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The effect of deposition of the anti-wear coatings of the TiN+TiAlSiN+TiN type on working properties of tool cermets*

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Properties are compared in the paper of the commercial tool cermets - uncoated and coated in the cathodic arc evaporation process (CAE) with the hard anti-wear coatings of the TiN+mono or multiTiAlSiN+TiN types. Results of the metallographic examinations on the light microscope and SEM, as well as results of the micro-hardness, roughness and adhesion tests of the deposited coatings to the substrate, and of the technological machining tests are presented.

1. INTRODUCTION

Deposition of hard anti-wear coatings based on transition metal carbides, nitrides, or oxides onto the sintered tool materials (including cermets) features one of the most intensely developing research directions, stimulated by the growing working requirements posed to machines and equipment, making it possible to improve significantly their properties. Using tools with such coatings reveals the significant increase of their life, compared with the conventional ones. Tools coated with the anti-wear coatings can operate at higher working parameters (temperature, loads, etc.).

Cermets coated with the anti-wear layers belong to the contemporary cemented tool materials with a fast growing importance in machining technology. Broader and broader employment of cermets – the fastest developing tool materials – is connected with transition of machining of semi-products from roughing to semi-finishing or finishing in one setting. The contemporary tool material like cermet meets in many cases requirements of new technologies, and first of all of the *„Near-Net-Shape"* one.

The goal of this work has been examining the influence of deposition in the CAE process the multi-layer coatings of the TiN+mono or multiTiAlSiN+TiN types on structure and properties of cermets, and comparing them with the commercial tool cermets.

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2. EXAMINATION PROCEDURE

The investigations were carried out on tool cermets: uncoated and coated using the PVD method in the (CAE - Cathodic Arc Evaporation) process of physical vapour deposition of coatings from the gaseous phase, with the TiN+mono or multiTiAlSiN+TiN wear resistant coatings. Specification of the examined materials is presented in Table 1.

Table 1
Specification of the investigated tool cermets

Material type	Coating	Coating designation	Coating thickness, μm	Process type
CM	–	–	–	–
T130A	–	–	–	–
T130Z	TiN+TiC+TiN	K1	5,0	PVD
CM	TiN+multiTiAlSiN+TiN	M1	3,5	PVD
T130A	TiN+multiTiAlSiN+TiN	M2	3,5	PVD
CM	TiN+TiAlSiN+TiN	S1	3,5	PVD
T130A	TiN+TiAlSiN+TiN	S2	3,5	PVD

The metallographic examinations of the substrate and the deposited coatings were made on the LEICA MEF4A light microscope with the maximum magnifications 1250x. Observations of surfaces and structures of the developed coatings were carried out on the transverse fractures on the Opton DSM 940 scanning electron microscope (SEM) on the on the Philips XL-30 one. To obtain the fracture images the Secondary Electrons (SE) and the Back Scattered Electrons (BSE) detection methods were used with the accelerating voltage in the range of 15-20 kV.

Tests of the coatings' adhesion to the substrate material were made using the scratch test, routinely employed in case of the coatings obtained in the PVD processes. The tests were made on the CSEM REVETEST device. The examinations were carried out with the following test conditions: load range 0-200 N, load increase rate (dL/dt) 100 N/min, indenter speed (dx/dt) 10 mm/min, sensitivity of the acoustic emission detector AE 1.2. The critical load L_C, at which coating adhesion loss occurs was determined basing on the acoustic emission (AE) recorded during the test. Observations of the defects developed during the „scratch test" were made on the OPTON DSM 940 scanning microscope.

The micro-hardness tests were made on the SHIMADZU DUH 202 ultra micro-hardness tester. The tests were made at the 70 mN load.

