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Methods for determining the rate of corrosion with the application of a corrosion inhibitor produced on the basis of secondary raw materials

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Abstract. This article describes the synthesis technology of a new corrosion inhibitor based on formalin, thiosemicarbazide, and orthophosphoric acid, as well as the method of determining the corrosion rate of the synthesized corrosion inhibitor by polarization resistance and gravimetric method. The effectiveness of the synthesized corrosion inhibitor against corrosion caused by the acid in the mixture of gases from mines in gas treatment plants has been reflected in the results of research and testing. Also, the effectiveness of the corrosion inhibitor and the braking coefficient were determined.

1 Introduction

Globally, damage caused by corrosion of metal products, equipment, structures and devices is 25-30% of the produced metals annually. In addition to this huge direct damage, there are also very large indirect damages. They include the loss of power of metal equipment, damages caused by their forced shutdown due to accidents, as well as the costs of eliminating the consequences of accidents that often lead to environmental catastrophes, etc. Therefore, higher efficiency can be achieved when the causes of corrosion are studied in each production plant and protected with anti-corrosion coatings and effective inhibitors suitable for this environment.

Nowadays, it is necessary to create multi-functional types of anti-corrosion inhibitors and anti-corrosion coatings for metals. Therefore, the production of inhibitors based on organic raw materials with high efficiency, protecting metals from corrosion, is becoming important in various industrial enterprises. Based on this, the production technology of TFO brand corrosion inhibitor synthesized on the basis of formalin, thiosemicarbazide and orthophosphoric acids was developed and its test research works were carried out by polarization resistance and gravimetric method [1,2].

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2 Research method

The scheme of the technological process of obtaining an inhibitor based on formalin, thiosemicarbazide and orthophosphoric acid consists of two stages: 1) obtaining dimethylol tar with thiosemicarbazide and formalin; 2) consists of the process of obtaining a modified oligomer through dimethylol resin and orthophosphoric acid [3,4]. The process of obtaining the synthesized corrosion inhibitor is carried out in the following technological scheme (Figure 1).

The solution of thiosemicarbazide is collected by screw pump 1 in volume 4 of 2m^3. The formalin solution is pumped into a 3m^3 capacity tank 5 through a centrifugal pump 2. Orthophosphoric acid is delivered to the 6th tank installed in the system through a special centrifugal pump 3 with a volume of 2 m^3.

The raw materials collected in the tanks are sent to the shell reactor 8 equipped with a mixing device designed for heating up to 100°C of the EMK R-1000 type. The reactor is divided into two parts, and the rotation speed is carried out in the control unit, and it moves at a speed of minimum 60 rpm and maximum 90 rpm. In this case, the solutions collected in 4 and 5 tanks are sent to the reactor and processed by mixing at 40°C temperature for 15 minutes. Then, the orthophosphate acid collected in the 6 tank is transferred to the mixture of thiosemicarbazide and formalin (dimethylol resin) produced as a result of processing in the reactor tank for modification. All three components are processed in the reactor for 25-30 minutes with the heating agent water vapor at a temperature of 60-65°C until the finished product oligomer is obtained. An exothermic process takes place in the reactor. The oligomer produced in the reactor is transferred to the sedimentation device 9. In the immersion device, the oligomer mixture passed through the reactor is separated from water and sent to the belt drying device 11 through the screw conveyor installed in the lower part of the device. In the immersion device, the separated water in the mixture is discharged through the valve 10.

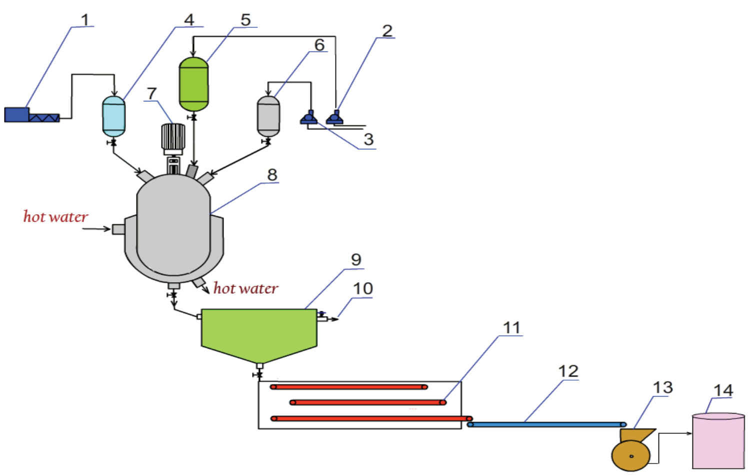

Fig. 1. Technological scheme of corrosion inhibitor production**.** 1-pump screw; 2,3 centrifugal pump; 4-tank for thiosemicarbazide; 5-tank for formalin; 6- tank for orthophosphate acid; 7- electric motor; 8-mixing reactor; 9-drowning device; 10-valve; 11- tape drying device; 12-tape conveyor; 13-grinding device; 14-storage capacity.

