BNC200 achieved an average tool life 1.5 times longer than that of conventional BNC200. Also, the minimum number of impacts at which the breakage occurred in new BNC200 was more than 2 times higher

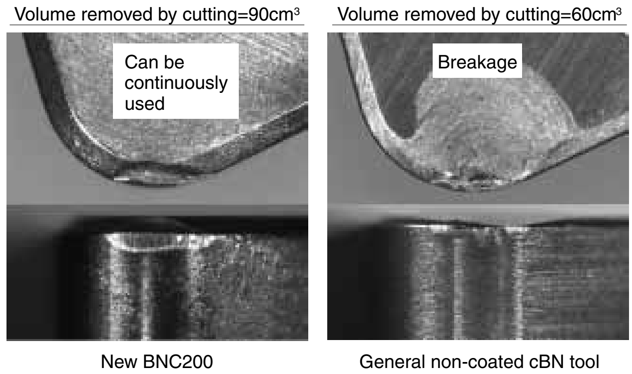


Insert type : 4NC-CNGA120408
Edge prep.: Standard-type
Workpiece : S55C (60 HRC)
Conditions : V_c=120m/min, a_p=0.15mm, f=0.12mm/rev, dry

Fig. 4. Results of cutting tests under interrupted cutting conditions

than that in conventional BNC200, and the variation in tool life until breakages was smaller in new BNC200 than in conventional BNC200, indicating that reliability against breakage is significantly improved. It is estimated that the former result is due to the increase in the average value of TRS, and the latter result is due to the increase in the Weibull modulus of TRS (m).

Figure 5 shows the cutting edge photographs of new BNC200 and a general non-coated cBN tool used at a machining efficiency of 4.5 cm^3/min and 2.0 cm^3/min, respectively. Although new BNC200 has a machining efficiency 2.25 times higher than that of a general non-coated cBN tool, new BNC200 exhibits a cutting edge that can still be used after cutting 1.5 times greater volume than the general non-coated cBN tool. These results indicate that new BNC200 realizes more than 2 times higher machining efficiency and more than 1.5 times longer tool life compared to the general non-coated cBN tool.



Insert type : 4NC-CNGA120408
Edge prep.: HS-type
Workpiece : SCM415 (62 HRC)

■Cutting conditions

Grade	Cutting speed V_c(m/min.)	Feed rate f (mm/rev.)	D.O.C. a_p(mm)	Efficiency $V_c \times f \times a_p$ (cm^3/min.)
New BNC200	150	0.15	0.2	4.5
General non-coated cBN tool	100	0.1	0.2	2

Fig. 5. Photographs of cutting edges in interrupted cutting tests

5. Cutting edge specifications of new BNC200

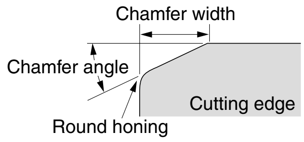
5-1 Edge preparations

In order to prevent the breakage of cutting edges during cutting of high-hardness workpieces such as hardened steel, cBN tools have chamfered cutting edges. New BNC200 standard stock items have edge preparation choices of standard-type, LS-type, and HS-type. (**Table 2**)

The standard-type is the primary recommendation for general use and can be used widely from general finishing to roughing. The LS-type is equipped with sharp cutting edges, with a chamfer angle smaller than that for the standard-type and cutting edge surfaces smoothed by a special surface treatment. It reduces cutting resistance and is recommended for continuous finishing of hardened steel parts where high dimensional precision is required. The LS-type is suited especially for machining of bearing parts that require IT6 class machining accuracy, and realizes both excellent wear resistance and longer tool life. The HS-type is designed to have a larger chamfer angle and width so as to realize stronger cutting edge strength that leads to improved breakage resistance. New BNC200 HS-type is described in detail in the following paragraphs.

Table 2. Edge preparations of new BNC200

Grade	Edge prep.	Chamfer angle[°]	Chamfer width[mm]	Round honing
New BNC200	Standard	25	0.12	Yes
	LS-type	15	0.1	Yes
	HS-type	35	0.17	Yes



5-2 Features of new BNC200 HS-type

As shown in **Fig. 6**, new BNC200 HS-type has a unique cutting edge structure with the cBN sintered body exposed at the chamfer. The purpose of this structure is to maintain improved wear resistance by applying a coating layer on the tool's flank face while preventing damage to the coating layer caused by the collision of workpiece with chamfer during interrupted cutting, so as to achieve more stable tool life even in interrupted cutting.

