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## Modern coatings of metal-cutting tools as a way to control the efficiency of noncorrosive steel treatment

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# Modern coatings of metal-cutting tools as a way to control the efficiency of noncorrosive steel treatment

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**Abstract.** Treating specialized stainless steels is always associated with the need to improve processing performance and efficiency of metal-cutting tools. Functional coatings for domestic metal-cutting tools are proposed, their efficiency is estimated by the efficiency parameters, the analysis of cutting forces is involved to explain the results

## 1. Introduction

The paper presents the results of developing and applying modern functional coatings on domestic metal-cutting tools for turning viscous and highly corrosion-resistant stainless steel, the grade of the steel is 09X17H7IO (09H17N7YU). As a criterion for evaluating the effectiveness of coatings, the paper applies a performance comparison of the feed-through turning cutters by the value of their wear on the back face for equal operating time under the same operating conditions.

The aim of the work is to identify the most rational coatings without reducing the productivity and treating quality.

Taking into account the actual absence of recommendations for treating such stainless steel, we selected domestic tool hard alloy of the VK8 (BK8) brand as the basic version of the tool material in the delivery condition from JSC "Kirovgrad hard alloy plant". The considered coatings were applied to the same material. The time to achieve wear on the back face, equal to 0.5 mm, was taken as the criterion of assessing the tool performance. Wear and tear measurements were carried out every 15 minutes of the tool performance.

## 2. Results and their discussion

### 2.1. Initial condition

The data are given only on quadrangular square plates (diameter of the described circle is 17,5 mm) with the central fixing aperture and without it, with a chip groove and without a chip groove.

The diameter of the workpiece varied during the treatment from 280 to 60 mm. The cutting speed was maintained within 50-55 m / min by varying the number of spindle revolutions. The screw-cutting lathe of model 16K25 was used. The cutter feed from the requirements of the treated surface roughness is selected equal to 0.21 mm / Rev. The cutting depth was taken equal to 0.5 mm for finishing conditions and 1 mm for roughing conditions. In both cases, the maximum permissible amount of wear on the back face was considered to be 0.5 mm. The cutting tool was compared according to the period of wear resistance, i.e. by the work time of cutting plates under the due roughness to achieve a wear of 0.5 mm for the back face.

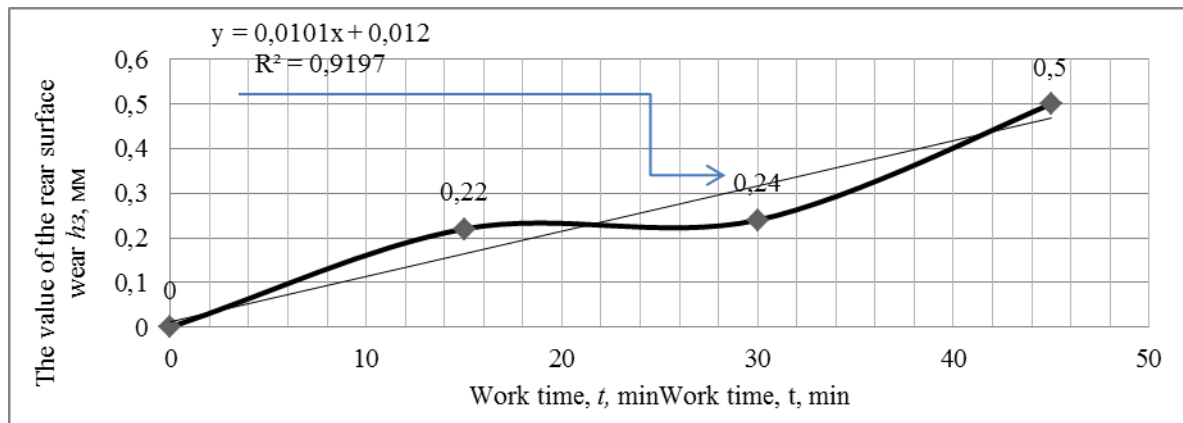
Wear measurement was carried out on a multi-sensor measuring center (video measuring machine) of the model Micro Vu Sol 161. The test results were duplicated and documented.

