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EVALUATION OF PROPERTIES OF SELECTED COATINGS ON STEEL 16MNCR5 IN TERMS OF THEIR USE IN GEAR TRANSMISSION

Summary. The work deals with attribute ratings of chosen hard thin coatings on substratum 16MnCr5. The work contains their tribological properties and based on review, hard thin coating applicable to material used for the manufacture of gear wheels of type 16 MnCr5 is designed aiming to increase surface carrying capacity of gear wheels made from 16MnCr5 material.
Keywords. Sandwich Cr/CrN and duplex CrN coating, PVD, substrate, roughness, nano-hardness, adhesion, friction coefficient, Pin-on-disc.

OCENA WŁAŚCIWOŚCI WYBRANYCH POWŁOK STALI 16MNCR5 POD KĄTEM ICH ZASTOSOWANIA W KOŁACH ZĘBATYCH

Streszczenie. Artykuł zawiera ocenę właściwości wybranych twardych, cienkich powłok substratu 16MnCr5. W niniejszym artykule zostały opisane ich właściwości trybiologiczne oraz na podstawie krytycznej oceny, została zaprojektowana twarda, cienka powłoka stosowana jako materiał do produkcji kół zębatych 16MnCr5 w celu zwiększenia wytrzymałości powierzchni kól zębatych wykonanych z materiału 16MnCr5.
Słowa kluczowe. Powłoka sandwiczowa Cr/CrN oraz dupleksowa CrN, PVD, substrat, chropowatość, nanotwardość, adhezja, współczynnik tarcia, Pin-on-disc.

1. INTRODUCTION

Increasing gearing carrying capacity and durability is one of the problems whose solution is available to fulfil by constructing (geometry of gearing) and technologically (new materials and technologies). In the technical approach of increasing gearing carrying capacity, so far the most important technologies included using methods of chemical and heat treatment. Mainly during the past few years with the development of material engineering, there have been

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various technologies (PVD, CVD, PACVD and others) for surface application of hard thin coatings aiming to increase their contact carrying capacity. In the field of gearing, some authors [1, 2] have performed various experiments focusing on materials that were not used very often for the manufacture of gearings. From experiments up to today it is very clear that deposition of hard thin layers on the tooth flank surface is one of the ways of increasing surface carrying capacity of gearings and therefore also durability which means that it would increase the carrying capacity keeping current durability. Given work deals with the attribute ratings of thin layers on testing samples and basic materials assigned for the manufacture of gearings 16MnCr5 aiming to define the most suitable coating. The purpose of solving the problem closely relates to the fact that there have been experiments performed [1, 2] on basic materials that were not used very often for the manufacture of gearings.

2. MATERIAL AND METHODS

One of the most often used materials for the manufacture of gearings is 16MnCr5, for which the experimentally defined bending fatigue limit value σ_{Flim} and fatigue limit of contact σ_{Hlim}, are necessary for the calculation of their hardness. Based on the above, for the purpose of testing samples steel material 16MnCr5 has been used while the testing samples were hardened in vacuum at the temperature of 860°C and yielded at 500°C. The testing samples made in this manner were metallographically coated to roughness Ra = 0,06 μm and subsequently coatings given in Tab. 1. were applied to their surface. Based on the review of possible technologies of applying coatings to the given substrate as well as possibilities of resolving workplaces, method PVD (Physical Vapour Deposition) of applying coating has been chosen. This technology uses evaporation in application from solid phase of thin coating of thickness up to 4μm Based on the chosen evaporating material, it is possible to obtain very low surface friction, high hardness, high wear resistance as well as resistance to temperature (standard 550°C, but depending on the coating up to 750°C and more), corrosion and acids . PVD polishing method has advantages mostly in lower temperatures of components polishing like in case of obtaining balanced chemical reaction (method CVD - Chemical Vapour Deposition). Substratum of 16MNCr5 material was plasma nitrided at 500°C for 6 hours before applying sandwich Cr/CrN and duplex CrN coating. The process of plasma nitriding and consignation of thin layer was made in one piece of equipment. The parameters of deposition of individual layers can be found in database of Thomson Reuters [5].

Table 1

Applied coatings

SUBSTRATUM	COATINGS				
16MnCr5	TiCN	CrN	DLCII	Sandwich coating Cr/CrN	Duplex CrN coating

Applied coatings given in Tab. 1 are in the work rated based on roughness, critical loading, course of friction coefficient and nano-hardness. The values of roughness of coated thin layers were found using surface roughness meter Mitutoyo SJ201. The measurements of layer widths were made using REM where it was possible to observe micro-structure of contact area between thin layer and substratum. The results of these measurements a shown in Tab. 2.

