CORROSION BEHAVIOR OF ASTM A106 GR.B CARBON STEEL EXPOSED TO SODIUM SULFATES SOLUTIONS

By

Mohamed Mohamed Nabil Abdel-Monem Mahmoud

A Thesis Submitted to the

Faculty of Engineering at Cairo University

in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

in

Metallurgical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

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Title of Thesis:

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Key Words:

Carbon steel; Polarization; SEM; Anodic dissolution; Weight loss

Summary:

The purpose of this research is to identify the effect of various parameters (concentration, temperature and stirring speed of sodium sulfates) in testing electrolytes on corrosion behavior of ASTM A106 Gr.B carbon steel pipelines. The morphology and composition of the corrosion product deposits were determined using optical and scanning electron microscopy while EDAX analysis was used to determine the chemical composition of the corrosion products. Based on weight loss as well as potentiodynamic polarization measurements, the highest corrosion rate was detected for electrolytes containing 0.5 M Na_2SO_4. Temperature influence was significant on oxide layer density and stability, with the appearance of thick cracked layer as the temperature as well as the sulfate concentration increased. Increasing solution speed had a corrosive effect on metal surface as the highest corrosion rate was observed for the highest speed (1250 rpm).

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

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Abstract

Corrosion of metals plays a crucial role because of its dual impacts for both safety as well as economy. Many types of steels are used extensively throughout industry (petroleum, nuclear, power, medical, chemical and electrochemical industries). Among these various types, carbon steel is used in large tonnages in petroleum production and refining industries. On the other hand, millions of dollars are lost each year because of corrosion. Much of this loss is due to the corrosion of carbon steels.

In the present work, the corrosion behavior of ASTM A106 Gr.B carbon steel subjected to Na_2SO_4 environments was studied in a range of sulfates concentration, different working temperature and different stirring speed. Chemical and electrochemical measurements such as immersion tests, open circuit potential (OCP) measurements and accelerated potentiodynamic polarization tests were used to characterize the corrosion process and evaluate the corrosion rates. Furthermore, Information about surface morphology and product film formation were examined by optical microscopy and scanning electron microscopy (SEM) while the chemical composition of the corrosion products was determined by EDAX analysis.

The results of immersion and potentiodynamic tests revealed that, the corrosion process was accelerated by increasing the sulfate ions concentration up to 0.5 M Na_2SO_4 and further increment in the sulfate ions concentration had an inhibition effect on the corrosion process. In addition, Increasing sulfates content results in a change in the open circuit potential (OCP) towards higher active values (-1000mv). The Morphologies of the corrosion attack after 3 month of exposure can be regarded as partially uniform. The results from potentiodynamic tests indicated the corrosion rates were drastically increased with increasing the working temperature. Furthermore, temperature influence was significant on corrosion product layer density and stability. Optical microscope and SEM confirmed the appearance of spongy cracked layer as the sulfate concentration increases up to 0.5 M and increasing temperature up to 60 ˚C. EDAX analysis showed that as the temperature increased, the weight percent of Fe, S, C, decreased and the percent of O increased (in agreement with the increase of corrosion rate at 0.5 M Na_2SO_4 at all temperatures). While, as the concentration increased, highest sulfur content was detected for 1M Na_2SO_4. The results from potentiodynamic tests indicated that stirring of test solution accelerated the corrosion process up to 1250 rpm. It was concluded that the most significant effect on corrosion process of all working parameters was the effect of temperature.

Chapter 1: Introduction

The issue of corrosion in petroleum industries is an extreme worldwide concern because corrosion impacts every side of exploration and production, from offshore rigs to casing. Corrosion problems appeared and affected petroleum industry in different areas: oil producing, transporting and storing and crude oil refining.

Regarding oil Producing, very salt water and sulfides generally exist in producing wells. Corrosion in wells takes place inside and outside casing and tubing due to the presence of H_2S and CO_2, which are the main corrosive species, with some organic acids aggravate the attack. For transportation and storage, the problems of internal corrosion in gasoline tankers are higher than oil tanks because oil forms a protective film while the gasoline does not. The settling water on tank bottoms is the main cause of internal corrosion in storage tanks. In oil refineries, the major corrosion problems are occurring because of inorganic such as water, H_2S, H_2SO_4, NaCl, CO_2 [1].

It is obvious that carbon steel pipelines are major part of the infrastructure of production of oil and gas. Transportation of crude oil, gas and refined petroleum products became easier by pipelines and it is the first choice for transportation for long distances and huge quantities [2]. On the other hand, the dissolved salts in water and oil have a significant effect on its corrosivity. The most commonly anions present in water are bicarbonate, sulfate and chloride. [3]. Such anions aggravate the following: scale formation and corrosion of pipes, equipment and structures; deposition and fouling in boilers; and pores of soil blockage and soil acidification [4].In addition, if some of these ions are present in oil, it can influence the steel performance in petrochemical industry, and this could lead to loss in humans or economics [5]. Some of the most aggressive anions are sulfates, these ions are generally found in sea water, underground water and several mineral wastewaters [4, 6, 7, 8]. Sulfates cause severe attack to boiler tubes, and are found in high concentration in crude oil leading to pipelines corrosion [3]. Furthermore, higher concentrations of sulfate ions could lead to massive problems for the environment, such as agricultural, mining, chemical and metallurgical sectors. There are many industries dealing with sulfates such as soaps, dyes, paper, leather and textiles. Sulfates may lead to many problems, commonly occurring problems are acidification of soil, metals corrosion and alteration of water taste [4]. Furthermore, presence of sulfates combined with other aggressive anions stimulates the anodic dissolution rate of metals as revealed in a study performed by Ismail et al. As shown in figure 1.1, it's clear that presence of sulfates in addition to chloride ions stimulated the corrosion process [9].

