IJEIT
The International Journal of Engineering and Information Technology
journal homepage:www.ijeit.misuratau.edu.ly
MISURATA UNIVERSITY

Study of the Effect of Temperature on Activation Energy and Corrosion Rate of Mild Steel Using Green Inhibitor: "*Posidonia Oceanica*"

Dr. Ali R. Elkais
El-Mergib University, Libya
elkaisali@gmail.com

Dr. Mohamed K. Zambri
El-Mergib University, Libya

Abstract - Newly extract "posidonia Oceanica" derivatives with different concentrations 2 %, 4%, 6% and 8 % as a corrosion green inhibitor of mild steel in sea water at different temperatures 25, 40, 50 and 60 ˚C. The corrosion comes from a sea water environment leads to serious consequences of the corrosion problems by reaction with its environment process which has become a problem of worldwide especially at high temperature. The inhibition efficiency of the extract posidonia Oceanica was calculated and compared. The results obtained revealed that the inhibitor tested differently reduced the kinetics of the corrosion process of steel. Its efficiency increases with the concentration and attained 95.2 % at 8 %. The thermodynamic data of activation were determined. Posidonia Oceanica extract is adsorbed on the steel surface according to a Langmuir adsorption model. The change of activation energy values indicates that the adsorption is a physical situation. The negative value of (ΔH) indicates that the adsorption of inhibitors is an exothermic process. The effect of temperature on the inhibition efficiency in the absence and presence of posidonia Oceanica of all samples were obtained and expressed as; Ea and ΔH .

Index Terms : Adsorption, Corrosion inhibition, Mild steel, Sea water media, posidonia Oceanica.

I. INTRODUCTION

In the recent 50 years mild steel has been considered one of the metals are commonly used in different industries which account approximately 80 – 90 % of the annual production around the worldwide. These different industries include such as, marine application, chemical and petroleum production, transportation, pipelines, etc. However, corrosion of mild steel in different environment lead to a big number of the total cost and looking for suitable and cheap way of protection is very important [1 – 3]. Addition of corrosion inhibitors is one of the requirements to protect metals and alloys against attack of corrosion in many industrial environments. The development of new corrosion inhibitors based on green inhibitor compounds to solve the corrosion problems and to reduce the economic cost of equipment.

This study is followed a previous experimental work presented in (ICCPGE-2016) [4], where a green inhibitor "Posidonia Oceanica" in different concentrations was used to protect the mild steel in seawater environment and corrosion rate measurements were carried out. This work will study the effect of different temperatures 25, 40, 50 and 60 ˚C on the activation energy and corrosion rate based on the weight losses measurements carried out before. Table 1 below shows the results collected of weight losses using different concentration of Inhibitor and different temperatures.

Table 1. : Results of Weight Loss in Absent and with Different Concentration of Inhibitors and Different Temperature in 6hrs [4]:

Weight Losses, gm Immersion time, 6hrs	**Temperature, °C**			
	25°C	40°C	50°C	60°C
inhibitor 0%	0.00070	0.0034	0.0043	0.0083
inhibitor 2%	0.00065	0.0026	0.0032	0.0067
inhibitor 4%	0.00062	0.0024	0.0027	0.0028
inhibitor 6%	0.00007	0.0011	0.0014	0.0016
inhibitor 8%	0.00005	0.0002	0.0003	0.0004

Received 1 May, 2020; revised 30 May, 2020; accepted 16 June, 2020.

Available online 17 June, 2020.

II. RESULTS AND DISCUSION

A. *Activation Energy and Corrosion Inhibition Efficiency*

The effect of the addition of extract inhibitor tested at different concentrations on the corrosion of mild steel in sea water environment was studied using weight loss at 298K to 333K after 6hr of immersion period. The effect of Activation energy and inhibition efficiency E (%) are calculated by:

$$\% E = (1- W1/W2) \times 100$$

Where W1 and W2 are the weight losses in grams for mild steel in the presence and absence of the inhibitor from “Posidonia Oceanica” extract in the sea water at a specific temperature [4].

B. *Activation Energy Calculations*

There was a clear effect of the temperature on the corrosion rate of mild steel in seawater involving different concentrations of inhibitor (0, 2, 4, 6, and 8%) in the range of temperature298 – 333 K and immersion time of 6hrs.

