MATTER: International Journal of Science and Technology
ISSN 2454-5880

Tadahiro Wada, 2018

Volume 4 Issue 2, pp. 256-265

Date of Publication: 2nd November, 2018

DOI-https://dx.doi.org/10.20319/mijst.2018.42.256265

This paper can be cited as: Wada, T. (2018). Propertıes of TAWN and TAN/TAWN Coatıng Fılm Deposıted on WC-CO-Based Cemented Carbıde usıng Magnetron Sputter ION Platıng. MATTER: International Journal of Science and Technology, 4(2), 256-265.

PROPERTIES OF T$_A$WN AND T$_A$N/T$_A$WN COATING FILM DEPOSITED ON WC-C$_O$-BASED CEMENTED CARBIDE USING MAGNETRON SPUTTER ION PLATING

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Abstract

Titanium based coating films are generally used as the coating film. In this study, the thickness, hardness and scratch strength of TaWN and TaN/TaWN coated tools were measured. The substrate used was a cemented carbide ISO K10. The work piece used was a hardened steel AISI D2. This work piece was turned with the TaWN and the TaN/TaWN coated tools. The tool wear of the TaWN and TaN/TaWN coated tools was investigated. Furthermore, the TaN coated tool was also used. (1) Droplets on the surface of both the TaWN and TaN/TaWN coating films were negligible. (2) The hardness of the TaWN and TaN/TaWN was 2340 HV0.25N and 2630 HV0.25N, respectively. (3) The critical load of both the TaWN and TaN/TaWN coated tools was over 130 N. (4) The friction coefficient of the TaN/TaWN and TaN was 0.44 and 0.53, respectively. (5) The wear rate of the TaN/TaWN coated tool was slower than that of the TaN or TaWN coated tool.

Keywords

Coating Technology, Physical Vapor Deposition Coated Tool, TaWN Coated Tool, Hardened Steel

1. Introduction

Many difficult-to-cut materials are widely used. For dimensional accuracy, these difficult-to-cut materials are required to be machined by the metal removal process (Tadahiro Wada et al., 2017). It is necessary that the tool materials have good wear-resistance. Polycrystalline cubic boron nitride compact (c-BN) seems to be an effective tool material (Tadahiro Wada et al., 2017).

However, in turning at a high feed or a large depth of cut, a major tool failure of c-BN occurs by fracture. Coated tools seem to be effective tool materials (Tadahiro Wada et al., 2014). Titanium based films have been widely used as coating films (e.g., K. Sakagami et al., 1998, H. Nakagawa et al., 2002). R.Westergard, M. Bromark, M. Larsson, P. Hedenqvist, S. Hogmark, 1997, reported that tantalum nitride coatings were deposited onto high-speed steel using reactive DC magnetron sputtering. And, the coating abrasive wear resistance was assessed by dimple grinding, the abrasive wear rates of the tantalum nitride coatings were small compared with the wear rate of the TiN coating. Maria Nordin et al., 1999, reported that the highest abrasive wear resistance was found for single layered TaN and the lowest for TiN, too. The TaN has both high hardness and good adhesive strength, and can be used as a coating film of cutting tools (Tadahiro Wada et al., 2011). And, in cutting the hardened steel using TaN and (Ti, Al)N coated tools, the wear rate of the TaN coated tool was almost equivalent to that of the (Ti, Al)N coated tool (Tadahiro Wada et al., 2011). M. Nordin et al., 2000, reported that in milling AISI 316 stainless steel the tool life of the TaN coated tool was longer than that of the TiN coated tool.

Adding Si (silicon), V (vanadium), C (carbon), etc. to the coating film is effective for improving the performance of the coating film and improving the cutting performance. M. Kathrein et al., 2005, reported the remarkable influence of additional elements on the properties of $Ti_{1-x}Al_xN$ based coatings. And, alloying with elements such as V, Ta, and B resulted in a significantly increased lifetime in various cutting applications. Yun Chena et al., 2016, reported that AlCrSiCN is harder than AlCrN.

It is considered that the TaWN coating film in which W (tungsten) is added to the TaN coating film is effective for improving the adhesion with WC, which is the main component of the substrate. However, no study has reported on the coating film performance and cutting performance of TaWN coating film with W added to TaN coating film.

