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Monosodium Glutamate as Corrosion Inhibitor for Low Carbon Steel in Circulated Crude Oil

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Abstract: Using monosodium glutamate as a corrosion inhibitor, the corrosion inhibition of low-carbon steel in a crude oil-circulated environment was examined. The corrosion measurement was analyzed using the method of weight loss. Researchers examined various monosodium glutamate concentrations and crude oil flow rates. Experiments were conducted using crude oil flow rates of 5, 10, 15, 20, and 25 L/min and inhibitor monosodium glutamate concentrations of 0, 50, 100, 150, 200, and 250 ppm. The corrosion rate, inhibition efficacy, and inhibition adsorption mechanism of low-carbon steel were measured. The study's results indicate that raising the flow rate raises the corrosion rate of carbon steel in crude oil while increasing the concentration of corrosion inhibitors decreases this rate. The effectiveness of monosodium glutamate as an inhibitor increased as inhibitor concentration, and flow rate increased. At a concentration of 250 ppm monosodium glutamate at a flow rate of 25 L/min, the highest inhibitory efficiency (75.21%) was observed. The monosodium glutamate adsorption on low-carbon steel surfaces follows Langmuir's adsorption isotherm.

Keywords: corrosion; low carbon steel; crude oil; circulated; monosodium glutamate; inhibitor.

1. Introduction

Because of the economic and natural asset losses caused by corrosion, metal corrosion protection has received much attention worldwide. Low-carbon steel is relatively inexpensive, and its properties make it suitable for a wide range of applications, primarily in petrochemical, oil and gas, chemical, food, power generation, electrochemical industries, and building constructions [1,2]. The main issue with low-carbon steel in many industries is its dissolution in aggressive media, such as crude oil as a corrosive medium in oil and gas industries [3-5]. The significant problem of metal corrosion is related to environmental, safety, and economic concerns. It can be reduced by approaching properly, delaying or breaking the anodic or cathodic reactions, or both [6-9].

Several authors have investigated the corrosion of metals in the crude oil environment. They report that some constituents that cause corrosion in crude oil refining are hydrogen sulfide, dissolved oxygen, carbon dioxide, water content, organic acid, naphthenic acid, and hydrochloric acid [10,11].

Corrosion inhibitors are commonly used in the industry to prevent metal dissolution and reduce the corrosion rate when in contact with a corrosive medium. Inhibitors are mostly organic compounds with nitrogen, sulfur, and oxygen in their molecule. Numerous scientific studies have been conducted on organic compounds as corrosion inhibitors for low low-carbon steel in crude oil medium [12-14]. The inhibition behavior results from the formation of a protective coating on the metal surface, which protects the metal from the corrosive substances present in the corrosive medium [6,15,16]

This study aimed to examine the effects of monosodium glutamate concentration and crude oil flow rate on the corrosion rate of low-carbon steel in a circulated crude oil medium. The inhibition efficiency and adsorption mechanism of the formed layer were also studied. The gravimetric weight loss technique was used to evaluate corrosion rate, inhibition efficiency, and adsorption mechanism.

2. Materials and Methods

2.1. Sample preparation.

The samples used in the experiment were low-carbon steel with the following compositions (wt%): 0.047 percent carbon, 0.197 percent manganese, 0.025 percent silicon, 0.014 percent phosphorous, 0.003 percent sulfur, 0.010 percent chromium, 0.004 percent molybdenum, 0.013 percent copper, 0.031 percent aluminum, and the remaining iron was used for weight loss evaluations. Mechanically cut samples were 50 x 12 x 1.5 mm in size. The samples were polished with fine-grade emery paper before being degreased, dried in acetone, and stored in a desiccator.

