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Investigation of the Inhibitory Effect of Sucrose on Corrosion of Iron (Libyan Steel) in Mineral Acid Solutions

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Corrosion inhibitory effect of sucrose ($C_{12}H_{22}O_{11}$) at different concentrations (0.1-10000 ppm) on corrosion of iron (Libyan steel) in various mineral acid solutions *viz.*, HCl, HNO_3 and H_2SO_4 of different concentrations (0.01-1.50 M) was investigated by weight loss measurements at 25 ºC temperature and different exposure time, up to 24 h. It was observed that the corrosion rate depends on concentration and exposure time. The corrosion rate decreases by increasing concentration of the inhibitor. It attains the lowest value at 10,000 ppm, which, is almost constant in this region. The corrosion rate also depends on the nature of mineral acid and its concentration. Sulphuric acid shows the highest rate of corrosion. The rate of corrosion changes with a change in the concen-tration of sucrose. The corrosion inhibition percentage is *ca.* 10 % at sucrose concentration of 0.1 ppm, whereas this percentage is almost 8 times higher (80 %) for sucrose concentration of (10,000 ppm).

Key Words: Inhibitory effect, Sucrose, Corrosion, Libyan steel.

INTRODUCTION

Detailed studies towards effect of sucrose on the properties of Portland cement pastes as a function of time have been made by Egan and Kirnade research group[1]. It has been shown that controlled addition of sucrose to the cement retards its hydration time. Further sucrose adds flexibility to the handling of cement paste particularly, during its transportation by trucks or through pipelines between treatment plants and disposal sites, without affecting its long-term performance[2]. During last decades, immense interest has arisen in corrosion inhibitors used to protect steel reinforcing bars embedded in concrete[3,4]. Emphasis was given to the most commonly used inhibitors such as amino alcohols[5], calcium nitrate and sodium monoflouro phosphate. Most of the studies represent information related to (a) basic mechanistic studies, which gives information about the inhibition mechanisms, (b) effectiveness of the inhibitors against the corrosion in concrete. Study of the inhibition effect of triphenyl tin-2-thiophene carboxylate on corrosion of steel in 2 M phosphoric acid solution[6,7] shows that the inhibitor is a good cathodic inhibitor. Electrochemical impedance spectroscopy suggested that the change in the impedance parameters with concentration is indicative of the adsorption of inhibitor molecules on the steel surface. These results are consistent with the observations made by Duwel *et al.*[8] who studied the inhibition of corrosion of iron in 1 M sulphuric acid solution by ethyl cyclohexane. From their studies, they suggested that the inhibitor is reduced and dehydrated initiating formation of a polymeric hydrocarbon film on the iron surface. Similar mechanism was deduced for corrosion inhibition by 3-butanyl-2-ol, 1-octyl-3-ol and polyethylene glycol (PEG-4000)[9,10]. Growock and Lopp[4,11] studied the inhibitory effect of cinnamaldehyde on iron corrosion in HCl solution and analyzed the film formed on steel in cinnamaldehyde-inhibited hydrochloric acid solution. It was revealed that the film is a complex mixture of low molecular weight aromatic hydrocarbon polymers.

From the results of previous studies, it is concluded that most of the inhibitors are organic compounds having electron rich atoms in their structure, such as nitrogen, oxygen and sulphur. These types of molecules are widely used as additive to minimize corrosion effect. The presence of the electron rich atom in the molecule of the inhibitor interact with the metals atoms involved in the corrosion environment and catalyze formation of polymeric film to protect the metal.

It is obvious that the electron rich atoms play an important role in the inhibition process and the formation of polymer film during the corrosion process. These facts inspire research groups to study the effectiveness of sugars as corrosion inhibitors. Present study investigated the inhibitive effect of sucrose on corrosion of iron in different mineral acids solutions.