The performance of the coating film and improving the cutting performance can be extended by the use of a multi-layer coating system (Maria Nordin et al., 1999, M. Nordin et al., 2000, M. Kathrein et al., 2005, Yun Chena et al., 2016, J.H. Hsieh et al., 1998, A.A. Vereschaka et al., 2014, Tsao Chung-Chen et al., 2002, M. Nouari et al., 2006, Q. Yang et al., 2015). However, it is unclear whether TaN/TaWN coating film can be used as a coating film of WC-Co cemented carbide cutting tools in cutting hardened steel.

In this study, the thickness, hardness and scratch strength of TaWN and TaN/TaWN coated tools were measured. The substrate used was a cemented carbide ISO K10. The work piece used was a hardened steel AISI D2. This work piece was turned with the TaWN and the TaN/TaWN coated tools. The tool wear of the TaWN and TaN/TaWN coated tools was investigated. Furthermore, the TaN coated tool was also used.

2. Experimental Procedures

The tool material of the substrate was ISO K10. The coating films used were TaN (Tadahiro Wada et al., 2011), TaWN, and TaN/TaWN. The TaN coating film has been used to investigate the effect of W, which is included in the TaWN coating film. The TaN or the TaWN coating film is a mono-coating film. The TaN/TaWN coating film is a multi-layer coating film. The inner layer of the TaN/TaWN coating system is the TaN coating film, the outer layer is TaWN coating film.

The conditions for the deposition of TaN, TaWN and TaN/TaWN coating films is shown in Table 1.

Table 1: *Conditions for deposition of TaN, TaWN and TaN/TaWN coating films*

Current	8.6 A (460 V)
Substrate DC bias	-105 V
Substrate temperature	473 K
Pressure	5.4×10^{-3} Torr
Cathode materials	Ta, TaW
Substrate	Cemented carbide ISO K10

The work piece used was AISI D2 hardened steel (60HRC). Table 2 shows the chemical composition of the work piece.

The inserts used were ISO TNGA160408. The turning tool holder used was MTGNR2525M16. The turning tests were conducted on a precision lathe. Table 3 shows the cutting conditions.

The friction coefficient was measured using a pin-on-disk tribometer (CSM Instruments). The tip of the pin has a sphere of radius of 5 mm, and the diameter of the pin is 6 mm. In this case, the contact type is point/flat. The test conditions are shown in Table 4.

Table 2: *Chemical composition of work piece (AISI D2)*

[mass%]

C	Cr	Mo	Mn	Si	V	Ni
1.45	11.6	0.81	0.36	0.23	0.22	0.12

Table 3: *Cutting conditions*

Cutting speed	Vc= 1.0 m/s
Feed rate	f= 0.2 mm/rev
Depth of cut	ap= 0.1 mm
Cutting method	Dry

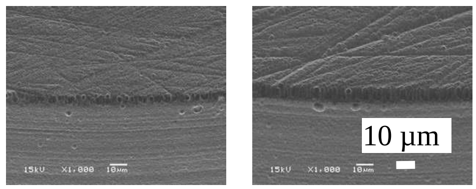
Table 4: *Test Conditions of the Friction Test (Pin-on-disk type)*

Disk	ISO C45 (AISI 1045)
Pin	Coated cemented carbide Coating film: TaN, TaN/TaWN
Sliding time	400 s
Sliding speed	0.25 m/s
Normal load	2.0 N
Temperature	294 K
Humidity	31.0 %
Atmosphere	Air

3. Results and Discussion

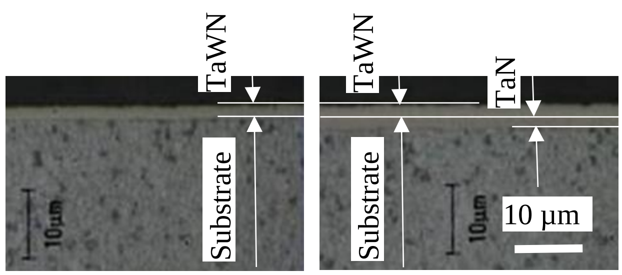
Figure 1 shows the scanning electron microscope micrographs of the coating surface. Figure 1(a) and (b) show the case of the TaWN and TaN/TaWN coated tools, respectively. No remarkable droplets on the surface are found in the case of both the TaWN and TaN/TaWN coated tools.

