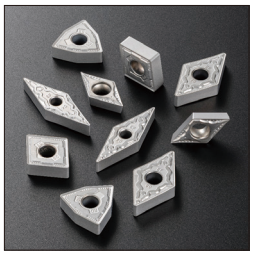


Turning Grades AC9115T and AC9125T for Titanium Alloys

Yuta SUZUKI*, Taisei TANAKA, Daiji TABAYASHI, and Hideaki KANAOKA

Titanium alloys are widely used for equipment and parts in the aerospace industry due to their lightweight, high strength and excellent corrosion resistance. Additionally, these alloys are also used in the medical field because of their high biocompatibility. In recent years, both industries have experienced significant growth, leading to a marked increase in demand for cutting tools for these alloys. However, when machined, titanium alloys are prone to adhesion due to chemical reactions with tools and heavy wear resulting from low thermal conductivity, leading to a significant reduction in cutting tool life. Thus, the demand for cutting tools with stable performance and a long tool life has been increasing. The newly developed "AC9115T" and "AC9125T" are designed to improve wear resistance by applying a new physical vapor deposition (PVD) coating. These coated carbide grades help reduce the frequency of cutting edge replacement and tool consumption by extending the tool life, contributing to the reduction of machining costs.

Keywords: titanium alloy, cutting tool, PVD, long tool life

1. Introduction

Indexable inserts used for cutting tools, made by coating the surface of a cemented carbide*1 base material (hereafter referred to as "coated grade") with a hard ceramic film, have better-balanced wear resistance and fracture resistance compared to other inserts. Due to such distinctive features, use of these inserts has been expanding year by year, and they currently account for more than 70% of all indexable inserts.

In recent years, titanium alloys,*2 which are lightweight, strong, corrosion resistant, and biocompatible, have been widely used for equipment and parts in the aerospace and medical industries, and their use is expected to increase substantially in the future. On the other hand, the issues associated with machining include adhesion to the tools caused by their susceptibility to chemical reactions and wear caused by low thermal conductivity, which can reduce tool life.

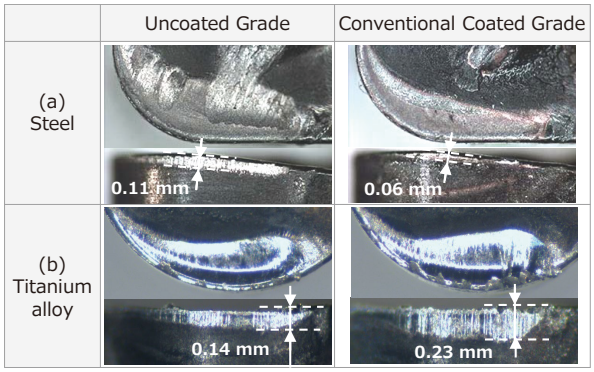
The aerospace and medical industries are growing rapidly, and there is a growing need for cutting tools that can machine titanium alloys for extended periods of time in order to reduce machining costs and improve productivity. In addition, their machined products require higher reliability than those in other industries; therefore, cutting tools are also required to have high performance stability.

In response to such market needs, we have developed and released two new PVD*3 coated grades, AC9115T and AC9125T, which realize stable and long tool life in turning of titanium alloys. This paper reports on the aims, features, and cutting performance of these two grades.

2. Technical Features of the New Grades

2-1 Titanium alloy turning issues

Titanium alloys are classified as difficult-to-machine materials because they are chemically very active metals, and therefore, during cutting, damage progresses due to reactions with the tool. As shown in Fig. 1, in most workpiece materials, including steel, damage is suppressed by coating the cutting tool, but in titanium alloys, the coating does not have the expected effect, and in fact, the damage progresses faster in the coated material type.



(a) Workpiece material : SCM435
Insert geometry : CNMG120408N-SU
Cutting conditions : vc = 240 m/min, f = 0.2 mm/rev, ap = 1.0 mm Wet, 5 min
(b) Workpiece material : Ti-6Al-4V
Insert geometry : CNMG120408N-EX
Cutting conditions : vc = 50 m/min, f = 0.2 mm/rev, ap = 0.8 mm Wet, 60 min

Fig. 1. Effect of coating on titanium alloy turning

Figure 2 shows the damaged cross section in the early stages of machining in titanium alloy turning. It was found that the Ti-6Al-4V workpiece material adhered to the coating, and a reaction layer with a high nitrogen concentration relative to the adhered material formed at the inter-

face between the adhered material and the coating. This reaction layer adheres tightly to both the adhered material and the coating, and the coating is degraded by the adhesion during machining, which is why the coating is not effective on titanium alloys.

Therefore, we have developed a new coating material that does not react easily with titanium alloys.

