Development of New Coated Carbide Grade "ACE COAT AC820P" and "AC830P" for Steel Turning

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Sumitomo Electric Hardmetal Corporation has newly developed a coated carbide grade "ACE COAT AC820P" and "AC830P." AC820P is a general grade used for a wide range of steel turning from highly-efficient continuous machining to interrupted rough machining. On the other hand AC830P, is used exclusively for heavy machining and interrupted machining. Both AC820P and AC830P are doubled in the tool life and improved in the reliability compared with conventional grades. AC820P and AC830P have successfully achieved such properties by optimizing the originally developed chemical vapor deposition (CVD) coating technology, "Super FF Coat," which consists of titanium film with fine, smooth surface and alumina film with a accurately cemented carbide substrate. By applying the new surface treatment technologies to AC820P and AC830P, Sumitomo Electric Hardmetal has significantly reduced chippings and damages of cutting edges, which used to be frequently caused during steel turning, preventing irregular wear and tool life shortening. Currently, the authors have also developed a highly-efficient, versatile chip breaker, "GE type." The combination of all the excellent technologies of ACE COAT AC820P and GE type, tool life and machining efficiency have remarkably improved. With the coated carbide series including the three steel turning grades: "AC820P" for general machining, "AC830P" for interrupted machining and "AC700G" for high-speed and continuous machining, wide-ranging needs from customers who wish to improve their productivity and cost efficiency of steel turning will be adequately met.

Keywords: steel turning, CVD, TiCN, Al_2O_3

1. Introduction

Among the various grades for indexable inserts used in cutting operations, carbide grades incorporating hard ceramic film (hereinafter called "coated grades") are gaining attention due to their balanced properties between good wear and fracture resistance. The popularity of the coated grades is growing rapidly and now they account for seventy percent of all grades for indexable inserts (**Fig.1**).

Inserts made of the coated grades are used for machining a variety of workpiece materials such as carbon steel, alloy steel, stainless steel and cast iron. Carbon steel, alloy steel and other steels, for example, are playing a key role as the main materials of parts for the automobile, heavy electric machinery, iron and steel fabricating, and construction machinery industries.

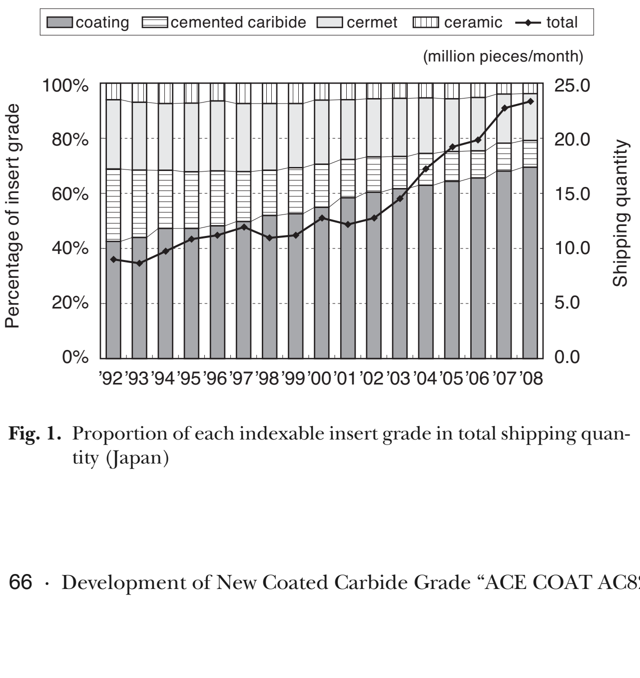


Fig. 1. Proportion of each indexable insert grade in total shipping quantity (Japan)

Recently, to fulfill diversified user demands, a wide variety of machining parts is being manufactured in small quantities. Lead-free parts are also highly desired with the aim of lessening possible negative impacts on the natural environment. Meanwhile, dry machining techniques and more efficient processes are required to shorten lead time and reduce machining costs. In addition to these demands, users desire cutting tools with longer tool life and more stable performance. To satisfy these user needs and cover most steel turning operations, Sumitomo Electric Hardmetal Corp. has developed two kinds of carbide grades incorporating chemical vapor deposition (CVD) coating. One is "ACE COAT AC820P" for general machining, and the other is "ACE COAT AC830P" for heavy and interrupted machining. Below is a report that describes the development background and characteristics of the new grades.

