Influence of diffusion metallization to hard alloys of WC-TiC-Co and WC-Co with functional TiC coating by Ni-Cu

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Abstract. Diffusion alloying effect of WC-8%Co and 15%TiC-WC-6%Co hard alloys by Ni-Cu over TiC deposited by diffusion alloying in a low-melting liquid metal medium melt has presented. Such operation abilities of cutting tool as toll life, wear resistance, quality of processed surface can be increase by diffusion alloying in liquid metal melts. Tool life increased by 2.5 times compared to uncoated tools. It was found that kinetic of coating formation depends of the temperature and alloying time. The thickness of the diffusion layer varied up to 27 microns on WC-8%Co; up to 9 microns for 15%TiC-WC-6%Co alloys. The maximum microhardness on 15%TiC-WC-6%Co alloys was 21500 MPa, for WC-8%Co alloys 18000 MPa. It was found that element-phase composition of hard alloy influence to kinetic of diffusion functional coating formation process. Functional diffusion layer on 15%TiC-WC-6%Co alloys have a higher hardness and thickness compared to WC-8%Co.

1. Introduction
One of the main popular way to production of machine pars is mechanical processing. It consists of cutting the material with the cutting tool from the surface of the workpiece in the form of chips. Powder hard alloys are very popular cutting material [1,2]. These alloys consist of TiC, WC, TaC powders and Co as binder. These alloys have high wear resistance, heat resistance (up to 800-1000°C) [1,2], provides high performance machining [3]. However, the necessity to higher operation abilities make demands to increase of wear resistance of cutting tool surface. This achieved by forming of functional coatings. Currently, two methods are mainly used for coating of carbide tools: chemical deposition method and physical deposition method. These technologies are widely used by leading world companies specializing in the production of carbide-tipped tools [1,6].

The coatings, forming by these methods are films with crystallite structure of such compounds as TiC, TiN, Al2O3, etc. These coatings increase such operation abilities as wear resistance, cutting speed, toll life, quality of processed surface. However, CVD and PVD coatings have a lot of disadvantages in relation to cutting tool. Among these disadvantages are: low adhesion, high brittleness, sophisticated equipment, thin films etc.

These disadvantages can be achieved by using diffusion alloying technology, which consists at applying a Ni-Cu coating to the surface of a hard alloy, which has previous TiC coating.

To apply this type of coating, it is rational to use the technology of diffusion alloying from a medium of low-melting liquid metal melts, which ensures high productivity of the alloying process and allows uniform coatings to be applied to the tool of the most complex configuration. [6,9]
In addition, Ni-Cu coatings have high tribological properties, what provides low friction coefficient in the cutting zone. That coatings have high heat conductivity and solderability, which allows the use of coated carbide inserts for the production of cutting tools not only with mechanical fastening of the plates, but also the brazed tool.

Aims of this work are investigation of Ni-Cu coating over TiC coating kinetics applying in medium of low-melting liquid metal melts and estimation of its operation abilities.

2. Methodic

Functional diffusion coatings based on Ni-Cu over TiC were applied to hard-alloy hexagonal plates WNUM-080404, five-sided plates PNUM - 110408 made of WC-Co, 15%TiC-WC-6%Co alloys.

During diffusion alloying in melts, the coated products are immersed in the melt, which is a reaction-transport medium. The Pb-Bi-Li melt has a eutectic composition that contains up to 5% Ni-Cu. The melt is heated to the required temperature, then the coated samples are immersed in it. Samples are in the melt for 10 minutes to 5 hours in isostatic mode. During this time, the coating elements diffuse into the surface layer of the product, alloying them, forming a diffusion coating. The technology of diffusion alloying in Pb-Bi-Li melts based on the phenomena of isothermal mass transfer. Thus, the diffusing element, being in the melt, diffuses to the surface of the coated product, forming a coating on the surface of the product.

The study measured the Rockwell hardness of the plates. The hardness was determined on the hardness tester TK-2M on the scale of "A". Metallographic studies were performed on oblique microglides. The microhardness of the structural components of the surface layer was also measured. Microhardness was determined using the Vickers method on the EmcoTest DuraScan80 microhardometer under loading - up to 0.49 N. a series of 3 series of measurements was made, after which a graph of the change in microhardness was plotted.

The tool life tested on a 6P10 horizontal milling machine with a face mill of 100 mm diameter with mechanical fastening of the plates.

3. Analysis of research results

It fended out the coating formed on hard alloy surface due diffusion alloying. The microphoto has shown figure 1.