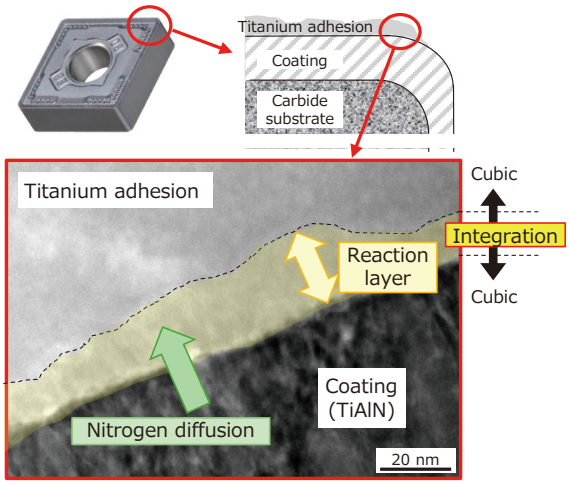


Fig. 2. Cross-sectional image of the damage in the early stages of titanium alloy machining

2-2 Features of new coating for titanium alloy turning

Figure 3 shows the development concept of the new coating. Conventional coatings are mainly of cubic crystalline structure such as TiAlN (titanium aluminum nitride) or AlCrN (aluminum chromium nitride), but we thought that a hexagonal crystalline structure of WC (tungsten carbide) would be suitable for the new coating. This is because titanium alloy adhesion is cubic, and the hexagonal type, which has a different crystalline structure, suppresses atomic diffusion from the coating to the adhesion and prevents the formation of a reaction layer. Another key point is that WC-based materials poses superior mechanical strength.

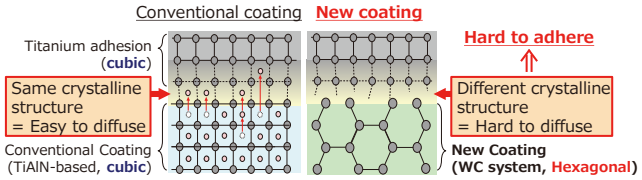


Fig. 3. Development concept of new coating

Figure 4 shows the results of sliding tests using Ti-6Al-4V ball. The new coating showed a stable friction coefficient profile compared to the conventional coating, and the average friction coefficient for 50 seconds was reduced by about 70%. The sliding marks also showed that the new coating has superior anti-adhesion properties.

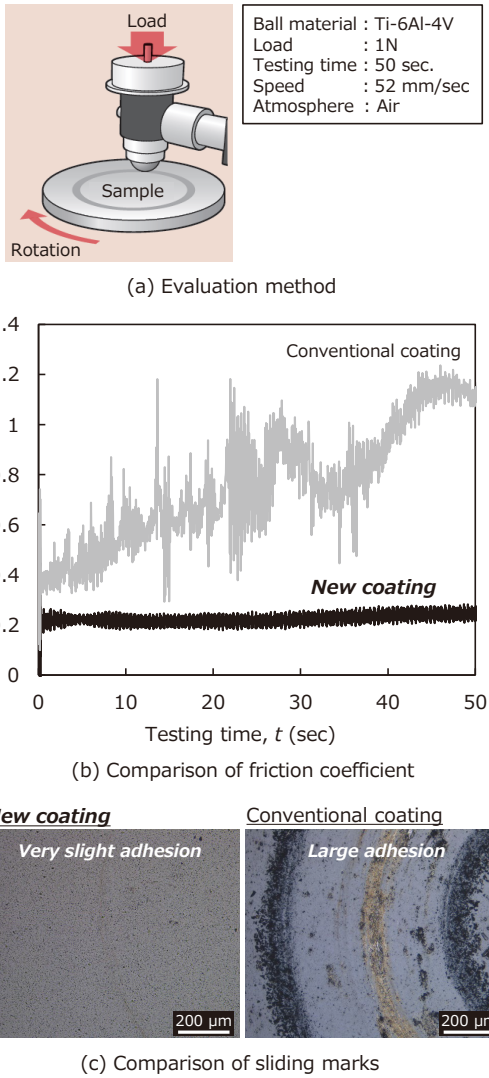


Fig. 4. Sliding test using Ti-6Al-4V

2-3 Application ranges of AC9115T/AC9125T

The application ranges of “AC9115T” and “AC9125T” for titanium alloy turning are illustrated in Fig. 5. AC9115T is the first recommended grade for titanium alloy turning that can be used in a wide range of applications from continuous to partially interrupted machining, and AC9125T is the grade that achieves stable and long life in interrupted machining and forged skin machining.