The oligomer brought to the belt dryer is processed until it produces a dry substance. The dried oligomer is sent to the 12-thru 13-hammer grinding device, where the oligomer is reduced to a powder state of 0.5-1 μm and then sent to the 14th sieve.

Oligomers obtained under production conditions can be used even after 6-7 months. Only in this case, in order to reduce the viscosity of the solution, it is advisable to dilute the drug with water before use [2,5].

Research method. The polarization resistance method of determining the corrosion rate was carried out on the R-5035 device. In the device, a steel electrode, i.e. a 09G2S steel plate, was immersed in a 20% aqueous solution of HCl saturated with a concentrated inhibitor at a temperature of 25°C for 1 hour.

The device for determining the corrosion rate by the polarization resistance method is presented in Figure 2 [3,6].

Fig. 2. Device R-5035 for determination of corrosion rate by polarization resistance method.

The inclusion of TFO inhibitor in aqueous solution of HCl increases the polarization resistance, and it is shown in Table 1 that the resistance increases with increasing inhibitor concentration. This result shows that the electrochemical process is strongly inhibited and allows to obtain preliminary results on the effectiveness of the inhibitor.

Protection efficiency (η) and braking coefficient (γ) calculated by the polarization resistance method are presented in Table 1.

Table 1. Results of determining the effectiveness of the TFO inhibitor by the method of polarization resistance.

Corrosion inhibitor concentration Cing, mg/l	R, Ohm/cm2	Protection efficiency, η (%)	Braking coefficient, γ
0	39	–	–
20	256	6.7	84.1
40	378	9.9	87.9
60	447	12.1	90.8
80	623	16	91.8
100	664	17.1	93.1

The results obtained by the polarization resistance method show that a stable inhibitor layer is formed [1,7,8].

Metal 09G2S steel plate, 20% aqueous solution of HCl, and synthesized TFO corrosion inhibitor were used in the study. The composition (%) of the 09G2S steel plate sample is presented. In this, Fe=96-97; Si=0.5-0.8; Cr=0.3; Cu=0.3; Ni=0.3; As=0.08; Mn=1.3-1.7; S=0.04; P=0.035; N=0.008; C=0.12.

In the research work, steel plates were first prepared in the size of 20x40x4mm (20 cm^2) and thoroughly cleaned with 100x100 mm sandpaper. Then it was washed several times in distilled water and ethyl alcohol and then dried.

Determination of the corrosion rate the effect of concentration and temperature on the effectiveness of the corrosion inhibitor was studied by finding the mass change by the gravimetric method according to GOST 9.905-82. The process was carried out in the laboratory setup shown in Figure 3.

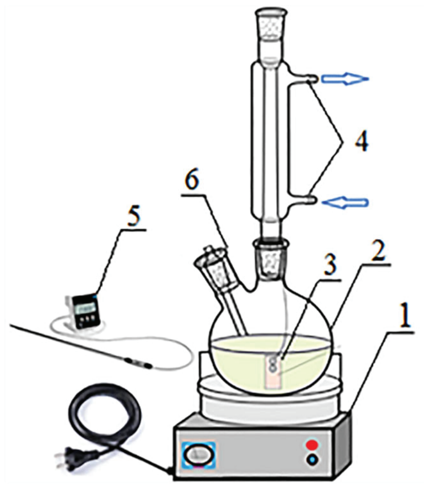

Fig. 3. Laboratory device for determination of corrosion rate by gravimetric method. 1-oil bath; 2-three-necked flask; 3-metal plate; 4-refrigerator; 5-thermometer; 6- place of product.

A two-necked flask was selected in the laboratory, and a water cooler was installed on the upper part. The flask was placed in an oil bath. A 09G2S steel plate, 1000 g of background 20% HCI and 100 mg of inhibitor were placed in the flask and heated to 150°C. The vaporized gas from the solution was condensed into the flask through a water cooler. The process was carried out for 180 hours in medium with and without inhibitor [2,6,9].

During the test study, the higher the temperature, the higher the corrosion rate, only by increasing the inhibitor concentration in it, the corrosion rate was slowed down to a certain extent, and the results are shown in Table 2.

Table 2. Analysis of results of gravimetrically determined corrosion rate of background solution and corrosion inhibitor on 09G2S steel plate for 180 hours (t) with and without inhibitor at different concentrations.

Sample	**Temperature t, oC**	**Metal surface S, 10-4 m2**	**Concentration C, mg/l**	**Mass mo, g**	**Mass m, g**	**Δm=m0-m, g**	**Corrosion rate, g/m2 cm2·h. (υ=Δm/S·τ)**	**γ**	**Z, %**

1	150	20	0	0.0995	0.1151	0.0995	0.1151	-	-
2	150	20	20	0.0361	0.0417	0.0361	0.0417	2.75	82.28
3	150	20	60	0.0264	0.0305	0.0264	0.0305	3.64	84.42
4	150	20	80	0.0148	0.0171	0.0148	0.0171	6.72	86.45
5	150	20	100	0.0082	0.0094	0.0082	0.0094	12.13	89.92

3 Result

In the study, the corrosion rate was 0.1151 g/(cm^2·h) at a temperature of 150°C in the solution without the inhibitor, while the corrosion rate was 0.0417 g/(cm^2·h) at a concentration of 25 mg/l of the inhibitor, when it reached 100 mg/l the corrosion rate decreased to 0.0094 g/(cm^2·h) and the corrosion protection level Z was 89.92 %, the braking coefficient g was equal to 12.13.