2.2. Gravimetric measurement.

The study used the gravimetric method to evaluate corrosion rate, efficiency inhibition, and adsorption mechanism. The gravimetric technique (weight loss) is probably the most widely used inhibition evaluation technique. The gravimetric method's simplicity and dependability in measuring provide the method procedures that have been used in numerous corrosion observations. In this experiment, the weight loss method was used to evaluate the effectiveness of monosodium glutamate corrosion inhibitor as a corrosion inhibitor in a crude oil environment in a circulating flow system. The cleaning of carbon steel metal with sandpaper, starting with the numbers 400, 600, 800, 1000, and 1200, is the first step in the testing procedure. The metal is then measured for the sample hole's length, width, thickness, and diameter, after which it is weighed to determine its initial weight using a Metler Toledo analytical balance with 0.1 mg precision. The low-carbon steel is then placed in the sample holder and mounted to the equipment. The crude oil test solution is added to the tank, and the monosodium glutamate inhibitor is added following the test parameters. The pump is then turned on, and the crude oil flow rate is adjusted following the test parameters using a flowmeter. After the test time has expired, shut down the equipment and remove the low-carbon steel sample from the sample holder, cleaning off any corrosion products that have formed. The sample is then immersed in a 10% hydrochloric acid solution, dried, and weighed to determine its final weight.

The corrosion rates were calculated using the equation below.

$$r = \frac{534\,W}{DAT} \quad (1)$$

Where r is the corrosion rate in mpy, W is the weight loss in mg, D is the density of low carbon steel in g/cm^3, A is the surface area in square inches, and T is the time of exposure in hours.

The following formula was used to calculate the efficiency of monosodium glutamate as a corrosion inhibitor:

$$E, (\%) = \frac{r_{unhibited} - r_{inhibited}}{r_{unhibited}} \, x \, 100\% \quad (2)$$

Where E denotes inhibition efficiency, $r_{unhibited}$ denotes the corrosion rate in the absence of an inhibitor, and $r_{inhibited}$ denotes the corrosion rate in the presence of an inhibitor.

The following equation can be used to calculate the surface coverage (θ) of monosodium glutamate on the surface of low-carbon steel:

$$\theta = \frac{r_{unhibited} - r_{inhibited}}{r_{unhibited}} \quad (3)$$

Where θ is the surface coverage, $r_{unhibited}$ denotes the corrosion rate without an inhibitor, and $r_{inhibited}$ denotes the corrosion rate with an inhibitor.

3. Results and Discussion

The gravimetric technique is used to measure the corrosion rate and has a wide range of practical applications [17-19]. According to Eq. 1, the corrosion rate can be explained as the relationship between the weight loss of the samples concerning their area and the immersion time. The advantage of this technique is that it is relatively simple and readily available. Furthermore, the technique uses a direct parameter for quantitative corrosion estimation, which is the mass loss of the metal in the process.

Figure 1 depicts the results of an investigation into the effect of crude oil flow rate on the corrosivity of carbon steel metal in a crude oil environment. It can be seen in the figure that the corrosion rate of carbon steel increases as the flow rate of crude oil increases. The corrosion rate of carbon steel increases to 38.2936 mpy when the flow rate is increased to 25 L/min. The increase in corrosion rate is due to the addition of frictional force between the flowing crude oil and the surface of the carbon steel metal due to the increased flow rate, which causes metal erosion to occur more quickly.

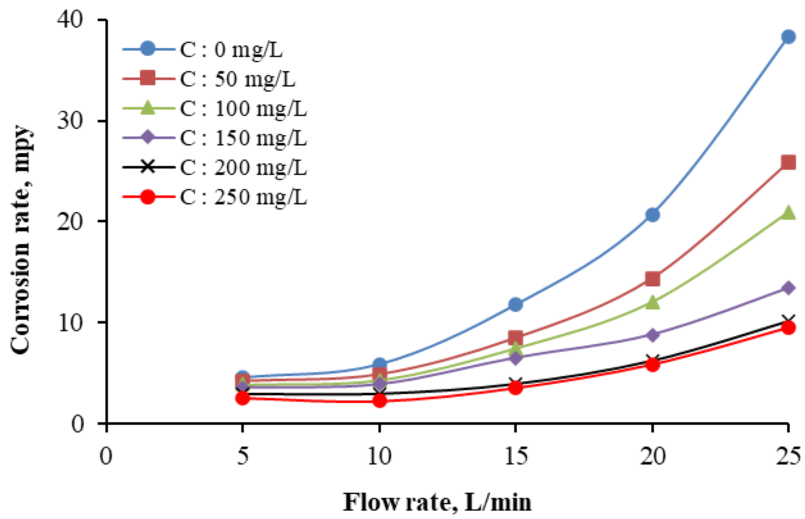

Figure 1. The influence of flow rate on the corrosion rate of carbon steel in a crude oil environment.

