Formation of diffusion titanium coatings from liquid metal media solutions on hard alloys WC-Co and TiC-WC-Co

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Abstract. The technology of diffusion titanium coating from the liquid metal media to the carbide-tipped tolls 15%Ti-WC-6%Co and WC-8%Co have described. The thickness of the coating varies depending on the temperature and holding time of diffusion saturation, and ranges from 2,6 to 5,6 μm on alloys of the 15%Ti-WC-6%Co type, from 2 to 5,4 microns on WC-8%Co alloys. It is revealed, that the elemental composition depended of composition of hard alloy. The microhardness of coating on hard alloy 15%Ti-WC-6%Co is 30000 MPa, and for hard alloy WC-8%Co is 24750 MPa. The high microhardness of the coating is provides by its formation on the basis of titanium carbide TiC. It was found that the elemental composition of the coating depends of the composition of the hard alloy to which it is applied. It was found that the surface layers consist of titanium carbide TiC, α-Ti like bind, intermetallide Ti₂Co for 15%Ti-WC-6%Co alloy. The WC-8%Co alloy also include tungsten carbide WC.

1. Introduction
The most popular turning tools are hard-alloy tools WC-Co and WC-Co-TiC systems. These materials provide high strength, wear resistance, heat resistance of tolls. But, despite all the advantages of carbide tools, the intensification of production, automation of the treatment process, the need to process difficult materials, are place increasingly high demands on operational properties of the cutting tool [1-3]. The way, provides the improve of operational properties is applying of surface coatings titanium carbide TiC base. The carbide of titanium has high microhardness, thermal stability and tribological properties.

There are a lot of technologies of coatings applying, but the main are chemical deposition of coatings (CVD), physical deposition method (PVD), and chemical-thermal treatment [1-3].

The method of chemical deposition of coatings, CVD (Chemical Vapor Deposition) based on obtaining various types of coatings due to heterogeneous chemical reactions at vapor-gas medium surrounding the coated tool.

Physical method of coating deposition, PVD (Physical Vapor Deposition) based on deposition with pre-ionization of the elements of the coating in a vaporous aggregate state to the solid substrate.

One of the most common methods of improving the performance of cutting tools is chemical-heat treatment. The essence of chemical-heat treatment is in the heating and holding at a given temperature of the active products in solid, liquid, or gaseous media, whereby, owing to diffusion processes in the surface layers of the products changes of elemental and structural phase composition, and, consequently, the properties of these surface layers [3-5].
Authors suggest using the technology of diffusion metallization from media of the fusible liquid metal solutions. This technology based on the phenomenon of isothermal, selective transfer of elements of the coating dissolved in the melt low-melting, at the surface with subsequent diffusion interaction of elements of the coating to the base material of the product [3].

There are a lot of works have described of formation coatings TiC base. But these works investigated of coatings formation have got CVD and PVD methods. The quantity of works has described of formation diffusion coating TiC base are boundedly. The technology of coating formation from carbon tetrachloride is known. This technology provides simultaneously adsorption titanium and carbon of saturate medium. The formation layer on surface consist of titanium carbide unbound of coating and matrix material as a result. This reduces of operation properties of coated product. The technology of diffusion metallization from media of the fusible liquid metal solutions is devoid of such deficiencies. However, the formation of diffusion coatings has got this technology weakly studied.

The aim of this work is investigate of formation process of titanium coating applied by diffusion metallization from media of the fusible liquid metal solutions technology.

2. Research methodology

Diffusion titanium coatings deposited on the original plate is not covered. We used carbide hex plate WNUM-080404, pentagonal plates PNUM - 110408 made WC-8%Co and 15%TiC-WC-6%Co alloys.

The coating applied by diffusion metallization with use of our technology [3,4] by immersing the carbide plates in the ampoule with the melt fusible and exposure under isothermal conditions in the environment of inert gases. As fusible melt delivering the item to the surface of the coated products were used, the melt eutectic Pb-Bi-Li-Ti.

Before coating, the plates subjected to short-term high-temperature carburization. Carburization used to saturate the surface of the instrument by carbon, which subsequently the coating formed. Carburization carried out using the technology of vacuum carburizing in propane-butane mixture.

The hardness of the plates tested by the method of Rockwell and the method of micro-Vickers. Rockwell hardness was determined on the hardness tester TK-2M according to standard methods, on a scale of "A". Metallographic studies carried out on the microsections prepared by standard methods. Studies to determine the thickness of the coatings, their structure and microhardness conducted on PMT-3.

