American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-9, pp-12-21
www.ajer.org
Research Paper Open Access

The Effect of Carica Papaya Leaf Extract Addition on the Corrosion of the Magnetized Mild Steel in Hcl Solution.

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ABSTRACT: *The corrosion rates of magnetized mild steel coupons immersed in HCl solution and HCl solution bearing 1.5ml/litre to 4.5ml/litre of carica papaya leaf extract. The coupons were magnetized with a locally designed and fabricated electromagnetizer. Varied magnetization values ranging from 0.1mTesla to 3.3mTesla were attained across the coupons profiles, and their values were averaged for use in the analyses of the results. The corrosion rates of the magnetized coupons were markedly lower than those of their not magnetized counterparts, attaining a maximum inhibition efficiency of 75% at 0.6mTesla magnetization. Addition of carica papaya leaf extract further lowered the corrosion of the magnetized mild steel coupons and showed the maximum inhibition efficiency of 89% at 0.41mTesla. Results were explained on the basis of adsorption on the mild steel coupons of paramagnetic species and constituents of the carica papaya leaf extract. These provided appreciable surface coverage of the mild steel coupons and thus reduced attack by the acid.*

Keywords*- Corrosion rate, carica papaya leaf extract, electromagnetism, inhibition, paramagnetism*

Date of Submission: 21-08-2019 Date of acceptance: 05-09-2019

I. INTRODUCTION

Metals occur in nature as ores of naturally occurring compounds of silicates, oxides, carbonates, halides, sulphates etc. and large amount of energy is expended in their extraction. When these metals are exposed to natural environment, they tend to revert to their original stable states. The deterioration of extracted metals in the bid to return to their original ore state by interaction with the environment is referred to as corrosion. Ferrous metals that are extensively used in the construction industry experience corrosion. It is estimated that about 150 million tons of steel are destroyed per year due to corrosion [1]. Their inevitable corrosion leads to loss of mechanical strength resulting in structural and functional failure of plants and systems. When these take place the plants are extensively damaged and their functions impaired, farmlands are destroyed and rivers are polluted in the case of oil spillages, bridges collapse, aero planes crash as the case may be. Majority of these corrosion-related failures give rise to collateral fire outbreaks which result in extensive fatalities. The huge costs of remediation are enormous. Cleanup of farmlands with the compensation to affected communities resulting from damaged lands and fatalities and cleanup of the plant itself with the resultant repairs are very expensive. Many corrosion mitigation research works consequently evolved and are still ongoing to redress the challenge. Some of these works are coating, cathodic protection, anodic protection, use of inhibitor and the use of magnetic field.

The effect of carica papaya leaf extract on the corrosion of metallic materials had been studied by many researches, and they all agreed that carica papaya leaf extract inhibited the corrosion of metallic materials. Loto et al in their study, “the inhibition effect of extracts of carica papaya and camellia sinensis leaf on the corrosion of duplex(αβ) brass in 1M nitric acid” [2], showed that the two extracts inhibited the brass specimen in 1M nitric acid. Ebenso et al in the study, “The inhibition of mild steel corrosion by some plant extract in acidic medium” [3], found that carica papaya extract reduces the corrosion rate of mild steel. They observed that their inhibition increases as the concentration and temperature of the inhibition increases, Okafor and Ebenso in their study, “Inhibitive action of carica papaya extracts on the corrosion of mild steel in acidic media and adsorption characteristics” [4] supported the hypothesis, Ugwuoke and Amalu in their study, “Inhibitive influence of carica papaya and azadirachta indica leaf extracts on the corrosion of mild steel in H_2SO_4 environment” [5]. Also agrees that both leaf extracts are corrosion inhibitors that function by the adsorption of the inhibitor molecules on the metal surface.

Magnetic effect on electrochemical processes have attracted attention basically because of their