Figure 2 shows a micrograph of the cross session of the TaWN and TaN/TaWN coated tools. It is found that the TaWN enters into irregularities of the substrate at the interface between the TaWN film and the substrate as shown in figure 2(a). The TaWN coated tool has a 2.0-µm-thick TaWN film on a substrate. On the other hand, in the case of the TaN/TaWN coated tool shown in figure 2(b), the TaN enters into irregularities of the substrate at the interface between the TaN film and the substrate. And, the TaWN enters into irregularities of the TaN at the interface between the TaN and the TaWN, too. The thickness of the TaN and TaWN coated tools is 1.5 µm and 2.0 µm, respectively.



(a) TaWN (b) TaN/TaWN

Figure 1: *SEM micrographs of coating*

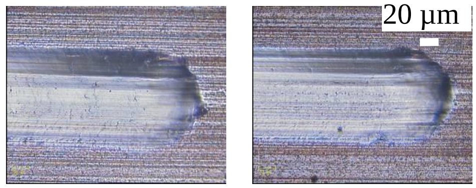


(a) TaWN (b) TaN/TaWN

Figure 2: *Cross section of coating film*

In order to evaluate the adhesion between the substrate and the TaWN and TaN/TaWN coating films, a scratch test was conducted for two types of coated tools. Figure 3 shows microscopic photographs of the wear track in the scratch test. The critical load of both the TaWN and TaN/TaWN coated tools was over 130 N.

Table 5 shows the properties of coating films of the TaN, TaWN and TaN/TaWN coated tools. The 1.5 µm thickness of the TaN coating film is the thinnest, and the 3.5 µm thickness of the TaN/TaWN coating film is the thickest. The hardness of the TaWN 2340 HV0.25N is slightly lower than that of the TaN 2570 $HV_{0.25N}$ or TaN/TaWN 2630 $HV_{0.25N}$. The critical scratch load of the three types of coated tools is over 130 N.



(a) TaWN (b) TaN/TaWN

S.L.=130 N S.L.=130 N

Figure 3: *Microscopic photographs of the wear track in the scratch test (S.L.: Scratch load)*

Table 5: *Properties of coating film*

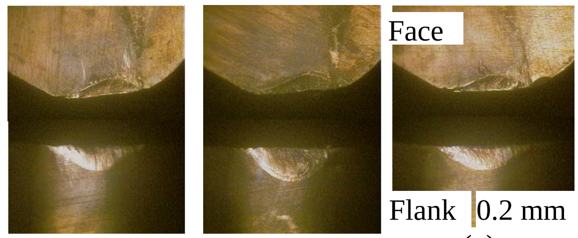
Coated tool	Thickness of coating film (µm)	Micro-hardness ($HV_{0.25N}$)	Adhesiveness (Critical load*) (N)
TaN (Tadahiro Wada et al., 2011)	1.5	2570	>130
TaWN	2.0	2340	>130
TaN/TaWN	3.5 (1.5/2.0)	2630	>130

*: Measured value by scratch test

Figure 4 shows the tool wear with three types of coated tools. In the case of the TaN coated tool (Tadahiro Wada et al., 2011) shown in figure 4(a), the remarkable adhesion and flaking of the coating film are not found (Tadahiro Wada et al., 2011). Figure 4(b) and 4(c) show the tool wear of the TaWN and TaN/TaWN coated tools, respectively. In the case of the TaWN and TaN/TaWN coated tools, the remarkable adhesion and flaking of the coating film are not found too.

It is found that the main tool failure of the coated tools was flank wear. The flank wear width (VBmax) was measured.

Figure 5 shows the relationship between the cutting distance and the flank wear width. There is little difference in wear progress between the TaN (Tadahiro Wada et al., 2011) and TaWN coated tools. However, the wear rate of the TaN/TaWN coated tool is slower than that of the TaN or TaWN coated tool. Therefore, it is found that the TaN/TaWN is the best coating film in cutting hardened steel.



