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Corrosion of Electrical Submersible Pumps (ESP) In South Rumaila Oil Field

Dr. Talib Abdullah Saleh, *Dr. Safaa Husain Sahi and Layla Sideeq Mohamed
Petroleum Engineering Department/University of Baghdad
*Ministry of Oil

Abstract

Rotating cylinder electrode (RCE) is used . in weight loss technique , the salinity is 200000 p.p.m, temperatures are (30,5060,7080Co) . the velocity of (RCE) are (500,1500,3000 r.p.m). the water cut (30% , 50%). The corrosion rate of carbon steel increase with increasing rotating cylinder velocity. In single phase flow, an increase im rotational velocity from 500 to 1500 r.p.m, the corrosion rate increase from 6.88258 mm/y to 10.11563 mm/y respectively.

In multiphase flow, an increase in (RCE) from 500 to 1500 r.p.m leads to increase in corrosion rate from 0.786153 to 0.910327 mm/y respectively. Increasing brine concentration leads to increase in corrosion rate at water cut 30%.

Key Words: rotating cylinder electrode, Weight loss, polarization, protective film.

Introduction

Corrosion is an important and costly problem in the petroleum industry, requiring special consideration in the design of production equipment. Severe environments involving CO_2 and H_2S pose particular difficulties. Corrosion cost the petroleum industry hundreds of millions of dollars annually. Water flood, CO_2 flood, deep gas wells are excellent examples of cases have provided many materials and corrosion problems are expected to continue to do so [1]. Corrosion rate in neutral, low salinity solution is normally very low. In contrast, corrosion rates are very high in low pH solution that forms the presence of acidic materials or high CO_2 partial pressure [2]. Most of the southern Iraqi oil fields produced large quantities of water, often a brine, with produced oil. This water has high salinity about 200,000 ppm in addition to this brine, compounds such as carbone dioxide (CO_2), H_2S, oxygen mineral acids, organic acids or other chemicals that affect pH, these corrodants are highly corrosive to the carbon steel which has low resistance to the corrosion, these compounds combine to form a corrosive environment under different environmental conditions. Carbone dioxide (CO_2) corrosion also known as sweet corrosion is one of the major problems in the oil and gas industry costing billions of dollars every year [3] .Corrosion in gas and oil industries mainly deals with CO_2 gas, as it is the species presenting in oil field. The hydration of CO_2 to carbonate acid causes corrosion on carbone steel [4]. It is due to carbonate acid can decrease pH of the medium. Degree of corrosiveness due to CO_2 gas influenced by environmental conditions such as temperature, CO_2 partial pressure, corrosion film properties and flow conditions. Due to its low cost and availability, carbone steel is used as the primary construction material for pipelines in the oil and gas industries and electrical submersible pumps, but it is very susceptible to corrosion in CO_2 environment. Aqueous carbone dioxide (carbonic acid) is corrosive and corrodes the carbone steel pipelines and ESP [5]

Experiment Setup

Specimen Preparation

A rotating cylinder electrode (RCE) is a cylindrical material embedded in to a non-conducting material such as Teflon, and attached to an electric motor with a controlled rotation speed. The working electrodes were carbon steels, before every test the specimens washing with running tap water, cleaned with emery paper of grades 100, 150, 200, 320, 400 and 600 to remove the weakly adherent corrosion scale, washed by tap water, rinsed with distilled water, dried with A rotating cylinder electrode (RCE) is a cylindrical material embedded in to a non-conducting material such as Teflon, and attached to an electric motor with a controlled rotation speed.

