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STUDY OF PEELING WITH Cr_xN COATED STEEL KNIVES

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The subject of the examination were tribological behaviour and wear of steel knives during peeling of beech wood and the effect of the tools surfaces modification with Cr_xN thin layer onto these properties. Cr_xN layers were deposited with the use of triode reactive cathode sputtering method. Chemical content of the deposit was estimated using EDS method and its phase content was determined using XRD method. The experiment was conducted on home-made peeling laboratory Micro-lathe apparatus. The friction coefficient was measured in situ.

The reduction of the cutting edge was measured with an optical microscope perpendicularly to the clearance face along cutting edge from a base line.

Key words: PVD, Cr_xN, knife, wood peeling, wear resistant, industrial applications

INTRODUCTION

Modification of metal-cutting tools surfaces based on covering them with CrN coating improves their life (Navinsek, Panjan and Milosev 1997). All attempts to employ antiabrasive materials, which are applied with the very good results in metal cutting, for wood cutting are facing unexpected difficulties caused by wood tribological properties. Wood shows a high friction coefficient value with tools' materials and antiabrasive coatings, which amounts to about 0.75 for dry wood and 0.31 for wet wood (normal force = 39N, sliding speed = 1 m/s) (Beer, Miklaszewski and Sokołowska 1996, Beer et al. 1997).

For the experiment we have chosen the peeling process during which the tool works under respectively mild conditions from the mechanical point of view (heat-treated wet wood, cutting in tangential direction) but in difficult conditions from the corrosive environment point of view. Nevertheless, some of the hard coatings, verified in the peeling process, have not raised the tools lifetime (Beer et al. 1997).

The aim of the study was to examine how a modification of the Cr_xN coating affects knives edge wearing phenomena in wood peeling process.

EXPERIMENTAL

The low alloy steel is commonly used for producing the cutting tools for peeling lathes. The tempering temperature of this steel is as low as 200-300°C and raises severe problems when subjecting its surface to modifying treatments, which usually require a temperature >500°C. That is why the presented study has been conducted with the deposition method that enable a comparison examination of low alloy steel, high speed steel (tempering temperature 500-600°C) and those steels modified with Cr_xN coating.

The cutting tools used in the experiments were made of:

- 60SMD8 low alloy steel (57-59HRc) commonly used for producing the cutting tools for peeling lathes, which is composed of: C-0.6, Si-1.8, Mn-0.7, Cr-0.3, Mo-0.5, V-0.2.
- Z90WDCV high speed steel (64-66HRc), which is composed of: C-0.9, Si<0.4, Mn<0.4, P<0.03, S<0.03, Cr-4.1, Mo-5.0, W-6.4, V-1.9.

Each of the knives had an edge angle of 20°.

The Cr_xN, coating has been deposited with triode reactive sputtering method (Fig.1) under optimised conditions (Beer et al. 1997, Beer et al. 1999): pressure= 0.5Pa, U target= 1500V, I target= 30mA, U anode=180V, I filament= 25A, temperature= <200°C. The gas composition has been changed: argon from 0 to 80% and nitrogen from 100 to 20%.

a) b)

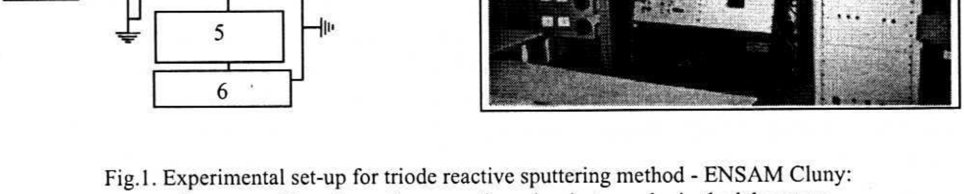


Fig.1. Experimental set-up for triode reactive sputtering method - ENSAM Cluny:
a- equipment and its schematic connections, b- photography in the laboratory
1- coils power supply, 2- target HT power supply, 3- anode power supply,
4- filament power supply, 5- impedance mismatch, 6- RF generator

Fig.1. Układ stanowiska doświadczalnego procesu reaktywnego rozpylania triodowego - ENSAM Cluny:
a- schemat, b- fotografia
1- zasilacz cewki, 2- zasilacz grzania podłoża, 3- zasilacz anody,
4- zasilacz włókna żarzonego, 5- sprzężenie, 6- generator w.cz.