practical application in industry such as enhancing mass transfer, better electro deposition and control of corrosion. Most of the studies on the effect of magnetism on metallic materials were carried out using externally applied magnetic field and the results obtained are discordant with respect to the corrosion of these materials. Yee and Bradford, states that it is uncertain whether enhancement, retardation or both are the results of magnetic electrochemical interaction [6]. Several authors have reported that externally applied magnetic fields decreased the corrosion rate of some metals such as brass, aluminum, zinc and stainless steel [7-14]. Also Ji-nan Li et al [15] reported that corrosion of copper was inhibited under the influence of magnetic field. Conversely, it has also been reported that magnetic field increased the corrosion rate of some metallic materials [16-19]. Pondichery studied the effect of external magnetic field on the corrosion behavior of materials in 3.5% NaCL and found that external magnetic field increases the corrosion rate of 416 stainless steel and 108 carbon steel with no effect on 304 stainless steel and Ti alloy[20]. Results from experiments done by Waskaas using combination of electrode materials (iron, nickel, platinum, zinc, and copper) and electrolytes (iron (11) chloride, iron (11) sulphate, iron (11) oxide, copper(11) chloride), showed no effect of 600mT magnetic field strength[21]. The reason for differences in the results obtained is that the externally applied magnetic field as reported by many authors [22-27] gave rise to many dynamic scenarios which differently influenced the corrosion of the immersed substrates. These are: flow of the stream of corrosive solution, interaction of the electrolyte with the magnetized surface, effect of magnetic field and magnetic field gradient on moving ions, effect of magnetic field on the concentration of ions and also the effect of magnetic field on mass transport.
In this work, afore-magnetized substrate, mild steel, applied in situ in an acid medium, will be used to constrain the dynamic scenarios to a unidirectional flow. The envisaged effect will be that paramagnetic species will tend to be attracted to and adsorb on the magnetized substrate to give a distinct corrosion attenuation result.

II. EXPERIMENTAL

2.1 MATERIAL SELECTION

Mild steel was used for the experiment, its elemental composition C 0.15-0.29wt%, Mn 0.6-0.9wt%, P≤0.04wt%, and S≤0.05wt%, balance Fe.

2.2 SAMPLE PREPARATION

The mild steel was prepared into coupons with dimensions; Length, Width, Thickness
(a) 76mm × 22mm × 3mm
(b) 76mm × 19mm × 3mm
(c) 79mm × 19mm × 3mm

The samples of mild steel coupon with uniform bored hole of 8mm used to suspend it in the electrolyte was numbered prior to testing; the sample was polished using emery papers of grids 800, 1000 and 1200, and mirror like surface finish (as shown in the fig 2.1) was obtained.

Fig 2.1: Samples as after surface preparation (with mirror finish)

2.3 ELECTROLYTE

The electrolyte used for the corrosion testing was a solution of HCl. Distilled water and analytical grade of HCl was prepared with varying pH ranging from 0.9 - 1.8. The pH of the HCl solutions used for the experiment was calculated using the equation 1

$pH = -\log_{10}[H^+]$ Equation 1

Pocket sized pH tester made by Hanna instrument was used to confirm the pH of the solutions.
After surface preparation, the mild steel coupons were weighed using ohaus 4 digits weighing balance

2.4 INHIBITION EXTRACTION

Fresh leaves of pawpaw (carica papaya) leaf used for the investigation were harvested from farm around the Federal University of Technology Owerri campus, ground using manual grinding machine and then squeezed to obtain corresponding extract without the addition of water, after which the juices collected were filtered.

2.5 SAMPLE MAGNETISATION

An electromagnetizer was used to magnetize the coupons. The electromagnetizer has a hollow opening into which the mild steel coupons to be magnetized are placed. The mild steel coupons to be magnetized even help to concentrate the flux hence increase the field. The magnetizing unit uses a direct current (DC) to generate high magnetic field. The magnetizing system consists of two parts namely

(a) Power station
(b) The magnetizing unit

Power station is a long cycle unit that consists of DC generating circuit. Power from the AC line is filtered and converted to a lower voltage of around 60volts and current of around 40amps. This power is further passed through a voltage regulator and conditioning circuit which filter the unwanted pulses and ripples. This signal is fed to a conditioning and control circuit which automatically controls the temperature and power levels. The output power signal is fed from the back of the unit through a set of thick detachable power cable into the magnetizing fixtures. The output electric current supplied to the magnetizing fixture is controlled by a switch and control knob.

The magnetizing unit: This assembly is mounted on the power station in the rack. The unit has an opening into which the part to be magnetized are placed. It consists of a solenoid on a metallic holder.

