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PODEJŚCIE TERMODYNAMICZNE DO BADANIA WZORCÓW FORMOWANIA STRUKTURY POWŁOKI DO UTWARDZANIA CZĘŚCI SAMOCHODOWYCH

Streszczenie: Tworzenie powłok utwardzających na powierzchniach roboczych części samochodowych w celu zwiększenia odporności na zużycie, odporność na korozję jest pilnym zadaniem. Artykuł bada kwestię tworzenia struktury nikotriowanych powłok na częściach samochodowych w celu poprawy właściwości operacyjnych i regulacji tych właściwości w oparciu o podejście termodynamiczne.

Formowanie struktury podczas nikotacji badano na stali 38KHN3MFA. Badając wpływ charakterystyk czasowo-nasyceniowych nasycenia na podstawowe prawa tworzenia struktur w różnych strefach warstwy nikotriowanej, należy wziąć pod uwagę rozkład pierwiastków wzdłuż głębokości warstwy i skład fazowy. Badania te pozwalają tworzyć modele powłok o określonej strukturze i właściwościach. Wiodące interakcje chemiczne podczas nikotacji zostały zidentyfikowane w tej pracy przy użyciu metody termodynamiki chemicznej poprzez obliczenie zmiany standardowego potencjału izobaryczno-izotermicznego układu w wyniku reakcji, gdy reagujące substancje są w stanie standardowym.
Praca pokazuje, w jaki sposób termodynamiczne modelowanie procesów zachodzących w oddziaływaniu z metalami wieloskładnikowych atmosfer nikotrialnych pozwala nam określić kierunek reakcji chemicznych tworzących struktury w powierzchniowej warstwie stali, co zapewnia dany poziom charakterystyk wytrzymałości konstrukcyjnej. Zatem regulacja tworzenia struktury nikotriowanych powłok na częściach samochodowych pozwala zwiększyć właściwości operacyjne powierzchni roboczych i regulować te właściwości.

Słowa kluczowe: termodynamika, nikotracja, utwardzanie, odporność na zużycie, samochód

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THERMODYNAMIC APPROACH TO THE STUDY OF THE PATTERNS OF STRUCTURE FORMATION OF HARDENING COATINGS FOR CAR PARTS

Summary: The creation of hardening coatings on the working surfaces of car parts in order to increase wear resistance, corrosion resistance is an urgent task.

The paper investigates the issue of structure formation of nicotriated coatings on car parts in order to improve operational properties and regulate these properties based on the thermodynamic approach. The structure formation during nicotation was studied on steel 38KHN3MFA. . When studying the influence of temperature-time characteristics of saturation on the basic laws of structure formation in different zones of the nicotriated layer, it is necessary to consider the distribution of elements along the depth of the layer and the phase composition. These studies allow you to create models of coatings with a given structure and properties. The leading chemical interactions during nicotation were identified in this work using the method of chemical thermodynamics by calculating the change in the standard isobaric-isothermal potential of the system as a result of the reaction when the reacting substances are in a standard state.
The work shows how thermodynamic modeling of the processes occurring in the interaction with metals of multicomponent nicotriating atmospheres allows us to determine the direction of chemical reactions forming structures in the surface layer of steel, which provides a given level of structural strength characteristics. Thus, the regulation of the structure formation of nicotriated coatings on car parts allows to increase the operational properties of the working surfaces and to regulate these properties.

Keywords: termodynamica nicotration, hardening, wear, resistance, car

1. Introduction

The creation of hardening coatings on the working surfaces of car parts in order to increase wear resistance, corrosion resistance is an urgent task. In this case, the methods of chemical-thermal treatment, in particular, nicotriation, which allows the preservation of dimensions of parts of complex shape due to low-temperature saturation, belong to universal coating methods.

The paper investigates the issue of structure formation of nicotriated coatings on car parts in order to improve operational properties and regulate these properties based on the thermodynamic approach.

The structure formation during nicotriation was studied on the base structural steel 38XH3MFA, which is widely used in machine production for parts operating under cyclic loading and wear conditions.

In order to study the influence of the main alloying elements on structure formation during saturation, model technical iron, 40 and 40X steels, were selected in comparison with 38XH3MFA steel. All grades of structural steel were industrial smelted and saturated in a thermally improved condition. Technical iron was obtained by carbonyl refining. The nicotriation process was carried out in a gas mixture of ammonia and carbon-containing gas (natural gas or endogas). In the process of saturation, the temperature, pressure and flow rate of the gas mixture were controlled, as well as the degree of dissociation of ammonia. These four technological factors varied:

- Temperature - in the range from 560 to 600 ° C;
- Duration of saturation - in the range from 1 to 12 hours;
- The composition of the gas mixture at a ratio of ammonia and carbon-containing gas is 1: 2; 1: 1; 2: 1;

2. Basics of thermodynamic modeling of nicotration

The pressure of the gas mixture is from 400 to 2000 Pa. When studying the influence of temperature-time characteristics of saturation on the basic laws of structure formation in different zones of the nicotriated layer, it is necessary to consider the distribution of elements along the depth of the layer and the phase composition. These studies allow us to create models of coatings with a given structure and properties [1].

