Faculty of Technology and Education

Selected modifications of tools for woodworking, a review

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6th International Workshop on Surface Engineering
&
3rd International Workshop on Applied and Sustainable Engineering
6-9 June 2018, Koszalin

Our activity in the field of modified woodworking tools investigations

interreg POLSKA 2004-2006

2005 - 2006

“Implementation of modern vacuum technology in the producion of tools for woodworking and wood-like products for the purposes of furniture industry in Pomerania Euroregion”

HYBRYDOWE TECHNOLOGIE MODYFIKACJI POWIERZCHNI NARZĘDZI DO OBRÓBKI DREWNA

You are only as good as your tools

2009 - 2013

„Hybrid technologies of modification tools for woodworking”

OPTI_WOOD BIOSTRATEG

2018 - 2020

„Improving the efficiency of the process and material in the sawmill industry”

Results of the projects

Development and implementation of multilayer coatings based on CrN, i.e. TiAlN/CrN, Mo_2N/CrN, CrCN/CrN and other.

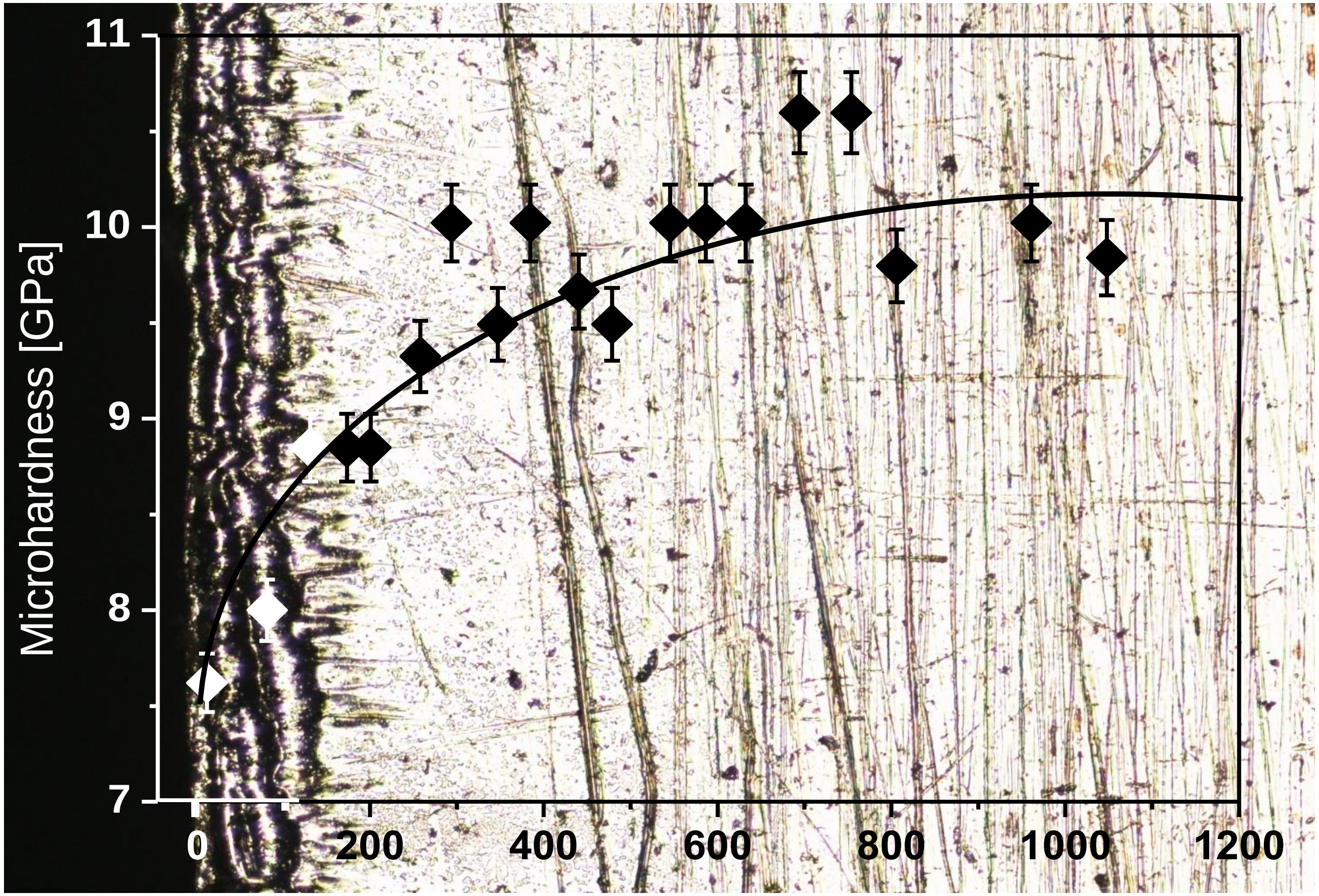
Implementation of the deposition technology of multi-layered coatings based on CrN and carbon on woodworking tools for the GOPOL Company in Jarocin.

Replacement of knives with a sintered carbide insert by HSS tools with a modified rake face with a hard CrCN/CrN coating at Swedwood IKEA Resko Company and ABWood Sławno, Poland.

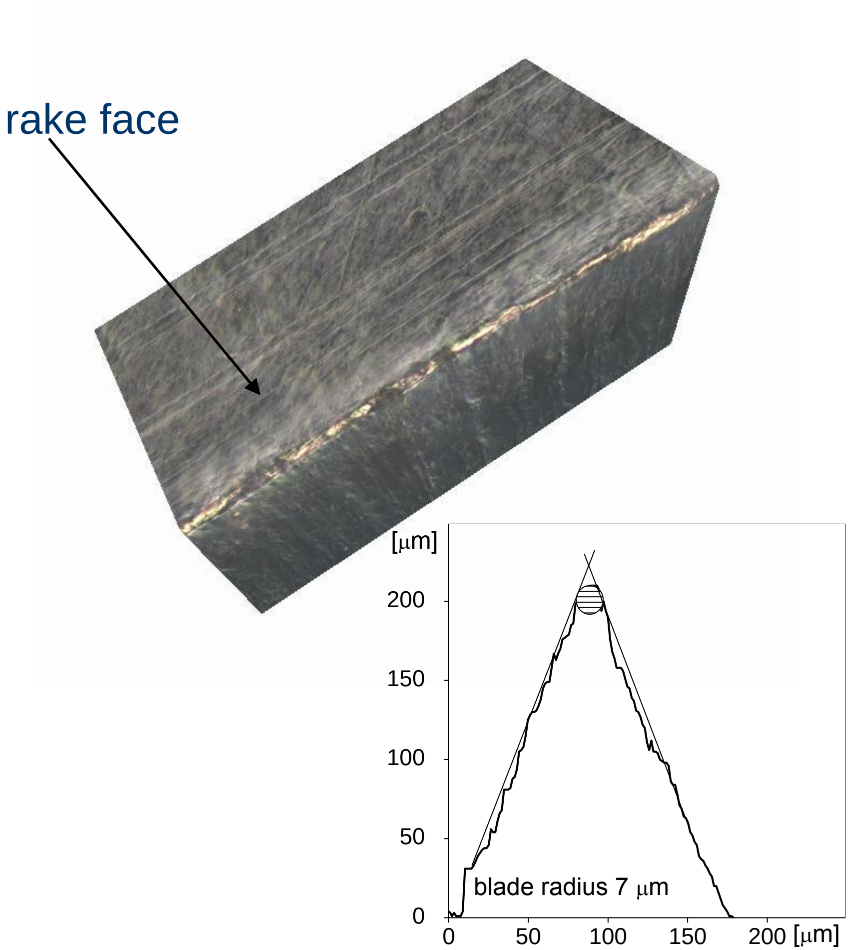
Outline

- Instead of introduction
- Tools modification
- Hard coatings – what is it?
- The state of the art of cooating for woodworking
- A few of exampes