Various kinds of aggressive species such as sulfates, chlorides and bicarbonates are present in injection water used in Qarun East Baharia oilfields injection network. In particular, sulfates and chlorides ions are the reason of the internal corrosion problems. An example of these corrosion problems is presented in figure 1.2 which shows corroded pipelines from East Baharia oilfield (internal corrosion problems) caused by chloride and sulfate ions dissolved in injection water. Most common internal corrosion problems are mainly general corrosion (figure 1.2.a) and scale formation (figure 1.2.b).

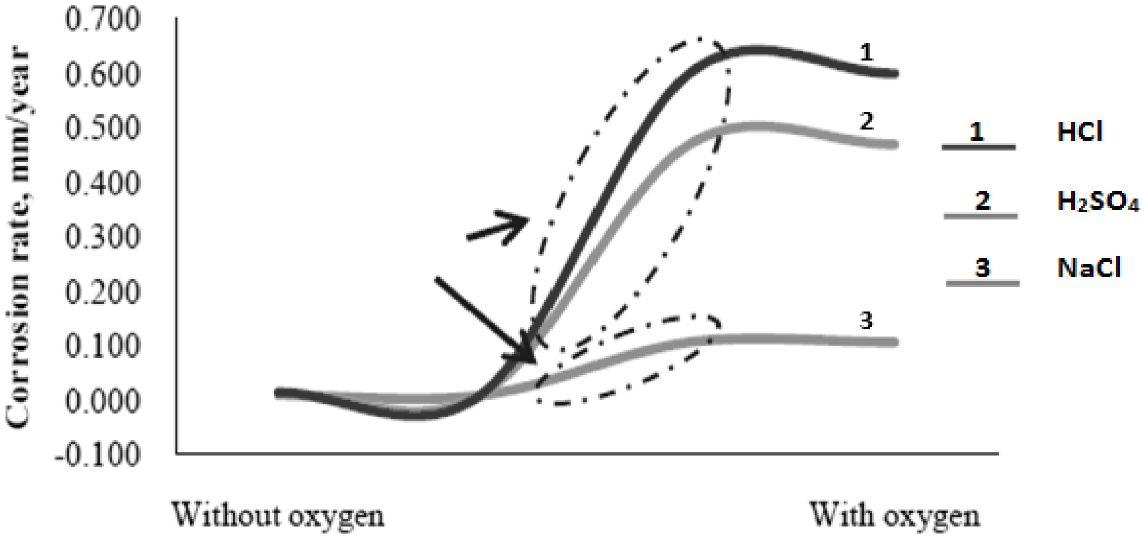
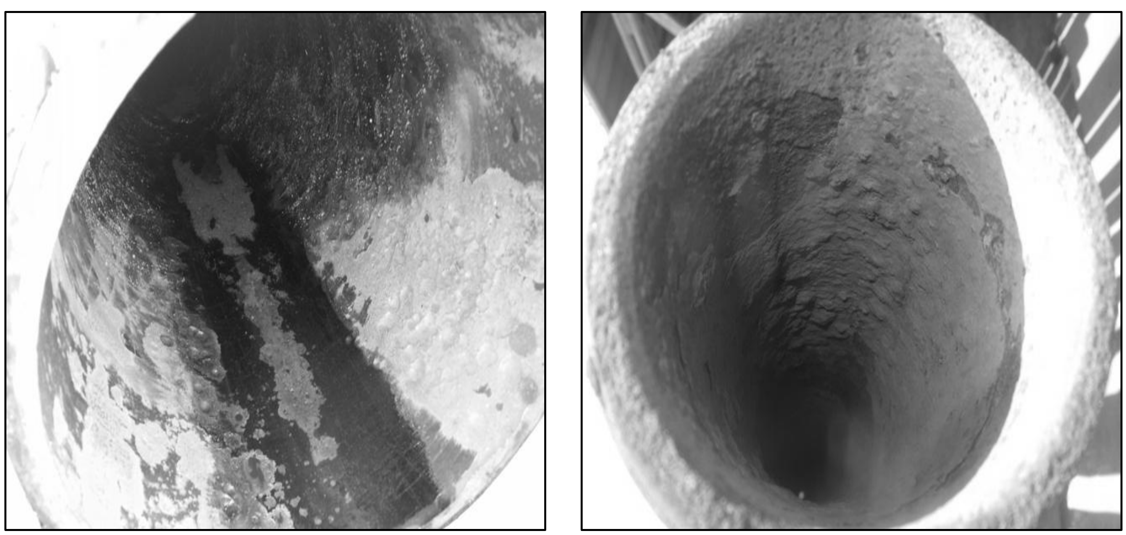


Figure 1.1: The critical corrosion rate indicating the drastic increase on corrosion rate which explains that the aggressive anions accelerate corrosion attack on carbon steel [9]



(a) **(b)**

Figure 1.2: Main internal corrosion problems occurring in East Baharia oilfield: a. general corrosion, b. scale formation