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ORIGINAL ARTICLE

A new Corrosion Inhibitor Based on Modification of Polyacrylic acid in acidic Solution

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ABSTRACT

Background: A polymer is any of a class of natural or synthetic substances composed of very large molecules, called macromolecules, which are multiples of simpler chemical units called monomers. Polyacrylic acid It is a derivative of acrylic acid. In addition to the homo polymers, a variety of copolymers and cross-linked polymers, and partially deprotonated derivatives therefore are known and of commercial value.

Objectives: This search investigates the corrosion inhibition properties of polyacrylicacid.

Methods: The corrosion inhibition performance of carbon steel (CS) in a 1M HCl solution treated with the polyacrylic acid inhibitor was evaluated using potentiodynamic polarization measurement, Field Emission-Scanning Electron Microscopy (FE-SEM) and Energy Dispersive X-ray Spectroscopy (EDS).

Results: The findings of this study demonstrate that polyacrylic acidexhibits significant effectiveness as corrosion inhibitor for CS in acid solution. The inhibitor acts as a mixed-type inhibitor, and its corrosion inhibition efficiency increases with higher concentrations of polyacrylic acid concentration up to 89.9%obtained at 298 K for a 400 ppm concentration, while decreasing with increasing acid concentration.

Keywords: Polyacrylic acid, Scanning Electron Microscopy, Corrosion Inhibition, Carbon Steel

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INTRODUCTION

Polymers serve as efficient corrosion inhibitors for steel. The use of polymers as corrosion inhibitors have drawn considerable attention recently due to their inherent stability and cost effectiveness [1] . Owing to the multiple adsorption sites, polymeric

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compounds adsorb more strongly on the metal surface compared with their monomer analogs[2] . Therefore, it is expected that the polymers will be better corrosion inhibitors. The literature reveals that a wider range of polymeric compounds have been successfully investigated as potential inhibitors for the corrosion of metals in aqueous media. Polymers such aspolyvinylpyrrolidone[3] [4] , polyvinyl alcohol[5] , poly (oanisidinecometanilic acid)[6] , poly anthranilic acid[7] , Polyacrylic acid[8] [7] , Polyaniline[9] .

Corrosion inhibitors are widely used as an economical method of corrosion control[10] , [11] . Environmental restrictions imposed on heavy metal-based corrosion inhibitors oriented scientific researchers towards the study of non-toxic and environmentally friendly corrosion inhibitors[12] . The influence of several organic compounds containing polar functions such as nitrogen, oxygen, phosphorous or sulphur on the corrosion inhibition behavior of mild steel in aqueous solutions has been documented[13] [14] [15] [16] [17] . These groups of atoms or bonds facilitate electronic interactions between organic corrosion inhibitors and metal surface thereby aid adsorption of the inhibitors onto metal surface. The quest for eco-friendly compounds as corrosion inhibitors has shifted research focus to exploring potential application of polymers as corrosion inhibitors in the past few years. The use of polymers as corrosion inhibitors has attracted considerable attention recently because: (i). they have low cost and are stable to metallic materials in aqueous media, (ii). possession of multiple adsorption sites and (iii) through their functional groups, they form complexes with metal ions, and on the metal surface, these complexes occupy a large area, thereby blanketing the surface and protecting the metal from corrosive agents present in the solution[18] [19] [14,20] [21] [22] . The inhibitive power of these polymers is related structurally to the cyclic rings, heteroatom (oxygen and nitrogen) that are regarded as centers of adsorption. Some polymers have been reported to inhibit the corrosion of mild steel in various aqueous media[23] [24] [25] [26] . Recently, polyacrylic acid reported to be very effective corrosion inhibitors for the protection of mild steel in aqueous media to promote eco-friendly environment. International[27] [28] .

The aim of the present work is to determine the inhibitive effect of Polyacrylic acid (PAA)on the corrosion of carbon steel in 400 ppm acidic medium by chemical and electrochemical methods. Surface characterization techniques (SEM, EDAX) are also usedto ascertain the nature of the protective film.

