Quality Evaluation of the Coatings and Its Influence on the Wood Machining Tool Wear

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Coating of the tools for metal machining has been used for a long time, application of the coating to wood machining tools is not so explored. The aim of research in this area is to expand the possibilities of the using of PVD coatings in untraditional field at wood wool production in company, that thermo isolation and sound isolation plates manufactures. In the production of wood fibers by technology like planning, during the work the cutting edge of the knife is worn-down and the resulting product loses quality. Often grinding is required, knife dimensions are changed and lose its functional surface. The article is focused on the choose of the coating type on the base of input analysis of the tool material. Analysis is aimed to detection of the chemical content of elements, evaluation of the microstructure and mechanical properties. On the basis of the results, we proposed the type of coating applied to the sample and the tool. Coated sample was evaluated in terms of coating properties namely the thickness, tribological properties, chemical composition (EDX analysis) and microhardness. After the experiment, we have evaluated the state of cutting edge and compared it with the uncoated tool. The positive effect of the coating on the change of the cutting properties of the knife and the quality of the wood wool have been recorded.

Keywords: wood machining tools, coatings, life time, mechanical properties, microstructure

1 Introduction

Different types of material are processed in the wood industry, such as natural, molded, laminated and also agglomerated wood. Wood is unhomogeneous, its structure is irregular. When the workability of wood is assessed, the density is standard. This is a certain measure of wood hardness because the hardness of the wood is increases in proportionally to its density. Hardness is also changed with humidity and temperature it follows that cutting resistance is different at each moment. The past research of the use of coatings on woodworking tools has confirmed, the coatings in contact with wood the friction reduce. As a result, they also affect the cutting force and quality of the cutting surface [1]. Coatings on tools during metal machining greatly improve of the cutting parameters. This results in the stresses reduction in the contact area of tool with machined surface. The friction and temperature are decreased too, that affects the final quality of the machined surface. Further research has confirmed, by the application of coatings, the lifetime of metal cutting tools is increased a several times [2]. The properties of coatings depend on substrate purity, process parameter settings such as deposition temperature, pressure and gas ratio in the chamber, as well as current and voltage parameters on electrodes, as is reported by Jaroš, Sedlák et al. [3] Bakalová, Petkov et al. [4] in their works.

2 Material and methods

New PVD technologies ensure high wear resistance under high-speed machining conditions when cutting tool oxidation wear is dominant [5]. The major cause of the high wear resistance of TiAlN and nACo (nanocomposite) coatings during high-speed machining is the formation of the protective alumina films on the cutting tool surface [6]. Evaluation of some properties of the system

thin layer – substrate needs specific methods and procedures. The most important mechanical properties from the point of view of their application are hardness and the adhesion of thin coating to substrate. The deposited types of coatings increase hardness and elastic modulus of the base material and the substrate-coating interface was without failures, which safeguards excellent adhesion properties of the system. Due to their specific properties, the coatings appear suitable for use in practical operations [7]. However, metals, are more homogeneous in comparison with wood. There are water and organic acids in the wood, during woodworking process, corrosive tool wear exists. That phenomenon impacts on the adhesion of a complex coating - substrate. For wood machining tools the higher quality of coatings properties is required. Research is progressing in this area, in many works the authors state that coatings on nitride and diamond base improve performance, increase the life of tools made of high-speed or alloy tool steel in planning operations. However, the unforeseen reactions of wood during its machining limit the industrial use of coatings. These problems the automation of woodworking processes slow [8]. According to Labidi et al. not only the coatings, but also the nitriding of cutting edges increase the lifetime of cutting tools. CrN coatings, according to the authors, have increased tool life 5time, nitriding only 2time, which was found when beechwood is splited [9].

