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Corrosion Inhibition of Low Carbon Steel Using Green Inhibitor (Bulrush) At Variable Conditions

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Abstract

This article proposes the effects of temperature on corrosion inhibition of hydrochloric acid (HCl) solution for low carbon steel with a weight loss process. The corrosion process was tested at temperatures of 25, 35, 45, 55, and 65oC, the inhibitor bulrush was used with concentrations of 0, 0.2, and 0.5 g/L, and hydrochloric acid was used as a solution. The experiment suggests that increasing inhibitor concentration leads to a decrease in corrosion rate in HCl solution due to diffusivity and oxygen solubility. Also, corrosion rate increases as temperature increment and bulrush inhibition efficiency increase with increasing inhibitor concentration up to a maximum of 97.73% at 25 oC and 0.5 g/L concentration. These results revealed that bulrush inhibitor is the best result due to creating a thicker and stronger adjacent layer on the metal surface to prevent dissolved oxygen to reach the metal surface. In the same matter, limited current density increased with increasing temperature and its decrease with increasing inhibitor concentration.

Keywords: bulrush, corrosion rate, inhibitor efficiency, low carbon steel.

Introduction

Is a natural process that converts a refined metal into a more chemically stable form such as oxide, hydroxide, carbonate, or sulfide. It is the gradual destruction of materials (usually a metal) by chemical and/or electrochemical reactions with their environment [1].To prevent corrosion there are several methods; such as Cathodic and Anodic Protection, Addition of Inhibitors, Impressed Current Protection, Protective Coatings [2]. Protection of corrosion generally includes bulk alloying, or coatings of surface that can lead to problems regarding adhesion and thermal expansion compatibility and the like [3]. Carbon Steel is a mix-up of iron and carbon including trace components like Chromium, Nickel, Molybdenum, Cobalt, Vanadium, and Copper, and other non-mineral like Phosphorous and Silicon. The proportion of carbon is the change among 0.06% - 1.5%. steels are classified by counting on carbon composed quantity [4]. Carbon steel metal has good properties such as buildability and comparatively low cost, so it can be more utilized in oil and gas production manufacture[5]. The characteristics of carbon steel are developed in two ways: micro-alloying and heat treatment [6]. Corrosion inhibitor is a chemical material that tests the effectively, reduces, or bans the metal reacts with the ambiance, when added to an ambiance in little concentricity, it is utilized to conserving minerals of corrosion, involving interim conserving through storage or carriage, and then centralized protection needed, for instance, to inhibit corrosion which can occur of small amounts accumulation from an attacker stage[7]. Our previous research has proven beyond a shadow of a doubt that plant roots release oxygen into their immediate surroundings, and the quantity of oxygen released by the roots changes with the degree of oxygen stress present in the immediate rhizosphere environment. However, it's unclear if all of a wetland plant's roots, like the ones we saw before, would be able to actively release oxygen. The quantity of oxygen released by wetland plants may be measured by connecting root oxygen release to the wetland surface area based on relevant field data if the number of active roots, their active lengths, and the radial oxygen loss (ROL) are known. [8-11] The selection of Inhibitors is depended on the mineral and the ambiance, there are two classifications of inhibitors, the environmental