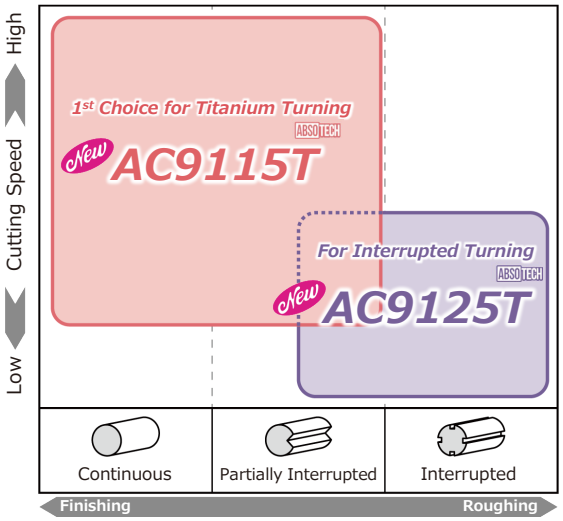


Fig. 5. Application range of AC9115T and AC9125T

2-4 Cutting performance of AC9115T/AC9125T

Figure 6 shows the results of continuous machining tests on titanium alloys using AC9115T. AC9115T exhibited excellent wear resistance and achieved three times longer tool life than that of other uncoated grades.

Figure 7 shows the results of interrupted machining tests on titanium alloys using AC9125T. AC9125T exhibited excellent wear and chipping resistance, and achieved three times longer tool life than that of other uncoated grades.

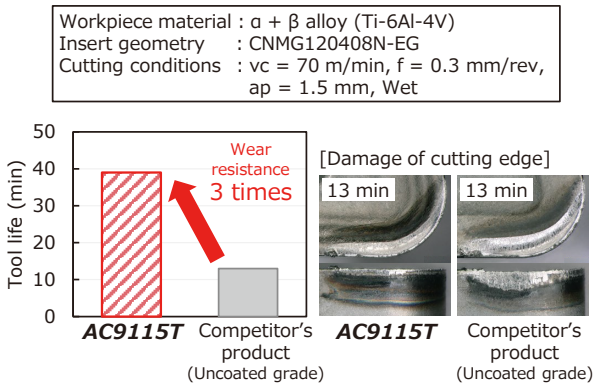


Fig. 6. Results of continuous cutting test of AC9115T

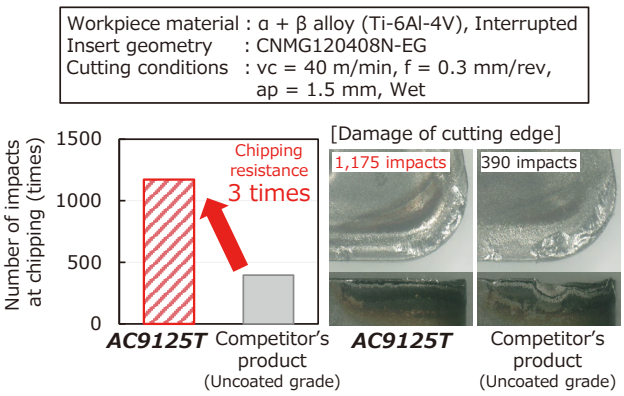


Fig. 7. Results of interrupted cutting test of AC9125T

3. Application Examples of AC9115T/AC9125T

Examples of titanium alloy turning by customers using the AC9115T and AC9125T are shown in Figs. 8-12.

Figure 8 shows the results of machining aircraft parts (α+β alloy, Ti-6Al-4V), showing that AC9115T reduces wear by about 60% at constant machining compared to conventional coated grades, enabling further life extension.

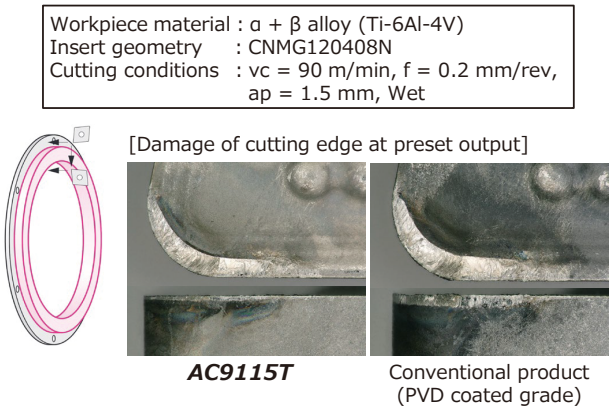


Fig. 8. Application example of AC9115T (1)

Figure 9 shows the results of machining medical parts (β-type alloy), showing that AC9115T suppresses wear and adhesion, and that it can be further extended in tool life with minimal damage even after machining twice as long as conventional uncoated grades.