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Fig. 1, Rotating Cylinder Electrode

Cell Solutions

The experiments were performed in both single phase (brine of salinity 200,000 ppm) and multiphase flow by injection gas CO_2 into the solution. In single-phase flow, the glass cell was filled with 2 liter of brine of salinity 200,000 ppm NaCl, while in multiphase flow the glass filled with different percents of brine with kerosene, which was stirred with motor. Weight loss technique system was shown in Fig. (2)

Corrosion rate measurement

A. Weight loss technique

Weight loss was used to measure the corrosion rate of the metal. During weight loss technique, the specimens were prepared as described above, and corrosion rate measured by weighting the specimens before and after each test, corrosion rate can be obtained from Eq.(1)

$$C.R(mdd)=\frac{weight\ loss\ (mgm)}{A(dcm^2)*t\ (day)} \quad \ldots(1)$$

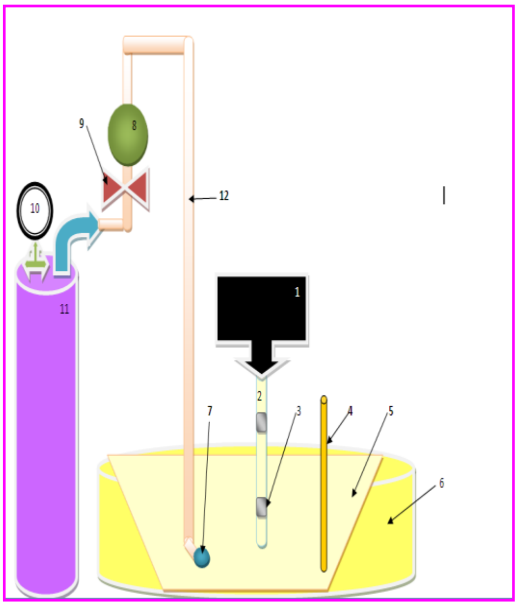

Fig. 2, Weight loss technique system:1-Rotating motor 2-Rotating shaft 3-Working electrode 4-Thermometer 5-beaker 6-Water bath 7-CO_2 Distributed 8-Gas flow meter 9-One way valve 10-Pressure gauge 11-CO_2 Source 12-High pressure tube.

Results and Discussion of weight loss Results

1. Effect of pH

The higher pH, the lower is the corrosion rate. The pH is influenced by changing the H^+ ions concentration, temperature and pressure, the increase of pH causes film thickening and film becoming more dense and protective. In the present investigation, the system is under the summation of both an appreciable rate of hydrogen evolution and oxygen depolarization because pH values were less than 4 [6]

$$2H^+ + 2e \rightarrow H_2 \quad \ldots(2)$$

$$2H_2CO_3 + 2e \rightarrow 2HCO^-_3 + H_2 \quad \ldots(3)$$

$$2HCO^-_3 + 2e \rightarrow 2CO^-_3 + H_2 \quad \ldots(4)$$

$$2H_2O + 2e \rightarrow 2OH^- + H_2 \quad \ldots(5)$$

While oxygen reduction is expressed by the eq.(6)

$$O_2 + 4H+ \ + 4e \rightarrow 2H_2O \quad \ldots(6)$$

An increase in temperature leads to an increase in pH values as a result of decreasing in the solubility of CO_2 gas so leading in decreasing in the acidity of the solution as shown in fig. (3)

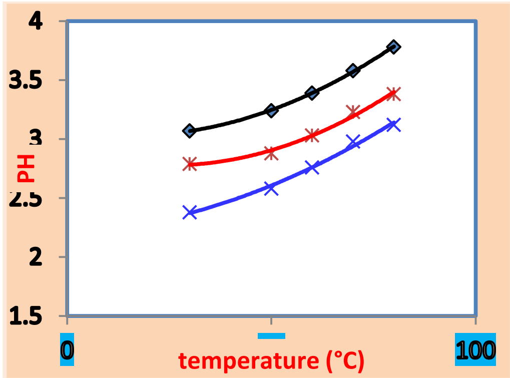

Fig.3, The relationship between pH and temperature at water cut= 30% and different CO_2 flow rates

2. Effect of Temperature

Corrosion likes any chemical reaction increases with an increase in the temperature, corrosion rates reach maximum value at 70° C then it start to decrease with farther increase in temperature from 70-80° C due to the formation of the protective film (iron carbonate) on the metal surface, this film protect the metal from the contact with the corrosive aqueous solution, and the other reason is due to the reduction of oxygen solubility in the solution as shown in fig.(4).

