Inhibitive Effect of Shea Butter on the Corrosion of Mild Steel

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Abstract- ***Corrosion in industries and all other ways of life must be avoided as its consequential effects cost heavy loss to economy and lives. There are several conventional methods of converting corrosion such as coating but with limitations of challenges especially to health and high cost of application. Recent researches have focus on using natural organic materials such as vegetable seeds as inhibitors for converting corrosion especially in food processing industries. In this work, the potentials of shea butter from the nut of African shea tree (vitellaria paradoxa) as corrosion inhibitor for mild steel in different media was investigated. Six (6) corrosion coupons were prepared from mild steel sheet for the experiment. Three (3) of the samples were covered with shea butter and immersed separately in distilled water, concentrated and diluted HCL, while the remaining three (3) samples were separately immersed in similar environments but not coated with shea butter. The corrosion effects on all the samples were studied using weight loss criteria. The result of the experiment indicated the variation in weight loss of shea butter coated mild steel for both concentrated and diluted HCL as compared to their initial weights. The weight loss of shea butter coated mild steel with concentrated HCL varies significantly with the day's interval as compared to the weight of mild steel with diluted HCL that had little or no change in weight. Concentrated HCL with shea butter coated steel readily corrode than in dilute HCL which showed no sign of corrosion. Based on the results, it can be concluded that shea butter can conveniently be used as inhibitor for mild steel.***

Indexed Terms- ***Weight loss, Distilled water, Mild steel, Corrosion inhibitor, Extracts***

I. INTRODUCTION

Corrosion is an irreversible damage or destruction of living tissue or materials due to chemical or electrochemical reaction [1, 2]. Metallic corrosion embraces all interaction of a metal or alloy (solid or liquid) with its environment, irrespective of whether this is deliberate and beneficial or adventitious and deleterious [3, 4]. Corrosion and its control is a problem of great importance to the engineering industry with the rapid multiplying use of metals, the increasing occurrence of corrosive environment and the depletion of suppliers of ores [5]. Corrosion is responsible for colossal loss of materials occurring everywhere and every moment involving billions of naira annually [6]. Corrosion costs in the industrialized countries amount to about 4% of the gross national product. These include the cost, which can arise in the form of corrosion protection measures, through replacement of corrosion – damage parts or through different effects deriving from corrosions, such as shut-down of production or accidents which lead to injuries or damage to property and occasional loss of lives [6, 7]. As a consequence of the economics of productions, environmental impact and ecological factors, it is becoming increasingly important to consider the "cradle – to – grave" life cycle of light alloy materials relative to the overall manufacturing process. This utmost necessitated the recent increase in the research of the behavior of metals subjected to different environments [8]. Therefore, it is essential to develop and apply corrosion engineering control methods and technique [10]. As a result of the corrosion, several inhibitors have been devised to control and prevent corrosion [11- 12]. Use of extracts of natural plant to control corrosion has been proposed and is being investigated by scientists. A possible plant of interest is shea tree and extract are known as shea butter which is extracted from shea nut. The reason why shea butter is considered here is because of its

compatibility in protecting materials, low cost and relatively low toxicity. Shea butter is technically a tree nut product, but unlike most tree nut it is very low in the proteins that can trigger allergies.

2.1 Corrosion and its Mechanism

Composition cells (also known as Galvanic cells) arise when a metal or alloy is electrically coupled to another metal or conducting nonmetal in the same electrolyte. The electromotive force and current of the galvanic cell depend on the properties of the electrolyte and polarization characteristics of anodic and cathodic reactions [13]. The term galvanic corrosion has been employed to identify the corrosion caused by the contact between two metals or conductors with different potentials. It is also called dissimilar metallic corrosion or bimetallic corrosion where metal is the conductor material.

2.2 Forms of Corrosion

It is suggested that a corrosion case should be described at least by its form, the corrosion reactions and corrosion products. This can also include their occurrence, mechanism, kinetics and description of galvanic cells that intervene. When well described, this could be considered as a type or subtype of corrosion. A type of corrosion is expected to characterize, and describe more profoundly the circumstances leading to corrosion or a failure of a certain material as listed below [14-16].

