CORROSION INHIBITION OF AUSTENITIC STAINLESS STEEL TYPE 316 IN SULPHURIC ACID SOLUTION USING ECO-FRIENDLY WASTE PRODUCT

[1]O .SANNI, [2]A.P.I. POPOOLA

Department of Chemical, Metallurgical and Materials Engineering, Tshwane University of Technology, Pretoria, South Africa
E-mail: tayo.sanni@yahoo.com

Abstract - Pitting corrosion of stainless steels causes tremendous damage in industries. The use of inhibitors for corrosion control of metals in aggressive medium is an accepted practice. Different organic compounds were studied and are being studied to investigate their corrosion inhibition efficiency. All these studies show that organic compounds especially those with N, S and O showed significant inhibition efficiency. Unfortunately most of these compounds are expensive and toxic. In view of this, there is need for the use of cheap, safe inhibitors for corrosion. In the present study, the inhibition of the pitting corrosion of stainless steel Type 316 by methanol extract of egg shell powder in 0.5M H_2SO_4 solution at ambient temperature was studied using gravimetric and potentiodynamic polarization measurements. The results showed that egg shell in H_2SO_4-stainless steel environment decreased the corrosion rate at all the concentrations studied. The effective performance of the egg shell gives values of 71.93% - 91.95% inhibition efficiency, at 2 and 10 gram inhibitor concentration from gravimetric analysis. It has been found that the percentage inhibition efficiency increases with an increase in the inhibitor concentration. The two methods employed for the corrosion assessment were in good agreement and the inhibition process was explained due to the adsorption of these compounds at the 316 SS surface.

Keywords - Stainless Steel, Pitting Corrosion, Corrosion Inhibitor, Inhibition, Sulphuric Acid

I. INTRODUCTION

The inhibition of pitting corrosion of stainless steel is the subject of many researchers due to its wide applications in industry (1-4). They are commonly used in various industries especially oil and petroleum, medical and electrochemical industries due to their resistance, high quality, weld ability, and mechanical properties. Stainless steels derive their corrosion resistance by forming thin passive films on their surfaces which give protection to the base alloy. Breakdown of these protective films leads to localized corrosion failures such as pitting corrosion which is one of the most dangerous forms of localized corrosion (5-6). Calcium and magnesium-based deposits in desalination plants face unavoidable problems, and acids used to remove such deposits include HCl, H_2SO_4, and HSO_3NH_2. The application of acid corrosion inhibitors in the treatment of scale parts in multistage flash desalination plants is widely used to prevent or minimize material loss during contact with acid. Inhibitors are practical and cheap means to minimize the corrosive attack of acids on metals. In order to solve the problems, many inhibitors have been used both inorganic and organic compounds containing hetro atoms in their chemical structures (7-13). The inhibition efficiency of the used inhibitors was found to reduce the rate of corrosion. Nevertheless, the use of chemical inhibitors has been limited because of environmental threat. The hazardous effects of most synthetic inhibitors are the motivation for the use of natural products. The inhibiting effect of these compounds was due to its adsorption on the metal surface and isolates the metal from the aggressive ions. Recently, plant extracts have again become important as an environmentally acceptable, readily available and renewable source for a wide range of needed inhibitors. Plant extracts are viewed as an incredibly rich source of naturally synthesized chemical compounds that can be extracted by simple procedures with low cost. Various natural products were used as scale inhibitors in different applications. The obtained data showed that plant extracts could serve as effective environmentally friendly scale inhibitors, such as palm leaves, fig leaf extracts as novel environmentally friendly inhibitors (14-16). The inhibitive mechanism was referred to the adsorption of inhibitor molecules on the metal surfaces. This study aims to gain some insight into the corrosion of stainless steel in acidic environment in the presence of waste product as an eco-friendly inhibitor. Our objective is to consider egg shell powder as inhibitor due its large economic benefits, and is advantageously used in a situation where organic or mineral inhibitors would be limited by environmental regulation or difficulties in application. The inhibitive effect of egg shell on stainless steel was investigated using gravimetric and polarization techniques. To our knowledge, no study has so far been reported about the inhibitive effect of egg shell powder on stainless steel corrosion.

