Corrosion and mechanical testing of steel wires protected by films of modified solid oil

Botin Alexander Valerievich
Bachelor
Perm State University
Medvedeva Natalia Alexandrovna
Candidate of Chemical Sciences, Associate Professor
Perm State University
Lisovenko Natalia Yurievna
Candidate of Chemical Sciences, Associate Professor
Perm State University

Annotation. It was found by gravimetric and mechanical tests that the films of the modified solid oil have an inhibitory effect on acid corrosion of 08kp steel in a 0.1 molar solution of CH_3COOH. It also provides data on the nature of the destruction of steel wires in the presence of putative inhibitors. The data obtained can then be used for further corrosion and mechanical tests in the presence of micromycetes.
Keywords: acid corrosion, corrosion inhibitors, corrosion rate, corrosion-mechanical destruction, steel 08KP, hydrogenation

Introduction

Corrosion is a persistent and pressing problem that is often difficult to completely eliminate. At present, this has become of great importance in connection with the large budgetary problems arising in industrialized countries in connection with the repair and protection of materials from wear and loss [1].

Losses from corrosion today in developed countries are estimated at 2–4% of the gross domestic product (GDP). Damage from broken metal structures, products and equipment is 10–20% of the annual steel production [2]. In Russia, the annual loss of metals due to corrosion is up to 30% of the metal produced [3].

Corrosion destruction of metal equipment is one of the main problems in oil and gas production [4]. Acid treatment of wells is a widespread method of intensification of oil and gas production processes and is used even at the stage of exploration of new hydrocarbon deposits [5], therefore, corrosion inhibitors are used to reduce the aggressive effect on steel structures of technological equipment [6]. They inhibit corrosion in several ways: (a) adsorption on the metal surface and the formation of a protective thin film; (b) the formation of oxide films on the base metal, which reduces the rate of oxygen transfer to the metal surface, and (c) interaction with a corrosive component present in an aqueous medium [7]. In modern practice of inhibitory protection, complex multicomponent compositions of complex action are mainly used as additives [8]. The most famous acid inhibitors are organic compounds containing nitrogen, sulfur and oxygen atoms [9].

Most of the research in the field of creating new inhibitors is aimed at developing compositions that inhibit the corrosion process of steels, which are one of the main structural materials [3].

Carbon steels (CS) are widely used in industry and in everyday life due to their amazing properties, and in addition, they are the most common type of steel alloys used in many industrial communities. Carbon steel is considered the backbone for most of the business and is widely used throughout the world. Every year, petrochemical enterprises and the oil and gas industry utilize colossal amounts of CD. One of the disadvantages of carbon steel is that it is easily damaged by moisture and corrosive environments [10].

Thus, the corrosion of this metal material is dangerous from the point of view of human life, biological diversity and the economic state of industry [11], therefore, studies aimed at developing new, more effective inhibitor compositions with a wide range of characteristics are of great scientific and practical importance [12]

Experiment

Corrosion and mechanical tests were carried out on wire samples of 08kp steel. Parameters of each sample: length 13 cm, wire diameter 0.45 mm. As potential inhibitors, there are two organic compounds (OC), the synthesis of which was carried out according to the method [13]: OC I – 1-(4-chlorophenyl)-4,4,4-trifluorobutane-1,3-dione, OC II – 4,4,4-trichloro-1-(4-chlorophenyl)butane-1,3-dione.

Table 1. Chemical composition of steel grade 08kp

Content, mass.%	C	Si	Mn	Ni	S	P	Cr	Cu	As
08kp	0,05 – 0,11	less than 0,03	0,25 – 0,5	less than 0,25	less than 0,04	less than 0,035	less than 0,1	less than 0,25	less than 0,08

On the surface of steel wire samples, modified protective films based on solidol and the studied organic compounds were formed. Thus, the studied protective films had the following composition: 5% OC solution in synthetic solid oil produced by Oilright.

Corrosion tests

Corrosion tests were carried out using the gravimetric method. A model solution of acetic acid with a concentration of 0.1 mol / L was used as an aggressive medium. The residence time of the steel samples in the solution was 7 days at a temperature of 27 ± 1 ° C. The corrosion rate was calculated by the formula:

$$V_{cor} = \frac{\Delta m}{S \cdot t} \quad (1),$$

where V_{cor} – corrosion speed, Δm – mass changing, S – sample area, t - time.

Mechanical tests

To check the elastic-mechanical properties after the effect of corrosion, a universal machine IR 5081-1.0 of the Impulse company was used with a universal electronic dynamometer ATSDU-1I-1 (1 kN) and clamps that prevent slippage of the samples under tension.

Experimental data were obtained for steel samples before and after exposure to a corrosive environment. The tensile curves are plotted taking into account the cross-sectional area of the wire samples.