2. Development goals and new technology of AC820P and AC830P

Figure 2 shows a grade map of our steel turning products. The coated carbide series include three grades for steel turning. "AC700G" has high wear resistance, and therefore, is suitable for high-speed and continuous machining. "AC820P" widely covers continuous machining and interrupted machining, and thus, is used for general purposes. "AC830P" has high strength and fracture resistance, and therefore, is suitable for heavy and interrupted machining.

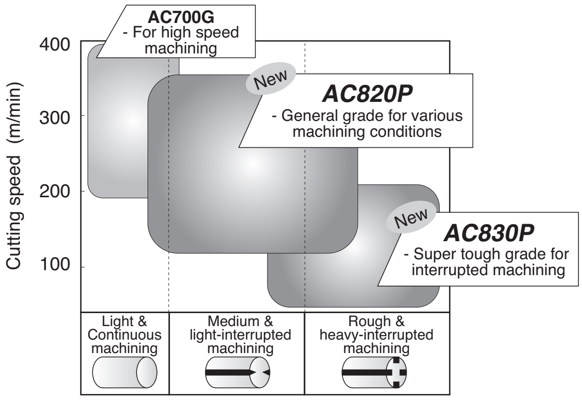


Fig. 2. Application domains of AC700G, AC820P and AC830P

2-1 Development goals of AC820P, a general purpose grade

In order to clarify the development goals of our new general grade, we collected data from our customers under some 100 different cutting conditions and investigated the cutting edges of their used inserts. As the result of sorted cutting conditions according to the cutting speed and workpiece material, we have revealed that the cutting speeds were less than 250m/min in over half of the cases of medium carbon steels, low alloy steels and bearing steels. The second most common classification was cutting speeds of over 250m/min. The above two areas account for as large as 80% of all our data. Under these conditions, the main failure was due to chipping of coating film, which also caused of the majority of failure under the all cutting conditions. Accordingly, we set the highest priority for developing new grades on the reduction of chipping damages, and the development target with a focus on 1.5 times longer tool life compared with conventional grades. For the in-demand field of high efficiency machining, crater wear was the failure mode accounting for 30 percent. Therefore, we also set our development goal of 1.5 times higher resistance against the crater wear compared with conventional grades so as to achieve longer tool life even under high efficiency machining.

2-2 Development goals of AC830P, a grade for heavy and interrupted machining

In machining processes involving interruption parts, impacts repeatedly caused by the interruption lead to troubles such as great damages and sudden breakage of insert edges. Large gaps in layered material characteristics (structure, hardness and surface roughness) as well as low rigidities in workpieces, lathes, or workholders (chucks) are also likely to contribute to such troubles. As a result, tool life varies and tool indexing becomes irregular, requiring users to stay with the machine all the time to replace damaged tools, otherwise, the service period of tools needs to be deliberately set low so as to avoid accidental sudden failure. Such situation results in a decrease in productivity and an increase in processing costs. To this end, we have given top priority to the development of a new grade for heavy and interrupted grades featuring at least twice as much fracture resistance as that of conventional grades.

2-3 Development of AC820P, a general purpose grade

Figure 3 shows a comparison of cross-sectional SEM images of a conventional grade and AC820P, our newly developed substrate incorporating CVD coating "Super FF Coat."

