Serbian Tribology Society

SERBIATRIB '11

12th International Conference on Tribology

Faculty of Mechanical Engineering in Kragujevac

Kragujevac, Serbia, 11 – 13 May 2011

WEAR BEHAVIOUR OF TIN COATINGS FOR COLD FORMING TOOLS UNDER DRY SLIDING CONDITIONS

Slobodan Mitrović[1], Miroslav Babić[1], Dragan Adamović[1], Fatima Živić[1], Dragan Džunić[1], Marko Pantić[1]

[1] Faculty of Mechanical Engineering, Sestre Janjic 6, Kragujevac, Serbia

babic@kg.ac.rs, adam@kg.ac.rs, boban@kg.ac.rs, dzuna@kg.ac.rs, pantic@kg.ac.rs

Abstract: *TiN coatings are very common themes of scientific works and are largely used in industry in metal cutting and cold forming processes; This work on quantitative way represents improvement, in terms of wear resistance, which is obtained by depositing of PVD TiN coating on foundation material. Wear testing is done on tribometer with block –on –disc contact geometry at sliding sample contact coated by TiN coat with steel disc. Testing was performed in conditions without lubrication at variable value of contact parameters (normal load, sliding speed). PVD TiN coatings in all contact conditions show smaller values of wear degree.*

Keywords: *TiN coating, Surface roughness, Dry sliding, Wear,*

1. INTRODUCTION

Intensive developing of complex physical-chemical processes in surface layer represents main cause of losing work capabilities of technical systems, energy and material wasting. Optimal choice is surface layer of high quality on basic material, of lower value and price, which directly refer to coating technology. Since 70s of the last century, when intensive development of this kind of surface modification has begun, a large number of coatings have been developed, as well as technologies for their application. Thin hard coating applied on soft foundation proved as tribological very suitable. First commercial tribological TiN coatings are applied by CVD technology on the tools. In 1980s, with PVD technology development, their commercial growth begins. They were primarily used for cutting tools of high speed steel, but were soon used in other tribological applications, such as the case of drawing tools, bearing, seals, as well as protection layer of erosive wear combination materials.

Tribological characteristic studies of TiN coatings are the subject of numerous studies both before and today. Number of papers containing „TiN coating" in its title is over 35 000 and it grows intensively, which only tells about scientific and technological potential of these coatings.

In this way, suitable mechanical, physical, and chemical properties can be obtained, using thin and hard one-layer or more-layers coatings over conventional constructional material [1]. One of the biggest advantages of PVD method is relatively low temperatures necessary for TiN coating. That makes this method suitable for materials whose hardness can be affected by uncontrolled annealing in the coating chamber such as reinforced and high speed steels [2].

Numerous factors affect tribological coating characteristics, staring with foundation material on which the coating is being applied, the way of final foundation processing, chosen way of deposition, while these two factors directly affect the third one, also very important factor, adhesion between foundation material and the coating itself.

The primary objective of TiN coating is to reduce wear and extend the life of the tool, therefore great number of papers refer to wear in different exploitation conditions. A large number of parameters have influence on both wear mechanism, and quantitive wear value. Influence of certain procedures of coating depositing and their parameters on tribological characteristics, especially on wearing, is the subject of numerous studies [3-6].

Very influential factor, both on mechanical and tribological characteristics, is the material on which the coating is being deposited, as the way of its previous preparation [7]. P. Harlin has presented the influence of surface roughness of TiN coating on tribological characteristics [8].

Having a constant distribution of titanium interlayer thickness is not necessarily the best solution to achieve maximum performance in terms of wear resistance and hardness. The residual stress distribution along the thickness is unlikely to be constant with the inner layers being more stressed due to a greater amount of thermal differential strain. Influence of thickness on tribological characteristics is shown in E. Bemporad's paper [9], where it was concluded that thick coatings (i.e. >10 μm) were achieved by alternate multi-layering of TiN with Ti inter-layers, leading to a tougher and less-stressed film.

Material of counter-bodies has huge influence on wearing [10-11], primarily on wear mechanism, that is to say, on tribo-chemical procedures, which in combination with other parameters, under which the contact is achieved, come to the force.

