CHIP AND CHIPLESS WOODWORKING PROCESSES, 11(1): 59–64, 2018
Zvolen, Technical University in Zvolen, ISSN 1339-8350 (online), ISSN 2453-904X (print)

WEAR OF THE ZrC AND ZrC/Ni-ULTRADISPERSE DIAMONDS COATED EDGES KNIVES OF WOOD-CUTTING TOOL

Vadzim Chayeuski[1] – Valery Zhylinski[1] – Andrey Kuleshov[2] – Pavel Rudak[1] – Štefan Barcík[3]

Abstract

In this work, laminated chipboards milled by a tool with knives were coated with ZrC and ZrC/Ni-nanodiamond (ultradisperse diamonds (UDD) layers. ZrC- and combined ZrC/Ni-UDD-coatings were synthesized on the surface of hard alloy tungsten carbide WC – 2 wt.% Co knives by electroplating as well as combined electroplating and cathodic arc physical vapour deposition (Arc-PVD) techniques. The wear of coated knives edges was investigated. Intensive abrasive wear of tool knives occurred. The wear intensity of the knife edges with deposited coatings was reduced. Knife edges with ZrC-coating are more wear resistant than cutter edge coated with combined ZrC/Ni-UDD. The value of wear of knife edges with coatings was calculated. If compared with bare tool, the wear of ZrC-coated edges is 1.3 times less.

Key words: *cutting tool, knives, wear, coating, nanodiamonds*

INTRODUCTION

Durability and reliability of cutting tools of modern equipment in the woodworking industry is one of the main conditions for the effectiveness of its work. The level of resistance and reliability of the cutting tool is determined primarily by the characteristics of the physical and mechanical properties of the tool material. When cutting composite materials on a wood basis (laminated chipboards, laminated plastics, glass fiber, etc.), the action of the abrasive-containing particles included in their composition, having a hardness commensurate with the hardness of the tool material, leads to an increase in the friction forces on the back surface of the cutter and to more intense abrasive wear of the contact surfaces of the tool [1]. Increasing the wear resistance of surfaces using special coatings, including composite electrochemical coating (CEC), which show high physical, mechanical and electrochemical properties [2], is still one of the most effective methods to improve the functional and operational characteristics of products and parts for various purposes. The use of ultradisperse diamonds (UDD), produced by detonation of explosives, as a composite material in electrochemical and chemical metal-diamond coatings also leads to an increase in their wear resistance, significant adhesion, a sharp decrease in the coefficient of friction [3]. It was found that the combined

[1]Belarusian State Technological University, 13a, Sverdlov str., 220006, Minsk, Republic of Belarus
[2]Belarusian State University, 4, Nezavisimosti ave., 220030, Minsk, Republic of Belarus
[3]Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovak Republic
e-mail: chaevskiv@gmail.com, zhilinski@belstu.by, kuleshak@bsu.by, RudakPV@belstu.by, barcik@tuzvo.sk

ZrN-Ni-Co-coatings formed by galvanic method and the method of cathodic arc physical vapour deposition (Arc-PVD) on the blades of steel knives of the tail mills provide an increase in the resistance period of the cutting tool [4] when cutting materials from laminated chipboards and softwood.

In this regard, the aim of this work was to form by Arc-PVD and electroplating methods gradient ion-plasma and galvanic (based on UDD) coatings on the surface of blades of tungsten carbide WC of wood-cutting tool and explore the physical and mechanical properties (phase and elemental composition, wear resistance) of the cutting elements of the tool and formed layers.

MATERIALS AND METHODS

The materials used were substrate and UDD. The substrate was a hard alloy tungsten carbide WC – 2 wt.% Co knife made in Germany (Leitz company) [5]. When preparing samples, UDD nanopowders of the detonation synthesis (nanodiamonds) with a particle size 4-6 nm were used [6].

