RESEARCH OF THE TRIBOLOGICAL CHARACTERISTICS OF THE COATINGS OVER 100Cr6 STEEL

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Abstract: *In the current work tribological characteristics are investigated of coatings on steel 100Cr6, applied method PVD. TiN, ncAlTiN/αSi_3N_4 and ncAlCrN/αSi_3N_4 were coated. To determine the adhesion, the method by dynamically loading a diamond cone (Rockwell-C impact test) and the method of scratching (Scratch test) were used. The coatings hardness was determined by Vickers method using hardness tester FISCHERSCOPE ® H100, and the coatings thickness was determined using Calotest. Based on the experimental results were identified and evaluated tribological properties of the coatings (coating adhesion, hardness and thickness) created by PVD method on 100Cr6 steel.*

Keywords: Hard coatings; PVD-method; Tribological characteristics

1. Introduction

Coatings are used very widely in modern technology and lifestyle. The coating properties and selection of the method for its creation depends on the properties of the construction material (substrate) on which it is applied. Same coating applied to different construction materials or articles may have substantially different properties and uses. Therefore, the functional properties of the coatings and methods of their creation depend on the requirements which are brought into the contemporary conditions of production and operation towards structural materials. In engineering are applied mainly two types of coatings: corrosion protective and enhancing the tribological properties of the parts. Corrosion resistant coatings are designed to protect the external surfaces of the parts from the weather, to pass the required vision of the product and others. The second main type coatings are to improve the tribological properties of the working surfaces of the parts and assemblies. Generally these coatings are made of metal, but in these days mainly composite coatings are develop [1].

2. Aim of the work

The aim of current work is to study the tribological characteristics adhesion, hardness and thickness of the coatings *TiN*, *ncAlTiN/αSi_3N_4* and *ncAlCrN/αSi_3N_4*, created by PVD method over substrate of *100Cr6* steel. To achieve this aim it is necessary to solve the following tasks:

1. Preparation of *100Cr6* steel samples and cover them with *TiN*, *ncAlTiN/αSi_3N_4* and *ncAlCrN/αSi_3N_4* coatings by PVD method;
2. Conducting experimental studies;
3. Analysis of the results and conclusions.

3. Hard coatings

Test samples from *100Cr6* steel (chemical composition: *C-0,963%; Si-0,26%; Mn-0,61%; P-0,013%; S-0,003%; Cr-1,81%; Mo-0,22%; Cu-0,05%; Al-0,011%*) have been made for carrying out the experimental tests in the form of a rectangular parallelepiped with dimensions shown in Figure 1. This steel is used for roller guides of machine tools.

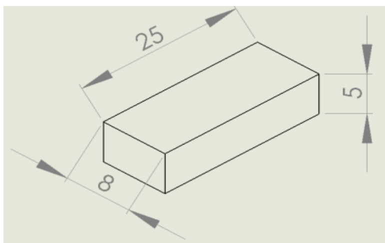


Figure 1: *Test samples shape and dimensions*

After making the samples were heat treated in sequence: annealing (200-250 HB), hardening (61-62 HRC) and tempering (59-60 HRC). After heat treatment the samples were grind and polished.

After polishing the samples were covered with three types of PVD coatings in the Central Laboratory of Applied Physics - Plovdiv - BAS:

- *ncAlTiN/αSi*$_3$*N*$_4$, gradient nanocomposite;
- *ncAlCrN/αSi*$_3$*N*$_4$, gradient nanocomposite;
- *TiN*.

4 Experimental research and results

4.1. Determination of the coatings thickness

A methodology to determine the coatings thickness by local delete with rotating steel sphere was used [3]. The quantitative values of the coatings thickness over *100Cr6* steel are shown in Table 1. In Figure 2 are shown photos of the imprints to determine the thickness of coatings *ncAlTiN/αSi*$_3$*N*$_4$ and *ncAlCrN/αSi*$_3$*N*$_4$. In Figure 3 is shown a photo of the imprint to determine the thickness of the coating *TiN*.

Table 1: *The coatings thickness over 100Cr6 steel*

Coating	***ncAlTiN/αSi*$_3$*N*$_4$**	***ncAlCrN/αSi*$_3$*N*$_4$**	***TiN***
H*$_{coat}$, *μm	2	3	2

Figure 2*: Photos of imprints to determine the thickness of coatings ncAlTiN/αSi*$_3$*N*$_4$ *and ncAlCrN/αSi*$_3$*N*$_4$ *over 100Cr6 steel*

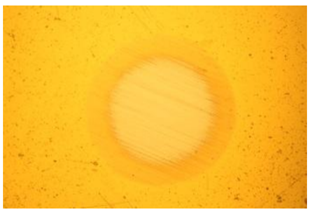


Figure 3*: Photo of imprint to determine the thickness of coating TiN over 100Cr6 steel*

4.2. Experimental studies to evaluate the coatings adhesion

The methods used for adhesion evaluation are: a method by dynamic loading of diamond cone (Rockwell-C impact test) [4] and the method of scratching (Scratch test) [2].