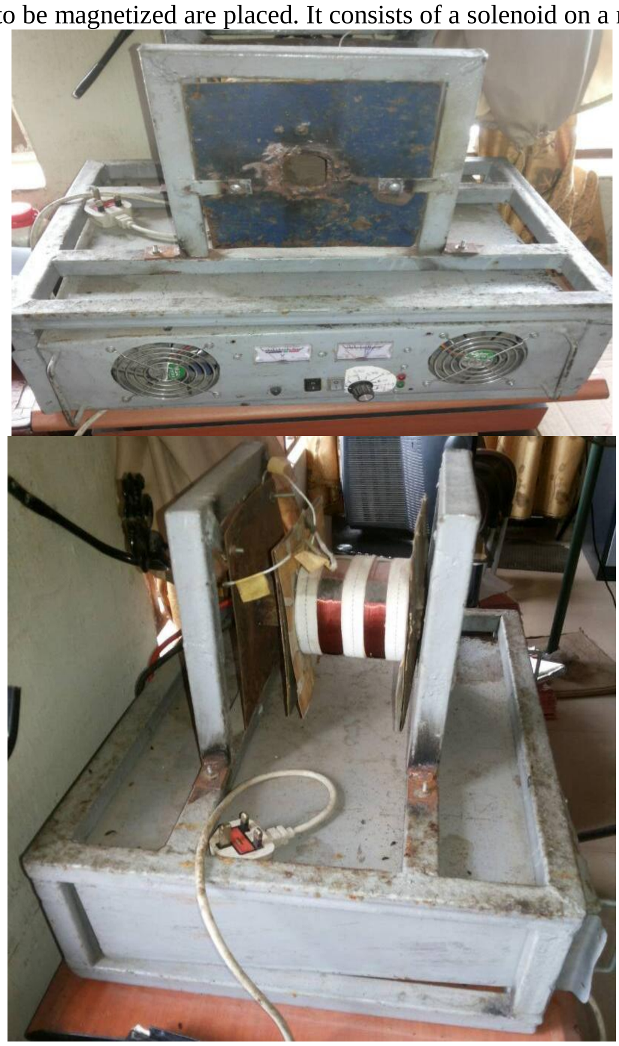


Fig**. 2.2:** Electromagnetizer

After magnetization of the coupons, tesla meter was used to measure the magnetic field on different points on each coupon. HT20 portable digital tesla meter measures magnetic field that ranges from 0 – 2000mT.

2.6 EXPERIMENTAL SETUP

After taking the weight of each coupon, magnetizing and measuring the magnetic strength, 12 non-magnetized coupons and 18 magnetized coupons; the samples were then immersed into circular beakers of four liters each containing three liters of 1.2pH HCl solutions with some beakers containing carica papaya leaf extract. The beakers were arranged in six per row and labeled accordingly and specified information written down. After a period of 1, 2,3,4,5 and 6 hours at room temperature accordingly, the samples were removed, washed in clean water, cleaned with acetone and cotton wool then weighed, the magnetic strength measured and the losses in weight were calculated.

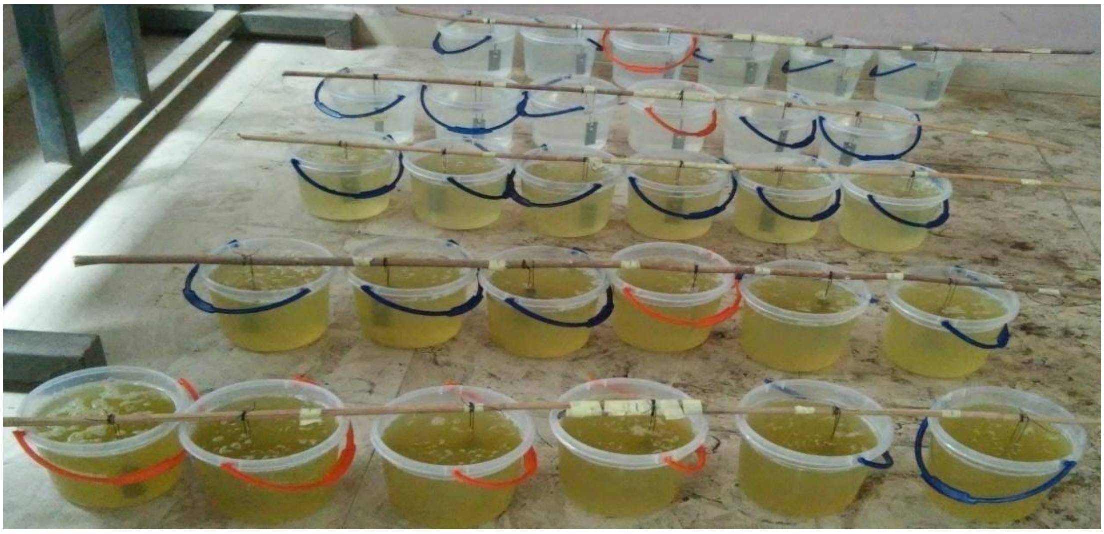


Fig2.3: The flow diagram representing the test inside a solution of HCl with carica papaya leaf extract.

