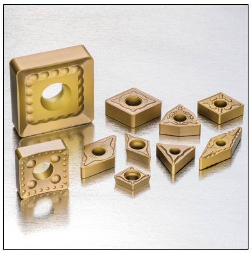

New Coated-Carbide Grade AC8020P for Steel Turning

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In steel machining, particularly in the automotive industry, various efforts are being made to reduce the environmental impact and to use resources efficiently. We released the AC8000P series for steel turning in 2016, which uses the new chemical vapor deposition (CVD) coating technology "Absotech Platinum," and are continuously expanding the product lineup. Meanwhile, there is a strong need for cutting tools that demonstrate a long tool life and stable performance. To satisfy these demands, we have developed a new steel turning carbide grade, AC8020P, which shows excellent wear resistance and chipping resistance in high-efficiency machining. Together with the existing AC8000P series, the new AC8020P will reduce machining costs in a wide range of steel turning operations.

Keywords: cutting tool, steel, CVD, high efficiency

1. Introduction

An indexable insert, a typical cutting tool, is usually made of cemented carbide*1 coated with hard ceramics ("coated grade" for short). Compared to other materials, coated grade has an excellent balance between wear resistance and chipping resistance, and they currently account for more than 70% of all indexable insert materials.

According to ISO 513:2004, the materials of objects that are machined ("workpieces" for short) with coated grade are classified into six categories: steel, stainless steel, cast iron, nonferrous metals, heat-resistant alloys, and high-hardness materials. Of these materials, steel is the most common and is further divided into carbon steel and alloy steel. The properties required of the tools used for machining these steels differ from each other.

In recent years, from the viewpoint of environmental impact reduction, efforts have been made to use steel free from lead, a hazardous component, and to enhance productivity by improving machining efficiency rather than increasing the number of machining equipment units. Implementation of these environment-protection measures leads to a decrease in machinability and an increase in cutting temperature, increasing the load imparted to the cutting tools. Therefore, the cutting tools to be used in such harsh environments are required to have higher performance than before. In addition, the Internet of things (IoT) is being introduced to the field of cutting. To realize an unmanned and automated machining process, it is important to prevent the equipment from stopping due to the sudden breakage of cutting tools and to maintain them in a highly stable condition.

In response to such requirements for machining steel, Sumitomo Electric Industries, Ltd. has developed and sold the AC8000P series, which ensures extremely long life and stable performance in a wide range of machining environments.(1) In order to further expand the application range of the AC8000P series in steel machining, the authors have recently developed and launched a new coated grade, "AC8020P." This new coated grade ensures stable performance and long tool life in high-efficiency machining of hard steels, such as medium- and high-carbon steels, where the tool is exposed to a particularly large load. This paper describes the positioning, features, and cutting performance of AC8020P.

2. Problems with Steel Turning and Positioning of AC8020P

In the cutting process, the characteristics required of the tool material differ depending on the shape of the workpiece and the machining conditions, making it necessary to select a tool material appropriate for the conditions. In continuous machining of a workpiece having no discontinuity, such as a hole or groove on the machining surface, the cutting edge of the tool stays in contact with the workpiece. As a result, the cutting edge is highly heated due to friction. Since such continuous machining heats the tool material to a high temperature and reduces its hardness, a material having superior heat resistance and wear resistance should be selected for the tool. On the other hand, in intermittent machining of a workpiece containing many holes or grooves on the machining surface, the tool's cutting edge comes into contact with these discontinuities many times during the machining, increasing the possibility of chipping due to impact. For this type of machining, a tool material with high chipping resistance should be selected.

The AC8000P series is available in three different grades that cover a wide range of machining conditions, from continuous to intermittent machining. On the other hand, in machining shops that have already succeeded in achieving stable performance and long tool life machining using the AP8000P series, there is a growing need for more efficient machining in order to further reduce machining costs and increase production capacity. In machining relatively hard steels such as medium- to high-carbon steels containing a large amount of carbon, improvement in machining efficiency exerts a particularly large impact on the cutting tools used. In particular, the tools accelerate wear and increase the frequency of abnormal damage such as chipping, as shown in Photo 1. Chipping can cause tool damage and workpiece defects, reducing productivity due to reduced tool life and the sudden stopping of machining equipment.

