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KORROZIYABARDOSH XROMLI PO‘LATLARNING TASNIFI VA XOSSALARI

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Annotatsiya. Mazkur maqolada yuqori korroziyabardoshlikka ega xromli po‘latlarning kimyoviy tarkibi, mikrostruktura sinflari va asosiy ekspluatatsion xossalari haqida ma'lumotlar keltirilgan. Tadqiqotda GOST 5632-72 standartiga muvofiq korroziyabardosh xromli po‘latlarning uchta asosiy sinfi (ferritik, martensitik-ferritik va martensitik) ko‘rib chiqilgan va ularning xromning miqdori (13 %, 17 %, 25 % va 28 %) bo‘yicha tasnifi tahlil qilingan. Issiqlik ishlovi berish, payvandlash, issiq plastik deformatsiya hamda metall sirti sifatining po‘lat va qotishmalarning xizmat xususiyatlariga ta'siri o‘rganilgan. Olib borilgan tahlil shuni ko‘rsatdiki, xrom miqdorining 12,5 % dan ortishi yuzada Cr_2O_3 himoya plyonkasini hosil qiladi va korroziyabardoshlikni keskin oshiradi.

Kalit so‘zlar: korroziyabardosh po‘lat; xromli po‘latlar; martensitik sinf; ferritik sinf; martensitik-ferritik sinf; GOST 5632-72; mikrostruktura; ekspluatatsion xossalar; HRC qattiqlik; passivlanish.

Аннотация. В настоящей статье представлены сведения о химическом составе, структурных классах и основных эксплуатационных свойствах хромистых сталей с высокой коррозионной стойкостью. В исследовании рассмотрены три основных класса коррозионностойких хромистых сталей (ферритный, мартенситно-ферритный и мартенситный) согласно ГОСТ 5632-72 и проведена их классификация по содержанию хрома (13 %, 17 %, 25 % и 28 %). Изучено влияние термической обработки, сварки, горячей пластической деформации и качества поверхности металла на эксплуатационные характеристики сталей и сплавов. Проведённый анализ показал, что увеличение содержания хрома выше 12,5 % приводит к образованию на поверхности защитной плёнки Cr_2O_3 и резко повышает коррозионную стойкость.

Ключевые слова: коррозионностойкая сталь; хромистые стали; мартенситный класс; ферритный класс; мартенситно-ферритный класс; ГОСТ 5632-72; микроструктура; эксплуатационные свойства; твёрдость HRC; пассивация.

Abstract. This article provides information on the chemical composition, structural classes, and main operational properties of chromium steels with high corrosion resistance. The study examines three main classes of corrosion-resistant chromium steels (ferritic, martensitic-ferritic, and martensitic) according to GOST 5632-72 and provides their classification by chromium content (13 %, 17

%, 25 %, and 28 %). The effect of heat treatment, welding, hot plastic deformation, and metal surface quality on the operational characteristics of steels and alloys is investigated. The conducted analysis showed that an increase in chromium content above 12.5 % leads to the formation of a protective Cr_2O_3 film on the surface and dramatically increases corrosion resistance.

Keywords: corrosion-resistant steel; chromium steels; martensitic class; ferritic class; martensitic-ferritic class; GOST 5632-72; microstructure; operational properties; HRC hardness; passivation.

1. INTRODUCTION.

Corrosion-resistant chromium steels constitute a group of metallic structural materials capable of withstanding the destructive action of aggressive environments. These steels are used for the manufacture of apparatus, pipelines, fittings, and other products intended for operation under the influence of acids, alkalis, salts, aggressive gases, and other agents [1]. The resistance of a material is understood as its ability to resist corrosion in a particular environment or in a group of environments. A material that is stable in one environment may be rapidly destroyed in another.

The performance, reliability, and cost of a product depend on the properties of the materials that compose it. The correct selection of materials can meet the performance, reliability, and safety requirements of parts. Meeting these requirements depends on the properties of the materials. Changes in material properties directly depend on the composition of materials and the types of alloying elements. For this reason, when selecting materials for manufactured products, the composition and types of materials must be studied [2].

Although there are many materials selection books available, most of them only cover the physical and mechanical properties of specific materials. However, information about the composition of materials and the types of elements is not provided. Nor is it discussed how these factors influence material selection and the control of material properties and manufacturing decisions.