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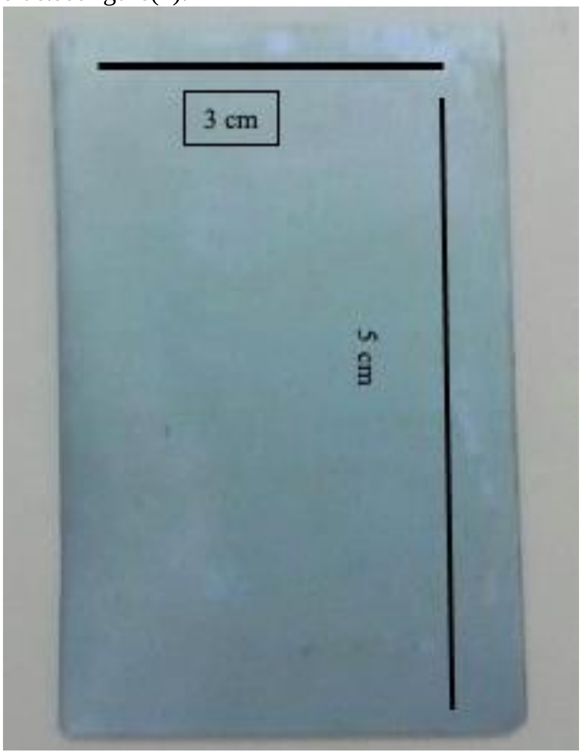
conditioners and interface inhibitors [12]. The corrosion rate of a mineral M subjected to a corrosive medium (electrolyte) is depending on the electrochemical reaction kinetics. In addition, thermodynamics divines the bearing of corrosion, however, it hasn't given the notifications about the happening of corrosion is slowly or quickly [13]. The corrosion rate of carbon steel was estimated utilizing the weight loss measurement, corrode aqueous solution pH, techniques of surface analytical through scanning electron microscopy (SEM) inspection, and energy dispersive spectroscopy (EDS) inspection [14].

Experimental Section

Materials

0.1N of HCl in 100 ml volum , Bulrush was used as inhibitor at concentration of (0, 0.2and 0.5) (g/l) which adding to HCl solution and under variable values of temperature (25,35, 45, 55,65) °C.The detail of the electrochemical technique consists of five carbon steel specimen of dimensions of 3cm width (w) and length 5 cm (L) ,Specimen area(A) of 15cm^2 for each side.seefigure(1).



Fig(1)Low carbon steel specimen after polishing with grit silicon carbide papers.

<u>Method</u>

By the weight loss process, the average corrosion rates of low carbon steel specimens in HCl solution can be calculated and the design of experiments was performed in transparent Pyrex glass. Before beginning the process the specimen was weighed using the sensitive balance and polished with grit silicon carbide papers as shown in figures (2 and 3). Record the first weight W1, and it's immersed in hydrochloric acid HCl for 3 hours at (25,35, 45, 55, 65) $_o$C, after removing it from hydrochloric acid solution washing the specimen by the water and immersing it in acetone solution for 5 minutes, and then drying it by filter paper, and drying it in an oven at 100 $_o$C for 15 minutes, Weighting it and record the second weight W2.

where: $\Delta W = W1 - W2$ (1)

The corrosion rate calculate in (gmd, mm/y, mpy):

$$CR = \frac{\Delta W}{A * t} \quad (2)$$

Where: Δw weight loss (g), A surface area of metal specimen (m^2)

The dissolution current density also calculation i_d(A/).

$$id = \frac{\Delta W.z.F}{Mwt.A.t} \quad (3)$$

were

Z = electrons number

F = number of faradays [96487 c/g. equivalents = nF(c/g.mol).

Mwt = molecular weight of metal = 55.845 g/gmol .

t = exposure time (s) = 10800 sec.

Fig (2) Picture of weight loss experiment with bulrush inhibitor.

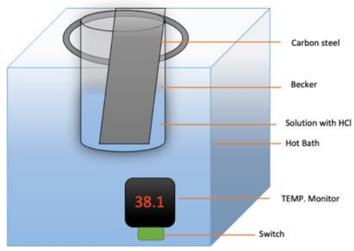


Fig (3) Digrame of expremint.

Results and Discussions

Results of weight loss experiments for the whole investigated ranges of temperatures, inhibitor concentrations in solution of HCl.These tables include the rate of corrosion in gmd, mpy, and mm/y, and the values of dissolution current density (i_d)

Table (1) Temperature effect of low carbon Steel Specimen on corrosion rate in HCL Solution.