Ni-UDD composite electrochemical coatings were electroplated on the prepared surface of knives edges at direct current densities of 200–250 A/m^2 using sulphate-chloride electrolyte of nikel plating at the concentration of nanodiamonds in the electrolyte corresponding to 4.5 kg/m^3. The composition of electrolyte was following (kg/m^3): $NiSO_4 \cdot 7H_2O$ – 30; $NiCl_2 \cdot 6H_2O$ – 4; H_3BO_3 – 3. Before the deposition of Ni-nanodiamond coating the surface preparation of sample was carried by chemical degreasing at the temperature 333–353 K for 360–480 s, rinsing in hot (313–333 K) and cold (291–228 K) water, etching in solution H_2SO_4 (5–10 kg/m^3) with inhibitor at the temperature 291–298 K, cold rinsing, activation, and washing.

The ZrC-coating was deposited by the cathodic arc physical vapour deposition (Arc-PVD) method on the samples in two stages [7]. At first, the surface of specimens was treated with zirconium ions for 60 s at a negative bias of 1 kV, the cathode arc burning current of 100 A, and the vacuum in the chamber 10^{-3} Pa. This stage resulted in heating the substrate to 723–773 K prior to deposition. Then, coating was precipitated for 600 s at CH_4 pressure in the chamber was 10^{-1} Pa under a bias of -120 V.

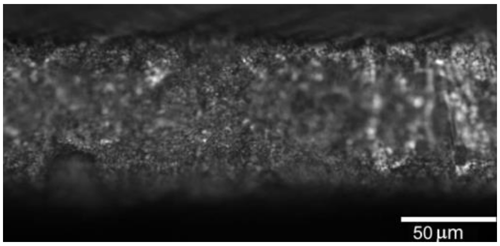
The prepared samples were characterized through X-ray diffraction (XRD) using Cu-K_α characteristic of X-ray radiation. The XRD measurements were performed by the Ultima IV diffraction meter (Japan). The microstructure of the coatings and the knife edges, and the surface morphologies of the coatings were analyzed for wafer surface samples and samples fracture, using scanning electron microscopy (SEM) equipped with energy-dispersive electron probe microanalysis (EPMA) by LEO-1455VP electron microscope (Japan).

The pilot tests of coated knives edges when milling laminated chipboard were carried out with the processing center RANC-330AE, using a mill with a diameter of $21 \cdot 10^{-3}$ m with mechanical fastening of the cutting element. Laminated chipboard with a thickness of $25 \cdot 10^{-3}$ m was milled. The computer numerical control (CNC) processing center is used at the following modes: the frequency of rotation of milling cutters – 200 s^{-1}; feed rate speed – 0.07 m/s; machining allowance – $5.0 \cdot 10^{-3}$ m/pass; average chip thickness at the contact arc – $0.15 \cdot 10^{-3}$ m. Appearance of defects on the treated surface was the criteria of losing the cutting ability of the cutting element.

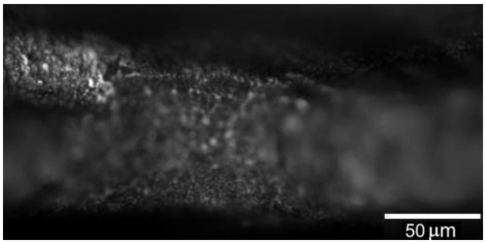
The volume wear of the knife edge after pilot tests was calculated by the method of determining the transverse dimensions of the knife edge along its entire length with the help of an optical microscope Microvert in 2 stages, taking into account the initial unworn blade sharpening angle [4]. To assess the wear of the edge of knives, taking into account large areas of destruction of the edge, mathematical processing of optical images of these areas was carried out.

RESULTS AND DISCUSSION

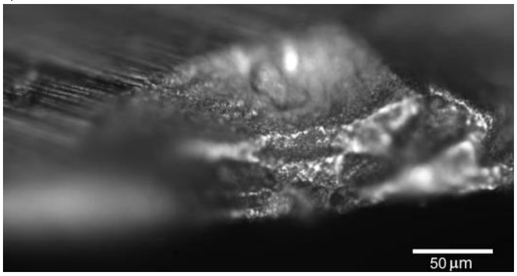
The process of cutting with modified cutters coated knife edges in industrial conditions was accompanied by intense abrasive wear of the milling tool. At the same time on the edges of knives there were numerous different size areas of destruction of the edges in the form of the remaining after tearing the base material (including coatings) recesses, voids, chips (Fig. 1-3), as well as abrasion of the knives edges (Fig. 3).



