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Research into the process of spraying complex titanium and zirconium nitride on structural steel and reaction times relating to the final finish and quality obtained

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Abstract: This article presents a literature review into the current state of the theory and practice of spraying complex titanium and zirconium nitride on steel P6M5, as well as a study of the effect of spraying time on the structural and mechanical characteristics of the applied coating. With the help of microstructural analysis and the measurement of the mechanical properties of the sprayed layers, it was found that the size of the voids and their number per unit surface area decreases with the spraying time. The highest values of hardness and crack resistance of the coating were obtained during the technological process – 15 minutes. It was found that the duration of vacuum-condensation spraying with Ti-Zr-N alloy significantly increases the wear resistance of structural steels, and the best results among the considered parameters showed a sample with a spraying time of 15 min, this figure can be considered optimal.

Keywords: spraying, hardness, crack resistance, titanium and zirconium nitride, drip phase

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Introduction

The use of coatings makes it possible to produce parts of machines and mechanisms of the appropriate designation from ordinary structural steels by spraying a special wear-resistant material on the working surfaces (Runkov, 1966). Spraying is the process of coating one material by another, during which the atomic materials of the material that is being sprayed settle on the surface of the parts forming a coating (Lisnikov at al., 1985). There are different methods of coatings, but in this work for the sake of the experiment, the reaction method in the vacuum-condensation method of atomization of titanium nitride to structural steel was used (Gumen et al., 2019). Some compounds cannot be sprayed onto the parts by direct evaporation or ion spraying due to partial or complete decomposition (Maslyuk et al., 2015). These compounds include elements whose partial vapor pressure is very different (for example, nitrides, carbides). Therefore, in the form of coatings, they are obtained by the reaction between the atoms of the steam flow of metals and atoms specially introduced into the chamber of chemically active gases (Paton, 1979; Dubovoy et al., 1986). The slight heating and slight deformation of the base material during the spraying process, as well as the possibility of coating only specified sections of the part, determine the high technological efficiency of the application of the vacuum-condensation spray method to increase wear resistance (Vinokurov, 1976; Denisova et al., 2009).

However, products with spray coatings have a superficial defect – a droplet phase (Gumen et al., 2019), whose manifestation essentially depends on the technological parameters of the spraying process that leads to additional machining of the finished product, and therefore unnecessary energy and resource consumption (Poltaev, 1980). This prompted a solution to the problem of eliminating this defect.

1. Aim

The purpose of the work is to study the dependence of the durability of steel P6M5 depending on the time of vacuum condensation spraying of their surfaces with Ti-Zr-N alloy for optimizing the process and improving the quality of the applied coating.

2. Methodology

The research is based on theoretical (research of scientific sources on the study of the droplet phase, the development of an experimental model, analysis of the results) and experimental (production of samples at different time, mechanical behavior studies) research methods.

3. Vacuum-condensation spraying of Ti-Zr-N on steel P6M5

The coating of the samples by the vacuum-condensation method of reaction spraying was carried out in accordance with the basic requirements of the spray technology in two stages: the preparation of the surface of the samples and the spraying stage (Gumen et al., 2019). The paper will consider each stage of spraying in more detail.

The surface of the sample should have a minimum amount of micronutrients and be completely contaminate free. Grease and silicone pollution will greatly reduce the effectiveness of the process, which will adversely affect the surface of the coating. Therefore, before the spraying process, the surface of the sample was ground and degreased with alcohol. To prevent the influence of air molecules on the chemical reaction between the vapor flow of titanium and nitrogen atoms, a vacuum was created in the chamber. Each sample was sprayed, changing the process time: 5, 10 and 15 min. With increasing spraying time, the spraying thickness increased to 5 μm (Table 1).

As the active gas, high-purity nitrogen N was introduced into the vacuum chamber under a total pressure of 0.12 PA, it entered into plasma-chemical reactions with Ti-Zr, and a layer of Ti-Zr-N alloy was formed on the surface of the products.

Table 1. Dependence of the thickness of the sprayed layer on the spraying time (*own study*)

No sample	Spray time, min	Spray thickness, μm
1	5	2
2	10	3.5
3	15	5

4. Investigation of the drip phase

To determine the dependence of the manifestation of the droplet phase and its parameters on the current strength of the arc discharge, a study of the surface of the samples was carried out by different microscopes, which made it possible to detect defects in the form of emptiness, to investigate their nature, to make linear measurements of tumors, and to investigate the structure of the surface.

It was observed that the size of the droplet phase decreased with increasing spray time (Fig. 1).

a b c

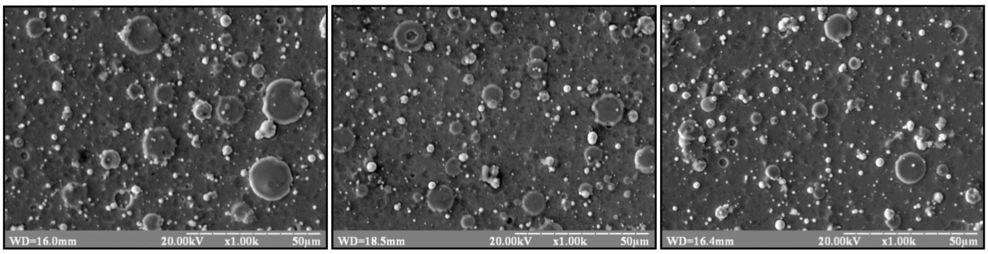

Fig. 1. Metallographic analysis of the sample by spraying 5 min (a), 10 min (b), 15 min (c) (*own study*)

5. Hardness measurement

After applying the Ti-Zr-N alloy on the surface of the steel of the three samples at different spraying times, the hardness of the coating was measured by the Vickers method (Table 2).