The corresponding results are summarized in table1. Understanding the mechanism of inhibited seawater-metal reaction is so difficult due to the changes occur on the metal surface such as desorption, rapid etching ‘

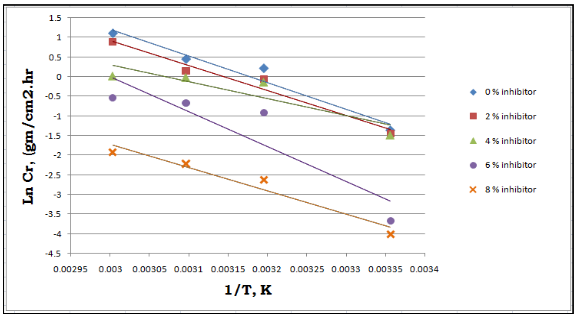

Figure 1. Arrhenius Plots of *ln* C_R Versus *1/T*

Decomposition, and Rearrangement [5]. It has been considered that the extract of inhibitor was adsorbed on the steel surface at all temperatures of study and the data presented in table1 shows that the corrosion rate is increasing in the absence and present of the inhibitor with increasing the temperature in the seawater environment. The relationship between the corrosion rate of mild steel in seawater environment and the temperature can be presented using the Arrhenius equation [5].

$$C_R = A \exp^{(-E_a/RT)}$$

Where CR is the corrosion rate, Ea is the activation energy of the corrosion reaction, R is the gas constant, T is the absolute temperature and A is the Arrhenius pre-exponential factor. The value of activation energy of the corrosion reaction in the absence and present of the inhibitor can be calculated by plotting the value of ln CR versus the value of 1/T, which introduce a straight line with a slope leading to the determination of Ea. Figure. 1 shows the plots of the relationship between the corrosion rate and temperature in the absence and present of the inhibitor for different concentrations.

For mild steel in seawater environment in the absence and present the inhibitor with different concentrations and temperatures .

The values of activation energy (Ea) for mild steel in seawater environment in absence and Present of inhibitor with different concentration and different temperature can be summarized in the table 2 below:

Table 2. Activation Energy Determination for Mild Steel in Seawater Environment

Inhibitor concentration & CR, gm/cm2.hr	**Temperature, K**				Ea , KJ/mole
	298	313	323	333	
0%	0.25550	1.241	1.5695	3.0295	56.4
2%	0.23720	0.949	1.1680	2.4455	52.7
4%	0.22630	0.876	0.9855	1.0220	35.8
6%	0.02555	0.402	0.5110	0.5840	74.1
8%	0.01825	0.073	0.1095	0.1460	49.3

Higher values of Ea in the presence of inhibitor can be correlated with increasing thickness of the double layer which enhances the Ea of the corrosion process [6].

It is also an indication of a strong inhibitive action of inhibitors by increasing energy barrier for the corrosion process, emphasizing the electrostatic character of the inhibitor’s adsorption on the mild steel surface (physisorption) [7].

C. *The Effect of Inhibitor Concentration*

The adsorption of inhibitor at metal/solution interfaces can markedly change the corrosion resisting properties of metals. The efficiency of inhibitor extract as good corrosion inhibitor mainly depends on their adsorption ability on the metal surface. So, the investigation of the relation between corrosion inhibition and adsorption is of great importance. The surface coverage (θ=E%/100) data are very useful while discussing the adsorption characteristics. When the fraction of surface covered is determined as a function of the concentration at constant temperature, adsorption isotherm could be evaluated at equilibrium condition [8]. The values of θ can be used to determine the thermodynamic parameters and the mode of the adsorption process. Flory–Huggins adsorption isotherm [9] can be applied to test the mechanism of adsorption process.

D. *The Effect of Temperature On Corrosion Inhibition Efficiency*

The effect of temperature on the steel in different containing inhibitor at a maximal concentration (8 %) was studied in the temperature range 298–333 K, the corresponding results are summarized in table 3. The results suggest that the extract was adsorbed on the steel surface at all temperatures studied.

The data in table 3 indicate that the corrosion efficiency increase with increased concentration absence and presence of the extract inhibitor with the rise in temperature in sea water environment. This is because an

increase in temperature usually accelerates corrosive, particularly in processes in oxygen oxidation media. A decrease in inhibition efficiencies at (2%) with the increase temperature as shown in Figure. 2 in presence of inhibitor might be due to weakening of physical adsorption of this inhibitor at high temperature with low values of concentrations which can be clear seen for other high concentrations and different temperatures .

Table 3. Effect of Temperature on the Inhibition Efficiency at Different Concentrations of Posidonia Oceanica Extract.

Concertation %	**Temperature, K**			
	298	313	323	333
	E %	E %	E %	E %
2	7.1	23.5	25.6	19.3
4	11.4	29.4	37.2	66.3
6	58	67.6	68.2	80
8	92.8	93	94.1	95.2

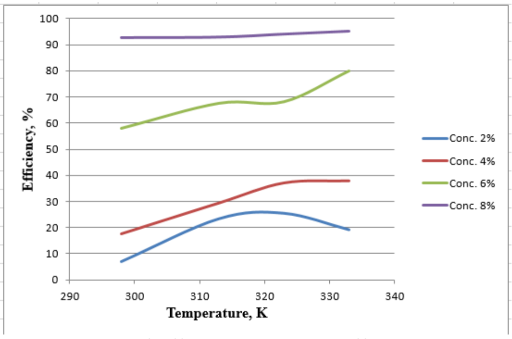

Figure 2. Variation of Efficiency (%) with Different Temperatures

E. The Effect of Inhibitor Concentration

The adsorption of inhibitor at metal/solution interfaces can markedly change the corrosion resisting properties of metals. The efficiency of organic molecules as good corrosion inhibitors mainly depends on their adsorption ability on the metal surface. So, the investigation of the relation between corrosion inhibition and adsorption is of great importance. The surface coverage (θ = E%/100) data are very useful while discussing the adsorption characteristics. When the fraction of surface covered is determined as a function of the concentration at constant temperature, adsorption isotherm could be evaluated at equilibrium condition [8]. The values of θ can be used to determine the thermodynamic parameters and the mode of the adsorption process. Flory–Huggins adsorption isotherm [9] can be applied to test the mechanism of adsorption process.

