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Evaluation of the Inhibition Effectiveness of Ampicillin in the Corrosion Steel in Acid Solution

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Abstract: The increasing number of applications for carbon steel not only in industry and everyday life, but especially in medical applications requires knowledge on its susceptibility towards electrochemical corrosion in different environments, especially in acidic and neutral environments, including the human body. Moreover, the interest of the research community is still focused on finding suitable compounds, which provide good inhibition effectiveness in the specific corrosion environment, are affordable and are considered environmentally friendly. Ampicillin is a common β-lactam antibiotic of the penicillin family used to treat bacterial infections. In this work, we discuss the inhibition effectiveness of ampicillin as corrosion inhibitor for carbon steel in acidic solution at room temperature, using the weight loss method, at different concentrations of ampicillin. The inhibition effectiveness of ampicillin in 0.02 M HCl solution increased with increasing its concentration. Indeed, the highest inhibition effectiveness (90.7%) was achieved for the highest inhibitor concentration (1.0 wt.% ampicillin).

Keywords: Corrosion, Carbon steel, Ampicillin, Acid solution, Weight loss

Introduction

Electrochemical corrosion is a process dating a long time ago and so is the use of metals. Electrochemical corrosion deals with the damages of the metals and the loss of mechanical abilities as a consequence of their electrochemical interaction with the surrounding environment. A crucial role in the electrochemical corrosion, along with the selection of the accurate metal is played by the corrosive environment where the metal is located.

The industrial development of nowadays emphasizes the need for a deep acknowledge of the electrochemical corrosion process, that is related with the mechanism and the protection of the metal from this accompanying aggressive phenomenon (Schweitzer, 2010). This electrochemical phenomenon is more emphatic in the solutions of electrolytes, for instance the HCl solution, NaCl solution etc., used these for different purposes in several industrial processes.

Regarding to the literature is assumed that the loss from corrosion in some of the industrial countries is estimated to be approximately 4% of the general production. The loss from corrosion includes a big economical cost for the replacement of metallic objects but are also related with preliminary investments for its prevention. To the latest one we can include the electrochemical protection, the anode protection, the cathodic protection, the use of the inhibitors etc. The corrosion besides the damage of the metallic objects through the loss of material, is related to negative effects to the environment and to numerous accidents and breakdowns, decreasing so the security at work and their effectiveness. In these aspects we can mention damage of bridges, demolition of metal structures of industrial plants, technological lines etc. (Bardal, 2004).

The corrosion phenomenon is assessed as a life threatening, reducing their mechanical skills and denaturing their function. Although the use of metals is very old dated, the science of corrosion still coincides, because corrosion cannot be completely stopped but can be minimized and prevented by applying different methods (Owens & Blum, 1967, Raja & Sethuraman, 2008).

Today's corrosion science is an integral part in testing and selecting metal matrices. In this aspect, the laws of Faraday are an important basis, as they evaluate the relationship between chemical action and electrical current. Through these laws calculations of the corrosion rates of different metals can be calculated. Corrosion control can be performed on the electrochemical survey base (Fouda et al., 2017). Currently there is extensive literature and many results of scientific articles to recognize and take into account the phenomenon of corrosion (Ahmad, 2006, Valek et al., 2008, Abdulreda, 2014, Xhanari et al., 2015, Shkirskiy et al., 2015).

Antibiotics are known for their inhibition effect against various infections or diseases as well as for their antibacterial action. In this regard, ampicillin finds a lot of uses in these areas (Rocco & Overturf, 1982; Kumar et al., 2013; Niwa et al., 2016). From the family of antibiotics, a representative, such as ampicillin, is selected to evaluate its influence and its role in the electrochemical corrosion of metals (El-Naggar, 2007; Gece, 2011; Chudobova et al., 2014).

In this paper we evaluate the inhibition efficiency of ampicillin in the corrosion of carbon steel in different concentrations of HCl solution. The efficiency of the ampicillin was determined using the weight loss method. The measurements were performed at four different inhibitor concentrations (i.e. 0.25 g/L, 0.50 g/L, 0.75 g/L and 1.00 g/L) at different concentrations of HCl solutions (0.02 M; 0.05 M; 0.07 M and 0.10 M) at room temperature.

Experimental Part

Preparation of the samples for weight loss method

The samples used in the weight loss method were in parallelepiped shape with dimensions (40 mm x 25 mm x 3.5 mm and a diameter hole of 3.25 mm. Table 1 shows the composition of the carbon steel. The remainder is Fe.

Table 1. Chemical composition of the carbon steel samples

Element	C	Mn	Cr	Si	V	S	P
Content (%)	0.55-0.60	0.65-0.70	0.35	0.25	0.20	0.03	0.03

Preparation of the corrosion environment

HCl solutions of different concentrations were prepared starting from a 36% HCl solution (d = 1.179 g/cm^3). Different amounts of ampicillin added to 100 ml of acid solution with the desired concentration and mixed with a magnetic stirrer for 15 min.

