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GRAVIMETRIC ASSESSMENT OF THE EFFECT OF *2-ACETYL-6-(10H-PHENOTHIAZIN-10-YL)-3A,6-DIHYDRO-1H-BENZO[DE]ISOQUINOLINE-1,3(2H)-DIONE* ON THE CORROSION BEHAVIOR OF STEEL IN SULFURIC ACIDIC ENVIRONMENT

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Abstract: *In this study, we present the results of research on the inhibitory properties of the organic substance (2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione) concerning the corrosion of steel in a sulfuric acid environment. The experiments were conducted under laboratory conditions, and the inhibitory action of the substance was investigated using the gravimetric method. Although this method does not provide insights into the mechanism of corrosion processes, it is suitable for evaluating the inhibitory effects of various substances. Studies were carried out to examine the influence of the inhibitor's concentration (0 – 1x10^{-4} mol dm^{-3}) on the corrosion rate, degree of protection (Z), and the inhibitor's efficiency coefficient (Y). The impact of the inhibitor on the corrosion process characteristics was studied at three temperatures (25°C, 35°C, and 45°C). Due to the strong temperature dependence of corrosion processes, sample exposure at different temperatures was chosen for 48, 23, and 2 hours, respectively.*

The obtained results clearly demonstrate that with an increase in the concentration of the inhibiting substance under all investigated conditions, the protective effect noticeably increases. Considering the fact that the substance is practically insoluble in water and has very low solubility in ethanol, it is worthwhile to explore other suitable solvents that would allow for the introduction of larger quantities into the corrosion environment. Undoubtedly, this is a good approach to enhance the effectiveness of its protective action. The proposed experimental procedure is suitable for a rapid assessment of the inhibitory properties of this and other organic compounds with different functional groups.

Keywords: *corrosion, inhibitors, 2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione*

INTRODUCTION

It is well-known that corrosion has an extremely detrimental impact on the durability of metal components and structures. The magnitude of losses due to corrosion has been demonstrated to be exceptionally significant. By employing effective methods for corrosion protection, these losses can be significantly reduced. Numerous methods for protecting metal products from corrosion have been proposed. One of these methods, inhibitor protection, is finding increasingly widespread application due to its cost-effectiveness, efficiency, and universality. This method can be applied without disrupting the corresponding technological processes, often requiring minimal additional specialized equipment. In a vast number of systematic studies, it has been shown that by introducing small quantities of suitable organic and inorganic chemical compounds into aggressive corrosive environments, the corrosion rate can be greatly reduced.

The protective action of inhibitors is associated with changes in the surface condition of the metal as well as the kinetics of partial reactions that determine the corrosion process mechanism. Many organic compounds have been investigated as inhibitors of acid corrosion of iron (Haralanova, T., Girginov, Ch., Dishliev, A., 2017).

In this current study, we present the results of research on the inhibitory properties of the organic substance *(2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione)* concerning the corrosion of steel in a sulfuric acid environment.

EXPERIMENTAL

The investigations were conducted using samples cut from sheet Steel 3 (grade *EN-S235J2*). The samples were in the form of a parallelepiped with a working surface of approximately $30.0100x10^{-4}m^2 \pm 0.0001x10^{-4}$.

The inhibitory action of *2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione* was studied. Its structural formula is shown in Figure 1.

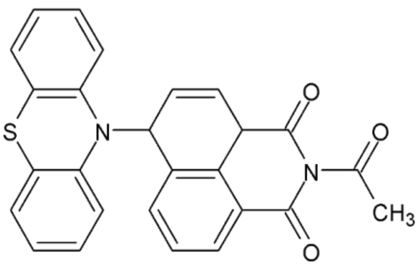

Fig. 1. Structural formula of the studied organic inhibitor (2-acetyl-6-(10*H*-phenothiazin-10-yl)-3a,6-dihydro-1*H*-benzo[*de*]isoquinoline-1,3(2*H*)-dione)

A 0.1M solution of sulfuric acid was used as the corrosive medium. The solution was prepared using “Merck” brand sulfuric acid.