(a)	(b)	(c)
TaN	TaWN	TaN/TaWN
L=1.0 km	L=1.2 km	L=1.5 km

Figure 4: *Tool wear (L: Cutting distance)*

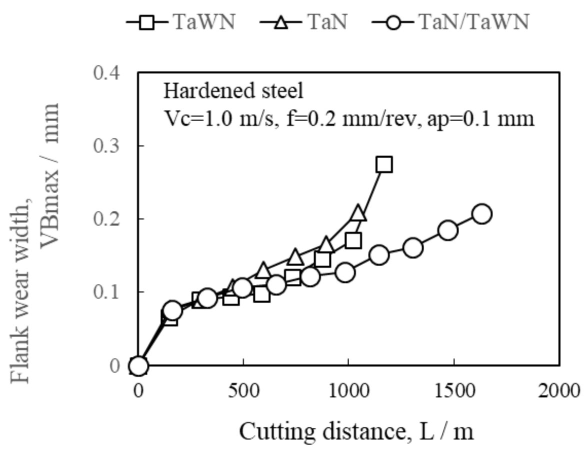
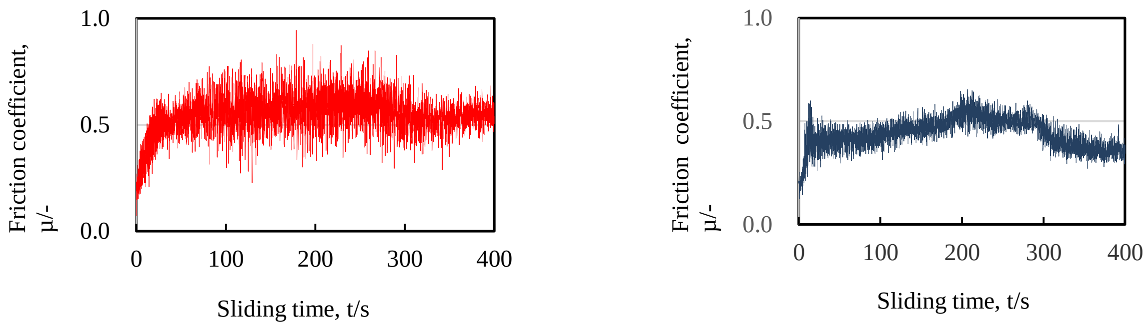


Figure. 5: *Relationship between cutting distance and flank wear width*

The friction coefficient was measured with a pin-on-disk tribometer. Figure 6 shows the relationship between the sliding distance and the friction coefficient. The maximum sliding time was 400 s. In the case of the TaN coated tool shown in figure 6(a), there is remarkable a fluctuation in the friction coefficient. However, in the case of the TaN/TaWN coated tool shown in figure 6(b), the variation width of the friction coefficient of the TaN/TaWN coated tool is smaller than of the TaN coated tool.

The friction coefficient is shown in Table 6. The friction coefficient is the average value under the sliding time of 0 to 400 s. The friction coefficient of the TaN/TaWN coated tool, 0.44, is smaller than that of the TaN coated tool, 0.53.



(a) TaN coated tool (b) TaN/TaWN coated tool

Figure. 6: *Relationship between sliding distance and friction coefficient*

Table 6: *Friction coefficient*

Coated tool	Friction coefficient
TaN	0.53
TaN/TaWN	0.44

4. Conclusions

In this study, the thickness, hardness and scratch strength of TaWN and TaN/TaWN coated tools were measured. The substrate used was a cemented carbide ISO K10. The work piece used was a hardened steel AISI D2. This work piece was turned with the TaWN and the TaN/TaWN coated tools. The tool wear of the TaWN and TaN/TaWN coated tools was investigated. Furthermore, the TaN coated tool was also used.

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- The critical load of both the TaWN and TaN/TaWN coated tools was over 130 N.
- The friction coefficient of the TaN/TaWN and TaN was 0.44 and 0.53, respectively.
- The wear rate of the TaN/TaWN coated tool was slower than that of the TaN or TaWN coated tool.