Ampicillin Composition

Ampicillin was purchased from "Profarma" company as capsules. Each capsule contains 500 mg of ampicillin as ampicillin trihydrate and apart from the active component thiamine clorhidrate. The other ingredients are

magnesium stearate, erythrosine, indigocarmine, titanium dioxide, gelatine, etc. The term "ampicillin" used throughout the paper refers to the capsules.
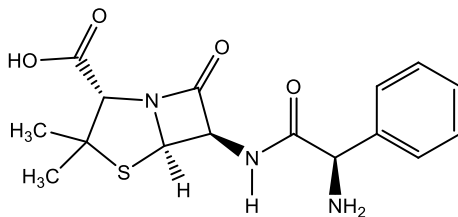

Figure 1. Chemical structure of ampicillin.

Chemical formula of ampicillin is $C_{16}H_{19}N_3O_4S$ and chemical name is (2S,5R,6R)-6-([(2R)-2-amino-2-phenylacetyl]amino) -3,3-dimethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]heptane-2- carboxylic acid.

Preparation of the Corrosion Environment

HCl solutions of different concentrations (0.02 M; 0.05 M; 0.07 M and 0.10 M) were prepared starting from a concentrated solution. Different amounts of ampiciline added to acid solution with the desired concentration and mixed with a magnetic stirrer for 15 min. The volume of the solution that contains the corrosive test environment is 100 mL. In each of the hydrochloric acid solutions (0.02 M HCl; 0.05 M HCl; 0.07 M HCl and 0.10 M HCl) was added relevant quantities of ampiciline: 0.25 g/L (1/2 capsule), 0.50 g/L (1 capsule), 0.75 g/L (3/2 capsules) and 1.00 g/L (2 capsules). Table 2 summarizes all the acid-inhibitor combinations tested.

Table 1. Composition of the corrosion environment

Acid concentration	0.02 M HCl	0.05 M HCl	0.07 M HCl	0.10 M HCl
	–	–	–	–
Inhibitor concentration	0.25 g/L	0.25 g/L	0.25 g/L	0.25 g/L
	0.50 g/L	0.50 g/L	0.50 g/L	0.50 g/L
	0.75 g/L	0.75 g/L	0.75 g/L	0.75 g/L
	1.00 g/L	1.00 g/L	1.00 g/L	1.00 g/L

Working Procedure

The prepared samples are marked and their surface is polished using emery paper of different grades (120, 240, 320, 600 and 1000). They are then rinsed with distilled water and dried with warm air pressure. Finally the samples surface is treated with acetone to degrease it and then rinsed with distilled water and dried with warm air. The samples were left in the corrosion environment for 4 hours. After they have been removed from the solution they were rinsed with distilled water, neutralized with an aqueous solution of Na_2CO_3 and then dried with warm air pressure.

Results and Discussion

The results obtained from the weight loss method are used to calculate the corrosion rate in g/m^2hour:

$$v_{(g/m^2 hour)} = \frac{\Delta m}{S \cdot t} \tag{1}$$

and in mm/year:

$$v_{(mm/year)} = \frac{8.76 \cdot v_{(g/m^2 hour)}}{d} \tag{2}$$

Δm – change in weight (in grams) of the sample before and after exposure
S – sample surface (in m^2)
t – exposure time in the corrosion environment (in hours)
d – density of steel (7.86 g/cm^3)

The inhibition efficiency of ampicillin is calculated using the formula:

$$E(\%) = \frac{v_{corr}^0 - v_{corr}}{v_{corr}^0} \cdot 100 \qquad (3)$$

E (%) – inhibition efficiency
v_{corr}^0 – corrosion rate without inhibitor addition
v_{corr} – corrosion rate with inhibitor addition

Table 3 summarizes the corrosion rates in g/m^{2}hour and mm/year and the respective corrosion efficiency values calculated according to formulas 1-3, for all inhibitor-acid combinations investigated.

Table 2. Corrosion rates and inhibitor efficiencies for different corrosive environments.

