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Inhibitive effect of Arachis hypogeae on the corrosion of mild steel in sulphuric acid solution

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Abstract

The corrosion assessment of mild steel in H_2SO_4-*Arachis hypogeae* natural oils have been studied using electrochemical technique. The surface morphology of as-corroded samples was assessed with scanning electron microscopy equipped with energy dispersive spectroscopy (SEM-EDS). The results revealed that corrosion rate of mild steel with *Arachis hypogeae*-H_2SO_4 environment decreased significantly. Results of the linear polarization indicate a higher potential value and inhibitor efficiency of 98.68, 86.87 and 97.10% at 100%v/v *Arachis hypogeae* with an increase in polarization resistance (R_p) and lower current density for the inhibited samples than the uninhibited mild steel. There exists some level of correlation in the corrosion efficiency between the methods used as criteria for the corrosion evaluation of mild steel/*Arachis hypogeae* in 2M H_2SO_4 solution.

Keywords: Arachis hypogeae, Inhibitor efficiency, SEM-EDS, thin film

1. Introduction

The industrial applications of mild steel have been attracted by some unique properties it exhibit for most engineering requirements. Their applications have been driven by a number of issues, such as its low cost and availability for the manufacturing of reaction vessels; cooling tower reservoirs, pipelines [1]. In particular, its application in acid pickling, industrial cleaning, acid descaling, oil-well acid and the petrochemical process are reasons that have attracted much research attention [2-5], water cooling system, steam generators and ballast tanks [5]. However, the ability of mild steel to resist corrosion attack in majority of environment is insufficient and a continuous search for techniques or methods for controlling this behavior remain relevant in the field of corrosion control and integrity. Although various techniques has been put forward to address the deterioration behavior of mild steel in some service environments. Among the methods, the use of inhibitors for controlling and reducing the corrosion rate of mild steel have been reported to be effective and promising corrosion control technique with high level of protection in most environments [1-14]. Some reports [15-18] indicated that synthetic corrosion inhibitors are not ecologically-friendly. Therefore, efforts toward identifying any potential ecologically-friendly and cost effective corrosion inhibitors become subject of interest. Equally, the growing interest among researchers for green inhibitors remained a top research focus. In that direction, plant extracts and oils has gained recognition as corrosion inhibitors that are considered safe, ecologically-friendly, available and cost effective for most metals and alloys [2,4,19,20]. In the present study, the potential of natural peanut oil (*Arachis hypogeae*) as corrosion inhibitor for mild steel in 2M H_2SO_4 solution have been investigated using potentiodynamic polarization method.

2. Materials and methods

2.1 Materials and sample preparation

A mild steel specimen of dimension 20 x 10 x 3 mm with chemical composition shown in Table 1 was used. The samples were degreased in ethanol, dried, weighed and stored in a desiccator. The initial weight of each sample was taken and recorded. A concentration of 2M sulphuric (H_2SO_4) were prepared fresh as required for the experiment. *Arachis hypogeae* as inhibitor was used with H_2SO_4 acidic solution. The *Arachis hypogeae* natural oil and the mild steel was obtained from Technology Innovation Agency, Chemical Station, Ga-Rankuwa, Tshwane University of Technology, Pretoria with molecular structure shown in Figure 1. The corrosion measurement was conducted at 298K.

Table 1: Chemical composition of the mild steel used

Element	C	Mn	Si	P	S	Al	Ni	Fe
% Composition	0.15	0.45	0.18	0.01	0.031	0.005	0.008	Balance

