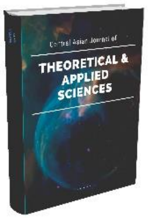

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Types and Applications of Corrosion-Resistant Metals

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Abstract: *This article analyzes the research work on improving the service life of working surfaces and considers suggestions and recommendations on improving the corrosion resistance of working surfaces, types of corrosion, their efficiency in the process of operation.*

Keywords: *coatings, mechanical corrosion, corrosion fatigue, fretting corrosion, friction corrosion, electrochemical corrosion, stress corrosion cracking..*

The most widespread are two classifications of protective coatings (CP): 1) by purpose; 2) according to the technology of education and the materials used. The first classification includes the following types of coatings:

- for protection against atmospheric corrosion and corrosion in liquid media (in normal and industrial atmosphere, in fresh and sea water, in chemical liquid media);
- for protection against destruction at high temperatures (in oxidizing and other aggressive environments, with high-temperature erosion, under conditions of intense heat fluxes);
- to protect against wear (during mechanical, molecular-mechanical and corrosion-mechanical interaction of mating surfaces in friction pairs);
- coatings with special electrical and optical properties (conductive, electrically insulating and shielding coatings, coatings with magnetic properties, reflective coatings, coatings with a high degree of emissivity);
- coatings for restoring the dimensions of worn parts.

In order to reveal the main features of corrosion-resistant coatings, it is first necessary to consider a rather complex mechanism for the occurrence of corrosion. In the general case, corrosion is the destruction of metals due to chemical or electrochemical interaction with an aggressive environment. This is a spontaneous process associated with the transition of the metal–environment system to a more thermodynamically stable state (oxidized, ionic). Chemical corrosion of metals (it is often called gas corrosion) usually occurs in oxidizing environments at high temperatures. This type of corrosion will be discussed in detail in the next section.

Electrochemical corrosion is the process of interaction of a metal with an electrolytic medium (water or aqueous solutions of salts, acids, alkalis, a humid atmosphere), accompanied by the flow of an electric current. Hereinafter, electrochemical corrosion will be referred to simply as “corrosion”, and the corresponding protective coatings will be referred to as corrosion-resistant coatings.

According to the nature of the destruction of the metal surface, corrosion is divided into the following types (Fig. 1).

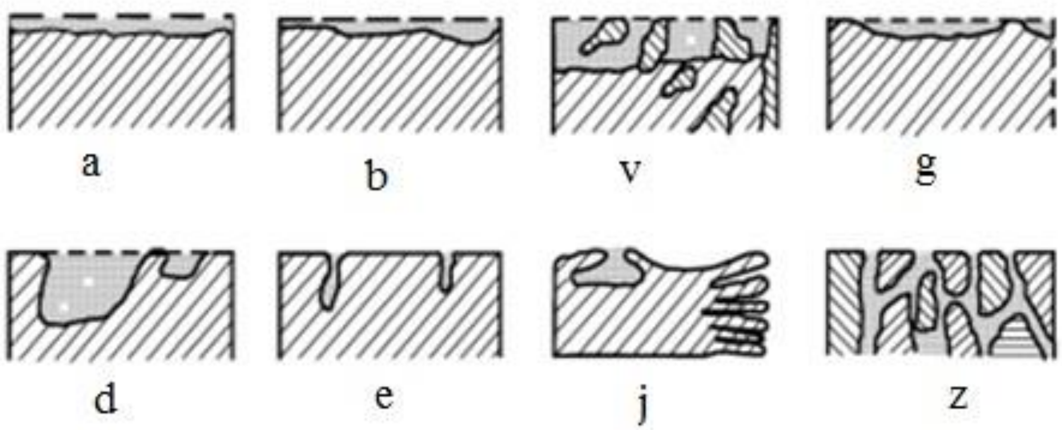

Fig. 1. Main types of corrosion:

a - continuous uniform; b - continuous uneven; c - structural-selective; d - spots; e - ulcers; e - dots; g - subsurface; h - intergranular

The so-called. mechanical corrosion (stress corrosion), in which the destruction of the metal occurs under the simultaneous action of constant or variable loads and a corrosive environment. Mechanical corrosion is subdivided into the following types:

- corrosion cracking - simultaneous action of mechanical tensile stresses and a corrosive environment with the formation of transcrystalline cracks;
- corrosion during friction - the destruction of the metal under the simultaneous action of friction forces and a corrosive environment;
- fretting corrosion - local destruction of metals during high-frequency oscillatory microdisplacement of two contacting surfaces relative to each other under the influence of a corrosive environment;
- corrosion fatigue - the destruction of the metal caused by the application of alternating mechanical stresses in the presence of a corrosive environment and is accompanied by a decrease in the fatigue limit and the formation of intergranular cracks.

The corrosion rate is determined using various indicators:

- by the depth of corrosion destruction (mm/year);
- according to corrosion loss of metal mass after removal of corrosion products [g/(m^2*h)];
- according to the gas component - the volume of released hydrogen or absorbed oxygen [cm^3/(m^2*h)];
- by changing the mechanical characteristics of the metal (in%);

- by the change in electrical resistance in the metal (in %).

The ability of metals to resist the corrosive effects of the environment is called corrosion resistance. It is determined by the depth of corrosion damage and by the resistance score (Table 1). Metals and RFPs with high corrosion resistance are called corrosion-resistant.

