Increasing the Corrosion Resistance of the Material of Oil and Gas Equipment in Water-Salt Solutions by Changing the Electrochemical Parameters

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Abstract. The high aggressiveness of process liquids associated with the presence of dissolved gases, mechanical impurities, salt ions, mineral acids and bases in them contributes to the destruction of oil and gas equipment. The main way to increase the corrosion resistance of the material of oil and gas equipment under the action of acidic components is the injection of a chemical reagent - a neutralizer. To study the effect of an electric field on production media, a method has been developed to control the electrochemical parameters of these media. According to the method, the flow of the medium is processed in a special unit by an electric field, which helps to separate the liquid into two oppositely charged flows - anolyte and catholyte. In this work, the study made it possible to establish the effect of catholyte on the kinetics of corrosion, and also revealed the dependence of the corrosion rate of carbon steel 09G2S on the concentration of the reagent alkali and catholyte at different pH values. A comparative assessment of the use of the most effective concentration of catholyte to increase the corrosion resistance of the material has been carried out.

1. Introduction
The main reasons that significantly reduce the resource of oil and gas equipment include corrosion processes occurring on its surface, as well as high corrosive activity of working environments inside oilfield equipment. The corrosive activity of the medium is caused by the presence of mechanical impurities, dissolved acid gases, salt ions, anaerobic and aerobic microorganisms in it, which are involved in the processes of depolarization or dissolution of the metal. To effectively reduce the rate of corrosion, there are reagent (inhibition) and reagentless methods of dealing with complications in the processes of oil recovery and treatment. The injection of chemical reagents into the technological environment in order to reduce its aggressiveness leads to the need for further purification of oil and oil products from them, or to the formation of new substances that negatively affect the health of the service personnel due to high toxicity.

Reagent-free methods of dealing with complications (ultrasonic action on oil fluids, lowering their temperature and pressure, the use of magnetohydrodynamic treatment (MHDT), etc.) are based on the use of technologies that contribute to a positive change in the properties of technological media. The limitation of reagent-free methods in oil fields is associated with insufficient elaboration of the
theoretical base and calculation methods for creating the corresponding units and devices, as well as the lack of stable and effective results of their application.

Due to the high water cut of oil wells, it is important to understand what effect formation water has on the corrosion process of the material of oil and gas equipment.

In the course of the experiment, a step-by-step study of the effect of catholyte and sodium hydroxide solutions on the formation of surface structures on carbon steel samples in water-salt solutions was carried out. A comparative assessment of the corrosion resistance of iron hydroxide films in the model of formation water obtained on the surface of samples in solutions of sodium hydroxide and catholyte is shown.

2. Experimental Procedures

2.1. Materials
The object of the study was samples of 09G2S low-alloy steel, which is widely used for the construction of oil and gas facilities. As a technological medium, we used model mineralized media as the most dangerous for oilfield metal equipment. The investigated corrosive medium was the model of formation water No. 3, which includes sodium bicarbonate (NaHCO₃) - 138 mg/l, calcium chloride (CaCl₂) - 333 mg/l and sodium sulfate (Na₂SO₄) - 213 mg/l.

The study was carried out in order to determine the corrosion rate of 09G2S carbon steel in mineralized solutions with different pH values, due to which films of insoluble corrosion products were formed by adding a chemical reagent and a catholyte - a solution saturated with negative ions (hydroxyl ions).

2.2. Experiment techniques
In total, 3 series of experiments were carried out.
In the first series of experiments, we studied the corrosion rate of carbon steel placed in a technological environment as close as possible to real conditions without the addition of chemical reagents. The exposure time for all tests was 2 weeks (336 hours). The average corrosion rate of the samples made of 09G2S steel was 0.235 mm/year.

At the second stage of the experiment, the corrosion rate of 09G2S steel samples was studied in the model of formation water with the addition of sodium hydroxide solution with a pH value of 10 and 12 and concentrations of 10, 20, 30 and 50%. The test results are shown in Table 1.