One of the specific areas of the research in our department is increasing of the lifetime of tools for manufacturing of the wood wool. The wood wool used for production of the plates for thermal and sound isolation, is made from soft wood. It has characteristic shape. There are the thin fibers with length of 150 to 200mm, width of 5mm as is seen in Fig. 1. Its quality is markedly influenced by the state of the chipping knife, that cuts a wood wool from a semi product. However, when a tool is very

worn out, the wool has not the required quality. The research presented in this article was initiated on the base of requirement of the praxes. By the increasing of the tool wear resistance it will be keep a good quality of the product longer time.
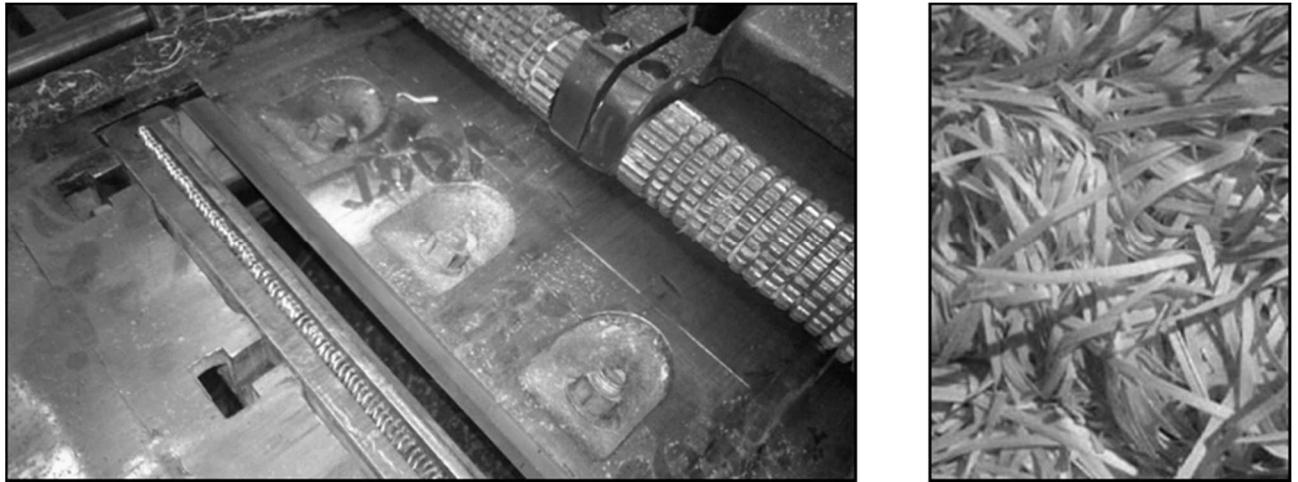
Fig. 1 Machine with mounted chipping knife and wood wool

Machine with the chipping knife, that was used for production of the wood wool in the company OP TIM Krupina is documented in Fig. 1. Based on the analysis of the chipping knife material properties, we have proposed application of the coatings to improve its functional properties. The damaged knife in Fig. 3 was produced in Germany several decades ago. After decommissioning, two damaged knives were after adaptation provided for the experiment. One of them was coated, the second was without treatment and they were tested in operation. In Fig. 4 we can see damaged knife in the cross-section, where is the thickness of peeled part. Damaged part of the knife (Fig. 2) was cut using WEDM technology. Subsequently, new cutting wedges of the required geometry were created.
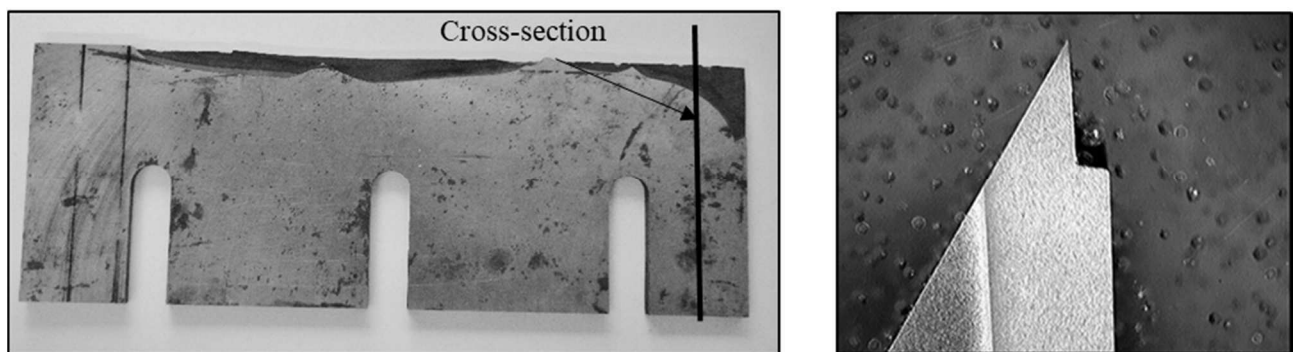
Fig. 2 Chipping knife with damage of the cutting part and cross-section of the cutting edge