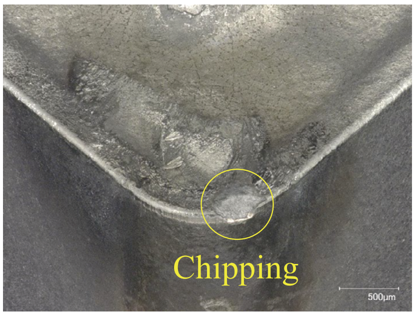


Photo 1. Example of cutting tool edge damaged in high-efficiency machining

AC8020P is a new coated grade having both high wear resistance and chipping resistance, thereby ensuring stable performance and long tool life in harsh environments such as high-efficiency machining. With the expansion of AC8020P, the AC8000P series is now able to provide a cutting tool that is more suitable for the type of steel to be cut, cutting conditions, and workpiece shape, as shown in Fig. 1.

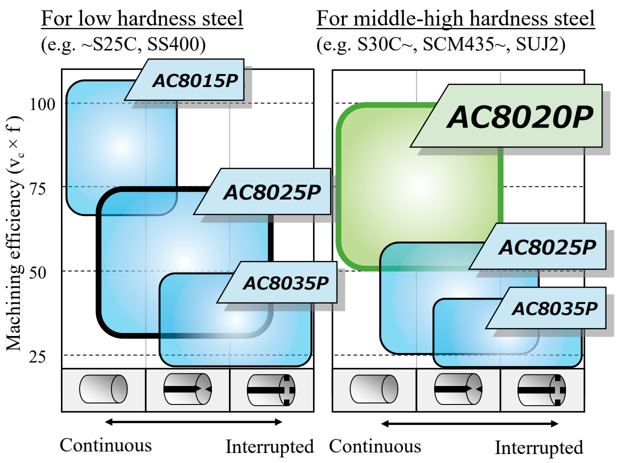


Fig. 1. Application range of AC8000P series

3. Advantages and Cutting Performance of AC8020P

The CVD*2 coating technology "Absotech Platinum," which is used for the AC8000P series as a common specification, coats cemented carbide with a multi-layer film consisting of titanium carbonitride (TiCN) and alumina (Al_2O_3). The overall thickness of the coating film is controlled depending on the purpose of use of the specific tool. For AC8015P and AC8020P, for which Al_2O_3 film with higher wear resistance is required, a crystal orientation-controlled Al_2O_3 film is used. In this film, the crystal orientation is aligned in the direction of the film's thickness to increase the resistance to the shearing load caused by chips rubbing against the tool surface. Further, the outermost surface of the film has a use state recognition layer that makes it easy to determine whether or not the cutting edge of the tool is in use. In addition to this film structure, the tool is subjected to special surface treatment suitable for the purpose of use.

As described above, AC8020P is a series of coated grade that exhibit both wear resistance and chipping resistance at a high level. However, these properties are in a trade-off relationship. The wear resistance of AC8020P increases in proportion to an increase in the hardness of the cemented carbide base material and the thickness of the coating film. On the other hand, this material also reduces chipping resistance. In particular, when a CVD coating is applied to cemented carbide, tensile residual stress*3 is generated in the coating film due to the difference in the thermal expansion coefficient between the cemented carbide and coating film. The disadvantage of this is that cracking occurs inside the coating film when the tool is subjected to an impact load, making it easy for the cutting edge of the tool to be chipped off.

Sumitomo Electric has a technology that can reduce tensile residual stress or add compressive residual stress by applying a special treatment to the coated surface after deposition. However, this technology was unable to obtain sufficient chipping resistance by assuring a thick coating film sufficient to maintain a level of wear resistance that can cope with high-efficiency machining. In the development of AC8020P, the strength of the Al_2O_3 film itself was improved and a new stress imparting technology was used to solve this problem. As a result, chipping resistance increased to 2.5 times or more the conventional value. Figure 2 shows the evaluation test results for the chipping resistance of AC8020P. The test workpieces were alloy steel (SCM435) round bars. Discontinuities were given to

