Journal of Molecular Liquids 271 (2018) 240–245

Contents lists available at ScienceDirect

Journal of Molecular Liquids

journal homepage: www.elsevier.com/locate/molliq

The effect of disodium cocoamphodiacetate on corrosion-erosion resistance of steel in saline water

M.A. Deyab

Egyptian Petroleum Research Institute (EPRI), Nasr City, Cairo, Egypt

ARTICLE INFO

Article history:
Received 1 July 2018
Received in revised form 28 August 2018
Accepted 1 September 2018
Available online 04 September 2018

Keywords:
Zwitterionic surfactant
Saline produced water
Erosion-corrosion
Steel

ABSTRACT

The inhibitory actions of disodium cocoamphodiacetate (zwitterionic surfactant, abbreviated as ZS) on the erosion-corrosion of API ×52 steel in sand-containing saline produced water (SSPW) were explored by using electrochemical techniques. The scanning electron microscopy (SEM) and atomic force microscopy (AFM) were used to analyze the steel surface. The results showed that the ZS reduced the effects of the erosion-corrosion of API ×52 steel in SSPW solution. The extent of ZS performance depends on ZS concentration, solution temperature, static and dynamic conditions. The nature of ZS surfactant (i.e. mixed type of inhibitor) was extracted from polarization curves. ZS is more effective in static condition than in dynamic condition. The maximum inhibition efficiency of ZS is 93.2% and 66.7% at static and dynamic conditions, respectively.

1. Introduction

During the transportation of sand-containing saline produced water, steel pipes are suffering from erosion-corrosion effects [1–3]. This harmful effect causes a high cost in the petroleum field [4,5].

The troubles arising from erosion-corrosion pushed the researchers to produce several methods for reducing the effects erosion-corrosion. The injection of corrosion inhibitors is considered an effective method to control erosion-corrosion [6–8].

Previous studies by researchers indicated that the corrosion inhibitors can suppress both the reduction of metal loss during erosion and active corrosion [9–12].

Senatore et al. [9] indicated that the $FeCO_3$ film and corrosion inhibitors gave a significant effect on the erosion-corrosion resistance of carbon steel pipeline. Zeng et al. [10] investigated the inhibition of the erosion-corrosion of steel bend using thioureidoimidazoline inhibitor. They found that the inhibition of corrosion by inhibitor is far more than that of erosion. Neville et al. [11] focused on the using of the two commercial corrosion inhibitors reduce erosion–corrosion damage in liquid–solid flows. They indicated that erosion–corrosion inhibition is mainly due to the inhibitor film formed on the metal surface.

Surfactants are widely used to control the corrosion of steel in saline waters and acidic solutions [13–15]. The essential role of surfactants inhibition depends on the adsorption ability of surfactant molecules on the metal surface forming a protective layer [16–19].

The types of surfactants represent the main factor in the efficiency of the adsorption process. Zwitterionic surfactants are characterized by two charged groups (positive charge and negative charge groups) in one molecule. This allows using the zwitterionic surfactants in a wide range of pH solutions and covering positive and negative active sites on the metal surface. This makes zwitterionic surfactants promising materials to work as corrosion inhibitors. In addition, zwitterionic surfactants are characterized by the low cost, low poisoning, and effortless production.

In this work, disodium cocoamphodiacetate as a zwitterionic surfactant ZS is used for reducing the effects of erosion-corrosion of API ×52 steel in SSPW solution. The study was carried out using electrochemical measurements, SEM and AFM analysis.

2. Materials and methods

API ×52 steel rod (composition wt%: S 0.025, Mn 0.9, C 0.12, Si 0.45, and Fe 98.505) was used as tested material (exposed circular area = 0.45 cm^2).

Before the experiments, the surface of API ×52 steel stripes was prepared and cleaned according to ASTM G1-03.

Tafel polarization and anodic polarization experiments were performed by Potentiostat/Galvanostat EG-G: 273A (EG&G PRINCETON APPLIED RESEACH). All experiments occurred in three- electrode cell. The reference electrode here is a saturated calomel electrode (SCE) and the counter electrode is platinum wire.

The experimental cell (500 ml) for erosion-corrosion measurement had been previously described [20].

E-mail address: hamadadeiab@yahoo.com.

https://doi.org/10.1016/j.molliq.2018.09.002
0167-7322/

Table 1
Physical properties of the produced water.

Physical property	Value
Total dissolved solids	89,000 mg/l
Conductivity	12.30 mohs/cm @ 21.8 °C
Resistivity	0.093 Ω/m @ 21.8 °C
pH	6.8@ 25 °C

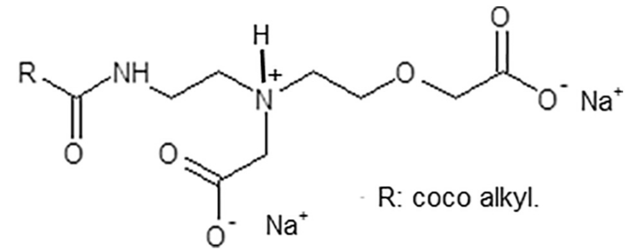

Fig. 1. The formula of zwitterionic surfactant (ZS) - Disodium cocoamphodiacetate.

