Biocorrosion processes of offshore of oilfield equipment

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Abstract. The issues of corrosion of offshore oilfield equipment are considered. The factors influencing the corrosion processes in the conditions of offshore fields are determined. These include-the temperature of the environment, the salt composition of sea water, the speed of currents and the presence of mechanical damage to the platform, as well as marine fouling with living organisms. The characteristics of the types of corrosion damage of marine oilfield equipment are given. The concept of biological corrosion is formulated and discussed. The reasons and consequences of the influence of this process on metal structures and non-metallic materials used for the construction of offshore platforms are highlighted. The choice of methods and methods of anticorrosive protection of offshore oil platforms requires taking into account and analyzing several parameters of the state of both the environment and the structure itself.

Introduction

Modern gas and oil production utilizes different types of vessels and facilities, with derricks being replaced by new, well-designed platforms (floating oil storage tanks with offloading facilities) capable of storing recoverable hydrocarbons. Oil and gas are transported by pipeline, stored in floating storage facilities or in tender vessels serving offshore rigs.

Currently, there are about 8,000 oil and gas facilities in operation around the world, with more than half of them located in the Gulf of Mexico. Asia, the Middle East, the North Sea, West Africa and South America are also areas of high concentration of offshore oil production. At present, exploration work is being carried out in new areas, in particular, in the Arctic. [1,2]

Coastal structures are exposed to flooding, sea spray and salt air. The corrosion rate of steel structures under extreme conditions can exceed 10 mm per year. Direct exposure to reactive oxygen and chloride compounds combined with temperature variations, changing

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pH levels, tides and microbial growth put structures at great risk. The rate of metal corrosion in these areas increases by 8-10 times compared to atmospheric exposure, while at full immersion the corrosion process is only 3-4 times more active. High wear of the hull and additional corrosion damage of the surface in contact with water add to the problems (fig. 1).

Fig. 1. Oil platform

The most important factor affecting the corrosion rate of offshore steel structures is temperature. The rate of electrochemical corrosion increases significantly with increasing temperature, which is a consequence of galvanic couples due to the temperature difference between separate sections of the same structural element. The above-water section of the offshore platform, heated to a higher temperature under the influence of solar energy serves as an anode and is subjected to more intensive corrosion wear in contrast to the cathode, the section with small temperature differences, located under water. [3,4]

Seawater is a strong electrolyte with high electrical conductivity. This significantly increases the corrosion rate of metal elements of offshore oil platforms (fig. 2).

Also, a significant influence on the speed of corrosion processes of offshore structures is exerted by sea currents, which constantly deliver new corrosive-active elements to the already corroded areas of structural elements of the oil platform, thereby multiplying the rate of destruction of metal structures.

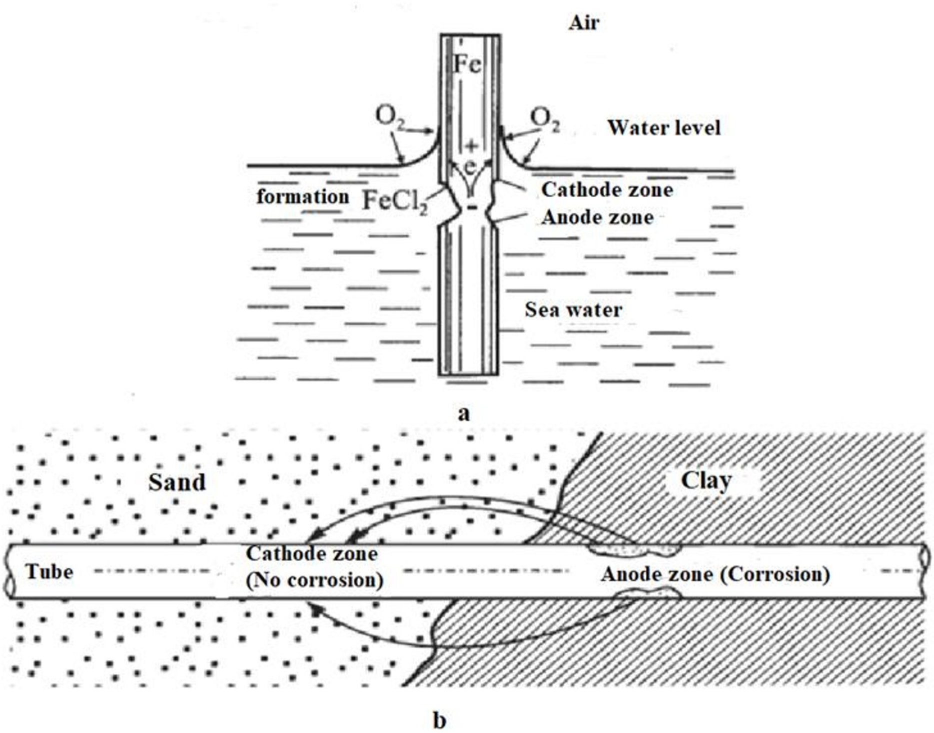

Fig. 2. Scheme of the corrosion process in seawater (a) and in soil (b)