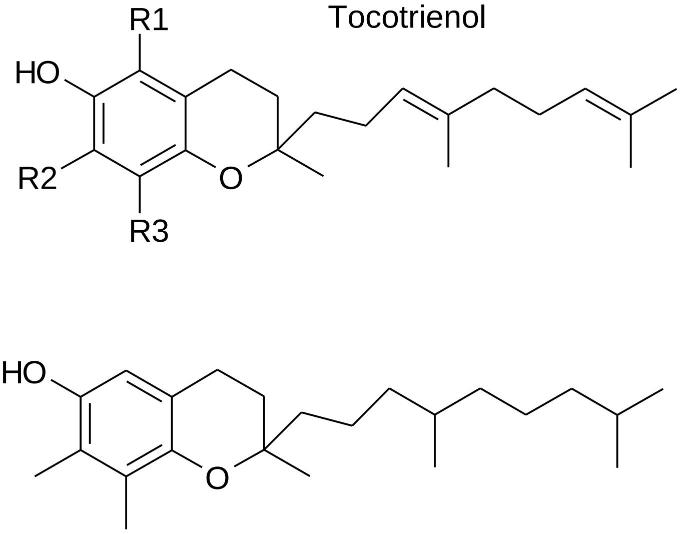

Figure 1: Molecular structure of *Arachis hypogeae* natural oil

2.2 Electrochemical corrosion measurement

The potentiodynamic polarization was used to evaluate the corrosion rate of the mild steel in *Arachis hypogeae*-H_2SO_4 solution. All electrochemical measurements were obtained using Autolab frequency response analyzer (FRA) coupled to potentiostat was connected to a computer system as source of data acquisition. A glass of corrosion cell kit with a platinum counter electrode, saturated Ag/Ag reference electrode and mild steel sample as working electrode were used for the electrochemical study. The working electrode samples were positioned at the glass corrosion cell kit, leaving 1 cm^2 surfaces in contact with the solution. Polarization test were carried out in 2M H_2SO_4 solution at room temperature using a potentiostat (Model: AuT71791 and PGSTAT 30) with a scan rate of 0.003V/sec. From the Tafel corrosion analysis, the corrosion rate, potential and linear polarization resistance was obtained.

2.3 Surface morphology

The as-received and as-corroded mild steel surfaces were examined with scanning electron microscopy equipped with energy dispersive spectroscopy (SEM/EDS) to analyze the elements on the surface of the samples (Model: Joel 6100).

3. Results and discussion

3.1 Results

The result of the electrochemical corrosion for mild steel in 2M H_2SO_4 - *Arachis hypogeae* environment is presented in Table 2. The linear polarization curves can be found in Figure 2. The SEM-EDS micrographs of the as-received and as-corroded uninhibited/inhibited mild steel were shown in Figures 3 and 4. Figure 5 shows the variations in the inhibitor efficiency with concentration of inhibitors for potentiodynamic polarization method under different criteria. Figure 6 illustrates the Langmuir adsorption isotherm for the inhibitor.

3.2 Discussion

3.2.1 Potentiodynamic polarization

The potentiodynamic measurement for the mild steel in 2M H_2SO_4/*Arachis hypogeae* is presented in Table 2. Potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion density (PP-I_{corr}), and linear polarization resistance (LPR) were used as criteria for evaluation of corrosion resistance of mild steel in the environment. Figure 2 shows the polarization curves for 2M H_2SO_4-*Arachis hypogeae* at 298K. In general, the environment demonstrated a decreased in the corrosion rate and current density with addition of the inhibitors at all concentrations. While the corrosion potential (E_{corr}) and polarization resistance (R_p) increases with inhibitor concentrations. The trend in the corrosion under this study is similar with the previous study [21]. The inhibited mild steel in H_2SO_4-*Arachis hypogeae* revealed that corrosion rate decreased from 0.6421 mm/yr to 0.008499, 0.08429 and 0.01859 mm/yr at 20, 50, and 100%v/v *Arachis hypogeae* (see PP-CR). Comparatively, it is worthy to note that corrosion resistance of the mild steel- H_2SO_4 is higher in 20%v/v *Arachis hypogeae* with IE of 98.68% as compare to 86.87 and 97.10% at 50 and 100%v/v *Arachis hypogeae* respectively. Similarly, the changes in anodic and cathodic region suggest the mixed-type corrosion inhibition for mild steel-2M H_2SO_4/*Arachis hypogeae*.

Table 2: Electrochemical corrosion data obtained for mild steel in 2M H_2SO_4-varying concentration of *Arachis hypogeae* environment at 298K

S/N	C (%v/v)	I_{corr} (A/cm^2)	b_a (v/dec)	LPR R_p (Ωcm^2)	-E_{corr} (V)	CR (mm/yr)
1	0	4.231E-5	0.024	3.452E-1	0.478	6.421E-1
2	20	1.555E-6	0.004	1.201E+0	0.416	8.499E-3
3	50	1.542E-5	0.008	9.926E-1	0.418	8.429E-2
4	100	3.402E-6	0.005	8.274E+0	0.417	1.859E-2