Table 2. Hardness of the coating Ti-Zr-N (*own study*)

Time, min	d, μm	Hardness, GPa
5	39	24,37
10	38	25,67
15	37	27,15

It was found that the hardness of the surfaces after spraying increased. For the coating with a time of application of 15 minutes, the strength, compared to the surface sample without spraying, increased tenfold. Therefore, the Ti-Zr-N coating should be used to increase the hardness and wear resistance of steels (Fig. 2).

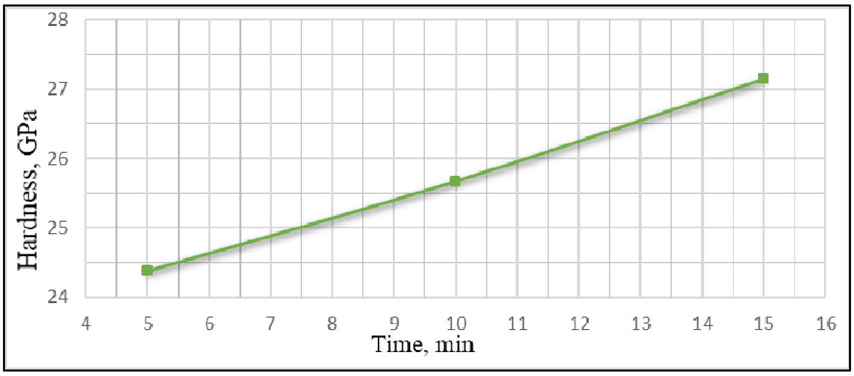

Fig. 2. Dependence of hardness of a covering on spraying time (*own study*)

6. Measurement of crack resistance

Measurement of crack resistance (the ability of the material not to collapse in the presence of cracks at different spray times) the layers in the surface of steel samples showed an increase in crack resistance as length of application and the thickness of the sprayed layer increased (Table 3).

Table 3. Crack resistance of Ti-Zr-N coating (*own study*)

Time, min	Crack resistance, $MPa \cdot m^{1/2}$
5	12
10	15
15	17

The graph shows that with increased spray time, crack resistance increases, and therefore the material becomes stronger and more durable (Fig. 3).

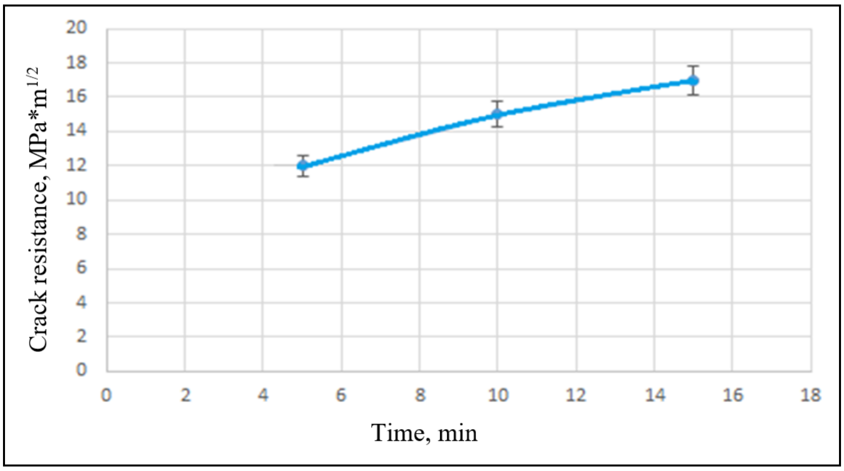

Fig. 3. Dependence of crack resistance of a covering on time of spraying (*own study*)

Conclusions

The use of the method of coating one material by some other materials in the manufacture of parts is promising, since it allows you to create elements with increased wear resistance properties using fewer resources. Vacuum-condensation spraying allows the application of both pure materials and mixtures: this is the main advantage of the method of spraying compared with electrolytic coating. The spraying process takes place fairly quickly, creates an even layer and saves energy when compared with other coating methods.

The main disadvantage of this method of spraying is the formation of droplets on the surface of the product. To solve the problem of reducing the droplet sizes, spray times were changed: 5, 10 and 15 min. Using microstructural analysis and measurement of the mechanical properties of the sprayed layers, it was found that the size of the voids and their number per unit surface area depends on the spray time. The smallest dimensions of droplets and, accordingly, the largest values of hardness and crack resistance were obtained during the technological process of 15 minutes.

The promise of advanced technology in vacuum-condensation spraying is due to a decrease in the number of defects on the surface of the spray product. The proposed technology for the manufacture of materials can be used in manufacturing for producing sprayed surfaces, which are damaged with the passage of time. This will make the parts more economical and will extend their lifespan.

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