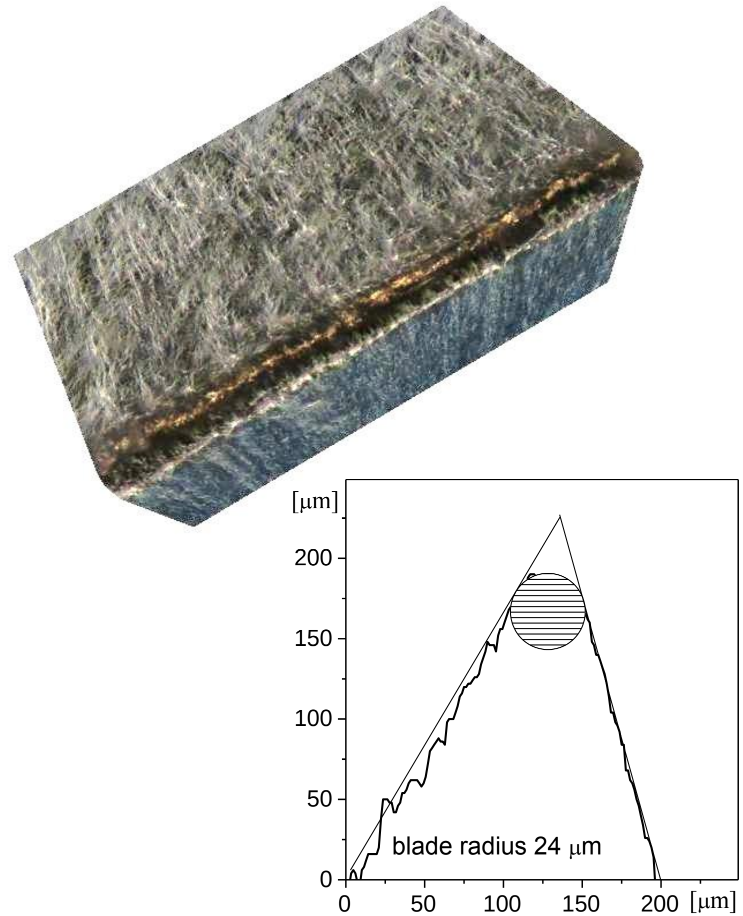
Instead of introduction - uncoated tool after machining



B. Warcholinski, A. Gilewicz, J. Ratajski, *Cr_2N/CrN multilayer coatings for wood machining tools*, Tribol. Int. 44 (2011) 1076-1082



3D image of the HS6-5-2 steel knife blade for the cutterhead after sharpening



3D image of the HS6-5-2 knife blade for the cutterhead after planning dry beech wood. After a distance of 6000 m.

Three groups of activities to improve the durability of the tools:

- introduction of new materials for their production or modification of the properties of the materials used and selection of the geometry of the working parts of the tools,
- application appropriate cooling and lubricating agents,
- selection the proper surface-coating system and shaping the surface properties in terms of increasing the durability of the tools.

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Beginning

In the early 1980s one of the most modern tools were sintered carbides. On a dramatic question "Is there life after tungsten carbide?" [1] the answer was already waiting - "PCD replacing carbide in woodworking applications„ [2].

In this time there was an abrupt increase of interests in modified woodworking tools.

The polycrystalline diamond (PCD) has displaced traditional steel and cemented carbide tools in woodworking.

Significantly better mechanical and tribological properties of PCD, such as hardness and wear resistance should enable increase in tool durability.

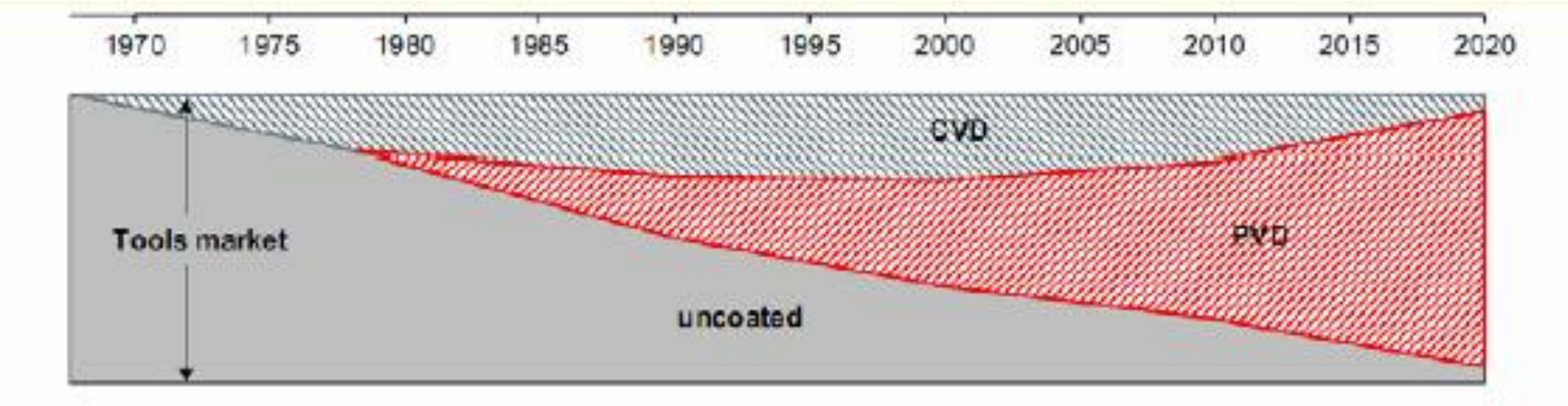
PCD tools offer considerable potential for cost savings in the machining of wood and wood-like materials. Boyle[2] indicated that life ratio of PCD tool compared to carbide cutter is about 17:1.

Due to high costs the researchers looked for new solutions. Thin hard coatings deposited on the tool's working surfaces seemed to be a good idea.

[1] J.M. Yates, *Is there life after tungsten carbide?*, Wood & wood products 92(10) (1987) 77-87.

[2] G.R. Boyle, *PCD replacing carbide in woodworking applications*, Cutting Tool Engineering 35(5-6), (1983) 60-61.

Development of PVD and CVD technologies for coating tools, by Oerlikon Balzers



Improvement of the properties

The development of tool materials is to combine high hardness with high toughness, improve their mechanical, tribological and thermophysical properties leading to extend the durability of cutting tools. One can specify two groups of technologies that improve the wear resistance of tools:

- the first one includes methods for improving the mechanical properties of the **surface of the tool material** (such as heat or thermo-chemical treatment), about 200 – 400 μm,
- the second group of technologies includes the **surface modification** techniques for tools by applying coatings with special properties, about 1-5 μm.