The material subjected to the cutting experiments was beech wood (*Fagus sylvatica* L.) without defects, since, among various kinds of wood, it is relatively hard and homogeneous and thus permits comparative examinations.

The experiment was conducted on home-made peeling laboratory Micro-lathe apparatus (Butaud, Decés-Petit and Marchal 1995).

The cutting parameters for peeling beech wood were maintained constant in all the peeling operations: the linear cutting speed: 1m/s, the clearance angle: 1°, and the peeling thickness: 0.3mm.

The friction coefficient was measured on the base of "in situ" method with laboratory Micro-lathe apparatus (Butaud, Decés-Petit and Marchal 1995).

The reduction of the cutting edge is representative to the tool wear and it was measured with an optical microscope perpendicularly to the clearance face along cutting edge from a base line. The base line was led through the part of the edge which did not take part in the cutting process. The mean value of the reduction for each sector of the cutting path was calculated from 50 measurements taken 350μm apart each from other. This way of measurement of the cutting edge reduction is commonly used in cutting wood analysis (there is no ISO standard).

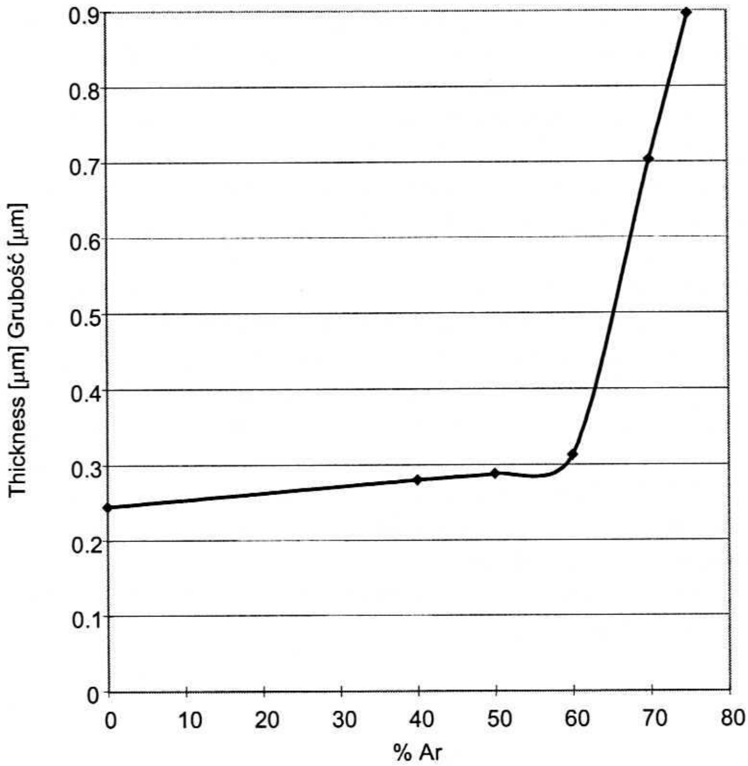
Chemical content and phase composition of the deposited layers was estimated using EDS and XRD measurements.