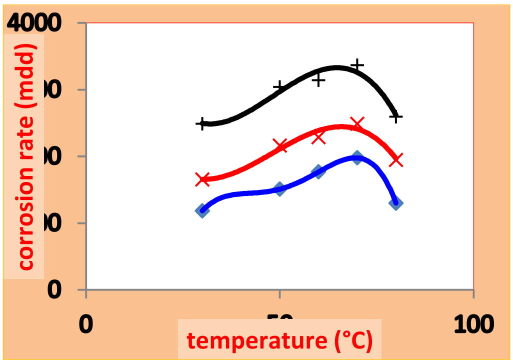

Fig.4, The relationship between the corrosion rate and the temperatue at different velovities for single phase flow

3. Effect of CO_2 partial pressure

An increase in CO_2 partial pressure leads to an increase in corrosion rate as shown in fig. (5).

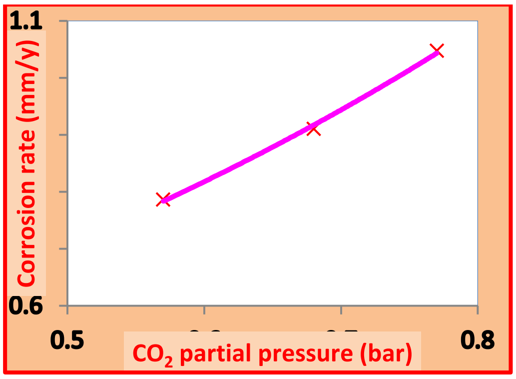

Fig.5, The relationship between CO_2 partial pressure and the corrosion rate for water cut 30%, CO_2 flow rate 0.0464 m^3/hr and temperature 30 °

4. Effect of flow

Corrosion rate of the metal increases with an increase in fluid velocity, this is called erosion-corrosion and this occurs as a result of two causes the first one that is an increase in fluid velocity leads to an increase in the diffusion rate of active species in the solution to the metal surface, the second reason is that the high fluid velocity will decrease the diffusion boundary layer (thickness of the film through which oxygen must diffuse in the corrosion process as shown in fig. (6).

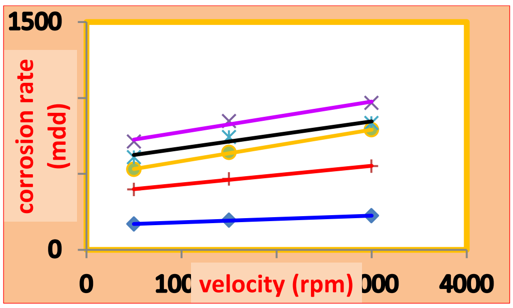

Fig.6, The relationship between the corrosion rate and rotating cylinder velocity at different temperatures at water cut=30% and CO_2 flow rate=0.0464m^3/hr

5. Effect of CO_2 flow rate

An increase in CO_2 flow rate leads to reduce pH of the solution, which in turn lead to increase the corrosion rate by dissolving the protective film as shown in Fig. (7).

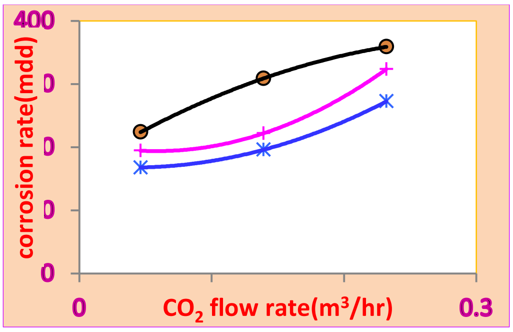

Fig. 7, The relationship between CO_2 flow rate and corrosion rate at 30 ° C and wter cut = 30 % and at different velocities

B. polarization Technique

In this technique the solutions and coupons preparation were similar to that in weight loss technique without weighting the coupons

Electrodes

Three-electrodes were used in all electrochemical experiments. A rotating cylinder electrode with a speed control unit was used as the working electrode. Graphite was used as auxiliary electrode and a saturated calomel electrode (SCE) used as reference electrode, which used to measure the potential of the working electrode.