The aim of this study is to provide systematic information on the classes, chemical composition, and properties of chromium steels with high corrosion resistance. The objectives of the research include: (1) classification of corrosion-resistant chromium steels on the basis of microstructural features; (2) analysis of the chemical composition of the main steel grades in accordance with GOST 5632-72; (3) examination of the influence of chromium content and alloying elements on the mechanical and corrosion-resistance properties; and (4) development of operational recommendations for industrial sectors.

2. RESEARCH METHODOLOGY.

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The study was conducted as a systematic analytical review and included four principal methodological approaches. First, scientific publications on corrosion-resistant chromium steels published between 2015 and 2024 were analyzed in the Scopus, Web of Science, and Springer databases. The keyword search was performed using the terms "stainless steel", "chromium steel", "ferritic stainless", "martensitic stainless", "corrosion resistance", and "passivation", which resulted in the review of more than 40 publications, 28 of which were selected for analysis.

Second, classical sources - the works of F. F. Khimushin, I. L. Rozenfeld, A. J. Sedriks, and H. H. Uhlig - were used to study the fundamental theoretical foundations. These sources provided essential information on the corrosion-resistance mechanisms of steel, passivation, and the role of alloying elements.

Third, GOST 5632-72 "High-alloyed steels and corrosion-resistant, heat-resistant, and refractory alloys. Grades" was fully analyzed and the composition of the main corrosion-resistant chromium steel grades was systematized.

Fourth, a comparative analysis method was used to identify the differences in properties (HRC hardness, corrosion resistance, mechanical properties, technological characteristics) between steels of different classes. The analysis results were systematized and presented in the form of tables and figures.

3. THEORETICAL ANALYSIS AND RESULTS.

3.1. Corrosion-resistance mechanism

In acidic oxidizing environments, such as nitric acid, chromium-nickel and chromium stainless steels exhibit corrosion resistance. The most widely used chromium-nickel austenitic stainless steel is grade 12X18N10T, which contains 0.1 % C, 18–20 % Cr, 9–11 % Ni, and 0.35–0.8 % Ti. Titanium, or niobium replacing it, is introduced to eliminate a specific type of destruction - intergranular corrosion. At the specified nickel content, the steel has an austenitic structure, providing high plasticity and the ability to undergo technological processing, in particular welding [3]. However, nickel is an expensive and scarce alloying element.

Therefore, in a number of austenitic stainless steels, nickel is partially or completely replaced by manganese. Stainless steel containing only chromium is more difficult to process but more durable. For products that require a combination of high corrosion resistance and strength, martensitic chromium steels containing 0.2–0.4 % C and 12–14 % Cr are used. Steels with a 25 % Cr content have high resistance but are brittle and poorly amenable to technological processing [4].

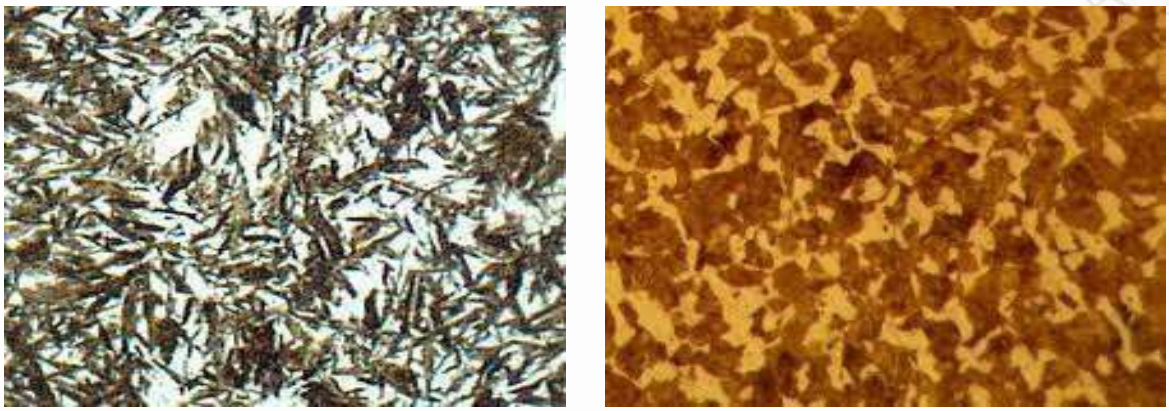
The resistance of steels under these conditions is determined by their ability to be passivated as a result of the formation of thin but very dense oxide films on

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their surface. Alloying steel with chromium increases this ability. When the chromium content in steel exceeds 12.5 %, a Cr_2O_3 oxide film with protective properties appears on the surface. This film ensures the corrosion-protective isolation of the steel from the service environment and, as a result of the transition to a passive state, significantly reduces the corrosion rate [5].