5-3 Cutting performance of new BNC200 HS-type

In the cutting performance evaluation of new BNC200 HS-type, conventional BNC200 standard-type and a commercially available general cBN tool were also tested for comparison purpose. SCr420H surface carburized to a hardness of 60 HRC was used as workpiece. The workpiece has chamfered holes on its end face, so interrupted machining was conducted. **Figure 7** shows the cutting test results. Cutting performance was evaluated as a ratio of tool life until breakage compared to that of new BNC200 standard-type (100%). Here, tool life until breakage was the cutting distance at which breakage occurred. The evaluation results show that new BNC200 HS-type achieved 1.3 times longer tool life and smaller variation in tool life until breakage than those for new BNC200 standard-type. **Figure 8** shows the SEM photographs of unbroken but

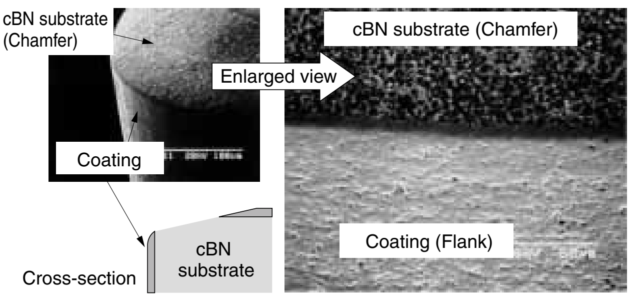


Fig. 6. Cutting edge structure of HS-type

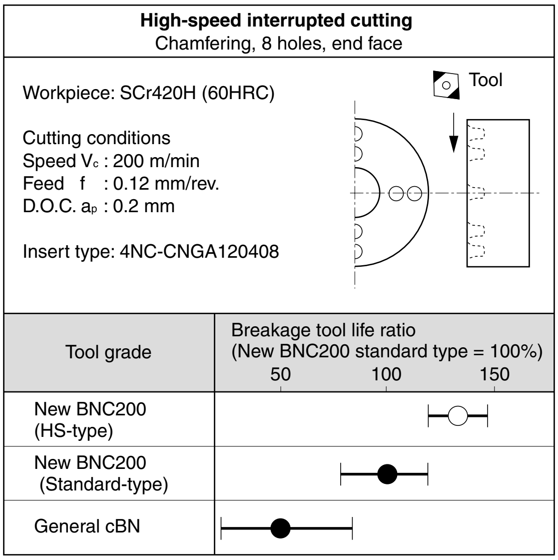


Fig. 7. Results of cutting tests of new BNC200 "HS-type" under high-speed interrupted cutting conditions

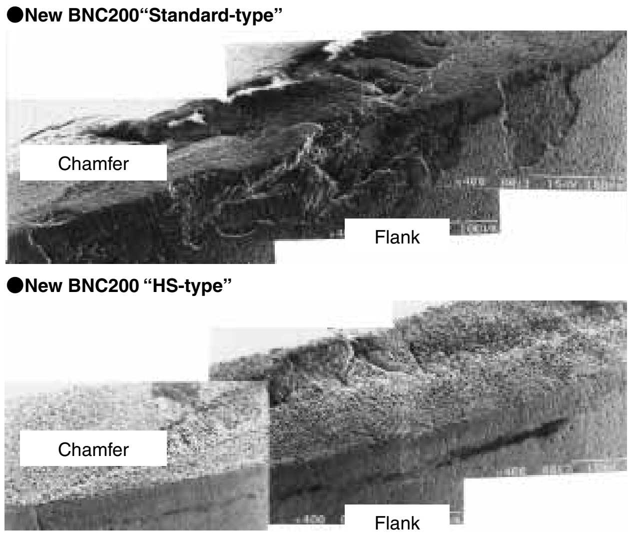
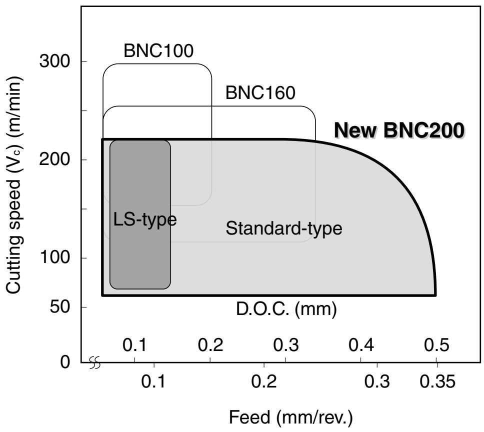


Fig. 8. Damages at cutting edges (SEM photographs)

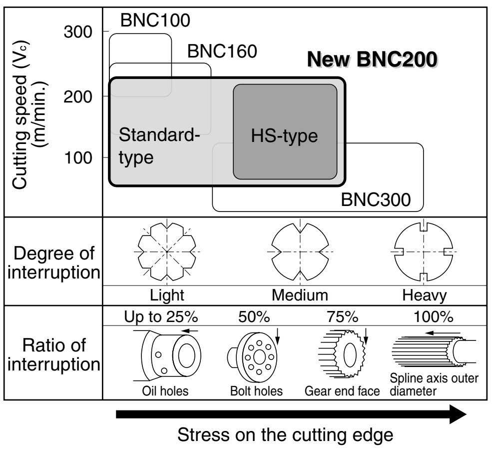
damaged cutting edges after the same cutting distance. In the standard-type cutting edge, the coating layer is destroyed from the chamfer to the land portion, and cracks propagated in the cBN sintered body. In the HS-type cutting edge, thanks to the strong mechanical property of the cBN sintered body, only few cracks appeared on the chamfer and flank wear developed normally as shown in **Fig. 8**. As a result, reliability against breakage in interrupted cutting improved significantly, and it also became possible to achieve excellent wear resistance.