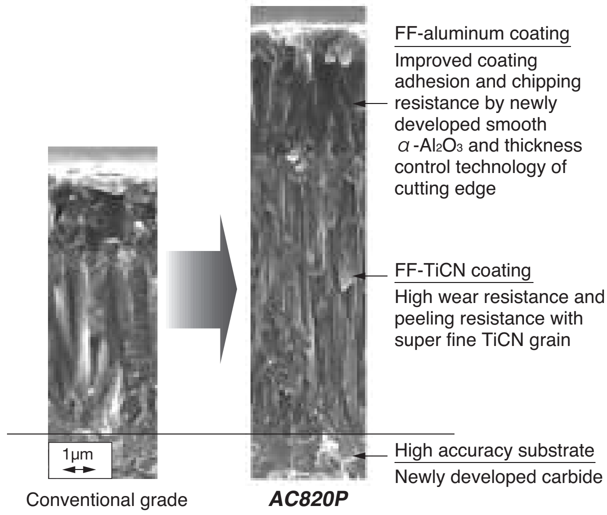


Fig. 3. Cross sectional SEM images of AC820P and conventional grade

(1) Improvement in chipping resistance

In order to increase chipping resistance, improvement in the toughness of the coating is vital. **Figure 4** shows a structural comparison of a conventional TiCN layer with the Super FF- TiCN coating layer. Compared to conventional coating film, Super FF Coating technology offers significantly small grain with dense and homogeneous structures. Because of these improvements in Super FF Coat, AC820P yields a high coating strength. Moreover, thermally stable and hard crystalline alpha-alumina coating is also applied so that AC820P is used even for high efficiency machining. However, conventional

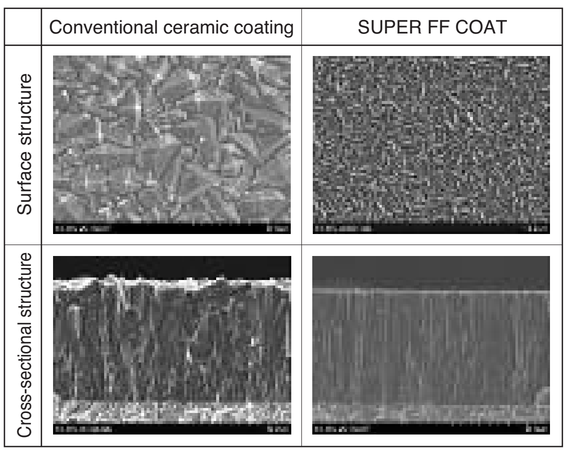


Fig. 4. Surface and cross-sectional images of conventional TiCN and SUPER FF COAT "FF-TiCN" (1)

alpha-alumina layers are relatively vulnerable to chipping damages due to their rough grains. The surface roughness of conventional alpha-alumina layers is also the cause of increasing built-up edges and adhesion. By halving the size of the alpha-alumina grains and optimizing the CVD process, we have achieved a smoother surface shown in **Fig. 5** and successfully improved the chipping resistance.

(2) Improvement in crater wear resistance

The newly developed TiCN and alpha-aluminum layers provide high strength and smoothness on the surface. By thickening their layers, the wear resistance is also improved. Such improvement is achieved when the TiCN and alpha-aluminum layers are thickened by 1.3 times and 4 times, respectively. **Figure 6** shows a comparison of cutting performance vis-à-vis the wear resistance under high efficiency machining conditions. AC820P, conventional products (AC2000) and a competitor's product (P20 grade) are used for comparison. As you can see, AC820P's tool life is twice as long as those of AC2000 and the competitor's. This result indicates that the flank and crater wear resistance is doubled with AC820P.

(3) Achieving both chipping and wear resistance

While the wear resistance is increased by thickening the coating layers, as a side effect of that, the chipping resistance is decreased. To solve this problem, we have newly developed a layer control technology that allows us to remove the alumina layer from the cutting edge where the most of chippings occur. With this technology, we have successfully achieved a high chipping resistance and a high wear resistance simultaneously. **Figure 7** shows the cutting performance vis-à-vis the chipping resistance. The chipping resistance was evaluated by testing the number of impacts to the cutting edge until it chipped. AC820P required over 1.5 times more impacts to chip than conventional product (AC2000) and the competitor's product (P20 grade).