The aim of this paper is to present the benefit in the sense of reducing tool wear in processing of metal deforming using PVD TiN coatings. Therefore, when choosing contact parameters of sliding speed and normal load it should be taken into account to match real exploitation conditions of these tools. The steel X165CrMoV12 is taken as the foundation on which the coating is being deposited and it is often used for tool making in processing of metal deforming. The paper presents the influence of PDV TiN coating on reducing wear values in comparison to foundation material in conditions without lubrication, as well as the influence of contact parameter change (normal load and sliding speed) on the value of wear degree.

2. EXPERIMENTAL

2.1 Material

Contact pairs are made of alloy tool steel with great toughness and hardness, label X165CrMoV12. This steel is wear resistant and scheduled to work on cold. Hardening in oil and loosening were done before mechanical grind processing. Mechanical characteristics are given in Table 1, and chemical composition in Table 2.

Table 1. Mechanical characteristics of alloy tool steel X165CrMoV12

Hardness after soft annealing HB max	Tensile strenght after soft annealing MPa max	Hardness after hardening in oil and loosening HRC	Measured hardness on the used tool HRC
250	830	57-65	58-63

Table 2. Chemical composition of alloy tool steel X165CrMoV12

C	Si	Mn	P max	S max	Cr	Ni max	Mo	V	W
~1.65	~0.30	~0.30	0.035	0.035	~12.0	0.25	~0.60	~0.10	~0.50

In order to test them, the samples were coated with hard coating of titan-nitride (TiN). It should be pointed out that the substrate was heat-treated alloy tool steel X165CrMoV12.

TiN coating is done by RTB Bor PVD (Physical Vapour Deposition) technique – high-vacuum plasma deposition technology of hard layers depositing on contact surfaces.

Characteristics and conditions of applying TiN coating are as follows:

- Micro-hardness: ≈2000 HV,
- Layer thickness: 3-4 μm,
- Adhesive force: over 50 N,
- Application speed: 6-7 min/μm,
- Time of application: 21 min,
- Application temperature: 450 °C,
- Gold coating.

2.1 Tribological test

The specimens were tested using a block-on-disc sliding wear testing machine with the contact pair geometry in accordance with ASTM G 77-83. A schematic configuration of the test machine is shown in Fig. 1. The test block was loaded against the rotating steel disc. This provides a nominal line contact Hertzian geometry for the contact pair.

The test blocks (6.35x15.75x10.16 mm) were prepared from tool steel X165CrMoV12, while one part of the samples is TiN coated. The values of surface roughness were measured on the prepared samples before and after depositing of coating. Measuring of surface roughness was done on Talysurf 6 device and appearance of material layout in surface layer on referent length l=1.2mm, is shown in Figures 1 and 2.

Surface roughness of sample, without coating was Ra=0.01µm, and with TiN coating was Ra=0.02µm, which suggests that after deposition there was no serious change of surface roughness.

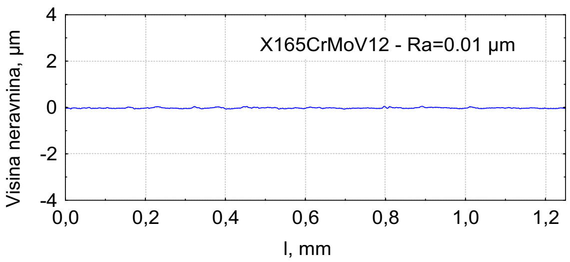


Figure 1. Surface profilometer X165CrMoV12,

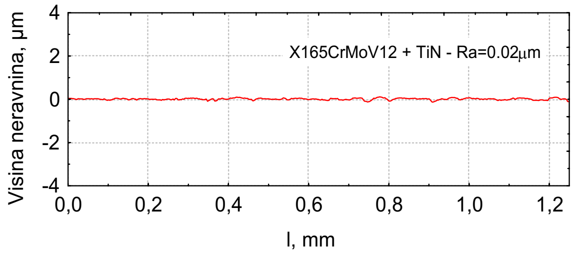


Figure 2. Surface profilometer X165CrMoV12 + TiN

A schematic configuration of the test machine is shown in Fig. 3. More detailed description of the tribometer is available elsewhere [12]. The wear behavior of the block was monitored in terms of the wear scar width - h (Fig. 4). Using the wear scar width and geometry of the contact pair the wear volume (in accordance with ASTM G77-05) and wear rate (expressed in mm^3) were calculated. The repeatability of the results for replicate tests was found as satisfactory (variation of wear scar width was under 5%).