### 2.2. Discussing the results



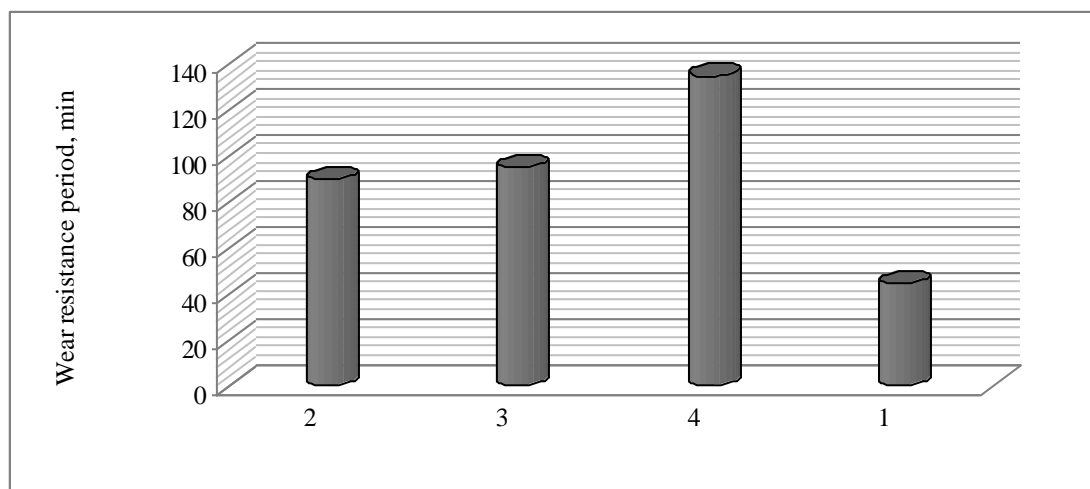
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Fig.1 shows a graph of the experimental dependence of the wear value  $h_3$  on the time  $t$  of the carbide tool of brand BK8 (VK8) in the delivery condition. This tool produced at JSC “Kirovgrad hard alloy plant” is taken as basic. All other tool materials (substrate + coating) are evaluated in relation to this base and among themselves. Similar graphs are obtained for different instrumental materials.



**Figure 1.** An example of the dependence of the wear value  $h_3$  on the work time  $t$  of carbide tool (grade VK8) (cutting mode  $v=55$  m/ min,  $n=160$  rpm,  $s=0.21$  mm / rev,  $t=1$  mm)

The visualization of individual results is shown in Fig.2, where: 1 is carbide brand VK8 in the delivery condition; 2 is tool material CCMT 120404-HMP of the company KORLOY; 3 is tool material VK8 coated with Ti (up to  $1\ \mu\text{m}$ ) + TiN( $1\ \mu\text{m}$ ) + (TiAl)N( $2\ \mu\text{m}$ ) + TiN( $0.5\ \mu\text{m}$ ) [applying coating layers\* by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]. In this case the thicknesses of the layers in the coating are given in parentheses, and the conditions for applying the layers are given in square brackets. Information on filtering the droplet phase and assisting with accelerated electrons is given in the work [1]; 4 is tool material VK8 coated with Ti (up to  $1\ \mu\text{m}$ ) + TiN ( $1\ \mu\text{m}$ ) + (NbZrTiAl) N ( $2.5\ \mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions].