The phase composition carried out by X-ray diffractometer Dron 7M. Diffractogram was conducted on radiation of CuKα under tension 30 kV, current strength 20 mA. The data base of ICDD PDF-2 used for identification of phases.

The element composition of surface layer investigated by X-ray microanalysis. Wherein used JEOL JSM-7500F scanning electron microscope and INCA x-sight oxford instruments spectrometer.

3. Analysis of research results

It was found the coating formation by diffusion saturation from liquid metal media solutions consist of titanium carbide TiC base. Also coatings include such phases as an α-Ti like bind and intermetallide Ti₂Co for 15%Ti-WC-6%Co alloy (figure 2). WC-8%Co alloy includes also tungsten carbide WC (figure 2).
Figure 1. Diffusion titanium coating on the top of the plate surface.

Figure 2. X-ray phase analysis of plates after diffusion saturation: a) WC-Co; b) TiC-WC-Co.
The coatings were applied using various technological modes. The temperature and duration of saturation varied. The temperature variation range was from 1000°C to 1100°C. The duration of saturation range was from 30 min to 120 min.

The coatings were characterized high hardness. The hardness of coating exceeds of uncoated hard alloy 1.3…1.5 times. This depends of carburization modes, diffusion saturation by titanium modes – the temperature and duration of saturation, and composition of hard alloy. The microhardness of surface layer on 15%Ti-WC-6%Co alloy after diffusion saturation at a temperature 1000°C during 30 minutes made up 27000 MPa. This 1.3 times higher as microhardness of matrix. For WC-8%Co the microhardness made up 22000 MPa these modes. When the temperature was increase the microhardness of surface layers increase too. Such microhardness of surface layer of 15%Ti-WC-6%Co alloy made up 30000 MPa with 1100°C, for WC-8%Co 24750 MPa (figure 3).

![Figure 3](image)

**Figure 3.** The microhardness of plates after diffusion saturation: a)TiC-WC-Co; b)WC-Co.

The increasing of temperature of process increased coatings formation intensity. The thickness of coating on 15%Ti-WC-6%Co alloy was 3.5 mkm when temperature was 1100°C, when the temperature
was 1000ºC, the thickness was 2.6 mkm. Similarly, the influence of temperature to thickness of titanium coating on WC-8%Co alloy. When the temperature of saturation was 1000ºC, the thickness was 2 mkm, when the temperature was 1100ºC, the thickness was 3.2 mkm.

The influence of duration of diffusion saturation was of great importance to coating formation process. When the time of saturation was increase, the intensity of coating formation declined. This was due to the fact that formation of titanium carbide TiC. When the carbide was formation, the diffusion fluxes of titanium to surface layers, and carbon from carburization layer to titanium, was decline. This was due to the fact that titanium carbide prevents of diffusion elements. And the higher the titanium carbide content the higher of prevents effect (figure 4).

Also, the influence of composition of hard alloy to coating formation process was high importance. The comparison of formation process on the alloys of TiC-WC-Co and WC-Co group showed that modes of saturation had a different effect (figure 4). The most significant difference of formation diffusion coating was observed which temperature of prosess was 1000ºC and duration of saturation was 30 min. The difference was 1.6 mkm. The difference of formation process explained that WC-8%Co include more quantity of tungsten and cobalt. During the carburization cobalt saturated by carbon. But, when the carbon concentration was higher the prevents effect higher too, that provides to less intensity of coating formation

![Figure 4](image)

**Figure 4.** Depend of thickness of coating of time and temperature of diffusion saturation: a)TiC-WC-Co; b) WC-Co.

During the research was fond that diffusion saturation by titanium from liquid metal medium solutions provides the formation of coating on titanium carbide TiC base. Formation process of coatings depended of composition of hard alloy and modes of diffusion saturation.

4. Conclusion

- The diffusion saturation of hard alloy by titanium provides the increase of microhardness 1.3…1.5 times exceeds of uncoated hard alloy.
- The surface layer composition consists of titanium carbide TiC, α-Ti like bind, intermatallide Ti$_2$Co for 15%Ti-WC-6%Co alloy. The WC-8%Co alloy also include tungsten carbide WC.
- The microhardness of surface layer of 15%Ti-WC-6%Co alloy can be upgrade to 30000 MPa and 24750 MPa for WC-8%Co alloy.

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