Wear behaviour of PN+CrN, PN+CrAlN and PN+AlCrTiN layer composite during ball-on-disk tests in higher temperature

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Extended Abstract

One of the most perspective directions of the development of surface engineering is related to hybrid technologies, which best fulfil the expectation of the industry concerning obtaining expected properties of the surface of tools and machine components. The mostly known and widely used surface treatment hybrid technology is a combination of gas or glow-discharge nitriding process with the process of deposition of hard antiwear coatings by means of PVD methods. The effect of the hybrid technology with such a configuration is a layer composite, consisting of a nitrided layer and a PVD coating deposited directly on it, which can be use for increase of durability of tools working in high mechanical and temperature loads, e.g. forging dies or moulds for pressure casting of aluminium. One of the main important parameters of the PN+PVD layer composite is the wear resistant in higher temperature.

This paper presents the results of materials investigations and ball-on-disk wear test of three different layer composites PN+CrN, PN+CrAlN and PN+AlCrTiN. The designed layer composites were obtained with the use of the hybrid technology, which consist of plasma nitriding (PN) followed by arc-evaporation coating deposition. Technological processes for the production of coating composites (plasma nitriding process and PVD process) were realised by means of hybrid, multi-stage method of surface treatment in continuous cycle, in the vacuum device produced by the Institute for Sustainable Technologies – National Research Institute (ITeE-PIB) in Radom, Poland (Fig. 1).

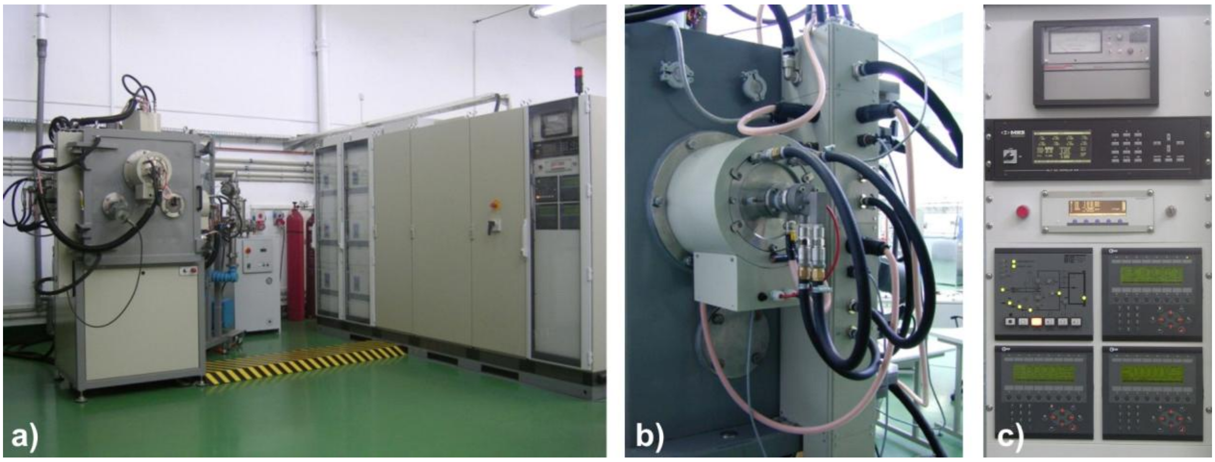

Fig.1. Device for the realisation of hybrid surface treatment processes a) entire technological system, b) arc plasma source, c) computer control system.

For all created layer composites the material properties like adhesion (Scratch test) and mechanical properties (Nano Hardness Tester) , chemical composition (GDOES method) – Table 1, microstructure (FIB+STEM technique) – Fig.2 were investigated.

Table 1. The material properties of three different PVD coatings which were investigated

Materials properties	CrN	AlCrN	AlCrTiN
Thickness [μm]	4.5	3.7	4.0
Hardness [HV]	2100÷2500	2100÷2650	2550÷3000
Young modulus [GPa]	260÷310	255÷380	315÷350
Friction coeficient	0.32	0.40	0.48
Rougness [μm]	R_a=0.43	R_a=0.40	R_a=0.29
	R_z=1.16	R_z=3.06	R_z=2.28
	R_t=1.92	R_t=4.49	R_t=3.40
Adhesion [N]	Fc_1=46	Fc_1=71	Not observed
	Fc_2=60	Fc_2=83	Fc_2=83
	Fc_3=103	Fc_3=124	Fc_3=110
Chemical composition [% at.]	N=46	N=44	N=47
	Cr=54	Cr=29	Cr=23
	-	Al=27	Al=22
	-	-	Ti=8

