Comparative tests of the metal cutting tools performance in the processing of stainless steels

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Abstract. Corrosion-resistant stainless steels like 09X17N7U do not fit into the generally accepted system of recommendations for the selection of a rational metal cutting tool and parameters of the cutting regime for them. An individual approach is required. A comparative study of the period of wear resistance of the developed domestic instrumental material has been carried out, and recommendations for their use have been given.

Introduction
Demand in specialized (developed for the needs of shipbuilding) stainless steel grade 09H17N7U grows both in shipbuilding and in other industries (oil and gas engineering, chemical, etc.). But the specificity of its composition, structure and physical and mechanical characteristics hinders its use because of the complexity of the choice for its processing of a rational metal-cutting tool and the processing regime for it. There is no foreign analogue of this, and accordingly there are no clear recommendations of foreign instrumental firms. There are general recommendations; they are typical for the processing of simpler engineering stainless steels of general purpose. The recommended cutting speed is more than 120 m/min. For steel 09H17N7U it is impracticable because of its specific heat conductivity and heat capacity, which leads to thermoplastic destruction of the carbide cutting tool.

Known recommendations on the use of domestic tools are obsolete for various reasons, including due to the bankruptcy of their producers.

There was a need to create a bank of recommendations on the use of tool materials for such steel. This article is aimed at solving this problem.

Discussion of the results
The uniqueness of the physical and mechanical characteristics and performance properties, Table 1 and Table 2, of specialized stainless steel grade 09H17N7U* creates difficulties [1,2] when machined with a blade metal cutting tool. High strength and toughness of this steel do not allow using high cutting speeds, the wear tool life of the cutting tool is low, which is not acceptable in cases when changing the cutting edge of the cutting insert or changing the cutting tool is unacceptable.
Table 1. Chemical compositions of steel grade 09H17N7U.

|   | C    | Si   | Mn   | Ni | S   | P   | Cr | Al |
|---|------|------|------|----|-----|-----|----|----|
|   | до 0.09 | до 0.8 | до 0.08 | 7 - 8 | до 0.02 | до 0.03 | 16 - 17.5 | 0.5 - 0.8 |

*GOST 5632-72* Steel highly alloyed and alloys corrosion-resistant, heat-resistant and heat-resistant.

Table 2. Physical and mechanical compositions of steel grade 09H17N7U.

| Strength limit | Yield limit | Relative elongation at break | Impact strength | Heat treatment |
|----------------|-------------|-----------------------------|-----------------|---------------|
| σв, MPa        | σт, MPa     | δ5, %                       | KCU, kJ/m²      |               |
| 830            | 735         | 12                          | 490             | Hardening and high release |

We carried out comparative studies of various instrumental materials [3, 4, 5, 6] to identify the rational ones for these operating conditions.

The external turning is considered by passing cutters with mechanical fastening of cutting inserts. Only the four-sided square plates (diameter of the circumscribed circle 17.5 mm) with and without a central fixing hole are shown here, with and without a flute groove. Information on the used tool materials is given below.

The diameter of the workpiece changed during processing from 280 to 60 mm. The cutting speed was maintained in the range of 50 - 55 m/min due to the variation in the number of spindle turns. Screw-cutting lathe of 16K25 model was used. The feed of the tool from the roughness requirements of the machined surface is chosen to be 0.21 mm/turn blanks. The cutting depth was taken to be 0.5 mm for the finishing conditions and 1 mm for the roughing conditions. In both cases, the maximum allowable amount of wear on the back face was 0.5 mm. The cutting tool was compared for the period of wear resistance, i.e., by the time of operation of the cutting inserts with a proper roughness, until a wear of 0.5 mm on the back face. To measure the attained wear value, the treatment was interrupted every 15 minutes. Wear measurements were made on a multi-sensor measuring center (video measuring machine) of the Micro Vu Sol 161. The results of the tests were duplicated and documented. Below is the information only on the wear data hз on the back surface.