EXPERIMENTAL

Commercial mild steel was used for this study. It was obtained from the Libyan Market in the form of sheets which was cut into pieces with an exposed surface area of 15 cm^2. Its per cent chemical composition is, C = 0.27; Mn = 0.07; S = 0.05; P = 0.50; Si = 0.35. The plates were polished using sand paper (Si-C emery paper grades 180-1200 μm). After the preparation the specimens were washed with doubly distilled water, degreased with acetone and dipped in cleaning solution 1 + 4 HCl for 10 min and then washed again with distilled water, dried in desiccators and accurately weighed. Solutions of mineral acids with different concentrations were prepared and used as corrosive mediums and the inhibitor (sucrose) was added to establish the required concentration in ppm. The temperature of the solution was set at 25 ºC, using a water bath equipped with temperature regulator. The corrosion tests were conducted by putting the iron plates in glass test tubes (4 cm × 20 cm) filled with testing solutions of different concentrations of sucrose. The plates hanged in the test solution (using a plastic supporter) and temperature of the solution was set at 25 ºC by keeping the test tubes in a temperature regulated water bath. The test tubes were then left for the required time. After that, the plates were removed, cleaned with washing solution (100 mL HCl + 2 g Sb_2O_3 + 5 g $SnCl_2$), washed again with distilled water and acetone, dried and reweighed accurately according to the steps given in ASTM 2688-97. The weight loss is the difference between initial and final weight of the plates in grams (Δw), The rate of corrosion (R) was calculated using the weight loss method as grams per unit area (A) per hour (g cm^{-2} h^{-1}) = Δw/A.t. The per cent of inhibition (% I) (protection efficiency) of sucrose was calculated as the following:

$$\%\ \text{Inhibition} = 1 - \frac{\text{Rate of corrosion in the presence of sucrose}}{\text{Rate corrosion in the acid solution}} \times 100$$

RESULTS AND DISCUSSION

The weight loss per area of mild steel plates were measured in 0.01, 1.0, 1.5 M of the mineral acids *i.e.*, HCl, HNO_3, H_2SO_4, solutions inhibited by different concentration of sucrose, 0.1, 10, 100, 1000 and 10000 ppm at temperature 25 ºC with the exposure times of 2, 4, 6, 8, 18 and 24 h. Figs. 1-3 represent the effect of the exposure time (t) and sucrose concentration on the weight loss per area of mild steel plates in sucrose-inhibited 0.1 M HCl; HNO_3 and H_2SO_4 solutions, respectively at 25 ºC. It is clear that as the concentration of sucrose increases, the weight loss decreases for each exposure time. The rates of inhibition of corrosion of steel by sucrose in (0.01 M HCl, HNO_3 and H_2SO_4 solution) were calculated from Figs. 1-3.

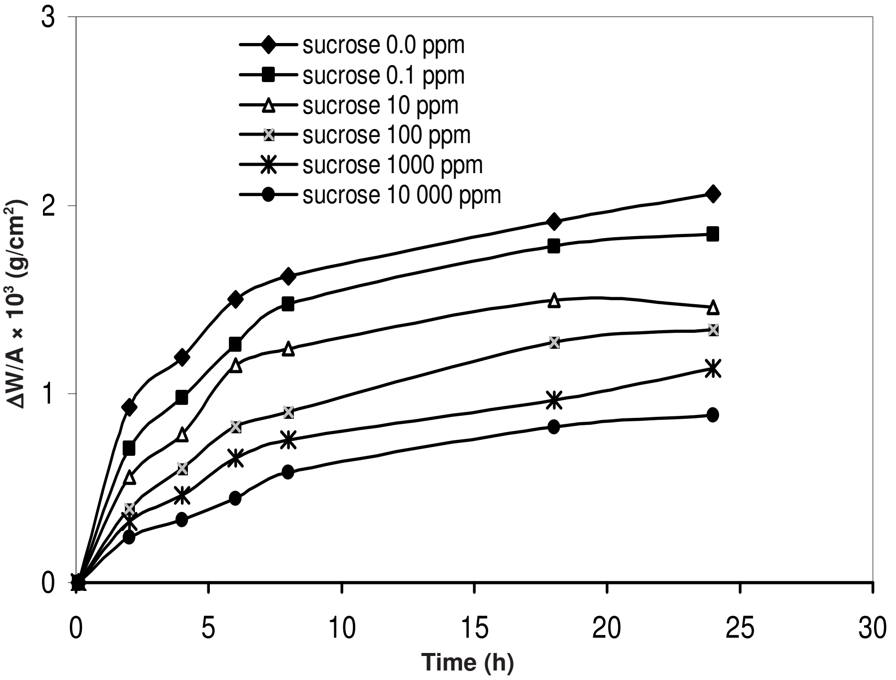

Fig. 1. Effect of sucrose concentration on weight loss (Δw) per area (A) of iron in sucrose-inhibited 0.01 M HCl

