IN VACUUM, THE WORKING SURFACE OF THE REACTIVE THIMBLE ANALYSIS OF COATING APPLICATION BY DIFFUSION METALLIZATION

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Abstract. *Protecting parts and equipment from erosive wear, improving the reliability of modern technology, reducing the cost of its maintenance, ensuring competitiveness, extending the service life, as well as its renovation through the use of modern technologies to restore the operability of components to the level of new products, however, are among the most urgent tasks facing engineers around the world. According to experts, about 20% of metal products fail annually in the world due to erosion, therefore, the creation of anti-erosion coatings is an urgent problem.*

Keywords: *coating, erosion wear, diffusion metallization, reactive thimble.*

Introduction

The use of special coatings designed to prevent direct contact of metal with aggressive media, contribute to their protection from erosion.

One of the most common methods of applying metal coatings to products is diffusion, therefore, the mechanism of formation of diffusion coatings is closely related to the diffusion process in solids, when at high temperatures the metal atoms of the coating are embedded in the crystal lattice of the protected metal, therefore the bond strength of the coating with the base material increases dramatically. Figure. 1 shows a diagram of the installation of vacuum diffusion metallization
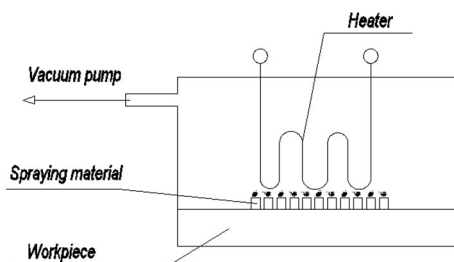

Figure 1. Vacuum diffusion metallization scheme

In order to improve or impart special properties to coatings, they are subjected to heat treatment or additional diffusion saturation with various elements. Recently, such coatings have become increasingly widespread.

When considering the formation of a diffusion layer, an attempt is usually made to trace this process using diagrams of the state of alloys.

At the same time, it is assumed that the formation of a layer on the diffusion isotherm follows an increase in the concentration and diffusing element in the alloy system and obeys the laws of phase transformations.

In this case, the phases of the lowest composition should first arise, then the middle and, finally, the highest (the theory of pure or atomic diffusion) [1]. According to another theory (the theory of reaction diffusion), the formation of a diffusion layer can begin with the formation of a phase of higher or medium composition, bypassing the stage of formation of a phase of lower

composition, such a situation is possible if the thermodynamic conditions for the formation of these phases are more favorable than for phases of lower composition. The formation of the higher composition phase in this case is the final stage of the diffusion process.

The available extensive theoretical and experimental material, based on the use of precision methods for studying the phase and chemical composition of the diffusion layer, convinces that in many cases of CTO practice, the formation of the diffusion layer does not obey equilibrium conditions, but proceeds intermittently and can begin with the formation of a phase of higher or medium composition. The structure of the diffusion layer in this case is not equilibrium.

Physico-chemical factors:
- thermodynamic characteristics of phases in the system of interacting elements;
- thermodynamic characteristics of the bulk medium (gas, steam, liquid and solid phases).
- Kinetic factors:
- the ratio between the speed of receipt of the item in the surface and the rate of diffusion; the rate of chemical reactions in the gas phase and the rate of sublimation of an element exceeds the rate of diffusion of the element in the metal, which determines not only the very high initial concentration of the diffusing element, but also a direct deposition on the surface, both of these conditions contribute to the formation of non-equilibrium diffusion layer;
- the reaction rate of the interaction at the metal-saturating medium boundary;
- the heating rate to the isotherm of the process and the cooling rate at the end of cooling;
- duration of the diffusion process on the diffusion isotherm;
- the ratio between the rate of diffusion of the element into the alloy surface and the rate of self-diffusion of the elements of the saturated alloy.

To explain the kinetics of the formation of diffusion chromium coatings and to determine their structure during chrome plating of iron and steel, it is necessary to know the diagrams of the state of the iron-chromium and iron-chromium-carbon systems (Figure. 2).
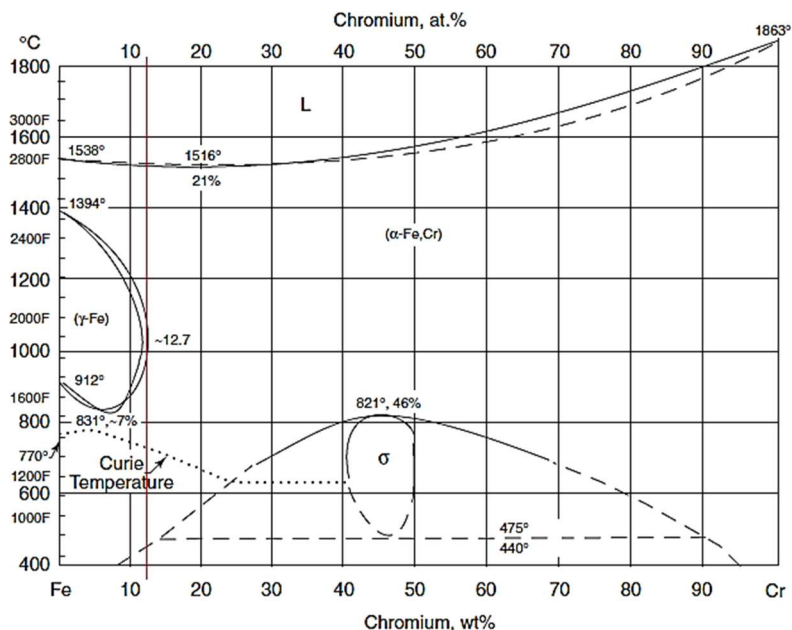

Figure 2. Diagram of the state of the iron-chromium system [2]

It follows from the diagram that in the high-temperature region there is a continuous series of α-solid solutions, which, after solidification, form a crystal lattice of O.C.K. and G.C.K. In the region of alloys rich in iron, there is a closed region of solid solutions (austenite), to which a heterogeneous region (α + γ) of solid solutions adjoins. Studies of alloys of the iron-chromium system using X-ray diffraction analysis allowed us to establish that the γ region disappears when 14.7% chromium is introduced into iron [3].