Figure 1 shows the experimental wear amount dependence hз on time t of the hard alloy work (grade VK8) of the tool.
Figure 1. An example of wear amount dependence $h$ on time $t$ hard alloy work (grade VK8) of the tool. 
(cutting mode: $v = 55$ m/min, $n = 160$ turns/min, $s = 0.21$ mm/turn, $t = 1$ min).

Similar graphs are constructed for different tool materials under identical operating conditions. An example of a comparative assessment of their wear resistance is shown in Figure 2.

Figure 2. An example of comparing the period of wear resistance of various tool materials: 1 – BK8; 2 – VK8 + покрытие** №1; 3 – VK8 + покрытие** №2; 4 - VK8 + coating** №3; 5 – VK8 + are subjected to a diamond thermojet [2] along the front surface and subsequent polishing on the back surface of the plate.

A comparative analysis of the results shows that the tool materials are significantly unequal in terms of wear resistance in the processing of this steel. The use of coatings [7, 8, 9, 10-14] on the domestic solid alloy grade VK8 significantly increases the efficiency of cutting plates. Technological acceptance of modification [2] of the cutting edges from the front and back surfaces also significantly improves the working capacity of the tool.

In Figure 3, several replaceable cutting plates of different shapes are conditionally shown in the working position in order to be able to visually assess their angle in plan.
Figure 3. Examples of cutting plates of different shapes. The conditional scheme of the arrangement of the plates for longitudinal turning external processing (a): 1 - the workpiece to be processed; 2 - square plate; 3 - pentahedral plate; 4, 5 and 6 - plates of triangular shape, installed in different positions in relation to the surface of the workpiece to be treated; examples of actual plates (b); examples of inserting plates into the tool body (c).

Comparative tests of wear resistance of such plates under comparatively identical operating conditions are carried out. Under wear resistance is meant here the operating time of the plate until a certain amount of wear on the rear surface is reached, this value is taken equal to 0.5 mm. The identity of the operating conditions could not be fully ensured, but the parameters of the cutting regime were the same in all cases (cutting speed 50-55 m/min, feed 0.21 mm/turn of workpiece, cutting depth 1 mm). The front corner at cutting at different plates differed not essentially. In all cases, the brand of the used instrumental material was VK8. The cutting forces are not analyzed here.

Table 3 shows the results obtained for individual plates.
Table 3. Information on separate used plates.

| N | Information on the cutting plate, her photo | Period of wear resistance, min. | Character of wear on the back surface | Example of shavings formed under specified operating conditions |
|---|---------------------------------------------|-------------------------------|--------------------------------------|---------------------------------------------------------------|
| 1 | A square plate (the diameter of the circumscribing circle is 17.5 mm) with a central hole | 45 | | |
| 2 | Pentagonal plate without chip shaving groove | 100 | | |
| 3 | Rhombic plate with two cutting edges CCMT 120404 – HMP Korea KORLOY. Inc | 90 | | |
| 4 | Triangular (with broken lines of the sides) plate (the diameter of the circumscribing circle is 21.5 mm) | 17 | | |
| 5 | The square plate is double-sided (the diameter of the circumscribing circle is 21.5 mm) | 65 | | |

Conclusion
1. The insignificant difference (rows 1, 2 and 3 of the table) in the dimensions and shape of plates of medium dimension (diameter of the circumscribing circle from 16.5 to 18 mm) entails a significant difference in the period of wear resistance, the nature of wear of the cutting plate. In this case, the pentagonal shape of the plate is preferred, not significantly, but inferior to the rhombic shape (line 3). The type of formed chips is similar.
2. For plates of higher dimension (diameter of the circumscribing circle 21.5 mm), the shape of the plate essentially determines its wear-resistance period (lines 4 and 5), with the quadrangular square shape being preferred.

3. At this stage of the work, it is not possible to qualitatively explain the advantage of a cutting plate of one form or another, but the information given can be used as recommendations. The obtained conclusions do not contradict the existing ideas about the cutting processes presented in various information sources and they are based on the synergetic mechanisms of the process of blade processing of viscous materials and offer recommendations for the selection and strengthening of domestic carbide materials for processing of this stainless steel.

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