a)

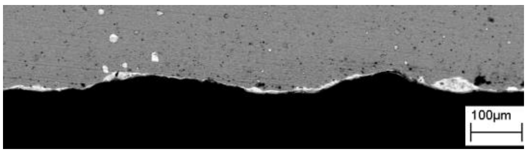


b)

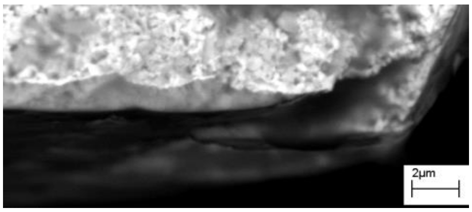


c)

Fig. 1. Optical images of the worn edge of the uncoated knife (a, b) and a large area of destruction of the knife with ZrC-coating (c)

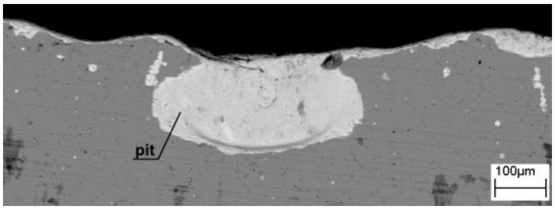


a)

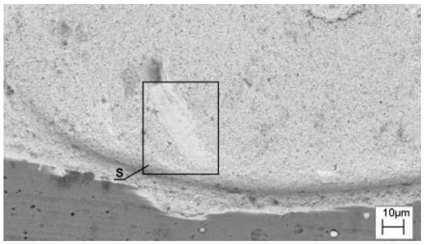


b)

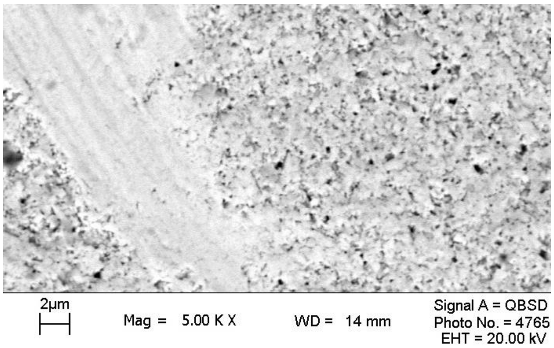
Fig. 2. SEM-images of the destroyed section of the knife edge with coating (a) and cleavage of the edge b)



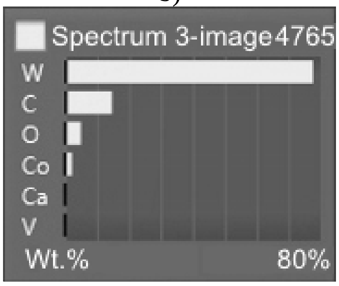
a)



b)



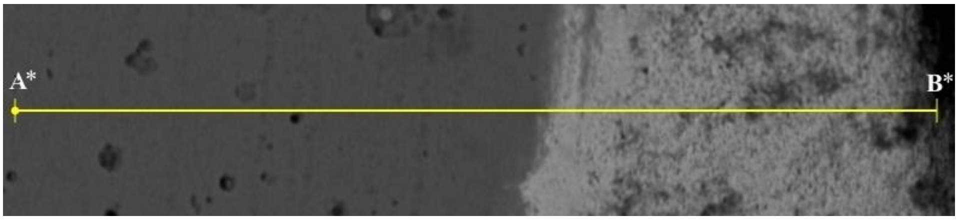
c)



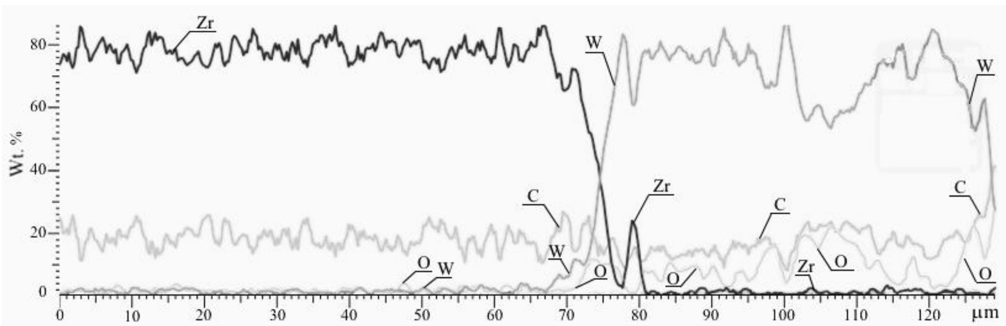
d)