Tool material modification

Heat treatment is to give them the desired mechanical, physical or chemical properties by changing the structure, while the thermo-chemical treatment is to enrich the surface layer of the alloy in a certain element, such as C, N, Al, Cr, Si, or group of elements, e.g. C and N, N and S, N and O. The aim of these treatments is to give the surface layer of specific physical properties - mainly resistance to abrasion, or chemical - usually resistance to oxidation at high temperatures. The quality of the tool is improved by applying heat treatment which allows to obtain the desired hardness of the blade, the appropriate fine-grained structure of steel and toughness.

Thermo-chemical treatment, especially nitriding has a beneficial effect on performance characteristics of tools. Many scientists indicate an increase in wear resistance of nitrided tools for woodworking. **Dependent on the type of technology used, this increase is as high as 100%.**

Coatings

The technologies applied:

CVD (Chemical Vapour Deposition,

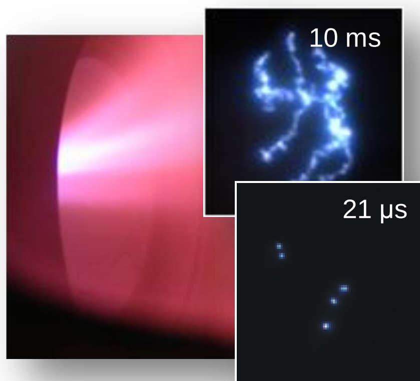
PVD (Physical Vapour Deposition)

Hard coatings deposition methods - PVD

Magnetron sputtering

- ❐ solid phase → plasma <u>(absence of macroparticles)</u>,
- ❐ low ionisation rate

Arc evaporation



- ❐ Solid phase → liquid phase → plasma <u>(high number of macroparticles)</u>,
- ❐ high ionisation rate

Electron beam evaporation

- ❐ solid phase → liquid phase → gaseous phase → plasma (<u>high number of macroparticles</u>),
- ❐ needed the gas ionisation systems,
- ❐ very high deposition rate

Coatings

The first coatings were two-element systems.

There are three main elements to synthesize protective coatings applied on tools for woodworking: titanium, chromium and carbon.

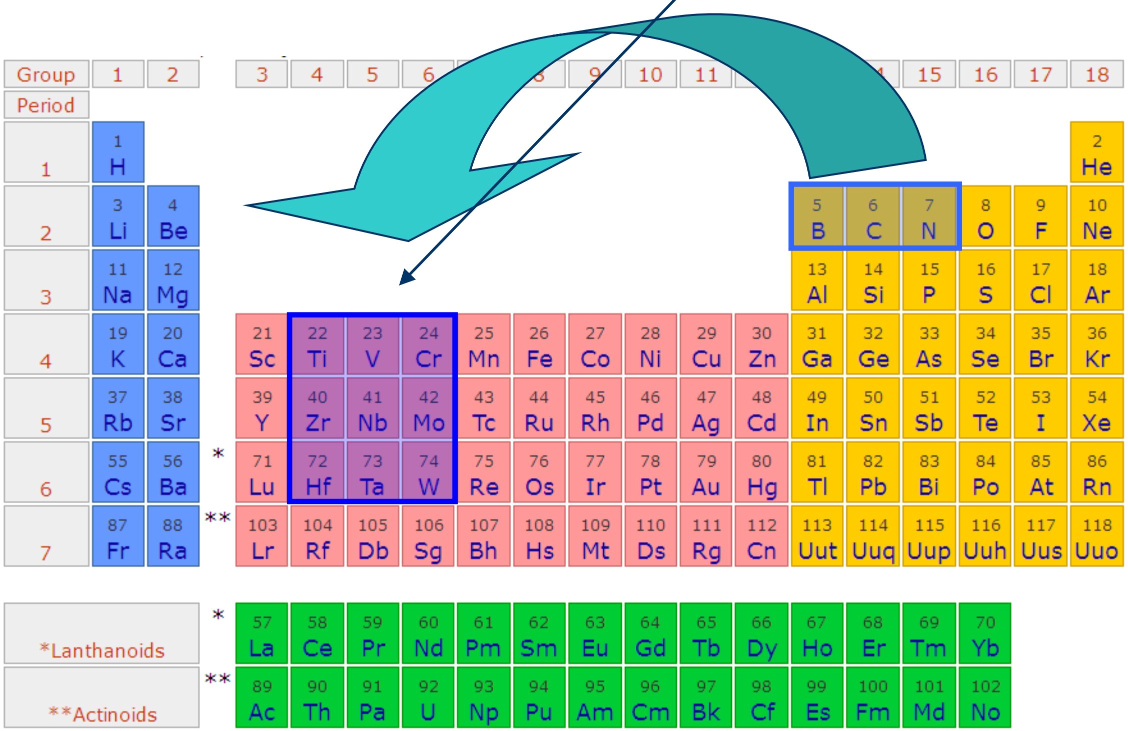
The transition metal nitrides were the most promising solution and they did not disappoint.

One of the first tests in wood machining by TiN coating was sawing the following materials: hardboard, polyvinylchloride coated particleboard, waste paper based paperboard, plywood and spruce. The results indicate various effects on tool wear. On the one hand when sawing hardboard and spruce the coating reduced the wear on the rake face about 50% and about 20% respectively, compared with the uncoated tools. On the other hand during sawing particleboard, paperboard and plywood, there was no increase in the durability of tools with a TiN coating. **This was one of the first signals that there is no universal coating.**

S. Osenius, A.S. Korhonen, M.S. Sulonen, *Performance of TiN-coated tools in wood cutting*, Surface and Coatings Technology 33(1987) 141-151.

Hard coatings

The hard coatings are the most often:
- nitrides, carbides, borides, carbonitrides and silicides, of high-melting metals (Ti, Cr, W, V, Mo, Ta, Zr, Nb, Hf),
- alumina oxide,
- synthetic materials based on diamond and cubic boron nitride,
- mixtures of above.



Hard coatings – why?

- high hardness – several times greater than steel,
- low coefficient of friction,
- low thermal conductivity,
- chemical inertness,
- thermal stability.

Thin hard coatings can help to solve the problems with:

friction,
erosion,
corrosion,
abrasive and adhesive wear.

Benefits of hard coatings

Improvement of the durability of coated elements

- increased lifetime of tools for several times,
- better quality of machined surface,
- possibility to increase the parameters of machining,
- better corrosion protection,
- elimination of the risk of so-called "cold pad welding" in injection molds,
- possibility to machine without cutting fluid or with a minimum amount of coolant,
- possibility to process materials usually considered to be "difficult” to machining.

Thin films - application

surface protection

decorative

optics

electronics

memory technology

barrier technology

optoelectronics

medical technology

Coatings

New requirements for tools related to the increase of machining parameters or type of machining and the processing of new materials led to the design and manufacture of new coatings.

Two directions of changes in coatings for woodworking tools were observed:

- formation of three- and more-component coatings. The influence of such elements as C, Si, Al, B, W, Zr on the properties of coatings based on titanium and chromium is intensively investigated.
- formation of multilayer coatings. Investigations of multilayered structures with chromium nitride as one of the layers indicates that it is possible to further improve both hardness and toughness.