RESULTS

In the beginning of this study we have deposited Cr_xN films by using 100% nitrogen plasma discharge, the deposition rate was relatively low 0.2-0.3 μm/h. In order to increase this deposition rate a mixture of argon and nitrogen was used. It can be seen in Fig 2-a. The deposition rate increases slightly with argon concentration in the discharge but after a threshold value of 60% this increase became very high and at 75% of argon concentration the deposited rate is multiplied by a factor of 4. Therefore we have applied the mixture of 75% Ar and 25% N_2 for the deposition of layer. Figure 2-b presents the thickness of Cr_xN layer versus the deposition time under mentioned above conditions and at 75% of argon in the discharge. The thickness of the coating is proportional to deposition time, which enables to control coatings thickness and the deposition rate is in the order of 1 μm/h which is more compatible with industrial applications The layers' thickness was 0.6 μm on 60SMD8 steel and 1.6 μm on Z90WDCV steel.

The composition of the films done by EDS shows (Fig.3) that we have twice amount of chromium than nitrogen (probably due to the effect of argon sputtering) and the deposited films are a mixture of Cr and Cr_2N rather than CrN (Fig.4). This was confirmed by the XRay diffraction investigations.

a)



b)

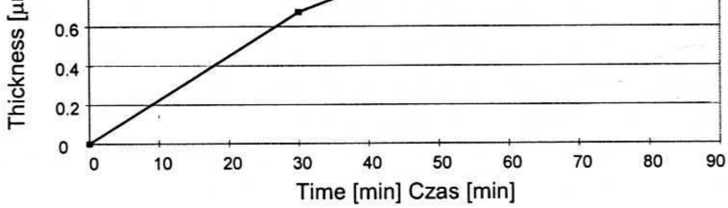


Fig.2. Thickness of Cr_2N films versus Ar% and deposition time: a- deposition conditions: target voltage 1500V, target current 40mA at constant time 45min, b- deposition conditions: target voltage 1500V, target current 40mA, at 75%Ar and 25 %N_2

Rys.2. Zależność grubości warstwy Cr_2N od zawartości Ar% i czasu nanoszenia: a- warunki nanoszenia: potencjał podłoża 1500V, prąd podłoża 40mA, stały czas 45min, b- warunki nanoszenia: potencjał podłoża 1500V, prąd podłoża 40mA, 75%Ar i 25%N_2

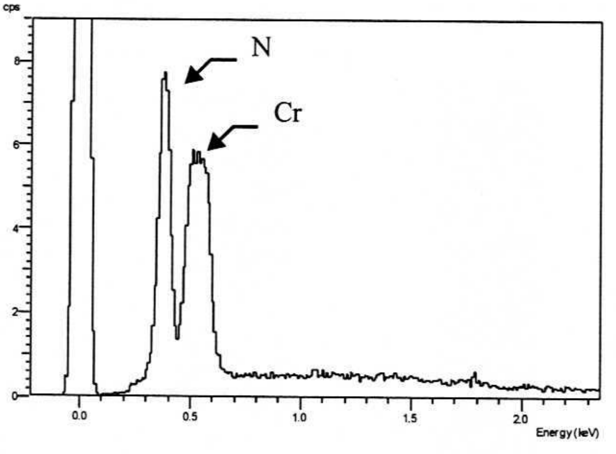


Fig.3. EDS spectra of Cr_2N(5kV) film: N=33.9%, O=6.4%, Cr=59.7%
Rys.3. Widmo EDS warstwy Cr_2N(5kV): N=33,9%, O=6,4%, Cr=59,7%