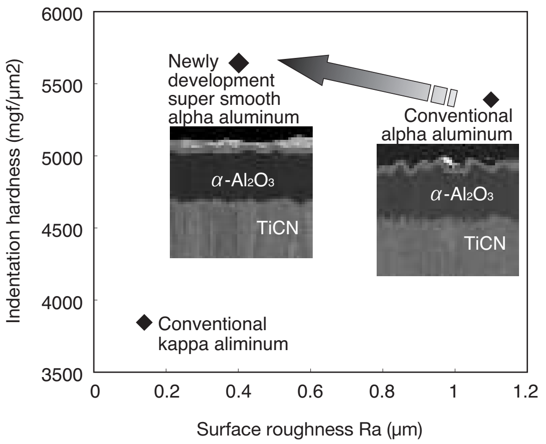


Fig. 5. Cross-sectional images and surface roughness of conventional Al_2O_3 and FF-α-Al_2O_3 with SUPER FF COAT

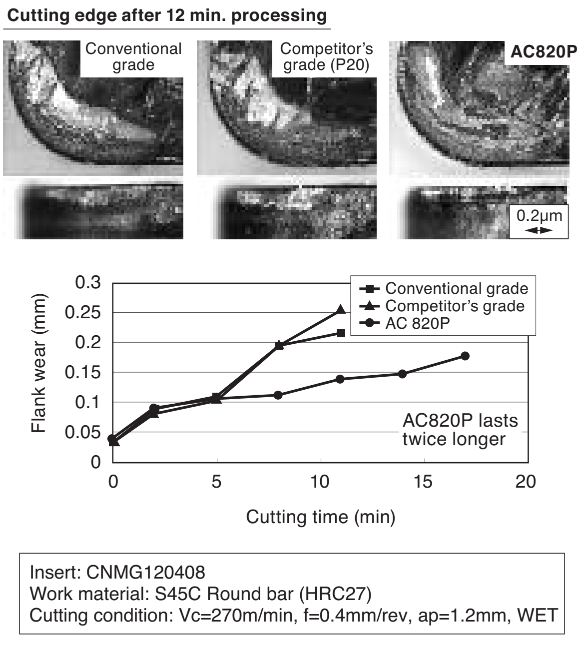


Fig. 6. Evaluation results on wear resistance under high speed and high feed rate machining

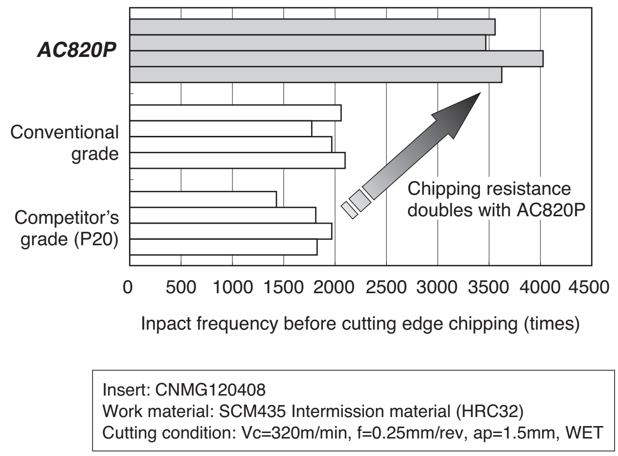


Fig. 7. Evaluation results on chipping resistance under light-interrupted machining

2-4 Development of AC830P, a grade for heavy and interrupted operations

For the development of such grades as AC830P, most competitors are likely to increase cobalt content in base materials up to 10 wt%, which can result in the decrease in inserts' accuracy. With such inserts, uncertain edge positions (index accuracy) cause a decrease in machining accuracy and holders' clamping power, leading to sudden failure and unreliable tool life. However, by optimizing the composition of the substrate and sintering process, AC830P has achieved a narrowed index accuracy range to two-thirds of conventional grades without lowering the cobalt content (See **Fig. 8**). Thus, the workpiece stability and reliable tool life are realized with AC830P.