Coatings

Coating	Results	Year of publication
W-C:H (DLC with WC precipitation)	reduction of the knives' edges by 38%	1999
CrN	reduction of the knives' edges 52%	1999
ta-C	2.5-fold lifetime increase	1999
TiC/a-C	2.5-fold lifetime increase	1999
TiN, (Ti,Zr)N, CrN , W–C:H(DLC)	cutting edge reduction up to: Ti based coatings 17%, DLC - 60%, CrN - 130%.	1999
TiN	25% increase	2006
TiN	Life time increase 30-45%	2008
AlCrN	max decrease in nose width about 44%	2009
CrSiN	max decrease in nose width about 33%	2009
Ti-W-N/Ti-W Cr-W-N/Cr-W	reduction of average wear area: OSB Ti based coatings - to 54%, Cr - to 100%, Particle board Ti based coatings - to 215%, Cr - to 460%	2009
TiAlN/TiBN, TiAlN/TiSiN, TiAlN/CrAlN TiAlN	multilayer-coated tools experienced a smaller amount of delamination wear than the monolayer-coated tool. The best multilayer coating was TiAlN/CrAlN	2010

CrN/CrCN	reduction of average wear area to 170%	2010
Cr_2N/CrN	reduction of average wear area of 60%	2011
TiCN CrN DLC	wear compared to the uncoated cutters TiCN - smaller by 1.6 times DLC -1.9 smaller CrN - smaller twice	2015
(TiAlN), TiAlN/TiSiN TiAlN/TiBON	reduction of edge recession 30-55%	2016
ZrN MoN	reduction of volume wear to 150% (MoN) and 110% (ZrN)	2016
CrN/CrCN	170% increase	2018
CrN	100% increase	2018

Difficulties in results comparison:

- different deposition methods
- different substrates
- different wood machining
- probably different machining parameters
- different coatings

The Centers working and testing the coatings for woodworking tools

Belarus - 1 team

China - 1 team

Ghana - 1

France - 7 teams

Germany - 4 teams

Indonesia - 1 team

Japan - 3 teams

Lithuania - 1 team

Poland - 4 teams

Portugal - 1 team

Spain - 2 teams

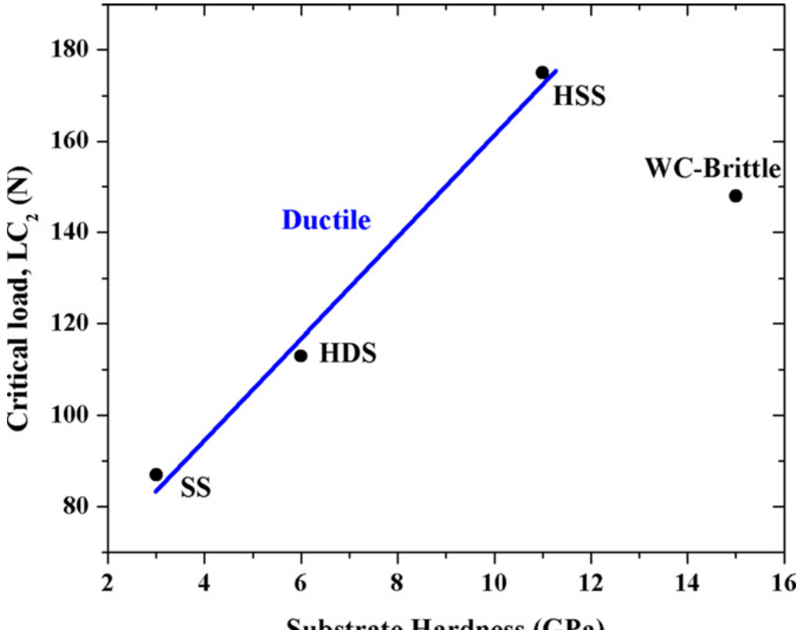
Slovakia – 1 team

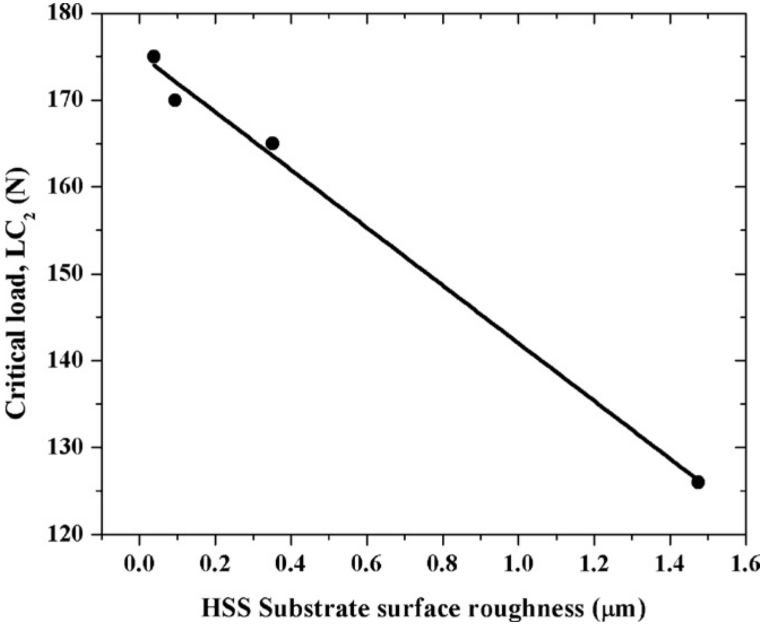
Switzerland – 3 teams

Thin coating properties modification

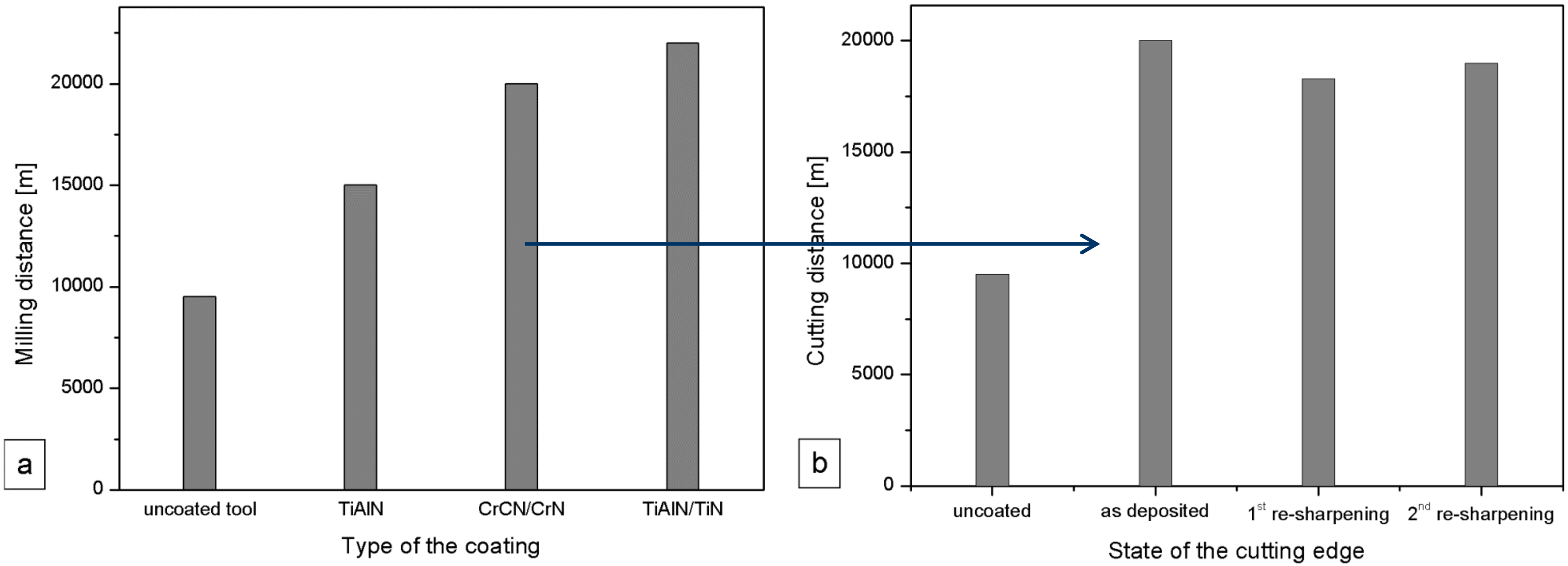
Type of substrate
Substrate temperature
Gas pressure
Substrate bias voltage
Arc current, magnetron power