Adherence of individual layers was rated by scratch test using equipment called CSM Revetest in alternating normal force increasing in a constant speed (100N/min) with standard speed of table movement. During the measurement, acoustic emission was observed and the rate of change of friction coefficient depended on normal loading Fn. Morphology of infraction was documented using light microscope Nikon Eclipse.

Table 2

Widths of deposited layers in basic material 16MnCr5 in μm

Thin layers	Surface roughness Ra, μm	Layer width, μm	Critical loading Lc, N
TiCN	0,53	2,67	40
CrN	0,35	3,75	70
DLC II	0,46	1,31	58
Cr/CrN sandwich	0,46	3,6	78
Duplex CrN	0,23	3,57	76

The procedure of finding critical loading values when spoliation of layer occurs can be represented by assessment of abrasion test Fig. 1 with highlighted spoliation and their subsequent comparison with acoustic emission signal Fig. 2 and the course of friction coefficient read during the test - Fig. 3 and their corresponding values are shown in Tab. 2.

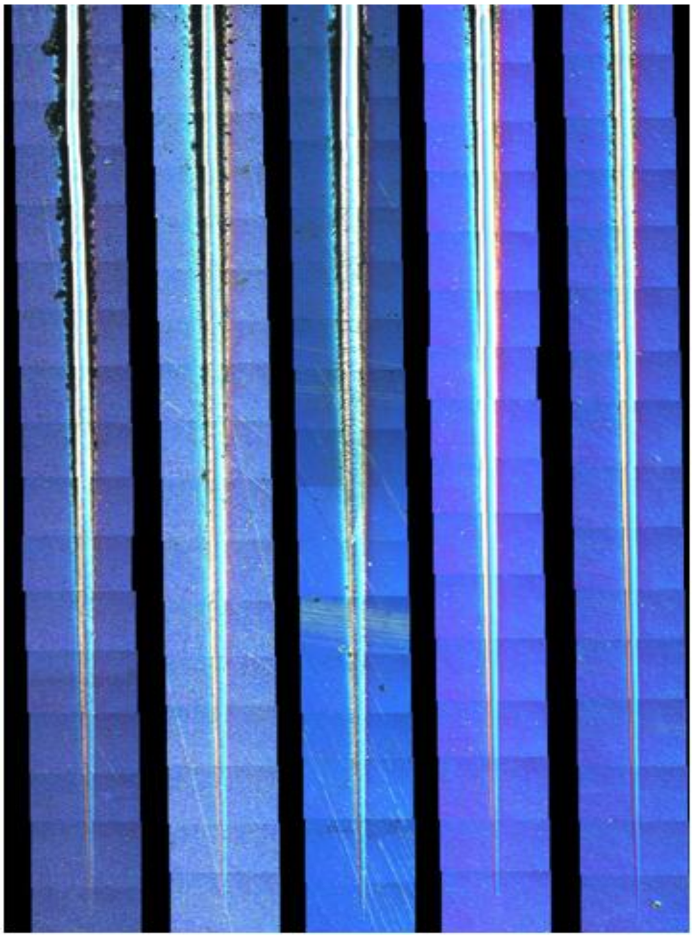

Fig. 1. Abrasion tracks in basic material 16MnCr5 – from above TiCN, CrN, DLC, Sandwich Cr/CrN and Duplex CrN respectively

Rys. 1. Ślady rys w materiale podstawowym 16MnCr5, w kolejności od góry TiCN, CrN, DLC, Sandwich Cr/CrN, Dupleks CrN