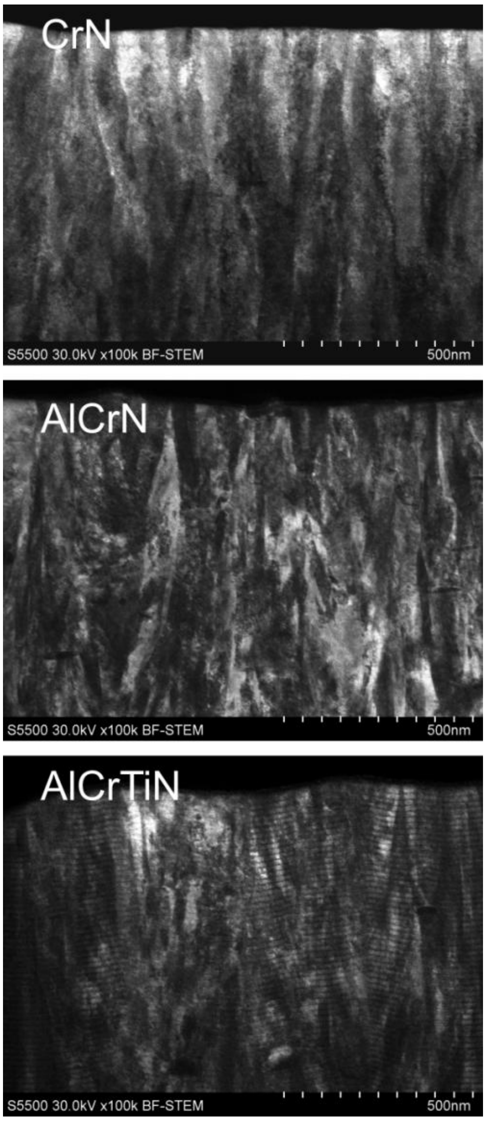

Fig.2. The results of microstructure investigations obtained by Scanning Transmission Electron Microscopy with used the Focus Ion Beam method for preparation of samples.

The microstructure investigations obtained by Scanning Transmission Electron Microscopy (Fig.2), proved that the CrN and AlCrN are typical monolayer coatings with columnar microstructure, whereas in the AlCrTiN coating the nanomultilayer microstructure was observed. The reason for nanomultilayer microstructure of AlCrTiN coating was the used of two different types of targets, i.e. AlCr and AlTi, placed in two opposite walls of vacuum chamber.

The ball-on-disk tribological tests, for cylindrical samples made of EN X32CrMoV3.3 hot working steel covered by investigated layer composites, were carried out in the range of temperatures 25^{o}C ÷ 600^{o}C. The tribometer from CSM Instruments and the following parameters: linear velocity – 0.1 km/min, load – 10 N, the radius of wear track – 10mm, ball – made of Si_3N_4 ϕ = 6mm were used. After the test, the wear track geometry was measured by non contact 3D profiler type: Talysurf CCI from Taylor Hobson and the volume of removed material of coating *(V)* was calculated. The methodology of ball-on-disk tribological tests is presenting on Fig.3.