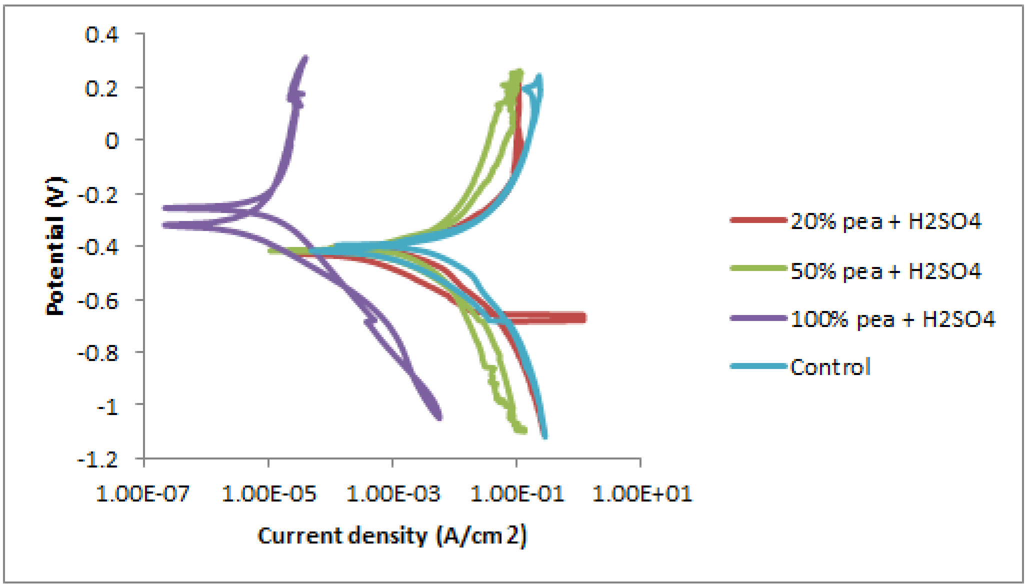

Figure 2: Linear polarization of mild steel in 2M H_2SO_4 solution/*Arachis hypogeae* environment at 298K

3.2.2 Scanning electron microscope-Energy dispersive spectroscopy (SEM-EDS)

The SEM microstructures of mild steel surface are shown in Figures 3 and 4. The as-received mild steel sample (Figure 3), Figure 4 shows that *Arachis hypogeae* natural oil was able to exhibit some degrees of inhibition which retarded the corrosion rate of the mild steel in H_2SO_4 solution. In addition, the inhibited samples can be observed to be protected with thin film layers of the corrosion inhibitor resulting to a decrease in the corrosion rate of the mild steel in the solution. From the EDS in Figure 4, the presence of oxygen is as a result of ferrous hydroxide formation. While the combination of C, O and other elements are due to the constituent contained in the structure of the inhibitors (Figure 1). This acts as a good inhibitor which in turn increases the corrosion resistance of the mild steel in the acidic medium.

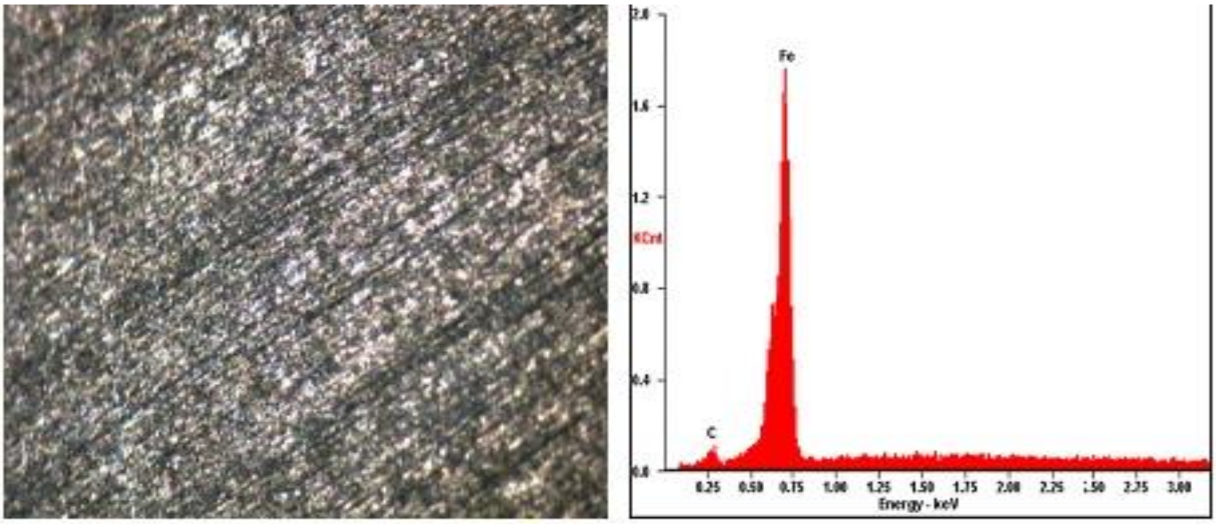

Figure 3: SEM micrograph of the as-received mild steel sample with the EDS spectrum

