Diffusion metallization of carbide cutting tools as a way to improve the surface treatment quality

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Abstract. The application of diffusion nickle-copper coatings on hard alloys leads to an increase in the durability of carbide-tipped cutting tools when machining even hard carbide-containing steels at the high cutting speeds, which improves the productivity of the machining process. The analysis of the influence of deposition of nickle-copper coating by the diffusion metallization from environment of the fusible liquid metal solutions at the resistance of alloy carbide inserts of type WC-Co and TiC-WC-Co, and to the quality of the processing of hard alloy high viscosity has been performed.

1. Introduction

High-performance machining of materials is achieved by using carbide cutting tools.

Despite the fact that the total amount of cutting tools made of hard alloys does not exceed 25%, this cutting tool removes up to 65% of chips from the total amount of chips removed by a tool made from all used tool materials.

However, the intensification of production, using in construction hard-to-process materials in constructions and the automation of the processing process impose ever-increasing demands on tool life, tool reliability, and quality of cutting. As a result of which the problem of increasing, the service life of carbide tools is quiet relevant not only in our country, but also in entire world.

Improving the performance in operations of carbide tools is carried out in two directions.

First; is traditional way, which consists in optimizing the composition of the hard alloy by using multi-element solid solutions as a binder, and carbides, carbonitrides, metal elements non-traditional for these alloys (Cr, Hf, Zr, etc.) as a solid phase.

Second; direction is a change in the mechanical characteristics (specificly, wear resistance) of the surface layers of the cutting part of the tool due to a change in their composition, which is carried out by coating.

Second direction is being intensively developed by leading world companies such as Sandvik Coromant (Sweden), Hertel (Germany), Kennametal(USA), Mitsubishi (Japan) and others, as well as Russian manufacturers: Kirovograd Tool Plant, Sandvik MKTC, Holding Company CJSC “Tool factories”, and others.

Both methods are currently the most common used for coating carbide tools: the first is the CVD chemical deposition method. Its advanced MT-CVD low temperature deposition method. The second is the PVD physical deposition method.
Coatings obtained by these methods are layers with a crystalline structure of chemically inert and refractory compounds, such as titanium carbide, titanium nitride, alumina, zirconium, etc. Coating hard alloys can significantly increase the cutting speed. Consequently, the productivity of the processing process increases the tool life and its geometric stability, and the quality of processing. However, CVD and PVD coatings have a number of significant operational and technological disadvantages. These disadvantages include; low adhesion - this is especially characteristic for coatings obtained by CVD methods, high brittleness, which can lead to a decrease in the strength properties of the hard alloy and imposes restrictions on the sharpness of the tool cutting edge. Blunt cutting edge means increasing forces in the cutting zone and the heat. In addition, nitride, carbide, oxide coatings have low thermal conductivity which also contributes to an increase in temperature in the cutting zone and heating in the cutting zone leads to a decrease in tool life, and build-up on the tool, which leads to a decrease in processing quality [1]. In addition, chemical and physical deposition methods require the use of complex, expensive, energy-consuming equipment, and technological processes involves the use of aggressive and toxic environments.

The solution to the problems above can be achieved by applying the coating technology of diffusion metallization of hard alloys from the environment of low-melting liquid metal solutions. In particular, it is proposed to apply multicomponent nickel-copper coatings on the surface of carbide inserts with a combination of unique properties, with such as high viscosity and wear resistance [2]. Diffusion of nickel-copper coatings were applied to initially to uncoated plates by their diffusion metallization using the above-mentioned technology of diffusion metallization from a medium of low-melting liquid metal solutions.

2. Research methodology

Metallization was carried out in a lead-lithium melt in which nickel and copper were dissolved. The coatings were applied by immersion and soaking for a predetermined time of carbide plates in a bath with low-melting melt. The process was carried out in the modernized SGV–2.4-2/15-IZ electric furnace, that allows heating products in an inert gas environment [3].

Modernization of the furnace was carried out in order to ensure the possibility of coating in an open liquid metal bath. Coating was carried out in the temperature range from 900-1200°C in the isothermal cycle and in its thermal cycling cycle. The exposure time ranged from 10 minutes to 30 hours.

Coated hard alloy plates were subjected to metallographic studies by using a Zeiss AxioObferever A1.m research metallographic microscope. Measuring micro-hardness by using a Dura Scan 80 electronic hardness tester. Distribution of elements in the surface layers of carbide plates - coatings and adjacent areas were determined by X-ray microanalysis. Using microanalysis "Camebax micro” equipped with an INCA ENERGY 350 energy dispersive spectrometer with an electron energy of 15 keV. Locality determination of 2 microns. The phase composition over the thickness of the diffusion layer was determined by the method of x-ray phase analysis on a DRON - UM2 diffractometer.

Studies to assess the effect of the composition and properties of the surface layers of carbide tools on the quality of processing were carried out by turning aluminum alloy AMg6 and stainless steel 12X18H10T, as well as titanium alloy VT1-00. The aluminum alloy blanks were in the form of a bar with a diameter of 50 mm, and stainless steel blanks were in the form of a thin-walled pipe (wall thickness 2 mm) with a diameter of 50 mm, the titanium alloy blank was a bar with a diameter of 20 mm. Turning was carried out at cutting speeds of 60 m / s, 80 m / s, 100 m / s, feed 0.14 mm / rev. Assessment of the resistance of the cutters was carried out by turning a bar with a diameter of 60 mm from steel X12MF in the delivery state. Cutter lost its cutting properties during the period of resistance time.