Form of Langmuir equation is written as below:

$$\theta / 1- \theta = AC \exp(-\Delta H/RT)$$

Where A is the independent constant, C is the inhibitor concentration, ΔH is the standard heat of adsorption, and θ is the surface coverage by the inhibitor molecules. The log [θ / (1 - θ)] versus 1/T at the optimum concentration of inhibitors is plotted Figure. 3. The slopes of the linear part of the plot are equal to (- $\Delta H/R$) from which the heat of adsorption (ΔH) values was calculated and listed in tables 4a, 4b, 4c and 4d.

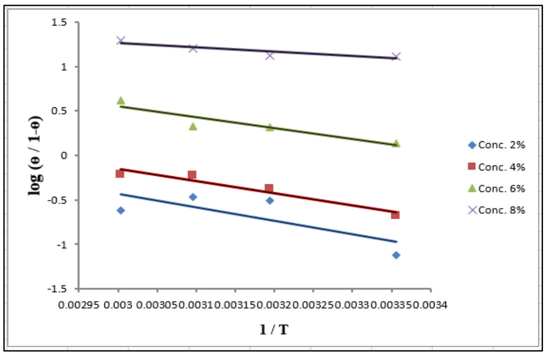

Figure 3. Log (ɵ / 1-ɵ) Versus 1/T at the Different Concentration of Inhibitors

Table 4-a: at 2% Inhibitor Concentration.

CR gm/cm2.hr	**ɵ**	**ɵ / 1-ɵ**	**log (ɵ / 1-ɵ)**	**1/T K-1**	**ΔH kJ/mole**
0.2372	0.071	0.076426	-1.11676	0.003356	- 12.516
0.9490	0.235	0.30719	-0.51259	0.003195	
1.1680	0.256	0.344086	-0.46333	0.003096	
2.4455	0.193	0.239157	-0.62132	0.003003	

Table 4-b: at 4% Inhibitor Concentration.

CR gm/cm2.hr	**ɵ**	**ɵ / 1-ɵ**	**log (ɵ / 1-ɵ)**	**1/T K-1**	**ΔH kJ/mole**
0.2263	0.1743	0.211094	-0.67552	0.003356	-11.453
0.8760	0.2941	0.416631	-0.38025	0.003195	
0.9855	0.372	0.592357	-0.22742	0.003096	
1.0220	0.3802	0.613424	-0.21224	0.003003	

Table4-c: at 6% Inhibitor Concentration.

CR gm/cm2.hr	**ɵ**	**ɵ / 1-ɵ**	**log (ɵ / 1-ɵ)**	**1/T K-1**	**ΔH kJ/mole**
0.0255	0.58	1.380952	0.140179	0.003356	-10.191
0.4020	0.676	2.08642	0.319402	0.003195	
0.5110	0.682	2.144654	0.331357	0.003096	
0.5840	0.8072	4.186722	0.621874	0.003003	

Table 4-d: at 8% Inhibitor Concentration.

CR gm/cm^2.hr	**ɵ**	**ɵ / 1-ɵ**	**log (ɵ / 1-ɵ)**	**1/T K^{-1}**	**ΔH kJ/mole**
0.0182	0.9286	13.0056	1.11413	0.003356	-4.209
0.0730	0.9302	13.32665	1.124721	0.003195	
0.1095	0.9412	16.0068	1.204305	0.003096	
0.1460	0.9518	19.74689	1.295499	0.003003	

III. CONCLUSION

All different inhibitor concentrations on metal surface under investigation undergoes enhancing of the corrosion protection properties in seawater at the temperature range from 298 K to 333 K. The corrosion rates and inhibition efficiencies of mild steel were monitored and controlled in from 2% to 8% solutions inhibitor at different temperatures. The corrosion of mild steel in sea water was increased with increase temperature, and decreased with inhibitor concentration was due to formation of physical layer on metal surface. The inhibition efficiency of posidonia Oceanica extract increases with the rise of temperature. The posidonia Oceanica extract studied was adsorbed on the steel surface according to the Langmuir isotherm model. The activation energy of the corrosion process increases in the presence of extract indicating inhibitor physical adsorption. The result authorizes that in the extract of "Posidonia oceanica" was found to be a good environmentally friendly inhibitor as the corrosion control of mild steel.

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