Evaluation of Corrosion Behavior of API-5L X52 Steel in Oilfield Formation Water with Inhibitors

By
Ali Mohamed Saad Abdel-Wahab Abdel-Kader

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

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Summary:

In oil industry, carbon steel pipelines are used for transporting the produced crude oil or produced formation water from wells to processing stations. The present study aimed to investigate the electrochemical behavior of corrosion of API 5L-X52 carbon steel grade, where the tested steel grade is immersed in uninhibited and inhibited oilfield formation produced water. Results showed that corrosion rates of carbon steel increases with temperature till a certain degree and decreases with inhibitor concentration till also a certain value. Besides, the in-field weight loss technique gives more severe measured corrosion rate data than that measured by laboratory potentio-dynamic polarization technique.

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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Table of Contents

List of Tables

List of Figures

Abstract

In oil industry, carbon steel pipelines are used for transporting the produced crude oil or produced formation water from wells to processing stations. This produced crude oil is not alone; it is flowing with the produced formation water, which is responsible for corrosion of carbon steel pipelines at service temperature in higher rates. The present study aimed to investigate the electrochemical behavior of corrosion of API 5L-X52 carbon steel grade, where the tested steel grade is immersed in uninhibited and inhibited oilfield formation produced water, which is brought from an Egyptian oilfield, at different applied temperatures, which simulate the oilfield's service upstream temperatures. This investigation is applied using laboratory potentio-dynamic polarization and in-field weight loss measurements for comparison purposes. Results showed that corrosion rates of carbon steel increases with temperature till a certain degree and decreases with inhibitor concentration till also a certain value. Besides, the in-field weight loss technique gives more severe measured corrosion rate data than that measured by laboratory potentio-dynamic polarization technique.

Chapter 1: Introduction

Carbon steels are the most commonly used material for constructing pipelines in the oil and gas industry, but they are very liable to both high general corrosion rate and severe localized corrosion. In these pipelines, oilfield formation produced-water accompanies the flowed oil from the wells. Generally, the pipelines can carry the fluid extracted from oil-producing or water-producing wells. For water injection purposes inside the reservoirs for maximizing oil production for the adjacent wells, the oilfield formation produced water will be utilized through making it flow inside pipelines, which are devoted to this purpose.

Due to oilfield formation produced water is corrosive by nature; it will constitute a significant threat to operation safety and also leads to huge economic losses. Therefore, one of the most common used techniques for combating corrosion in oilfields is the inhibition of the transported corrosive fluid's effect by injecting proper corrosion inhibitors of specific dosages. In oilfields, the usage of organic corrosion inhibitor compounds is highly-recommended in comparison with inorganic ones. Organic molecules can inhibit corrosion via adsorption at the metal–solution interface. There are two primary mechanisms of adsorption are associated with organic compounds: blocking the reaction sites or generating a physical barrier to reduce the diffusion of corrosive species to the metal surface. The mode of adsorption is highly-dependent on the following influencing factors: chemical and electronic structure of the molecule, inhibitor concentration, solution chemistry, nature and surface charge of the metal surface, electrochemical potential at the interface and the temperature of the corrosion reaction[19].

Despite the effect of temperature on corrosion and inhibition of carbon steels are somewhat complex, temperature still has a great effect on the rate of metal corrosion and its variation is a beneficial tool for studying the adsorption mechanism of an organic inhibitor[19].

In this study, the electrochemical behavior of corrosion and inhibition of API 5L-X52 carbon steel grade is investigated, where the tested steel grade is immersed in oilfield formation produced water, which is brought from an Egyptian oilfield, at different applied temperatures, which simulate the oilfield's service upstream temperatures. This investigation is applied using laboratory potentio-dynamic polarization and in-field weight loss measurements.

Chapter 2: Literature Survey

I-Corrosion Forms in Oil Industry

1-Introduction

Corrosion phenomenon is considered a problematic issue over production, transportation, and refining stages in oil and gas industry; it leads to disastrous losses for assets and economics of oil and gas sector. The total corrosion costs the oil and gas production sector in the U.S. by $1.372 billion annually, divided into $589 million for surface assets, $463 million for downhole assets, and $320 million for overall expenses related to corrosion [1]. But, we should inquire about the main factor leading to corrosion in oil and gas fields. To answer this inquiry, we should know first that the formation water is often accompanying crude oil produced from the wells, and both are transported in carbon steel pipelines [2]. The presence of water is the essential reason behind corrosion, so it can lead to internal corrosion problems when free water contacts/wets the pipe wall surface.

2-Corrosion Forms

2-1-General (Uniform) Corrosion

When the morphology of corroded metal surface is described as a fairly uniform, then the corrosion form can be referred to as uniform or general. This attack (i.e. corrosion) is mainly caused by a local corrosion cell action, which this means that there are multiple anodes and cathodes are operating simultaneously on metal surface at any time. Anodes and cathodes are not fixed areas, because their locations are moving continuously along the entire metal surface. Uniform corrosion – according to pure technical viewpoint – is not of too great consideration, in comparison with other corrosion forms; the life of assets can be estimated easily and accurately on the basis of immersion tests. However, the corrosion uniformity causes the greatest destruction of metal on a tonnage basis. This form of corrosion results often from exposure in atmosphere, water, soils, or chemicals [3].