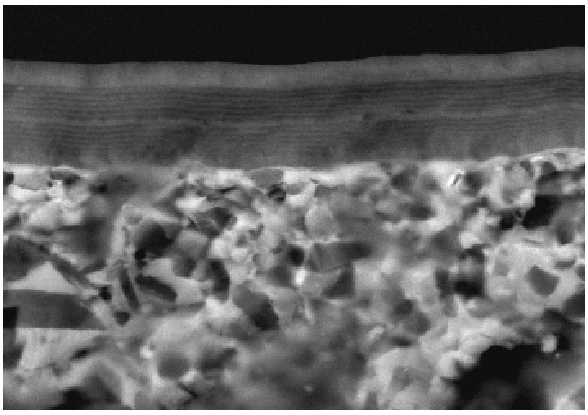
The roughness measurements of the developed coatings and the substrate were made in two orthogonal directions on the Taylor-Hobson Sutronic3+ device. The R_a parameter was assumed to be the value describing the surface roughness.

Working properties of the developed coatings were determined basing on the technological cutting tests of the continuous dry turning of the C45E type (according to PN-EN 10083+A1:1999) unalloyed steel quenched and tempered. Inserts' life was determined basing on the wear land measurements on the tool flank, measuring the average wear land VB and the maximum one VB_{max} after cutting for a predetermined period. Cutting tests were stopped when the VB value exceeded the assumed criterion for finishing, i.e., VB= 0,2 mm., specifying the tool life T in minutes. The following parameters were used in cutting tests: feed f=0,1 mm/rev, depth of cut a_p=1 mm, cutting speeds v_c=250; 315; 400 m/min.

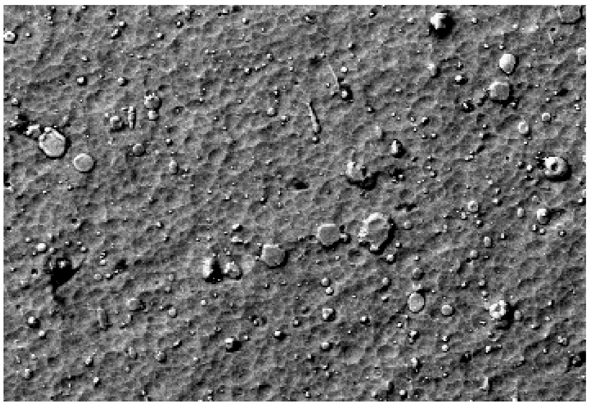
3. DISCUSSION OF THE TEST RESULTS

It was found out, basing on the metallographic examinations of fractures made on the scanning electron microscope, that the TiN+mono or multiTiAlSiN+TiN coatings deposited onto the investigated tool cermets have the laminar packing. The particular TiN, mono, or multiTiAlSiN layers and the TiN interlayer have the poreless structure and adhere closely to the substrate with no cracks or discontinuities (Fig.1). Observations of the surface morphology reveal its inhomogeneity connected with occurrences of numeorus drop-shaped micro-particles on them (Fig. 2). Some of these micro-particles assume the elongated shape, caused probably by their spattering when they hit the cermet substrate surface during the CAE process. Examinations of the chemical compositions of the droplet shaped micro-particles made using the X-ray energy dispersive spectrometer (EDS) indicate that titanium dominates inside of these micro-particles, which suggests that they are the pure titanium droplets knocked out from the titanium disk, which settle and solidify on the substrate surface. Basing on the metallographic examinations of the commercial tool cermets on SEM it was found out that the TiN+TiC+TiN type coatings deposited in the PVD process onto the T130Z cermet were put down evenly onto the substrate. The coating is characterized by a dense, poreless structure with no cracks and adheres closely to the substrate.

Basing on the roughness tests surface profiles were determined for the deposited coatings and average deviations of the R_a roughness profile was determined. It was found out that the smallest value of R_a=0,2 μm is characteristic for the T130A specimen surface, whereas the surface of the CM type cermet displays R_a=0,22 μm. After depositing the TiN+TiAlSiN+TiN coatings onto the cermet substrate, the surface layer roughness increases and is within the range of R_a=0,60-0,67 μm. The surface roughness increase after depositing the coatings should be – probably – linked with the character of the CAE process, which was confirmed with examinations of the surface morphology on the scanning electron microscope. However, no influence of the substrate (cermet) on the obtained values of the roughness parameter of the deposited coating was observed.