Chemical composition
Phase composition
Density
Grain size
H & E
Surface quality (roughness)





K. Valleti, C. Rejin, S.V. Joshi, Factors influencing properties of CrN thin films grown by cylindrical cathodic arc physical vapor deposition on HSS substrates, Mater. Sci. Eng. A 545 (2012) 155–161



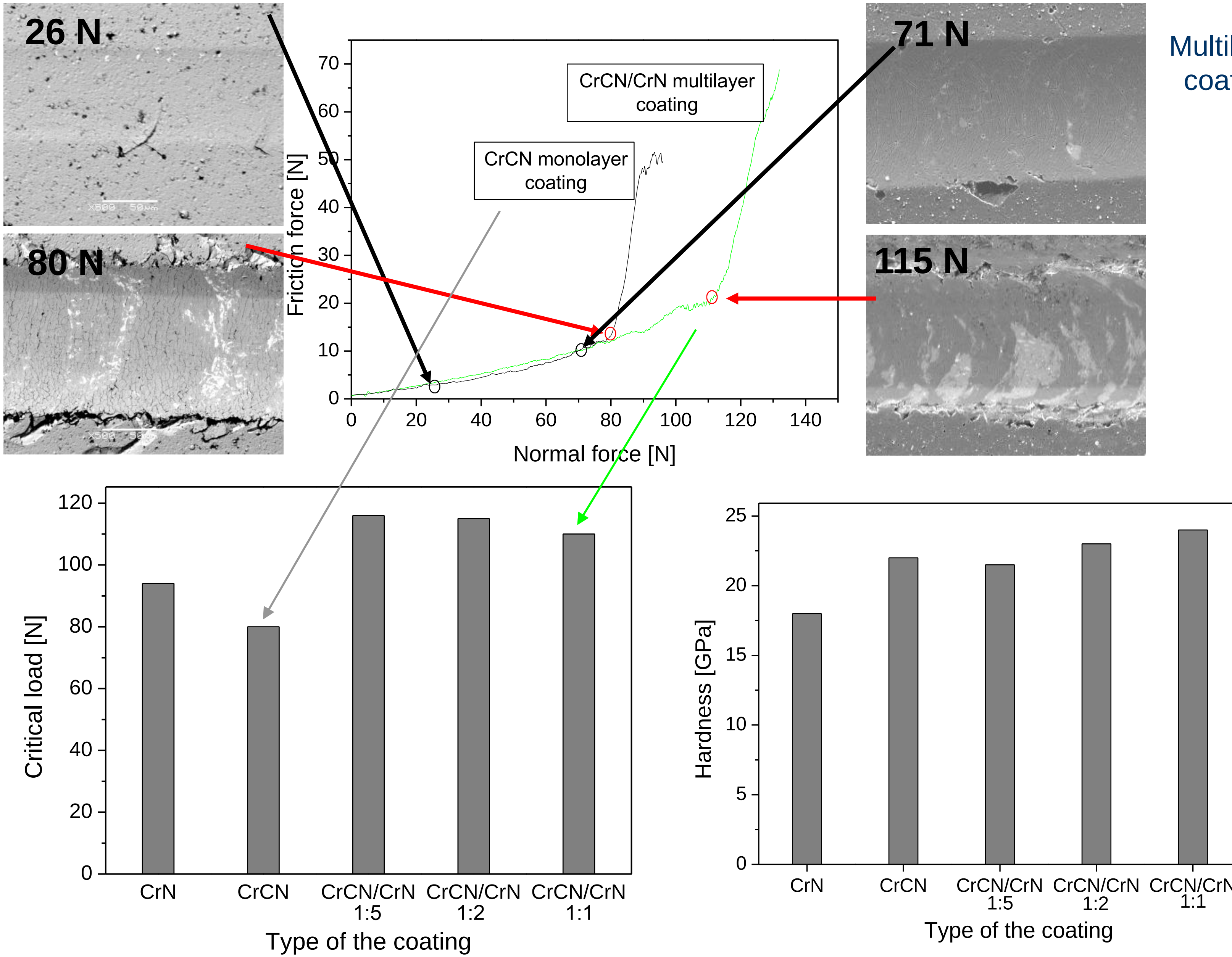
The milling distance of the tested coatings to the first re-sharpening (a) and the milling distance of the cutting knife with the CrCN/CrN coating after successive re-sharpening (b).

B. Warcholinski, A. Gilewicz, *Multilayer coatings on tools for woodworking*, Wear 271 (2011) 2812–2820

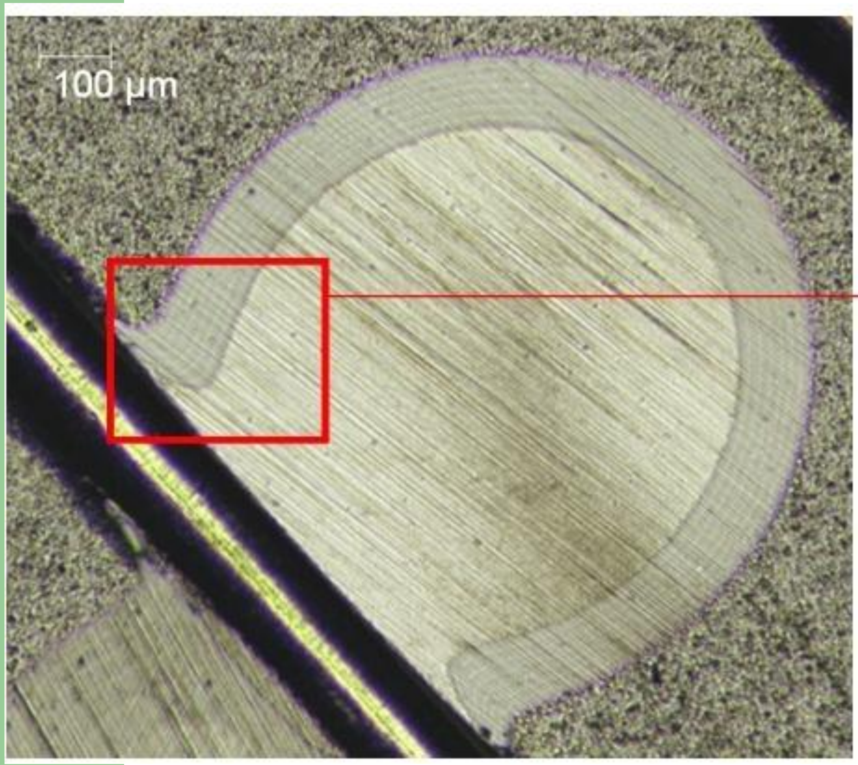
Multilayer coatings - constant bilayer thickness