One of the knives and the sample from tool were coated in the company Staton Turany with a CrN/TiN coating. Both, coated knife and the knife withour modification (Fig. 3) were mounted to the machine for production wood wool in the OP TIM Krupina.
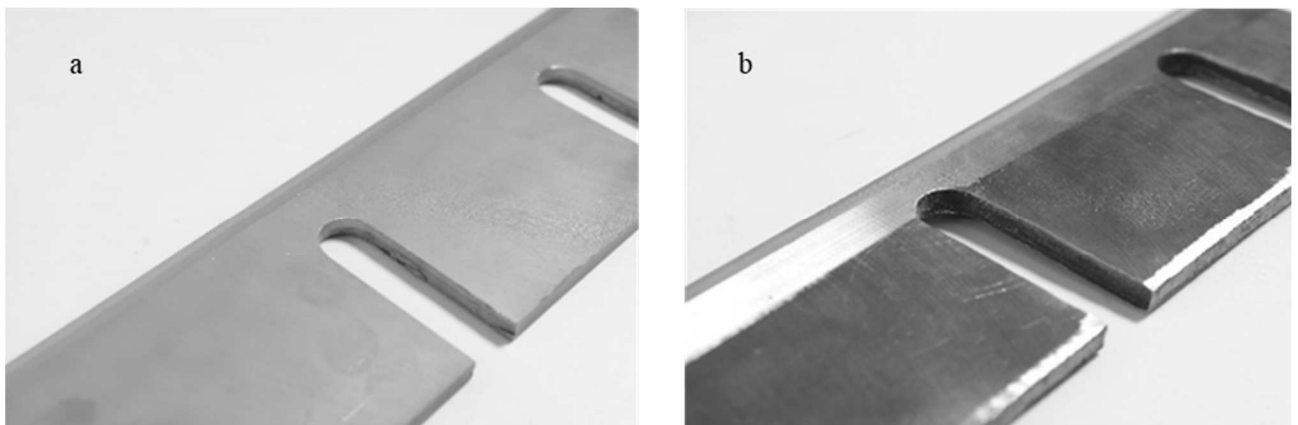
Fig. 3 Chipping knife used in experiment a) coated knife, b) uncoated knife

In operation simultaneously on two workplaces (at the same operating conditions) each have processed 75 pieces of the semiproduct. At the end of the experiment we have examined both knives. We have measured cutting edge wear, we have evaluated the quality of the machined surface on the semiproducts and the quality of the produced wood wool to determine the benefits of coating.

3 Experiment

From the damaged chipping knife, we have made the following input tests to determine of the material properties:

a) Hardness measurement
b) Spectral analysis
c) Microstructure of the material

Hardness measurement

We have measured the hardness according to the sketch as is seen in Fig. 4. At the front of the knife we found that from a cutting edge to the grooves for clamping into the machine, there is the zone with high hardness of 54÷57HRC.
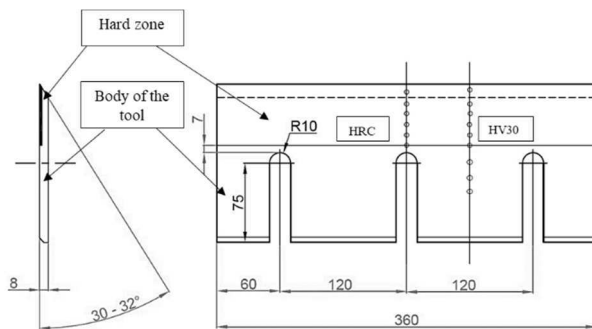
Fig. 4 *Sketch of the knife after adaptation with the points for hardness measurement*