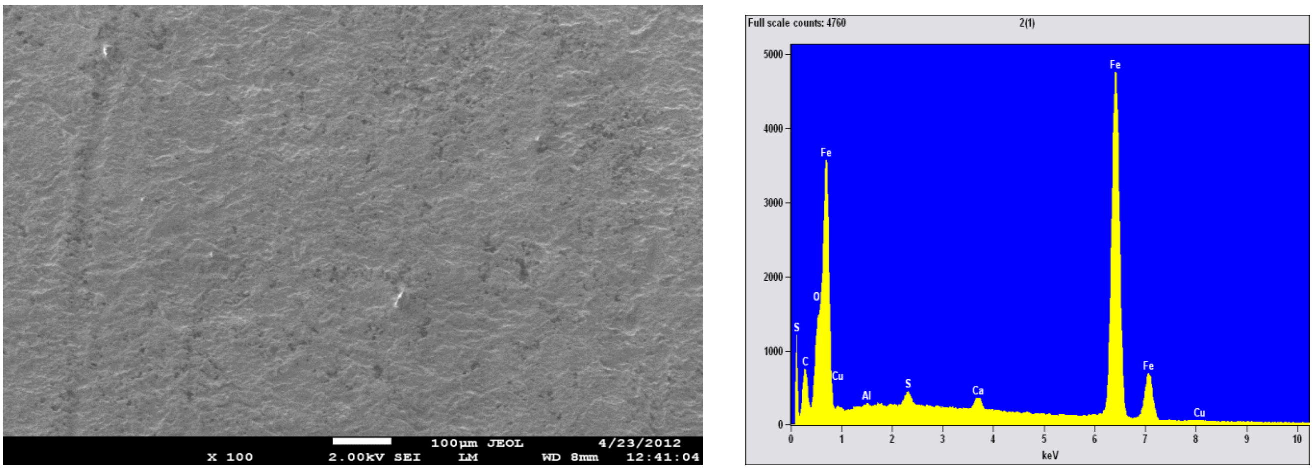

Figure 4: SEM micrograph of mild steel in 50%v/v *Arachis hypogeae*-2M H_2SO_4 solution with the EDS spectrum

3.2.3 Inhibitor efficiency and adsorption behavior

The percentage inhibitor efficiency (% IE) of the mild steel-*Arachis hypogeae* in H_2SO_4 solution was computed using the equation in the report [16]. The computed data for the IE using potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion density (PP-I_{corr}), and linear polarization resistance (LPR) are presented in Figures 5 for 2M H_2SO_4/*Arachis hypogeae*. The result shows that % IE of the *Arachis hypogeae* oil increases with an increase in the inhibitor concentrations. The reason been that, as the inhibitor concentration increases, the surface area covered by this inhibitor increased hence IE was enhanced significantly. From this behavior, coupled with simultaneous change in the anodic and cathodic region during the electrochemical measurement *Arachis hypogeae* oil can be said to exhibit a mixed-type corrosion inhibition. This occurrence agrees with previous reports [6,11]. The adsorption mechanism was shown from the variation between C/θ with C indicating linearity at 298 K for the environment (Figure 6). The correction factors (R^2) are approximately unity; PP-CR (0.9925), PP-Icorr (0.8985), LPR (0.9161), then, the adsorption behavior is believed to have obeyed Langmuir adsorption isotherm.