2.2.1 Surface Corrosion

Surface corrosion appears as a general roughening, etching, or pitting of the surface of a metal, frequently accompanied by a powdery deposit of corrosion products as shown in Plate 1. Surface corrosion may be caused by either direct chemical or electrochemical attack. Sometimes corrosion will spread under the surface coating and cannot be recognized by either the roughening of the surface or the powdery deposit. Instead, closer inspection will reveal the paint or plating lifted off the surface in small blisters which result from the pressure of the underlying accumulation of corrosion products.

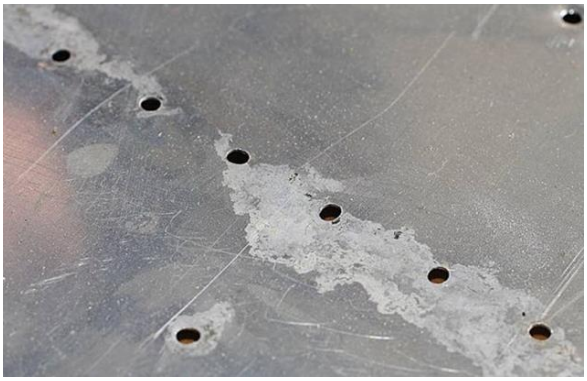

Plate 1: Surface corrosion

2.2.2 Filiform Corrosion

This gives the appearance of a series of small worms under the paint surface. It is often seen on surfaces that have been improperly chemically treated prior to painting. A pictorial representation of a filiform type of corrosion is shown in Plate 2.

Plate 2: Filiform Corrosion

2.2.3 Dissimilar Metal Corrosion

Extensive pitting damage may result from contact between dissimilar metal parts in the presence of a conductor. While surface corrosion may or may not be taking place, a galvanic action, not unlike electroplating, occurs at the point or areas of contact where the insulation between the surfaces has broken down or been omitted as shown in Plate 3. This electrochemical attack can be very serious because in many instances the action is taking place out of sight and the only way to detect it prior to structural failure is by disassembly and inspection. The contamination of a metal's surface by mechanical means can also induce dissimilar metal corrosion. The improper use of steel cleaning products, such as steel wool or a steel wire brush on aluminum or magnesium, can force small pieces of steel into the metal being cleaned,

which will then further corrode and ruin the adjoining surface.

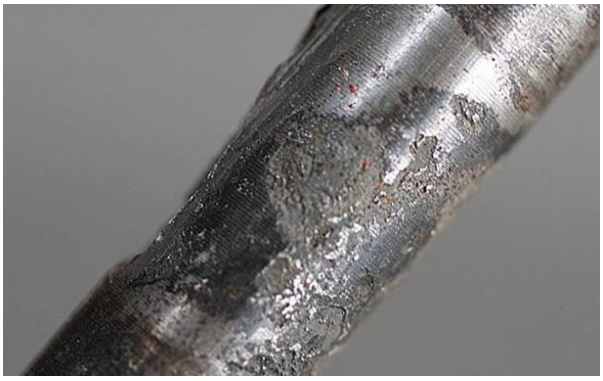

Plate 3: Dissimilar metal corrosion.

2.2.4 Intergranular Corrosion

This type of corrosion is an attack along the grain boundaries of an alloy and commonly results as a lack of uniformity in the alloy structure. Aluminum alloys and some stainless steel are particularly susceptible to this form of electrochemical attack. Lack of uniformity is caused by changes that occur in the alloy during heating and cooling during the material's manufacturing process. Intergranular corrosion may sometimes cause the surface of a metal to exfoliate. This is lifting or flaking of the metal at the surface due to delimitation of the grain boundaries caused by the pressure of corrosion residual product buildup. This type of corrosion is difficult to detect in its initial stage. Extruded components such as spars can be subjected to this type of corrosion. Ultrasonic and eddy current inspection methods are being used with a great deal of success.