4.2.1. Adhesion evaluation using the method of dynamic load diamond cone (Rockwell-C impact test)

Rockwell hardness tester was used equipped with diamond cone indenter loaded with 1500*N* load force for 10 seconds. For each coating were carried out imprints in three areas (1, 2 and 3 of Figure 4) and visualized with an optical microscope МИМ-10 with 100 times magnification.

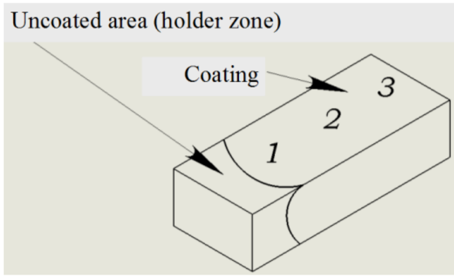


Figure 4: *Scheme of a covered sample with designated areas for imprints*

The imprints obtained for the coated samples with the coatings *ncAlTiN/αSi*$_3$*N*$_4$, *ncAlCrN/αSi*$_3$*N*$_4$, *TiN* and the graphic illustration of the evaluation criteria are given in figure 5, figure 6 and figure 7.

Area 1 ***Area 2*** ***Area 3***

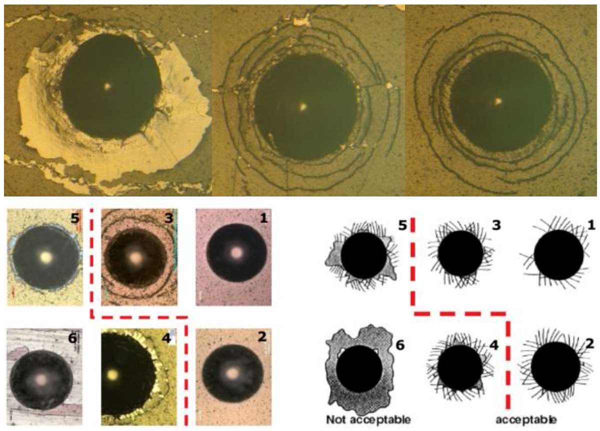
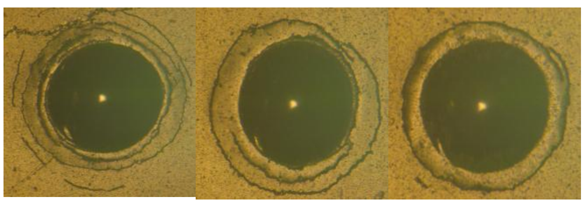


Figure 5: *Experimental imprints obtained for coating ncAlTiN/αSi*$_3$*N*$_4$*, compared with the adhesion evaluation criteria*

Area 1 ***Area 2*** ***Area 3***



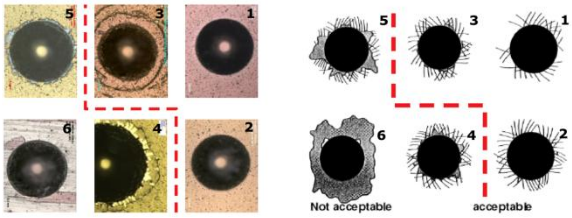


Figure 6: *Experimental imprints obtained for coating $ncAlCrN/\alpha Si_3N_4$, compared with the adhesion evaluation criteria*

Area 1 ***Area 2*** ***Area 3***

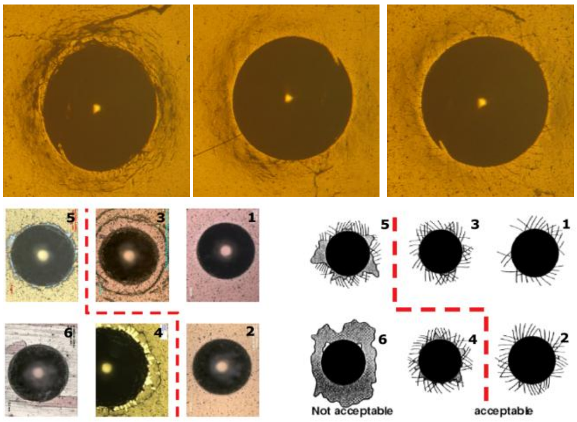


Figure 7: *Experimental imprints obtained for coating TiN compared with the adhesion evaluation criteria*

4.2.2. Determination of coatings adhesion by scratching process (Scratch test)

The results from the experimental tests are given in table 2 and represent the quantitative values of the critical loads F_{C1} - appearance of the first cracks over coating surface and F_{C2} - destruction of the coating (75% fully separated from the substrate coating).