Tab. 1 *Measured values of HV30 – body of the tool*

Measure-ment	Size of diagonal u[mm]	HV30
1	0.642	135
2	0.619	145
3	0.654	130
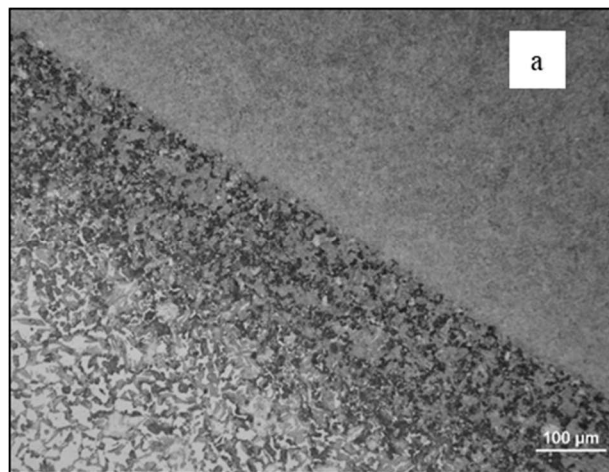
In the body of the tool, the HRC was not measurable, so we made repeatedly measurement with HV30 method according to STN EN ISO 6507-1:2006. The results are in Tab. 1 and Tab. 2.

From the values in Table 1 we can conclude the tool body is made of soft structural steel. There were no visible characteristic properties on the hard zone that we can help identify the production technology of tool.

Tab. 2 *Measured values of HV30 – hard zone of the tool*

Measure-ment	Size of diagonal u[mm]	HV30
1	0.284	690
2	0.282	700
3	0.274	740

Spectral analysis

Spectral analysis was performed on the device Belec Compact Port in HTS Vlkanová s.r.o. The results of the chemical analysis of material are in Tab. 3 and 4.

Tab. 3 *Chemical composition of the body knife in weight %*

C	Si	Mn	Cr	Mo	Fe
0.038	0.401	0.446	0.101	<0.010	Rest

Tab. 4 *Chemical composition of cutting part of knife in weight %*

C	Si	Mn	Cr	Mo	Fe
1.086	0.277	0.31	0.191	<0.010	Rest

From tables 3 and 4 it can be seen that the knife body and its cutting section have a different elemental content, in particular a significant difference in carbon content. This has led to the need to investigate the method of manufacturing these knives.

Microstructure evaluation – light microscopy

The sample was taken as a cross-section of the functional part of the knife, as is seen in Fig. 2. The sample was prepared by the standard methods, microstructure was etched by the 2% Nital.

Fig. 5 *Micrustructure of teh knife materiál a) the transition region from the body to the cutting part of knife b) microstructure of the body knife*

The hard zone of the knife (1%C) has a microstructure consisting of fine-grained high carbon martensite with a hardness of 54 to 57HRC (Fig. 5a). In martensite, fine globular carbides along the borders of the original austenitic grains are excluded, which may cause peeling on the cutting edge of the knife. The martensitic region is separated from the material of body knife by a sharp interface. There is a transition region that is coarser, with martensite and perlite content. The body of the tool has a coarse-grained ferritic-pearlitic structure with a higher ferrite part (Fig. 5b), as was confirmed by spectral analysis (less carbon than 0.1%). From this state it can be predicted, the microstructure could correlate to state after cementation, where the zone of knife with higher carbon content was inductively hardened.

4 Results

4.1 Coating design

According to the chemical composition of the knife (we supposed equivalent according to STN is steel STN 41 2020, according to DIN C15) was chosen CrN/TiN coating, but applicated at lower deposition temperature. In order to achieve optimal hard film properties, PVD coatings is needed to apply at temperatures up to 500°C. Company Staton Turany also produces CrN/TiN coatings by PVD method even at lower temperatures of approx. 200°C, but this is insufficient to achieve the optimal thickness and hardness of the coating. Manufacturers (Eifeler, Staton, IONBOND IHI Group) generally disclose the following coating properties:

CrN coatings are characterized by their high resistance to high temperature - the working temperature is up to 700□. They have high corrosion resistance, good adhesion properties, low internal stresses, it is possible to create thicker layers of 1-7µm. Temperature of deposition is 220□ to 480□. The coating is determined for milling, turning, drilling, tools for machining non-ferrous materials. The colour of the coating is metallic-silver.

