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Structure and Tribological Properties of Thin TiAlN Coating

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Abstract

The paper presents a method for measurement of tribological properties of tool steels made by powder metallurgy deposited thin coating. TiAlN coating was deposited on the steel surface by PVD technology. The tribological pin-on-disc test was used for the determination of coating quality in terms of lifetime. The wear track of coated samples, after testing, was evaluated by light and electron microscopy. The structure of coated samples was observed by scanning electron microscopy.

Key words : thin coating, PVD, tribological properties, structure

Introduction

The reliability and lifetime of utility surfaces of tools and machine parts is, in most cases, influenced by wearing character. Technological methods of surface treatment allow for resolving the problems of short-term lifetime of mechanically stressed parts. The process of thin coating deposition can significantly decrease the friction coefficient. PVD (Physical Vapour Deposition) methods enable to form coatings with high hardness, high wear resistance and chemical stability. Importantly, the quality of thin coatings depends on preparation of steel substrate and technological parameters of the PVD process.

Materials and Experimental Procedures

The experiments were carried out on tool steels produced by powder metallurgy. The structure of steels, following their heat treatment to hardness of 63 - 65 HRC, was martensitic – carbidic. The specimen surface was prepared by polishing.(1) The chemical composition of steels is presented in Table 1.

The thin TiAlN coating was deposited on steel substrate surface using the reactive cathode arc method.(2) The technological parameters of the used procedure are given in Table 2.

The structure of thin coatings is determined particularly by technological parameters of the deposition process, namely the pressure of working gas, substrate temperature, bias on the substrate and deposition period. The structure of TiAlN coating deposited on steel substrate was observed using scanning electron microscopy.

Tribological tests were used to analyse friction and wear. The measurement of friction coefficient was realised by Tribometer.(3,4) The changes on the coated specimens' surfaces were observed by light microscopy and scanning electron microscopy.

Table 1. Chemical composition of steels

Steel	Chemical composition [wt. %]							
	C	Mn	Si	Cr	V	Mo	W	Co
K 190	2.3	0.33	0.4	12.5	3.94	1.1	-	-
Vanadis 4	1.5	0.4	1.0	8.0	4.1	1.5	-	-
Vanadis 30	1.28	-	-	4.2	3.1	5.0	6.4	8.5

Table 2. Technological parameters of PVD process

Coat	Substrate - steel	Substrate temperature [°C]	Nitrogen pressure [Pa]	Accelerating voltage [V]	Coat period [min]
TiAlN	K 190	480 – 500	2.0	200	30
	Vanadis 4				
	Vanadis 30				

Results and Discussion

The structure of the TiAlN coating was observed on fracture surface obtained by brittle failure of the specimens at temperature of liquid nitrogen. The metalograph obtained using scanning electron microscopy, Figure 1. shows a column-like structure of thin coating on top layer. The thickness of TiAlN coating, established on the fracture surface in Figure 1. is about 2 μm. The thickness thus affects the tool's lifetime as well as cutting forces during cutting. The coating thickness, by using the kind of tool, is given. The EDX analysis, Figure 2. shows the estimated chemical composition of coating. Figure 1 allows the observation of microparticles, which were integrated into the coating and formed protuberant protrusions on its surface. This phenomenon negatively affects some properties of the produced coating, e.g. surface roughness, coefficient of friction and corrosion resistance.(1) The presence of microparticles had direct influence on the increase of microgeometrical characteristics of coating surface. Roughness on hard surfaces influences their behaviour during contact with another cell, affecting stress force distribution. The decrease in contact area is observed. Therefore, local stress in the layer with greater roughness is higher than those in the layer with smaller roughness.