6. Application area of new BNC200

Figure 9 shows the application area of new BNC200 in both continuous and interrupted cutting of hardened steels. New BNC200 exhibits excellent cutting performance from finishing to roughing in the machining conditions of cutting speed of 50 to 220 m/min, feed rate of 0.05 to 0.35 mm/rev, and depth of cut of 0.05 to 0.5 mm. The LS-



i) Application areas in continuous cutting



ii) Application areas in interrupted cutting

Fig. 9. Application areas of new BNC200

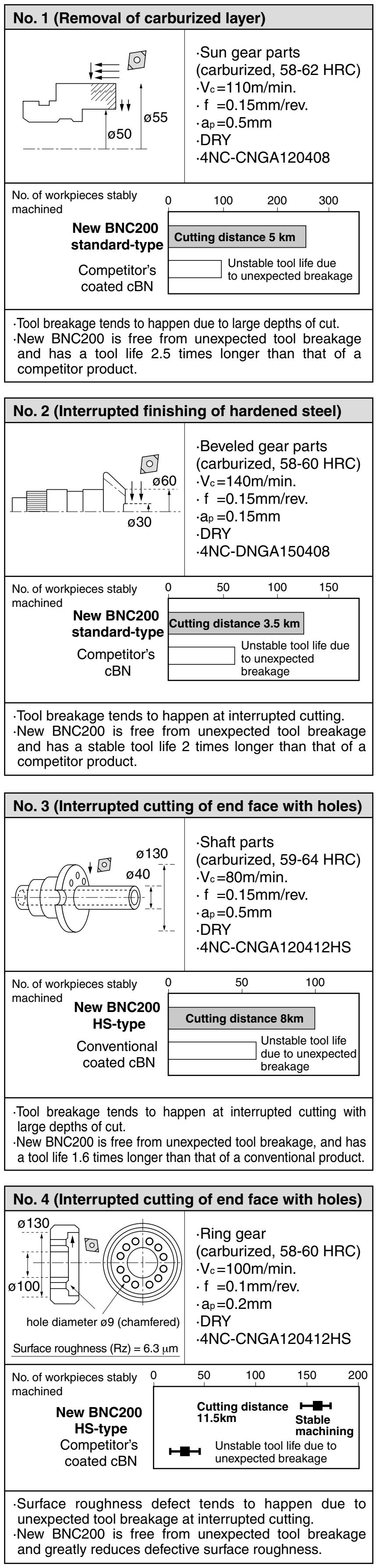


Fig. 10. Application examples of new BNC200

type realizes excellent machining accuracy in continuous finishing with the machining conditions of feed rate and depth of cut less than 0.10 mm/rev and 0.15 mm, respectively. The HS-type yields stable tool life until breakage in medium interrupted cutting with relatively high degrees of interruption. **Figure 10** shows the examples of applications of new BNC200. In high-efficiency machining of various hardened steel parts, new BNC200 shows more stable and longer tool life than conventional tools.

As described above, the reliability against breakage has been significantly improved in new BNC200 compared to the conventional grades. Therefore, by selecting appropriately from different edge preparations, machining efficiency can be improved and machining cost can be reduced in cutting of various hardened steel parts.

7. Conclusion

By using coated SUMIBORON new BNC200, better machining efficiency and longer tool life can be achieved in cutting of hardened steel parts. Moreover, because it has a stable and long tool life, new BNC200 can be used for hardened steel parts to which grinding has been employed conventionally because the cost for grinding had been lower than that for cutting. It is expected that the use of new BNC200 accelerates improvement in machining efficiency and the shift from grinding to cutting makes significant contributions in cutting machining costs and solving environmental issues.

References

(1) Hara et al. : Sumitomo Electric Technical Review, No.113, 161.1978
(2) Harada et al. : Sumitomo Electric Technical Review, No.158, 75.2001
(3) Okamura et al. : Sumitomo Electric Technical Review, No.165, 87.2004
(4) Okamura : Tool Engineer, Dec., 42.2007
(5) Teramoto et al. : Sumitomo Electric Technical Review, No.172, 89.2008

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