Methods

2:1 Materials and sample preparation

Polyacrylic acid (PAA) and Steel coupons (with a diameter of 10 millimeters and the following chemical elements composition(wt.%): 0.046% Cr, 0.035%P,0.01%S, 0.202% C,0.161% Mn, 0.007% Mo, 0.065% Si, and 99.3% Fe) were supplied froma local market in Iraq

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Analytical grade 36M HCl was used in the preparation of 1M HCl dilute solutions.

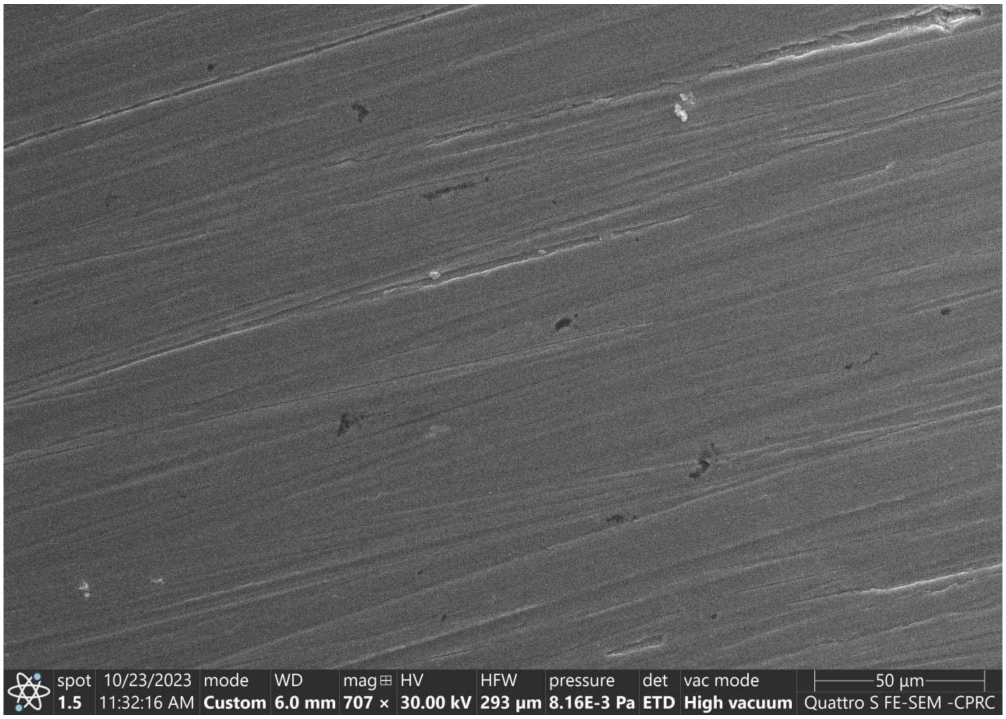
Distilled water was exclusively used in the formulation of corrosion solutions. To this end, 1M HCl solutions containing concentrations of 0, 10, 50, 100, 200,300,400 ppm of polyacrylic acid were meticulously prepared. Prior to immersion, steel coupons were rigorously abraded using SiC papers of varying grits (120, 400, 800, and 1500 grades), degreased with acetone, and thoroughly rinsed with distilled water. Thepre-treated steel coupons were then placed in the coupons holder and immersed in these corrosion solutions.