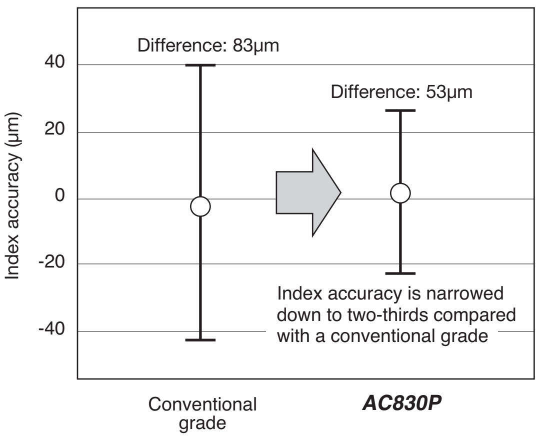
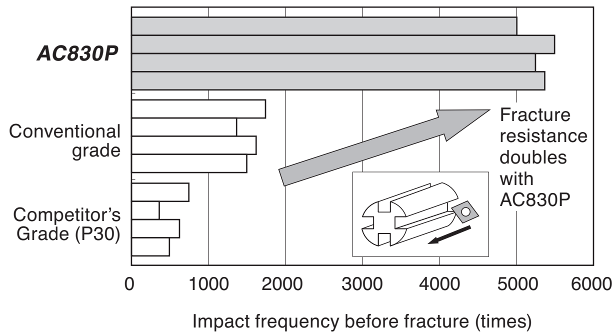


Fig. 8. Accuracy of cutting edge position (Index Accuracy)



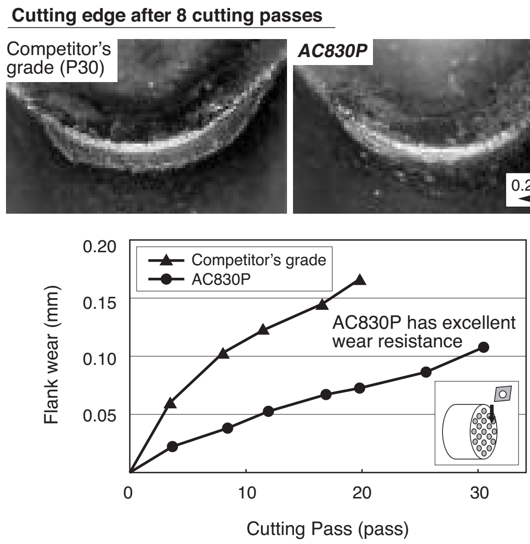
Insert :CNMG120408
Work material :SCM435 Intermission material (HRC30)
Cutting condition :Vc=220m/min, f=0.3mm/rev, ap=1.5mm, WET

Fig. 9. Evaluation results on fracture resistance under interrupted machining

Moreover, AC830P has achieved high wear resistance and peeling resistance by optimized Sumitomo Electric Hardmetal's CVD coating technology "Super FF Coat," which consists of a fine-grained TiCN coat and a flat, smooth-surfaced kappa-aluminum coat. Additionally, our newly developed stress control technology has dramatically improved the rigidity of AC830P during the CVD coating procedure, leading to a twofold increase in the fracture resistance compared to both our conventional product (AC3000) and a competitor's P30 grade.

In addition, **Fig. 10** shows the cutting performance of AC830P and a conventional grade in heavy interrupted machining of low carbon steel. The tool life of P30 grade ends with 20 passes due to the wear resulting from coat peeling, whereas, AC830P shows an excellent damage resistance of 30 passes.