Table 1. Corrosion resistance of metals

Resistance group	Metal corrosion rate, mm/year	Score
Completely resistant	<0,001	1
Very resistant	0,001-0,005	2
Persistent	0,005-0,01	3
	0,01-0,05	4
Low resistant	0,05-0,1	5
	0,1-0,5	6
Low resistance	0,5-1,0	7
	1,0-5,0	8
Unstable	5,0-10,0	9
	> 10,0	10

Now let's consider how the interaction of metals with a corrosive environment is carried out. Let us assume that a plate of some pure metal (for example, iron) is placed in an aqueous electrolyte solution. As a result of the dissociation of metal molecules, positive ions (cations) under the action of polarized water molecules will break away from the surface of the plate, flow into the electrolyte and hydrate. The metal, due to the excess amount of remaining electrons, will be negatively charged, and the electrolyte solution, due to the acquired cations, will be positively charged. In this case, part of the hydrated metal ions, as a result of the reaction with oxygen in the water, will be oxidized and turn into loose insoluble hydroxyl compounds (rust), weakly associated with the base metal.

The specified corrosion process is short-term. It continues until the number of electrons and hydrated metal ions are equal. Such an equilibrium is established due to the fact that excess metal ions in the electrolyte resist the transition of new cations into solution, and excess electrons on the metal surface prevent further decomposition of its molecules. In the double electric layer formed at the metal-electrolyte interface in the equilibrium state, charged particles are distributed asymmetrically. The resulting charge difference is called the electrode potential.

Pure metals have different ability to pass into the electrolyte solution, because. have different solubility. Therefore, if plates of such metals are alternately placed in any electrolyte, then their electrode potentials will differ significantly.

To date, methods for measuring the absolute values of electrode potentials have not been developed, therefore, to determine their relative values, the so-called. reference electrodes. For practical purposes, when evaluating the corrosion behavior of metals (especially alloys) in electrolytes, calomel reference electrodes are usually used. However, the reference (standard) is the hydrogen reference electrode (platinum plate coated with hydrogen bubbles).

The values of the standard electrode potentials of pure metals in aqueous solutions with respect to the hydrogen reference electrode, the potential of which is conventionally taken as zero, are given in Table. 2.

Table 2. Values of standard electrode potentials of pure metals in aqueous solutions.

Element	*φ0, V*	*Element*	*φ0, V*	*Element*	*φ0, V*
Gold	+1,40	Lead	-0,13	Zinc	-0,76
Mercury	+0,86	Tin	-0,14	Manganese	-1,18
Silver	+0,80	Nickel	-0,24	Titanium	-1,63
Copper	+0,34	Cobalt	-0,28	Aluminum	-1,66
Bismuth	+0,22	Iron	-0,44	Magnesium	-2,34
Hydrogen	0	Chromium	-0,71	Sodium	-2,71

The presented series of voltages makes it possible to judge the electrochemical behavior of metals. So, metals, the electrode potential of which is more negative than hydrogen, corrode in water the more actively, the greater the negative value of the potential in modulus.

If the plates (electrodes) of two different metals at one end are electrically connected to each other using a conductor, and the other two ends are placed in an electrolyte, then in such a galvanic pair, the metal with a more negative electrode potential is called the anode, and the other is called the cathode. Due to the fact that metals have different electrode potentials, an electric current flows between them. In this case, electrons move from a more reactive metal (anode) to a less reactive metal (cathode), where they react with oxygen and water to form hydroxide ions. These ions, in turn, react with anode cations that have flowed into the electrolyte. The product of this reaction is anode metal hydroxide, which is oxidized in the presence of oxygen to insoluble hydroxyls. In the considered galvanic pair, the equilibrium state is not reached under any conditions, and the corrosion process can occur until the anode is completely destroyed, while the cathode remains unchanged.

Thus, two types of corrosion cells can be clearly distinguished: without electrical contact; with electrical contact (Fig. 2).

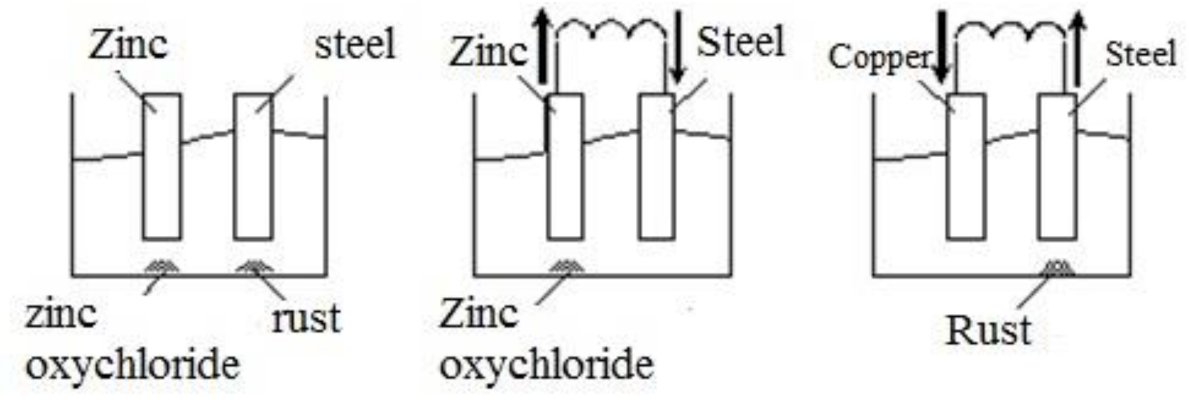

Fig. 2. Corrosion cells: a - without electrical contact; b - with electrical contact

In a cell without electrical contact, the corrosion destruction of zinc and steel occurs only in the initial period before the onset of an equilibrium state, and in galvanic vapors, the corrosion process goes on continuously: in one case, zinc, dissolving as a more active metal, completely stops the corrosion of steel, in the second case, due to increase the corrosion of steel does not corrode copper. It follows that the anodic process of metal dissolution plays a decisive role in the corrosion process.

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