The methodological approach to building models involves modeling the basic physical processes that occur during chemical-thermal processing of metals:

- thermodynamic models describe the interaction of a metal, alloy or its individual components with components of a saturating medium;
- diffusion-kinetic models describe the saturation kinetics of metallic materials under various environmental conditions.

Thermodynamic models are aimed at predicting the structure and phase composition of the diffusion layer depending on the parameters of the chemical-thermal treatment process (for example, process temperature, composition of the saturating medium). Thermodynamic models are developed based on:

- analysis of chemical reactions between the components of the metal alloy and the active components of the saturating medium in the range of changes in the basic parameters of the process;
- -definition of thermodynamic conditions and directions of the course of chemical reactions;
- calculation of the free energies of formation of various phases and determination of the thermodynamic possibilities of the formation of phases in the modified layer.

The creation of thermodynamic models for describing the processes of chemical-thermal treatment of complex alloyed alloys, or the combined processes of chemical-thermal treatment in multicomponent gas, opens up particularly wide possibilities media, when the variety of possible formed phases and their combinations increases significantly, which gives new opportunities achieving a set of mechanical properties.

The leading chemical interactions during nicotration were identified in this work using the method of chemical thermodynamics by calculating the change in the standard isobaric-isothermal potential of the system as a result of the reaction when the reacting substances are in a standard state.

Thermodynamic modeling of processes occurring in the interaction with metals of multicomponent atmospheres, allows you to determine the direction of chemical reactions depending on the partial pressure of gas components. The model of the phase composition of the diffusion layer of steels nitrided in a mixture of ammonia and air is based on the analysis of chemical reactions that occur during the interaction of a metal with a gas phase.

To assess the possibility of controlling the composition of the layer during the nicotration, the chemical laws of the interaction of the constituents of the mixture with the steel base at various temperatures were studied. When analyzing the physical and chemical processes in the working volume of the furnace, the following system is considered: the gas phase and the solid phase. At the same time, it is assumed that at high temperatures all components of the controlled atmosphere interact with each other, as well as with the components of the solid phase. These interactions include:

- chemical interaction of the components of the medium with the transition of reaction products into a gas or solid phase;
- dissolution of the components of the gas phase in the solid phase or the reverse process of selection;
- adsorption of gas phase components on the surface of the solid phase with the formation of an adsorption surface layer.

The purpose of using controlled atmospheres during nicotration is to directionally change the composition of the solid phase to a predetermined depth due to the distribution of carbon and nitrogen in the surface layer of the coating being formed.

3. Identification of leading chemical nicotration reactions

The composition of the gas phase is determined from the condition of equilibrium of the system by the reactions determining this equilibrium.

The leading chemical interactions during nicotration were identified in this work using the method of chemical thermodynamics by calculating the change in the standard isobaric-isothermal potential ΔG_T of the system as a result of the reaction when the reacting substances are in the standard state

$$\Delta G^\circ = \Delta H_T^O - T\Delta S_T^O$$

Where: ΔH_T^O и ΔS_T^O - accordingly, the change in enthalpy and entropy of the studied system.

An approximate entropy method was used to calculate isobar potentials.

$$\Delta G_T^0 = \Delta H_{298}^0 - T \Delta S_{298}^0$$

In the calculation, reference data were used [2].

According to the limitations of thermodynamics, a positive value ΔG_T^0 shows that the reaction rate in the direction of the formation of reaction products is less than in the direction of the formation of starting materials, i.e. reaction is impossible. Negative value ΔG°, on the contrary, indicates the predominance of the rate of direct reaction over the rate of reverse.

First of all, we conducted studies on the choice of a gas medium, therefore, we considered nicotriation in a mixture based on natural gas (Fig. 1) or based on endogas (Fig. 2).

