Corrosion Inhibition of Rosemary Oil on High Carbon Steel in Sulphuric Acid Medium

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Abstract. Rosemary oil was investigated on carbon steel in 0.5M sulphuric acid through weight loss technique. It was observed that weight loss, inhibitor efficiency and corrosion rate differ in concentration of the oil and exposure time. Maximum inhibitor efficiency of 78.45% was obtained at 10ml concentration of the oil. The performance of the oil was associated with the existence of organic compounds such as alkaloids, flavonoids, tannins, among others which form a protective film and act as a barrier against corrosion attack in sulphuric acid environment.

1. Introduction

Corrosion is a process that occurs naturally resulting in the gradual breakdown of a material by reaction with their environment [1]. The corrosion process in metals is inevitable but controllable [2]. The effects of corrosion are seen in the destruction of bridges, marine equipment, automobiles, energy production systems, airplanes, household devices and other structural materials [1]. Corrosion constitute a severe global issue in industries and has a notable influence on a country’s development. Billions of dollars are lost annually to corrosion. In the United States, annual metallic corrosion cost rose to over 200 billion dollars [2].

Carbon steels are widely utilised in industrial processes and structural applications since they are cheap and possess the capacity to be easily shaped. Corrosion of carbon steels have gained international attention as a result of their safety and economic effects from their destruction. Carbon steels have low corrosion resistance in acid medium, particularly in sulphuric acid [3]. Sulphuric acids are used for cleaning boilers through the removal of calcareous deposits, pickling, acidizing of oil wells and cleaning of refinery equipment materials [1].

Corrosion in metals can be controlled through cathodic protection, coatings, suitable selection of materials and the use of inhibitors [4]. Inhibitors are chemicals that lessen the effect of corrosion in metals in harsh conditions. Inhibitors work by preventing the destructive effects of corrosive anions in different conditions. Inhibitors are cost effective relative to other corrosion control methods [5]. Organic inhibitors are used in preventing carbon steel from corrosive chemicals [3]. Organic compounds that contain nitrogen, oxygen and sulphur atoms are regarded as efficient corrosion inhibitors. Unfortunately, organic inhibitors are relatively quite expensive and harmful to the environment. Alternatively, inexpensive environmentally friendly inhibitor compounds have been considered and have progressively gained wider recognition [5].

Green inhibitors are eco-friendly inhibitors. These inhibitors are not toxic to the environment [6]. They are biodegradable, biocompatible and readily available materials [2]. Organic green inhibitors such as extracts from plants have been described by different researchers as excellent corrosion inhibitors [2]. Plant extracts include Allium Sativum, Gossipium Hirsutum, Carica Papaya, Telfaria Occidentalis,
Hibiscus Subdariffa, Rosemarinus Officinalis among several others. The performance of rosemary oil in reducing the corrosive effect of sulphuric acid on carbon steel is being investigated.

2. Materials and Methods

High carbon steel samples used for this study were acquired commercially with nominal weight composition of 0.9% C, 0.5% Mn, 0.04% P, 0.05% S and 98.51% Fe [5]. After machining into the desired cylindrical shape, the following dimensions were obtained: 1cm length, 1.2cm diameter and 6.03cm$^2$ surface area. The carbon steel surface was prepared with abrasive papers.

Rosemary essential oil was used as the inhibiting compound obtained from Jannys beauty salon, Ikoyi, Lagos State. It is a yellowish transparent liquid. Rosemary oil has a density of 0.908 g/mL with a boiling point of 176˚C [5].

2.1. Weight loss Experiment

The weight of the cylindrical steel pieces was determined by an electronic weighing balance and dipped completely in 0.5 M sulphuric acid concentration at fixed quantity of rosemary oil with no variation in temperature. The samples were taken out of the solution and analysed every 24 hours for 21 days. During analysis, samples of carbon steel were carefully cleansed with distilled water and acetone, air-dried completely and reweighed. Parameters such as the surface coverage ($\theta_s$), inhibitor efficiency (IE) and rate of corrosion (C) were obtained through the following equations [5].

\[ \theta_s = 1 - \frac{W_n}{W_i} \]  \hspace{1cm} (1)

\[ \%IE = \theta_s \times 100 \]  \hspace{1cm} (2)

The rate of corrosion, C expressed in mm/y is calculated as:

\[ C = \frac{87.6 \times WL}{D \times A_s \times T_e} \] \hspace{1cm} (3)

Where WL is the weight loss (g), $T_e$ is the exposure time (h), $A_s$ is surface area of steel surface (cm$^2$), D is the steel density (g/cm$^2$).