The corrosion rate of mild steel was calculated in g/cm^2/hr using the equation 2

Corrosion Rate = $\frac{\text{Weight loss (g)}}{\text{Area (cm2)} \times \text{Exposure time (hr)}}$ Equation 2

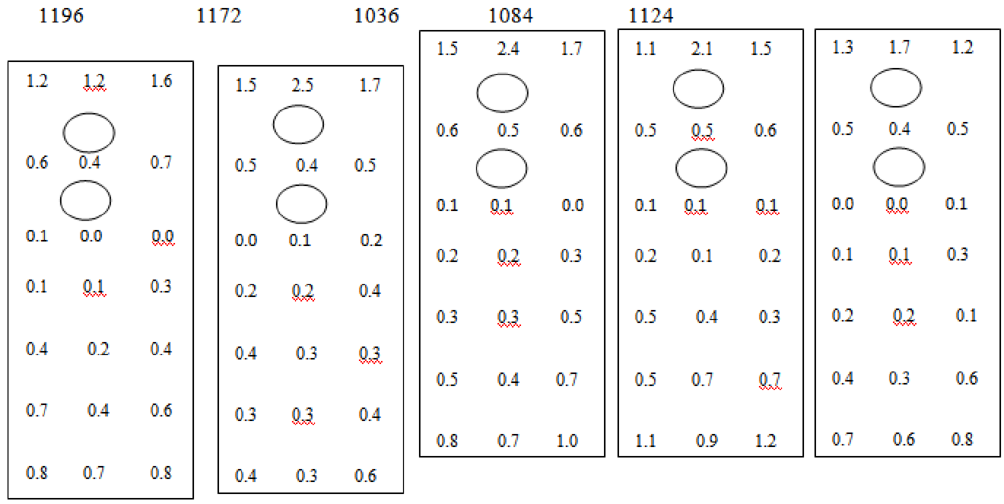
From the corrosion rate values, the inhibition efficiency was calculated using equation 3

Percentage Inhibition Efficiency = $\frac{\text{corrosion rate of not magnetised} - \text{corrosion rate of magnetised}}{\text{corrosion rate of not magnetised}} \times 100$ Eqn 3

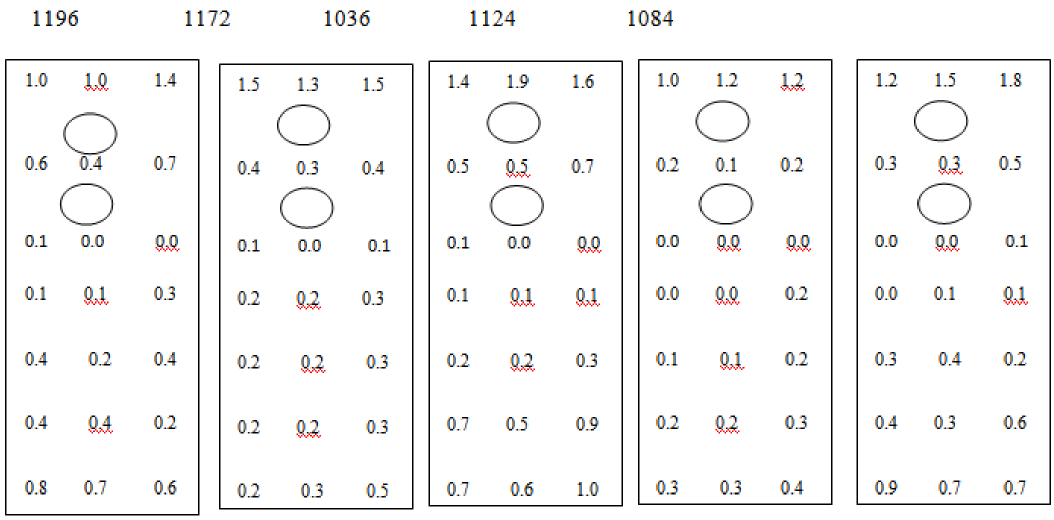
Fig 2.4: Some of the pictures of magnetized coupons with iron filings

III. THE MAGNETIC STRENGTH PROFILE ACROSS COUPONS USED FOR THE STUDY.

The magnetic strength of the coupons before immersion, for coupons used in pH 1.2 “magnetized without carica papaya leaf extract”.