The organic inhibitor was previously dissolved in ethanol and introduced into the corrosive medium in the form of an ethanol solution. The concentration of the inhibitor was studied in the range of $0 – 1x10^{-4}$ mol dm^{-3}.

The influence of the inhibitor on the characteristics of the corrosion process was studied at three temperatures: 25°C, 35°C, and 45°C. Due to the strong temperature dependence of corrosion processes, the exposure of the samples at different temperatures was selected for 48, 23, and 2 hours, respectively.

Method of Investigation

The experiments were conducted under laboratory conditions. The inhibitory action of the substance was studied using the gravimetric method. It is known that this method provides information about the corrosion rate but not about the mechanism of corrosion of the samples. Nevertheless, gravimetric measurements can provide a real insight into the inhibitory action of different substances (Haralanova, T., Ilieva M., Girginov, Ch. , 2016).

The measurements conducted allowed for the evaluation of the corrosion rate and the effectiveness of the investigated inhibitor.

Corrosion Rate (k)

The corrosion rate (k) is calculated using the equation:

$$k = \frac{(m_0 - m)}{S \times t}\left[gm^{-2}h^{-1}\right], \qquad (1)$$

where $m_0[g]$ and $m[g]$ are the mass of the steel sample before and after exposure, $S\left[m^2\right]$ is the surface area of the sample, and $t[h]$ is the exposure time in the corrosive medium (0.1M H_2SO_4).

As criteria for the effectiveness of the inhibitor, the following quantities have also been calculated:

Degree of Protection (Z)***:***

$$Z = \frac{(k_0 - k)}{k_0} \times 100[\%], \qquad (2)$$

where k_0 is the corrosion rate of the metal in the corrosive medium without the addition of the organic substance, and k is the corrosion rate of the metal in the corrosive medium with the addition of the organic substance.

Inhibitor Efficiency Coefficient (Y)***:***

$$Y = \frac{k_0}{k} \qquad (3)$$

It is worth noting that the gravimetric method is suitable for systematic research and for assessing the impact of the inhibitor on the characteristics of the corrosion process.

RESULTS AND DISCUSSION

The corrosion rate of the metal in the corrosive medium without the addition of the organic substance (k_0) was determined at all three investigated temperatures (t), along with the respective exposure times (τ). The obtained results are presented in **Table 1**.

Table 1. Results obtained for (k_0) at all three investigated temperatures (t), along with the respective exposure times (τ).

$t[^oC]$	$\tau[h]$	$k_0[gm^{-2}h^{-1}]$
25	48	1.7523
35	23	6.6442
45	2	7.5630

The results of the investigations regarding the corrosion rate with the addition of the organic substance in the corrosive medium (k) are shown in Figure 2.

The obtained results indicate that with an increase in its concentration, the corrosion rate decreases. This effect is more pronounced at higher temperatures (35°C and 45°C).

The dependence of the degree of protection (Z) on the concentration of *2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione* in the corrosive 0.1 M H_2SO_4 medium is graphically represented in Figure 3.

The results show that with an increase in the inhibitor concentration, the coefficient increases under all experimental conditions.

Similar dependencies for the influence of the inhibitor concentration on the inhibitor efficiency coefficient (Y) are presented in Figure 4.