T°C	ΔW(g)	CR(gmd)	CR(mm/y)	CR(mpy)	$I_d(A/m^2)$
25	0.0349	93.066	33.965	1337.204	3.722
35	0.0922	245.866	89.732	3532.770	9.833
45	0.2106	561.6	204.963	8069.409	22.460
55	0. 3309	882.4	332.043	3072.559	35.291
65	0.3776	1006.9	367.481	4467.755	40.271

Table (2) Inhibitor bulrush concentration & temperature effect on corrosion rate of low carbon steel specimen in HCl solution.

T°C	C(g/l)	ΔW(g)	CR(gmd)	CR(mm/y)	CR(mpy)	$I_d(A/m^2)$	Effeciency (η%)
25	0	0.0349	93.066	33.965	1337.204	3.722	---
	0.2	0.0221	58.933	21.508	846.791	2.357	36.67
	0.5	0.0005	1.333	0.4866	19.158	0.053	97.73
35	0	0.0922	245.866	89.732	3532.770	9.833	---
	0.2	0.0201	53.6	19.562	770.159	2.143	78.19
	0.5	0.0009	2.4	0.875	34. 484	0.095	95.52
45	0	0.2106	561.6	204.963	8069.409	22.460	---
	0.2	0.0122	32.533	11.873	467.459	1.301	94.20
	0.5	0. 0021	5.6	2.043	80.463	0.223	82.78
55	0	0. 3309	882.4	332.043	3072.559	35.291	---
	0.2	0.0425	113.33	41.362	1628.446	4.532	87.15
	0.5	0.0023	6.1333	2.238	88.127	0.245	94.58
65	0	0.3776	1006.9	367.481	14467.755	40.271	---
	0.2	0.0325	86.666	31.630	1245.282	24.79	38.42
	0.5	0.0201	53.6	19.562	770.159	5.343	82.75

Temperature effect on corrosion rate

From figure (4 a,b,and c) and tables(1), as the temperature increased the corrosion rate increased due to the increase the oxygen diffusion to the surface of the metal and decreasing the viscosity which affected the diffusion it oxygen, this in agreement with the observation remarked by reference [14]. The increasing temperature made the protective films on the metal surface extra soluble. A high concentration of oxygen led to the fast corroding of metal. Generally, the solubility of solids increased with increasing temperature, this can be clarified how the solid protective film turns out to be soluble with increasing temperature, this is obtained by reference [15]. The molecular diffusion coefficient increases due to an increase in temperature that is accelerating the diffusion rate of oxygen species and the reaction, the temperature affects the corrosion rate by changing two parameters, diffusivity, and oxygen solubility according to reference[16].

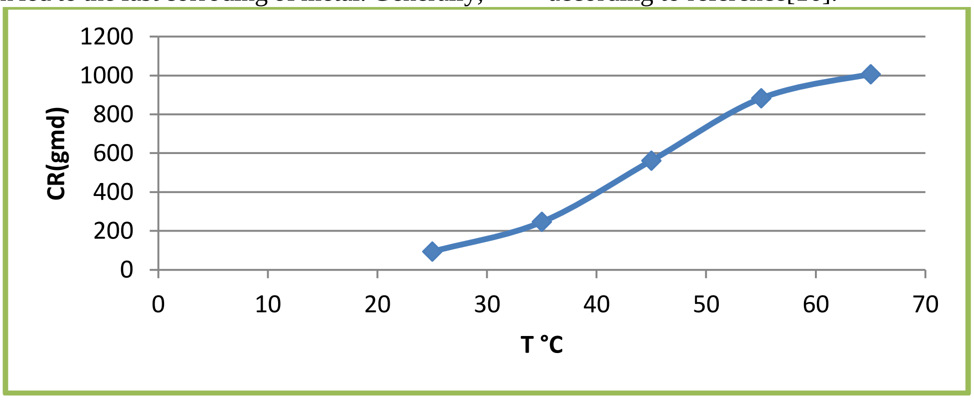
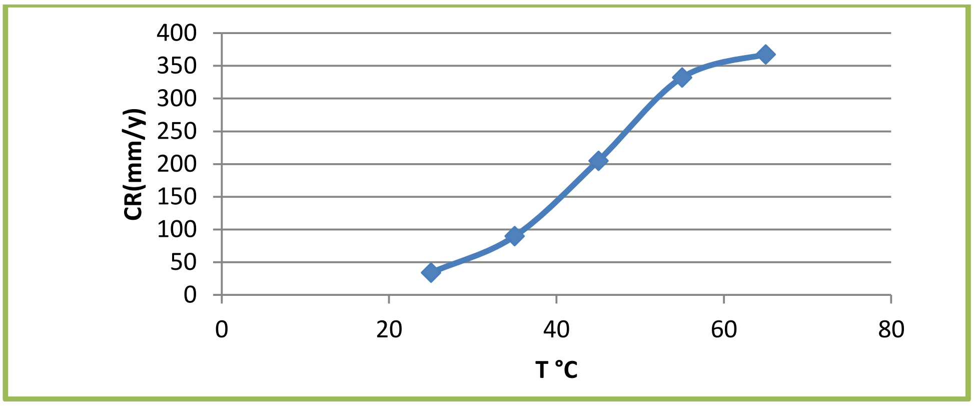