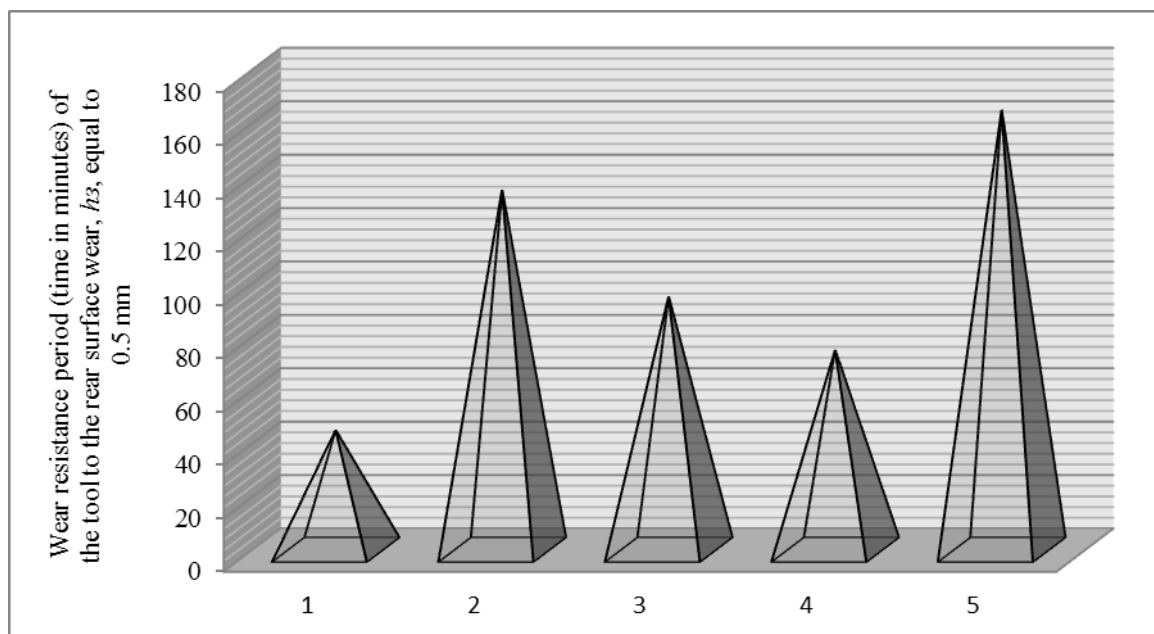


**Figure 2.** Comparing the period of wear resistance of various tool materials for specified operating conditions

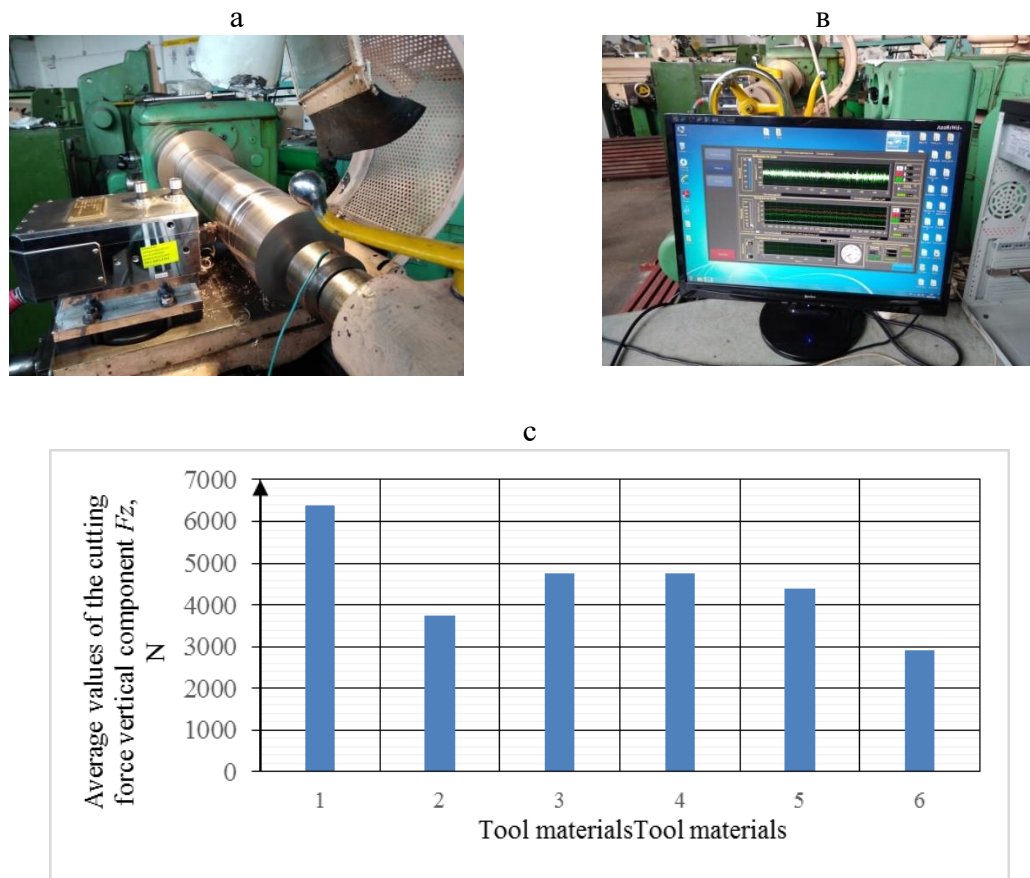
Another example of comparing wear resistance of tool materials is shown in Fig.3, where: 1 is VK8 in the delivery condition; 2 is VK8 + coating No. 1; 3 is VK8 + coating No. 2; 4 is VK8 + coating No. 3; 5 is VK8 + subjected to the diamond thermal sharpening of the front surface and polishing the rear surface of the plate: coating №1 is Ti (up to 1  $\mu\text{m}$ ) + TiN(1  $\mu\text{m}$ ) + (NbZrTiAl) N (2.5  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]; coating No. 2 is Ti (up to 1  $\mu\text{m}$ ) + TiN (1  $\mu\text{m}$ ) + (NbZrTiAl) N (2.5  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]; coating No. 3 is (AlCr)N(1.5  $\mu\text{m}$ ) + (AlTi)N(2  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and without assisting with accelerated ions].