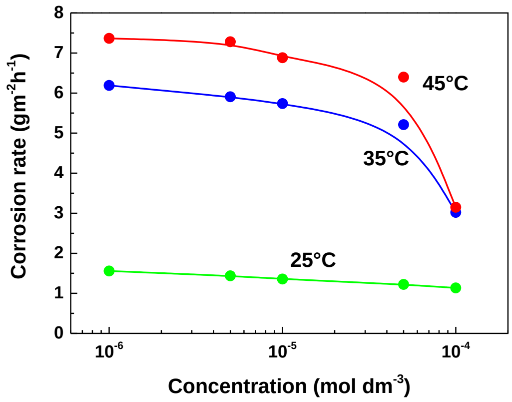

Fig. 2. Dependence of the corrosion rate on the concentration of the inhibiting substance

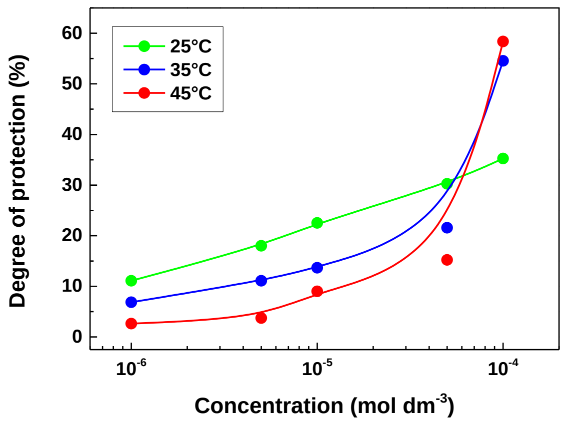

Fig. 3. Dependence of the degree of protection on the concentration of the inhibiting substance

The obtained results clearly demonstrate that with an increase in the concentration of the inhibiting substance under all investigated conditions, the degree of protection increases significantly.

In the literature (Wang, Z. Z., Li Y.Y., Zhang G. A., 2019), it has been demonstrated that some of the most effective inhibitors of acid corrosion are aromatic compounds containing N, S, and O, as well as those with complex bonds.

The presence of multiple functional groups in the molecule of the compound also significantly enhances its protective action. The compound studied in this work *(2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione)* meets these criteria. It is worth noting that the compound introduced into the corrosive medium has a very low concentration. This is due to the fact that it is practically insoluble in water and has very low solubility in ethanol.

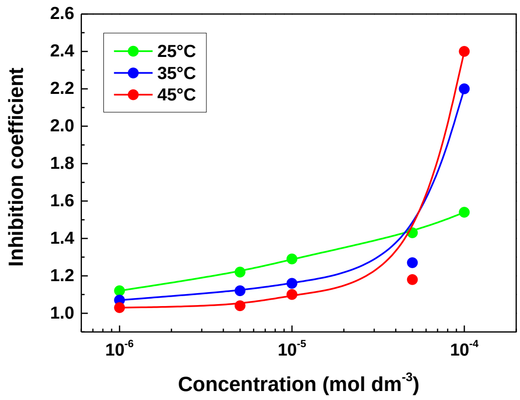

Fig. 4. Dependence of the inhibitor efficiency coefficient on the concentration of the organic substance

The obtained results are logical - the corrosion rate decreases with an increase in concentration. In a certain sense, the interesting fact emerges that at the maximum concentration ($1x10^{-4}$ mol dm^{-3}), the degree of protection (Z) and the inhibitor efficiency coefficient (Y) sharply increase at two (35°C and 45°C) of the investigated temperatures. It can be expected that by choosing another suitable solvent, the studied substance could be introduced into the corrosive medium at higher concentrations, thus demonstrating more effective inhibitory properties.

CONCLUSIONS

The conducted research has enabled the formulation of the following main conclusions:

The organic substance *2-acetyl-6-(10H-phenothiazin-10-yl)-3a,6-dihydro-1H-benzo[de]isoquinoline-1,3(2H)-dione*, when added to an aggressive corrosive environment (0.1 M H_2SO_4), reduces the corrosion rate of the studied steel.

It has been established that the corrosion rate of the steel decreases with an increase in the concentration of the organic additive and increases with an increase in temperature.

The relatively low values obtained for both the degree of protection (Z) and the inhibitor efficiency coefficient (Y) should not be perceived as the absence of a good inhibitory effect, considering that the solubility of the studied substance is very low.

The proposed computational procedure is suitable for a rapid assessment of the inhibitory properties of this and other organic compounds with different functional groups.

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