

# МОДЕЛЮВАННЯ ТА ОПТИМІЗАЦІЯ ВИРОБНИЧИХ ПРОЦЕСІВ

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Y. A. Fedoran<sup>1</sup>, V. M. Volkogon<sup>1</sup>, V. S. Antoniuk<sup>2</sup>

<sup>1</sup>I.N. Frantsevich Institute for problems of materials science  
Of National Academy of Sciences of Ukraine, Kyiv, Ukraine

<sup>2</sup>National Technical University of Ukraine  
“Kiev Polytechnic Institute”, Kyiv, Ukraine

E-Mail: [vp@kpi.ua](mailto:vp@kpi.ua)

## INFLUENCE OF CUTTING CONDITIONS AND RADIUS OF THE ROUNDING OF TOOL MADE OF COMPOSITE 10N ON SURFACE LAYER STATE DURING TURNING OF HARDENED STEELS

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Наведені результати досліджень впливу виду механічної обробки та інструментального матеріалу на структурний стан поверхневого шару сталі ХВГ під час механічної обробки. Показані переваги токарної обробки різцями з композиту 10 порівняно із шліфуванням. Обробка інструментом із композиту 10 в поверхневому шарі для  $\alpha$ - і  $\gamma$ -фаз супроводжується тільки стискаючими залишковими напруженнями, у той час як абразивна обробка супроводжується виникненням розтягуючих напружень I-роду в  $\alpha$ -фазі структури швидкісного відпуску.

Ключові слова: нітрид бору, загартовані сталі, тонке точіння, шорсткість, напружений стан.

Приведены результаты исследований влияния вида механической обработки и инструментального материала на структурное состояние поверхностного слоя стали ХВГ при механической обработке. Показаны преимущества токарной обработки резцами из композита 10 по сравнению с процессом шлифования. Обработка инструментом с композита 10 в поверхностном слое для  $\alpha$ - и  $\gamma$ -фаз сопровождается только сжимающими остаточными напряжениями, в то время как абразивная обработка сопровождается возникновением растягивающих напряжений I-рода в  $\alpha$ -фазе структуры скоростного отпуска.

Ключевые слова: нитрид бора, закаленные стали, тонкое точение, шероховатость, напряженное состояние.

The results of studies of the type influence of treatment and tool material on the structural state of the boundary layer 107WCR5 during treatment are shown. The advantages of turning chisels with composite 10 compared with the process of grinding. Processing treatment with composite 10 in the surface layer for  $\alpha$ - and  $\gamma$ -phase is accompanied by compressive residual stresses only, while the abrasive treatment is accompanied by tensile stresses in the kind of I- $\alpha$ -phase structure of high-speed dispensing.

Key words: boron nitride, hardening steel, finish cutting, roughness, streets state.

**Introduction.** Introduction in manufacture of modern technological processes that ensure high and stable performance characteristics of the working surfaces of parts as well as improvement of the reliability of machines and mechanisms requires new approaches to research and development of recommendations.

The geometrical accuracy and surface quality can not be fully secured by traditional methods of processing, as the process of grinding and polishing is accompanied by the formation of adverse residual tension stresses in surface layers, structural and phase changes [1]. Turning as a method of finishing is known for its benefits, such as building higher quality surface finish and geometric accuracy of any complex shape. In addition, the absence of impregnation and the significant reduction of the need for multiple control of form of surface during processing makes the hyperfine turning more efficient compared to other methods of finishing products.

Use of superhard tool materials with the highest hardness and the ability to manufacture very acute blade tools for fine turning operations, greatly improving productivity in machining, gets a high quality surface finish and improves the structure of the surface layer of the material, and provides manufacturing of details with hard profiles [2].

The quality of the machined surface is in direct proportion to the perfection of forming cutting faces and cutting edge tools and is one of the most important criteria for its performance. High quality of tweaking surfaces tool as a result of defective surface layer is removed and shaping sharpening the cutting edge, it reduces wear, resulting in reduced production costs, unit costs of production and operation of the cutting tool. Of particular importance is increasing stability and quality of tool in the processing of high-precision parts with minimal roughness of the machined surface.

In this respect, the development of advanced, high-performance processes using tools from tool superhard materials with ultrafine granular structure and study the characteristics of fine and superfine material processing machining is considerable scientific and practical interest.

**The aim of the research** was to study the characteristics of the process of fine sharpening hardened steel cutting tools with polycrystalline superhard materials based on wurtzite boron nitride (wBN) of nanocrystalline granular structure in turning operations.