Adding corrosion inhibitors to a corrosive environment is intended to slow the rate at which metals corrode in specific environments. Figure 2 illustrates the effect of monosodium glutamate concentration on the corrosion rate of carbon steel in a circulating crude oil environment. It can be seen in Figure 2 that increasing the concentration of monosodium glutamate inhibitor lowers the rate of corrosion of carbon steel in a circulating crude oil environment. The corrosion rate of 38.2936 mpy was obtained without the addition of inhibitors at a flow rate of 25 L/min, but the corrosion rate decreased to 9.4916 mpy after adding 250 mg/L monosodium glutamate. The study's findings revealed that organic inhibitors were adsorbed on the metal surface, forming a thin layer that prevented direct contact between the corrosive medium and the metal. Consequently, as the concentration of monosodium glutamate increases, the layer becomes wider and covers more of the metal, resulting in a reduction in the rate of metal corrosion.

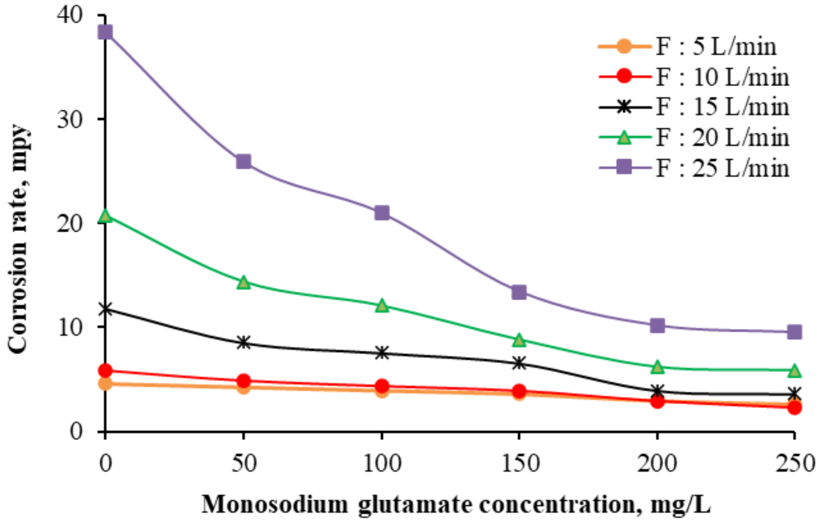

Figure 2. Effect of monosodium glutamate concentration on carbon steel corrosion rate in crude oil.

Figure 3 illustrates the inhibitory efficiency of monosodium glutamate inhibitors in inhibiting the corrosion rate of carbon steel in a circulating crude oil environment. It can be seen that the inhibitory efficiency of monosodium glutamate on carbon steel in a circulating crude oil environment increases with an increase in monosodium glutamate concentration. The maximum inhibition efficiency obtained was 75.21%, achieved at a concentration of 250 ppm and a flow rate of 25 L/min. This pattern holds the inhibitory efficiency of monosodium glutamate regardless of the amount of flow rate variation. This phenomenon can be explained by the fact that increasing monosodium glutamate concentrations result in an increase in the amount of monosodium glutamate covered on the surface of low-carbon steel as a result of the adsorption process on the surface of low-carbon steel. It also explained that as the concentration of monosodium glutamate in the solution increases, the adsorption of monosodium glutamate molecules on the surface of low-carbon steel increases, resulting in the formation of more dense layers. The low-carbon steel surface is thus isolated, and the adsorbed film of inhibitor acts as a physical barrier between the low-carbon steel and the corrosive medium, preventing corrosion of the low-carbon steel.