The magnetic strength of the coupons after immersion, for coupons used in pH 1.2 “magnetized without carica papaya leaf extract”.



Tables 3.1: The average magnetic strength values for coupons used in pH 1.2 “magnetized without carica papaya leaf extract”

Coupon design. Number	Average Magnetic strength before immersion(mT)	Average Magnetic strength after immersion(mT)
1196	0.54	0.47
1172	0.54	0.41
1036	0.64	0.58
1124	0.48	0.30
1084	0.64	0.45

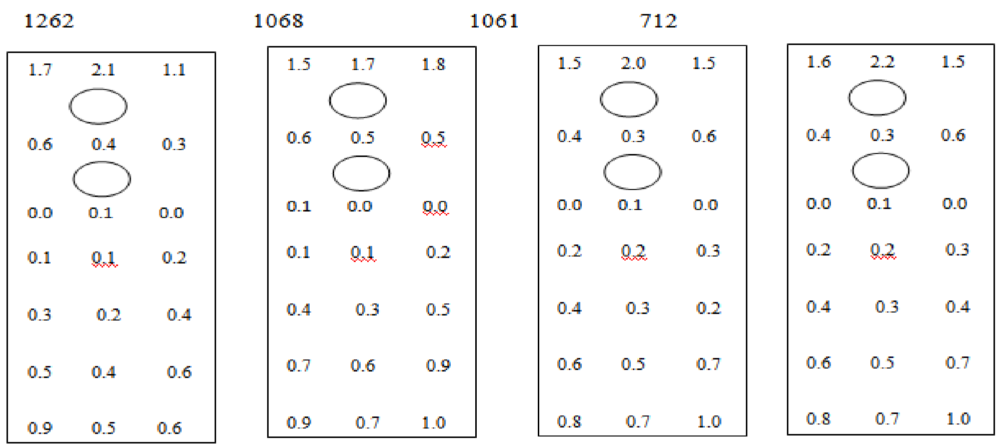
The magnetic strength of the coupons before immersion, for coupons used in pH 1.2 “magnetized with 1.5ml of carica papaya per liter”.

The magnetic strength of the coupons after immersion, for coupons used in pH 1.2 “magnetized with 1.5ml of carica papaya per liter”.

Table 3.2: The average magnetic strength values for coupons used in pH 1.2 “1.5ml of carica papaya per liter”

Coupon design. Number	Average Magnetic strength before immersion(mTesla)	Average Magnetic strength after immersion(mTesla)
413	0.59	0.42
1237	0.56	0.54
21829	0.57	0.53
10356	0.57	0.51
1075	0.59	0.39

The magnetic strength of the coupons before immersion, for coupons used in pH 1.2 “magnetized with 3ml of carica papaya per liter”.



The magnetic strength of the coupons after immersion, for coupons used in pH 1.2 “magnetized with 3ml of carica papaya per liter”.