On the basis of the tensile curves, the influence of the investigated organic compounds on the ultimate strength (σB) and the value of the coefficient of loss of strength (K_p) of steels was determined. The value of σB was determined from the tension diagrams, and K_p – according to equation (2). The effect of the proposed protective films was assessed by the coefficient of loss of strength:

$$K_p = \frac{\sigma 0 - \sigma}{\sigma 0} \cdot 100\% \quad (2),$$

where σ0 and σ – tensile strength of the tested steel, untreated and treated in a corrosive environment.

After mechanical tensile tests, the nature of the destruction was assessed using photomicrographs of the ends of the wire. Micrographs were obtained using a Hitachi S-3400N scanning electron microscope in SE mode at magnifications in the range of × 200÷250.

Results

Table 2 shows the results of gravimetric tests. All investigated OCs reduce the corrosion rate of steel and the depth index, but to a different extent. To a greater extent, a decrease in the corrosion rate is observed in the presence of solid oil, which also determines the high protective effect of this compound, which is 77.9%. It is possible that the greater efficiency of OC I in comparison with OC II is associated with the presence of fluorine in the molecular structure of this compound.

Table 2. Corrosion characteristics of steel in a model solution of acetic acid (0.1 mol / L) in the presence of protective films at an exposure time of 7 days

Steel surface	Corrosion rate, (g / (sm^2 · day)) ·10^3	Depth index, (mm/year)	Protective effects Z, %	Inhibition coefficient γ, %
without protective film	1,62	0,75	–	–
solid oil	0,67	0,17	77,9	4,4
OC I (lis-86)	1,00	0,45	39,5	1,7

OC II (lis-24)	1,30	0,60	19,7	1,3

The list of properties that modern corrosion inhibitors must possess includes protection against hydrogen saturation and the resulting embrittlement of steel [14]. When in acidic corrosive environments, steel can also become hydrogenated, which is accompanied by a change in the mechanical characteristics of the material. Figure 1 shows tensile diagrams of steel wires. Table 3 shows the results of processing these diagrams.