II. EXPERIMENTAL STUDIES

2.1. Solution Preparation

Test media

0.5 M H_2SO_4 solutions were prepared by dilution of 98% analytical grade sulphuric acid with distilled water which serves as corrosive test medium.

Inhibitor

Synthesized egg shell powder was used as inhibitor in this study with concentration ranges from 2, 4, 6, 8 and 10grams. The structural formula is shown in Figure 1

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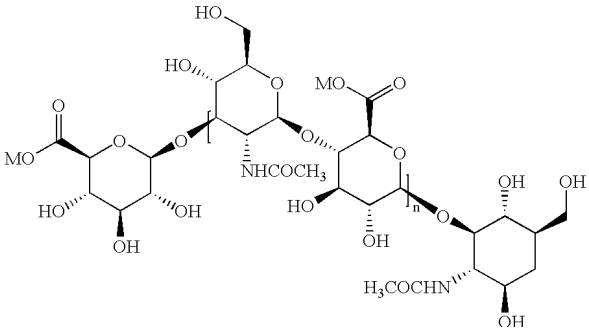


Figure 1: Chemical structure of egg shell powder

2.2 Samples preparation

Rectangular stainless steel specimen were mechanically cut to size of 20 × 20 × 3 mm with the area of 3 cm^2 was used for study of the mass loss. The samples used for electrochemical study were mechanically polished with different grades of emery papers then rinsed with distilled water and allow to dry with acetone.

2.3 Weight loss experiment

Stainless steel samples of dimension 20 × 20 × 3mm was drilled at the centre with hole 3 mm polished with abrasive paper then degreased in acetone and rinsed thoroughly with distilled water. The cleaned and weighed samples in duplicate were suspended in beakers using glass hooks and rods containing the test solutions of different concentrations of 2, 4, 6, 8 and 10 g. The pre-weighed samples were retrieved from the test solutions after every 24h, appropriately cleaned, dried and reweighed. The weight loss was taken to be the difference between the weight of the samples at a given time and its initial weight. The weight loss (WL), corrosion rate (R) and Inhibition efficiency values were obtained using the equation reported elsewhere (17).

2.4. Potentiodynamic polarization method

A three electrode system was used in the potentiodynamic polarization measurements. The working electrode was made of stainless steel Type 316 plate which was embedded in resin with an exposed area of 1.0 cm^2. A coiled platinum wire was used as the counter electrode and a saturated calomel electrode (SCE) as the reference electrode, which was connected to the cell through a Luggin capillary. Nova software was used with Linear polarization resistance (LPR) and the current was set to 10 mA (max) and 10 nA (min). LSV staircase parameter start potential -1.5 v, step potential 0.001 m/s and stop potential of +1.5 v set. The solution was stirred with a magnetic stirring bar and maintained at a constant temperature of 297K with a water bath. Before the experiment, the electrode was polished and then degreased in acetone and rinsed thoroughly with distilled water. Applied potential versus current density was plotted. Extrapolation of linear part to the corrosion potential gives the corrosion current. In anodic and cathodic plot, the slope of the linear part gives Tafel anodic and cathodic constants (ba and bc) respectively.

III. RESULTS AND DISCUSSION

3.1 Weight loss measurements

Weight loss measurements of the stainless steel (SS) in 0.5 M H_2SO_4 in the absence and presence of different concentrations of the studied inhibitor were carried out at 297K and the results are reported in Figures 2 and 3. As shown from the results, the corrosion rate of the SS decreased in the presence of the inhibitor and the inhibition efficiency increased with an increase in the concentration of the inhibitor. The egg shell powder (ES) provides good inhibition efficiencies within the concentration range under study. The values of inhibition efficiencies calculated from the weight loss method are in good agreement with those calculated from the polarization method.