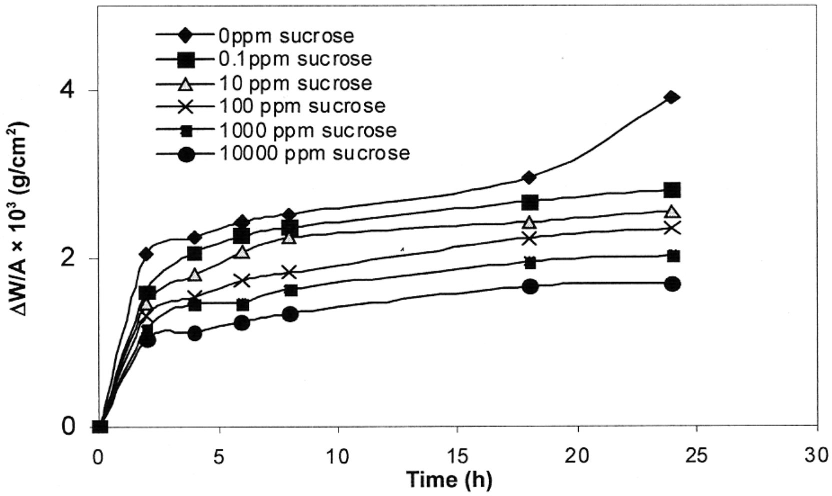

Fig. 2. Effect of sucrose concentration on weight loss (Δw) per area (A) of miled steel in sucrose-inhibited 0.01 M HNO_3 at 25 °C

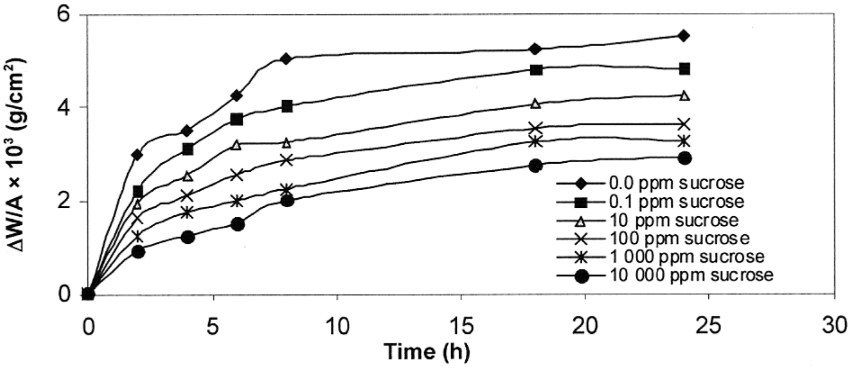

Fig. 3. Effect of sucrose concentration on weight loss (Δw) per area (A) of steel in sucrose-inhibited 0.01 M H_2SO_4 at 25 °C

These rates were plotted as a function of exposure time and sucrose concentration (Figs. 4-6). It is clear from the figures that as the exposure time increases, the corrosion rate drops rapidly reaching to a low value within *ca.* 8 h. After an exposure period of 8 h, the corrosion rate appears to continue falling slowly or almost remains constant. This is in agreement with the previous studies of different corrosion inhibitors. Further, it was observed that sulphuric acid is more corrosive and less inhibited by sucrose. This suggests that diprotic acids such as H_2SO_4, are less inhibitive than monoprotic acids such as HCl and HNO_3.