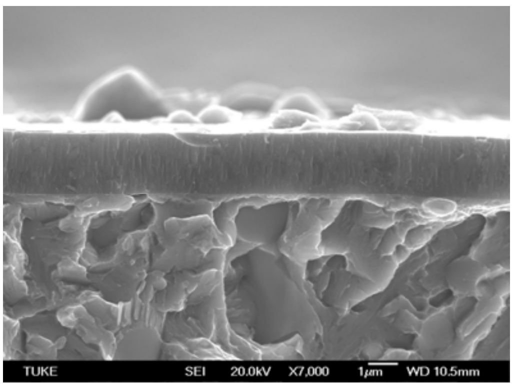


Figure 1. The TiAlN coat deposited on steel substrate, SEM

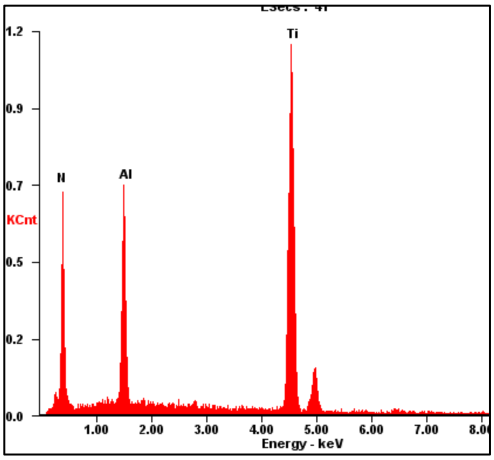


Figure 2. EDX analysis of TiAlN coating, SEM

Microhardness was measured by static indentation method according to the Vickers method by using a load of 50 g. Table 3 shows the values of microhardness of the coated specimens. The hard coating decreases the wear resistance. Its application is effective especially under abrasive strain conditions.

Table 3. Values of microhardness

Sample	Microhardness HV 0.05
TiAlN - K 190	2097.16 ± 236.1
TiAlN - Vanadis 4	2303.8 ± 232.1
TiAlN – Vanadis 30	2537.5 ± 306.5

Friction between two moving surfaces of materials is determined by processes of wear, which decrease their lifetime and operative capacity. The friction characteristics of coated samples were evaluated by *pin-on-disc* method using CSEM High Temperature Tribometer.(4) The test parameters are presented in Table 4.

Table 4. *Pin–on–disc* test parameters

Pin	Speed [cm.s^{-1}]	Number of cycles	Pin load [N]	Track radius [mm]	Temperature [°C]
Al_2O_3 ball ϕ 6 mm	2.0	10 000	5	2.0	20
	4.0			4.0	
	6.0			6.0	

The dependence of friction coefficient to number of cycles for each sample with TiAlN coat and wear track radius is summarized in Figures 3 – 5. Behaviour of this tribological parameter of coated samples is similar, its value is in the range of 0.82 – 0.86 for each sample. Consolidation of friction coefficient was observed up to 2000 cycles. Coefficient draw, sample K190 in Figure 5. was connected with formation of bearing aluminium film. The break of this film caused immediate growth of friction coefficient.

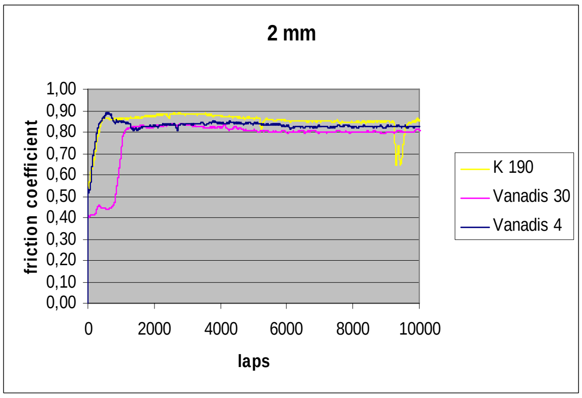


Figure 3. Behaviour of friction coefficient for each sample with TiAlN coat. Wear track radius of Al_2O_3 ball = 2.0 mm

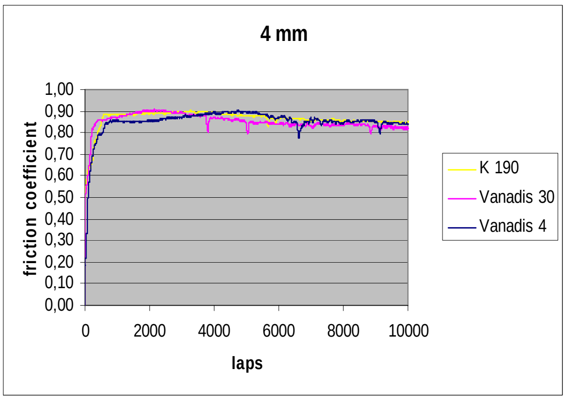


Figure 4. Behaviour of friction coefficient for each sample with TiAlN coat. Wear track radius of Al_2O_3 ball = 4.0 mm

