

CONDITIONS AND CHARACTERISTICS OF CORROSION PROCESSES IN OIL AND GAS FIELD EQUIPMENT

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Abstract

The article investigates the conditions and characteristics of corrosion destruction of oil and gas field equipment. The combined effect of various external factors on the strength of the metal is analyzed. General and local types of corrosion, mechanisms of their occurrence, and their impact on the safety of equipment operation are described. Methods for calculating the corrosion allowance for metal thickness are also provided.

Keywords

corrosion destruction, oil and gas equipment, mechanical stress, general corrosion, localized corrosion, pitting, intergranular corrosion, corrosion allowance, structural integrity, aggressive environment.

Introduction. Equipment used in the oil and gas industry operates in extremely complex and aggressive environments. Corrosion stands as one of the primary factors leading to equipment failure. Corrosive processes occur not only due to the chemical environment but also through the combined influence of high pressure, temperature, mechanical stress, and friction. It is well established that the synergistic effect of these combined factors can be several times more potent than the impact of each factor acting individually.

The objective of this article is to systematize the types of corrosive destruction encountered in oil and gas field equipment, investigate their impact on metal strength, and analyze the technical safety standards applied in practice. A profound study of these processes is of paramount importance for extending the service life of equipment and preventing unforeseen accidents.

Equipment utilized in oil and gas fields operates under the simultaneous influence of multiple factors: corrosive media, mechanical stresses (tensile, alternating, etc.), friction, pressure, and temperature. The combined effect of all these factors exceeds the simple arithmetic sum of their individual impacts:

$$\Sigma A+B+V+\dots > A+B+V+\dots$$

Where:

A — represents the destructive impact resulting from factor A;

B — represents the destructive impact resulting from factor B, and so forth.

In this scenario, not only is the corrosion rate accelerated, but the fundamental nature of the metal's degradation also changes. Depending on the specific conditions of the metal's interaction with these external factors, various distinct types of equipment failure and destruction may be observed.

Types of Corrosive Destruction (Figure 1). Based on the nature of the destruction, corrosion is classified into *general* and *local (localized)* categories. General corrosion includes electrochemical processes where the reaction products do not remain on the metal surface.

In particular, rapid development of general corrosion is observed in the following cases:

- *reaction of iron with hydrochloric acid;*
- *reaction of aluminum with caustic alkalis;*
- *reaction of copper with nitric acid;*
- *reaction of zinc with sulfuric acid;*

High-temperature gas corrosion (where the entire surface is covered with a scale layer - "okalina").

General corrosion can be classified as *uniform* (even) or *non-uniform* (Figure 1: 1 and 2). Uniform corrosion is considered the least hazardous type of destruction, provided its rate does not exceed the specified standards for the given equipment. However, general corrosion poses a significant threat to components operating under bending and torsional stresses, as it destroys the outer metal layers that bear the maximum mechanical load.

Losses occurring due to general uniform corrosion can be compensated for by providing a *corrosion allowance* to the calculated dimensions of the equipment parts.

The thickness of the anti-corrosion metal allowance is calculated using the following formula:

$$\Delta s = \Pi * t$$

where:

t — is the service life (depreciation period) of the equipment, years;

Π — is the corrosion rate, mm/year.

A corrosion allowance is provided for equipment operating under the following conditions:

- for equipment operating under pressures of 2.5 mpa and above (regardless of the metal's durability group);
- at pressures below 2.5 mpa, only when the corrosion rate exceeds 0.1 mm/year;
- in any case where the corrosion rate exceeds 3 mm/year.

There are no definitive recommendations regarding the maximum permissible limits for corrosive destruction in pressure vessels (values beyond which operation is strictly prohibited).

According to safety technical requirements, there are no specific mandatory guidelines for prohibiting the further use of equipment. However, it is recommended to consider a corrosion rate that leads to a 10% annual reduction in metal wall thickness as the maximum permissible limit. If the corrosion exceeds this threshold, immediate protective measures must be implemented. Furthermore, it is not recommended to commission or continue the operation of equipment whose walls have thinned by more than 20% of the original design thickness due to corrosion.

The consequences of localized (local) corrosion are significantly more hazardous, as even a minimal loss of metal mass can result in the perforation of the equipment wall. Stress concentrators form at the sites of localized corrosion, leading to a substantial decrease in the metal's mechanical strength.

There are several types of localized corrosion:

Spots, Ulcers, and Pitting Corrosion: These types are distinguished by the ratio of the diameter of the affected area to its depth (Figure 1: 4, 5, 6). Ulcers and spots form in areas where the protective layer is insufficient, porous, or damaged. Pitting corrosion is characteristic of passivated metals (such as chromium, aluminum, stainless steel, etc.). Pitting occurs in aggressive media when both an oxidizing agent (acting as a passivator) and depassivating ions—such as chloride or sulfate ions—are present simultaneously.

Selective Corrosion (Figure 1, 3) is classified into two types: component-selective and structural-selective.