Table 2: *Quantification of the experimental results*

Coating / Load, N	*$ncAlTiN/\alpha Si_3N_4$*	*$ncAlCrN/\alpha Si_3N_4$*	*TiN*
F_{C1}	24	25	37
F_{C2}	38	52	65

The photos of the signs from Scratch test for coatings *$ncAlTiN/\alpha Si_3N_4$*, *$ncAlCrN/\alpha Si_3N_4$* and *TiN* are shown In Figures 8, 9 and 10.

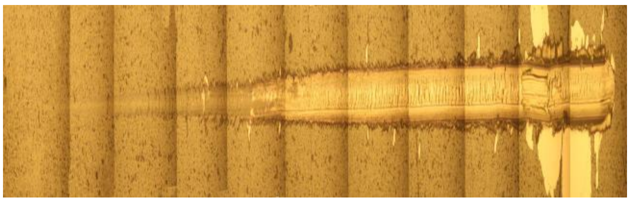


Figure 8: *Photo of the sign from Scratch test for $ncAlTiN/\alpha Si_3N_4$ coating over 100Cr6 steel*

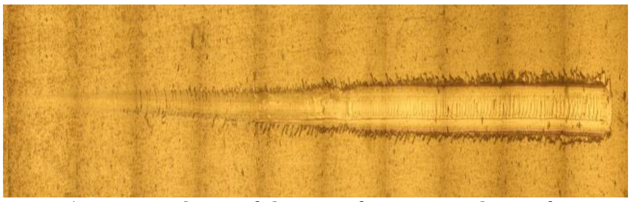


Figure 9: *Photo of the sign from Scratch test for $ncAlCrN/\alpha Si_3N_4$ coating over 100Cr6 steel*

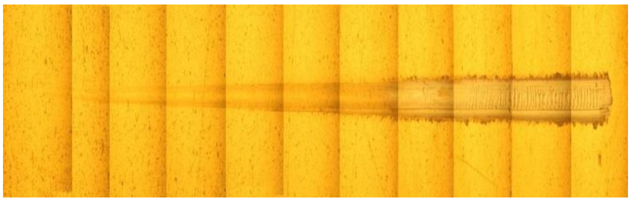


Figure 10: *Photo of the sign from Scratch test for TiN coating over 100Cr6 steel*

4.3. Determination of the coatings hardness

The coatings hardness was determined by Vickers method using nanohardness tester FISCHERSCOPE ® H100 [5]. Obtain quantitative values for the measured parameters are given in table 3. In figure 11, figure 12 and figure 13 are given the diagrams force - deformation of indenter penetration into the coating during the hardness measurement.

Table 3: *Coatings hardness over 100Cr6 steel*

Coating	*F, mN*	*HU, MPa*	*H_{plast}, MPa*	*E*, GPa*	*W_{tot}, nJ*	*W_r, %*
$ncAlTiN/\alpha Si_3N_4$	10	15912	19427	164	0,63	21,68
$ncAlCrN/\alpha Si_3N_4$	10	17676	20695	181	0,61	22,67
TiN	10	23302	27502	235	0,60	27,97

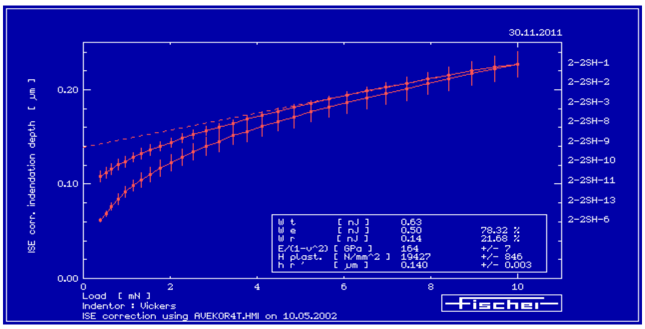


Figure 11: *Load-unloading diagram of the process for hardness measuring of $ncAlTiN/\alpha Si_3N_4$ coating*