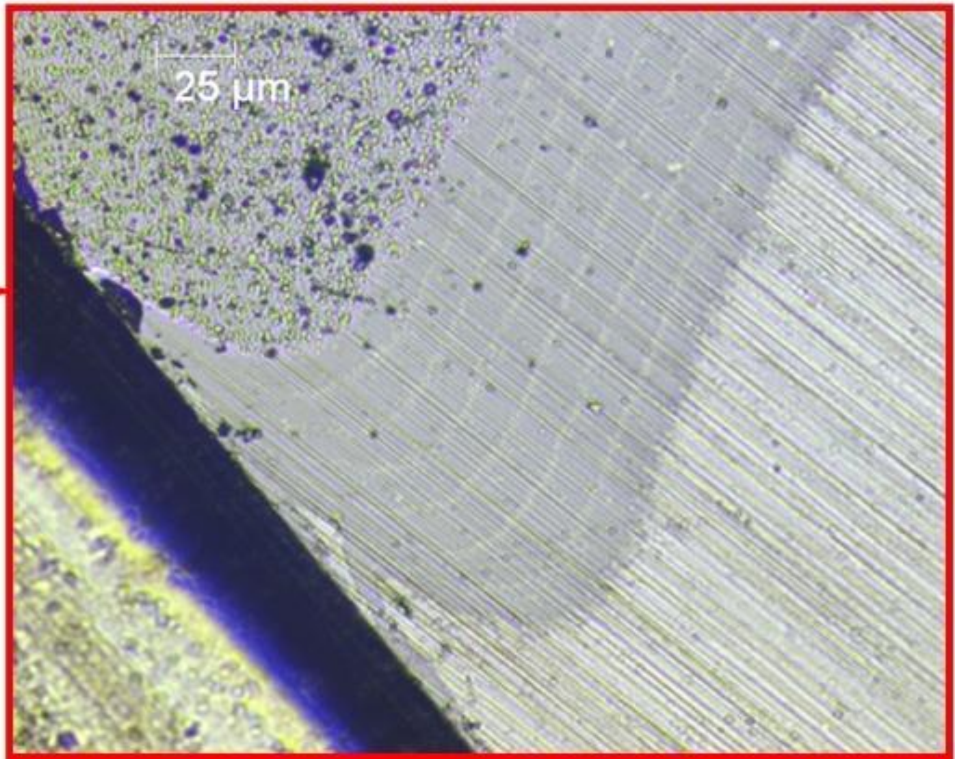
Monolayer coating

Multilayer coating

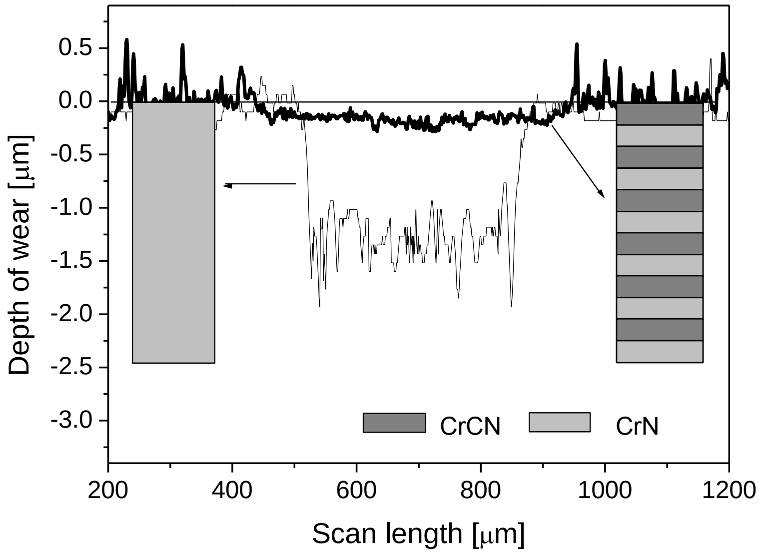


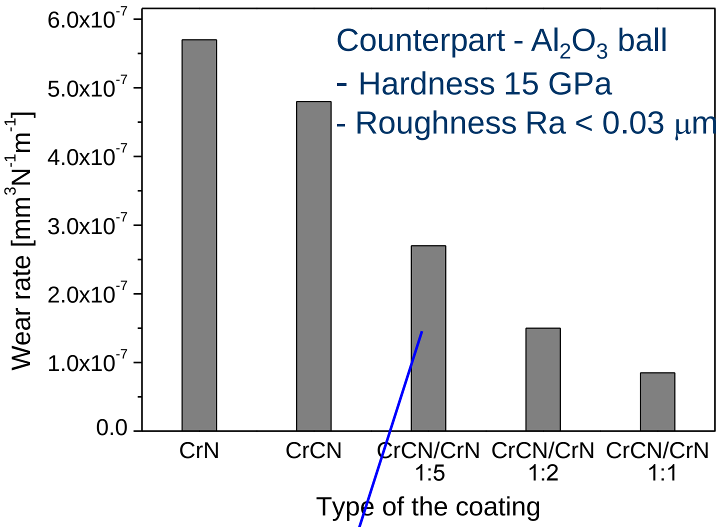
Adhesion – scratch test & Calo test

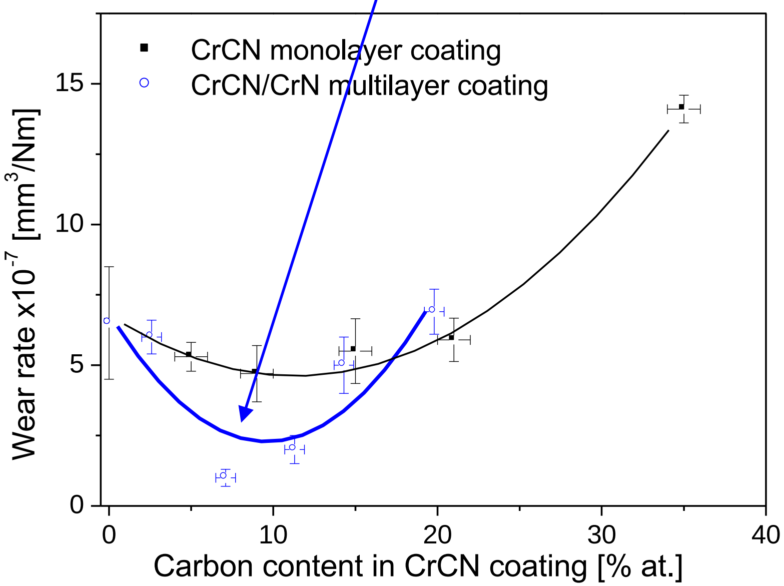




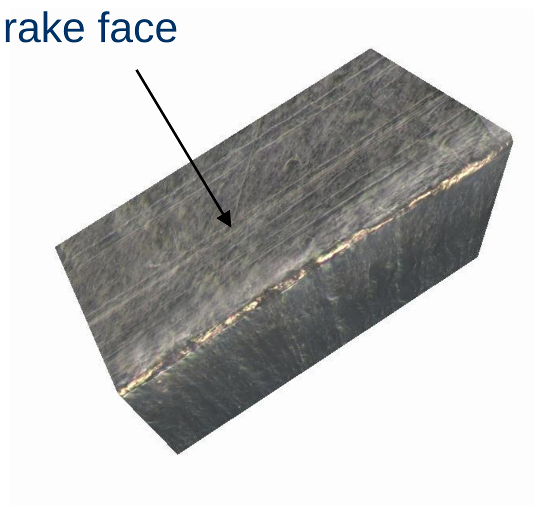
Multilayer coatings - wear







Cutting edge

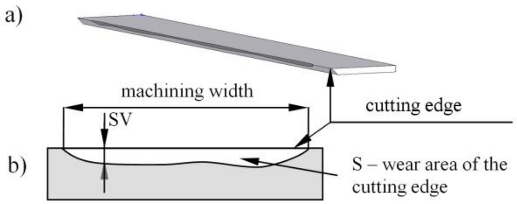


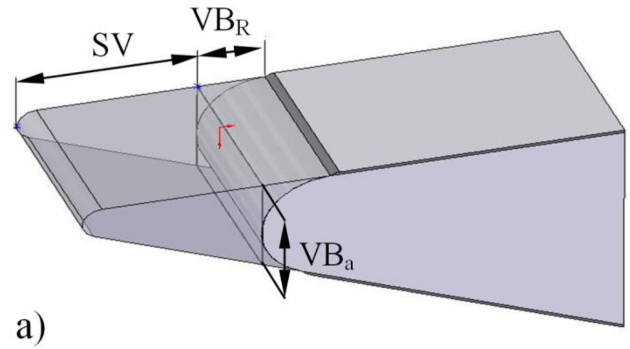
3D image of the HS6-5-2 steel knife blade for the cutterhead after sharpening

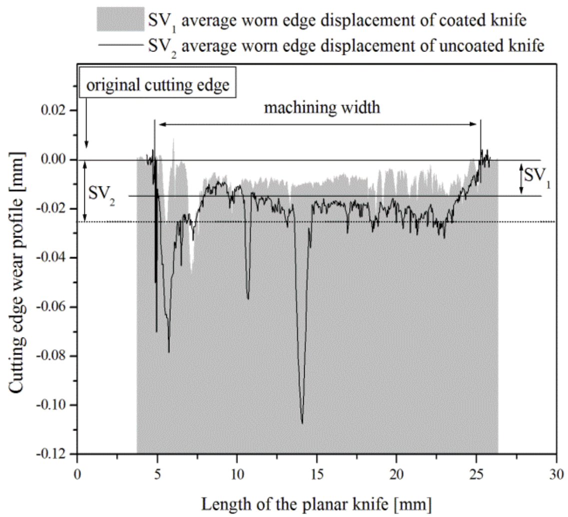