Rys. 1. Fracture surface of the TiN+multiTiAlSiN+TiN coating deposited onto the CM type cermet



Rys. 2. Surface topography of the TiN+multiTiAlSiN+TiN coating deposited onto the CM type cermet

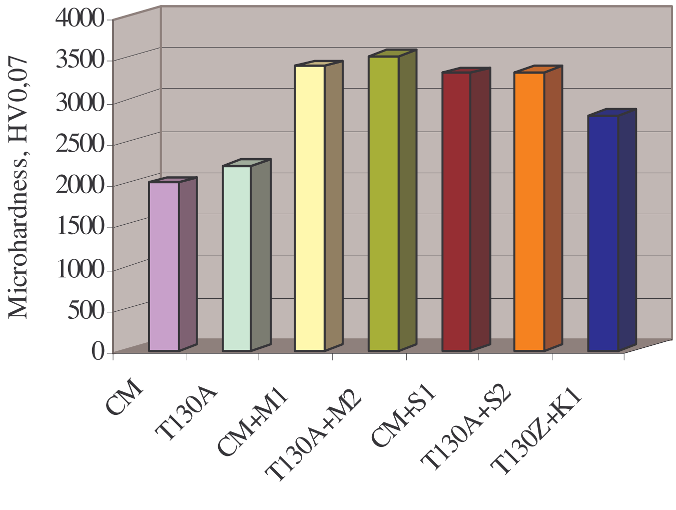


Fig. 3 The HV $_{0,07}$ microhardness values for substrate and coating surfaces

Basing on the micro-hardness tests it was found out that the micro-hardness of the uncoated CM and T130A cermets was 2450 and 2500 $HV_{0,07}$ respectively. Depositing the TiN+TiAlSiN+TiN coating onto the cermet substrate results in the significant surface hardness increase within the range of 3100-3330 $HV_{0,07}$. The observed hardness increase of the surface layer, compared with the hardness of substrate with no coating is about 50%. In case of the TiN+multiTiAlSiN+TiN coatings a significant increase of the surface layer was also observed. Hardness of the TiN+multiTiAlSiN+ TiN coating is 3200-3520 $HV_{0,07}$. No relationship was found between the substrate hardness and hardness of the deposited surface layer.

The critical load values L_c (AE) were determined using the scratch method with the increasing load, characterizing adhesion of the investigated coatings to the cermet substrate. It was found out in case of the TiN+TiAlSiN+TiN coating that the critical load values of L_c=131,2 N and L_c=114,8 N are displayed by a coatings put down on tool cermet, for the CM and T130A types respectively. Similar relationships were observed in case of the TiN+multiTiAlSiN+TiN coating. For the CM type cermet the value of L_c=120,9 N was found out, and for the T130A type cermet L_c=114,8 N was obtained. In case of the commercial coatings deposited onto the T120Z cermet value of L_c=57,27 N was obtained.

In case of the TiN+multiTiAlSiN+TiN and TiN+TiAlSiN+TiN coatings deposited on the CM and T130A type cermets it was observed that the first coating failure symptoms are the conformal cracks resulting from tension, turning into single spallings located at the bottom of the developing crevice and in the coating-crevice contact zone. Chipping and spalling failures develop in the central zones of the crevices and at their edges in the form of the fine arc-shaped craters. Similar effects are observed at the edges in the ending part of the crevice (Fig. 6). Single failures are often connected forming bands of the local coating delamination, not more. In all examined cases, even at the biggest loads, total delamination never occurs for any of the investigated coatings. (Fig. 5).