TiN coatings based on titanium nitride, due to their properties, are the most commonly used. They have high chemical stability, which makes it possible to use it in the wood industry as well. These coatings are characterized by a high hardness of 24GPa. Maximum working temperature is about 500-600□, standard coating thickness is 1-4µm, even up to 7µm, colour gold [10].

4.2 Evaluation of coating quality - light and raster electron microscopy

The coated sample is shown in Fig. 6a, the knife with CrN/TiN coating that is determined for experiment is in Fig. 3a. The metallographic sample was prepared for evaluating of the coating parameters by the light microscopy as well as by the scanning electron microscopy (SEM). In Fig.7a is a microstructure of the soft part of knife with coating, that has a ferritic-pearlitic structure. The coating has the thickness of 1µm. In Fig. 7b is a CrN/TiN coating on the hard part of knife, thickness of the coating is cca1µm.
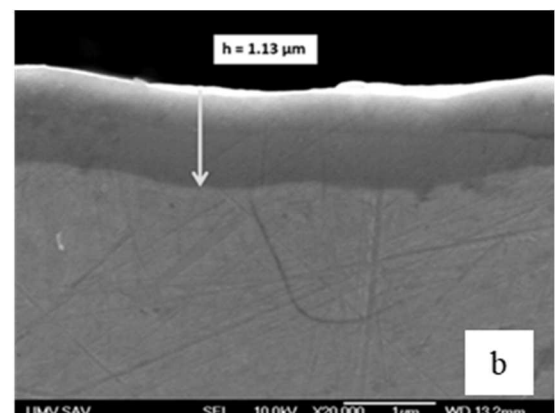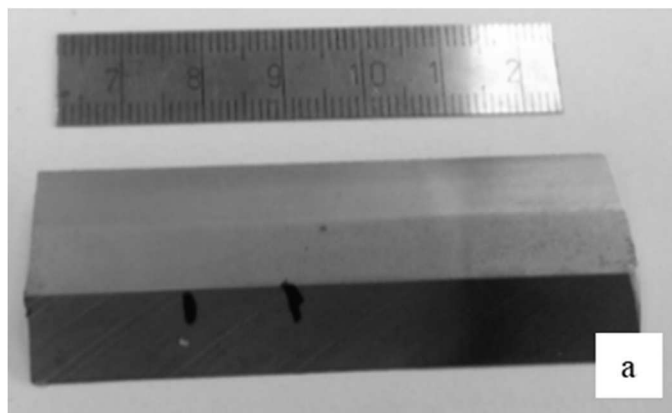

