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Artificial aging of hard-alloy cutting tool with titanium diffusion coating as a way to increase its persistence

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Abstract. The paper describes the technology of applying titanium diffusion coating to the cutting tool from low-melting liquid metal solutions. The results of thermal treatment of the carbide cutting blades (WC and TiC type) after titanium diffusion coating from low-melting liquid metal solutions are given. The results of thermal treatment influence on the firmness of cutting tool having titanium coating are shown. It is found out that thermal treatment temperature, its duration and material composition influence affect tool durability and coating micro-hardness. It is revealed that thermal treatment of the carbide instrument with titanium diffusion coating lets to increase its persistence by 1.79 times comparing to the tool without coating. But without thermal treatment persistence of the instrument with coating increases by 9 times in comparison to the tool without coating.

1. Introduction

Nowadays, hard-alloyed cutting tool is most popular in metalworking. Meanwhile, surface functional coatings are most commonly used in order to increase its persistence. Such coatings can be made from carbides, nitrides, oxides, borides, and other mixtures of such elements as titanium, chromium, aluminum, silicon etc. [1-4].

Coatings can be applied by means of such technologies as PVD, CVD, XTO. Chemical and thermal means of coating are of interest since these techniques can provide diffusion alloying of the coated surfaces. Diffusion coatings of these types can be deposited to the objects of any shape. Furthermore, the composition of the formed surfaces is complex-alloyed, it has high compatibility with the base material because under the coating there is transition layer characterized by slow decrease concentration of coating elements [1-4].

In this work the coatings were applied by means of diffusion metallization from the environment of low-melting liquid metal solutions. The technology is based on the phenomenon of isothermal mass transfer of a diffusing element to the surface of a coated item in the environment of low-melting liquid metal solutions [5].

The aim of the paper is to study how aging affects the persistence of the hard-alloyed cutting tool with diffusion titanium coating.

2. Methodology

Diffusion titanium coatings were applied to originally clean plates PNUM - 110408 from hard alloys. According to the technology, the items are immersed into the melt of a low-melting metal element, in which coating elements are dissolved in a certain proportion. The items are kept in the melt at preset temperatures from 10 minutes to 5 hours. During this time, the elements of the coatings diffuse into the surface layer of the item, alloy them, forming a diffusion coating [5-8].

Before coating, the plates were subjected to short-term high-temperature carburizing. Cementation is necessary to saturate the surface of the instrument with carbon, which subsequently forms the coating. Cementation was carried out using vacuum cementation technology in a propane-butane mixture medium in a BMI BMICRO vacuum furnace.

After coating, the plates were aged at 500-8,000 degrees Celsius according to the technology developed and patented by the authors of the paper [5]. Aging was carried out with the aim of redistributing carbon over the coating and separating the second disperse phase in the form of titanium carbide.

Studies to evaluate the effect of diffusion titanium coatings on the resistance of the cutting tool were carried out by full-scale tests during turning machining. Turning was carried out by passing cutters with mechanical fastening of plates. Carbide pentahedral plates of hard alloys without coatings and titanium diffusion coatings applied according to the proposed technology were used.

Characteristics of tool resistance were determined by turning rods made of U10 steel, after hardening and medium tempering, HRC = 43 ... 45.

Turning was carried out at a cutting speed of 130 m/min, feed of 0.8 mm/rev, cutting depth of 1 mm. Time during which the tool lost its cutting properties was taken as the period of persistence.

Plate hardness was verified using the Rockwell method and the micro-Vickers method. Rockwell hardness was determined on the TK-2M hardness tester according to the standard method, "A" scale. Metallographic studies were conducted on microsections prepared according to a standard procedure. Studies to determine the thickness of coatings, their structure and microhardness were carried out on PMT-3 microhardnesser.

3. Results and discussions

As a result of the diffusion saturation of the carbide tool with titanium from the alloys of WC and TiC type, a diffusion coating with a thickness of 3-6 μm is formed on its surface. In this case, the coating has a surface layer formed on the basis of titanium carbides and a transition layer between the coating and the material to be coated containing both the elements of the material to be coated and the diffuser elements. A photomicrograph of WC8 alloy is shown in figure 1.

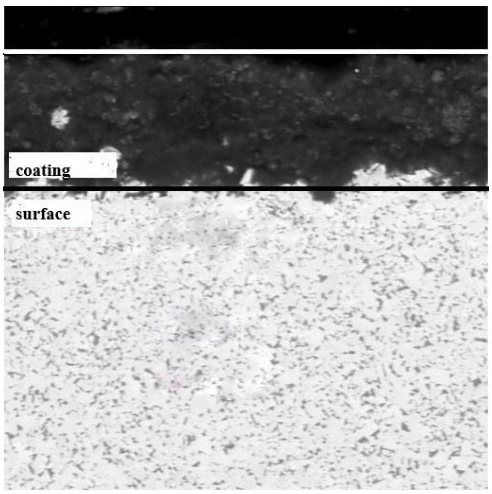


Figure 1. Micrograph of WC8 alloy with diffusion titanium coating.