The Tafel curves were recorded in the range −200 to +200 mV vs. corrosion potential (E_{corr}) with 0.125 mV s^{-1} scan rate.

For potentiodynamic anodic polarization measurements, the potentiodynamic *E*/*j* curves were implemented properly by moving the potential *E* from −1.5 V to more positive potential with 0.125 mV s^{-1} scan rate. Polarization experiments were undertaken in static and dynamic system. Each experiment was repeated three times to provide a statistical basis for the results.

The surface characterizations of API ×52 steel specimens were defined by employing SEM and AFM analysis. The SEM images were taken by electron microscope (type: JEOL-JEM 1200 EX II). AFM images were performed with a multimode microscope stand controlled by a nanoscope III electronic (Digital Instruments).

The test solution was composed of 5.0 wt% silica sands (average size = 80 μm) and produced water balance. The solution pH value was 6.8 before and after addition of sands. Produced water was collected from Egyptian Western Desert oil-field. Whatman filter paper was used to remove fine substances from water. Information about the physical features and chemical composition of produced water were listed in Tables 1 and 2, respectively. In the experiments, the volume of corrosive solution is 500 ml.

Total dissolved solids (TDS) were determined according to ASTM –D5907. Conductivity and resistivity of produced water were determined using conductivity mete WTW 3301 according to ASTM –D1125. The pH of test solutions was recorded by digital pH meter (metler Toledo-Seven Co.) according to ASTM –D1293.

The formula of zwitterionic surfactant ZS (Disodium cocoamphodiacetate) is presented in Fig. 1. ZS surfactant was purchased from KOA Chemicals Company. The concentration range of ZS surfactant was 20–80 ppm (by weight). The ZS surfactant is completely soluble at all suggested concentrations.

3. Results and discussion

3.1. Influence of ZS surfactant concentrations

Fig. 2 represents the influence of ZS surfactant concentrations on the Tafel behavior of API ×52 steel in SSPW solution with velocity of 2 m s^{-1} at 303 K. It is clear that the presences of ZS surfactant give rise to the shifting of Tafel lines (anodic and cathodic lines) to lower current densities. This indicates that ZS surfactant has a great inhibitory effect on the erosion-corrosion of API ×52 steel in SSPW solution. The inhibitory effect of ZS surfactant increases with its concentrations.

To observe the influence of ZS surfactant on the corrosion behavior of API ×52 steel in SSPW solution, the electrochemical parameters i.e. corrosion current density (j_{corr}), corrosion potential (E_{corr}) and cathodic and anodic Tafel slopes (b_c and b_a), were extracted and listed in Table 3. Also, the corrosion inhibition efficiency (η%) of ZS surfactant is computed using the relationship [21]:

$$\eta\% = \left[\left(j^0{}_{corr} - j_{corr}\right)/j^0{}_{corr}\right] \times 100 \quad (1)$$

here j_{corr} and $j^0{}_{corr}$ represent the corrosion current densities with and without ZS surfactant, respectively.

Table 3 lists the inhibition efficiency of ZS surfactant at various concentrations.

The values of j_{corr} (Table 3) are extremely minimized by adding ZS surfactant, and the η% values increase with the concentration of ZS surfactant. The maximum η% of ZS surfactant was achieved at 80 ppm. Beyond this concentration (i.e. 80 ppm), no significant change takes place in the η% value.

The inhibitory effect of API ×52 steel in SSPW solution by the ZS surfactant can be illustrated according to adsorption mechanism. The effectiveness of ZS surfactant as corrosion inhibitor depends on its chemical

Table 2
Chemical composition of produced water.

Constituents	Concentration (ppm)
Sodium	22677
Magnesium	986
Potassium	1432
Calcium	7430
Chloride	50455
Bromide	256
Bicarbonate	298
Sulfate	1564

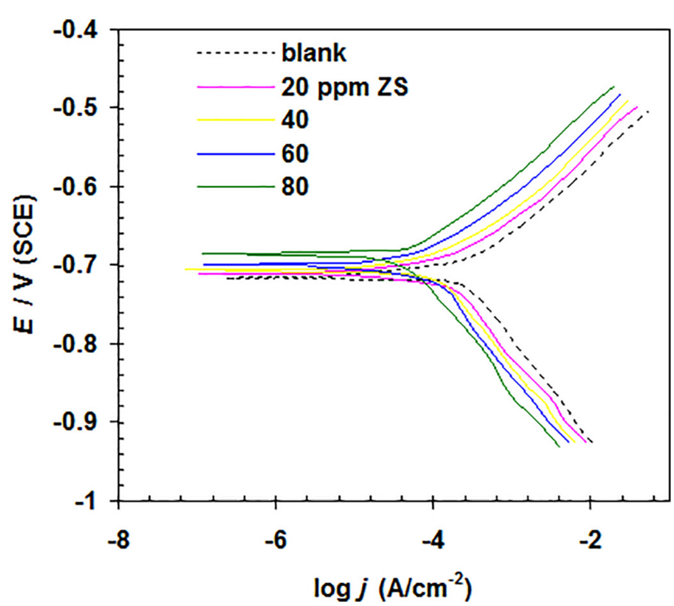

Fig. 2. Tafel polarization curves for API X52 steel in SSPW solution in the absence and presence of ZS surfactant with solution velocity of 2 m s^{-1} at 303 K.