The object of research was polycrystalline superhard materials (PSHM) based on wurtzite boron nitride powders obtained under shock compression, which determined their dispersion and state of structures. In the manufacture of cutting tools with superhard nanocrystalline material based on instrumental superhard materials with ultrafine granular structure polycrystalline samples subjected to vacuum metallization adhesive-active mixture of titanium based powders [3].

Sharpening cutters performed to universal grinding machine mod. 3V642, which used diamond wheels on organic conjunction with 160/125-125/100 with high durability granule and of 100 % concentration. Wheel rotation speed was 25-30 meter per second. To form the top of the cutting tool radius  $R_0 = 2.5-3.5$  mm, used a special device in which the incisors were fixed in an adjustable tool carriers.

Tweaking faces of tool were performed on cast iron disk, rotating, and mechanical beating of disk on periphery does not exceed 0.5 microns. The surface of the disk impregnated diamond suspension with oil: for rough tuning granularity 20/14-14/10 microns, and for the ultimate tuning – 1/0 microns, or submicron diamond powder, with the highest purity surface tool is provided after tuning among nitrate or chlorate potassium, which promotes as a strong oxidant, perhaps microscopic smoothing the surface of the tool.

As a result, formed a perfect cutting edge tool for operations superfine turning with radius sharpening the cutting edge of the tool  $\rho = 0.05-0.07$  microns and the roughness of the front and rear surfaces of the blade within 0.025 microns. Data on surface roughness and value radius of the rounding cutting edge for PSHM based on serial and ultrafine wurtzite boron nitride is shown in Table.

#### **The roughness of the surface and the radius of the rounded top of cutting edge cutters**

PSHM based wBN	The granular size, microns	Surface roughness Rz, microns	Rounded cutting edge radius $\rho$ , microns
Serial composite 10	0.1-0.27	0.056-0.059	0.14-0.15
Ultrafine (nanostructure)	0.02-0.035	0.025	0.04-0.06

Effect of cutting speed blank of steel 107WCR5 (chrome-vanadium-manganese) (HRC 60-62) on the path length of the cutting tool in various modes of treatment was studied when the cutting speed varied within 0.2–7 meters per second, feed – from 0.003–0.2 millimeter per rev at variations in the depth of cut 0.003–0.27 mm, and the dependence of the roughness of the machined surface of the cutting – with continuous and interrupted turning blanks with longitudinal groove width of 4 mm. The criterion for the stability of the cutting tool is wear on the back face of  $h_b = 0.4$  mm.

**Discussion of results.** In experimental studies using instrumental polycrystalline superhard materials based on wurtzite boron nitride – composite 10 and polycrystalline superhard materials based on wurtzite boron nitride granular nanocrystalline structure. As evidenced by electron microscopic studies PSHM structure of nanocrystalline materials is represented by two phases of extremely high dispersion (wBN – 0.01 microns and cubic boron nitride (cBN) – 0.01-0.02 microns), and is characterized by uniformity of granular size, minimum content of inclusions and pores determines its high rigidity and extremely high fracture toughness.

Thermal processes in the contact tool with the work piece significantly affect how the stability of the instrument and the quality of treatment and the condition of the surface layer of detail that defines its operational durability. In the process of machining materials in the contact details of a tool developed sufficiently high temperatures, the magnitude of which will depend on the process parameters, especially the cutting speed, and will determine the operational stability of the tool [4].

The experimental data show (Fig. 1), for ultrafine PSHM based on wurtzite boron nitride maximum tool life is within the cutting speed equal to 40–70 meters per minute, whereas for conventional composite-10 optimal cutting speed is  $v = 90$ -130 meters per minute.

When in continuous turning ultrafine structure of superhard materials based on wBN has a maximum tool life of at lower processing speed, due to the magnitude of the temperature in the cutting zone and increased wear at higher values of cutting speed, due to the intensification of reverse phase transformations in polycrystalline superhard material. Interrupted cutting such materials has an advantage over conventional instrumental material from wurtzite boron nitride – composite 10.

The roughness of the machined surface is determined by the technological process parameters such as speed, feed and depth of cutting, and their influence is manifested in different ways. According to the data shown in Fig. 2a, increasing cutting speed from 12 to 250 meters per minute results in a decrease of the machined surface roughness in 2–3 times. The most significant change in the parameter  $R_a$  is observed in the range of cutting speeds from 20 to 100 meters per minute, and then it stabilizes. A further increase in cutting speed does not affect the roughness of the workpiece. Reduction of machined surface roughness with increasing cutting speed 100 meters per minute can be explained by the increase of temperature cutting, resulting in reverse phase transformation wBN  $\rightarrow$  hBN (hexagonal boron nitride) in microvolumes polycrystalline cutter in contact with the workpiece, which helps reduce the friction force between the back of the instrument and processed detail, reducing cutting forces and oscillations of the technological system.