Materials and methods

Very often corrosion damage of the support block starts as a result of failure of the existing corrosion protection systems. Analysis of the technical condition of offshore platforms located in the Black Sea showed that corrosion processes are most active in areas with damaged paint coating or other insulation system. Weak or absent paint coating resulted in significant corrosion damage even in the presence of operating electrochemical protection systems.

It should also be noted that the rate of the process is influenced by the condition and chemical composition of the platform material, time of year, concentration of dissolved oxygen in water, temperature of atmospheric air and sea water, air humidity, condition of welded seams, service life of the platform, nature of loading on the main elements, presence of microorganisms in the water, amount of precipitation and its distribution over the studied period of time, as well as many other factors. [5]

In addition, the presence of mechanical damage to the structural elements of the support block, such as dents, significantly accelerates corrosion processes.

The factor of marine fouling for elements located in the underwater zone plays a major role in controlling the corrosion rate. Fouling of structures by hard-shelled living organisms restricts the flow of oxygen (oxidizing agent) to the metal surface, thus slowing down the rate of the process. [6]

Biological corrosion of metal structures of oil production equipment can be caused by several groups of microorganisms.

The first group is sulfate-reducing bacteria inhabiting the oil-water interface.

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The second group is actinomycetes developing on the nutrient medium of petroleum products.

The third is microscopic fungi forming molds and bioemulsions on metal surfaces.

The optimal conditions for the processes of biocorrosion are the ambient temperature in the range of 6-40 °C and acidity in the range from 1 to 10.5 pH. At the same time, impurities of water, sulfur, nitrogen and oxygen may be present in the medium. The growth of the activity of microorganisms in these conditions of existence occurs in the first 15-30 days.

Results and discussion

Sulphate-reducing bacteria present in the environment of produced oil products can stimulate increased corrosion rates of metal elements of platforms during offshore and onshore oil production. The bacteria can form anodic sites with high corrosion rates by absorbing hydrogen from the environment. [7-9]

Microbial growths on steel, aluminum, zinc, magnesium and chromium nickel are often filamentous (fig. 3). However, stainless steel, copper, nickel, lead and noble metals are not affected.

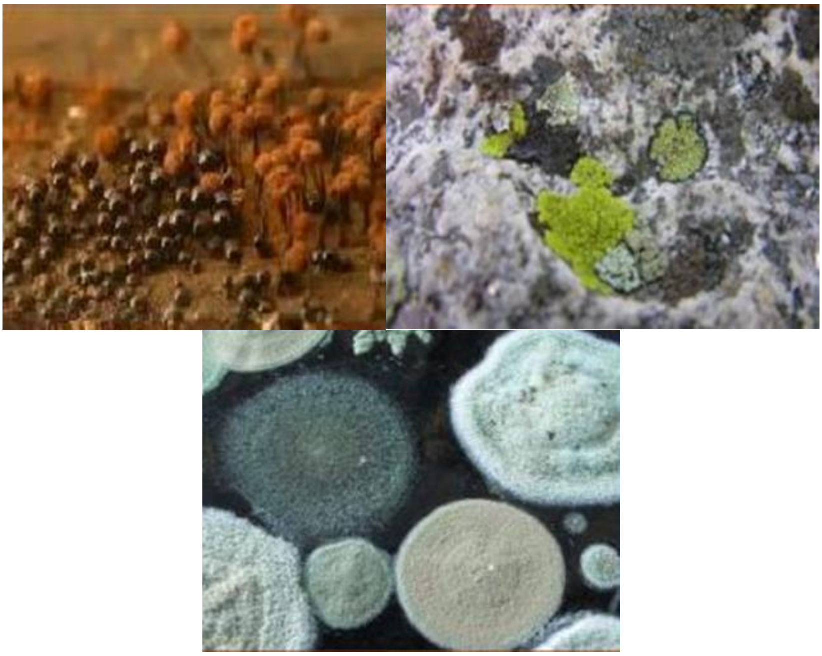

Fig. 3. Microorganisms that cause corrosion

The "germ" of filamentous corrosion on steel is formed by blue or green salts of ferrous iron, and the corrosion center itself is a red crust, the formation of ferric oxide hydrate. Structures containing magnesium produce black corrosion products, and the hearth is filled with white hydroxide.