3.2. Microstructural classification of steels

Depending on the basic structure obtained by air cooling after high-temperature treatment, corrosion-resistant chromium steels and alloys are divided into the following classes: (1) martensitic stainless steels; (2) martensitic-ferritic stainless steels; and (3) ferritic stainless steels. The microstructural appearance of representatives of two main classes is shown in Figure 1.



a) martensitic structure **b) ferritic structure**

Figure 1. Internal structure of corrosion-resistant steels: a) martensitic (needle-lath structure); b) ferritic (rounded equiaxed grains)

Chromium is the main alloying element that makes steel stainless. If steel contains more than 12.5 % of this metal, a Cr_2O_3 oxide film with protective properties appears on the surface. Chromium is a fairly common metal, so chromium stainless steels are the most inexpensive. In addition, they have remarkable technological properties. It is desirable that carbon in such steels be as low as possible, since it forms carbides in combination with chromium and thus reduces the chromium content in the melt, decreasing the corrosion resistance of the steel [6]. It follows that the corrosion resistance of the alloy directly depends on the amount of chromium contained in it.

The classes of steel are characterized in more detail as follows:

Martensitic steels - steels with martensite as the main structure (containing 12–17 % Cr, more than 0.15 % C, and special additives such as Mo, W, V, together with a small amount of Ni up to about 3 %).

Martensitic-ferritic steels - steels containing at least 10 % ferrite in addition to martensite laths (chromium steels with 13–18 % Cr and up to about 0.15 % S, with additions of Al, Ti, Ni, Si).

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Ferritic steels - steels with a ferritic structure without the α↔γ transformation (chromium steels with 13–30 % Cr, up to 0.15 % S, additions of Ti ≥ 0.5 %, and sometimes Nb, Si, Mo, Al).

In other words, corrosion-resistant chromium steels can be divided into three groups: with phase transformation (martensitic class); with partial changes (martensitic-ferritic class); and without phase transformations (ferritic class).

3.3. Composition analysis according to GOST 5632-72

The main grades and chemical composition of corrosion-resistant chromium steels are summarized in Table 1.

Table 1.

Composition of corrosion-resistant chromium steels according to GOST 5632-72

Cr group, %	Steel class	Grade	C content, %	Cr content, %
13	Ferritic	08X13	≤ 0.08	12–14
13	Martensitic-ferritic	12X13	0.09–0.15	12–14
13	Martensitic	20X13	0.16–0.25	12–14
13	Martensitic	30X13	0.26–0.35	12–14
13	Martensitic	40X13	0.36–0.45	12–14
17	Ferritic	12X17	≤ 0.12	16–18
17	Ferritic	08X17T	≤ 0.08	16–18 (+ Ti)
17	Martensitic	14X17N2	0.11–0.17	16–18 (+ Ni 1.5–2.5)
25	Ferritic	15X25T	≤ 0.15	24–27 (+ Ti)
28	Ferritic	15X28	≤ 0.15	27–30

As can be seen from the table, at the same chromium content (for example, 13 %), an increase in the carbon content changes the steel structure from ferritic to martensitic. This pattern represents an important regularity in the field of metallurgy and serves as the main criterion for selecting a steel grade.

4. DISCUSSION OF STEEL PROPERTIES AND APPLICATIONS.

Chromium steels are used depending on their mechanical, physical, corrosion, and technological properties, in accordance with their chemical composition and structure. These steels are used in various fields: hydraulic

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presses, turbines, blades, fittings for valve assemblies, carburetor needles, ball bearings and screws for oil equipment, cutting, measuring, and surgical instruments, equipment for the food and light industries, household items, and kitchenware [7].

In practice, the following corrosion-resistant chromium steels are widely used:

Chromium-plated steels of the martensitic class - 20X13, 30X13, 40X13. These steels contain approximately 13 % Cr, which corresponds to the minimum content that increases corrosion resistance. These steels are mainly used in the heat-treated condition, often with a carefully ground and sometimes polished surface. The structure and properties of these steels largely depend on their carbon content: with a decrease in carbon content, structurally free ferrite appears in these steels, which deteriorates the mechanical properties, and they pass from martensitic to martensitic-ferritic (steel 12X13) and even completely ferritic (steel 08X13) classes; their corrosion resistance slightly increases. With an increase in carbon content, corrosion resistance decreases, hardness increases, but brittleness also increases.