Increased feed from 0.05 to 0.28 millimeters per revolution lead to a significant increase in surface roughness  $R_a$  values (Fig. 2b) than increasing the depth of cut (Fig. 2c), which can be explained by the geometric factor for the formation of machined surface roughness which is reflected in the geometry of the top copy of the tool in the workpiece. It should also take into account the growth of cutting forces that cause vibrations technological system and are accompanied by increasing height microscopic surface finish.

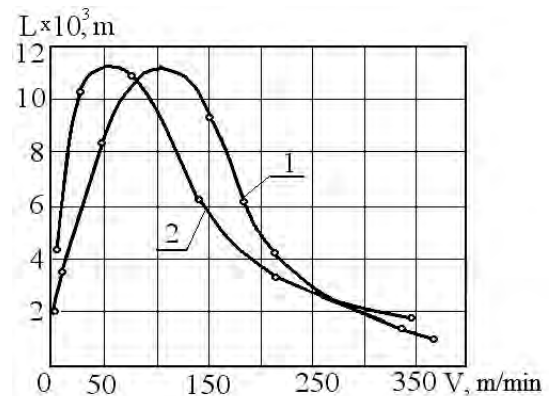


Fig. 1. Influence of cutting speed on cutting way in turning steel 107WCR5 (HRC 60-62):  
 1 – cutter with composite 10;  
 2 – cutter of nanocrystalline PSHM based on wurtzite boron nitride  
 ( $S = 0,075$  mm/rev;  $t = 0,2$  mm)

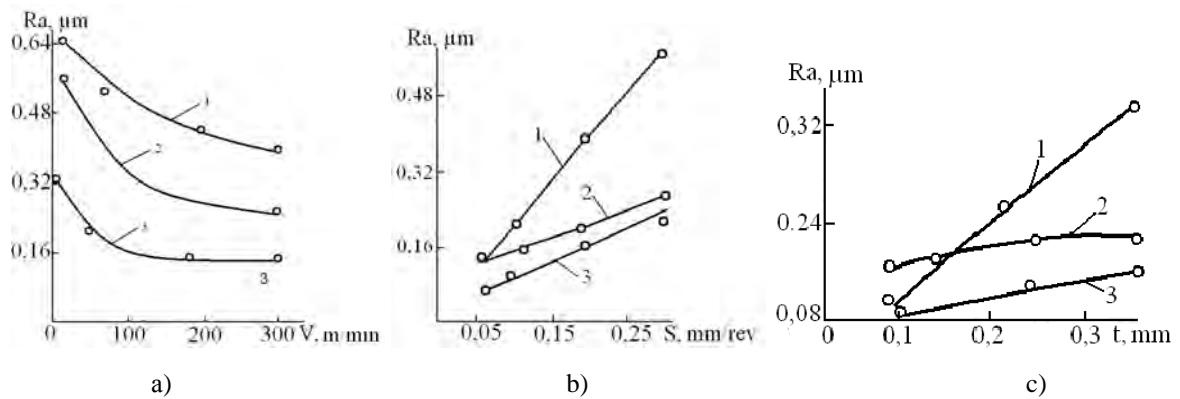


Fig. 2. Effect of cutting on the roughness of the machined surface when turning steel 107WCR5 (HRC 60-62) in continuous and interrupted turning (longitudinal groove width 4 mm) of cutting speed (a), feed (b), depth of cut ©: 1 – finishing cutter with serial composite 10 using interrupted turning; 2 – processing cutter with composite 10 in continuous turning; 3 – finishing cutter with nanocrystalline PSHM based on wBN

During treatment machine parts significant influence on forming surface layers has interaction of high temperatures and pressures in the cutting zone. Structural changes, those occur at the same time, depending on the values of these factors, as well as the chemical composition and structure of the original material. Unlike conventional heat treatment it is in the process of plastic deformation, which is caused by high contact pressure, and the rate of heating and cooling of the surface layers of metal are respectively  $10^5$ – $10^6$  and  $10^3$  –  $10^4$  degrees per second. In the case of high-strength structural steels in the surface layers formed two zones of structural state: directly at the surface – the zone of secondary hardening, manifested in the form of metallographic slightly staining “white” layer and the adjacent area of high etching, which corresponds to the structure of high-speed dispensing. Complete collapse of the original martensite structure and change of carbon in austenite, in accordance with the diagram iron – carbon, indicate the diffusion mechanism of austenite, which determines the depth distribution, phase composition and microstructure of these areas. Depth distribution of these zones of structural changes in the surface layers of parts in different modes of machining is determined by a combination of various temperatures and pressure of contact pairs. The temperature of heating surface determines the overall depth of the phase composition and microstructure. Role in the formation of pressure is more intense high- speed zone submicrostructure release, increasing the amount of residual austenite in the area of secondary hardening, in the limit of concentration and temperature inhomogeneities its collapse in the next tempering of steel.