3D image of the HS6-5-2 knife blade for the cutterhead after planning dry beech wood. After a distance of 6000 m

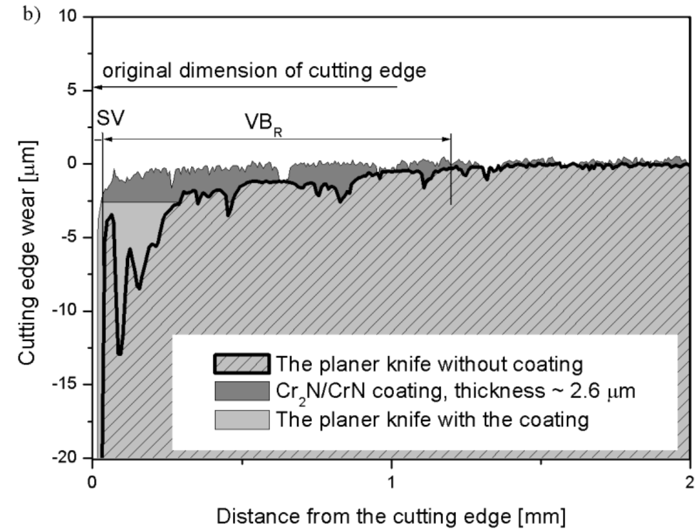
3D image of the HS6-5-2 knife blade for the cutterhead modified by CrCN/CrN multilayer coating after planning dry beech wood. After a distance of 6000 m

Cr_2N/CrN coating



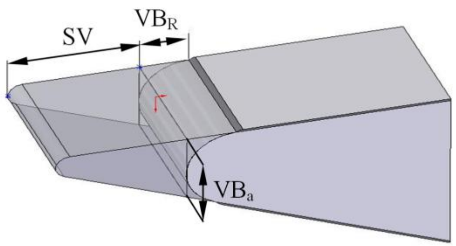


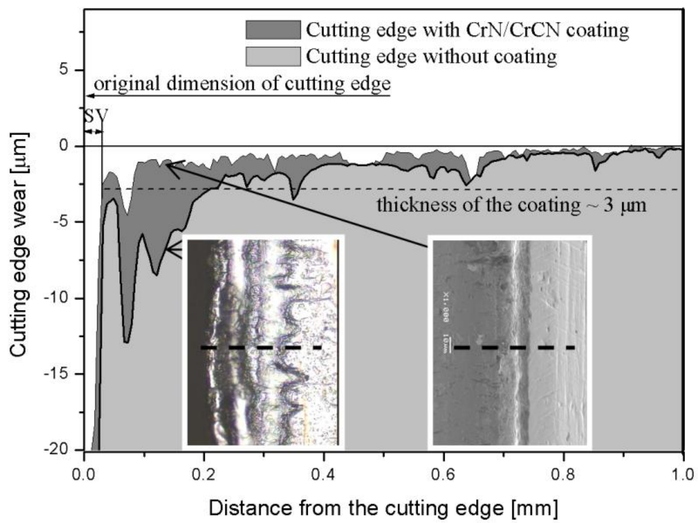




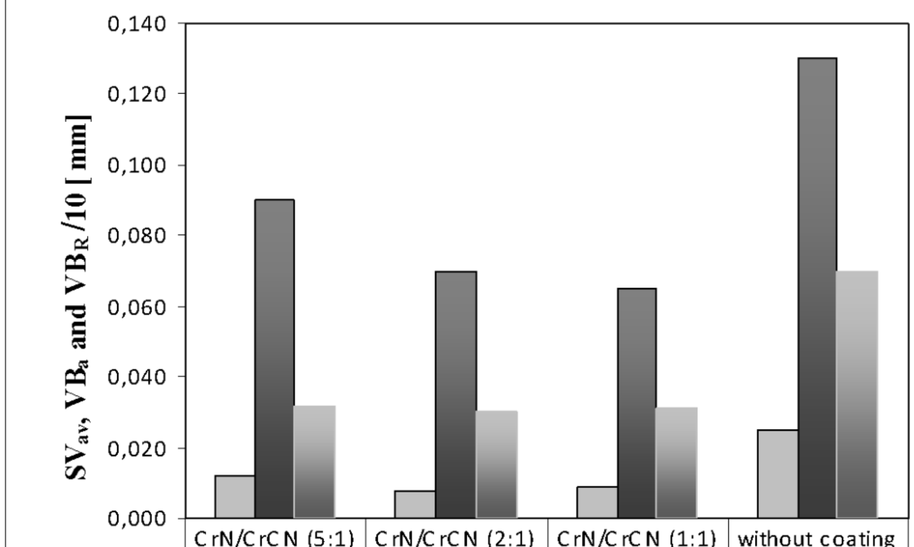
B. Warcholinski, A. Gilewicz, J. Ratajski, *Cr_2N/CrN multilayer coatings for wood machining tools*, Tribol. Int. 44 (2011) 1076-1082