Fig. 6 a) coated sample – CrN/TiN, b) coating thickness – SEM
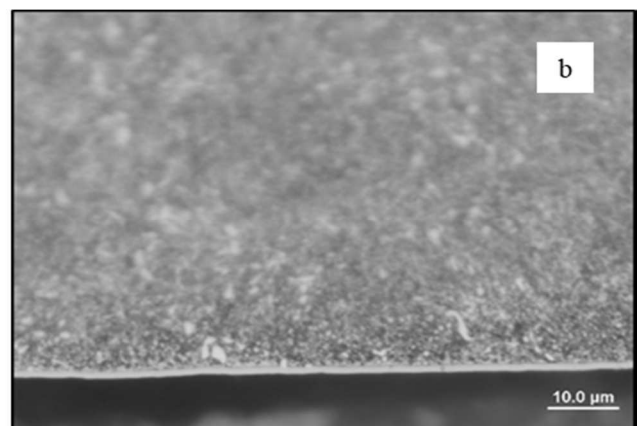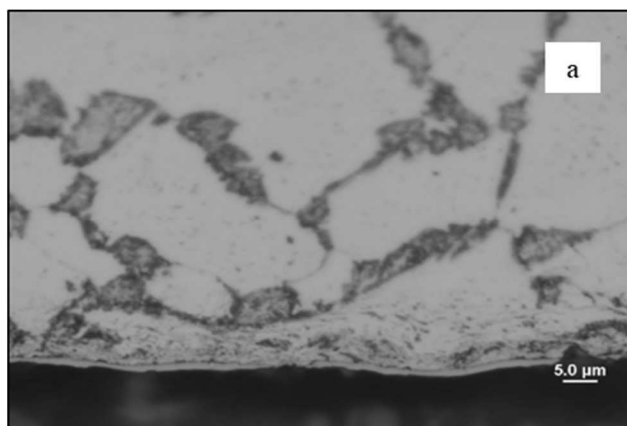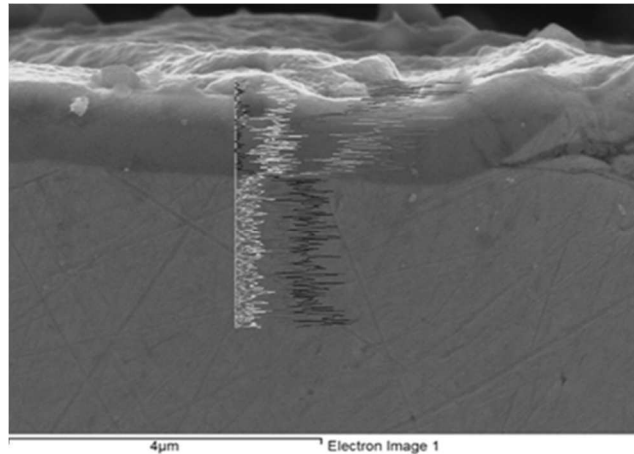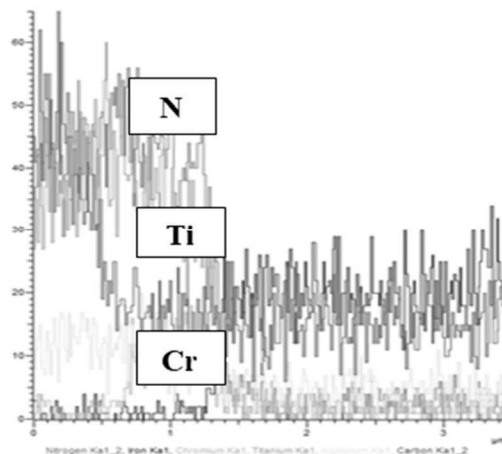

Fig. 7 Coating CrN/TiN on the of knife a) soft part, b) hard part

In Fig. 7b, the microstructure is no distinct because of limited possibilities of light microscopy when a very thin coating is documented (high magnification cause reducing the depth of acuity). The thickness of the CrN/TiN coating on the sample was then analysed on SEM (Fig. 6b). It reached only 1.13μm, because of deposition temperature was below the optimum value and was not sufficient to form a coarser layer, which may also affect other parameters of the applied layer.

4.3 SEM and EDX analysis of coating

In Fig. 8 is the result of EDX analysis of the coating and substrate. There is seen, as a first was applicate CrN layer as the second TiN layer.