From the results above, it is possible to achieve a twice or longer tool life with AC830P than conventional grades in interrupted machining.

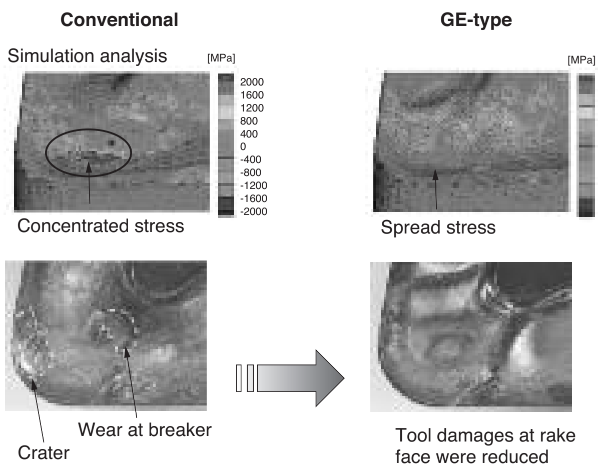


Insert: CNMG120408
Work material: SCM415 with hole (HRC25)
Cutting condition: Vc=200m/min, f=0.2mm/rev, ap=1.0mm, WET

Fig. 10. Evaluation results on low carbon steel under heavy-interrupted machining

3. Development of GE-type chip breaker for high efficiency machining

Along with the development of the grades above, we also developed a GE-style chip breaker. The breaker greatly reduces crater wear, which forms the main cause of the wear during high efficiency (fast feed or high speed) machining.



Work material: SCM435 Cutting times: 15min
Cutting condition: Vc=250m/min f=0.4mm, ap=1mm DRY

Fig. 11. Simulation analysis illustrating excellent property of GE-type chip breaker

3-1 Features of GE-type chip breaker

For the development of the GE-type chip breaker, we conducted a simulation test recreating crater wear conditions, and then analyzed the stress distribution over the chip breaker. As a result, it is clear that the crater wear is more effectively avoided with the stress spread across the chip breaker at a smaller hitting angle rather than with the stress sharply centered on a point. Consequently, we have applied this principle to the GE-type breaker to reduce crater wear and realize better performance in high efficiency cutting processing. This simulation results are shown in **Fig. 11**.

4. Cutting performance with AC820P and AC830P

4-1 Cutting performance with AC820P

Figure 12 illustrates comparisons of AC820P and a competitors' product (P20 grade) in use. The obtained values indicate balanced improvement in both chipping