Fig. 3 SEM-images of the destroyed section of the knife edge with tearing of the coating with the base, abrasion of the coating (a) and the selected fragment of the abrasion strip of the coating (b, c) with EPMA-determination of the elements on the strip (d)

For ZrC-coating deposited on a hard alloy knife edge, a fairly clear abrasion boundary is observed at distances up to ~50 µm from the edge tip (Fig. 4).



a)



b)

Fig. 4. SEM-image of the worn section of the knife edge with ZrC-coating (a) and the distribution of the concentration of elements along the A*B* line (b)

ZrC/Ni-UDD-coatings are characterized by a transition area of abrasion (up to ~100 μm), associated with the presence of a transition Ni-UDD-layer (Fig. 5).

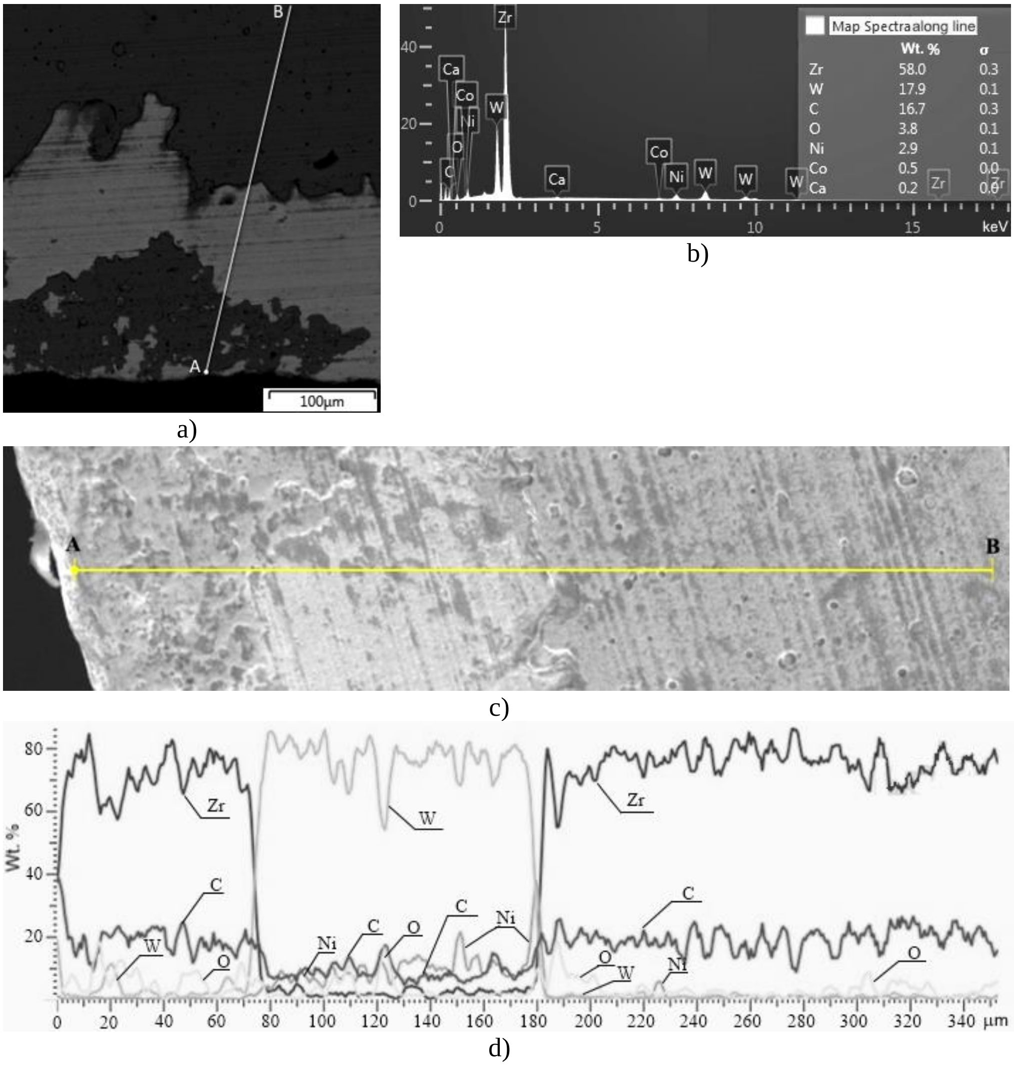


Fig. 5 SEM-images of the morphology of the worn section of the knife edge with ZrC/Ni-UDD-coating (a, c), the total spectrum (b) and the distribution of the concentration of elements along the line AB (d)

The calculated estimates of the volume wear of the knife edges after pilot tests of modified cutters (Table) indicate that the volume wear of the knife edges with ZrC-coating is reduced by more than 1.3 times compared to the bare edge knife. The volume wear of the knife edges with ZrC/Ni-UDD-coating is slightly reduced compared to the untreated tool. Optical images of the worn edge of the knife with ZrC- and ZrC/Ni-UDD-coatings confirm the calculations of volume wear and show that the degree of wear of the knife edges with ZrC-coating is less than in the case of the knife with ZrC/Ni-UDD-coating.

Table. Volume wear of knife edges modified by coatings after pilot tests of cutting laminated boards

Machining type	Volume wear, 10^7, [μm^3]
Bare edge knife	129.9 ± 0.9
ZrC-coating	93.6 ± 0.6
ZrC/Ni-UDD-coating	115.2 ± 0.8

CONCLUSION

