Development of “ACE-COAT AC510U/AC520U” for Machining of Exotic Materials

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1. Introduction

Aircraft demand has dropped and remained stagnant since year 2000. However, announcements made by the two leading commercial aircraft manufacturers Boeing and Airbus about their new aircraft models (B787 and A380, respectively) created a significant turnaround in aircraft orders in 2005, and currently the aircraft industry is experiencing an unprecedented boom.

Exotic materials such as titanium alloys and heat-resistant alloys are widely used for aircraft manufacturing. These materials that are generally defined as “hard-to-cut” have excellent mechanical and thermal properties, which mean that they have following drawbacks when being cut.

1) Low thermal conductivity resulting in the generation of high temperatures during cutting
2) Formation of work-hardened surface layers
3) High reactivity (affinity) to cutting tools

These factors create an extremely harsh operating environment for cutting tools (1). It is therefore important to reduce the generation of cutting heat when machining hard-to-cut materials, and thus machining of exotic materials is commonly practiced under low speed, low feed, and wet cutting conditions.

Because of the upturn in aircraft orders, the need to machine these exotic materials is expected to further increase in the future. Accordingly, there is a rising demand for cutting tools designed for exotic material cutting applications that exhibit stable long life and offer higher machining efficiency for production lead time reduction.

This report describes the features and use case examples of the new turning insert grades AC510U and AC520U that were developed by Sumitomo Electric Hardmetal Corporation for cutting of exotic materials to meet the needs of the market.

2. Features of Super ZX Coat

AC510U and AC520U are coated with Super ZX Coat, which is Sumitomo Electric Hardmetal’s proprietary newly developed physical vapor deposition (PVD) coating (2). As shown in Fig. 1, Super ZX Coat is a super-multilayer coating consisting of nanometer-thin layers of TiAlN and AlCrN alternately stacked up to 1,000 layers. Its hardness is improved 40%, and the oxidation temperature is 200°C higher as compared with conventional coating. And also the chipping resistance is improved by controlling its residual stress. Therefore, AC510U and AC520U show superior wear and thermal resistance in exotic material machining, and provide longer tool life and higher productivity.

Figure 2 shows the results of thermogravimetric analysis of Super ZX Coat and conventional coating. The weight change during temperature rise in the atmosphere was measured by using samples prepared by coating a 3-µm-thick film on Pt substrates. The results
Table 1. Characteristics of Super ZX Coat

<table>
<thead>
<tr>
<th>Coating</th>
<th>Hardness</th>
<th>Oxidation temperature</th>
<th>Residual stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>40GPa</td>
<td>950°C</td>
<td>-0.7 GPa</td>
</tr>
<tr>
<td>Super ZX Coat</td>
<td>56GPa</td>
<td>1150°C</td>
<td>-1.9 GPa</td>
</tr>
</tbody>
</table>

show that while the sample with conventional coating started to oxidize at about 850°C and completely oxidized at 950°C, the sample with Super ZX Coat started to oxidize at about 960°C and progressed slowly until reaching the complete oxidation at 1150°C, which is 200°C higher than the case of the sample with conventional coating.

**Figure 3** shows the results of thermal effusivity analysis using the light-pulse heating thermo-reflectance method. Thermal effusivity is a property that correlates strongly with thermal conductivity. Materials with low thermal effusivity have low thermal conductivity. As the analysis results show, Super ZX Coat has a lower thermal effusivity than the conventional coating, which also means a lower thermal conductivity. Therefore it can be said that Super ZX Coat offers high heat resistance.

In addition, controlling the compressive residual stress was found to be effective to improve the chipping resistance of a coating. As indicated in **Fig. 4**, by optimizing the coating conditions along with the growth of the coating so that the compressive residual stress in the coating becomes larger from the carbide substrate toward the surface, the chipping resistance can be successfully improved without sacrificing the peeling resistance.

**3. Features of AC510U/AC520U**

AC510U and AC520U are made by applying Super ZX Coat on special high-toughness cemented carbide. They are more resistant to wear and heat and can further withstand fractures than conventional grades. Therefore, these new grades drastically reduce damages caused by exotic material machining such as localized wear induced by extremely high cutting heat and resulting accidental chipping, as well as notch wear or breakage caused by the work-hardened surface layer of the material. AC510U and AC520U fulfill the market needs for stable long tool life and high cutting efficiency.

The applicable areas and recommended machining conditions of AC510U and AC520U are indicated in **Fig. 5**. AC510U is a general-purpose grade that delivers high cutting performance in a wide range of machining operations from rough to finish machining. AC520U is a
grade whose key feature is high strength and is suited for use in machining applications such as heavy interrupted cutting that require high cutting-edge strength.

4. Case examples of machining using AC510U/AC520U

Figure 6 shows a case example of turning of titanium alloys (Ti-6Al-4V) using AC510U. While the conventional PVD-coated grade showed significant wear and damage after turning for over 10 minutes, AC510U showed less wear after turning for up to 20 minutes, providing stable machining.

Figure 7 shows a case example of turning of Inconel 718 using AC510U. While the PVD-coated grade of a competitor showed large notch wear and crater wear after turning for 7 minutes, AC510U exhibited less notch damage and crater wear even after turning for more than twice longer time, thus achieving a stable and long tool life.

Figure 8 shows a case example of rough turning of iron-based heat-resistant alloys using AC510U. After machining the same number of work pieces, the competitor product showed notch wear at its cutting edge that is seen specifically after machining exotic materials while AC510U did not. This means that AC510U has a longer life span.

Figure 9 shows a case example of high-speed machining of inconel 718 using AC510U. After machining the work pieces at a cutting speed twice the conventional speed of 50 m/min (100 m/min), the competitor product developed severe cutting-edge damage that reduced its life to a third. AC510U, on the other hand, was capable of machining up to three work pieces at 100 m/min without showing breakage, thus achieving high machining efficiency.

Figure 10 shows a case example of rough turning of Inconel 718 using AC520U. After machining the same number of work pieces, the competitor product showed large flank wear and crater wear at its cutting edge. By contrast, AC520U showed less wear, thus achieving longer tool life span.
Figure 11 shows a case example of heavy-interrupt-used cutting of iron-based heat-resistant alloys using AC520U. While the competitor product showed breakage due to wear after turning two work pieces, AC520U was capable of turning twice larger number of work pieces. Also, the wear on AC520U after machining was small, indicating possible further life expansion.

5. Conclusion

This report described the features and use case examples of AC510U and AC520U, the new turning insert grades for exotic materials.

A future increase in the use of exotic materials is expected to increase not only in the aircraft industry but also in industries such as automobile and petroleum. AC510U and AC520U featuring more stable and longer life and higher cutting efficiency will contribute to reducing the tooling costs, production costs (by reducing machining time,) and environmental burden.

References
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