3. Results and Discussion

3.1. Weight-loss results

The results obtained from corrosion rate, inhibitor efficiency and weight loss in sulphuric acid concentration of 0.5M at exposure time of 504 hours are shown in table 1. Figures 3.1(a) portray the weight loss (g) against time (hrs) for carbon steel in 0.5M sulphuric acid solution. The loss in weight of the steel samples shown in figure 3.1(a) increased with the time of exposure and decreased when the concentration of inhibitor (rosemary oil) was increased. The control curve (0ml) contained no inhibitor (rosemary oil) possesses the highest weight loss value. A decline in the weight loss was noticed when the oil was added. Inhibitor quantity of 10ml produced the lowest weight loss. The order of increasing inhibition performance of the oil is as follows: 10ml>8ml>6ml>4ml>2ml. It is clear that the activity of the inhibitor was largely dependent on its concentration. Organic compounds such as flavonoids, tannins among others contained in plant extracts as reported by Mo et al [8] and Okafor & Ebenso [9] can be associated with the performance of rosemary oil.

Corrosion rate against time of exposure with different quantity of rosemary oil is shown in figure 1(b). The control experiment showed a higher corrosion rate than other experiments with inhibition addition. The corrosion rate for non-inhibitor and inhibitor solutions initially showed a sharp increase and then decreased progressively with higher time of exposure. Rosemary oil with quantity of 10ml produced the lowest rate of corrosion. The reduction in the corrosion rate was largely determined by the inhibitor concentration. This can be associated with the generation of film on the metallic surface which
shields the surface from corrosion attack and therefore reduce the corrosion rate as reported by Nnanna et al. [10].

Figure 1(c) shows the inhibitor efficiencies with exposure time at different concentrations of the oil. The increase in the quantity of the inhibitor led to an increase in the efficiency of the oil. The Inhibitor efficiency for non-inhibitor and inhibitor solutions initially showed a sharp increase and decreased and then increased progressively with exposure time. The inhibitor concentration of 10ml produced the highest inhibitor efficiency of 78.45%. Green inhibitors as reported by Amitha and Barathi [11] possesses phytochemical constituents which prevents the diffusion of ions and inhibits any form of corrosion attack on the metallic material. The inhibitor used was considered for use to prevent pollution from occurring in order to have a stainable environment. Research has shown that different mediums such as co [12-14], inorganic inhibitors [15, 16] are sources of pollution to our environment. They are highly harmful to human lives and are not encouraging in order to have an eco-friendly environment.

**Table 1.** Results of weight loss for carbon steel in 0.5M sulphuric acid solution after 504 hours.

| Sample | Inhibitor Conc. (ml) | Weight loss (g) | Surface Coverage (θₚ) | Inhibition Efficiency (%) | Corrosion Rate (mm/y) |
|--------|----------------------|-----------------|------------------------|--------------------------|-----------------------|
| A      | 0                    | 7.4812          | 0                      | 0                        | 0.0275                |
| B      | 2.00                 | 2.4383          | 0.6741                 | 67.41                    | 0.0090                |
| C      | 4.00                 | 2.0497          | 0.7260                 | 72.60                    | 0.0075                |
| D      | 6.00                 | 2.0440          | 0.7268                 | 72.68                    | 0.0075                |
| E      | 8.00                 | 2.1840          | 0.7081                 | 70.81                    | 0.0080                |
| F      | 10.00                | 1.6125          | 0.7845                 | 78.45                    | 0.0059                |
Figure 1. Graph of (a) Loss in weight (g) against time of exposure (b) Corrosion rate against time of exposure time (c) Inhibitor efficiency against time of exposure in 0.5M sulphuric acid medium.
4. Conclusion

Results obtained from weight loss experiment proved the effectiveness of rosemary oil in suppressing the corrosive effects on carbon steel in sulphuric acid environment. At increasing amounts of the oil, the rate of corrosion was reduced.

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