In addition to solid α and γ solutions, ferro-chromium alloys with a chromium and iron content of 47% and temperatures below 950°C have a brittle component phase, which is an intermetallic compound of chromium and iron of the FeCr type, the δ-phase is formed from both α- and γ-solid solutions with slow cooling. With rapid cooling, the δ - phase does not form. Chromium with carbon forms several types of carbides, the melting temperatures of which are different. Carbides of only three types are formed in this system: $Cr_{23}C_6$, Cr_7C_3, Cr_3C_2 having respectively face-centered cubic, trigonal and orthorhombic crystal lattices.

In the most common alloys, there are only two types of chromium carbides: Cr_3C_6 and O_7C_3. In the presence of iron, part of the chromium in both carbides can be replaced by iron. In carbide $Cr_{23}C_6$ up to 18-20% of Cr is replaced by iron, in carbide Cr_7C_3 from 30 to 50%. The presence of carbon in steel significantly affects the diffusion of chromium and the structure of the diffusion layer. It is established that carbon inhibits the diffusion of chromium, as a result of the formation of a carbide phase on the surface of steel. It is noted that the formation of carbides is associated with the diffusion of carbon from the core zones of steel towards the diffusing chromium, which is facilitated by the high chemical affinity of chromium to carbon.

The following suggestion can be made about the mechanism of formation of a diffusion layer with a non-equilibrium structure during chromium plating of iron. When the rate of chromium entering the metal surface significantly exceeds the rate of its diffusion into iron, an adsorption layer of 100% chromium is formed on the surface (the depth of the adsorption layer depends on physico-chemical and kinetic factors). Simultaneously with the formation of the adsorption layer at its interface with the base metal, a two-stage diffusion of iron atoms into the adsorption layer and chromium atoms from the layer into the base metal occurs. This leads to the formation of a diffuse layer consisting of a solid solution of chromium-based iron.

Since the diffusion rate of iron is greater than that of chromium, the concentration of iron in the adsorption layer increases, and the concentration of chromium decreases, despite the fact that the continuously occurring decrease in chromium concentration is partially compensated by its diffusion from an external saturation source. On the surface, depending on the saturation mode, an equilibrium chromium concentration of 15.7% is achieved at a process temperature of 1150 ° C for 30 minutes.

Thus, the formation of the diffusion layer occurs in the direction of increasing the concentration of chromium in the solid solution: at the beginning - on the basis of the γ-phase, and after the transformation - on the basis of the α-phase, and in the opposite direction by increasing the concentration of chromium in the diffusion layer. In this regard, the growth of the diffusion layer occurs in two directions: from the metal interface - the adsorption layer towards the condensed layer and in the direction of the core zones of the sample.

The choice of a method for obtaining coatings from corrosion-resistant steel depends on a number of factors: the thickness of the coating and its quality requirements, the properties of the metallized products, and economic efficiency. In this case, the quality of coatings is higher, and the energy consumption for the production of a unit of coating mass is significantly less than with other application methods. In addition, the specific conditions of deposition in vacuum (the need to observe vacuum hygiene) contribute to the solution of such an important national economic task as the protection of the environment from pollution.

From the above material, it can be concluded that the most effective method is vacuum diffusion chrome plating, which allows you to obtain high-quality coatings with high adhesion and reduce the process time to 7 hours, since vacuum facilitates the transfer of the diffusing element to the surface of the product.
This technology provides a uniform chrome coating, the thickness of which after chrome plating at a temperature of 1150 ° C and exposure for 8 hours is 220 microns for steel 10 (Figure. 3).
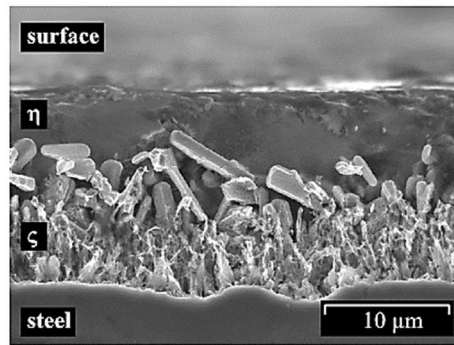
Figure 3. Microstructure of steel 38XH3MA after diffusion metallization

Chrome-plated products can be subjected to distribution and plastic deformation. Chrome-plated steel 38XH3MA for distribution showed that with slow cooling after chrome plating, the pipes withstand distribution up to 5.6%, and with rapid cooling 27.8. Chrome-plated pipes can be subjected to subsequent plastic deformation: irrevocable cold drawing and bending around a mandrel with a radius equal to 2.75 of the outer diameter of the pipe at 180° angles in a heated (up to 800-850 °C) condition.

Conclusions

The article discusses the technology of protecting the outer surface of metal products from corrosion, which solves two problems at once:

1. Industrial - increased heat resistance without loss of manufacturability of the product.
2. Economic – increased corrosion resistance and durability, ensuring harmless operation.

The proposed technology makes it possible to reduce energy costs, since the saturation of the outer surface occurs from one heating in one technological cycle. Due to the heating of the product, a counter diffusion of iron atoms occurs, which provides a stronger bond between the coating and the base metal.

The corrosion resistance and heat resistance of coatings with a thickness of 100 microns of low-carbon steels is not inferior, and sometimes even higher than high-alloy alloys of the type 50PA.

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