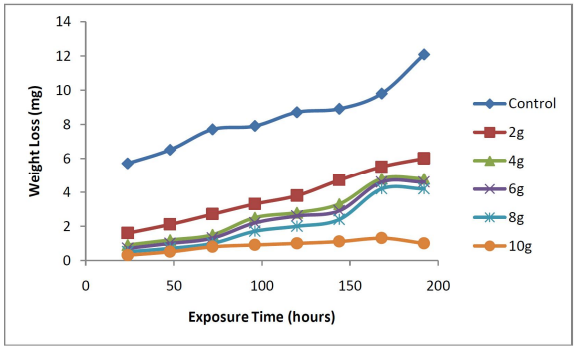


Figure 2: Variation of weight loss with exposure time in the presence and absence of ES in 0.5M H_2SO_4 solution

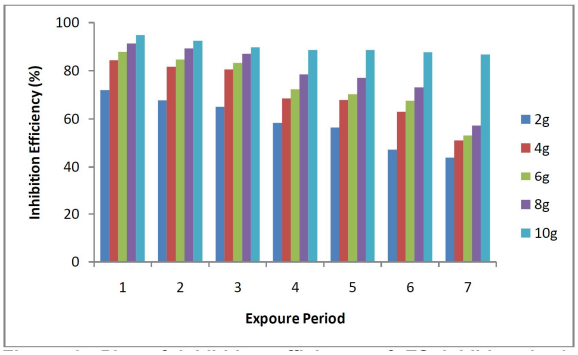


Figure 3: Plot of inhibition efficiency of ES inhibitor in 0.5M H_2SO_4 versus exposure time

3.2. Potentiodynamic polarization measurements

The effects of the synthesized inhibitors under study on the corrosion and polarization behaviors of the SS were studied in 0.5 M H_2SO_4 at 297K. Presence of the inhibitor shifted the steel potential -0.93929 V to the positive side, and this shift in potential increased by increasing inhibitor concentration -0.53561V as

shown in Table 1. Anodic-cathodic polarization of the SS in the absence and presence of the inhibitor in 0.5 M H_2SO_4 has been performed. Complete analysis of the polarization test, including cathodic–anodic Tafel lines and active–passive range, was done and the parameters are recorded in Table 1 for the inhibitor. From the corrosion current (icor), the inhibition efficiency (IE) was also calculated using equation reported elsewhere (1). In the presence of the highest inhibitor concentration, the corrosion current decreased from 0.000332 A/cm^2 to 1.24E-05. The constancy of the bc values indicates that the mechanism of hydrogen evolution is not changed in the absence and the presence of the inhibitor. The values of ba decreased at high concentration of the inhibitor, indicating change in the mechanism of metal dissolution. Presence of the inhibitor at any concentration did not affect the passive potential of the metal. However, the corresponding current decreased gradually with an increase in the inhibitor concentration. Data observed from the Tafel plot correlate with the observed polarization curve. The result obtained from the polarization study was also in conformity with the weight loss experiment which indicates the spontaneous improvement from 2 - 10g inhibitor concentration.

Table 1: Polarization data for uninhibited and inhibited SS in 0.5M H_2SO_4 solution

Sample	ba (V/dec)	bc (V/dec)	icorr (A/cm2)	Polarization resistance (Ω)	Ecorr (V)	Corrosion rate (mm/year)
control	0.040886	0.033505	0.000332	24.091	-0.93929	2.8163
2g	0.059611	1.946	0.000207	121.44	-0.82755	1.5054
4g	0.23691	0.016319	0.000157	42.121	-0.88251	0.94759
6g	0.054014	0.32332	5.39E-05	373.18	-0.80269	0.43181
8g	0.055633	0.12403	5.46E-05	305.65	-0.58957	0.37724
10g	0.008625	0.038164	1.24E-05	246.08	-0.53561	0.091971

CONCLUSIONS

The results obtained in this study indicated the effectiveness of the investigated compound, egg shell, as inhibitors for the corrosion of Type 316 stainless steel in 0.5 molar sulfuric acid solutions. The compound work as mixed type inhibitor and enhance the passivation of the stainless steel, and their inhibition efficiencies increase with inhibitor concentration.

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