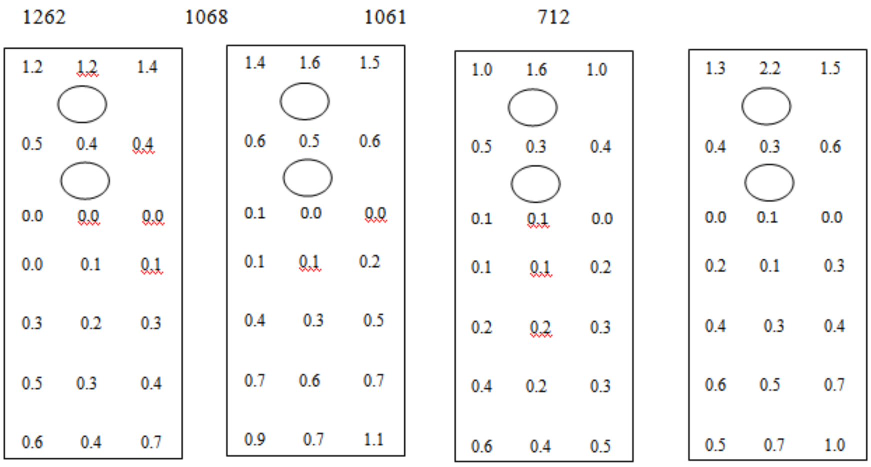
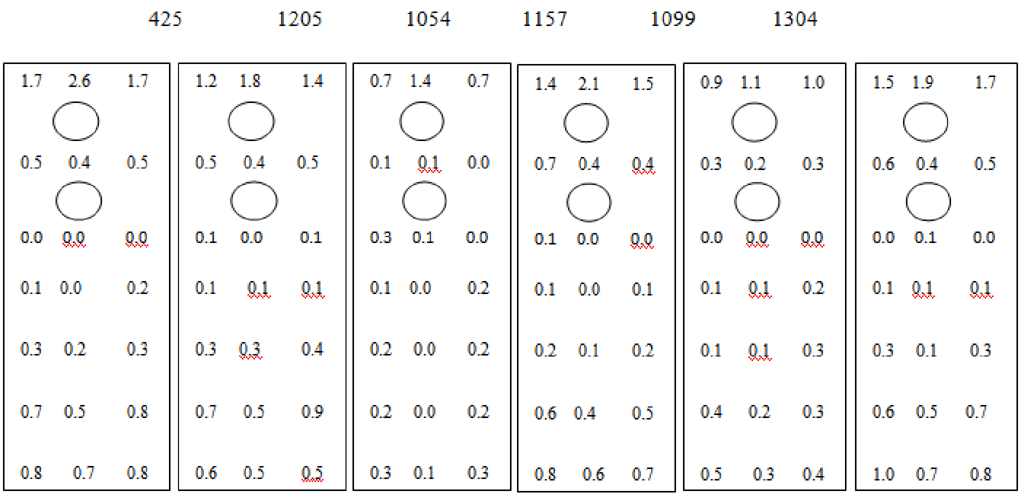


Table 3.3: The average magnetic strength values for coupons used in pH 1.2 “3ml of carica papaya per liter”

Coupon design. Number	Average Magnetic strength before immersion(mT)	Average Magnetic strength after immersion(mT)
1262	0.51	0.43
1068	0.62	0.59
1061	0.58	0.40
712	0.61	0.58

The magnetic strength of the coupons before immersion, for coupons used in pH 1.2 “magnetized with 4.5ml of carica papaya per liter”.



The magnetic strength of the coupons after immersion, for coupons used in pH 1.2 “magnetized with 4.5ml of carica papaya per liter”.

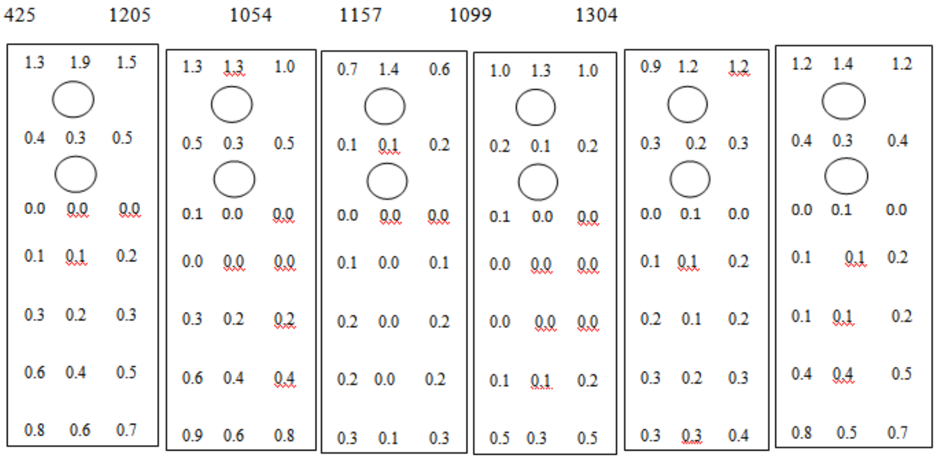


Table 3.4 The average magnetic strength values for coupons used in pH 1.2 "4.5ml of carica papaya per liter"

Coupon design. Number	Average Magnetic strength before immersion(mT)	Average Magnetic strength after immersion(mT)
425	0.61	0.51
1157	0.52	0.26
1205	0.52	0.45
1099	0.35	0.33
1054	0.26	0.22
1304	0.57	0.41