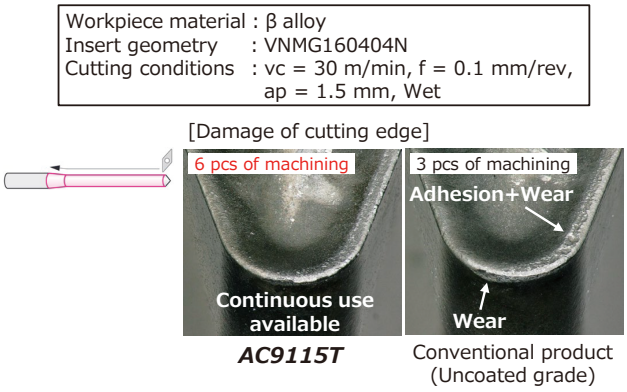


Fig. 9. Application example of AC9115T (2)

Figure 10 shows the results of machining medical parts (pure titanium, TB340), where AC9115T showed 1.9 times longer tool life than the competitor's coated grade due to reduced wear.

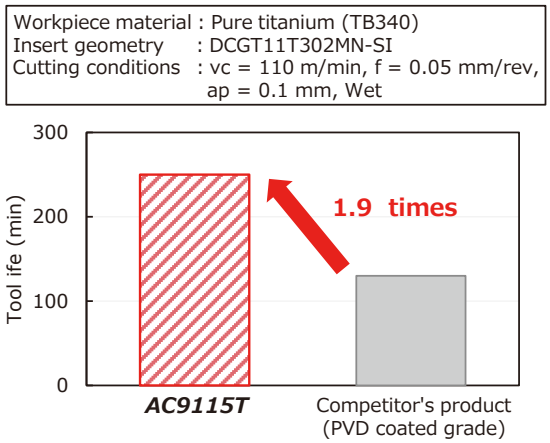


Fig. 10. Application example of AC9115T (3)

Figure 11 shows the results of machining aircraft parts (α+β alloy, Ti-6Al-4V), showing that AC9125T exhibited less wear and adhesion at the constant machining point than conventional coated grades, and that further tool life extension was possible.

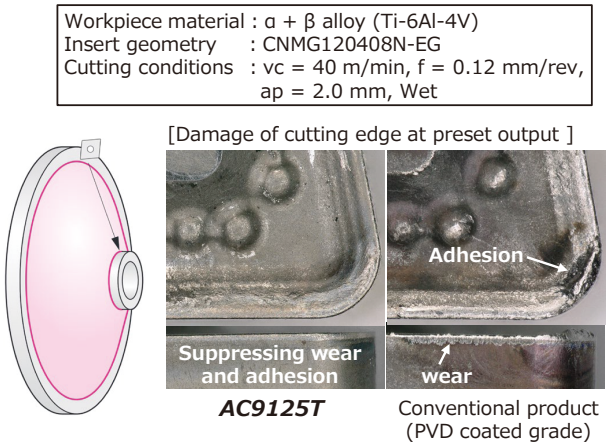


Fig. 11. Application example of AC9125T (1)

Figure 12 shows the results of machining industrial machine parts (α+β alloy, Ti-6Al-4V). AC9125T showed 1.3 times longer tool life compared to the other coated grades due to reduced wear and chipping.

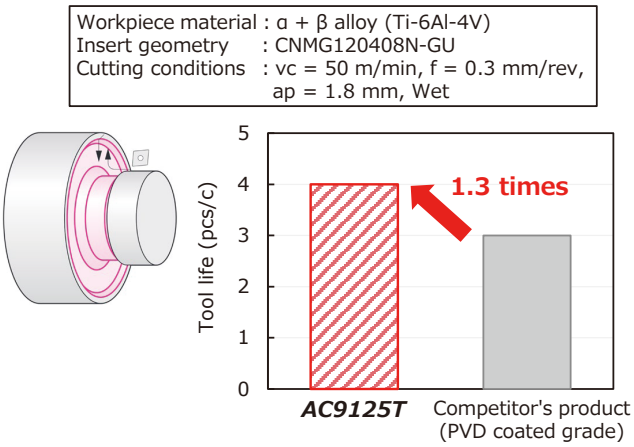


Fig. 12. Application example of AC9125T (2)

4. Conclusion

As described above, AC9115T and AC9125T have achieved more than twice the stable and long tool life of conventional products by applying a new PVD coating that is less reactive to titanium alloys. We are convinced that these two grades will make a significant contribution to the reduction of machining costs and improvement of productivity in titanium alloy turning operations.

Technical Terms

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

∗2 Titanium alloy: An alloy that is lightweight, corrosion resistant, and strong, in particular, its extremely high specific strength (tensile strength/specific gravity) makes it a material used in high-speed rotating bodies and aircraft parts. It is also widely used in the medical field due to its excellent biocompatibility.

∗3 PVD: An acronym for physical vapor deposition, a method in which target materials are ionized by arc discharge or other means and react with gases to deposit a ceramic film on a substrate.

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