Component-Selective Corrosion: For example, the dezincification of brass occurs when zinc transitions into a neutral or weakly acidic corrosive solution more intensely than copper. This results in the formation of a porous copper layer on the brass surface, which in turn facilitates increased electrochemical corrosion.

Structural-Selective Corrosion: For example, the corrosion of gray cast iron is primarily characterized by the destruction of the ferrite component, resulting in a graphite skeleton filled

with corrosion products. In this process, the mechanical strength of the gray cast iron drops sharply.

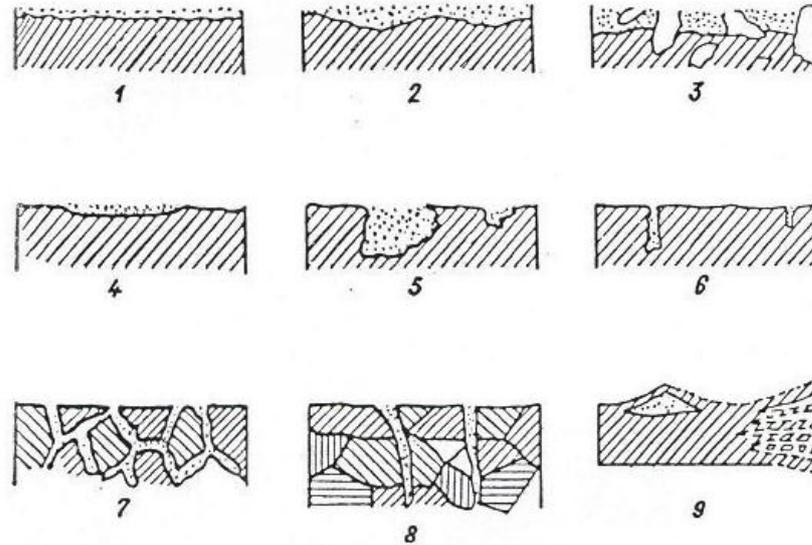


Figure 1. Corrosive failures occurring during metal degradation (Types of corrosive destruction). 1 – uniform (even); 2 – non-uniform; 3 – selective; 4 – spotting; 5 – ulcerative (pitting-like); 6 – pitting; 7 – intergranular; 8 – corrosion cracking (cracks); 9 – sub-surface corrosion.

Intergranular corrosion (Figure 1, 8) is characterized by the selective dissolution of the metal along its grain boundaries. Although it does not lead to a significant loss of mass, it causes a sharp reduction in mechanical strength (Figure 2).

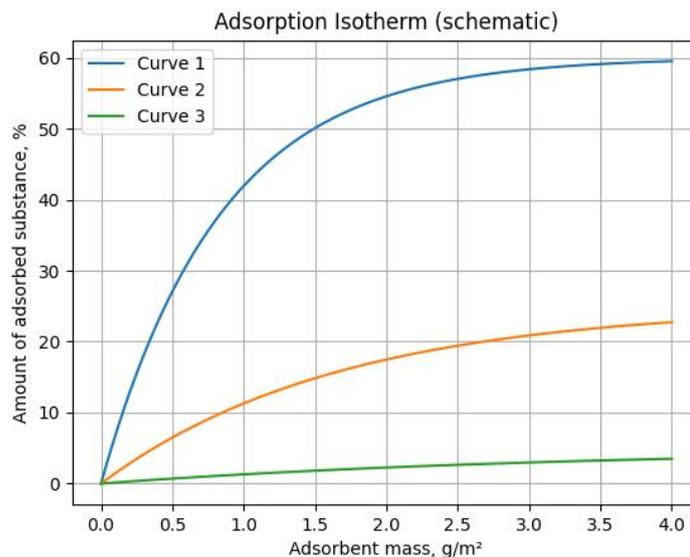


Figure 2. Impact of the nature of corrosive destruction on metal strength: 1 — intergranular corrosion; 2 — ulcerative (pitting-like) corrosion; 3 — general corrosion.

For instance, chromium-nickel stainless steels of the austenitic class become susceptible to intergranular corrosion after being heated to temperatures between 450–800 °C. A specific type

of intergranular corrosion is knife-line attack (knife-edge corrosion), which results in the formation of narrow fissures or slits in the heat-affected zone near weld seams (Figure 3).