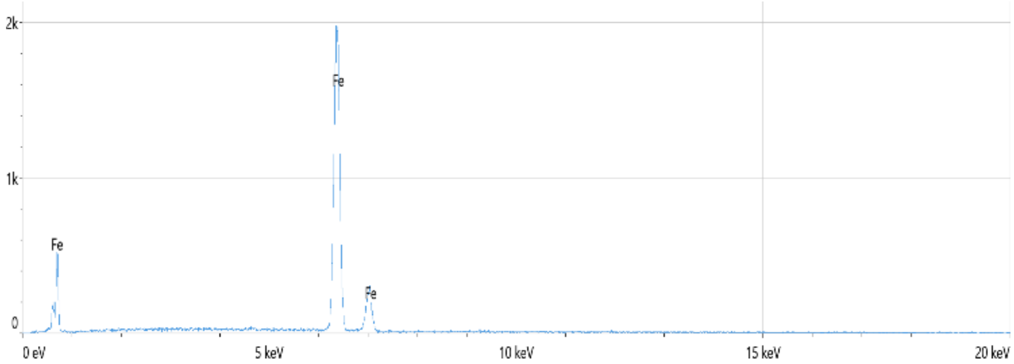
RESULTS AND DISCUSSION

3.1 Surface Morphology Analysis

A comprehensive assessment of the surface chemistry and morphology of the steel coupons in 1M HCl solutions, both with and without polyacrylic acid polymer , was conducted using a Field Emission Scanning Electron Microscope (FE-SEM). Surface Morphology of Specimen Surface morphology of the mild steel sample was studied before and after corrosion in presence and absence of the inhibitors. The surface morphology supported the formation of adsorbed polymer film over the steel samples were shown in the figures below.

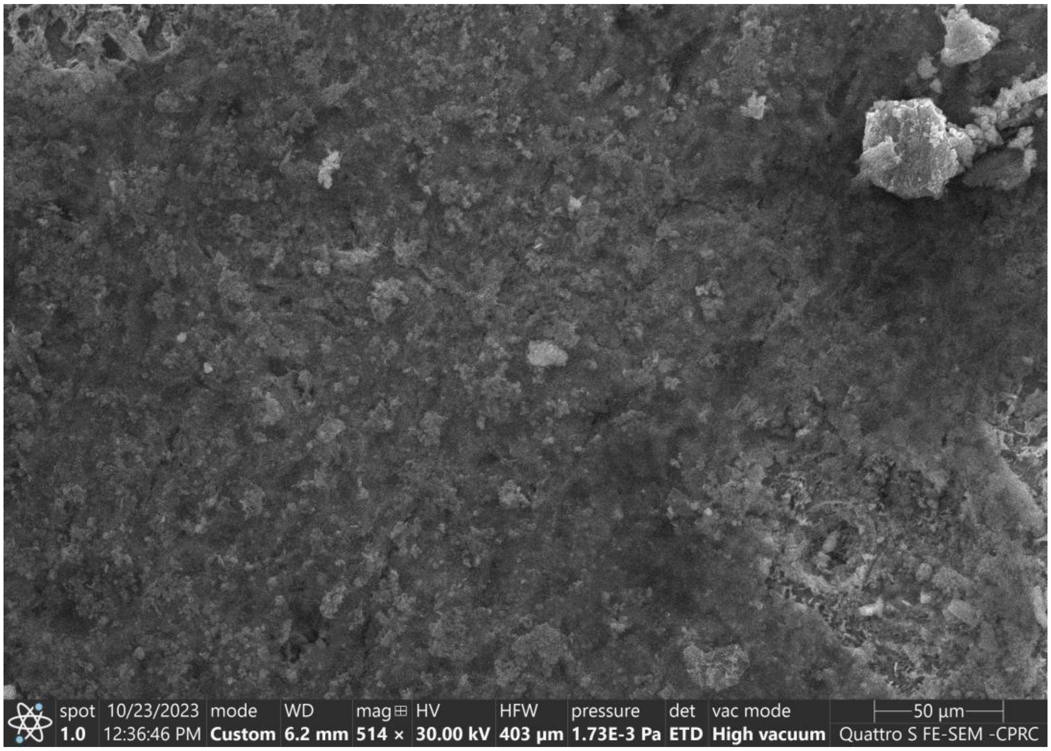
In the figure (1:1) (b) it is clearly shown in that the steel samples are getting cracks due to the acid corrosion. However, the presence of polyacrylic acid as inhibitor retard the corrosion and surface showed more smoothness in figure 1 (c) which is less smooth than figure 1(a).