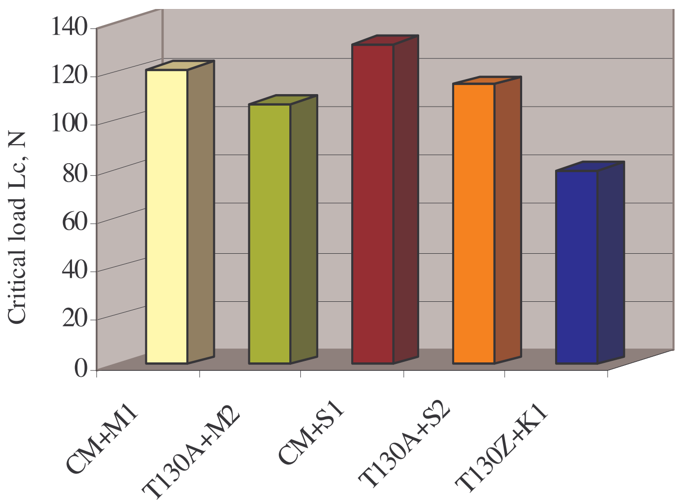


Fig. 4 Critical load Lc [N] values for the particular coatings

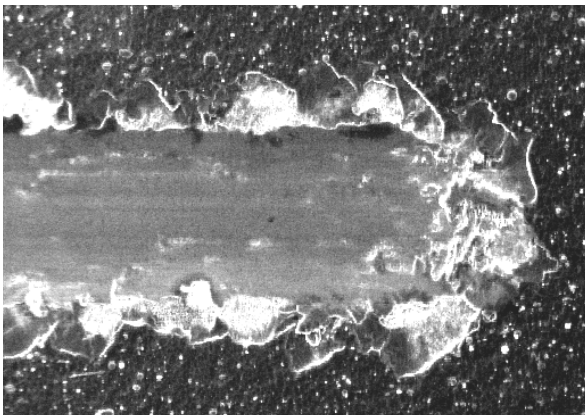


Fig. 5. Indenter trace with the maximum load on the TiN+multiTiAlSiN+TiN coating surface deposited onto the T130A type tool cermet

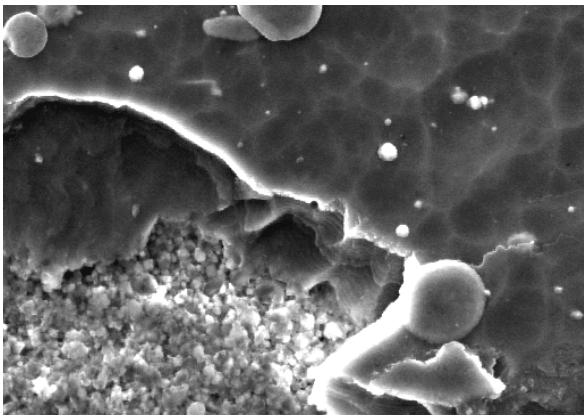


Fig. 6. Characteristic failures of the TiN+multiTiAlSiN+TiN coating deposited onto the T130A type tool cermet

It was found out, basing on the turning tests carried out with the tool cermets, that a clear anti-wear effect of the TiN+multiTiAlSiN+TiN and TiN+TiAlSiN+TiN coatings on the cutting inserts' life was demonstrated (Fig. 7). In case of cutting inserts with the TiN+multiTiAlSiN+TiN coating put down, for the following turning parameters: cutting speed $v_c = 400$ m/min, feed f = 0,1 mm/rev, depth of cut $a_p = 1,0$ mm, it was observed that the longest tool life was obtained for the CM type cermet, for which the VB= 0,2 mm tool flank wear land width criterion values were exceeded after 60 minutes of continuous turning, and for the T130A type cermet this criterion was reached after 43 minutes. A similar ranking was obtained in case of cutting inserts with the TiN+TiAlSiN+TiN coating put down. For the following cutting parameters: cutting speed $v_c = 400$ m/min, feed f = 0,1 mm/rev, depth of cut $a_p = 1,0$ mm, it was observed that that the longest tool life was obtained for the CM type cermet, for which the VB= 0,2 mm tool flank wear land width criterion values were exceeded after 55 minutes of the experiment duration, whereas for the T130A type cermet after 43 minutes. The comparative tests of the uncoated cermet inserts carried out in the same cutting conditions revealed that the longest life was obtained for the CM type cermet, for which the VB= 0,2 mm tool flank wear land width criterion value was exceeded after 17 minutes of continuous turning, whereas for the T130A type cermet the tool flank wear land width criterion value was exceeded after 14 minutes of cutting at the cutting speed of $v_c = 400$ m/min. Comparative tests of the commercial multi-point inserts made from the tool cermets coated in the PVD process, carried out in the same cutting conditions revealed that the longest tool life was for the T130Z type cermet, for which the VB= 0,2 mm tool flank wear land width criterion value was exceeded after 35 minutes of continuous turning.