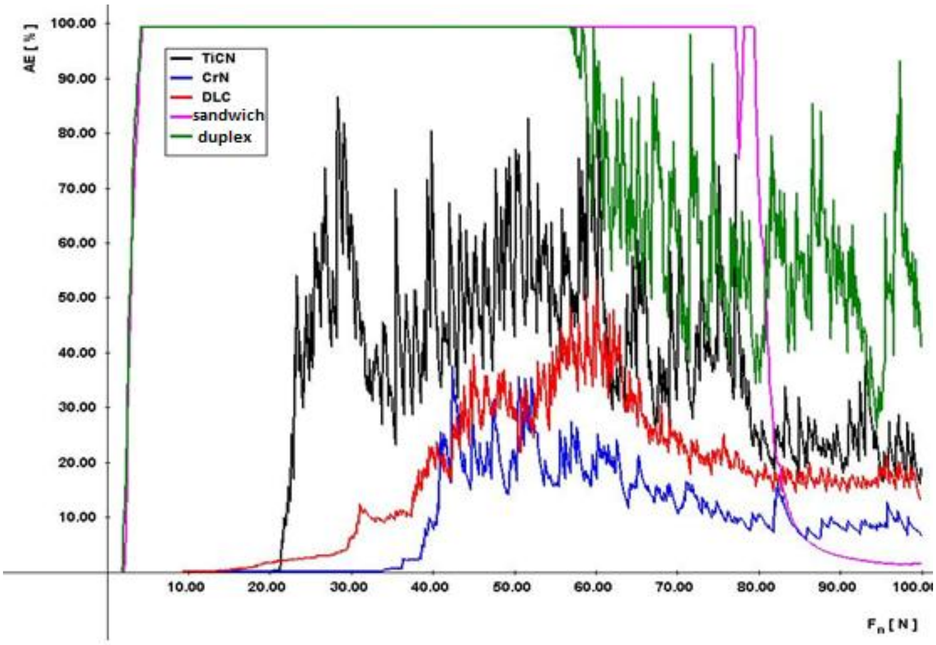

Fig. 2. The course of acoustic emission signal on substratum 16MnCr5
Rys. 2. Przebieg sygnału emisji akustycznej na substracie 16MnCr5

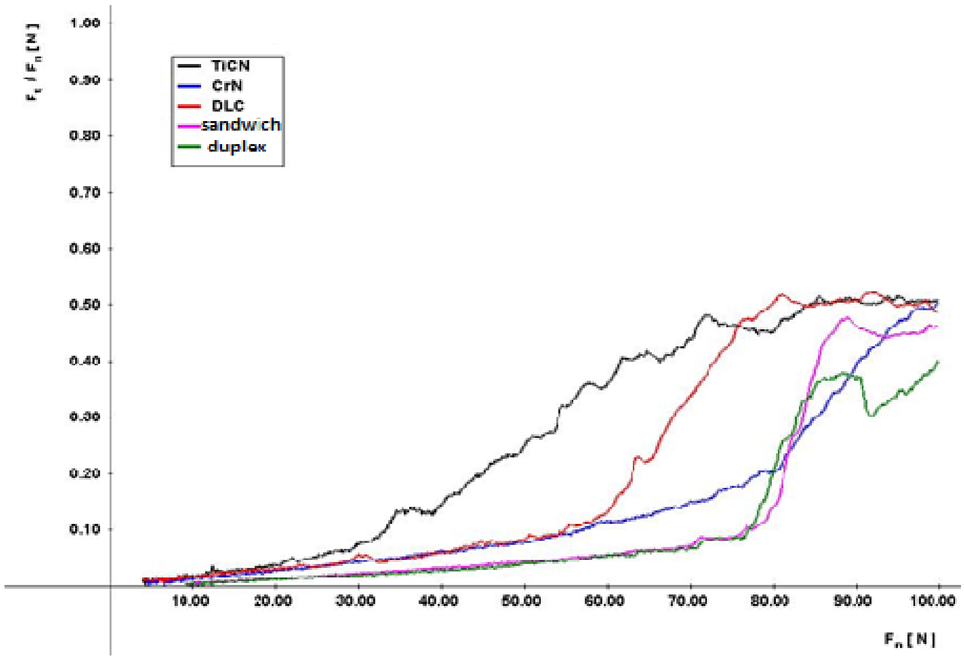

Fig. 3. The course of friction coefficient during scratch test on substratum 16MnCr5 (14 220)
Rys. 3. Przebieg współczynnika tarcia podczas scratch testu na substracie 16MnCr5 (14 220)

Nano-harnesses of individual layers were rated for weights of 25 g and 5 g, the results are shown in Fig. 4.