The third series of experiments consisted in investigating the corrosion rate of 09G2S steel samples in the model of formation water with the addition of a catholyte solution with a pH value of 10 and 12 and concentrations of 10, 20, 30 and 50%. The test results are shown in Table 1.

To obtain a catholyte solution with the required electrochemical parameters, a UBS 1-50-4.0 unit specially designed for this was used. The dependence of the electrochemical parameters of the water-salt solution processed in the unit on the speed of its movement was determined. A current of 2 A was applied to the electrodes of the unit, while controlling the speed of movement of the water-salt solution. The essence of the method for obtaining modified solutions is as follows: a constant electric current is supplied to the working electrodes of the unit, which creates tension in the water-salt solution and its partial electrolysis, due to which two charged flows leave the unit - catholyte and anolyte. To change the pH value of solutions, it is necessary to regulate the flow rate and the strength of the incoming current in the unit. The technique for studying the corrosion rate in media containing catholyte or sodium hydroxide is based on gravimetric tests of metal samples.

3. The results of studies and their discussion
The exposure time was 2 weeks. After that, the samples were removed from the flask, washed, the deposits of corrosion products were removed using a rubber spatula, and measurements of dimensions and weight were carried out. The corrosion rate of carbon steel in a saline corrosive solution without
the addition of alkali and catholyte was 0.235 mm/year. The results of the tests carried out with the addition of alkali and catholyte are shown in table 1.

The obtained experimental data were used to plot the corresponding dependences.

**Table 1.** Dependence of the carbon corrosion rate on the concentration of sodium hydroxide and catholyte.

| Inhibitor concentration | Corrosion rate, mm / year | \[\text{at solution pH 10}\] | \[\text{at solution pH 12}\] | \[\text{NaOH}\] | \[\text{Catholyte}\] | \[\text{NaOH}\] | \[\text{Catholyte}\] |
|-------------------------|--------------------------|-----------------|-----------------|-------------|---------------|-------------|---------------|
| 10%                     | 0.052                    | 0.067           | 0.056           | 0.056       | 0.051         |
| 20%                     | 0.078                    | 0.047           | 0.064           | 0.046       |
| 30%                     | 0.071                    | 0.048           | 0.113           | 0.077       |
| 50%                     | 0.093                    | 0.061           | 0.068           | 0.046       |

![Graph showing the corrosion rate vs. solution concentration](#)
**a)** pH of the added solution 10;  
**b)** pH of the added solution 12

**Figure 1.** Dependence of the corrosion rate of carbon steel on the concentration of the solution at different pH.

Figure 1 shows that the addition of alkali and catholyte increases the corrosion resistance of carbon steel. In this case, the addition of catholyte contributes to a more intense reduction in the corrosion process. It is also noticeable that the addition of solutions with pH=12 at a concentration of 30% leads to an increase in the corrosion rate, since a process of partial repassivation occurs, which is undesirable, since it leads to local types of corrosion - pitting, pitch, cracking. Thus, it was decided that the addition of catholyte to mineralized solutions is more profitable, since, firstly, the corrosion rate is lower, and secondly, there is no need for chemical reagents. The most effective dosage of catholyte was 30%.

4. **Conclusions**
1. The high aggressiveness of process fluids associated with the presence of acidic components in it, which significantly reduce the life of oilfield equipment, can be reduced by forcibly changing the main parameters of the processes responsible for the kinetics of electrochemical corrosion of oil and gas equipment.
2. On the basis of experimental data, they showed sufficient efficiency of using a catholyte solution with pH=10 and a concentration of 30%.
3. The corrosion rate of the samples in the presence of catholyte decreased by almost 5 times (from 0.235 to 0.0485 mm/year), which amounted to 80%. This efficiency is comparable to using a corrosion inhibitor. The catholyte was obtained by modifying water-salt solutions from tap water, which completely excluded the use of chemical reagents.

5. **References**
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