OXIDANTLESS HEATING OF HIGH-STRENGTH CORROSION-RESISTANT WELDABLE STEELS WITH ÉVT-100 PROTECTIVE COATING

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Process coatings (enamels) are an effective method for protecting the surface of parts made of different high-strength corrosion-resistant steels from oxidation during heat treatment. Such coatings, one of which is described in this paper, are low cost (low cost per unit area) and do not require much investment in equipment. The protective effect of the coating is achieved as a result of the change in its viscosity under the action of temperature and formation of a continuous plastic layer.

Oxidation and dealloying of the surface layer of parts occurs when they are heated, as a result of reaction of the furnace atmosphere with their surface. Oxygen, carbon dioxide, and water vapor promote rapid oxidative processes, leading to embrittlement of the metal, reduction of plasticity, and corrosion cracking.

When steel is heated, a layer of thickness up to 100 μm is formed on its surface in which oxidation occurs predominantly along the grain boundaries (Fig. 1a). The thickness of such a layer is greater than the thickness of the scale layer. The layer with oxidized grain boundaries is not removed upon treatment with electcorundum powder. In order to restore the plasticity of the steel, a layer of thickness 0.1-0.2 mm must be removed by mechanical treatment.

Neutral gaseous and liquid media and vacuum are used in order to prevent oxidation and dealloying when steels are heated up to high temperatures. Complex specialized assemblies, apparatus for continuous monitoring of the composition of the protective media or the degree of vacuum, etc., are used for this purpose.

In this paper, we have assessed the effectiveness of an ÉVT-100 coating in high-temperature heating of deformable cast steels 18Kh15N5D2T (VNS-2), 13Kh15N4AM3 (VNS-5), 08Kh14N5M2DL (VNL-3), and 10Kh13N3M2FBL (VNL-9).

The ÉVT-100 coating was deposited on samples of the steels and they were held at 800-1250°C. Heat-resistance tests and metallographic studies of the steels were performed.

Good wettability and continuity are characteristic for the ÉVT-100 coating. Inert to steel, it forms a viscous film and reliability protects the surface of the parts from oxidation and burn-off of the alloying elements. Grain-boundary oxidation does not develop (Fig. 1b).

Due to the difference between the linear thermal expansion coefficient of the coating (4.5 \cdot 10^{-6} 1/°C) and the coefficient for the steel (15 \cdot 10^{-6} 1/°C), self-removal (spalling) of the coating occurs from the surface of the parts after heat treatment. Spalling also promotes abrupt changes in the volume of the parts made from 13Kh15N4AM3: at temperatures below 100°C, the parts decrease in volume as a result of phase transformations. The cleaner the surface of the treated parts, the better is the self-removability of the coating.

The protective process coating is a component of a dynamic system which evolves in accordance with the laws of chemical thermodynamics. A characteristic feature of protective enamels is the fact that the components of the coating-alloy system react with each other and with the gaseous medium. With an increase in temperature, usually the thermodynamic instability of the metals and alloys increases and the viscosity of the enamel decreases. Upon heating, the enamel spreads to form a continuous viscous layer, which makes it possible to significantly reduce the rate of corrosion processes on the surface of the steels as a result of slowing down diffusion of the aggressive components of the gaseous medium and suppression of chemical reactions.

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Fig. 1. Microstructure of the surface layer of samples of 08Kh14N5M2DL steel without a coating (a) and with a coating (b) after heating for tempering up to 1100°C in an air atmosphere.

Fig. 2. Distribution of elements in the metal—enamel transition layer (semiquantitative analysis).

The rate and mechanism of high-temperature oxidation of chromium steels depend on the content of iron, nickel, and other elements in the scale, and also on the change in its chemical composition in individual sections of the oxidized surface. The iron and chromium content in the scale may vary over a broad range. Some sections are enriched in chromium, others are enriched in iron. The dimensions of the iron-enriched sections increases more rapidly upon heating in an oxidizing medium.

In studying the protective action of enamels, we need to consider the possible effect of the coating on the composition of the scale and on the diffusion of alloy components into the scale. In particular, upon heating chromium—nickel steels, we observe mutual dissolution of the enamel and the scale and retardation of the growth of the scale layer as a result of the decrease in the rate of diffusion of iron into the transitional layer between the coating and the steel (Fig. 2).

Upon heating samples of 08Kh14N5M2DL steel with ÉVT-100 protective coatings up to 1100°C, the oxidation rate is two orders of magnitude lower than the oxidation rate of samples without the coating (Fig. 3). The results of mechanical tests of heat-treated samples of 08Kh14N5M2DL steel with the coatings and without them show that the coatings not only do not reduce the strength and plastic properties, but also promote some increase in the impact toughness (see Table 1).

In order to study the effect of the coatings on the oxidizability, the mechanical properties, the corrosion resistance, and the microstructure of the steels and also on the quality of the surface, samples with the coating and without it were held at different temperatures for 10 h. We established that the protective properties of the coating are most effective at 950-1250°C.

The oxidizability of the samples depends on the state of their surface. The greatest oxidizability was possessed by samples with a rough surface, obtained as a result of sandblasting treatment.