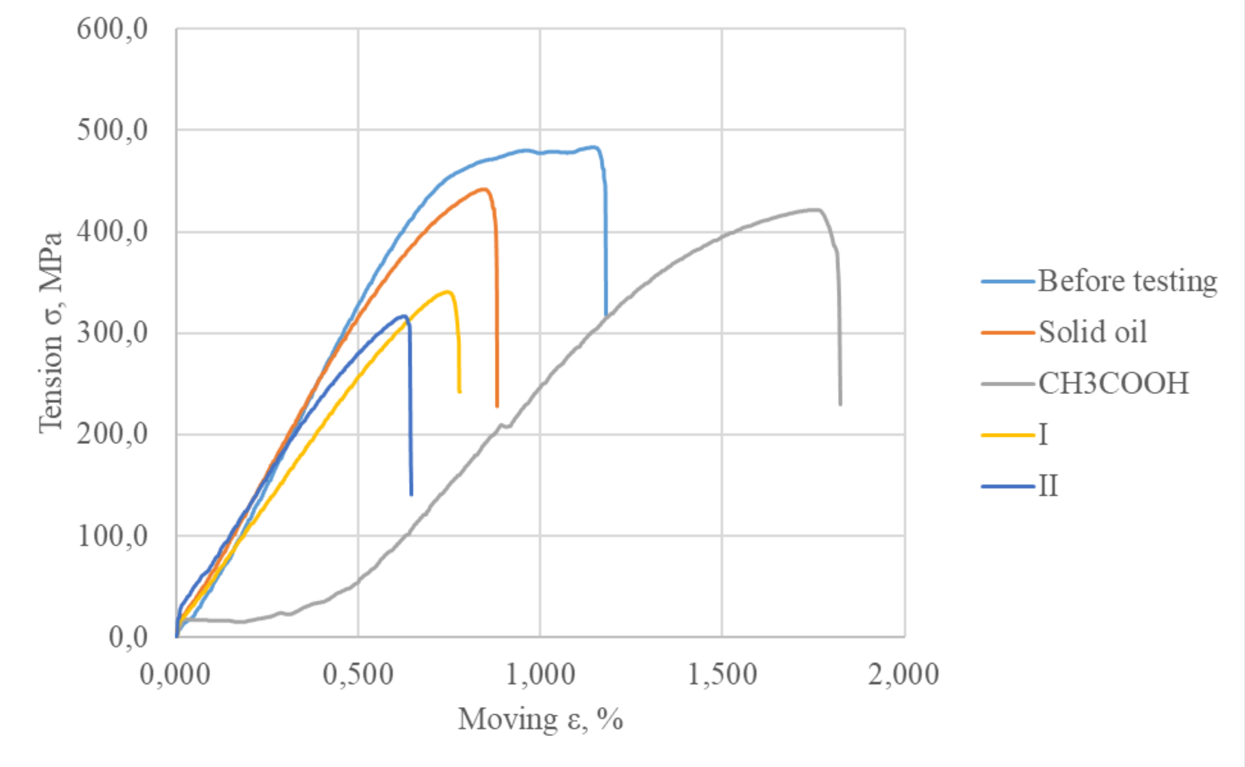


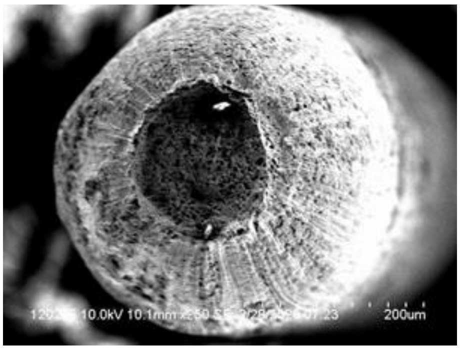
Figure 1. Tensile diagrams of steel wire before and after being in a corrosive environment for 7 days

Table 3. Mechanical characteristics of steel before and after being in acetic acid (0.1 mol / L) in the presence of test compounds

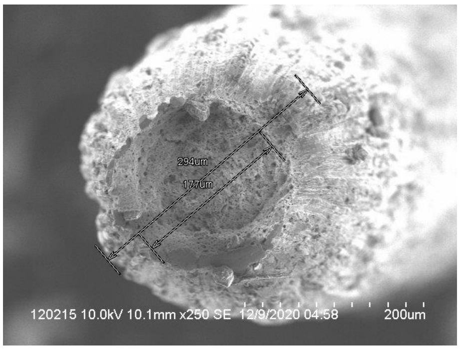
Steel surface	Tensile strength σ_B, MPa	Coefficient of loss of strength K_p, %
Before testing	476,2	–
Without protective film	421,9	11,4
Solid oil	432,4	9,2
OC I (lis-86)	343,2	27,9
OC II (lis-24)	339,3	28,8

The values of the strength loss limit and the strength loss coefficient of steel in the presence of OC in a model solution of acetic acid correlate with gravimetric tests. From table 3, it can be seen that in the presence of solid oil without additives of the studied compounds, the mechanical characteristics of steel are higher compared to steel without an inhibitor, and compounds I and II reduce the strength characteristics of the steel.

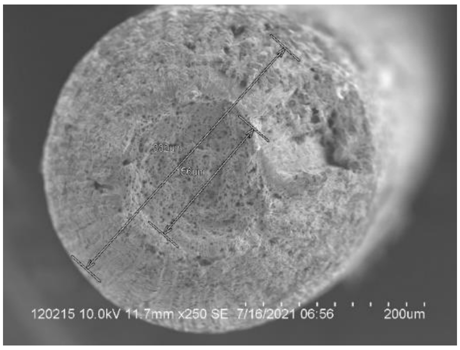
The nature of the damage after corrosion tests was assessed by means of photomicrographs of the ends of the wire after mechanical tensile tests. The results are shown in Fig. 2.



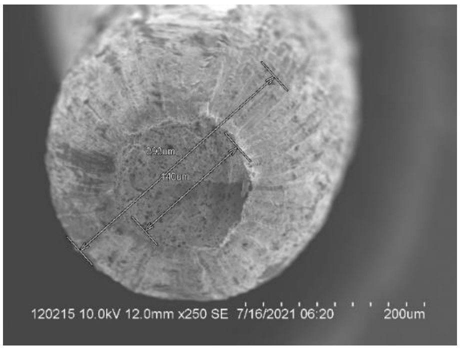
Steel before testing



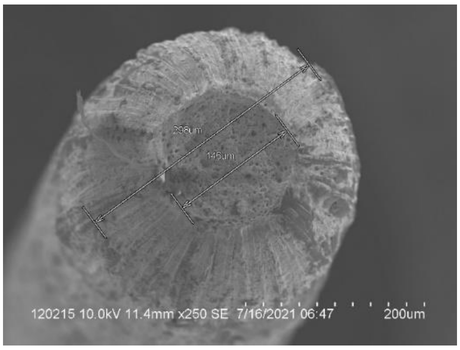
Steel without protective film



Solid oil



OC I



OC II

Figure 2. The nature of the destruction of steel wires before and after being in a corrosive environment for 7 days

It should be noted that these organic compounds have a pronounced fungistatic effect at low concentrations. OC I and OC II inhibit the growth of cultures of Aspergillus pss., Penicillium pss., Trichoderma pss. at a concentration of 3.9 - 7.8 μg / ml, the fungicidal effect of the compounds on micromycetes varies significantly, acting on cells at concentrations from 15.6 to 125.0 μg / ml. At the same time, synthetic lubricants are susceptible to destruction by micromycetes [15], therefore, the use of bioprotectors, along with a decrease in the corrosion rate of steel, will provide additional protection for the lubricant used on the open surface of structures.

Conclusion

It was found that the presented 1-substituted-4-trihalomethylbutane-1,3-diones inhibit the corrosion of steel in an acetic acid medium. In the future, these compounds are recommended to study the fungicidal properties of protective films modified with organic compounds based on diketones in relation to mycological corrosion of steel.

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