Thus, machining cutters with PSHM contributes to the formation of residual compressive stresses, the value of which depends on the type of treatment, type of PSHM and their physical and mechanical properties. The greatest influence on the formation of residual stresses in the surface layers of hardened steel, while turning from PSHM of boron nitride has a power factor that creates tension compression (Fig. 3). In contrast to the grinding process by turning the temperature has short-term effects on the work surface and shallow depth distribution, which does not lead to phase transformations and recrystallization of the material.

Influence of processing modes, geometric parameters of the cutting tool and other factors on the sign and magnitude of residual stress appears to change one of the factors influencing the residual stress – strength, temperature changes and phase composition. The development of compressive residual stress is associated with an increase in the share value of the deformed metal, accompanied by a non-uniform plastic deformation of the surface layer during processing. Localized heating of thin surface layers gives rise to residual stresses are tensile, and phase changes in different layers of the metal leads to the formation of these different structures with different specific volume, which give rise to residual stresses of different sign and magnitude. According to experimental data when turning hardened steel 107WCR5 (HRC-60-62) increasing cutting speed from 40 to 150 meters per minute results in lower compressive residual stresses from 0.85 to 0.35 GPa (Fig. 4).

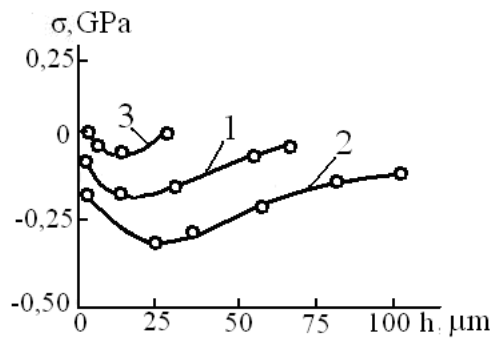


Fig. 3. Influence of type of tool material PSHM based on w-BN on the size and depth of residual stresses in steel turning 107WCR5 (HRC 60-62):  
1, 2 – composite 10 serial; 3 – nanocrystalline PSHM based on wBN

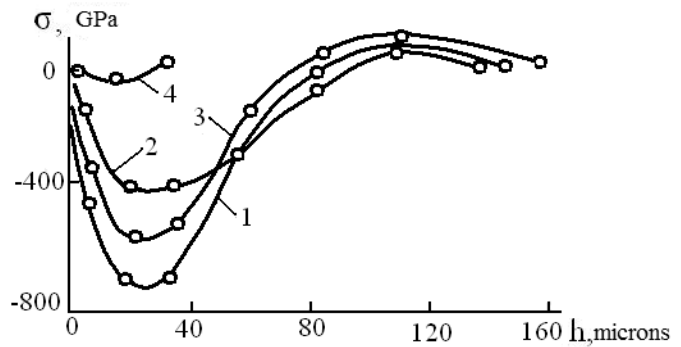


Fig. 4. Effect of cutting speed on residual stresses in steel turning 107WCR5 (HRC 60-62) cutters with PSHM based on wBN:  
1–3 – serial composite 10;  
4 – PSHM of nanocrystalline wBN

In this case, an increase in cutting speed is accompanied by a rise in temperature in the cutting zone, which leads to lower compressive residual stresses. Given the fact that even at high cutting speeds on the surface tension components are compressions, it can be argued that when factor of treatment PSHM is dominant.

The value of feed during the cutting process is also essential, since an increase in feed leads to a marked increase in the cutting force. Increased feed from 0.02 to 0.12 millimeters per revolution accompanied by an increase to 2.5 times the value of compression stress (Fig. 5) and increase the depth of their occurrence. It should be noted that the magnitude of residual stresses and the depth of their occurrence is largely dependent on the radius of rounding of the cutting edge of the tool.

Increasing the radius of rounding of the tool leads to changes in processing – along with the cutting process is a smoothing surface, which contributes to a compressive residual stress at greater depth, with the larger radius of rounding, the greater extent reflected the effect of smoothing. Dependence of compressive residual stresses in the surface layer of the workpiece on the value of the radius of curvature of the tool PSHM is shown in Fig. 6.