This process leads to the loss of chromates from the surface of zinc passivated steel structures and the formation of corrosion areas consisting of zinc carbonates and zinc hydroxide.

The further process of interaction with the atmospheric environment leads to the formation of zinc oxide, the so-called "white rust" is formed, the zinc coating is destroyed. The last stage is the corrosion of the steel component of the structure.

Effective protection of aluminum and zinc components against biological filament corrosion is the use of acrylate paints as a coating.

Biological corrosion is also corrosion that occurs when a metal (alloy) comes into contact with inorganic materials. Phenoplasts and aminoplasts, rubber and Teflon, polyamide and polystyrene, paint and epoxy coatings, oak and beech actively affect metals and their alloys. Phenol-formaldehyde mass with wood flour or saturated with a binder at a relative humidity of 100%, temperature 35°C activates corrosion of zinc (the process rate can reach 3.7 μm/(m-s)) and copper (process rate up to 0.3 μm/(m-s)).

The active agent in phenoplastics is formaldehyde, which is converted into formic acid, and impurities of hexa-methylenetetetraamine, releasing ammonia, which reacts actively with metals. Wood flour in the process of hydrolysis leads to the formation of two acids, acetic acid and formic acid. The corrosive effect of phenolic plastics on metals is intensified in the places of the gap between plastic and metal, the size of the gap is within 5-10 mm.

Corrosion rates under such conditions are 0.5-1 for steel, 0.5-20 for zinc, 0.1-1.5 for copper and brass, and 0.05-0.2 μm/month for aluminum. For the same metals, epoxy materials cause corrosion going at a rate of 0.1-10 μm/month, and rubber and rubber – 0.05-1 μm/month.

Of non-metallic materials, concrete is the most susceptible to biological corrosion. The main damage to concrete caused by microorganisms is disruption of the adhesion of its components, arising under the influence of organic and mineral acids. There is a chemical interaction between bacterial products and cement stone.

Microorganisms involved in corrosion reactions actively multiply in the porous structure of concrete. [10-12]

As early as 1901, the role of bacteria in the corrosive failure of concrete was first documented. Nitrifying bacteria were identified in the surface layer of deteriorating concrete.

The structure of cement stone can become impervious to microorganisms having dimensions smaller than the diameter of the pores, due to changing cross sections. Microorganisms multiplying in the pores interact with cement.

In the process of life bacteria release aggressive components of the corrosive environment - sulfides, ammonia, acids, which destroy not only concrete, but also reinforcement in reinforced concrete structures. [13]

The cured concrete is covered with a film of calcium carbonate, which has protective properties. These properties are manifested by resisting the diffusion of water into the interior of the concrete structure. The integrity of the carbonate layer can be destroyed by thionic bacteria, which produce acid and thus change the pH of liquids that fill the pores of the concrete.

In addition, thione bacteria can release sulfates into the environment, which are also actively involved in cement stone degradation.

Technogenic environments provoke the development of corrosion of concrete and reinforced concrete structures. Mass development of microorganisms causing corrosion damage occurs in the presence of favorable conditions for them, such as high humidity, presence of ammonia, acids and organic compounds (fats and products of their hydrolysis) [14-16]. If the purification of man-made waters, for example, mining enterprises, from mechanical impurities and characteristic ion pollution is possible in stationary conditions [17-19], then a different approach is needed for the microbiological protection of building structures of the oil and gas complex. These can be multilayer polymer matrices populated with microbiota that are initially non-aggressive towards concrete and metal, but replace and are antagonists to microorganisms aggressive towards concrete and metal. The development of biocorrosion-activating microorganisms occurs on all building materials. In particular, cultures of thionic, nitrifying and sulfate-reducing bacteria have also been identified on waterproofing, bricks and plaster.

The choice of methods to protect offshore platforms from corrosion damage is determined primarily by the operating conditions, as well as by the type of structure presented. An economically feasible type of corrosion protection should work in a wide range of conditions. The lower part of the platform is constantly in seawater, the upper part - under the influence of atmospheric corrosion factors. [20,21]

Conclusion

Two methods are most often used to protect offshore oil and gas production platforms – electrochemical protection and paint and varnish coatings. It is recommended to use these methods in an integrated way, although each of them can work independently. Electrochemical protection can be realized through protector or cathodic protection.

Comprehensive protection of structures permanently exposed to seawater should include such elements as proper selection of steel grade, clean surface finish and welds, optimal paint coating scheme and use of protector or cathodic protection.

The conducted studies of the condition of offshore oil production facilities have shown that there are no unambiguous solutions for corrosion protection. The choice of methods and techniques of corrosion protection requires consideration and analysis of several parameters of the state, both the environment and the structure itself.

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