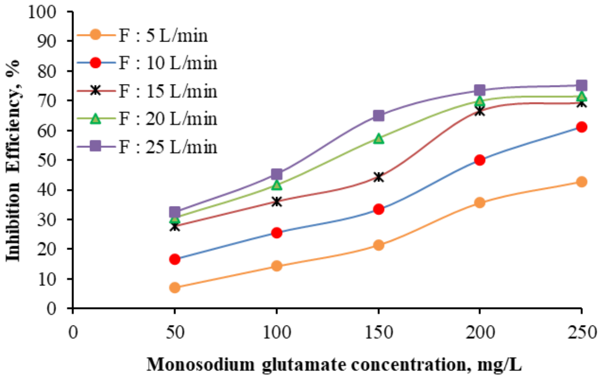

Figure 3. Monosodium glutamate's inhibitory effect on carbon steel in a crude oil environment.

Understanding the mechanism of the corrosion inhibition reaction is critical. The adsorption behavior of the corrosion inhibitors can be used to explain the mechanism of corrosion inhibition. The isotherms Langmuir [20-22], Freundlich [23,24], Frumkin [25,26], and Temkin [27,28] are the most commonly used. The Langmuir adsorption isotherm assumes that there is no interaction between molecules adsorbed on the metal surface, Freundlich indicates that multilayer resulted in the surface of metals, whereas the Frumkin adsorption isotherm assumes that there is some interaction between the adsorbates, and the effect of multiple layer coverage represents the Temkin adsorption isotherm.

In this result, Langmuir's postulate was developed assuming that the layer formed is a monolayer or a single layer. Using this postulate, the data obtained from the research is analyzed and plotted in a graph. Suppose the plot of the research data follows Langmuir's postulate. In that case, it can be concluded that the mechanism of inhibition of monosodium glutamate in inhibiting the corrosion rate is by forming a layer on the surface of the carbon steel so that the contact between carbon steel and the environment is inhibited.

Figure 4 depicts a plot of research data created using Langmuir's postulate. According to the graph in Figure 4, it can be seen that the curves and lines obtained are in good agreement with the Langmuir adsorption isotherm postulate, which indicates that the adsorption of monosodium glutamate follows the Langmuir postulate. As a result, according to the Langmuir isotherm, a single layer of low-carbon steel was formed on the surface of the steel.

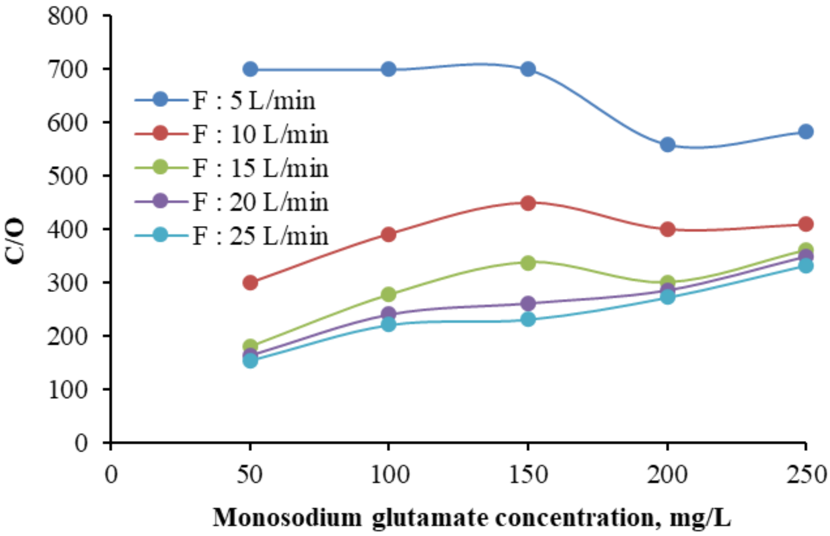

Figure 4. Graph of Langmuir isotherm inhibitor monosodium glutamate on carbon steel in crude oil.

4. Conclusions

The corrosion of carbon steel is affected by the flow rate of crude oil. The rate of corrosion increases with the crude oil flow rate. The concentration of monosodium glutamate inhibitor affects carbon steel corrosion in circulating crude oil. The concentration of monosodium glutamate affects the corrosion rate. The lowest corrosion rate of 2.6184 mpy was achieved at 250 ppm and 5 L/min. The efficiency of inhibition increased with monosodium glutamate concentration. The highest inhibition efficiency was 75.21%. The adsorption of monosodium glutamate on carbon steel surfaces follows the Langmuir isotherm postulate.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this paper.

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