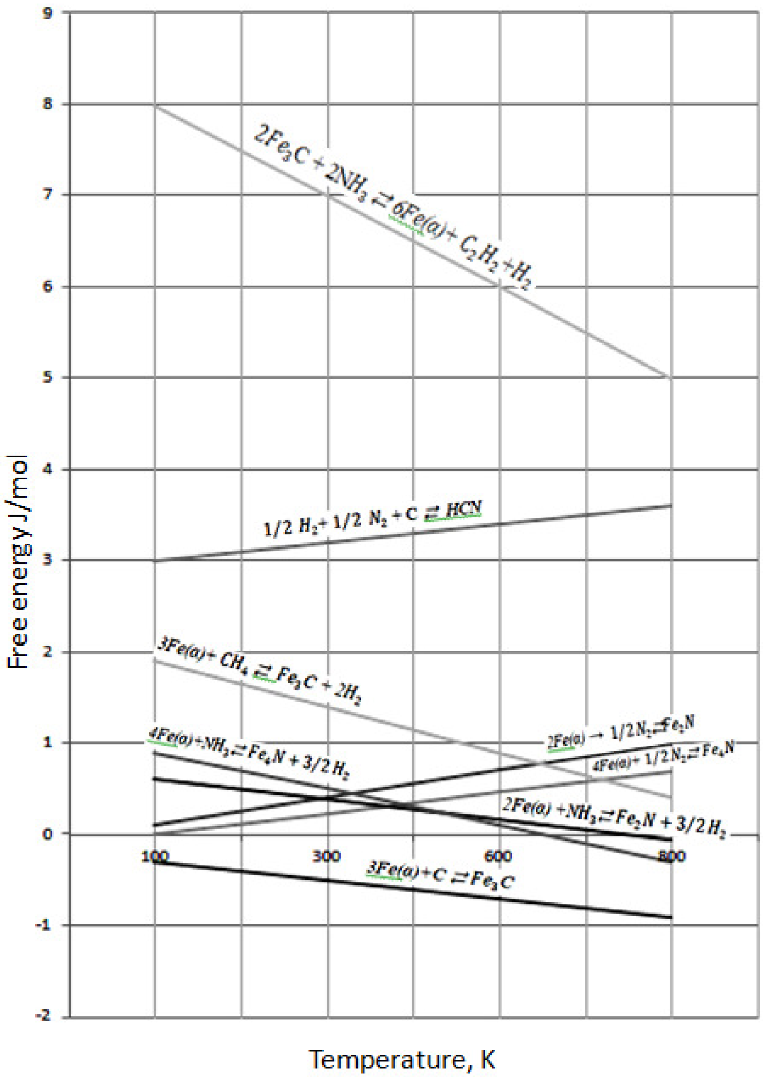

Figure 1. Nicotriation in a mixture based on natural gas

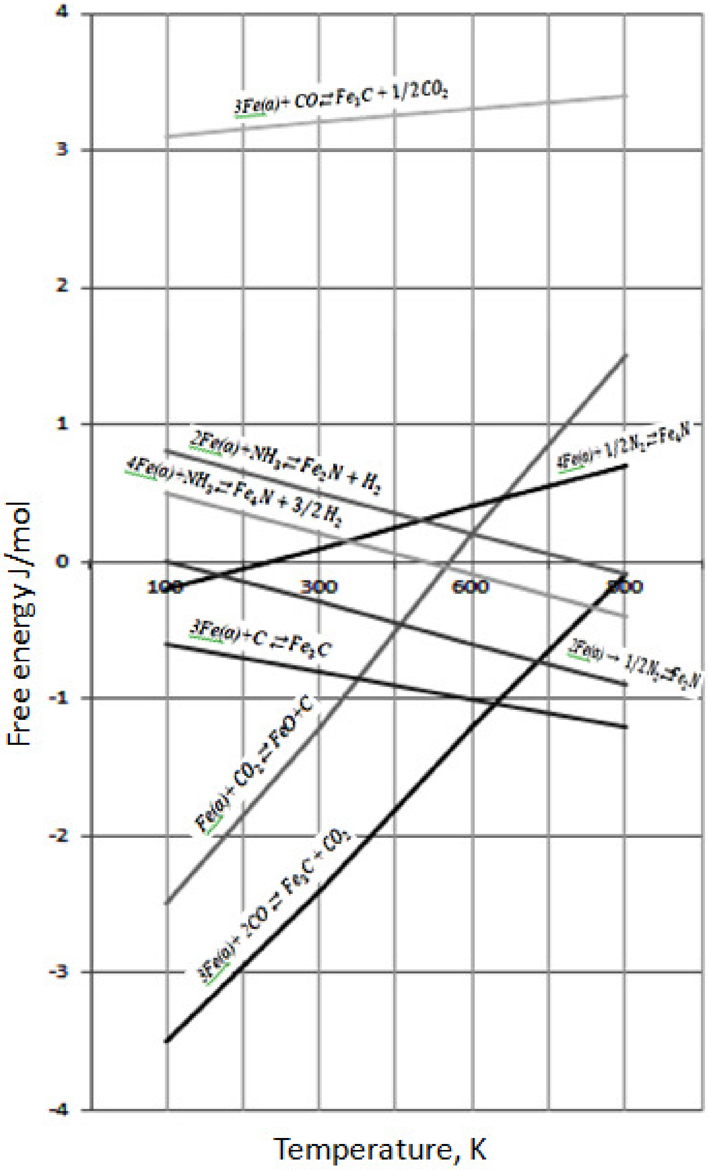

Figure 2. Nicotriation in a mixture based on endogas

4. Conclusion

It has been found that when nicotriating in an environment based on natural gas a cementite crust forms on the surface, which slows down diffusion processes during nicotriation. In an endogas-based environment, the process of cementite formation on the surface is slowed down, therefore, nicotriation based on endogas should be recommended.

The work shows how thermodynamic modeling of the processes occurring in the interaction with metals of multicomponent nicotriating atmospheres allows us to determine the direction of chemical reactions forming structures in the surface layer of steel, which provides a given level of structural strength characteristics. Thus, the regulation of the structure formation of nicotriated coatings on car parts allows to increase the operational properties of work surfaces and to regulate these properties.

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