Based on the results of Table 2, the concentration dependence of the corrosion rate, braking efficiency and protection efficiency in solutions with and without inhibitors at a temperature of 120°C can be seen in graphs 5, 6, and 7 below.

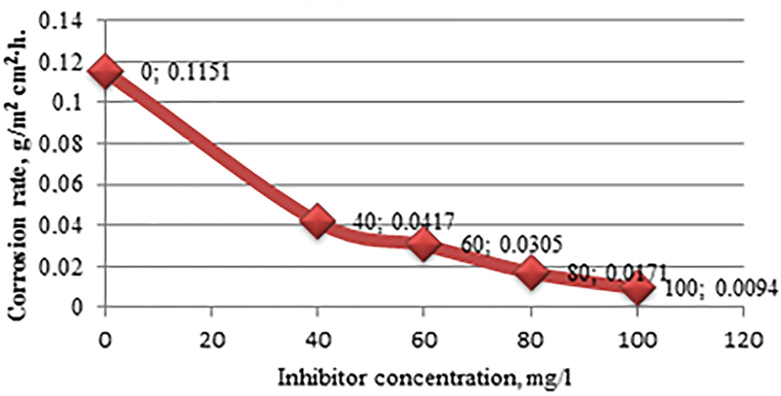

Fig. 4. Corrosion rate versus concentration graph in solutions with and without an inhibitor.

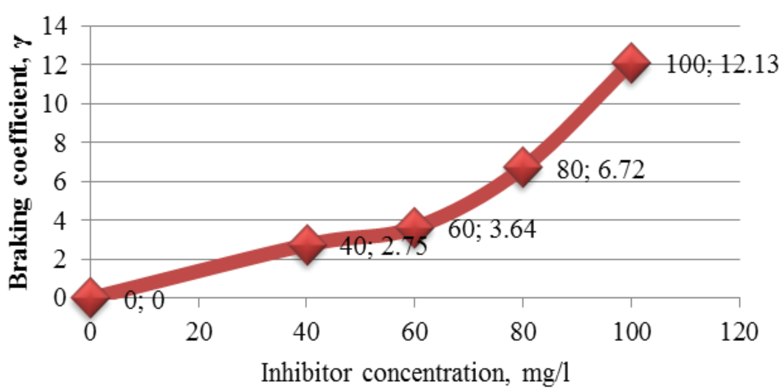

Fig. 5. Concentration dependence graph of inhibition efficiency in solutions with and without inhibitor.

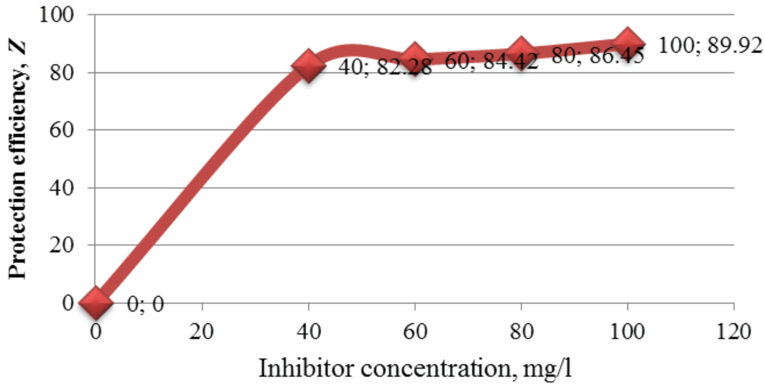

Fig. 6. Concentration dependence graph of protection efficiency in solutions with and without inhibitor.

It can be seen from the graphs that the synthesized TFO corrosion inhibitor has a corrosion rate of 0.0094 g/m^2*s, an inhibition coefficient of 12, when 100 mg/l (0.1%) of the corrosion inhibitor is added at a temperature of 150°C in solutions with and without an inhibitor saturated with acidic components. 13, it can be seen in the graphs that the protection efficiency is 89.92% (Figures 4,5,6).

Variation of the synthesized oligomeric inhibitor concentration significantly affected the anticorrosion performance and corrosion rate. Correspondingly, the anticorrosion efficiency of TFO inhibitor increased from 82.28% to 89.92% with increasing inhibitor concentration [2,10].

4 Conclusion

During the test studies, which were determined using the polarization resistance and gravimetric method of determining the protective ability of the corrosion inhibitor, nitrogen, phosphorus and sulfur compounds for the TFO corrosion inhibitor, even electrons are very mobile and interact well with the metal and have an inhibitory effect on metals, especially steel. The inhibitor formed a thin film layer on the metal surface, revealing its protective layer against corrosion in the external environment.

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