Fig (4 a) The Temperature Vs. corrosion rate of low carbon steel.



Fig(4 b) The Temperature Vs. corrosion rate of low carbon steel.

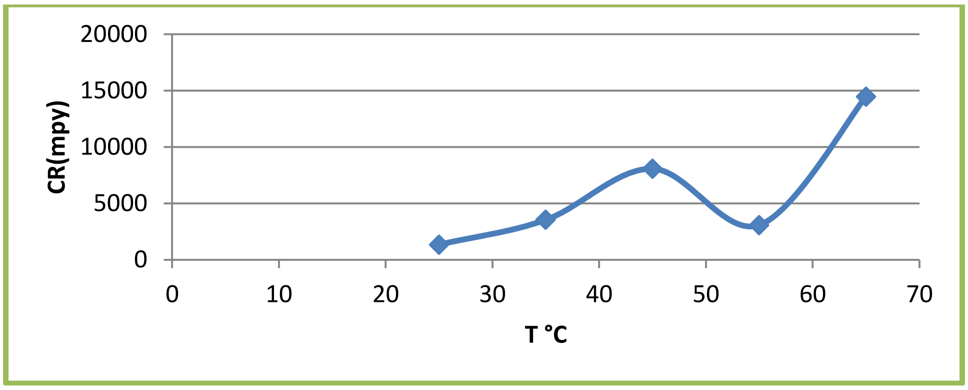


Fig (4 c) The Temperature Vs. corrosion rate of low carbon steel.

Temperature effect on limiting current

From figure(5), it can be seen the limiting current increased as the temperature increased when the corrosion was enhanced by increasing oxygen diffusivity, and decreases the oxygen solubility led to a decrease in the corrosion rate. This explains the effect of the temperature on the limiting current according to reference [17].