References

Vereschaka, A.A., Grigoriev, S.N., Vereschaka, A.S., Popov, A.Yu. and Batako, A. D., (2014). Nano-scale multilayered composite coatings for cutting tools operating under heavy cutting conditions, Procedia CIRP, 14, 239-244. https://doi.org/10.1016/j.procir.2014.03.070

Nakagawa, H., Hirogaki, T. et al. (2002). Study On Tool Life In End-Milling Of Hardened Steel, in Proc. 6th Int. Conf. on Progress of Machining Technology, 81-86.

Hsieh, J.H., Liang, C., Yu, C.H., Wu., W. (1998). Deposition and characterization of TiAlN and multi-layered TiN/TiAlN coatings using unbalanced magnetron sputtering, Surface and Coatings Technology, Vol. 108-109, 132-137. https://doi.org/10.1016/S0257-8972(98)00684-7

Sakagami, K., Yongming, G. and Yamamoto, T., (1998). Effects of Substrate and PVD-Coated Layers on Flank Notch wear of Carbide Tool in Stainless Steel Cutting, in Proc. 4th Int. Conf. on Progress of Cutting and Grinding, 38-42.

Kathrein, M., Michotte, C., Penoy, M., Polcik, P., Mitterer, C. (2005). Multifunctional multi-component PVD coatings for cutting tools, Surface & Coatings Technology, 200, 1867-1871. https://doi.org/10.1016/j.surfcoat.2005.08.105

Nordin, M., Sundstrom, R., Selinder, T.I., Hogmark. S. (2000). Wear and failure mechanisms of multilayered PVD TiN/TaN coated tools when milling austenitic stainless steel, Surface and Coatings Technology, Vol. 133-134, 240-246. https://doi.org/10.1016/S0257-8972(00)00933-6

Nouari, M., Ginting, A. (2006). Wear characteristics and performance of multi-layer CVD-coated alloyed carbide tool in dry end milling of titanium alloy, Surface & Coatings Technology, 200, 5663-5676. https://doi.org/10.1016/j.surfcoat.2005.07.063

Maria Nordin, Mats Larsson, Sture Hogmark. (1999). Wear resistance of multilayered PVD TiN/TaN on HSS, Surface and Coatings Technology, Vol. 120-121, 528-534. https://doi.org/10.1016/S0257-8972(99)00493-4

Q. Yang, R.McKellar. (2015). Nanolayered CrAlTiN and multilayered CrAlTiN-AlTiN coatings for solid particle erosion protection, Tribology International, 83, 12-20. https://doi.org/10.1016/j.triboint.2014.11.002

R.Westergard, M. Bromark, M. Larsson, P. Hedenqvist, S. Hogmark. (1997). Mechanical and tribological characterization of DC magnetron sputtered tantalum nitride thin films, Surface and Coatings Technology, 97(1), 779-784. https://doi.org/10.1016/S0257-8972(97)00338-1

Tadahiro Wada, Koji Iwamoto, Keizo Tsukamoto and Kazuki Hiro. (2011). Properties of TaN Coating Film Deposited on WC-Co-based Cemented Carbide using Magnetron Sputter Ion Plating, Applied Mechanics and Materials, 87, 186-190.

Tadahiro Wada, Mitsunori Ozaki, Hiroyuki Hanyu, and Kinya Kawase. (2014). Tool Wear of Aluminum-Chromium Based Coated Cemented Carbide in Cutting Hardened Sintered Steel, International Journal of Engineering and Technology, 6(3), 223-226. https://doi.org/10.7763/IJET.2014.V6.701

Tadahiro Wada, Hiroyuki Hanyu. (2017). Tool wear of (Ti,Al) N-coated polycrystalline cubic boron nitride compact in cutting of hardened steel, IOP Conference Series: Materials Science and Engineering. https://doi.org/10.1088/1757-899X/264/1/012017

Tsao Chung-Chen, Hocheng Hong. (2002). Comparison of the tool life of tungsten carbides coated by multi-layer TiCN and TiAlCN for end mills using the Taguchi method, Journal of Materials Processing Technology, 123(1), 1-4. https://doi.org/10.1016/S0924-0136(01)01152-9

Yun Chena, Hao Du, Ming Chen, Jun Yang, Ji Xiong, Haibo Zhao. (2016). Structure and wear behavior of AlCrSiN-based coatings, Applied Surface Science, 370, 176-183. https://doi.org/10.1016/j.apsusc.2015.12.027