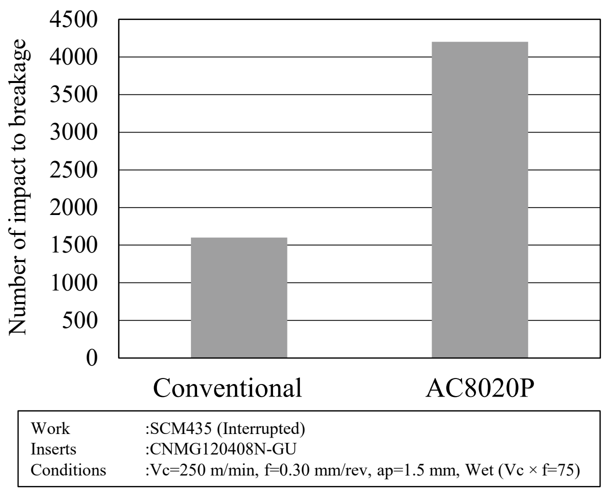


Fig. 2. Chipping resistance of AC8020P

them to simulate intermittent machining in which the cutting edge of the tool is often chipped off. The test was carried out under the cutting conditions of cutting speed (Vc) = 250 m/min, feed rate per revolution (f) = 0.30 mm/rev, depth of cut (ap) = 1.5 mm, and use of cutting oil (wet). The test results were evaluated in terms of the number of times the cutting edge came into contact with the discontinuities (number of impacts) until the tool reached the end of life. Figure 3 shows scanning electron microscope (SEM) images of the cross-section of the coated film at the initial stage of cutting in the chipping resistance evaluation test, together with photos of the damage to the cutting edge (side) of the tool after each impact.

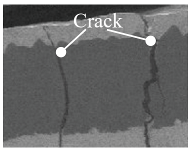
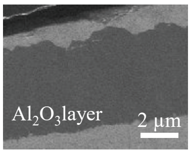
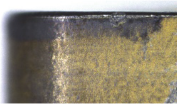
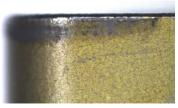
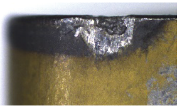
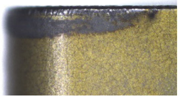
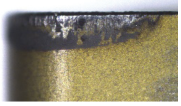
		Conventional	AC8020P
SEM images of the cross-section of initial stage tool edge			
Photos of tool edge	Number of Impact 400	 Minute chipping	 Fine
	1600	 Breakage	 Fine
	4000	Broken	 Minute chipping

Fig. 3. Comparison of damage occurred in chipping resistance evaluation

The conventional coated grade generated cracks in the coated film at the initial stage of cutting, causing minute chipping of the cutting tool. This minute chipping progressed and damaged the tool, bringing it to the end of life. In the case of AC8020P, cracks in the coated film, which constitute the starting points of minute chipping, were not observed at the initial stage of cutting. This test result verified that the chipping resistance of AC8020P has been significantly enhanced by the new technology described above.

Figure 4 shows the results of wear resistance evaluation in terms of the correlation between cutting time and the flank wear (Vb) in continuous machining of an SCM435 round bar. The data were obtained by cutting the round bar under the conditions of Vc = 270 m/min, f = 0.30 mm/rev, ap = 1.5 mm, and wet. These conditions were determined to simulate high-efficiency machining, where the cutting edge tends to be heated to a high temperature and accelerates wear. It was confirmed from this evaluation

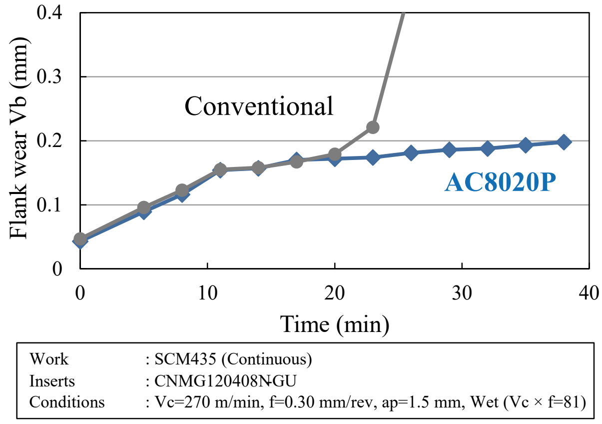


Fig. 4. Wear resistance of AC8020P

test that the conventional coated grade is worn rapidly and reaches the end of life since the cutting edge loses the ability to withstand the load as the wear of the edge progresses, while AC8020P has high wear resistance due to thick film coating.