The wear resistance here refers to the time of the plate to reach a certain amount of wear on the rear surface, this value is taken to be 0.5 mm.

To explain the identified results and patterns strain gaging was made in all three of its components (Fig.4), in which the cutting mode was the following: cutting speed was 50 m / min, feed was 0.21 mm / rev., depth of cut was 0.5 mm: *a* is a test stand using Stand STD.2012-2 model dynamometer; *b* is visualizing and documenting the process of recording the cutting force components; *c* is a graph sample showing the effect of the tool coating on the vertical component value of the cutting force (1-VK8 in the delivery condition; 2-VK8 + (AlCr)N (1.5  $\mu\text{m}$ ) + (AlTi)N (2  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and without assisting with accelerated ions]; VK8 + Ti (up to 1  $\mu\text{m}$ ) + TiN (1  $\mu\text{m}$ ) + (NbZrTiAl)N(2.5  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]; 4-VK8 + Ti (up to 1  $\mu\text{m}$ ) + TiN (1  $\mu\text{m}$ ) + (NbZrTiAl)N (2.5  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]; 5-VK8 + Ti (up to 1  $\mu\text{m}$ ) + TiN (1  $\mu\text{m}$ ) + (NbZrTiAl)N (2.5  $\mu\text{m}$ ) [applying coating layers by the condensation method with ionic bombardment (CIB) using filtered droplet phase and assisting with accelerated ions]; 6 is MC2210).



**Figure 3.** Sample of comparing wear resistance period of different tool materials



**Figure 4.** Sample of entering components of cutting force when treated the workpiece made from a specialized stainless steel of grade 09X17H7IO with various tool materials

### 3. Conclusions

The conducted researches allow drawing the following conclusions.

1. The use of coatings [2, 3, 4, 5] on the domestic hard alloy of brand VK8 significantly increases the performance of the cutting plates.

2. Technological method of refinement (thermal sharpening of cutting edges from the front and rear surfaces) also significantly increases the tool efficiency.

3. The insignificant difference in the size and shape of the medium dimension plates (the circumference diameter is from 16.5 to 18 mm) entails a significant difference in the wear resistance period, the cutting plate wear. The pentagonal shape of the plate is preferred. A rhombic form is a little bit inferior. The type of chip scraps produced is similar.

4. For plates of larger dimensions (the circumference diameter is 21.5 mm), the shape of the plate significantly affects its wear resistance period. In this case, a four-sided square shape is preferred.

5. The findings do not contradict the existing ideas about the cutting processes [5, 6, 7, 8, 9], they are based on the synergetic mechanisms of the blade treatment process of viscous materials and allow us to offer recommendations for selecting and strengthening domestic hard-alloy materials for treating the said stainless steel.

6. Analyzing the results of recording the components of the cutting forces showed that their value and the ratio between them depend significantly on the tool material used. It is established that the role of the coating in improving the tool performance depends significantly on the operating conditions, including the cut depth. The coating, which was the most effective (of the considered) at a cutting depth of 0.5 mm, may not be so at a cutting depth of 1.5 mm and may give primacy to the coating,

which was the second or third in efficiency at a depth of 0.5 mm. This does not contradict the existing ideas, but on this specialized steel the coating is displayed most clearly. This is typical not only for turning, but also for end milling [10, 11]. For end mills, the effect of coatings is evaluated by modeling, including using ANSYS software.

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