IV. RESULTS AND DISCUSSION

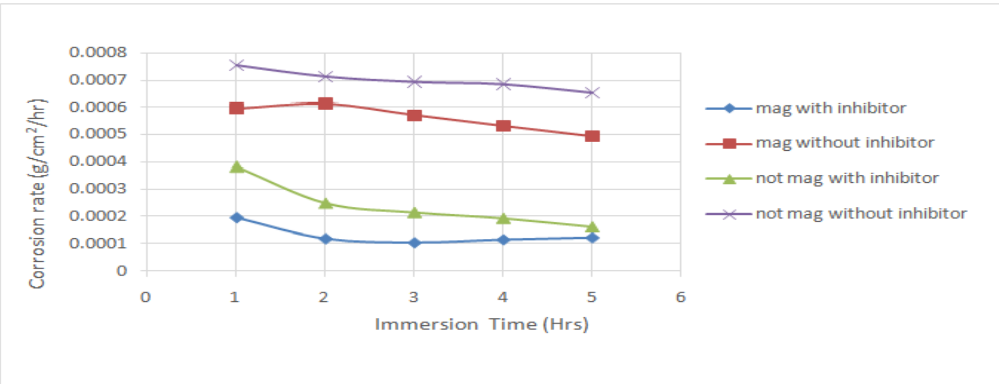


Fig 4.1: corrosion rate versus time for magnetized and non-magnetized coupons with average magnetic strength of 0.57mTesla immersed in 1.2 pH HCl with 1.5ml/liter carica papaya leaf extract

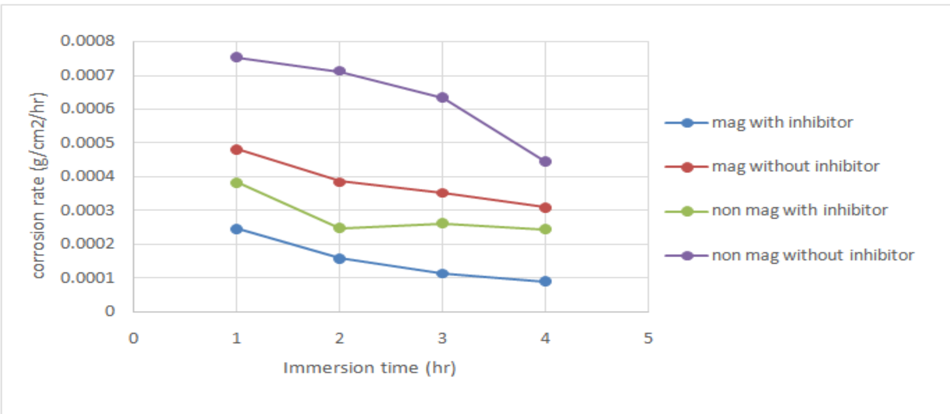


Fig 4.2: Corrosion rate versus time for magnetized and non-magnetized coupons with average magnetic strength of 0.58mTesla immersed in 1.2 pH HCl with 3ml/liter carica papaya leaf extract

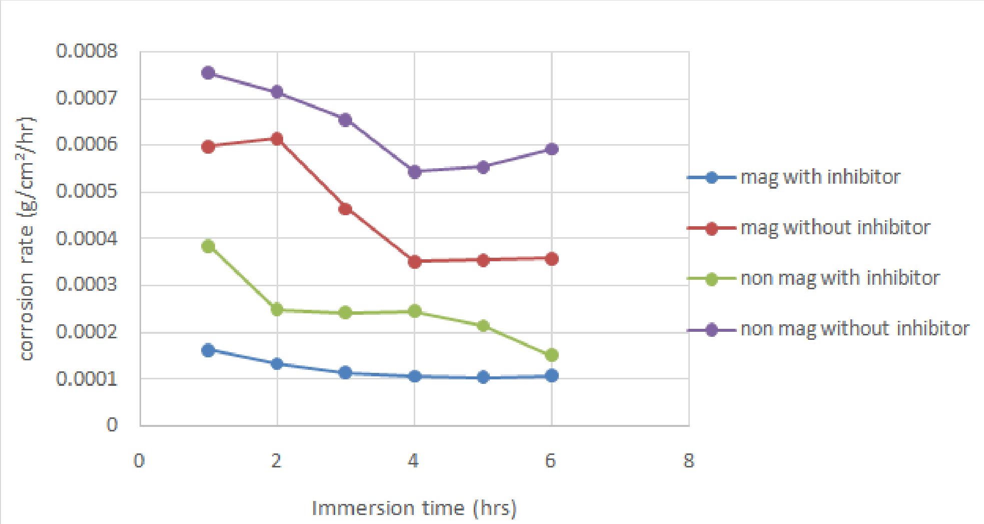


Fig 4.3: Corrosion rate versus time for magnetized and non-magnetized coupons with average magnetic strength of 0.56mTesla immersed in 1.2 pH HCl with 4.5ml/liter carica papaya leaf extract.