Fig. 8 *Line EDX analysis of coating CrN/TiN with substrate*

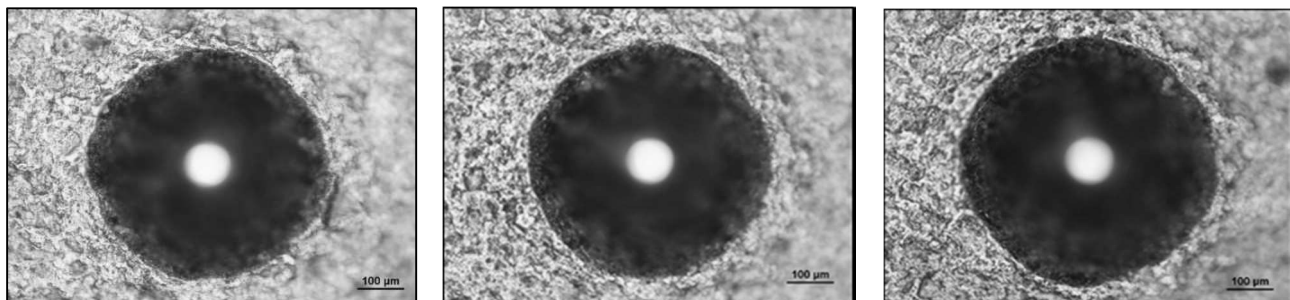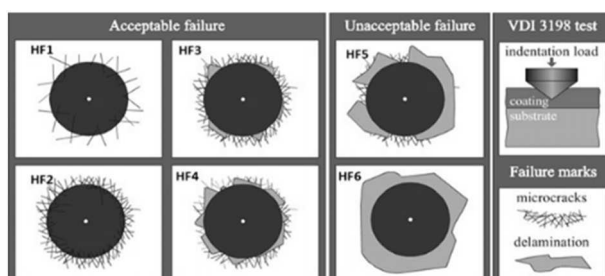### 4.4 The adhesive properties evaluation

By the HRC hardness tester an adhesion test of the coating was performed - Mercedes test [11]. The test is done by pressing a diamond cone under a load of about 1,500N. Under pressure of diamond cone, the stresses are generated in the interface of the substrate-layer. This effect is classified according to the shape and size of the cracks and the delamination of the coating layers. On the basis of morphology, the prints are divided into individual classes with the assignment of adhesion (A) and cohesive (K) numbers, which characterize the degree of layer damage (cracking and peeling), as shown in the works [12,13]. The test results are shown in Fig. 9, the surroundings of the footprint is no damaged, the adhesion properties are evaluated according to the etalon by the HF1(Fig. 10).


Fig. 9 *Results of the Mercedes test*

Fig. 10 *Etalon for evaluation of the adhesive properties*

4.5 Evaluating of the coating condition on the chipping knife after the load in service

In operation at OP TIM Krupina two knives were monitored under the same conditions: load time approx. 8 hours, number of processed of semiproduct - 75 pieces, that represents the length of the wood wool of about 8,500m. After removing the knives from the device, we assessed the condition of the cutting edge on the front and back surfaces (Fig. 11a, b).
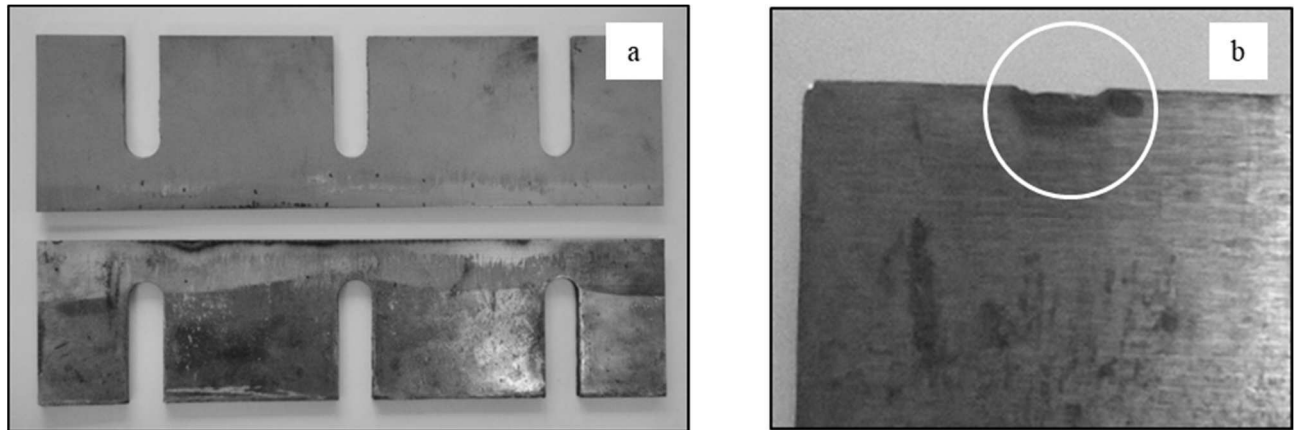
Fig. 11 a) Comparison of the state knives after experimental loading, b) Jagged cutting edge of the uncoated knife

On the chipping knives we also have measured cutting edge wear using a profile meter along the length of the edges. It was confirmed the knife with PVD coating has a less worn cutting edge than uncoated. As can be seen in Fig. 11a, the coated knife had a coating without damage the cutting edge, the uncoated knife has had coloured areas on the cutting edge with local overheating and there was jagged in the numerous places (Fig. 11b).