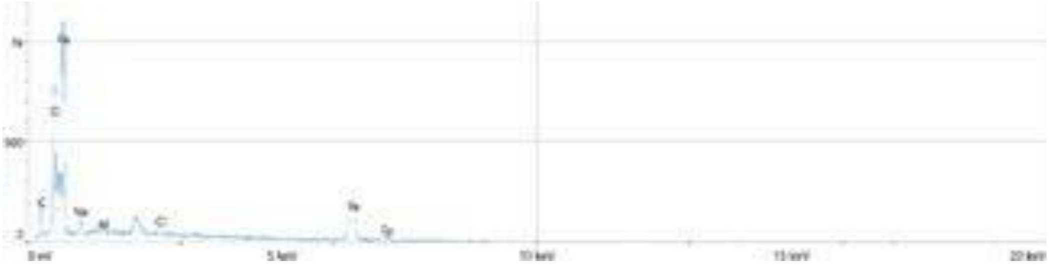


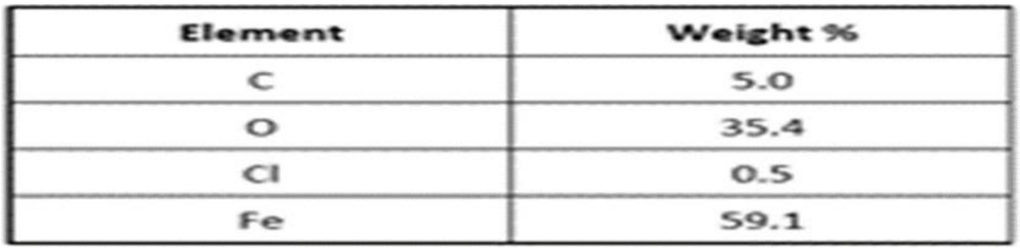


Element	Weight %	Weight % Error
Fe	100.0	0.1

Figure 1 (a) FE-SEM and EDS spectra images of CS before immesion

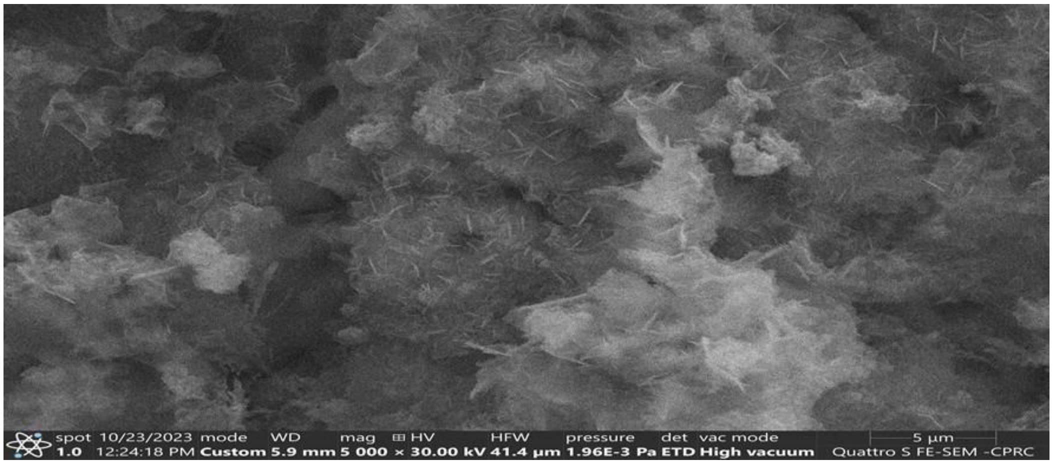


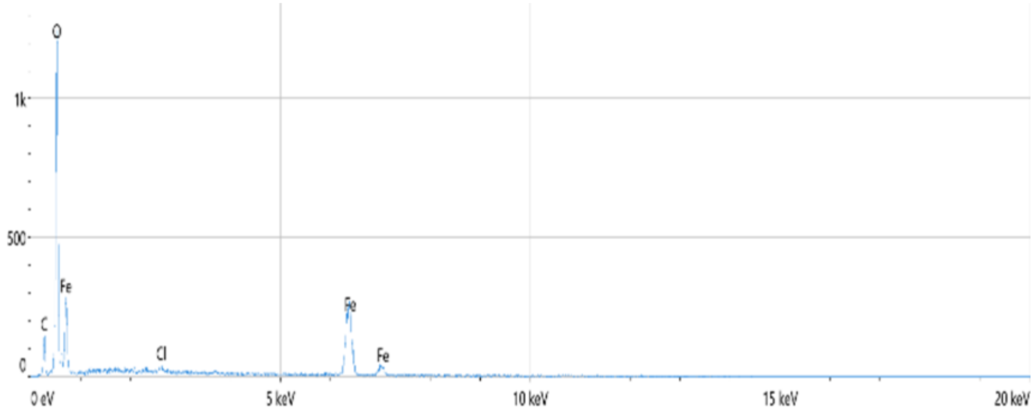


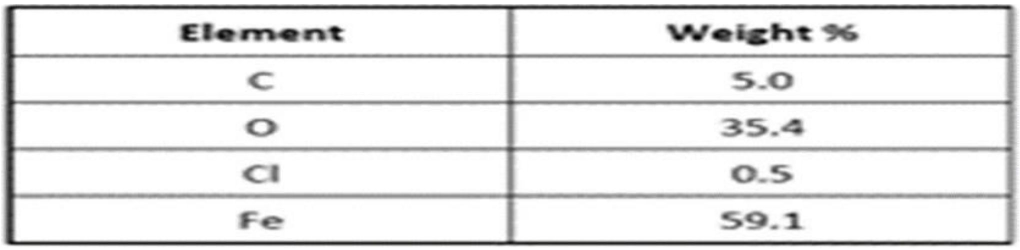


Element	Weight %
C	5.0
O	35.4
Cl	0.5
Fe	59.1

Figure 1 (b) FE-SEMand EDS spectra images of CS after immersion







Element	Weight %
C	5.0
O	35.4
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Fe	59.1

Figure 1 (c) FE-SEM and EDS spectra images of CS after immersion and addition of 400ppm polymer at 298K.

parameters such as corrosion current density (i_{Corr}), corrosion potential (E_{corr}), and the cathodic and anodic Tafel slopes (β_c and β_a) for comprehensive analysis.

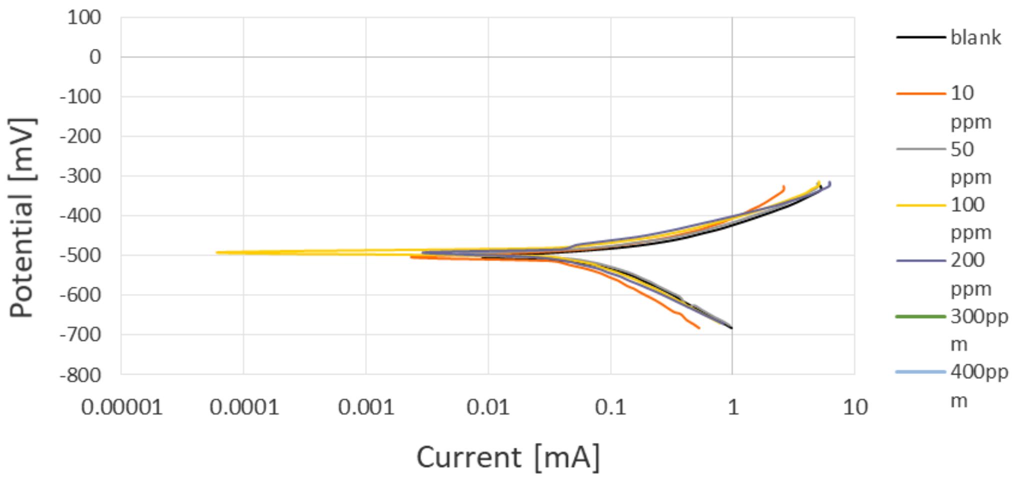

Figure 2 **Tafel plots for CS immersed in 1M HCl solution at different concentrations of polymer and 298K.**

3:2 Potentiodynamic PolarizationAnalysis

Figure (2) illustrates the potentiodynamic polarization plots (Tafel plots), representing the corrosion behavior of steel coupons in 1M HCl solution at 298 K, both with and without polymer. The data derived from potentiodynamic polarization, as depicted in Tafel plots (Fig.!2), have been meticulously organized in Table(1). It presents crucialelectro chemical

The introduction of polymer into the 1M HCl solution results in heightened anodic and cathodic over-potentials, alongside a noteworthy reduction in i_{Corr}. Notable changes in the cathodic and anodic Tafel slopes, as outlined in Table(1:1) , indicate that the adsorption of polymer alters the mechanism of anodic dissolution and cathodic hydrogen evolution. This alteration uniformly retards both cathodic and anodic polarizations, subsequently enhancing corrosion inhibition with increasing inhibitor concentration.

