1. Introduction

Indexable inserts used for cutting tools, which are made by coating on the surface of a cemented carbide substrate with a hard ceramic film (hereinafter referred to as coating grade), have better-balanced wear resistance and fracture resistance compared to other inserts. Due to such distinctive features, use of these insert grades has been expanding year by year, and they currently account for 70% of all indexable insert grades.

Recently, nickel-based alloys, cobalt-based alloys, and titanium alloys are often used for equipment and parts in the aerospace, oil and gas, medical, and automotive industries, and their use is expected to further expand in the future. These materials have excellent high-temperature strength, and tools are likely to have adhesion onto the cutting edge during cutting, resulting in significant reduction in the tool life due to sudden fracture of the cutting edge of the tool and other factors. Therefore, there has been an increase in demand for cutting tools with stable performance and long tool life in order to cut difficult-to-cut materials.

To meet such market needs, Sumitomo Electric Industries, Ltd. has developed and released two new grades, ACS2500 and ACS3000. ACS2500 is a new PVD*1 coated grade that achieves long tool life and high-efficiency machining when milling difficult-to-cut materials, especially titanium alloys, and ACS3000 is a new coated grade that achieves stable performance and long tool life when machining heat-resistant alloys in a wide application range. This paper reports the development targets, features, and cutting performances of these two grades.
2-2 Application ranges of ACS2500 and ACS3000

Figure 2 shows the application ranges of two grades: ACS2500 for titanium alloys and ACS3000 for Inconel alloys along with their recommended usage ranges. ACS2500 is a grade for titanium alloy milling, having a newly developed cemented carbide substrate and coating film with excellent thermal-crack resistance. ACS3000, applying a newly developed coating film, achieves long tool life with its excellent wear resistance for Inconel milling.

2-3 Features of the new PVD film

The newly developed coating film is applied to both ACS2500 and ACS3000. The coating film mainly features (1) improved strength and wear resistance with the super-multilayered structure of ultra-fine grained AlTiBN and (2) improved stability with higher adhesion strength between the coating film and cemented carbide substrate. To understand the mechanism of damage of coating films during difficult-to-cut material milling, we machined Inconel 718 using a milling tool with a conventional coating film and closely observed the cutting edge. Photo 1 shows the results the cross sectional pictures of damaged cutting edge.

In addition, in the milling of difficult-to-cut material using a tool with a conventional coating film, tool life tends to be unstable due to delamination of the coating between the cemented carbide substrate and the film. To address this problem, we applied our original high adhesion technique to the interface. The new coating film has achieved an adhesion strength of 1.5 times that of conventional coating films in a scratch adhesion strength test** (Fig. 3).

2-4 Features of the new cemented carbide substrate

To improve thermal-crack resistance, efforts were made to increase the strength of the cemented carbide

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<th>Conventional carbide substrate</th>
<th>Newly developed carbide substrate</th>
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<tr>
<td>Transverse rupture strength (GPa)</td>
<td>3.8</td>
<td>4.4</td>
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<td>Microstructure</td>
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The picture reveals that the crack in the conventional coating film parallel to the interface between the film and substrate enlarged the damaged area. Suppressing these cracks is critical because damage will rapidly escalate when cracks are developed. We have made several trials to add new elements in order to obtain a finer coating structure and improve the coating strength. As a result, we have succeeded in developing the film structure as fine as several nm by adding boron (B) (Photo 2).
substrate. We have successfully developed a new cemented carbide substrate that achieves a transverse rupture strength 1.2 times that of conventional substrates by uniform WC raw materials and improved sintering conditions (Fig. 4).

2-5 Cutting performances of ACS2500 and ACS3000

We have rolled out ACS2500, which is the combination of the ultra-fine grained AlTiBN film and the S20-grade cemented carbide substrate, and ACS3000, which is the combination of the film and the S30-grade substrate.

The cutting test of titanium alloys was conducted using ACS2500. The results are shown in Fig. 5. The higher transverse rupture strength of the cemented carbide substrate has reduced chippings caused by thermal cracks and the tool life of ACS2500 is 1.9 times that of conventional grade.

The cutting test of Inconel 718 was conducted using ACS3000. The results are shown in Fig. 6. ACS3000 demonstrated a longer tool life 1.6 times that of conventional grades.

3. Examples of Machining with ACS2500 and ACS3000

Figures 7 and 8 show examples of machining by end users using ACS2500 for titanium alloy milling and ACS3000 for heat-resistant alloy milling. The results of the machining of an airplane part (titanium alloy) using ACS2500 are shown in Fig. 7. The tool life of ACS2500 was double that of a competitor’s product with the excellent thermal-crack resistance.

The results of the machining of a machine part (Hastelloy*) using ACS3000 are shown in Fig. 8. The tool life of ACS3000 was five times that of a competitor’s product with the excellent wear resistance.
4. Conclusion

As described above, we have developed a new PVD coating film with superior wear resistance and a new cemented carbide substrate with outstanding thermal-crack resistance, and applied them to ACS2500 and ACS3000, which have achieved stable performance and double the tool life than that of conventional grades. These two grades will make a significant contribution to cost reduction and productivity improvement in milling difficult-to-cut materials.

Technical Terms

*1 Physical vapor deposition (PVD): A method for depositing a ceramic film on the substrate surface, by reacting target materials ionized by arc discharge or other means with gas.

*2 Inconel: A type of Ni-based heat-resistant alloy. It is a trademark or registered trademark of Huntington Alloys Corporation.

*3 Scratch adhesion strength test: A test method for measuring a load at which delamination occurs when a diamond indenter is pressed onto a coating film surface and moved across the surface with elevated load.

*4 Hastelloy: A type of Ni-based heat-resistant alloy. It is a trademark or registered trademark of Haynes International, Inc.

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