4.6 Quality evaluation of the wood wool

The wool produced by the coated knife have had white colour and optimal dimensions. The wool produced by the uncoated knife was coloured to the yellow colour (Fig. 12a). On the machined surface of the semiproduct there were marks after overheating of Fig. 12b. In terms of dimensions, the wool contained many smaller fractions.
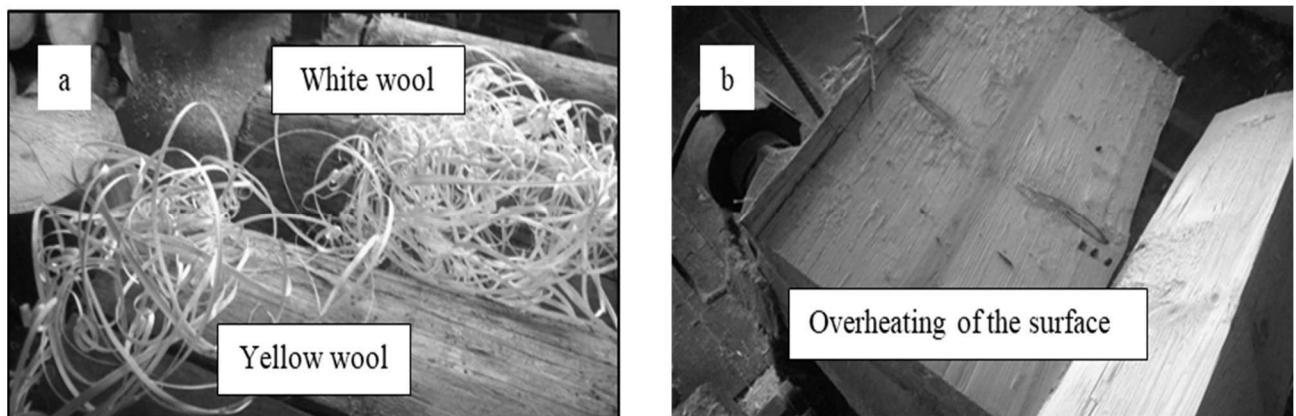
Fig. 12 a) Comparison of the wood wool colour b) Cut surface after cutting by the uncoated knife

5 Conclusion

In the experiment we used treated old discarded tools, which were made by lesser-known technology for us. At complex analysis of these tools we have found at the front of the functional surface, the chipping knife have had a zone with high hardness (54-57HRC) in area of about 10mm from the clamping grooves to the cutting edge (Fig. 7). This area gradually became less because of grinding the tools after 8 hours of operation. The tool has been decommissioned when they by grinding removed the hard part of the knife. Chemical analysis showed a significantly higher carbon content in this tool area, we can suppose the tool has been cemented and inductively hardened. (Fig. 8a).

The use of the CrN/TiN coating on tools for described woodworking technology resulted in a significant increasing of the resistance against thermal influence so abrasive wear of the cutting edge too. Uncoated tool has been worn on the front and back side of cutting edge, it has been jagged at numerous places (Fig. 16b). This was reflected also in a quality of the cut surface of the semiproduct, on the colour and size of the wood wool (Fig. 17a and 17b). The coating on the back of the cutting edge was slightly damaged. The product has had until the end of the experiment a good quality.

This research has confirmed the benefits of coating for increasing of the lifetime tools used in specific operations such as chipping and planning associated with impact load of functional knife surfaces, as reported by Warcholinski, Labidi et al in his research [1,3,14].

Acknowledgement

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