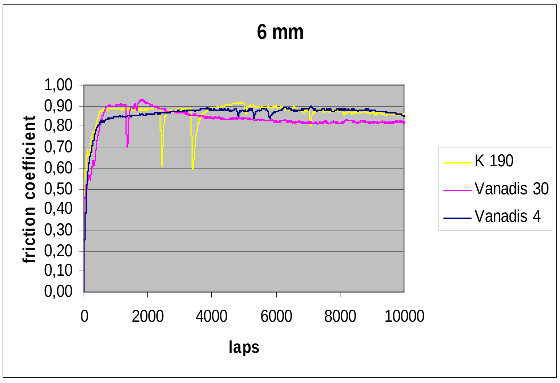
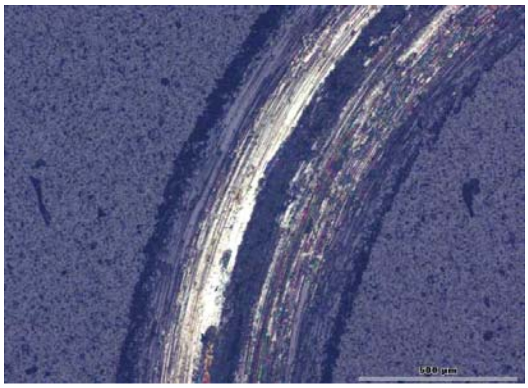


Figure 5. Behaviour of friction coefficient for each sample with TiAlN coat. Wear track radius of Al_2O_3 ball = 6.0 mm

The wear track appearance after the tribological test was observed by light microscopy with metallography analysis and by electron microscopy. Evaluations included the characters and dimensions of the tribological track on the coated specimens. The assessment was completed by EDX analysis of wear track.

Wear character after *pin-on-disc* test was evaluated by light microscopy with metallography analysis. The results of these analyses are documented in Figures 6 – 8.



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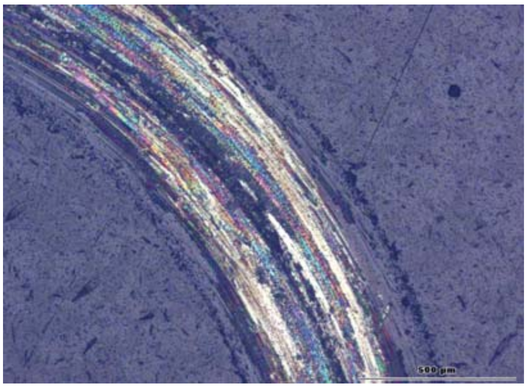

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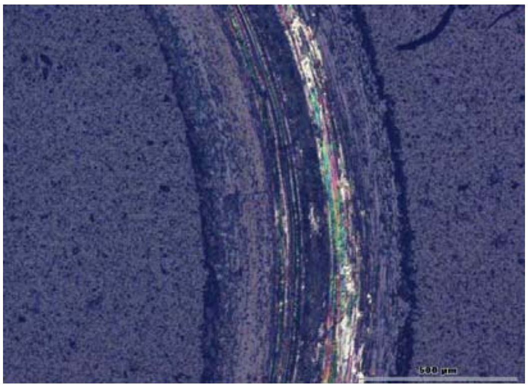

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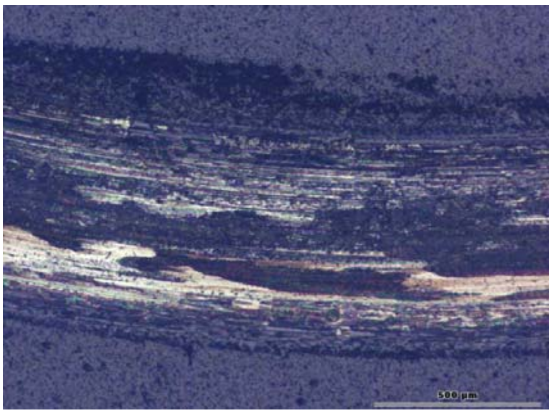
Figure 6. Pin–on–disc test - wear track on the surface: a) TiAlN - K190, b) TiAlN - Vanadis 4, c) TiAlN - Vanadis 30. Wear track radius of ball = 2 mm.