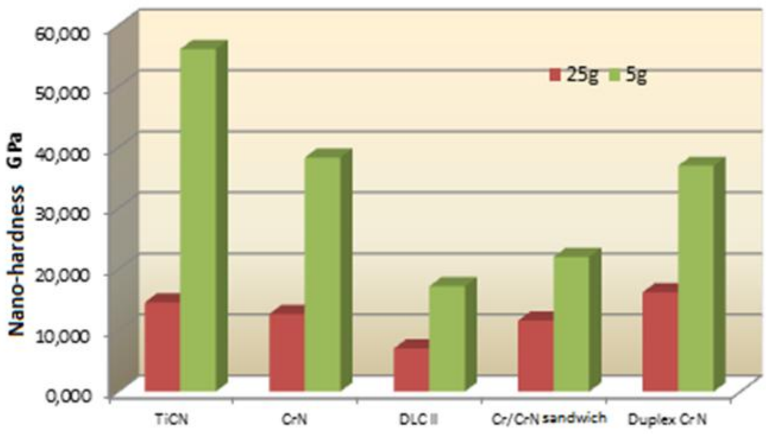

Fig. 4. Nano-hardness of coatings in different loadings
Rys. 4. Nanotwardość powłok przy różnych obciążeniach

The courses of friction coefficient measured by pi-on-disc method are shown in Fig. 5.

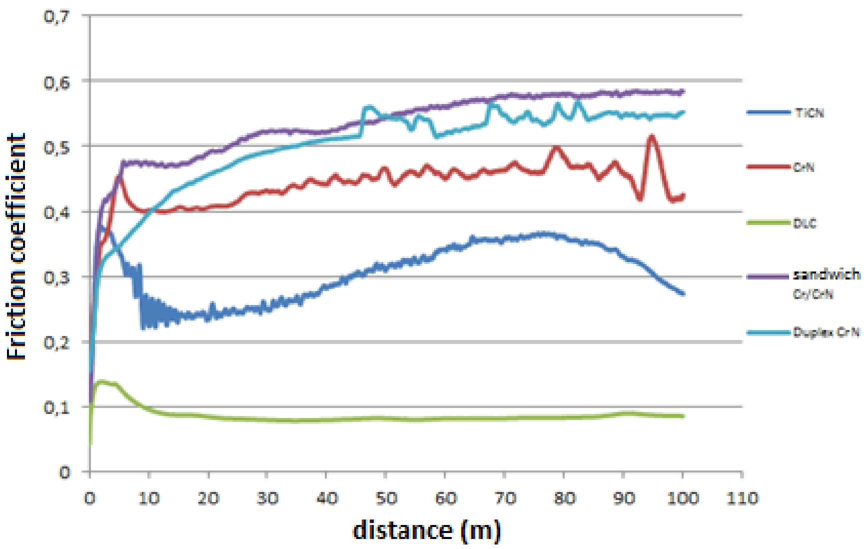

Fig. 5. The process of change of friction coefficients in thin layers
Rys. 5. Przebiegi współczynnika tarcia w cienkich warstwach

3. RESULTS AND DISCUSSION

The values of roughness in test samples after coating are shown in Tab. 2 and it is clear that coating causes friction to decrement and coating method with its parameters represents a very powerful agent. The thinnest of all tested coatings was layer DLC (Tab. 2).

The adhesion of individual thin layers approves positive effects of plasma nitriding to cohesion of coatings. Values of critical loadings when spoliation of thin layer occurred are shown in Tab. 2.

Nano-hardness rating for 5 g loading represents clear differences in hardness of individual layers while TiCN and subsequently both layers CrN have one of the highest hardness values. Hardness of DLC layer is the least.

For 25 g loading, the information concerning measurement of hardness, behaviour and properties of material system are provided by thin layer-substratum that shows that the best hardened surface can be achieved by duplex CrN layer.

Method Pin-on-disc revealed slippery properties of individual coatings when the least values of friction coefficient were achieved by DLC layer. The deterioration of CrN, TiCN and sandwich Cr/CrN is almost twice as big when compared to duplex CrN a DLC layers.

4. CONCLUSION

In experiments, properties of hard thin layers deposited on the surface of basic material 16MnCr5 were assessed using PVD technology. Hence duplex treatment and subsequent coating deposition of CrN provide with very good mechanical properties, positive adhesion and guarantee low adhesive wear. On the other hand, thanks to outstanding friction properties, DLC coating has very positive wear effects. Possibilities of their application in gearings in the basic material will, however, be determined only at Niemann's stand. The remaining coatings do not show sufficient data for their application in gearings for 16MnCr5 materials.

The work was elaborated within the solution of grant projects VEGA 1/0277/12, 1/1035/12.

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