2.2.5 Stress Corrosion

Stress corrosion occurs as a result of the combined effect of sustained tensile stresses and a corrosive environment and mostly found in metal systems. However, it is particularly characteristic of aluminum, copper, certain stainless steels, and high strength alloy steels (over 240,000 psi). It usually occurs along lines of cold working and maybe transgranular or intergranular in nature. Aluminum alloy bell cranks with pressed in bushings, landing gear shock struts with pipe thread type grease fittings, clevis pin joints, shrink fits, and overstressed tubing B-nuts are examples of parts which are susceptible to stress corrosion cracking.

2.2.6 Fretting Corrosion

Fretting corrosion is a particularly damaging form of corrosive attack that occurs when two mating surfaces, normally at rest with respect to one another, are subject to slight relative motion. It is characterized by pitting of the surfaces, and the generation of considerable quantities of finely divided debris. Since the restricted movement of the two surfaces prevent the debris from escaping very easily, an extremely local sized abrasion occurs. The presence of water vapor greatly increases this type of deterioration.

2.3 Corrosion Inhibitor

Inhibitors can be considered as a retarding catalyst and are used as a means of controlling and preventing corrosion. Inhibitor include substances which on addition to the corrosive medium in very small amount retards the degradation of metals and can be use either in liquid media, gaseous media as well as solid and semi-solid materials such as point file, packing material and protective grease [17]. Most of the corrosion inhibitors are synthetic chemicals which are expensive and very hazardous to environments [18]. As a result of the toxicity of some corrosion inhibitors, there has been an increasing search for green corrosion inhibitors. The use of plant extracts as corrosion inhibitor has become important because they are environmentally acceptable, readily available and are a renewable source for a wide range of green inhibitors. Works of literature revealed that plant leaves extract such as those from *Moringa oleifera, Carica papaya, Dodonaea viscose, Carica papaya* and *Camellia sinensis, Baphia nitida, Psidium guajava, Musa paradisiacal, Azadirachta indica, Centella asiatica,* have been studied for corrosion inhibition of mild steel in acidic media [19]. Oil extracts from *Arachis hypogeae, cyperus esculentus, Sesamum indicum* had been proven to exhibit good corrosion inhibition on mild steel in acidic media [20]. Also, the use of peels from some plants such as *Musa sapientum,* Aqueous extract of *Mangifera indica* and *Citrus aurantium peel, Theobroma cacao* was identified as a good corrosion inhibitor on mild steel. Seed husk and roots of some plants were also studied and the result showed good corrosion inhibition property. For instance corrosion inhibition study of curcas seed husk and Vernonia amygdalina root showed that both were good corrosion resistance in mild steel in acidic media.

2.4 Factors Affecting Corrosion

Many factors affect the type, speed, cause, and seriousness of metal corrosion. Some of these factors can be controlled and some cannot. Climate the environmental conditions under which an aircraft is maintained and operated greatly affect corrosion characteristics. In a predominantly marine environment (with exposure to sea water and salt air), moisture-laden air is considerably more detrimental to an aircraft than it would be if all operations were conducted in a dry climate. Temperature considerations are important because the speed of electrochemical attack is increased in a hot, moist climate [21]. Among the controllable factors which affect the onset and spread of corrosive attack is foreign material that adheres to the metal surfaces. Such foreign material includes: Soil and atmospheric dust, Oil/grease/engine exhaust residues, Salt water/salt moisture condensation, Spilled battery acids/caustic cleaning solutions and Welding/brazing flux residues.

III. EXPERIMENTAL

3.1 Materials and Equipment

The materials used in this research are distilled water, mild steel, shea butter, concentrated and diluted HCL while the equipment used include steel tape, vernier caliper, weighing balance, beaker, cutting equipment (hack saw) and a thermometer.