CrN/CrCN coating





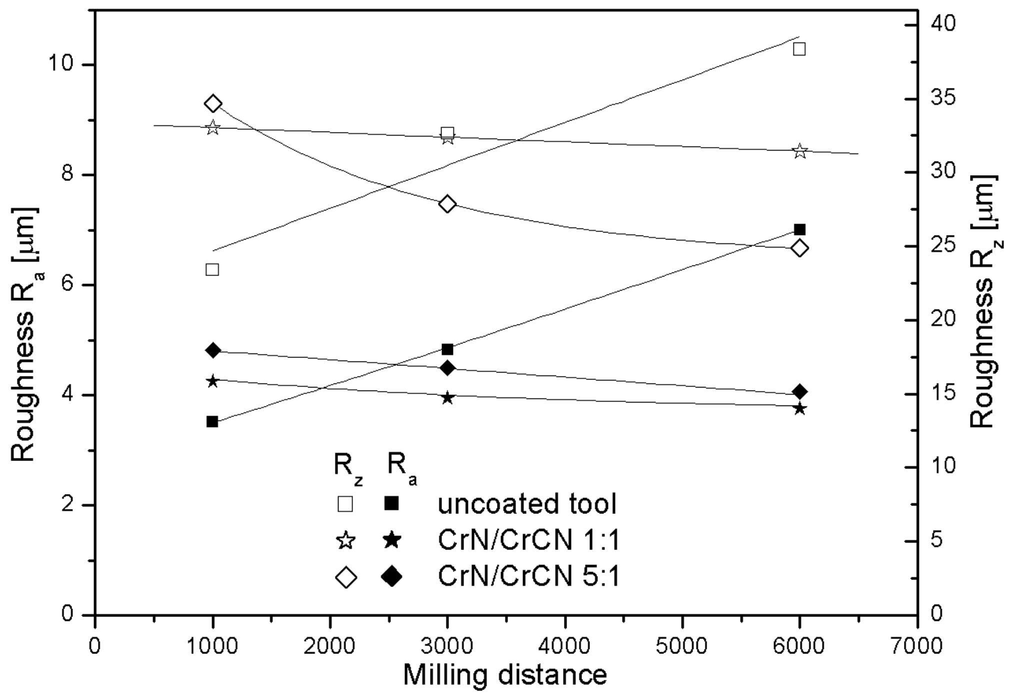
Planer knife with hard coating on the rake face and cutting edge profile after 6000m of milling



	CrN/CrCN (5:1)	CrN/CrCN (2:1)	CrN/CrCN (1:1)	without coating
SV av	0,012	0,008	0,009	0,025
VBR/10	0,090	0,070	0,065	0,130
VBa	0,032	0,030	0,031	0,070

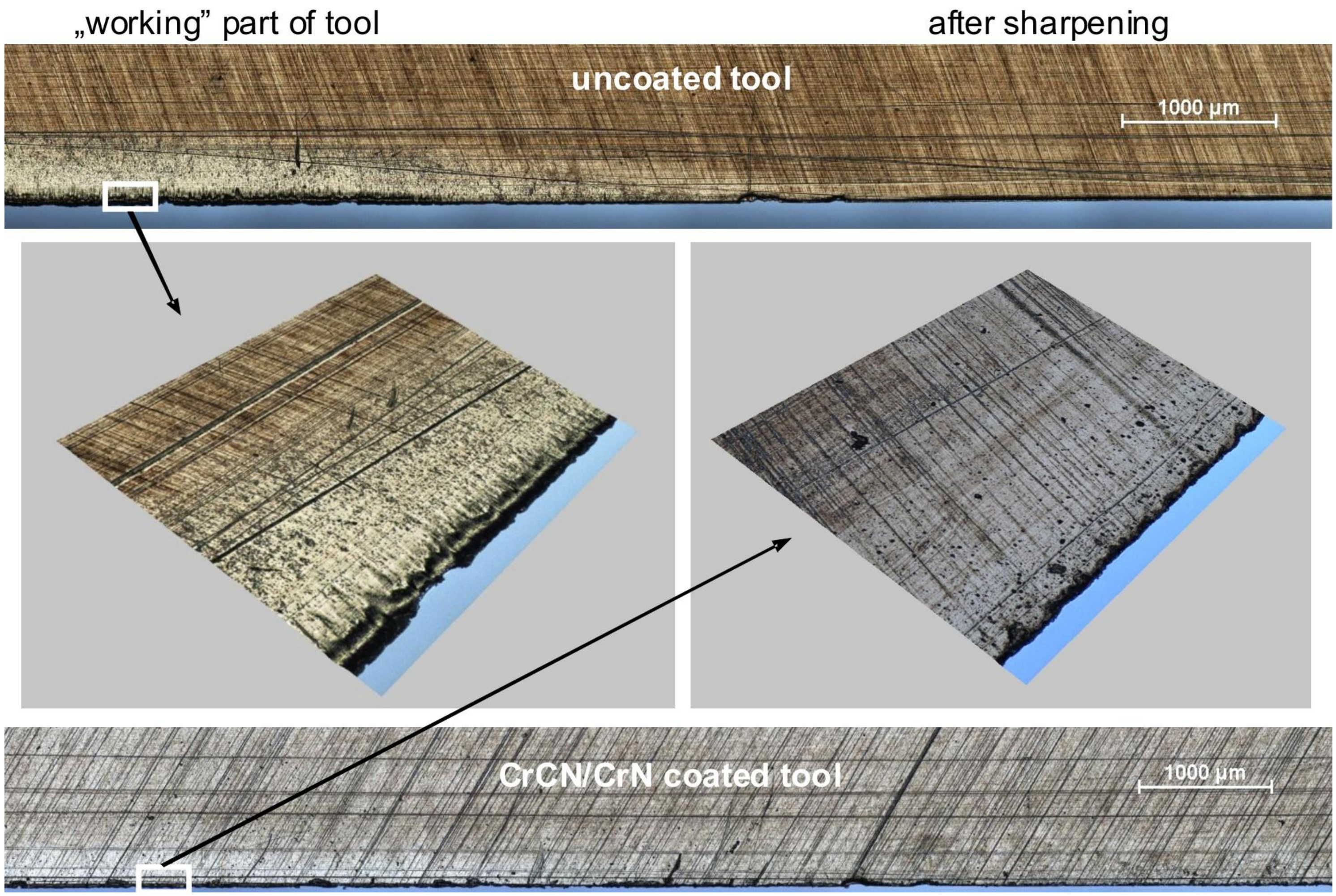
Worn edge displacement (SV), rake face wear (VB_R) and nose width (VB_a) for tested coatings deposited on planer knives. The milling distance – 6000 m.

A. Gilewicz, B. Warcholinski, P. Myslinski, W. Szymański, *Anti-wear multilayer coatings based on chromium nitride for wood machining tools*, Wear, 270 (2010) 32-38



Roughness of the milled pinewood surface measured across fibers

A. Gilewicz, B. Warcholinski, P. Myslinski, W. Szymański, *Anti-wear multilayer coatings based on chromium nitride for wood machining tools*, Wear, 270 (2010) 32-38


„working” part of tool
after sharpening
uncoated tool
1000 µm
CrCN/CrN coated tool
1000 µm

Thank you to your attention