3. Analysis of research results

As the result, study showed the diffusion metallization of hard alloys of the VK and TC types from the medium to low-melting liquid metal solutions of nickel and copper in a lead-lithium melt leads to the
formation of a two-layer diffusion coating on their surface (figure 1). The outer coating layer is a solid solution of nickel, copper and cobalt [4]. The thickness of this layer depends on the metallization conditions and lies within 10 ... 25 μm, and its initial micro-hardness of the surface layer is 3000-3200 MPa.

A layer of increased hardness is formed under the solid-solution surface layer on TK-type alloys. Micro-hardness of this layer is 21000 MPa, i.e. more than 2 thousand MPa higher than the hardness of the base. After this, a monotonic decrease in hardness to the hardness of the base is observed - H50 = 18660 MPa.

![Figure 1. shows view of an etched metallographic thin section of a T15K6 alloy with a nickel-copper coating. X500.](image1.jpg)

Photos of plates made of T15K6 alloy with and without nickel-copper coating are presented in figure 2.

![Figure 2. WNUM-080404 carbide hexagonal plates with nickel-copper coatings (light) and without coatings (dark).](image2.jpg)

High viscosity of nickel-copper coatings significantly increases the viscosity of the surface layers of hard alloys. Which allows you to create sharp cutting edges on the tool and significantly reduce their tendency to chipping when shock loads occur during cutting. Low coefficient of friction, the high thermal conductivity of the nickel-copper coating, and the sharpness of the cutting edge make it possible to exclude buildup on the tool, therefore, improves the quality of processing and its productivity. Comparative tests of the cutting properties of tools with carbide inserts without coatings, with PVD coatings (TU 19-4205-77-2004) based on titanium nitride and with nickel-copper diffusion coatings carried out during turning showed that the coating on carbide tools provides a significant increase in processing quality.
So, when turning aluminum alloy AMTs with cutters equipped with plates with PVD coatings, a decrease in surface roughness is observed, compared to machining with cutters in which the plates were uncoated. At cutting speeds of 80 and 100 m / min, cutters with PVD coatings relatively uncovered. The roughness parameter of the machined surface Ra decreases by a factor of 2.4. However, processing the same alloy with nickel-copper diffusion coated cutters provides more significant improvement in the quality of processing. Comparison of the roughness parameters of the treated surfaces with cutters equipped with plates with diffusion nickel-copper coatings and without coating at cutting speeds of 80 and 100 m / min shows that nickel-copper coatings provide a 4.3-fold decrease in the roughness parameter of the treated surface Ra. So, at a cutting speed of 100 m / min Ra coating Ni + Cu = 1.57 μm, and Ra non-coating. = 6.71 microns. The reduction in the roughness of the treated surfaces with cutters equipped with plates with diffusion nickel-copper coatings compared to cutters with plates with PVD coatings at cutting speeds of 80 and 100 m / min, is 1.8 times, i.e. 180%.

Thus, the application of diffusion nickel-copper coatings on hard alloys provides a significant improvement in the quality of finishing of aluminum alloys. This improvement in the quality of processing, as the analysis of the state of the front surface of the cutter shows, absence of outgrowth on surface on carbide plates with a nickel-copper coating. Improving the quality of processing due to the coating of carbide tools is also observed. In the processing of titanium and its alloys. Studies to assess the effect of the type of coating on the roughness of the machined surfaces carried out on the VT1-00 alloy have shown that the roughness of the machined surface depends on the cutting speed. At a cutting speed of 30 m / min, PVD-coated carbide inserts provide a slight decrease in surface roughness compared to uncoated inserts, while the surface roughness after applying nickel-copper coated inserts decreased by 2.4 times. At a cutting speed of 40 m / min, there is a slight increase in surface roughness treated with PVD coated inserts compared to uncoated inserts. Nickel-copper coatings in this mode provide a 2.75-fold reduction in the roughness of the treated surface relative to plates with PVD coatings.

Further, increase in cutting speed, in particular, up to 50 m / min, provides an improvement in the quality of machining with cutters having PVD coatings and nickel-copper coatings. Similar results are observed when processing austenitic stainless steel. For example, when processing a thin-walled pipe with a diameter of 50 mm and a wall thickness of 2 mm from austenitic stainless steel 12X18H10T due to the low stiffness of the walls, the decrease in the quality of the treated surface is observed not only at the micro, but also at the macro level. The buildup on the working surfaces of cutters with uncoated plates and with PVD coatings causes the formation of shagreen on the treated surface. At the same time, treatment with a similar nickel-copper coated carbide plate ensures high quality of the processed surface up to a pipe wall thickness of 0.5 mm. The cutting speed during processing was 140 m / min, cutting depth 0.5 mm, feed 0.14 mm / rev.

4. Summary
Thus, the deposition of nickel-copper coatings on hard alloys provides a significant improvement in the quality of processing viscous difficult-to-treat alloys, which is associated with a decrease in the tendency of hard alloys with nickel-copper coatings to adhesion hardening - growth, mechanical and corrosion-mechanical wear. In this case, the surface roughness (parameter Ra) can decrease by a factor of 4.3 relative to the surface treated by uncoated plates and by 1.8 times relative to the surface treated by PVD coated plates. When processing thin-walled products, the formation of shagreen on the treated surface is excluded.

The application of diffusion nickel-copper coatings on hard alloys leads to an increase in the resistance of a cutting tool with carbide inserts when machining even hard carbide-containing steels at high cutting speeds, which increases the productivity of the processing process. So, when turning with carbide inserts, the durability period of plates with nickel-copper coatings relative to uncoated plates is higher relative to plates with PVD coatings.
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