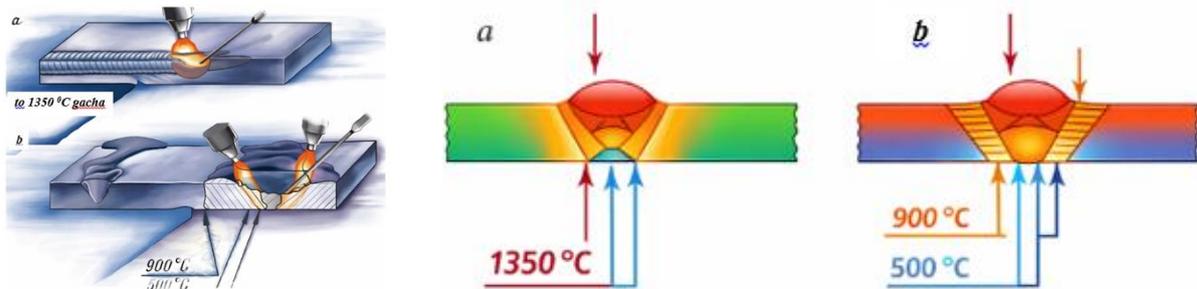


Figure 3. Corrosion in weld seams: a — knife-line attack; b — intergranular corrosion.

Corrosion cracking (crack formation) (Figure 1, 8) occurs as a result of the simultaneous action of tensile stresses and a corrosive environment. The resulting crack primarily propagates in a direction perpendicular to the maximum tensile stress.

Sub-surface corrosion (Figure 1, 9) initiates from the exterior but spreads primarily beneath the metal surface, leading to swelling and exfoliation (layering) of the metal.

Conditions for the occurrence of corrosion processes. Industrial equipment is often operated under complex conditions that facilitate the emergence and rapid progression of localized corrosion. The primary cause of such negative processes is the contact between different types of metals within a structure, which triggers galvanic (contact) corrosion. Furthermore, the presence of technical gaps and cavities within the equipment creates a favorable environment for the development of crevice corrosion.

Additionally, the simultaneous impact of an aggressive electrolyte and mechanical stress on the metal surface leads to severe forms of destruction, such as stress corrosion cracking, corrosion fatigue, and corrosion erosion. Electrolytic environments containing hydrogen sulfide (H_2S) are particularly detrimental to the internal structure of the metal, accelerating the processes of hydrogen embrittlement and sulfide stress cracking.

Conclusion. The analyses conducted demonstrate that the synergistic interaction between corrosion processes and mechanical stresses intensifies metal degradation and fundamentally alters its character. Unlike general corrosion, which can be managed through calculated allowances, localized corrosion types such as pitting, intergranular corrosion, and stress cracking are significantly more hazardous due to their potential to cause unpredictable perforations and compromised structural integrity. Notably, intergranular and selective corrosion do not lead to substantial mass loss but drastically reduce mechanical strength by destroying internal structural bonds. According to safety standards, a reduction in equipment wall thickness exceeding 10% annually or a total degradation of more than 20% of the overall thickness serves as a primary indicator for immediate decommissioning or urgent protective intervention. Consequently, to prevent adverse phenomena such as galvanic, crevice, and hydrogen-induced failures, it is essential to rigorously account for metal compatibility and environmental aggressiveness during the initial design phase.

References:

1.M.N.Murodov, H.B.Do'stov, E.R.Panoyev, J.M.Murodov. Nordon gazlarni absorbsion tozalash texnologik jarayoni muhiti uchun gravimetrik usulda po'lat namunasining korroziya

- tezligini aniqlash. // “Fan va texnologiyalar taraqqiyoti” ilmiy-texnikaviy jurnali. 2025-yil 3-son. 95-100 b.
2. Защита от коррозии оборудования при подготовке углеводородного сырья. (Сер.: Борьба с коррозией в нефтегазовой промышленности). Обзор зарубеж. лит. - М.: ВНИИОЭНГ, 1983 .- 48 с.
3. Коррозионный контроль оборудования моноэтаноламиновой очистки в производстве аммиака. Новицкий В.С. и др.// Химическая промышленность, 1984.-№4.-с.20.
4. M.N.Murodov, E.R.Panoyev, A.H.Temirov, J.M.Murodov. Gazlardan absorbsion tozalash qurilmasida kuzatiladigan asosiy korroziya turlari, ularga xos kimyoviy reaksiyalar va korroziyadan himoya qilish usullari. // “Development of science” jurnali. Iyun 2025/6. 161-166 b.
5. Семенова И.В., Флорианович Г.М., Хорошилов А.В. Коррозия и защита от коррозии / Под ред. И.В. Семеновой. — М.: Физматлит, 2010. — 416 с.
6. Абдуллаев А.Ф. Нефть ва газ конлари ускуналарининг коррозияси ва ундан химоя қилиш. — Тошкент: ТГТУ, 2015. — 180 б.
7. Jones D.A. Principles and Prevention of Corrosion. — 2nd Edition. — Pearson, 1996. — 572 p.
8. Fontana M.G. Corrosion Engineering. — 3rd Edition. — McGraw-Hill Education, 2005. — 556 p.
9. ГОСТ 9.908-85. Единая система защиты от коррозии и старения. Металлы и сплавы. Методы определения показателей коррозии и коррозионной стойкости.
10. Uhlig H.H., Revie R.W. Corrosion and Corrosion Control: An Introduction to Corrosion Science and Engineering. — John Wiley & Sons, 2008. — 512 p.