Electrical apparatus

The apparatus that used during polarization technique were DC power supply, resistance box; voltmeter was used to measure the potential of the electrode with respect to reference electrode, ammeter which used to measure the current of the cell. Fig. (8-a) and fig.(8.b) show the electrical cell of rotating cylinder electrode:

Fig.8, a Rotating Cylinder Electrode (RCE) electrical cell

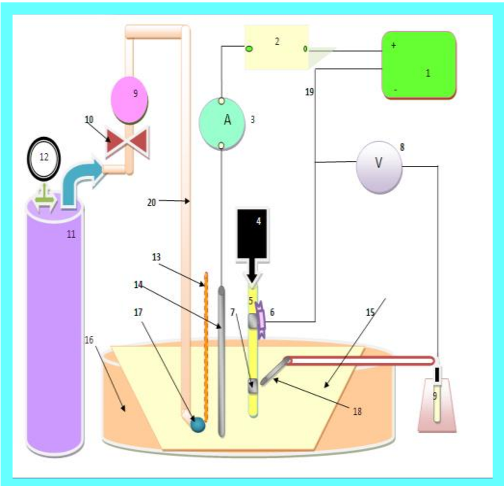

Fig.8, b Polarization system:1-Power supply 2-Resistance box 3-Ammeter 4-Rotating motor 5-Rotating shaft 6-Carbone brush 7-Working electrode 8-Voltmeter 9-Reference electrode 10-One way valve 11-CO_2 Source 12-Pressure gauge 13-Thermometer 14-Auxilary electrode 15-Beaker 16-Water bath 17-CO_2 Distributed 18-Lugging-haber capillary 19-Wires connection 20-High pressure tube

Corrosion rate measurement

The experimental limiting current densities values are obtained by taking the average of points representing the

Concentration polarization in the Tafel curve, Tafel curve for CO_2 flow rate=0.1392m^3/hr, temperature= 30 ºC and velocity=1500 rpm shown in fig. (9)

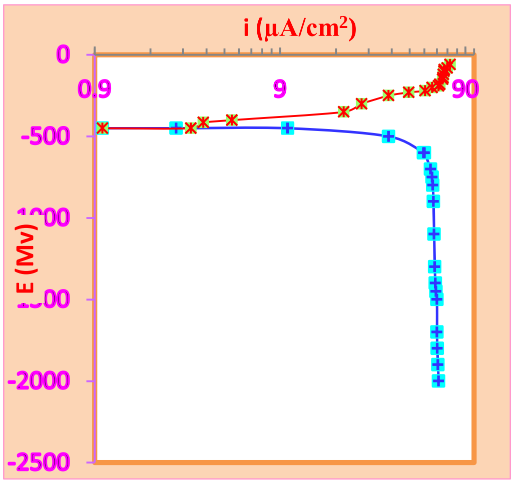

Fig.9, Polarization diagram at CO_2 flow rate=0.1392m^3/hr, temperature= 30 ºC and velocity=1500 rpm

Results and Discussions of polarization technique

❖ Effect of Temperature

An increase in temperature leads to an increase in limiting current according to Eq. (7)

$$i_L = \frac{nfD}{\delta} Cb \qquad \ldots\ldots\ldots (7)$$

as shown in Fig. (10)

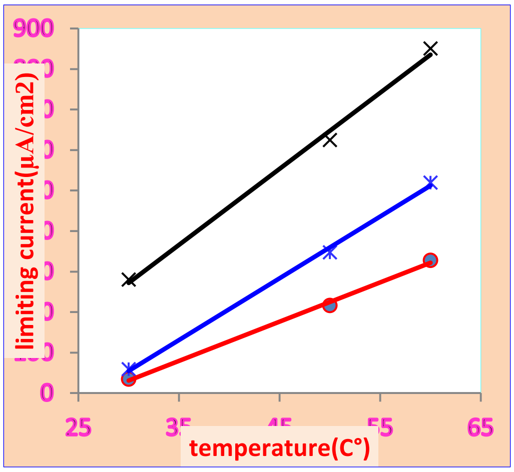

Fig. 10, The relationship between the temperature and the limiting current density at CO_2 flow rate=0.1392 m^3/hr and at different velocities

