Technology of hard alloy tool working capacity increase by applying composite coatings

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Abstract. Technological methods of increasing the working capacity of metal-cutting tools from hard alloy are reviewed. Data on the tool hardening efficiency is given. Comparative tests of the tool subjected to various types of strengthening thermoplastic processing show a relative increase in its performance. Paper presents a comparative evaluation of hard alloys and their coatings. Attention is paid to the technological control of the working capacity of the carbide tool using the coating. The structural features of working capacity control are considered in the example of composite end-to-end carbide cutters and tangential plates for restoring wheel-rolling processing.

The current choice of the instrument design and its material is carried out by the technologist in accordance with generally accepted recommendations. All the informational material is, in fact, made up experimentally for certain processing conditions. If the machining requirements differ from the standard ones, the technologist does not have the option to select the tool, and he must perform a set of trial studies or carry out a selection for risk.

This led to the following:

- tool-making enterprises produce tools for typical processing conditions, and making tools for special (non-standard) conditions is problematic because of the need to perform research and development work and small production volumes;
- enterprise-consumers of the instrument are obliged to organize production sites where the tool purchased for standard machining conditions is adapted to meet their non-standard machining requirements.

First of all, untypical processing conditions here are described as the processing of specific materials that are not covered by general engineering recommendations, for example, a number of alloyed steels from a group of shipbuilding, low-magnetic, stainless materials, high-strength cast-iron, titanium alloys and others; machining under shock-cycling loading conditions, for example, turning a cylinder with a discontinuous surface or with variable cut geometry, for example, unbalanced milling or gear milling.

In such processing conditions, the tool life period is much shorter than that predicted by the
recommendations for typical machining methods. This entails significant costs for the tool component and forces to work on improvement of the performance of a typical tool. The possibilities to carry out the improvements of the working capacity of the tool for a consumer enterprise are limited by many reasons. One of which is the lack of technological equipment on the market for tool hardening.

In some cases, especially when cutting hard-to-work materials, such requirements can be brought to the coating [1, 2], which can not be satisfied with the same coating composition. Selecting the composition of the coating for strength characteristics can reduce other indicators, which include adhesion interaction with the processed metal, thermal conductivity, or incompatibility with the coefficient of thermal expansion [3, 4, 5]. For conditions where a mediated solution of the coating features is required, it can be achieved by creating a coating using composition materials. This should be understood as a structure which consists of an alloy of more than one metal, for example, when the alloy contains titanium nitride and zirconium nitride, i.e. (TiZr)N.

The spectrum of applied coatings is very wide, they differ in composition, in the number of layers, in thickness, in the method of coating, etc. Figure 1 presents the illustrations of coatings made via electron HITACHI S-3400N microscope with a magnification of x3000.

![Coating Illustrations](image)

**Figure 1.** Catalog illustration of Pramet coatings: a) alloy 9210; b) alloy 9315; c) coating layers of alloy 9215 of Pramet LNUX 301940SN-DM; d) alloy 9230; e) alloy 9235.

The preparation of a composite-based coating is possible in several ways. It is simpler to obtain a composite coating on the basis of the CIB method. Let's consider several ways. The first is as follows: the construction of the cathode used as a source of metal ions to form a refractory compound in the plant chamber is prefabricated, and the ratio of the metal working areas corresponds to the ratio of the nitrides of these metals in the coating. Fig. 2.
Figure 2. Assembled cathode.

Part 1 of the cathode is made of titanium, part 2 is made of zirconium. At the ratio of the areas of the burning surface of the arc (spark) at the cathode \( S_2: S_1 = 1: 3 \), the coating composition will have approximately the same ratio of the nitrides of these elements, i.e. 60-70% TiN and 40-30% ZrN.

Technologically this method is simple, but it is significantly more complicated if a composition of more metals is needed. Moreover, far from always the required refractory metals are present in the parameters of the billet in terms of geometry.

The next way of obtaining composite coatings is the technology on the basis of which the given coating composition is made by evaporation of a cathode, the composition of which is selected from powder components and sintered by the powder metallurgy method.

The data on the use of sintered cathodes for obtaining complex composite coatings is presented below.