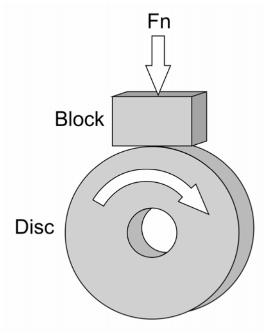


Figure 3. The scheme of contact pair geometry

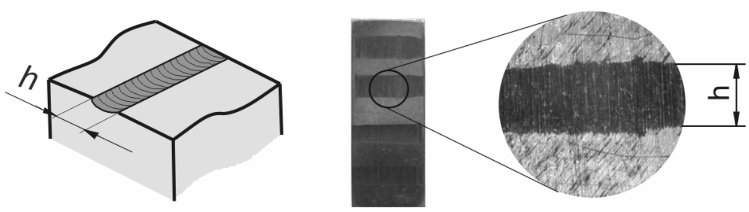


Figure 4. Wear scar

The counter face (disc of 35 mm diameter and 6.35 mm thickness) was made of EN: HS 18-1-1-5 tool steel of 62HRC hardness. The roughness of the ground contact surfaces was R_a=0.45 µm. The tests were performed in dry sliding conditions at sliding speeds (0.25 – 1m/s) and applied loads (10-30 N). Each experiment was repeated five times. Sliding road for all tested samples was 200 m.

3. RESULTS AND DISCUSSION

In the paper steel samples are tested with and without coating in order to qualify the improvement of coating resistance to wearing in relation to foundation material. Prepared samples are tested in conditions without lubrication, with varying values of sliding speed and normal load. Sliding speed in contact was taking three values 0.25, 0.5 and $1ms^{-1}$.

The normal load value also had three values 10, 20 and 30N during the tests. The normal load values are selected to avoid coating perforation during the testing, which was achieved.

Figure 5 shows diagram of wear degree dependence on change of normal load value with constant sliding speed value in contact zone. The Figure clearly shows that, with increase of normal load in contact zone, the wear degree of all tested samples increases. It is also clear that wear degree of TiN coatings in relation to the samples without coatings for the same values of tested parameters is always smaller. Wear degree values for steel samples at the highest speed of $1ms^{-1}$ stand out among the results. At this speed with increase of load it comes to certain increase of wear degree, based on which we can conclude that further increase of normal load would very quickly cause catastrophic wearing of tool material in processing of metal deforming.

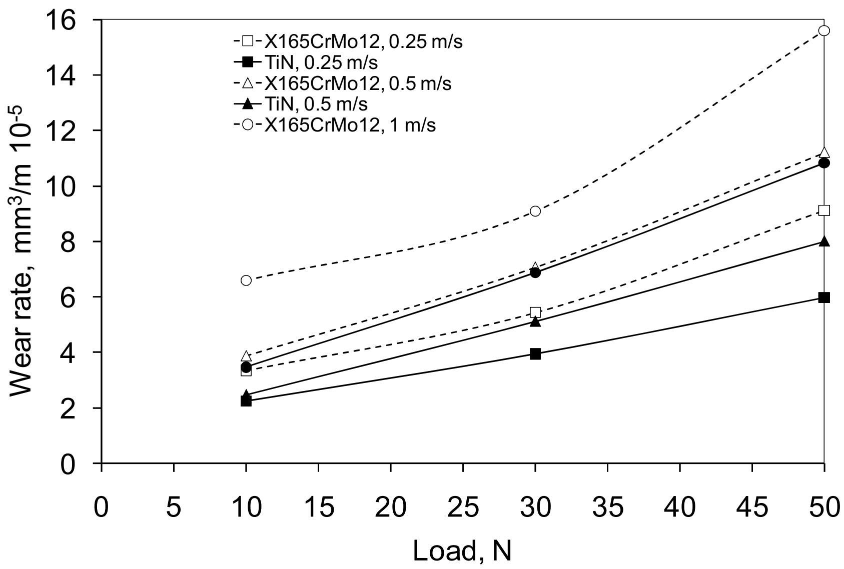


Figure 5. Wear degree dependence of tested samples on the normal load value (10, 20 and 30N)