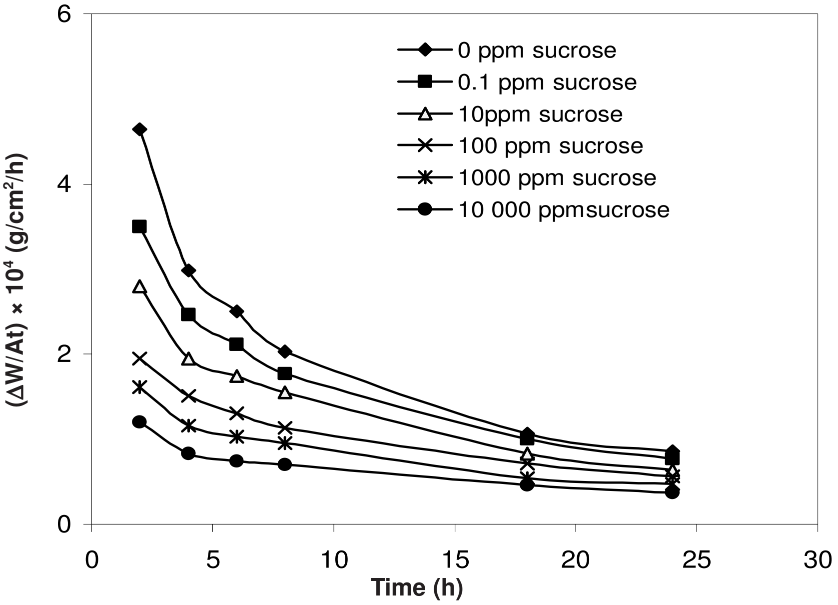

Fig. 4. Effect of exposure time (t) on corrosion rate of mild steel in sucrose-inhibited 0.01 molar HCl solution at 25 ºC at different concentration of sucrose

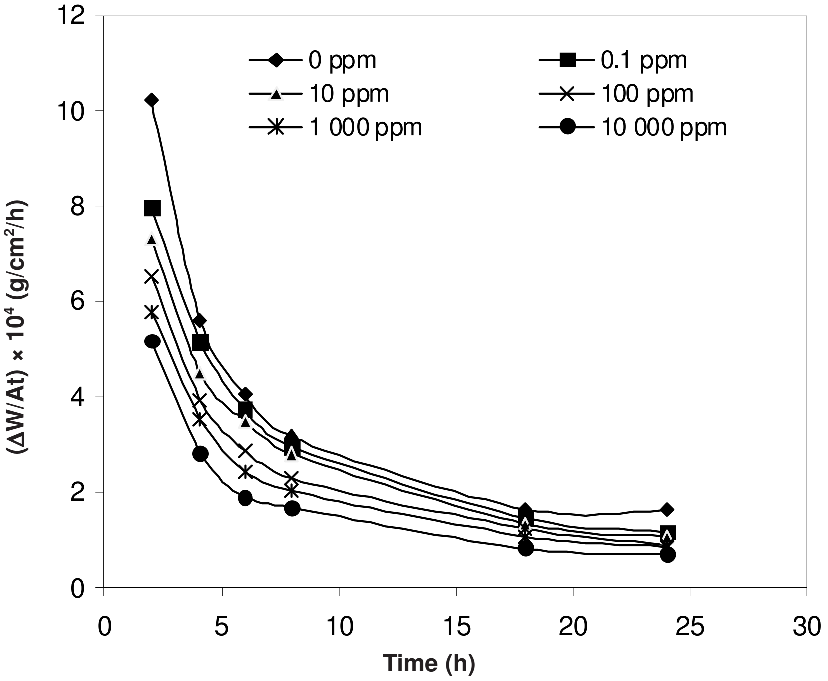

Fig. 5. Effect of exposure time (t) and sucrose concentration on corrosion rate of miled steel in sucrose-inhibited 0.01 molar HNO_3 at 25 ºC