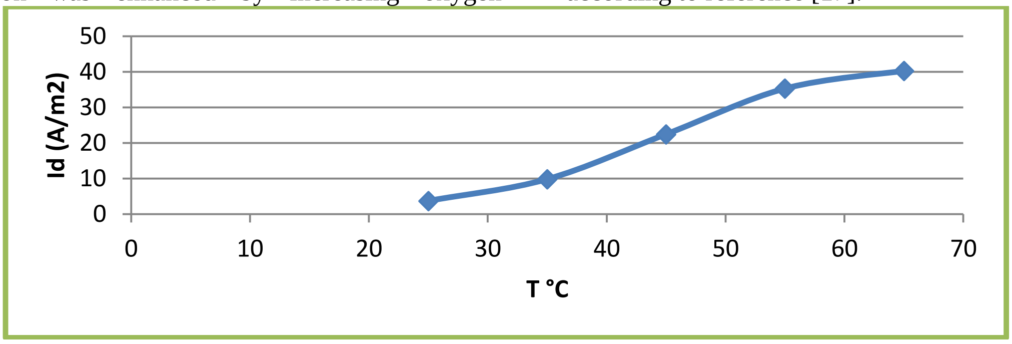


Fig (5) The Temperature Vs. Current Density

Inhibitor concentration effect on corrosion rate

From figure (6) and tables (2), it can be shown that the corrosion rate decreased due to an increase in the concentration of inhibitors. Inhibitors form films, passive layer, adsorption on the metal surface, and by the bulky precipitates that formation. A mechanism consisted of cause to corrode the metal in a way that a combination corrosion product forms a passive layer and adsorption, according to reference [18].

Efficiency effect on concentration

From figure (7), and table (2), it can be noticed that with increasing inhibitor concentration and decreasing corrosion rate the efficiency increased, and efficiency of bulrush inhibitor high because of inhibitor creates a thicker and stronger adjacent layer on the metal surface, which in turn isolates the arrival of dissolved oxygen to the metal surface, this is the agreement with the observation remarked by reference [19].

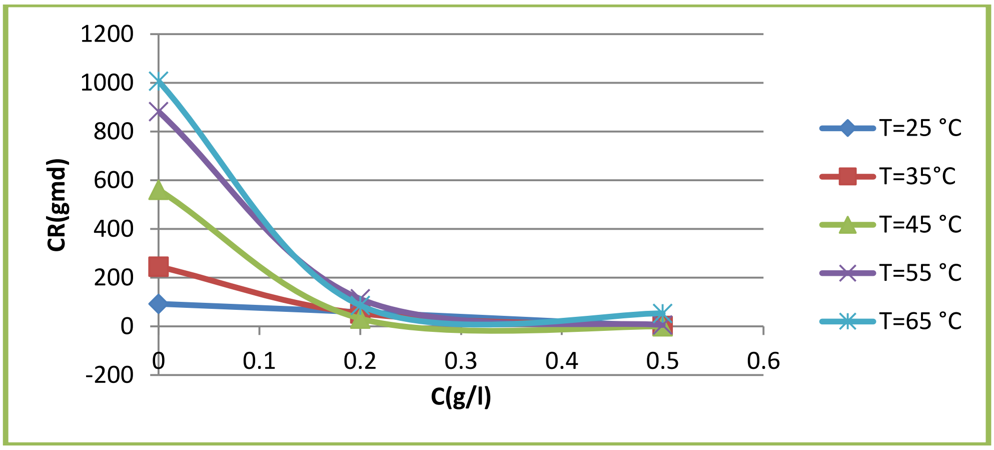
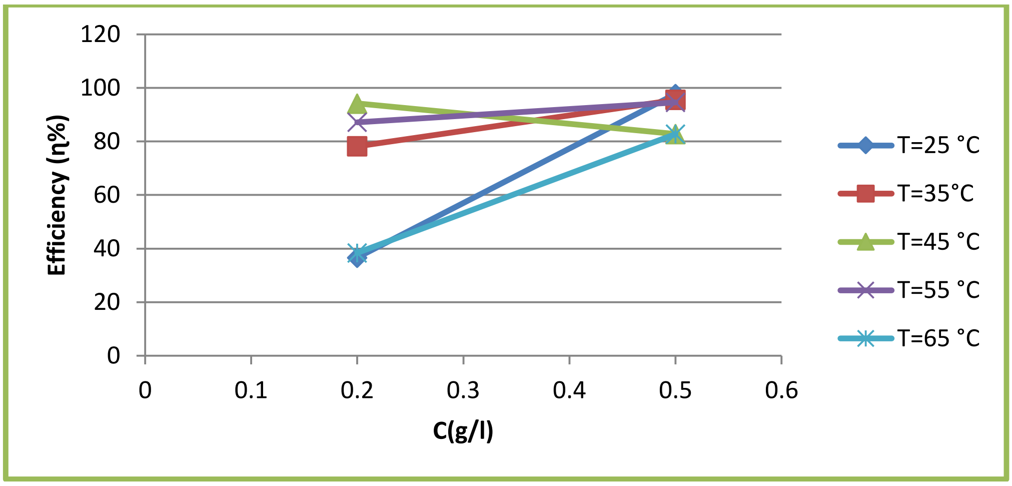