This is confirmed by measurements of microhardness data sample surface steel 107WCR5 (HRC 60-62) after treatment with cutter tool superhard materials with ultrafine granular structure with different radius of curvature, are shown in Fig. 7.

It seems that when cutting cutters with larger radius of curvature of the top, the processing of the workpiece surface is exposed to a much higher elastic-plastic deformation dominated elastic as strengthens the surface layer to 1.5 times.

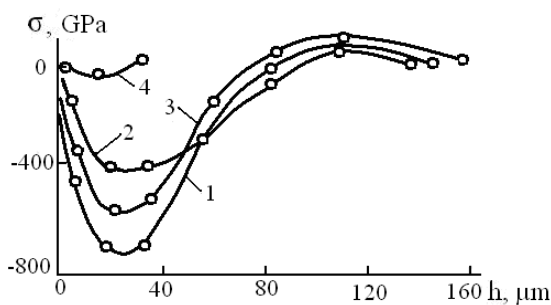


Fig. 5. Effect of feeding on the magnitude of residual stresses in turning steel 107WCR5 (HRC 60-62) nanocrystalline PSHM based on wBN:  
1 –  $S = 0.12$  mm/rev; 2 –  $S = 0.05$  mm/rev;  
3 –  $S = 0.02$  mm/rev

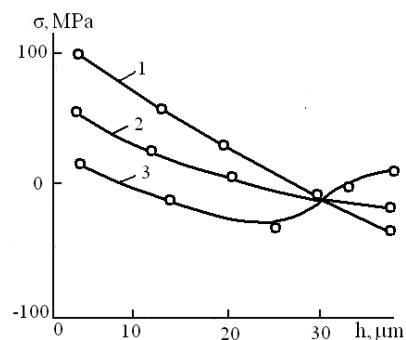


Fig. 6. The effect of the radius of curvature of the blade of the cutter nanocrystalline PSHM on the size and depth of the residual stress ( $v = 140$  mm/min,  $t = 0.01$  mm,  $S = 0.05$  mm/rev):  
1 –  $\rho = 0.04$  micron; 2 –  $\rho = 0.06$  micron;  
3 –  $\rho = 0.1$  micron

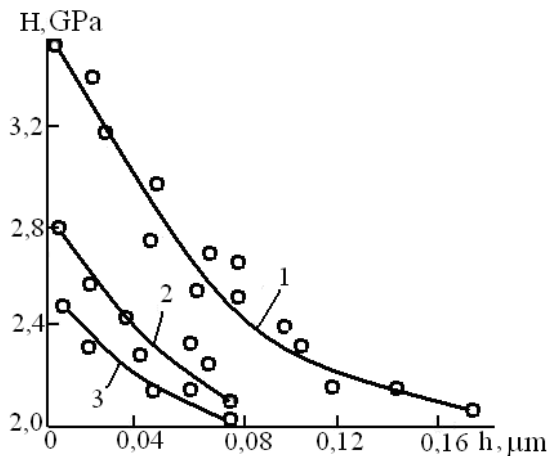


Fig. 7. Distribution of microhardness in depth of the treated sample, depending on the radius sharpening the cutting edge of the tool with nanocrystalline PSHM:

1 –  $\rho = 0.09$  microns; 2 –  $\rho = 0.06$  microns;  
3 –  $\rho = 0.04$  microns

**Conclusion.** Experimental study of the processes of thin blade handling various structural steels polycrystalline superhard materials based on wurtzite boron nitride, different structural state indicate that treatment with cutter PSHM based on ultrafine boron nitride gives a surface appearance without it structural defects in the formation of compressive residual stresses, that enhance the performance characteristics of machined parts.

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Y. Shakhbazov, V. Storoschuk, I. Griner

Ukrainian Academy of Printing,  
Department of materials technology and printing machinery

## MODELING TECHNOLOGICAL SUPPORT THE PROCESS OF GRINDING ABRASIVE ABOUT

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**Consider the impact of technological regimes polishing surface finish and establish the optimal conditions for grinding and abrasive wheels revision in view of their period of stability.**

**Key words: quality, grinding, abrasive wheel, roughness, accuracy, stability, optimal mode, simulation, manufacturing software.**

**Statement of the problem.** Current areas of manufacturing engineering involves extensive use of advanced technological processes of machining workpieces machine parts. Technological capabilities grinding process can be considered as a method to improve the efficiency of roughing and finishing