Improve wear resistance of composite coatings on cutting tool from high-speed steel

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Abstract. Some ways of improving the tribotechnical characteristics of wear-resistant coatings from high-speed steel on cutting tools after ionic surface modification are considered. The above studies show that the formed coating significantly increases (by 2.1–2.4 times) the wear resistance of the cutting tool due to the expansion of the stage of normal wear.

1. Introduction
One of the ways to improve the cutting properties of tools is the development of a new type of multilayer coatings that would combine increased wear resistance and antifriction properties [1–3]. It is known that the high wear resistance of tools with hard coating is determined by the fact that they function as a screen for the contacting surfaces of the tool, thereby protecting them from external influences during cutting. This mainly occurs during the stationary stage of wear (normal wear). However, inevitable wear of the coating leads to further impact on the base material of the tool, the friction properties of which are much worse than the properties of the coating. As a result, tool wear quickly enters its catastrophic phase. Extending the normal friction stage, however, is quite feasible.

2. The deposition of multilayer coatings on the cutting tool
This is achieved in multilayer coatings by applying an additional bottom layer on the surface of the tool base, combining the properties and the ability to create protective secondary structures in the interphase layer of the coating and the substrate. One of the ways to create such layers is ion modification (doping or mixing) of the tool surface.

In this paper, multilayer triplex coatings were investigated. The high-speed steel used as the base was pre-nitrated in a glow discharge. Then the tool surface was modified by adding ions before applying a hard coating. Finally, the modified layer (Ti, Cr) N was synthesized by the method of physical deposition of coatings (PVD).

Ion nitriding of the substrate from high-speed steel was carried out in a special device for ion nitriding in combination with heating. The hard coating was applied with a cathode arc discharge plasma (CADP). The surface layer was cleaned before implantation with a special small time treatment in a glow discharge to improve the PVD adhesion – the coating with the substrate. Before applying the PVD coating, each of the samples was implanted with ions from one of sixteen different elements using a high-energy ion implant with an energy of approximately 60 keV at room temperature.

Wear tool with coatings was investigated in the processing of carbon steel (steel 45). The cutting speed was 70 m/min, the cutting depth was 0.5 mm, the feed was 0.28 mm/rev. Cutting was carried...
out both with and without coolant. The wear of four-sided quick-change high-speed steel plates with multilayer coatings was investigated. The effect of ionic surface modification on the wear resistance of the cutters was evaluated by comparing the tool life periods with the proposed multilayer coatings of tools with conventional coatings without additional ionic modification. The adhesion of the coating to the substrate was determined using the scratching method.

The results of field tests showed that the effect of implantable elements on tool durability is largely determined by the cutting conditions. The working temperature for high-speed cutting is about 600 °C. If coolant is used, the temperature is reduced by at least 100 degrees [3, 5, 6]. In this case, the ionic modification of the cutter's surface significantly affects its wear resistance.

Experiments have shown that the most preferable from the point of view of a complex of properties is a coating with an implanted indium layer. This makes it possible to increase the wear resistance of the tool as much as possible, independently of the use of coolant.

The study of the dependence of the friction coefficient on temperature for samples with a modified surface showed that indium (In) improves the frictional properties of high-speed steel (figure 1).

![Figure 1](image)

**Figure 1.** The effect of temperature in the test on the friction properties cutting tools made of high-speed steel with a modified surface: ○ – ion nitriding of P6M5; □ – ion nitriding R6M5 + Implantation In.

Acting as a lubricant, In reduces the shear resistance τ_{nn} of adhesive bonds that occur in tribocouples.

This, however, is not enough to explain the wear resistance of incisors with an indium-modified surface by two or more times. As shown by spectrometric analysis of the mass of the wear zone, the effect of indium is more complex. In addition to indium in the mass of the metal, in the wear zone, the
presence of indium oxide, which appeared as a result of the decomposition of both indium and indium nitride, was detected when heated during friction.

Implanted indium exists in two phase states: in the free and in the nitride group (InN). As the upper solid (Ti, Cr) N coating wears, the modified layer becomes unprotected on the rubbing surface. Under conditions of high loads and at high temperatures, the partial oxidation of In will most likely begin before the destruction of the PVD coating, which still plays its protective role. It should be noted that normal friction is characterized by a minimum depth of damage to the contacting surface. Therefore, even a small depth of the modified layer can affect the increase in wear resistance of the tool. Dissolved indium In improves the frictional properties of the surface and reduces the intensity of adhesion to the frictional surface. Thus, modifying the In surface contributes to lowering the heat supply to the friction zone through the dispersion channels that protect the tool surface. The double influence of In enhances the self-organization of the system and expands the stage of normal and sustainable wear, thereby implementing the basic laws of friction control [5].

3. Conclusion
In general, the results of the work found that:
- The optimum combination of high strength and reliability (characterized by high adhesion of the coating to the base) is manifested in a multilayer coating with a lower layer enriched with In. This element is present in the lower layer, both in the free and bound (In - N) states;
- The positive effect of In ion implantation on tool durability can be explained by complex processes. Acting as a liquid phase at cutting temperatures, indium helps reduce the friction coefficient. In addition, when the cutter is heated by friction, the indium-containing oxygen-containing phases formed on the wear surface protect the tool, preventing the transition from normal to catastrophic wear. This allows you to increase the stage of normal wear and significantly increase the tool durability;
- As a result of two step-hardening of the surface layer of the tool: by diffusion saturation with nitrogen (ion nitriding of high-speed steel) and by applying a wear-resistant coating with complexly doped nitrides (Ti, Cr) N with an additional modified bottom layer, it can significantly increase (2.1–2.4 times) tool wear resistance, due to an increase in the stage of normal wear.

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