Improvement of wear resistance of austenitic steels by applying of carburization and diffusion saturation in liquid metal media solutions

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Abstract. The technology of the increase of wear resistance of austenitic steel products by combining the technologies of carburization and diffusion alloying in the medium of fusible liquid metal solutions has been described. The preliminary and subsequent carburization led to increase of surface layers microhardness of coated material to 5600 MPa. At the same time, the depth of the doped layer can reach 420 microns.

1. Introduction
Currently, one of the most popular types of steel in the food, chemical and oil and gas engineering are austenitic steels. The widespread use of steels of this class is due to their special physical and chemical properties that provide products with corrosion resistance, heat resistance, cold resistance, etc. At the same time, steels of this class have very significant drawbacks, which include low wear resistance and anti-friction properties. These disadvantages significantly complicate the use of austenitic steels in friction units, in particular, in shut-off and control valves with a metal-on-metal seal, operated at high temperatures and erosion-mechanical wear. One of the most promising technologies that improve the wear resistance of austenitic steels, as well as their antifriction properties, are the technologies of chemical thermal treatments, which allow to form allowing to form on the surface of austenitic steel products diffusion-saturated layers with high hardness and wear resistance.

In this paper we consider a method of surface alloying austenitic steels, providing, along with increasing the wear resistance of austenitic steels, resistance to high contact stresses and aggressive working environment. Increasing the wear resistance and resistance to high contact stresses and aggressive working environment of austenitic steel products in the method under consideration is achieved by combining the technologies of carburization and diffusion alloying (diffusion metallization) in the medium of fusible liquid metal solutions [1]. Chromium and nickel were chosen as the main metal alloying elements. In this composition, chromium provides due to the interaction with carbon introduced into austenitic steel in the carburization process, the formation of a layer on the surface of the product consisting of chromium carbides, giving this layer a high hardness, and Nickel provides a solid-solution bond of the carbide layer with the base material [2].

The aim of this work was to analyze the influence of the stages of technology based on the combination of carburization and diffusion alloying processes in the medium of fusible liquid metal solutions, as well as their modes, on the properties of surface and near-surface layers of products made of austenitic steels.
2. Research methodology
Studies to assess the impact of stages and modes of carburization and diffusion alloying were carried out in the laboratory on flat samples made of steels 12X18H10T, 08X18H10T under industrial use of the technology in question, within the framework of import substitution, to restore the operability of the locking elements of the ball valve "GROVE" type VT1 with a seal "metal on metal".

The coating was 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-Ni-Cr.

To assess the impact of the stages and modes of carburization and diffusion saturation, the following technological options were studied:

Option 1-the samples were subjected to the carburization process;
Option 2-the samples were subjected to pre-carburization, diffusion saturation with chromium and Nickel in a fusible solution and subsequent carburization.

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 was carried out by X-ray microanalysis. The scanning electron microscope JEOL JSM-7500F is used for electron microscopy.

3. Analysis of research results
The carburization by Option 1 with temperature 850º C during 5 hours increased the microhardness of the surface layer to 2.7 times relatively matrix material. However, at a depth of 7 microns there is a sharp drop in microhardness from 2800 MPa to 2000 MPa, and then, at a depth of 75 microns, the microhardness decreases to the microhardness of the matrix 1030 MPa. The hardening of the surface layer after carburization was conducted to a slight increase of the wear resistance (figure 1).

![Figure 1. Distribution of microhardness in the depth of the diffusion-doped surface layer after carburization 900º C, 8 hours.](image-url)
The most effective process occurred by Option 2. All of technological process stages lasted 8 hours with temperature 900° C. This leaded to depth of the carburized layer more than 500 microns. Reducing the temperature of diffusion alloying the surface of austenitic steels with chromium and nickel to 900° C, in turn, conducted to a decrease in the microhardness of the surface layer to 5600 MPa while increasing its length to 70 microns.

At a depth of 105 µm the microhardness is drastically reduced to 4670 MPa and a depth of 280 µm microhardness reaches 4110 MPa. After this phase of gradual reduction of microhardness, a more intense decrease in hardness is observed and at a depth of 420 microns, the microhardness is 2700 MPa.

The carburization does not lead to an increase in hardness, and therefore wear resistance of austenitic steels. Similarly, there is no increase in hardness due to diffusion alloying austenitic steels with chromium and nickel. As follows from the results of our previous studies, diffusion alloying of austenitic steels with chromium and nickel in the medium of fusible solutions conducted to the formation of solid solutions based on nickel, chromium and iron in their surface layers. Such a diffusion layer has a very high corrosion resistance, in particular, in hydrogen sulfide-containing media, but a low microhardness of 3000 ... 3500 MPa, which does not provide an increase in wear resistance of austenitic steel products.

A significant increase in hardness provides an introduction to the technological process of pre-carburization, which increases the concentration of carbon in the surface layers of the product material, causes a subsequent stage of diffusion saturation of its chromium and nickel inhibition of chromium diffusion deep into the product material, resulting in an increase in the concentration of chromium in the surface layer from 30 to 85 %. This, ultimately, provides the formation of hard layers on the surface of austenitic steels (microhardness 28000 MPa) on the basis of chromium carbides, which have high hardness and corrosion resistance. In addition, at the same time, due to the fact that carbon does not block the diffusion of nickel deep into the material of the product, under the upper layer enriched with chromium, a viscous layer enriched with nickel is formed in the coating.

Carburizing after diffusion alloying with chromium and nickel, without pre – carburizing also provides the formation of austenitic steels on the surface of the carbide layer having a microhardness-19000 MPa. At the same time, unlike pre-carburization, carburization carried out after diffusion alloying provides a smoother and longer reduction of microhardness into the depth of the base material, which reduces the probability of punching the surface carbide layer under the influence of contact stresses.
Figure 3. Microstructure of the surface layer of steel 12X18H10T after diffusion two-component saturation with chromium and nickel and subsequent carburization.

The most effective option that provides high hardness of the surface layer and large depth of the hardened beneath the layers is a variant of the process, in three stages: 1st stage – pre-carburization; stage 2 – diffusion doping of chromium and nickel; 3rd stage re-carburization. Such organization of technological process provides formation without heat treatment under a firm carbide layer of the strengthened layers depth more than 500 microns. In addition, this technological process allows by varying the temperature and duration of the process stages to change in the desired direction the element-phase composition, and, consequently, the properties of the surface layers of austenitic steels.

4. Summary
- The combination of carburization and diffusion alloying technologies in the medium of fusible liquid metal solutions leads to an increase in the microhardness of the surface layers up to 5600 MPa
- Increasing of the temperature and duration of the preliminary and final stages of carburization and reducing the temperature of diffusion alloying the surface of austenitic steels with chromium and nickel to 900º C leads to a significant increase in the depth of the carbon saturated layer
- The described technology is able to increase the wear resistance of austenitic steels by regulating the microstructure and the cement composition of their surface layers

References
[1] Sokolov A G, Bobylyov E E and Popov R A Method of diffusion saturation of austenitic steel products to obtain a wear-resistant coating on the surface of steels 2679318 (Moscow: Rospatent)
[2] Balogh Z and Schmitz B 2014 Diffusion in metals and alloys (Physical Metallurgy) pp 387-559
[3] Sokolov A G 2014 Device for diffusion metallization in medium of low-melting liquid metal solutions 2521187 (Moscow: Rospatent)
[4] Bel’iakova V I, Vereschagina A A and Banas I P 1991 Diffusion-dispersion method of austenitic steel surface hardening Metallurgy and heat treatment of metals 11 2-4