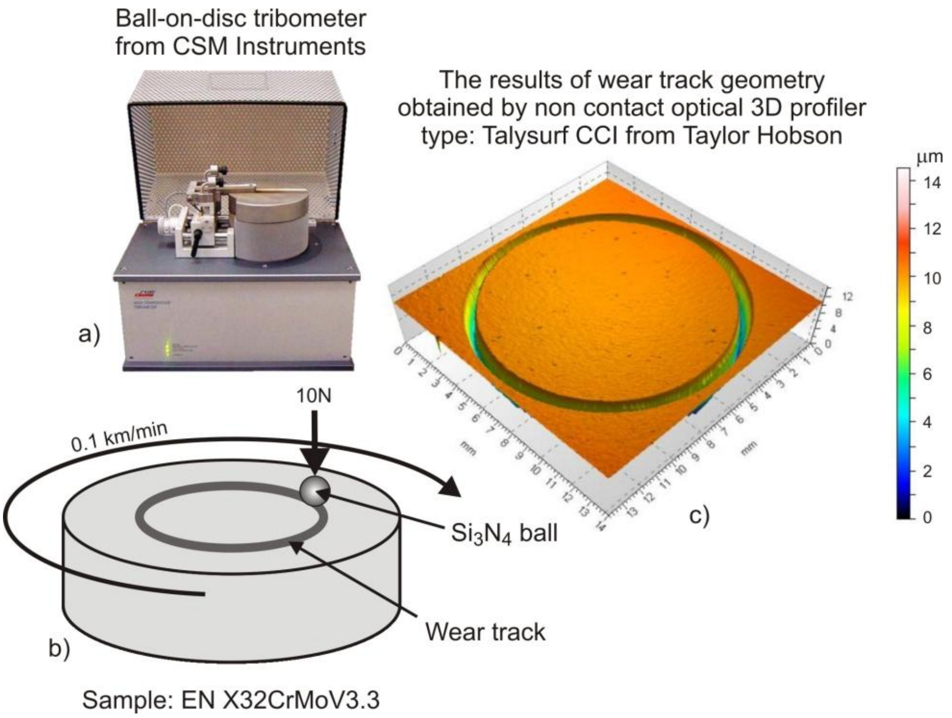

Fig.3. Realisation of ball-on-disc tribology tests: a) ball-on-disc tribometer from CSM Instruments, b) ball-on-disc tribology system, c) wear track geometry obtained by non contact optical 3D profiler.

In the next step according to the formula: $W = V / F \cdot S$, the value of Wear index *(W)* was calculated; V – volume of removed material of coating, F – load of the ball on sample, S – length of wear track. The results of changes of wear index *(W)* with the increase of temperature of sample in the ball-on-disc tribology tests are presenting in the Fig.4.

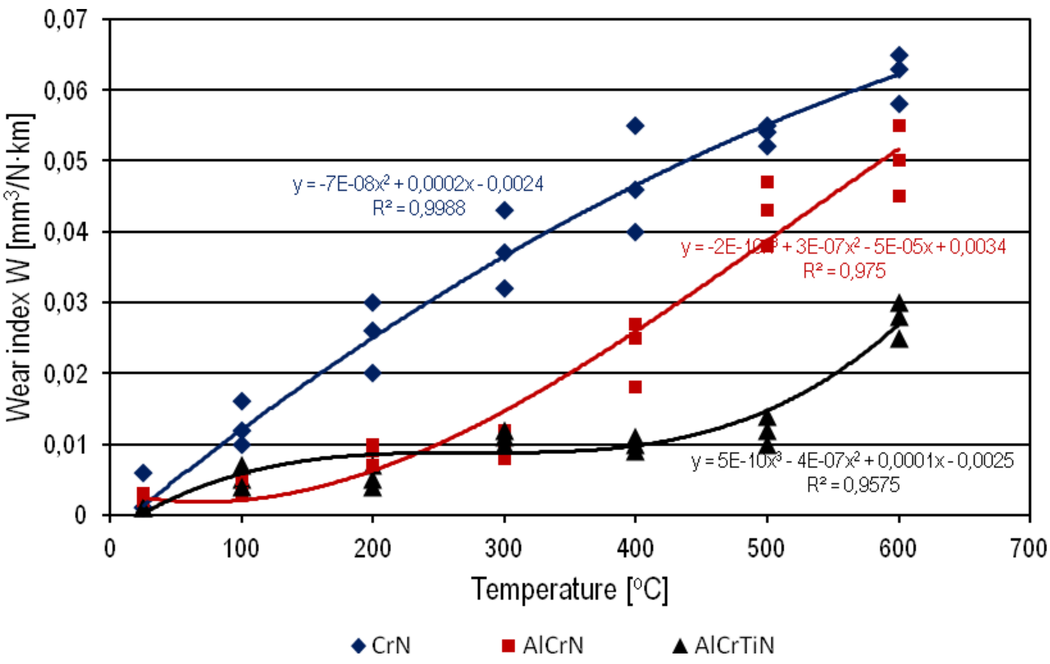

Fig.3. The results of ball-on-disc tribology tests obtained for three different investigated layer composites: PN+CrN, PN+CrAlN and PN+TiCrAlN.

Basing on the obtained results authors proved that the proper chemical composition and microstructure of thin PVD coatings, is the effective way for increase of stability of wear resistant of layer composites type “PN+PVD coating” in high temperature. The most important role in this process fulfil the participation of different metals in deposition process. It increase the possibility of creation of multicomponent nitrdes, i.e. Cr-Al-N, Ti-Al-N, Ti-Cr-N and Al-Cr-Ti-N, which characterized higher hardness and higher stability in high temperature.