We have selected the deposition modes and obtained Ni-UDD-CEC and combined ZrC/Ni-UDD-coatings on the knife edges of the hard alloy wood-cutting milling tool. It is shown that during the cutting of laminated chipboards in the pilot tests, untreated knife edges and knife edges with coatings experience intense abrasive wear. The wear of the knife edges with a ZrC-coating reduced in 1.3 times in comparison with untreated tool.

REFERENCES

1. Abrazumov V.V., Kotenko V.D., The analusis of the phenomena on contact surfaces of a cutting at cutting board wood composite materials, *Vestnik Moskovskogo gosudarstvennogo universiteta lesa*, *Forestry Bulletin*, 2006, no 6, pp. 138-141, in Russian.
2. Kubrak P.B., Drozdovich V.B., Zharski I.M., Chaevskiy V.V., Electrodeposition of Composite Coatings Containing Carbon-based Nanomaterials and Properties of Coatings Obtained, *Electroplating and Surf. Treat.*, 2012, v. XX, no2, pp. 43-49, in Russian.
3. Burkat G.K., Dolmatov V.Yu., Application of ultrafine-dispersed diamonds in electroplating, *Phys. Solid State*, 2004, v. 46, no 4, pp. 703-710.
4. Chayeuski V., Zhylinskiy V., Grishkevich A., Rudak P., Barcik Š., Influence of high energy treatment on wear of edges knives of wood-cutting tool. *MM Science Journal*, 2016, no. 6, pp. 1519-1523.
5. LEKSIKON Leitts: catalog firmy Leitz (LEKSIKON Leitz: Leitz Co. Catalog), on CD-ROM, Moscow, *Leitts Instrumenty*, 2011, in Russian.
6. Kononov A.G., Sachivko Ya.S., Korzhenevskiy A.P., Shtemplyuk R.G., Thermal stability of chromium coatings modified with nano-sized oxygen-containing additives, *Mechanics of Machines, Mechanisms and Materials*, 2015, no 4, pp. 353-357.
7. Kuleshov A.K., Uglov V.V., Rusalsky D.P., Grishkevich A.A., Chaevski V.V., and Haranin V.N., Effect of ZrN and Mo–N Coatings and Sulfacyanization on Wear of Wood-Cutting Knives, *J. Frict. Wear*, 2014, v. 35, no 3, pp. 201-209.