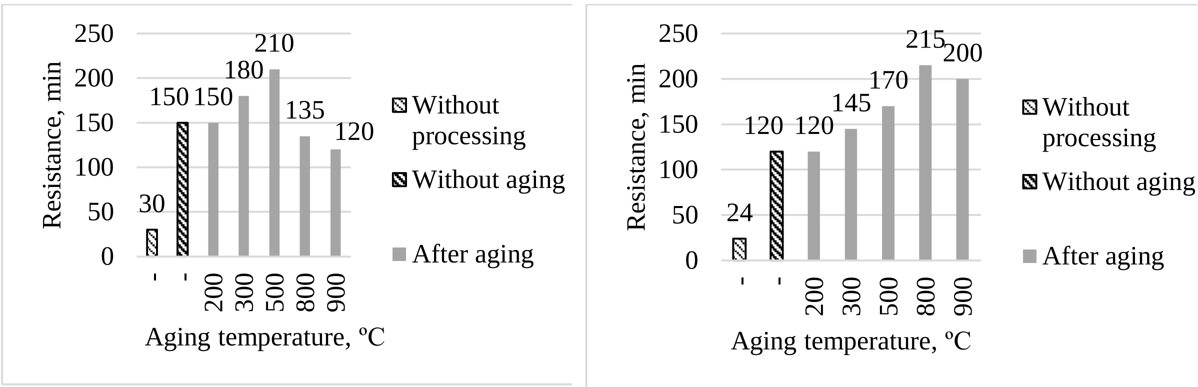
The research revealed that the artificial aging of a hard-alloy cutting tool having a diffusion titanium coating causes the secondary carbide phase to separate in the coating, which contributes to an increase in tool life. In this case, the degree of resistance increase depends on the modes of artificial aging, i.e. temperature and duration.

To determine the effect of aging regimes on cutting carbide tool resistance, diffusion titanium coatings were applied to a plate of WC8 alloy at a temperature of 1100 degrees Celsius, and a plate of

T15K6 at a temperature of 1000 degrees Celsius. Preliminary high-temperature carburizing was carried out at a temperature of 1100 degrees Celsius. Cooling after the coating process was carried out at a speed of 200 degrees Celsius per minute. The choice of preliminary high-temperature carburization modes, diffusion metallization, and the cooling rate after the coating process is justified by the greatest value of tool life in laboratory tests.

Artificial aging was carried out at a temperature range of 150-900 degrees Celsius in an inert gas atmosphere. The exposure time varied from 60 to 120 minutes.

As studies have shown, the stability of the tool is influenced by parameters of artificial aging regimes, such as temperature, duration, elemental composition of the material to be coated. The firmness of a carbide tool subjected to diffusion titanization is increased due to the redistribution of carbon and titanium carbides of TiC type in the coating during aging. Due to aging, the element-phase composition is leveled, the secondary carbide phase is recovered in the coating, the microhardness of the surface layer of the coating increases, which positively affects the tool resistance [8]. Figure 2 shows histograms reflecting the increase of a carbide tool resistance having a diffusion coating subjected to artificial aging. Resistance increases by about 9 times in comparison to to the uncoated tool for WC group alloys and about 7 times for alloys of the TiC group.



a) T15K6 b) WC8

Figure 2. Artificial aging influence on the resistance of a carbide tool with a titanium diffusion coating.

The experiments showed that the aging temperature has a defining impact on the resistance of plates after the diffusion titanation process. When aging is carried out at temperatures below 300 degrees Celsius, the tool resistance remains at the tool level after coating, but without aging. In the temperature range from 300 to 800 degrees Celsius an increase in resistance is observed for WC alloys and from 300 to 500 degrees Celsius – for alloys of the TiC type.

TiC alloys have the greatest increase in resistance after aging at a temperature of 500 degrees Celsius. At this aging temperature, the tool life is increased 7 times in comparison to the uncoated tool and 1.4 times with respect to the coated tool, but without aging. When the temperature rises above 500 degrees, the tool life decreases. This effect is associated with an increase in the coating of titanium carbide TiC, which has a high hardness and brittleness, which leads to embrittlement of the surface layer of the coated item and, as a consequence, to a decrease in tool life.

For alloys of the WC group, the most effective aging temperature is 800 degrees Celsius. Aging at this temperature contributes to an increase in the durability of the titanized tool by 8.95 times compared to the uncoated tool and 1.79 times compared to the tool having a coating but not aged. When the temperature is increased to 900 degrees Celsius, the wear resistance of the tool is reduced, the same as in the case of a tool of the TiC type, due to the increase in the brittleness of the surface layer.

Such difference of the aging temperature influence on T15K6 and WC8 alloys is explained by the alteration in the elemental composition. In the case of preliminary high-temperature carburization, the element that is saturated with carbon is cobalt. With the increase in the aging temperature above the optimum, intensification of the diffusion processes takes place, which leads to the formation of a large amount of titanium carbides and to a decrease in tool life due to the coating embrittlement.

In addition to temperature, the duration of the diffusion titanation process has an effect on the resistance. We found that the optimal range of exposure time is an interval of 80 to 90 minutes. This time is sufficient to complete the necessary diffusion processes and to separate the second disperse phase in the form of titanium carbide. With an increase in the holding time of over 90 minutes, no changes in the tool wear resistance are observed.

The experiments showed that the artificial aging of the cutting carbide tool with diffusion titanium coatings can increase the tool life up to 1.79 times compared to the tool without aging. Thus, aging of a carbide tool with diffusion titanium coatings can be used as an effective way to improve its performance properties.

4. Conclusion

Aging of a carbide cutting tool having diffusion titanium coatings can be effectively used to improve its resistance.

The aging temperature of the cutting tool with diffusion titanium coatings has a significant effect on its resistance. When the aging temperature is increased to 800 degrees Celsius, the durability of the WC group instruments is increased by 9 times compared to the uncoated instrument. The strength of the TiC group instruments increases when the temperature rises to 500 degrees Celsius.

The elemental composition of the coated materials also affects the results obtained after aging. Thus, it is irrational to age alloys with low cobalt concentration at temperatures above 500 degrees Celsius. And on the contrary, with increasing cobalt concentration, the aging temperature of coatings can be increased.

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