Figure 5 shows application examples of the use of AC8020P at customers. In case example (a), crater wear of progressed noticeably. In particular, the conventional coated grade was worn away at the protruding portion of the rake face after the machining of 26 workpieces, resulting in chip elongation and the end of tool life. In contrast, AC8020P suppressed the progress of wear of the rake face and 40 workpieces were machined, about one-and-a-half times the quantity that could be achieved by the conventional grade. In case example (b), the workpieces were machined at a high feed rate of f = 0.55 mm/rev, a condition where the load on the cutting edge was extremely high. In this case, AC8020P was able to suppress both flank and crater wear, increasing the machining quantity to three times or more the quantity achieved by the conventional grade. Case example (c) involved the machining of bearing steel (SUJ2), a material that tends to accelerate tool wear, at a high speed of Vc = 300 m/min. As the flank wear progresses, the machining load increases, causing the machining to stop. In this example, AC8020P demonstrated stable machining by minimizing flank wear even after the machining quantity was increased. Case example (d) is of a machining operation that exhibited a conspicuous difference in chipping resistance between AC8020P and the other grade. For competitor’s grade, it was impossible to increase machining quantity any more due to chipping of the cutting edge ridge (indicated by red circles in the photo). In contrast, AC8020P machined the workpieces without chipping even after the machining of one-and-a-half times or more as many workpieces as those machined with the competitor’s grade, thereby ensuring stable performance and long life of the tool.

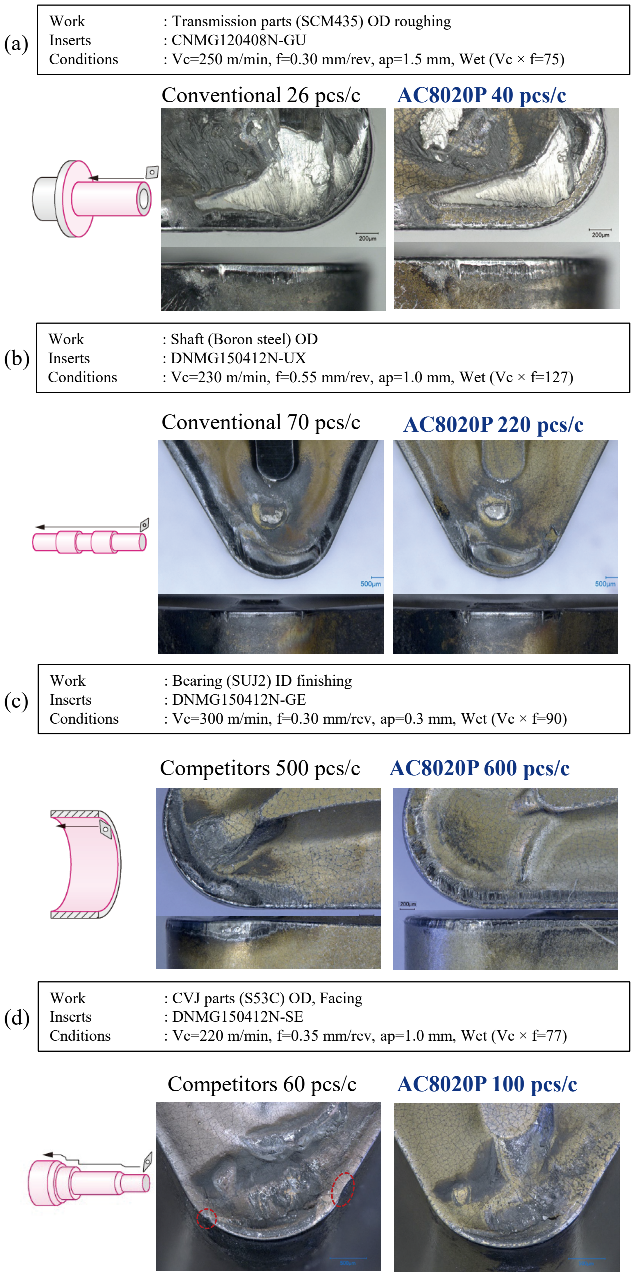


Fig. 5. Application examples of AC8020P

4. Conclusions

AC8020P, the strength and chipping resistance of which have been enhanced by CVD coating and impartation of stress, respectively, ensures stable performance and long life of the tool in high-efficiency machining of medium- to high-carbon steels.

The addition of AC8020P has enabled the AC8000P series of coated grade for steel turning to meet the needs of the steel machining industry for a wider range and more advanced machining than ever before, thereby helping cutting tool users reduce machining costs and improve productivity.

Technical Terms

*1 Cemented carbide: A composite material of ceramics and a metal, consisting mainly of tungsten carbide (WC) and cobalt (Co).

*2 Chemical vapor deposition (CVD): A method of depositing ceramics on the surface of a substrate using a chemical reaction.

*3 Tensile residual stress: A tensile force that remains in an object in a process such as heat treatment. Tensile residual stress in a coated film reduces its strength. A force acting in the opposite direction is called compressive residual stress.

Reference

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