Martensitic grade 14X17N2 chromium-nickel steel has higher mechanical properties and corrosion resistance than steel with 13 % chromium; this steel is well supplied by hot and cold stamping, can be processed by cutting, and is welded by all types of welding. The hardness of the surface layer of 14X17N2 steel products can be increased to HRC 58–60 by gas cyanidation or carburizing, if necessary.

Ferritic class steels 12X17 and 08X17T with 17 % chromium content are used in the welded state. These steels have satisfactory hot and cold ductility. However, due to the decrease in the ductility of welded joints caused by the growth of grains in the adjacent zones during welding, the effect of high temperature during welding, and the decrease in the corrosion resistance of zones near the weld, products made of these steels are mainly produced without the use of welding. The addition of Ti to the 17 % chromium steel, which binds carbon into carbides (TiC), increases the resistance to intergranular corrosion (steel 08X17T).

High-chromium steels, when heated in the temperature range of 400–500 °C, tend to embrittlement, which is manifested in a decrease in impact resistance, relative elongation, and an increase in hardness [8, 9].

4.1. Main operational properties of corrosion-resistant steel

The main physical properties of stainless steel that distinguish it from some other metals are summarized in Table 2.

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Table 2.

Main operational properties of corrosion-resistant chromium steel

No.	Property	Description
1	Durability	This quality of steel makes it possible to produce products that compare favorably with analogues. Resistance to physical stress does not allow the product to deform, retaining its original appearance for a long time. The reliability of high-quality stainless steel lasts up to 10 years
2	Resistance to aggressive environment	External conditions practically do not affect the material, which makes it possible to operate it for a long time with the preservation of all properties
3	Heat resistance	All products made of this metal have a high resistance to temperature effects, including direct heating by fire. They do not change their size, shape, and properties under large temperature differences
4	Environmental safety	The anti-corrosion properties of the material do not allow it to oxidize. The composition of the metal does not include components harmful to health, which makes it possible to use it in the food industry
5	Anti-corrosion properties	These are essential for stainless steel and prevent rust from appearing on the metal. Moreover, even alkalis and acids cannot affect the occurrence of corrosion
6	Appearance of products	It is very different from products made from other metals. The surface of the products remains shiny and clean for a long time
7	Technological compliance	Processing stainless steel is quite simple. It is easy to manufacture a product of the required shape from this metal

The corrosion resistance of materials can also be improved by applying protective coatings. To protect against atmospheric corrosion, zinc plating, anodizing, aluminizing, nickel plating, chrome plating, enameling, and organic materials - paint and varnish coatings - are used. Corrosion inhibitors are widely used to slow down the destruction of materials in aggressive environments [10].

5. CONCLUSION.

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Based on the study of corrosion-resistant chromium steels, the following main conclusions are formulated:

First, the corrosion resistance of steel is provided by a Cr_2O_3 protective film formed on the surface when the chromium content exceeds 12.5 %. With an increase in chromium content, corrosion resistance grows linearly and reaches its maximum at 25–28 % Cr.

Second, according to GOST 5632-72, corrosion-resistant chromium steels are divided into three main classes: ferritic (08X13, 12X17, 08X17T, 15X25T, 15X28), martensitic-ferritic (12X13), and martensitic (20X13, 30X13, 40X13, 14X17N2). Each class has its own mechanical and technological properties that determine its application in specific industrial sectors.

Third, the carbon content is a decisive factor in determining the steel class: its increase enhances hardness and martensitic properties, providing a transition from ferritic to martensitic class. However, an increase in carbon also raises brittleness and slightly decreases corrosion resistance due to the formation of carbides.

Fourth, additional alloying elements significantly modify the properties of steels: titanium (08X17T, 15X25T) increases resistance to intergranular corrosion; nickel (14X17N2) improves mechanical properties and ductility; molybdenum enhances corrosion resistance in aggressive environments.

The obtained results and the classification according to GOST standards help to correctly select corrosion-resistant chromium steel grades for modern mechanical engineering, oil and gas, chemical, and food industries. Future research should be directed at studying the operational properties of steels developed with modern nanocomposite coatings and mixed microstructures.

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