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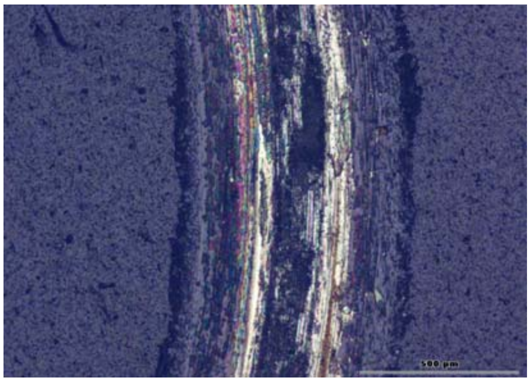

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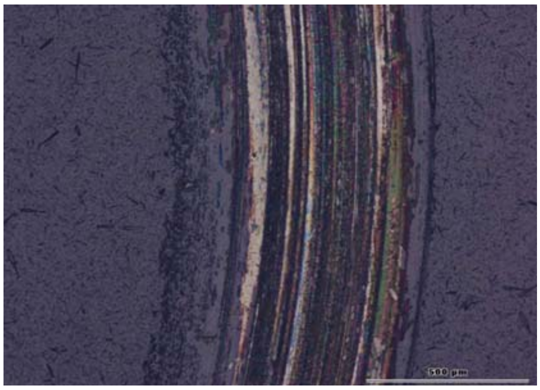


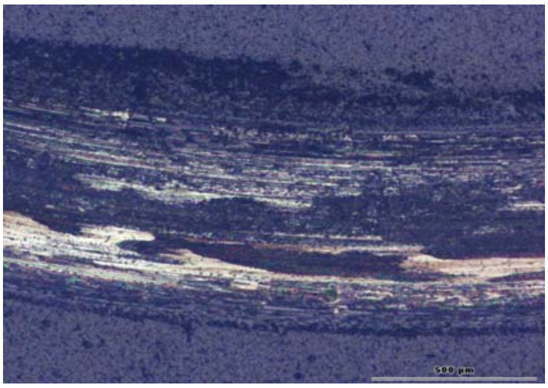
(c)

Figure 7. Pin-on- disc test - wear track on the surface: a) TiAlN – K190, b) TiAlN – Vanadis 4, c) TiAlN – Vanadis 30. Wear track radius of ball = 4 mm.

Figure 6 shows tribological track, which was the result of contact wear of coated sample surface and ball during *pin-on-disc* test. Damage dimension of surface was most clearly observed on the samples TiAlN – K190 steel. The sample surface TiAlN – Vanadis 30 shows adhesion wear in the middle of track. The ubroken brink of the track documented a good adhesion accouplement of thin coat and this steel substrate.

Figure 7 shows sample surface with TiAlN coat after *pin-on-disc* test. The least wear area was on the steel surface Vanadis 30 with TiAlN coating. The track width of this sample was also observed. Slight damage character responded to better adhesive properties of the coated sample.

Sample surfaces after tribological test and a wear track radius of the ball of 6 mm, is presented in Figure 8. During the testing, surface substrate was successively uncovered, separating material elements from damaged substrate and track ball. These elements were griped into wear track and caused a negative effect on tribological properties of coated materials.



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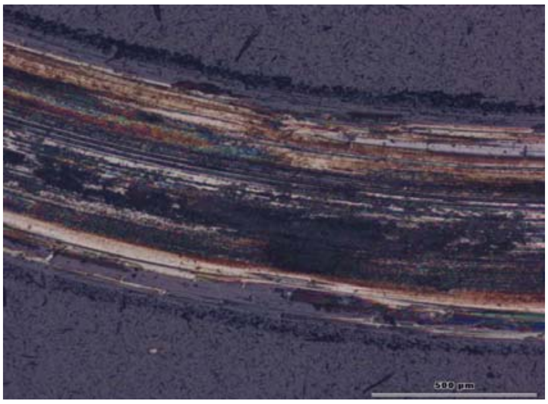