❖ Effect of rotating cylinder electrode

An increase in rotational velocity leads to an increase in limiting current as shown in Fig. (11)

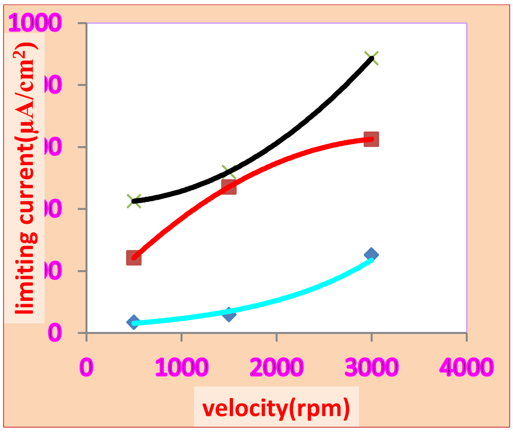

Fig. 11, The relationship between the velocity and limiting current density at CO_2 flow rate=0.1392 m^3/hr and at different temperatures

Conclusions

1. Weight loss technique:

A. Single phase flow

- ❖ Corrosion rates of the metal in the brine (200,000ppm NaCl) are more than the corrosion rates in the multiphase flow (brine-CO_2-kerosene) due to the dominate effect of oxygen diffusion comparing with the effect of the hydrogen evolution.
- ❖ An increase in the rotating cylinder electrode velocity leads to an increase in the corrosion rate of the metal.
- ❖ Increasing the temperature of the solution from 30 to 70° C leads to an increase in the corrosion rate of the metal to reach maximum value at 70° C, and then it begins to falling to reach minimum rate at 80° C due to formation of the protective film at 70 ° C and as a result of decreasing the solubility of oxygen and the injected CO_2 in the solution.
- ❖ The effect of rotating cylinder electrode velocity on corrosion rate is more than the effect of temperature.

B. Multiphase flow

- ❖ Through studying CO_2 corrosion mechanism, it can be concluded that CO_2 corrosion produce a very thin films. The film properties such as porosity, contour surface appearance and quality of the film change with time and influenced by solution compositions.
- ❖ Temperature and velocity approximately have combination effect on the corrosion rate of Carbone steel.
- ❖ An increase in brine concentration, lead to an increase in corrosion rate.
- ❖ Brine concentration has more influence on the corrosion rate compared to the temperature and rotating cylinder electrode velocity.
- ❖ An increase in CO_2 flow rate led to an increase in corrosion rate.
- ❖ Corrosion rates of the metal at higher pH values less than the corrosion rates at lower pH values; the decrease of corrosion rate in the higher of pH is controlled by the film formation.
- ❖ pH values of the solution were less than 4 and this means that the system was under the combination effect of hydrogen evolution and oxygen diffusion.

2. Polarization technique:

- ❖ An increase in rotating cylinder electrode velocity, lead to an increase in limiting current density, because when the velocity increase diffusion layer thickness will decrease which in turn leads to an increase in the limiting current density according to the eq.(7)

- ❖ An increase in temperature, lead to an increase in limiting current density
- ❖ CO_2 flow rate don't have any influence on the anodic reaction
- ❖ An increase in rotating cylinder electrode velocity lead to shifting the corrosion potential in the positive direction, while an increase in temperature of the solution lead to shifting the corrosion potential in the negative direction.
- ❖ pH values of the solution were less than 4 and this means that the system was under the combination effect of hydrogen evolution and oxygen diffusion.

Nomenclatures

A: area of the electrode
C.R: corrosion rate
ESP: Electrical submersible pumps
W.L: Weight loss technique
RCE: Rotating cylinder electrode
Cs : surface concentration of the reaction species
Cb: bulck *concentration* of the reaction species
σ = diffusion layer thickness
n: the number of electrons transferred

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