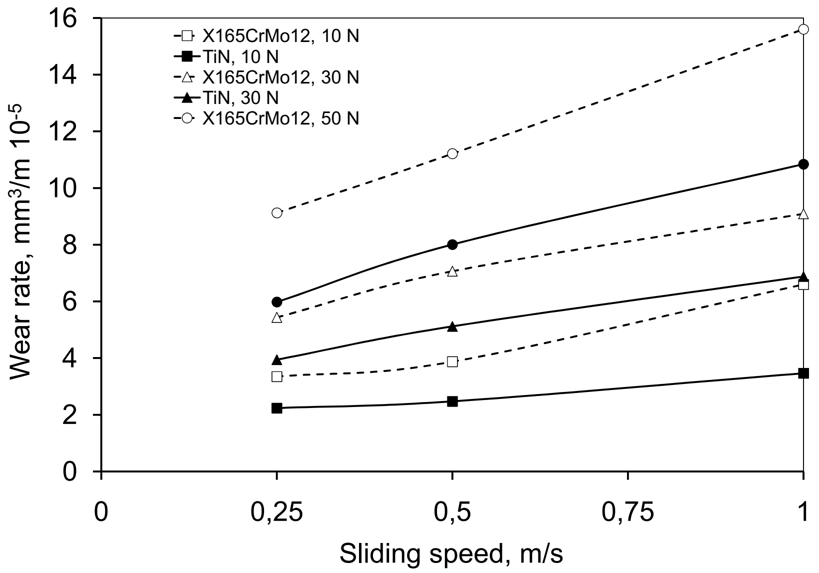


Figure 6. Wear degree dependence of tested samples on sliding speed (0.25, 0.5 and $1ms^{-1}$)

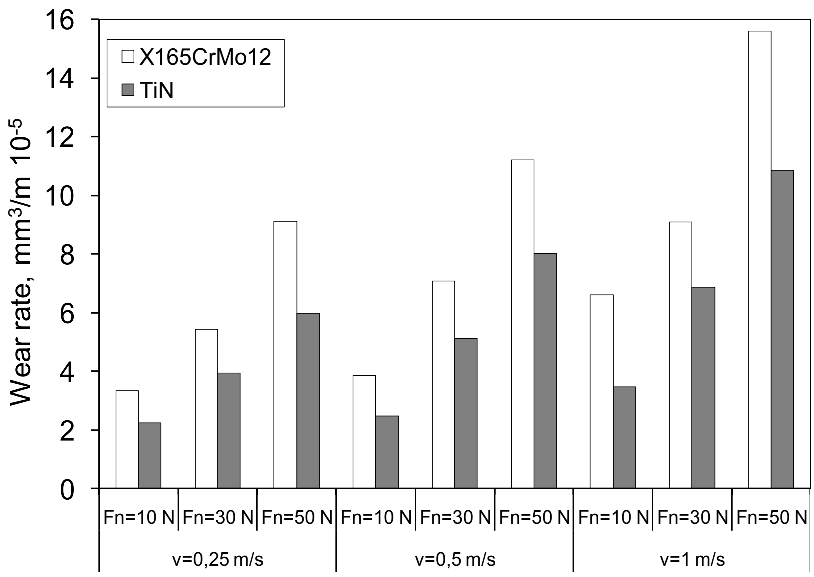
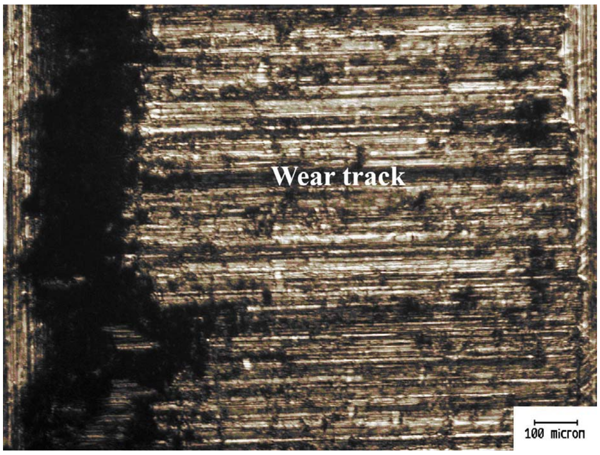


Figure 7. Histogram display of wear degree value for tested samples



a)

b)

Figure 8. Display of wear traces after sliding road of 200m, normal load value of 30N and sliding speed of $1ms^{-1}$ a) without coating; b)TiN coating.