All metals can corrode uniformly, excepting the passive materials, such as stainless steels or Ni-Cr alloys; it is normally liable to localized forms of corrosion. The rusting of steel, formed green patina on copper, and silver tarnish, are practical examples for general corrosion. In fact, the removed metal, such as steel, due to uniform corrosion, either dissolves in the corrosive environment or reacts with it producing a loosely-adherent, porous layer of corrosion products leaving a rough surface. On contrary, the silver tarnishing in air, leads easily to forming a thin, tight, adherent layers, which leave the metal surface smooth. Aluminum oxidation in air, and lead attack in sulfate-containing environments, also results in forming smoothly-protective layers [3].

To prevent, or reduce the resultant losses from uniform corrosion, the selecting of proper materials, inhibitors injecting, protective coatings using, or cathodic/anodic protection applying, are the most suitable recommended methods. Carefully-combined methods of corrosion prevention can maximize the desired protection level against corrosion. Uniform corrosion should be taken into consideration during design calculations for any asset. If the corrosion rate for a structure equals 100 μm/year, then the corrosion allowance calculations will permit to add a 500 μm to the thickness of metal; to provide five years of operation. The uniform corrosion rate measurements are based on published corrosion data in literature, prior service conditions, and experimental data determined by coupon exposures [3].

2-2-Localized Corrosion

Localized corrosion is less predictable than uniform one. Its traits appear obviously through pitting, a specific localized corrosion form, which its own pits' location, size, and distribution on the metallic surface are dependent on the predominant metal structure and environmental conditions. The accurate distinction between severe localized attack and pitting is somewhat hard task. However, Champion tried to distinguish between 'semi-local' corrosion and pitting, and he found the latter can be defined by pit geometry itself, through measuring the ratio of average pit width to average pit depth of the corroded area. He determined that if that ratio equals 4:1 or less, this attack will be classified as pitting. Currently, the more generally-acceptable ratio for defining pitting corrosion is 1:1 [4].

Pitting can lead to rapid drastic consequences. For instance, for fluid-transporting pipelines, it can rapidly cause perforation, and successive leakage. Therefore, pitting is frequently more detrimental than uniform corrosion. But, Hoar has noticed that uniform corrosion for a bearing is harmful, whereas, pitting is beneficial; the latter provides pockets for lubricant overcoming misalignment and seizure problems resulted from the former. Figure 1 shows the several types of corrosion that start from purely-uniform to clearly-localized and Figure 2 how pit initiation can lead to a corrosion crack [4].

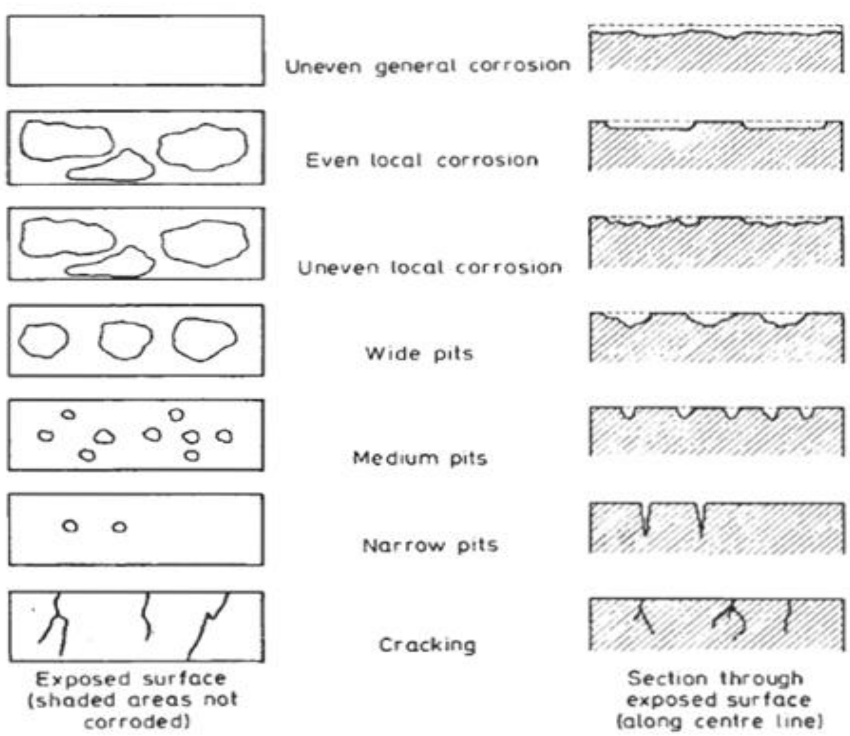

Figure 1 Different Types of Corrosion [4]