| Corrosive environment	Corrosion rate (g/m^{2}hour)	Corrosion rate (mm/year)	Inhibitor efficiency (%)
0.02 M HCl	1.5739	1.7541	–
0.02 M HCl + 0.25 g/L inhibitor	0.4552	0.5073	71.08
0.02 M HCl + 0.50 g/L inhibitor	0.3242	0.3613	79.40
0.02 M HCl + 0.75 g/L inhibitor	0.2678	0.2984	82.99
0.02 M HCl + 1.00 g/L inhibitor	0.1464	0.1631	90.70
0.05 M HCl	0.8003	0.8919	–
0.05 M HCl + 0.25 g/L inhibitor	0.6292	0.7013	21.38
0.05 M HCl + 0.50 g/L inhibitor	0.3647	0.4065	54.43
0.05 M HCl + 0.75 g/L inhibitor	0.3080	0.3432	61.53
0.05 M HCl + 1.00 g/L inhibitor	0.2528	0.2817	68.42
0.07 M HCl	1.4005	1.5608	–
0.07 M HCl + 0.25 g/L inhibitor	0.6828	0.7609	51.25
0.07 M HCl + 0.50 g/L inhibitor	0.5403	0.6021	61.42
0.07 M HCl + 0.75 g/L inhibitor	0.4418	0.4924	68.46
0.07 M HCl + 1.00 g/L inhibitor	0.2927	0.3262	79.10
0.10 M HCl	2.3741	2.6459	–
0.10 M HCl + 0.25 g/L inhibitor	1.7136	1.9098	27.82
0.10 M HCl + 0.50 g/L inhibitor	1.6073	1.7913	32.30
0.10 M HCl + 0.75 g/L inhibitor	1.5797	1.7606	33.46
0.10 M HCl + 1.00 g/L inhibitor	1.5297	1.7049	35.57
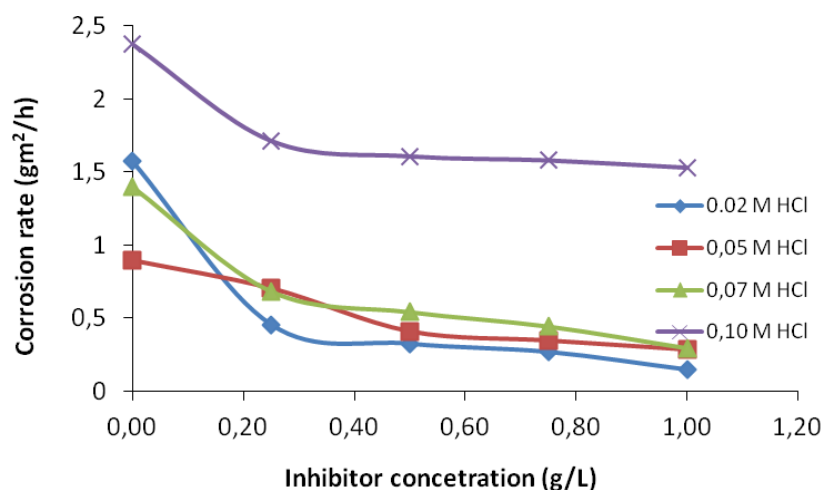
Figure 2. Inhibitor concentration effect on corrosion rate at different acid concentrations

The lowest corrosion rate (0.1464 g/m^{2}hour) was obtained for the most diluted acid (0.02 M HCl solution) using the highest concentration of ampicillin (1.00 g/L). It can be also observed from the data that for the same inhibitor concentration the corrosion rate decreases with the decrease of acid concentration. Figure 2 shows that the corrosion rate decreases with the increase of inhibitor concentration for all acid concentrations tested.
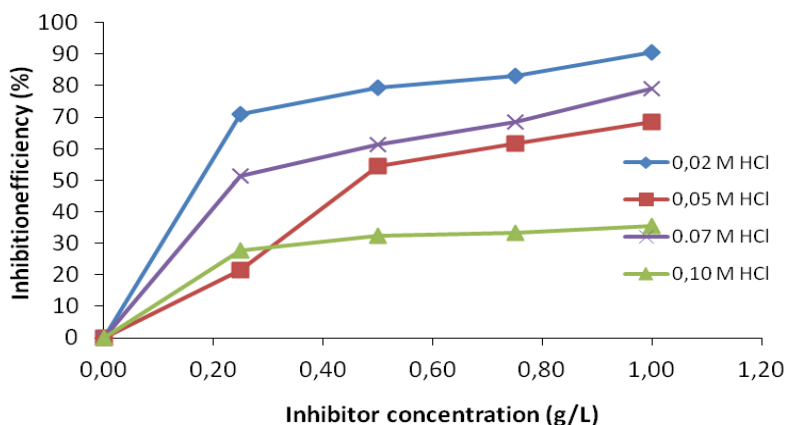

Figure 3. Inhibitor concentration effect on inhibition efficiency at different acid concentrations

The tests were performed in 0.02 M HCl solution, since this concentration gave the lowest corrosion rate at room temperature. The corrosion rates increase when increasing temperature.

Conclusion

Ampicillin showed good inhibition efficiency in the protection of carbon steel. The inhibition efficiency increased with the increase of the concentration of the ampicillin. The lowest corrosion rate obtained was 0.146 g/m^{2}hour for 0.12 g/L ampicillin used. The corrosion rate increased with increasing temperature, suggesting that ampicillin may be more appropriate as inhibitor at low temperatures.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPHELS journal belongs to the authors.

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