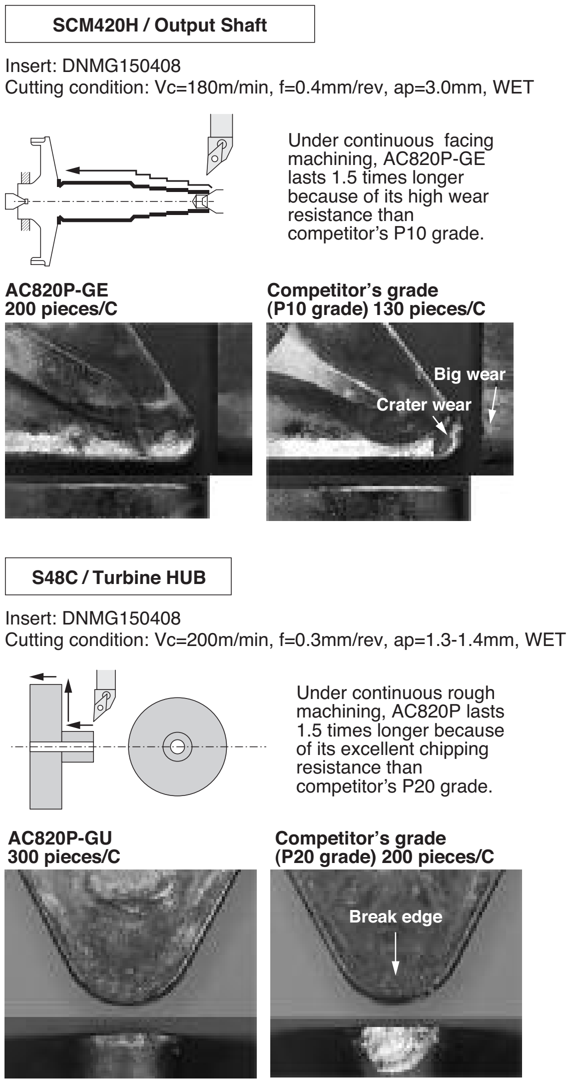


Fig. 12. Trial experiment of AC820P

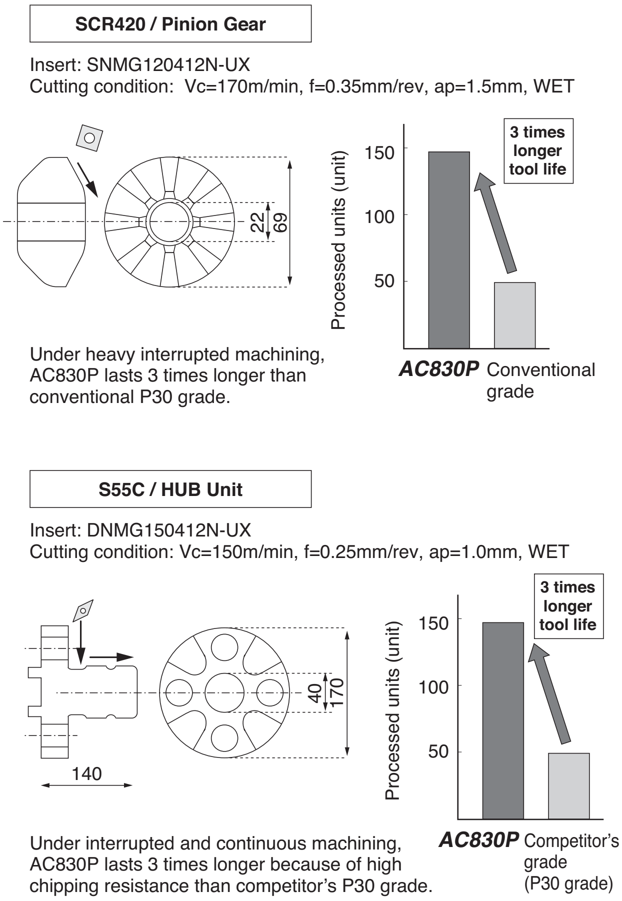


Fig. 13. Trial experiment of AC830P

resistance and wear resistance. In addition, the combination of AC820P and GE-type breaker leads to 1.5 times longer tool life under high feed rate machining.

4-2 Cutting performance with AC830P

Figure 13 gives comparisons of AC830P and a competitor's product (P30 grade) in use. It is clear that in heavy interrupted machining, AC830P has stable and long tool life, showing excellent reliability.

5. Conclusion

"ACE COAT AC820P" is a general grade widely used for various steel turning from highly-efficient continuous machining to interrupt rough machining. "ACE COAT AC830 P," on the other hand, is a grade with a great reliability in heavy machining and interrupted machining. A highly-efficient and versatile "GE-type chip breaker" is another feature we have currently developed to reduce damage to the rake face. In addition to our conventional "AC700G" for high-speed and continuous machining, with these novel products and technology: the new series of carbide coated grades "AC820P" and "AC830P" as well as "GE-type chip breaker," we expect to satisfy customers' various demands for productivity improvement and cost reduction in steel turning.

* "ACE COAT" and "SUPER FF COAT" are trademarks of Sumitomo Electric Hardmetal Corp.

Reference

(1) Okada et al. : Sumitomo Electric Technical Review , No. 64, 69. 2007

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