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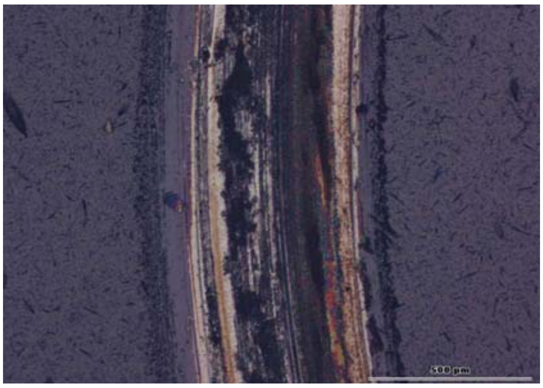

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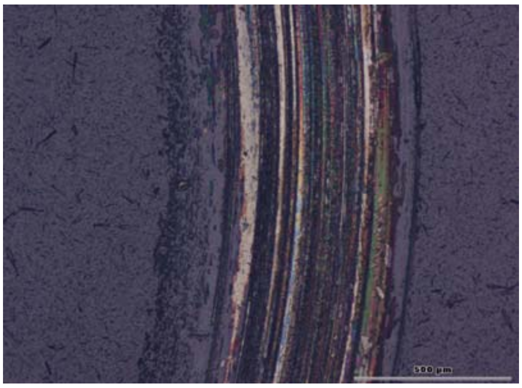
Figure 8. Pin–on–disc test - wear track on the surface: a) TiAlN – K190, b) TiAlN – Vanadis 4, c) TiAlN – Vanadis 30. Wear track radius of ball = 6 mm.

Surface sample TiAlN – Vanadis 4 and its EDX analysis of wear track after tribological test is illustrated in Figures 9 – 11. The presented pictures show that an increase of wear volume and damage area during testing also raises iron average from substrate.



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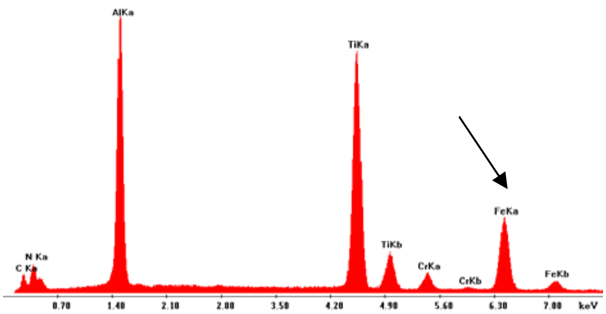
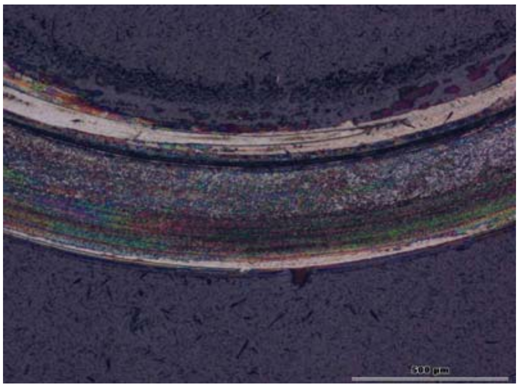


(b)

Figure 9. Surface of TiAlN – Vanadis 4: a) track at the begin of the test, b) EDX analysis from wear track – minimum iron average (place indicated by arrow)



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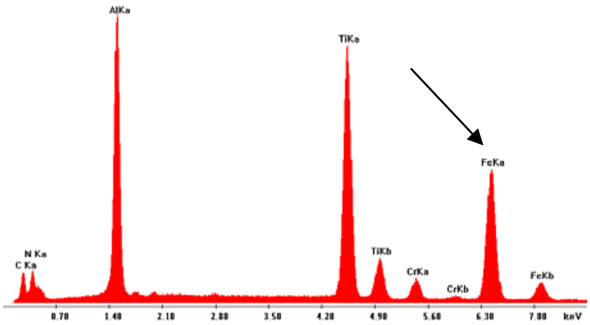

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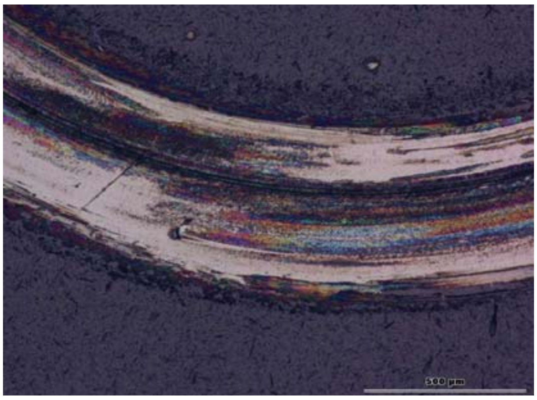
Figure 10. Surface of TiAlN – Vanadis 4: a) track in the course of the test, b) EDX analysis from wear track – medium iron average (place indicated by arrow)