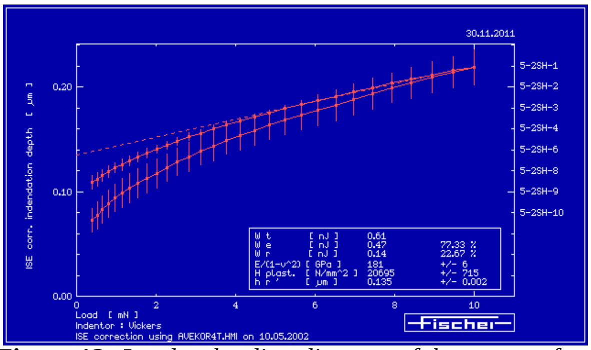


Figure 12: *Load-unloading diagram of the process for hardness measuring of ncAlCrN/αSi$_3$N$_4$ coating*

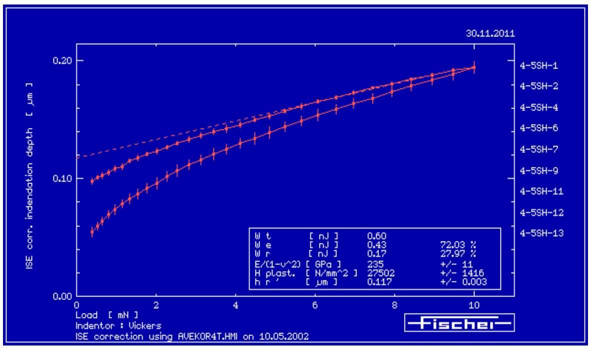


Figure 13: *Load-unloading diagram of the process for hardness measuring of TiN coating*

5. Conclusions

1. From the obtained experimental results using Rockwell-C impact test to evaluate the adhesion of *ncAlTiN/αSi$_3$N$_4$*, *ncAlCrN/αSi$_3$N$_4$* and *TiN* coatings over *100Cr6* steel can be summarized as follows:

- the imprints on *ncAlTiN/αSi$_3$N$_4$* coating showed the presence of concentric cracks around them and delamination areas. Imprints type relative to the evaluation criteria № 4 and № 5 (Imprint zone with cracks and delamination areas; Delamination areas all around the perimeter of the imprint), to which the coating adhesion can be considered for not good (unacceptable);
- the imprints on *ncAlCrN/αSi$_3$N$_4$* coating showed a single concentric cracks around them without delamination areas. Imprints type relative to the evaluation criteria № 2 (Imprint zone with cracks and without delamination areas) to which the adhesion of the coating can be considered for good (acceptable);
- the imprints on *TiN* coating showed cracks around them without any delamination areas. Imprints type relative to the evaluation criteria № 2 (Imprint zone with cracks and without delamination areas) to which the adhesion of the coating can be considered for good (acceptable).

2. From the obtained experimental results using Scratch test to evaluate the adhesion of *ncAlTiN/αSi$_3$N$_4$*, *ncAlCrN/αSi$_3$N$_4$* and *TiN* coatings over *100Cr6* steel can be summarized as follows:

- the traces on coatings *ncAlCrN/αSi$_3$N$_4$* and *TiN* indicate for a good adhesion evaluation. In none of the traces on the both coatings there was no presence of delamination areas and quantitative values of the strength F_{C2} occur after securing 40% of the length of the trace;
- *TiN* coating as one of the best established, universal and commonly used coatings showed the most high power for F_{C1} and F_{C2};
- good performance in terms of forces F_{C1} and F_{C2} showed *ncAlCrN/αSi$_3$N$_4$* coating;
- The forces F_{C1} and F_{C2} values for *ncAlTiN/αSi$_3$N$_4$* coating are lowest. F_{C2} occurs before securing 40% of the track length. There are also delamination areas most visibly at the end of the trace. This indicates that the adhesion of this coating is not good.

3. Tested coatings have high hardness and considering their good performance in terms of adhesion they can be offered for use in hard tribocouples.

Acknowledgments

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Reference

[1] Дишлиев С.И., Повишаване на износоустойчивостта на детайли и възли на производствената техника, Дисертация, Пловдив 2012
[2] Gitis N., Hermann I., Kuiry S.; Nano and micro indentation and scratch test of mechanical properties of thin films; Proceedings of the 7th international conference “THE” Coating in Manufacturing Engineering, 1-3 October, Chalkidiki, Greece, 2008, ISBN 978-960-243-648-6.
[3] www.csm-instruments.com
[4] www.platit.com
[5] www.fisher-micro-hardness.co.uk