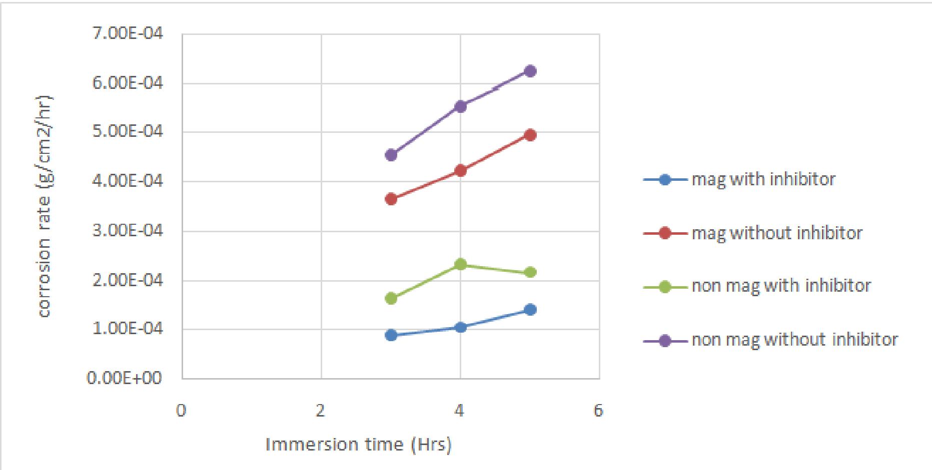


Fig 4.4: Corrosion rate versus time for magnetized and non magnetized coupons with average magnetic strength of 0.31mTesla immersed in 1.2 pH HCl with 4.5ml/liter carica papaya leaf extract

4.1 Effect of Magnetism on Corrosion of Mild Steel Immersed in HCl Bearing carica papaya Leaf Extract

Fig 4.1 to 4.4 show the corrosion rates against time for magnetized and non-magnetized coupons immersed in pH level of 1.2 with varying quantities of carica papaya leaf extract (1.5ml/liter, 3ml/litre, 4.5ml/litre). It is seen that magnetized coupons (the ones tagged “mag without inhibitor”) have lower corrosion rates than their non-magnetized counterparts. But with the addition of carica papaya leaf extract, (the ones tagged “mag with inhibitor”) there was a drastic decrease in the corrosion rate of the magnetized coupons. It had already been established by many authors that carica papaya leaf extract inhibits corrosion, Ebenso et al (1998) in their study; “the inhibition of mild steel corrosion by some plant extract in acidic medium”[3], found that carica papaya extract reduces the corrosion rate of mild steel. They observed that their inhibition efficiency increases as leave extract concentration and temperature increased. Okafor and Ebenso’s (2007) in their study; “inhibitive action of carica papaya extracts on the corrosion of mild steel in acidic media and adsorption characteristics” [4], supported the hypothesis. Ugwuoke and Amalu (2017) in their study; “inhibitive influence of carica papaya and azadirachta indica leaf extracts on the corrosion of mild steel in H_2SO_4 environment”[5], also agrees that both leaf extracts are corrosion inhibitors that function by the adsorption of the inhibitor molecules on the metal surface. It then could be the combination of organic inhibition and magnetism that brought about the drastic decrease in corrosion rates. It could also been seen from the magnetic strength profile across each coupons that the magnetized coupons appreciably retained their magnetism even after removing them from the solution. The inhibition efficiency was up to 89% when 3ml/liter of carica papaya leaf extract was added to the solution at the magnetic strength of 0.41mTesla after 6hours.

V. CONCLUSION

The following conclusions were made; the corrosion rates for the magnetized mild steel coupons were lower than the non-magnetized coupons. This was attributed to the formation of a field protective layer on the surface of the mild steel that suppressed the corrosion of the magnetized coupons more than the non-magnetized coupons.

The corrosion rates of the magnetized mild steel coupons were drastically reduced when carica papaya leaf extract was introduced into the solution of HCl.

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