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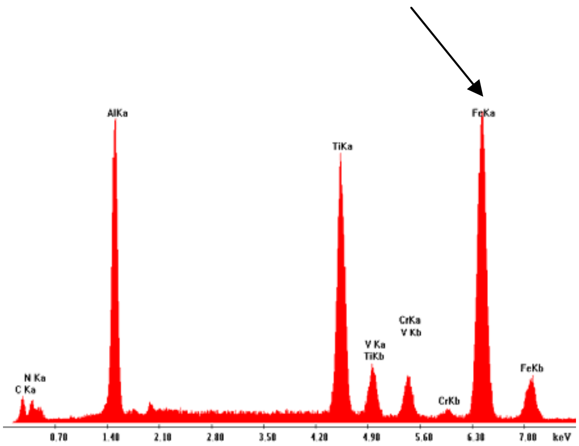

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Figure 11. Surface of TiAlN – Vanadis 4: a) track in the end of the test, b) EDX analysis from wear track – maximum iron average (place indicated by arrow)

Figure 12 shows details of tribological track after *pin-on-disc* test. This figure reveals massive wear of coating surface and its uncovering as well as particles which were fastened onto the brink of the track.

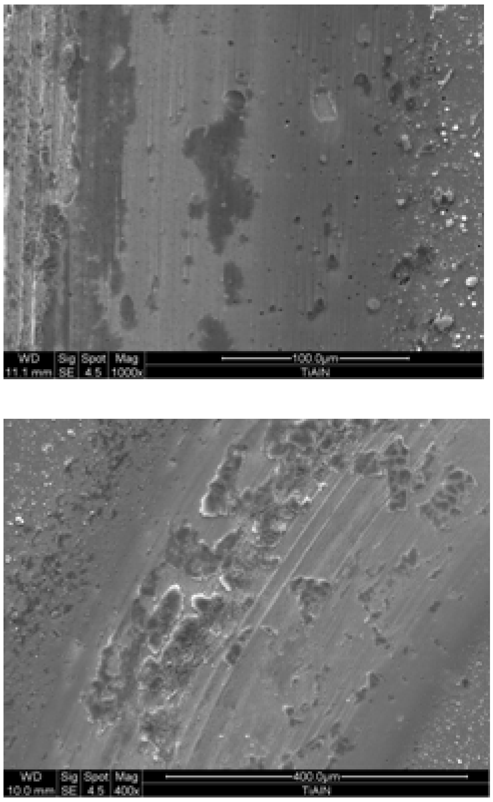

Figure 12. Detail of sample surface with TiAlN coat after "pin-on-disc" test, SEM

Conclusions

1. The formation of quality PVD coating depends on hardness, cleanness and morphology of substrate.

2. The structure of thin TiAlN coating layer was column-like. It was determined by the character of the deposition process.

3. The microparticles, which were in-built into the coat had a negative effect on the friction coefficient.

4. Friction coefficient values, determined by tribological test over 2000 cycles (in the range of 0.82 – 0.86). Draw of coefficient during testing was connected with formation of bearing aluminium film.

Acknowledgment

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References

1. Hagarová, M., Jakubéczyová, D. and Vojtko, M. 2007. PVD Coatings Applied on the Tool Steels. *J. Met. Mater. Miner*. **(17) 1**: 27-33.

2. Hagarová, M. and Halama, M. 2006.Corrosion resistance of TiAlN coatings. *Corrosao Proteccao Materiais* **(50) 4**: 78–83.

3. Hagarová, M. Experimental Methods of Assessment of PVD Coatings Properties. *J. Met. Mater. Minner*. **(17) 2** : 29-35.

4. Savková, J., Mrva, P., Kottfer, D. Adhesive-Cohesive Characteristics of TiAlN Coating on the Vanadis Steel 30. *Acta Mechanica Slovaca*. **4-C (11)** : 231-236.