Figures 8 show typical wear traces of tested samples in conditions without lubrication. Regardless of the value of contact parameters there was no coating penetration, which can be seen in these figures. Based on the appearance of wear traces at samples with and without coating we may say that the basic wear mechanism is abrasive wearing. At the very beginning of making contact we can talk about adhesive wearing, which is the consequence of contact block-on-disc, or high contact pressures which appears when contact is achieved only on the peaks of prominences. With further development, the wearing from linear contact passes into contact on surface where the oxides are the ones that appear when contacted with steel if they come in the contact zone and act as abrasive.

4. CONCLUSIONS

The results of wear studies, carried out to quantify the influence of TiN coatings on material resistance in processing of metal deforming on wearing, showed that in all contact conditions TiN coatings have lesser wear degree values in comparison to the material without coating. Based on the results, we can conclude that advantages of TiN coating in terms of resistance to wearing, in conditions without lubrication, in comparison to material without coating, come to the force at sliding speed values higher than $0.5ms^{-1}$ and normal load value higher than 20N.

These results are consequences of expected, by numerous studies confirmed, mechanical and tribological characteristics of TiN coatings. Based on that we can conclude that by TiN coating of material, the significant increase of tool life in processing of metal deforming is acquired, which is expressed at higher values of contact load and sliding speed.

In the conditions of making contact without lubrication, TiN coatings have proven as economically payable which is reflected in decreasing wear degree of tools, in some cases up to 40% in comparison to surfaces without coating.

ACKNOWLEDGMENT

This study was financed by Ministry of Science and Technological Development, Serbia, project No.35021.

REFERENCES

[1] K. D. Bouzakis, N, Widakis: Advanced Physically Vapor Deposited Coatings - State of The Art, Innovations and Future Trends Tribology In Industry, Volume 20, No.3, (1998).

[2] Spur, G. Byrne G., Bienia, B.: The performance of PVD coated High Speed Steel indexible inserts in the milling of ductile materials, ICMC17, San Diego, B 2-6, (1992).

[3] M. Diesselberg, H-R. Stock, P. Mayr: Corrosion protection of magnetron sputtered TiN coatings deposited on high strength aluminium alloys, Surface and Coatings Technology, 177 –178, 399–403 (2004).

[4] Branko Skoric, Damir Kakas, Natasa Bibic, Milan Rakita: Microstructural studies of TiN coatings prepared by PVD and IBAD, Surface Science, 566–568, 40–44 (2004).

[5] F. Borgioli, E. Galvanetto, F.P. Galliano, T. Bacci: Sliding wear resistance of reactive plasma sprayed Ti–TiN coatings, Wear, 260, 832–837 (2006).

[6] ZHAO Hui, WANG Xiao-hui, LIU Qiu-lei, CHEN Li-jia, LIU Zheng: Structure and wear resistance of TiN and TiAlN coatings on AZ91 alloy deposited by multi-arc ion plating, Transactio of Nonferrous Metals Society of China, 20, 679-682 (2010).

[7] S.V. Hainsworth, W.C. Soh: The effect of the substrate on the mechanical properties of TiN coatings, Surface and Coatings Technology, 163 –164, 515–520 (2003).

[8] P. Harlin, P. Carlsson, U. Bexell, M. Olsson: Influence of surface roughness of PVD coatings on tribological performance in sliding contacts, Surface & Coatings Technology, 201, 4253–4259 (2006).

[9] E. Bemporad, M. Sebastiani, C. Pecchio, S. De Rossi: High thickness Ti/TiN multilayer thin coatings for wear resistant applications, Surface & Coatings Technology, 201, 2155–2165 (2006).

[10] S. Wilson, A.T. Alpas: TiN coating wear mechanisms in dry sliding contact against high speed steel, Surface and Coatings Technology, 108–109, 369–376 (1998).

[11] E. Badisch, G.A. Fontalvo, C. Mitterer: The response of PACVD TiN coatings to tribological tests with different counterparts, Wear, 256, 95–99 (2004).

[12] Babic M., Mitrovic S., Jeremic B.: The Influence of Heat Treatment on the Sliding Wear Behavior of a ZA-27 Alloy, Tribology International Volume 43, Issues 1-2, 16-21 (2010).