3.2 Shea butter extraction

The traditional method of preparing unrefined shea butter was followed which consist of separating/cracking (where the outer pulp of the fruit is removed), then Crushing (done to make the shea nuts into butter), followed by roasting in open pots with continuous stirring with wooden paddles (to avoid burning of the butter). The roasted shea nuts is then ground to a smoother paste while gradually adding water followed by a thorough heating. Water is gradually added to separate the butter oils which float to the top. The butter oil which is in a curd state are removed and excess water squeezed out. The butter oil curds are then melted in large open pots over slow fires. A period of slow boiling will remove any remaining water by evaporation. The final stage is collecting and shaping where the shea butter which is creamy or golden yellow at this point is ladled from the top of the pot and put in cool places to harden and then formed into balls.

3.3 Chemical composition determination

The chemical composition of the steel samples used was determined using a Spectromaxx metal analyzer in the Defense Industry Corporation of Nigeria, DICON Kaduna.

3.4 Corrosion determination using weight loss method

Weight loss measurements were carried out using a weighing balance. The mild steel samples were obtained from the center for industrial studies (CIS) Abubakar Tafawa Balewa University, Bauchi. Three samples of dimension 20cm × 29cm were coated with shea butter, while the remaining three samples were used as test samples. The initial weight of the samples were taken using the weighing balance. Samples of the specimen as follows one coated with shea butter and the other one uncoated was dipped in concentrated HCL, dilute HCL and distilled water respectively. The setup is allowed to stay for a total of 60days (1440hrs), while weighing was done at 5days interval. The difference in the weight of mild steel (coated and uncoated) with shea butter was recorded at each interval. The setup of the experiment is shown in plate 4

Plate 4: Pictorial representation of the samples in different environments

Where

A. Hydrochloric Acid (diluted) + sample with shea butter
B. Hydrochloric Acid (concentrated) + sample with shea butter
C. Distilled water + sample with shea butter
D. Hydrochloric Acid (concentrated) + sample

E. Distilled water + sample
F. Hydrochloric Acid (diluted) + sample

The weight loss, corrosion rate, half-life and inhibition efficiency are calculated as follows
Weight loss $W_1 = M_1 – M_2$
Where M_1 = initial mass of specimen (mg)
M_2 = final mass of specimen (mg)
Therefore, corrosion rate, CR = $\frac{WL}{At}$
A = area of the specimen in (m^2)
t = time in hours (h)
The half-life is calculated as, $t_{12} = \frac{0.639}{k}$
Where k = rate constant and Rate constant = 1/ No of days of immersion
The inhibition efficiency (ŋ %) was computed as
ŋ % = $\frac{WL}{M1} \times 100$

IV. RESULTS AND DISCUSSION

4.1 Result of chemical composition of steel used

A spectromaxx metal analyzer was used to determine the chemical composition of the steel used and the results presented in Table 1.

Table 1: Chemical composition of the steel sample used

Element	C %	Si %	Mn %	P %	S %	Cr %	Ni %	Mo %
$\bar{x}$	0.179	0.277	0.53	0.0042	0.0033	0.022	0.0035	<0.00020
Element	Al %	Cu %	Co %	Ti %	Nb %	V %	W %	Pb %
$\bar{x}$	0.017	0.020	0.0021	0.0015	<0.00040	<0.00010	<0.010	<0.00030
Element	Mg %	B %	Sn %	Zn %	As %	Bi %	Ca %	Ce %
x	<0.00010	<0.0005	<0.00010	<0.00020	0.0050	0.0060	-0.0015	<0.00030

Element	Zr %	La %	Fe %
$\bar{x}$	<0.0015	0.0016	98.9

The result show that the metal is a mild steel with the carbon content of 0.179. There is a large percentage of manganese and silicon, which from literature have a positive effect on steel samples. Other elements present in smaller percentages are silicon, phosphorous, chromium, nickel etc.