An examination of the data in Table (1) reveals a maximum variation in E_{corr} values in the presence of varying concentrations of polymer within the 1M HCl solution a. This interesting observation suggests that polymer can be classified as a mixed-type inhibitor when utilized in 1M HCl solutions [29] .

Table 1. **The potentiodynamic polarization parameters extracted from CS immersed in 1M HCl solution at different concentrations of polymer and298K.**

400	300	200	100	50	10	blank	Sample Parameter
8.01	16.2	36.8	42.19	53.77	59.71	79.37	Icor(μA/cm2)
489	490	494	492	495.4	504	504.3	Ecor (-mV)
73.5	71.2	62.8	56.4	55.7	73.8	71.3	βa (mV/decade)
113.1	110.4	116.1	119.3	116.3	184.3	156.4	βc(mV/decade)
12.67	13.974	16.8176	19.28083	24.57289	27.28747	36.27209	Corrosion Rate (mpy)

3:3 Corrosion Inhibition Efficiency

In the context of this study, inhibition efficiency (%IE) signifies the corrosion current density when inhibitor is introduced. inhibition efficiency can be defined by the following equation(1).

$$\%IE = \frac{i_o - i_I}{i_o} \times 100 \qquad \dots (1)$$

Where, and stand the values of corrosion current density in the presence and absence of

Inhibitor, respectively. As illustrated in Table (1:1), the utilization of polymer proves highly effective in mitigating the corrosion rate of steel coupons, regardless of the immersion solution.

Notably, as the concentration of the polymer inhibitor is progressively increased, a corresponding enhancement in corrosion inhibition efficiency is observed.

This efficiencyrises to 89.9 %, reaching its peakat a polymer concentration of 400 ppmat 298K. Beyond this point, a marginal increase is observed when the concentration is further elevated to 400 ppm. It is postulated that increase in corrosion inhibition effectiveness at higher polymer concentrations may be attributed to high coverage and potential chemical interactions occurring between the adsorption layer which forming a passive film and the surrounding solution[30] .

CONCLUSIONS

The effectiveness of polymer as a corrosion inhibitor for CS protection in a 1M HCl solution was investigated using a comprehensive range of electrochemical and surface analysis techniques. Based on the analysis results, these conclusions can be summarized into.

Polyacrylic acid acts as an efficient corrosion inhibitor for protecting CS in the corrosive solution of a 1M HCl solution. It influences both anodic and cathodic reaction rates, classifying it as a mixed-type corrosion inhibitor.

The inhibitory efficiency exhibits a strong dependence on its concentration. Notably, it achieves an inhibitory efficiency exceeding 89.9% at a concentration of 400 ppm signifying its practical applicability. For optimal protection, applying this inhibitor at higher concentrations is advisable.

The molecular adsorption of polyacrylic acid molecules onto the CS surface, leading to the formation of a protective film, represents a key mechanism underlying its inhibitory capabilities. The resulting film exhibits hydrophobic properties.

Surface morphology analysis, consistent with electrochemical findings, confirms the presence of a well-dispersed protective film across the CS surface. Furthermore, a noticeable reduction in surface roughness is observed in the solution with the inhibitor compared to the solution without inhibitor.

DECLARATIONS

1. Authors' contributions

All authors contributed equally to the design, execution, and interpretation of the research, as well as the drafting and revision of the manuscript. All authors approved the final version of the manuscript and are responsible for its content

2. Conflict of interest

All authors declares no conflicts of interest.

3. Ethical approvals

(Institutional ethical approvals and informed consent)

4. Funding resources

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