A) The sintered cathode is made by the method of powder metallurgy from a mixture of Mo molybdenum powders and silicon nitride Si3N4. The ratio of the components was varied so that when the cathode was evaporated by the CIB method, a wear-resistant coating (MoSi)N with a ratio of Mo2N and Si3N4 from 4: 1 to 7: 3 was obtained in the Bulat equipment chamber. When comparing the performance of such a coating with Mo2N coating, a significant increase in efficiency is shown, figure 3. Variant 1 in Figure 3 is taken as a traditional basic one. The performance was assessed when drilling blind holes 45 mm deep, 32 mm in diameter in specialized shipbuilding steel AK-29 with a cutting speed of 60 m / min and 0.12 mm/rev feed to wear of 0.4 mm.

![Figure 3. Illustration of the dependence of the performance of carbide drills on the way they are hardened:](image)

Option 2 is taken as more efficient in relation to the base one due to a better thermal conductivity of the MoN coating. Option 3 is taken as representative of modern multi-layer coatings. Variants 4 and 5 are taken as examples of developed composite coatings with a different ratio of components. From these data it follows that the performance of composite coatings is somewhat higher.

B) The cathode is made from a mixture of powders of molybdenum, zirconium, boron, silicon and titanium in a predetermined ratio. The structure of this coating is close-packed with a substantial content of silicides and borides on the surface. The results of testing such a tool with an intermittent turning of specialized steel AK-32PK at a cutting speed of 80 m / min, feed of 0.2 mm / rev and a depth of 1.5 mm are shown in Fig. 4. Here, for comparison, the tests results of another developed composite coating and two typical (TiN and TiC) coatings are presented.

The performance of the instrument with composite coatings is much higher. Position 4 in Fig. 4 shows the wear rate of a tool with a composite coating obtained by evaporation of a cathode, the
manufacture of which uses powders of not only pure chemical elements but also their compounds, namely titanium, molybdenum, niobium diboride, tantalum diboride, zirconium diboride. The performance of composite coatings commensurates with the solutions, but judging by the intensity of wear, the tool is advisable to use in finishing stages, where significant wear values are unacceptable.

The tool performance with a simpler composite coating of Cr + (Hf, Zr) N depending on the ratio of the components of the composite coating is illustrated in Figure 5 through the wear value for end milling of the titanium alloy VT-20 at a cutting speed of 80 m / min, feed 0.16 mm / tooth and a depth of 2 mm. It follows from Fig. 5 that the problem of optimizing the ratio of components takes place, but for any of the relations considered, the performance of the composite coating is higher than that of a simple nitride coating.

This direction of increasing the efficiency of the tool using composite coatings is in agreement with the data of researches [6, 7, 8, 9-11].

Figure 6 illustrates an example of tool performance management under the same cutting conditions due to optimization of a coating composition in comparison with a modern coating.
Figure 6. Wear value, mm, for equal working time of BK8 coated tool: 1 - modern industrial coating TiC + TiCN + Al₂O₃; 2, 3, 4, 5, 6, 7, 8 - the developed composite coating of Mo + (Ti, Zr) N + Mo + ZrN with the amount (volume%) of titanium nitrides, respectively: 50, 40, 30, 25, 20, 10.

It follows from the figure that at a ratio (volume%) of titanium nitrides and zirconium nitrides 50:50, the efficiency of modern and developed coatings is commensurable. With a decrease in the proportion of titanium nitrides, i.e. with an increase in the share of zirconium nitrides, the effectiveness of coatings varies, the extremum of the efficiency of the developed coating with respect to the current coating is observed at (25-30)% of the content of titanium nitrides. In the absence of titanium nitrides, the coating efficiency is not maximal.

The solution presents the results of the development of a composite coating for turning (speed 160 m/min, feed 0.1 mm/rev, depth 1.5 mm) with a hard alloy T15K6 coated with Mo + (Ti, W) N + (TiW) + ZrN hard- (stainless) steel grade 31H19N9MVBT. The first layer is molybdenum, the second layer is titanium and tungsten nitrides, the third layer is titanium and tungsten, the fourth layer is zirconium nitride. They are illustrated in Figure 7 for an example of optimizing the composition of a composite (second) nitride layer with the corresponding same optimization of the third (metallic composite) layer.

Figure 7 shows an extreme dependence with an optimum in the region of 70%.
Conclusion
In general, on the use of composite coatings it can be concluded that, with an unimportant complication of the technology of their application, it is possible to obtain a noticeable increase in the performance of the tool in difficult processing conditions.

It is most simple to realize the application of a composite coating by the method of cathode-ion bombardment due to the use of compound composite cathodes obtained using the powder metallurgy method.

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