4.2 Result of weight loss analysis

Table 2 shows the weight loss at different time intervals and immersion while Table 3 show the corrosion parameters obtained from weight loss of mild steel at various corrosion rate together with the half-life. The weight loss method as a means of evaluating environments and inhibiting potentials of studied inhibitors is widely reported in the literature, such that the technique forms a baseline method of measurement in many corrosion monitoring programs [21].

Table 2: Result of weight loss analysis at different environmental condition

	Sample weight loss (g)					
Days	A	B	C	D	E	F
0	63.22	40.14	50.42	58.46	58.29	241.95
5	63.06	26.48	50.41	46.32	57.75	240.46
10	63.06	22.77	50.41	39.50	57.39	240.22
15	63.06	20.23	50.41	39.38	57.27	239.72
20	63.06	18.50	50.41	35.73	56.95	239.52
25	63.06	18.12	50.41	35.69	56.54	239.33
30	63.06	14.88	50.41	25.15	56.34	238.67

35	63.06	14.86	50.41	25.10	56.30	238.50
40	63.06	14.85	50.41	24.75	56.25	238.45
45	63.06	14.83	50.41	21.80	56.23	238.39
50	63.06	14.80	50.41	20.20	56.21	238.37
55	63.06	14.79	50.41	19.10	56.19	238.36
60	63.06	14.70	50.41	16.73	56.14	238.22

Table 3: Result of calculated value of corrosion rate and half-life.

S/N	Immersion Period (days)	Condition	Corrosion Rate (mg/m^2h)	Half-Life (days)
1	5	Distilled water.	273.35	3.155
		Conc HCL	6067.77	3.155
		Dilute HCL.	384.01	3.155
2	10	Distilled water.	227.96	6.39
		Conc HCL	468.97	6.39
		Dilute HCL	222.89	6.39
3	15	Distilled water.	172.24	9.59
		Conc HCL	3161.74	9.59
		Dilute HCL	191.34	9.59
4	20	Distilled water.	169.17	12.78
		Conc HCL	2820.81	12.78
		Dilute HCL	156.54	12.78
5	25	Distilled water.	177.30	15.98
		Conc HCL	2260.63	15.98
		Dilute HCL	135.02	15.98
6	30	Distilled water.	163.74	19.17
		Conc HCL	2829.59	19.17
		Dilute HCL	140.86	19.17
7	35	Distilled water.	144.02	22.36
		Conc HCL	2359.84	22.36
		Dilute HCL	126.99	22.36
8	40	Distilled water.	126.01	25.56
		Conc HCL	2086.41	25.56
		Dilute HCL	112.73	25.56
9	45	Distilled water.	115.95	28.75
		Conc HCL	2016.02	28.75
		Dilute HCL	101.92	28.75
10	50	Distilled water.	105.36	31.95
		Conc HCL	1947.31	31.95
		Dilute HCL	92.28	31.95
11	55	Distilled water.	96.71	35.145
		Conc HCL	1770.36	35.145
		Dilute HCL	84.10	35.145
12	60	Distilled water.	90.76	38.34
		Conc HCL	1720.10	38.34
		Dilute HCL	80.10	38.34

Comparing the six conditions it was observed that the sample immersed in concentrated HCL acid corroded faster than other sample conditions. Therefore, among the six environmental conditions of immersion, the samples immersed in concentrated HCL acid without been coated with shea butter was found to be the most corrosive medium while samples immersed in distilled water was found to be less corrosive similar reports have been made in [22].

CONCLUSION

From the analysis made, the following conclusions are drawn.

1. Spectromaxx metal analyzer shows that the metal is a mild steel with the carbon content of 0.179.
2. The weight loss of mild steel coated with shea butter in concentrated HCL varies significantly with the day's interval as compared to its weight in diluted HCL condition.
3. The sample coated with shea butter and immersed in concentrated HCL and samples without inhibitor but put in concentrated HCL had faster corrosion rate.
4. The samples coated with shea butter and immersed in diluted HCL did not corrode.
5. Finally, it can be concluded that shea butter can be used in preventing corrosion of mild steel in environments similar to that of diluted HCL.

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