![Figure 1. Diffusion Ni-Cu coating on a WC-8%Co alloy. Temperature 1100 °C, holding for 2 hours X1000.](image)

Diffusion alloying by Ni-Cu was in the temperature range from 900 to 1200 °C in an isothermal cycle. At a coating temperature of 900-1000 °C, on coatings were formed, which can be explained by the insufficient activating ability of the transport melt at these temperatures. Samples extracted after
alloying at these temperatures were not wetted by the transport melt, and, therefore, the transfer of Ni-Cu to the hard alloy did not occur, since the diffusion process was not intensive enough to form coatings. Upon reaching a temperature of 1000 °C, thin coatings began to form on the surface of alloying material. The formation of uniform coatings on hard alloys begins at process temperatures of about 1100 °C. At a temperature of 1200 °C, a decrease in the size of the plate is observed. Such kinetics of coating formation can be explained by the appearance of the process of dismelt of hard alloy components (back diffusion) in the transport melt, and a decrease in the intensity of coating formation was also observed. Kinetic of Ni-Cu over TiC coating thickness forming presented at figure 2.

Figure 2. Dependence of coating thickness on application temperature and exposure time: a) WC-Co; b) 15%TiC-WC-6%Co.

With exposure during 120 minutes, the depth of the diffusion zone on the WC-8%Co hard alloy was 8 μm, after exposure for 300 minutes it was 15 μm, in 600 minutes a coating with a thickness of 23 μm was formed on the surface of the hard alloy (figure 2a). At the same time, an increase in the coating temperature significantly intensifies the process of coating formation. So, when applying coatings at a temperature of 1100 °C, the coating thickness is 18 microns. With a longer exposure, the thickness of the coatings at elevated temperatures is also higher.

After exposure for 120 minutes, the coating thickness on the 15%TiC-WC-6%Co hard alloy was 9 μm, after exposure for 300 minutes it was 18 μm, in 600 minutes a coating with a thickness of 29 μm was formed on the surface of alloying material (figure 2b). At the same time, an increase in the coating temperature significantly intensifies the process of coating formation. So, when applying coatings at a
temperature of 1100 °C, the coating thickness is 17 microns. With a longer exposure, the thickness of the coatings at elevated temperatures is also higher.

In the course of research, it was found that the deposition of Ni-Cu coatings significantly affects the microhardness of the coated material. At the same time, it should be noted that the microhardness after diffusion titanation reached 30000 MPa, which negatively affected the properties of coatings during milling. On a tool having a hard but brittle coating based on TiC base, chipping was observed. During diffusion alloying of hard alloys by Ni-Cu, quite viscous coatings with low microhardness are formed on their surface; for example, on the 15%TiC-WC-6%Co alloy, the microhardness at a depth of 5 μm is 4000 MPa. When removed from the surface, an increase in microhardness occurs. This is due to the fact that diffusion alloying with Ni-Cu was carried out on precoated instruments with a functional coating of TiC base, the microhardness of which exceeds the microhardness of the base of the hard alloy. So, the maximum microhardness is observed at a depth of 15 μm, and amounts to 21500 MPa for 15%TiC-WC-6%Co alloys and 18000 MPa for WC-8%Co alloys (figure 3).

![Figure 3. Dependence of microhardness on depth.](image)

The plates were tested on a 6P10 horizontal milling machine with a face mill of 100 mm diameter with mechanical fastening of the plates (figure 4).

![Figure 4. Milling of a workpiece from 40XH steel with 15%TiC-WC-6%Co carbide inserts.](image)
During field tests, it was found that the application of Ni-Cu coatings contributes to a significant increase in the durability of the coated tool in comparison with uncoated tools and with tools having a TiC base coating. The milling process is characterized by impacts during the cutting process, which adversely affect tools having coatings based on titanium carbide TiC. Thus, chips of a coating were detected on a TiC titanium carbide coated tool, which determined the resistance of TiC base coated tools at the level of uncoated tools. With the subsequent Ni-Cu coating, an increase in resistance was observed for both 15%TiC-WC-6%Co brand tools and WC-8%Co brand tools. The increase in resistance occurred in proportion to the increase in coating thickness, so the maximum resistance was revealed upon diffusion alloying at a temperature of 1150 °C; in this case, the coating thickness was 25 μm for WC-8%Co, 27 alloy for 15%TiC-WC-6%Co alloy. Moreover, the increase in resistance was 2.5 times for WC-8%Co alloy and 1.6 for 15%TiC-WC-6%Co alloy compared to uncoated tools. The dependence of the resistance period of the cutting inserts on the temperature of applying Ni-Cu coatings is shown in figure 5.

![Figure 5. Tool life dependence of the 15%TiC-WC-6%Co and WC-8%Co alloys type of the coating mode.](image)

4. Conclusions
During diffusion alloying by Ni-Cu over TiC coating forming diffusion layer having total thickness of up to 29 μm.

The elemental composition of the coated tool affects the kinetics of coating formation. Thus, coatings of greater thickness and microhardness were formed on 15%TiC-WC-6%Co alloys.

It is established that the application of the above coatings contributes to an increase in tool life during milling of 40XH steel by 2.5 times.

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