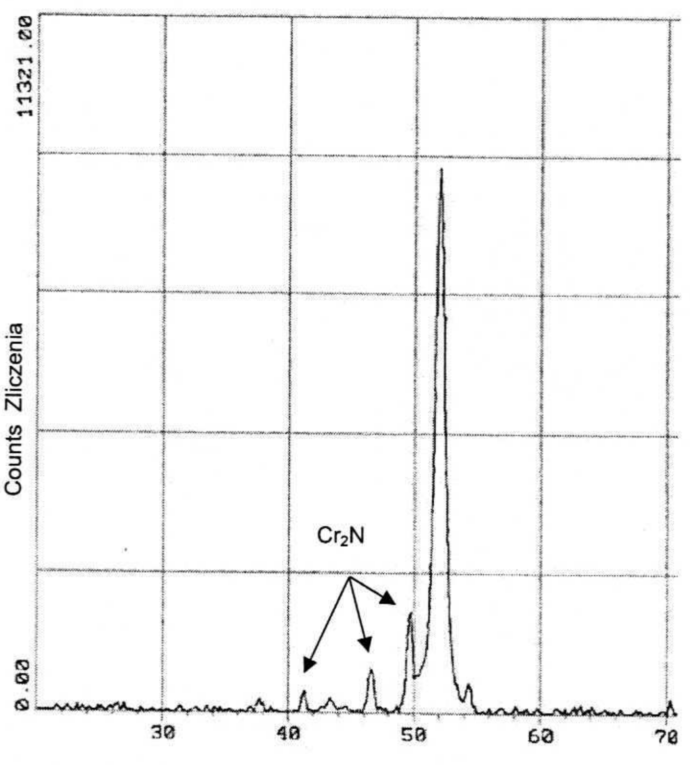


Fig.4. XRD spectra of Cr_2N film
Rys.4. Widmo XRD warstwy Cr_2N

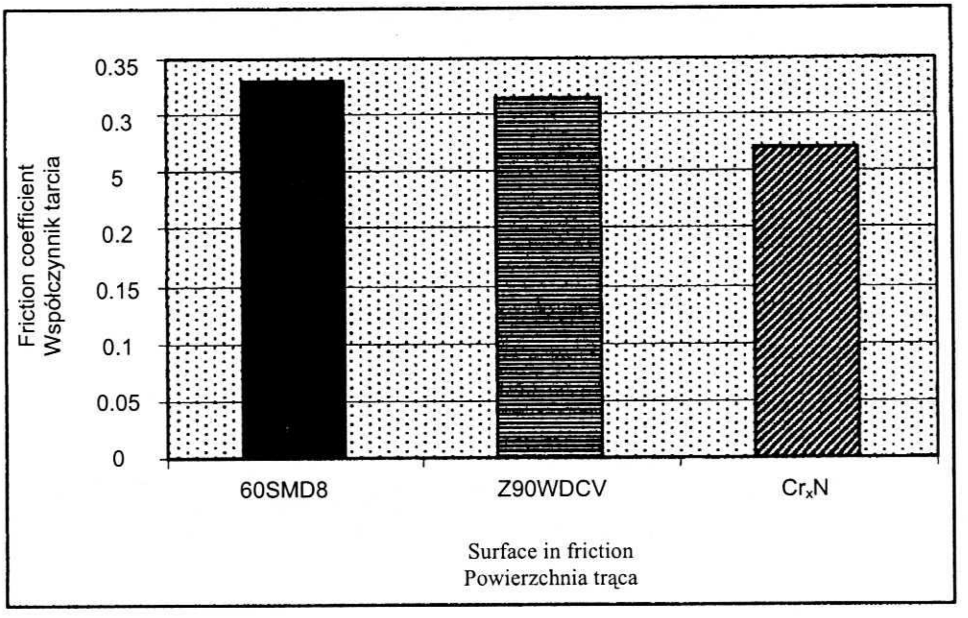


Fig.5. Values of the friction coefficient for steels and Cr_xN with wet beech wood (each value is a mean of 12 groups of more than 1000 measurements)
Rys.5. Współczynniki tarcia styków stali i Cr_xN z wilgotnym drewnem bukowym (każda wartość jest średnią 12 grup zawierających więcej niż 1000 pomiarów)