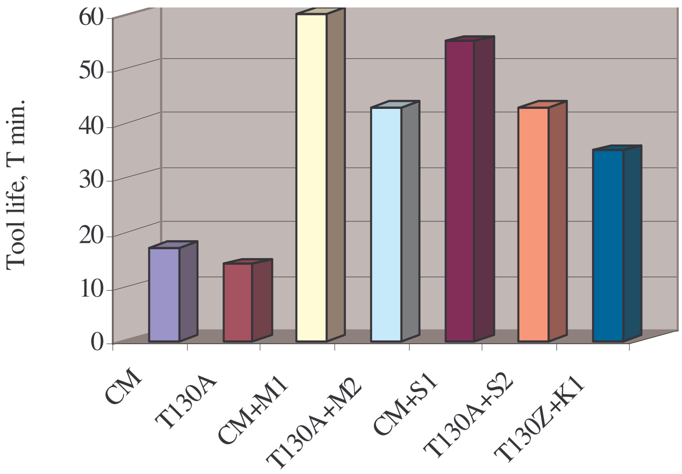


Fig. 7 Tool life T [min] for the particular coatings

4. CONCLUSIONS

It was found out, basing on the metallographic examinations that the TiN+multiTiAlSiN+TiN and TiN+TiAlSiN+TiN coatings deposited onto the tool cermets in the cathodic arc evaporation (CAE) have the laminar packing, poreless structure and adhere closely to each other, and the entire coatings have very good adhesion to the cermet substrate. In all investigated cases of adhesion, total delamination never occurred for any of the investigated coatings, even at the highest load. The technological turning tests of cutting ability of the C45E steel reveal that the cermet multi-point inserts with the TiN+multiTiAlSiN+TiN and TiN+TiAlSiN+TiN coatings put down, are characterized by the significantly better wear resistance compared to the uncoated commercial multi-point inserts and with the commercial coatings of the TiN+TiC+TiN type. The TiN+mono or multi TiAlSiN+TiN system coatings deposited with the CAE method onto the cermet substrate qualify for the widespread industrial use on cutting tools and offering the possibility to use them in the pro-ecological dry cutting processes without the use of the cutting fluids and in the *„Near-Net-Shape"* technology.

REFERENCES

1. L.A. Dobrzański, E. Hajduczek, J. Marciniak and R. Nowosielski, Metal Science and Heat Treatment of Toom Materials, WNT, Warsaw, 1990 (in Polish).
2. L.A. Dobrzański, K. Gołombek, J. Kopač and M. Sokovič: "Properties of the cemented carbides and tool cermets coated with hard surface layers", 16th Brazilian Congress of Mechanical Engineering "COBEM'01", Sao Paolo, 2001, Brazil, CD-ROM.
3. W. König and R. Fritsch: Surf. and Coat. Tech., 68-69 (1994), 747.
4. M. Soković: Structure and properties of the TiN and TiZrN PVD-coated tool cermets, PhD thesis, unpublished, Main Library of the Silesian University of Technology, Gliwice, 1997.
5. H.K. Tönshoff and C. Blawit: Surf. and Coat. Tech., 93, 1997, 119.
6. M. Wysiecki: Contemporary Tool Materials, WNT, Warszawa, 1997 (in Polish).