Fig (6) The Inhibitor Concentrations Vs. Corrosion Rate of Low Carbon Steel .



Fig(7) Inhibitor concentration Vs. inhibitor efficiency at 25 ◦C,35 ◦C,45 ◦C,55 ◦C,65 ◦C

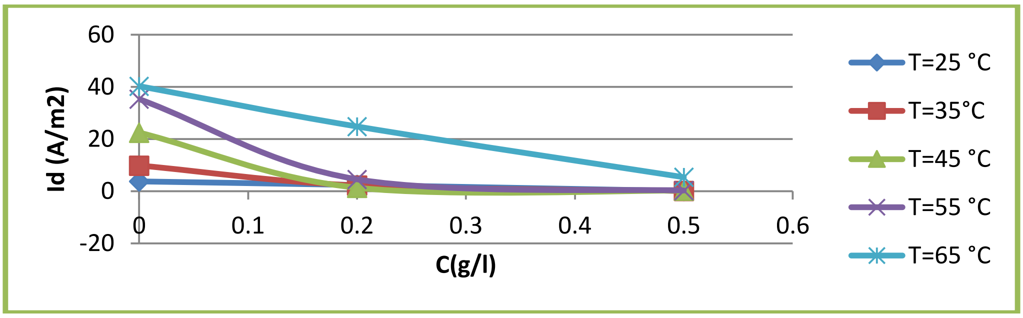


Fig (8) Inhibitor concentration Vs. current density at 25 ◦C,35 ◦C,45 ◦C,55 ◦C,65 ◦C.

Concentration effect on limiting current

From figure (8) it can be seen the limiting current density decrease with increasing inhibitor concentration for each temperature that led to increasing of mass transfer of oxygen then the high amount of oxygen arrived at the surface electrode, as mentioned by reference [18].

Conclusions

The corrosion rate increased due to increase of temperature, because of the removal of protective surface films and high-velocity flow which led to dissolved oxygen diffused to the metal surface due to a decrease in the boundary layer and diffusion layer. The limiting current increased as the temperature increased and decrease with increasing inhibitor concentration of bulrush.As inhibitor concentration increase and decrease with the corrosion rate this led to increasing with an efficiency of inhibitor.The bulrush inhibitor efficiency was 97.73% at a temperature of 25 $_{o}$C and 0.5 g/l concentration.

Abbreviation list

symbols	defined
T	Temperature °C
ΔW	weight loss (g) = W1-W2
W1	First weight (g)
W2	Second weight(g)
L	Length of specimen= 3 cm
W	Width of specimen = 5 cm
A	surface area of metal specimen =15cm^2
A	total area of metal specimen (m^2) =30cm^2
t	exposure time (s) = 3hr = 0.125 day =10800 sec.
CR	corrosion rate
gmd	corrosion rate in (gram per m2 per day) $=\frac{\Delta W}{A*t}$
mm/y	corrosion rate in (millimeter per year) $=\frac{1}{2.74}gmd$
mpy	corrosion rate in (milli-inch per year)= $\frac{mm/y}{0.0254}$
i_d	dissolution current density (A/ m^2) $id=\frac{\Delta W.z.F}{Mwt.A.t}$
z	electrons number **=2**
F	number of faradays [96487 c/g. equivalents = nF(c/g.mol).
Mwt	molecular weight of metal = 55.845 g/gmol
C	concentration of inhibitor (g/l)
(η%)	Effeciency of inhibitor

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