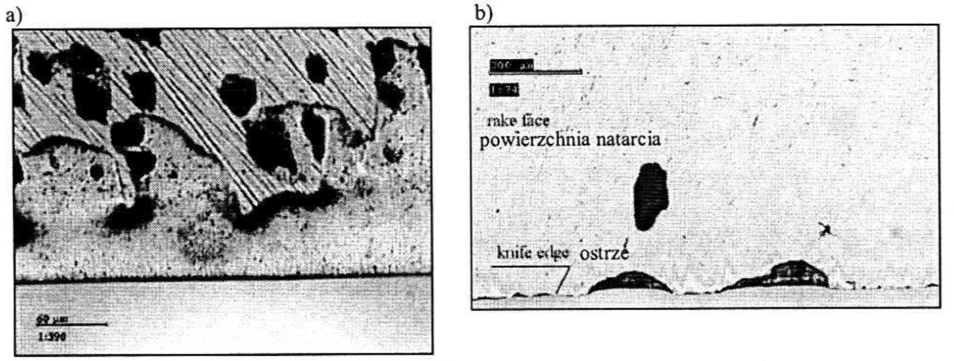


Fig.6. Photographs of the rake faces of the Cr_xN coated knives after 4000m of the cutting path: a- Cr_2N on the 60SMD8 steel, b- Cr_xN on the Z90WDCV steel
Rys.6. Fotografie powierzchni natarcia noży pokrytych Cr_xN po 4000m drogi skrawania: a- Cr_2N na stali 60SMD8, b- Cr_xN na stali Z90WDCV

Friction coefficient of Cr_xN coating with wet beech wood was lower than the friction coefficient with 60SMD8 and Z90WDCV steels (Fig.5). It was also lower than friction coefficient of wood with other well known antiabrasive coatings, i.e. TiN, (Ti,Zr)N, W-C:H(DLC) and nitrided steel (Beer, Miklaszewski and Sokołowska 1996, Beer et al. 1997).

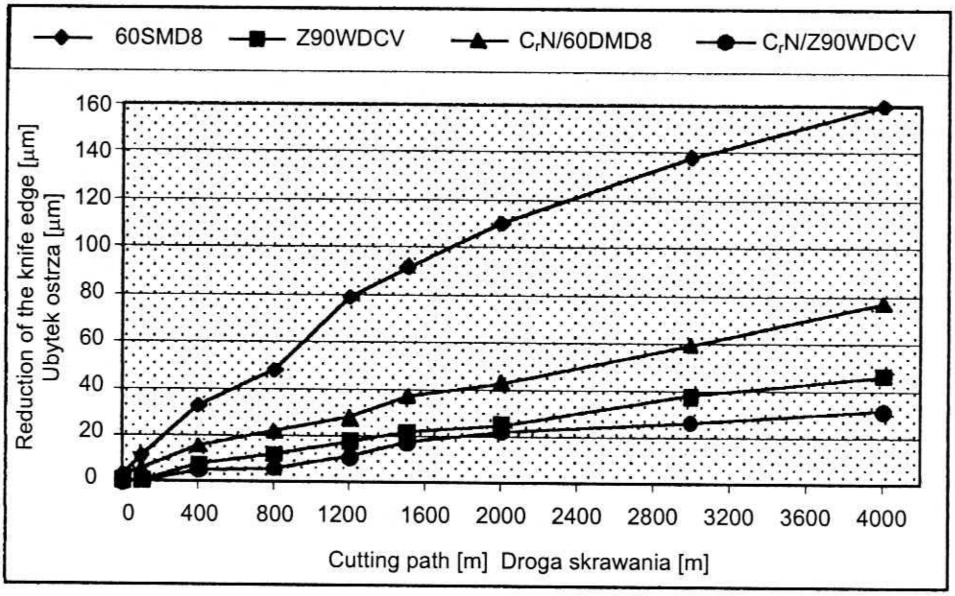


Fig.7. The reduction of the knife edge versus the cutting path
(each of the point represents mean value of 50 measurements)
Rys.7. Zależność ubytku ostrza noża od drogi skrawania
(każdy punkt odpowiada średniej wartości 50 pomiarów)

The Cr_xN coating remained on the knife edge surface even up to 4000 m of cutting path, which is shown on the photographs on the Fig.6.