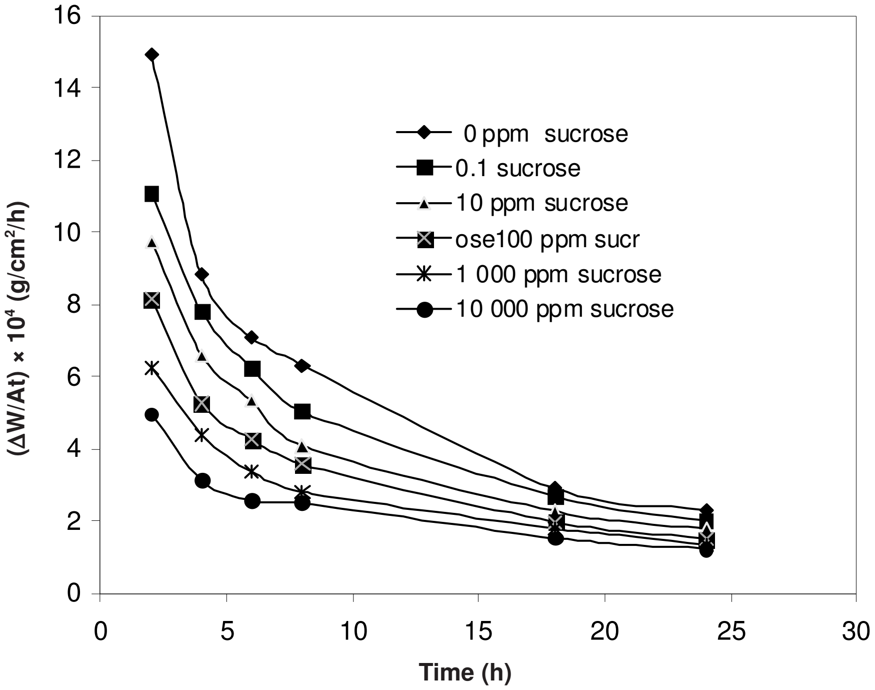

Fig. 6. Effect of exposure time (t) and sucrose concentration on corrosion rate of mild steel in 0.01 M H_2SO_4 at 25 ºC

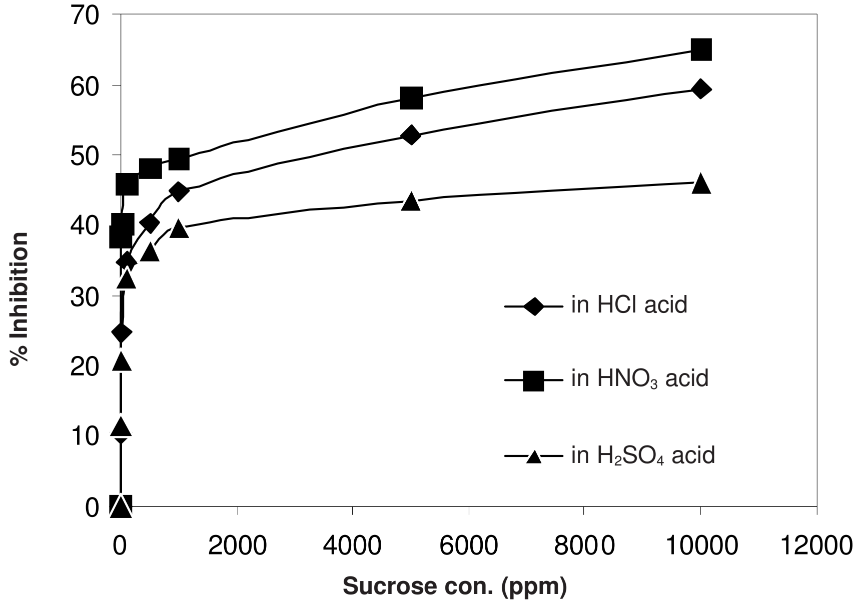

Fig. 7. Effect of sucrose concentration (ppm) on inhibition percentage % of iron corroson in sucrose-inhibited 0.01 M mineral acid solutions

It is noteworthy that a very low concentration of sucrose (0.1 ppm) induces as high as 80 % inhibition of corrosion of iron in sucrose-inhibited 1.5 M HCl solution. The rate of corrosion decreases with an increase in the concentration of the inhibitor and reaches to almost a constant value, where further addition of inhibitor has a very small effect or almost no effect. This observation suggests that the mechanism of the protection of iron include formation of protective film, after which no more effect is noted which is in agreement with the published results[12,13]. This mechanism suggests that iron adsorbs the inhibitor and catalyzes its polymerization to form a polymeric film on the surface of the metal. This film protects iron from the corrosion in the acidic medium.

Conclusion

Sucrose works as a good corrosion inhibitor against the corrosion of mild steel in the studied range of mineral acids concentration (0.01-1.5 M) at a temperature 25 ºC. The inhibition efficiencies for iron corrosion in HCl, HNO_3 and H_2SO_4 solution reach 80 % for 10000 ppm concentration of sucrose. This effect may be attributed to the formation of a polymeric protective film on the surface of the metal resistant against corrosion. Since sucrose is highly soluble in water and biologically safe, it could be used as corrosion inhibitor in many fields of industry. Especially, in the water tanks and pipelines and as an additive to cement paste to protect the concrete reinforced iron.

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