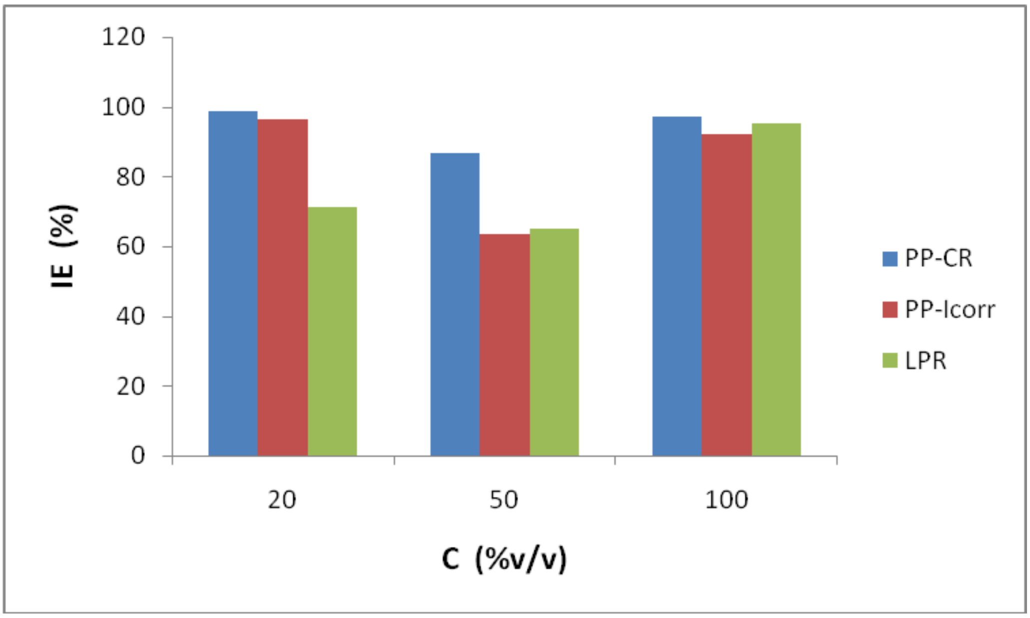

Figure 5: Comparative chart of inhibitor efficiency (IE) for 2M H_2SO_4 solution/*Arachis hypogeae* concentration obtained from potentiodynamic polarization-corrosion rate (PP-CR), potentiodynamic polarization-corrosion current (PP-Icorr) and linear polarization resistance (LPR)

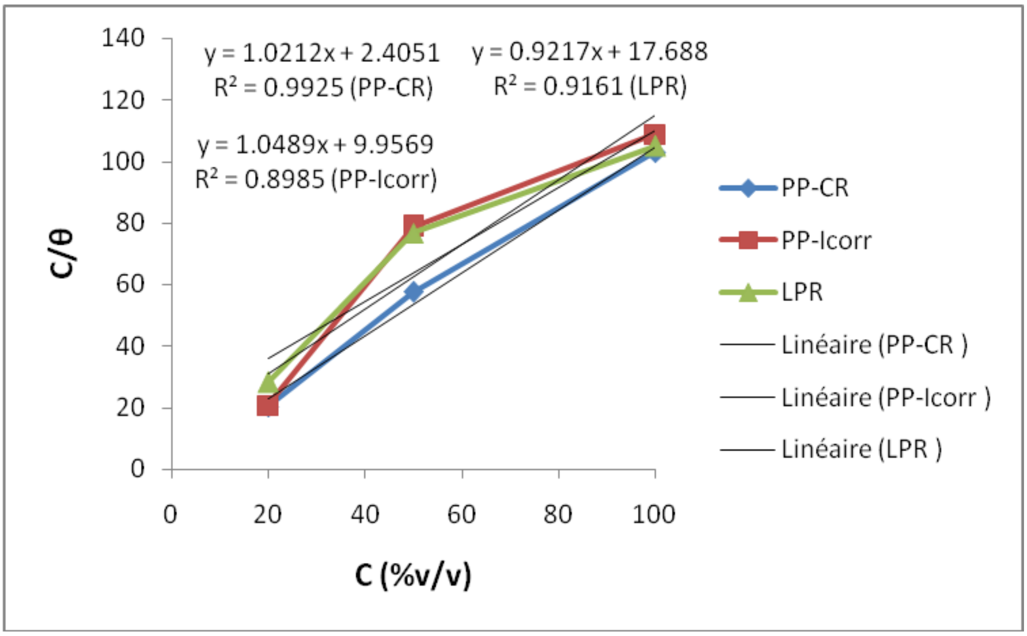

Figure 6: Langmuir isotherm for the adsorption of *Arachis hypogeae* compounds on the mild steel surface in 2M H_2SO_4 solution obtained from potentiodynamic polarization method at 298K

4. Conclusions

1. *Arachis hypogeae* natural oil has been found to be a good corrosion inhibitor for mild steel in H_2SO_4 solution at 298 K.
2. The percentage IE and corrosion resistance of the mild steel increased with inhibitor concentrations in the environment worked on.
3. The adsorption behaviour of the *Arachis hypogeae* in acidic media for mild steel can be said to have obeyed Langmuir adsorption isotherms.

and that the (4) *Arachis hypogeae* natural oil acts as a mixed-type inhibitor.

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