Figure 7 shows the results of investigations of wear resistance of 60SMD8, Z90WDCV steel and both steels covered with Cr_xN layer. The Cr_xN coating lengthens the time of reduction of the knifes' edges. In the region of the experiment conditions, the tools' life has been raised 3 times. The difference between Z90WDCV and 60SMD8 steels is obvious for the steels differ in their structure. The improvement of the 60SMD8 due to covering is higher than in the case of Z90WDCV approximately twice.

The differences of blunting process between low alloy steel and Z90WDCV (about 75% lower edge reduction of Z90WDCV knife) permits some examinations provided to this direction of research in spite of some technological problems with its heat treatment, when the long knives for wood peelers are taken into the consideration.

RECAPITULATION

Layers of Cr_xN deposited with the use of reactive triode sputtering revealed exceptional adhesion to the steel and wear resistance during wood peeling in comparison with other obviously known antiwear coatings like TiN, ZrN deposited with the use of vacuum arc method.

It seems that good mechanical properties of Cr_2N (especially hardness) as well as method of its deposition both are responsible for the good results. The good adhesion of the layers obtained during deposition on a surface at a respectively low temperature (<300°C) is very remarkable.

Improving tool life obtained as a result of Cr_xN coating is worth of technical application and the knowledge and experiences gained will serve in application of hard coatings in another wood processing like routing, planning, shaping.

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REFERENCES

Beer P., Djouadi M. A, Marchal R., Lambertin M., Grobelny T. (1997): The influence of knife modification by CrN on peeling and knife wearing process. Proceeding of the 3rd International Conference on the Development of Forestry and Wood Science/Technology, Belgrad & Mt. Goc, Serbia/Yugoslavia: 714- 721.

Beer P., Djouadi M.A., Marchal R., Sokołowska A., Lambertin M., Czyżniewski A., Precht W. (1999): Antiabrasive coatings in a new application – wood rotary peeling process. Vacuum 53: 363-366.

Beer P., Marchal R., Butaud J-C., Sokołowska A., Lambertin M., Miklaszewski S. (1997): Analysis of the rotary peeling of beech wood using tools covered with antiabrasive coatings. Proceeding of 13th International Wood Machining Seminar, UBC Vancouver, Canada: 699-707.

Beer P., Miklaszewski S., Sokołowska A. (1996): Współczynnik tarcia między drewnem a stałą narzędziową pokrytą różnymi powłokami antyściernymi. Proceeding 10 Konferencja Naukowa Wydziału Technologii Drewna SGGW. Warszawa: 239-248.

Butaud J.C., Decés-Petit C., Marchal R. (1995): An experimental device for the study of wood cutting mechanisms: the microlathe. Proceeding of the 12th International Wood Machining Seminar, Kyoto, Japan: 479-485.

Navinsek B., Panjan P., Milosev I. (1997): Industrial applications of CrN (PVD) coatings, deposited at high and low temperatures. Surface and Coatings Technology 97: 182-191.

BADANIA PROCESU SKRAWANIA OBWODOWEGO NOŻAMI STALOWYMI MODYFIKOWANYMI WARSTWAMI Cr_xN

Streszczenie

Jako cel badań przyjęto określenie wpływu powierzchniowej modyfikacji narzędzi na ich tępienie się w procesie skrawania drewna na laboratoryjnej skrawarce obwodowej.

Nożom wykonanym z francuskiej stali niskostopowej 60SM08 i szybkotnącej Z90WDCV nadano kąt ostrza równy 20^0, a na ich roboczych powierzchniach osadzono trudnościerne warstwy z Cr_xN.

Warstwy Cr_xN wykazały dobrą adhezję do podłoża oraz odporność na ścieranie podczas obróbki drewna. Modyfikowane noże po wykonaniu drogi skrawania 4000 m wykazały mniejszy o 52% ubytek ostrza w porównaniu z nożami niemodyfikowanymi.

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