UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Manufacturing Engineering

CORROSION ANALYSIS OF INTERNAL SURFACE OF CARBON STEEL NATURAL GAS PIPING

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Master of Manufacturing Engineering
(Manufacturing System Engineering)

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CORROSION ANALYSIS OF INTERNAL SURFACE OF CARBON STEEL NATURAL GAS PIPING

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A thesis submitted
in fulfillment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing System Engineering)

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ABSTRACT

Oil and gas industry has been contributing as a largest government income and this industry manage to control corrosion which causing wear failure in gas pipelines and potentially cause substantial human and economic losses. The objective of this study is to study the effect of H_2SO_4 solution concentration electrolyte to corrosion behaviour of the internal surface of natural gas pipeline by using Tafel Extrapolation Method. This research starts with sample preparation where the sample from gas pipelines has taken and cut into 10mm x 20 mm dimension. This sample has been tested in corrosion test experiment to collecting and analysing the data gain from Tafel slope analysis, Optical Microscopy (OM) and Scanning Electron Microscopy (SEM) to perform corrosion rate and it effect on the surface morphology and microstructure. Due to the result of this study, it is point out that corrosion rate increase with high concentration of H_2SO_4 which presence in natural gas composition. The data can be used to managing the pipelines effectively and prevention method can be taken in order to extend the life span of the pipeline.

ABSTRAK

Industri minyak dan gas telah menyumbang kepada pendapatan terbesar kerajaan di mana kegagalan menguruskan industri ini dalam konteks pengawalan kakisan pada paip gas akan menyebabkan kegagalan dan kerosakan kepada paip gas serta menyebabkan kerugian yang besar kepada manusia dan ekonomi. Objektif kajian ini adalah untuk mengkaji kesan kepekatan H_2SO_4 elektrolit kepada kelakuan atau ciri-ciri kakisan permukaan dalaman saluran paip gas asli dengan menggunakan kaedah Tafel ekstrapolasi. Kajian ini bermula dengan penyediaan sampel di mana sampel dari saluran paip gas telah diambil dan dipotong menjadi kepada dimensi 10mm x 20 mm. Sampel ini telah di uji dalam eksperimen ujian kakisan untuk mengumpul dan menganalisisa data berdasarkan kepada kecerunan lengkung Tafel, menggunakan 'optical microscopy' (OM) dan scanning electron microscopy (SEM) untuk menentukan kadar hakisan dan kesan ke morfologi permukaan dan mikrostruktur sampel yg di uji tersebut. Keputusan daripada kajian ini, ia menunjukkan bahawa kenaikan kadar kakisan berlaku apabila diuji dengan larutan H_2SO_4 yg berkepekatan lebih tinggi. Data hasil daripada kajian yang dijalankan ini boleh digunakan untuk menguruskan paip gas secara berkesan dan langkah pencegahan boleh diambil untuk memastikan jangka hayat paip gas dapat ditingkatkan.

DEDICATION

Dedicated to my beloved wife, child, father, mother and family, for giving me moral support and encouragement.

Also, I dedicate this to all my friends, lecturers and colleagues for their advice and motivation and

special thanks to Dr.Mohd Asyadi 'Azam Bin Mohd Abid for supervising me in completing this research.

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DECLARATION

I declare that this thesis entitle "Corrosion Analysis of Internal Surface of Carbon Steel Natural Gas Piping" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

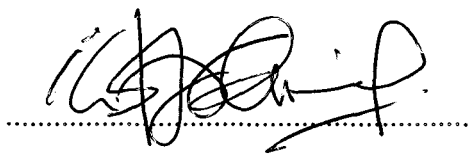
Signature : .....

Name : MOHD FUAD BIN IBRAHIM

Date : 25/04/2013

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Master of Manufacturing Engineering (Manufacturing Systems Engineering). The member of supervisory committee is as follow:



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LIST OF ABBREVIATIONS

WEDM	-	Electro discharge machine
SCC	-	Stress Cracking Corrosion
Ksi	-	kilopound per square inch
SEM	-	Scanning Electron Microscope
EDX	-	Energy Dispersion X-Ray
XRD	-	X-Ray Diffraction
OM	-	Optical Microscopy
μm	-	Micrometer

CHAPTER 1

INTRODUCTION

1.1 Background of the study

Oil and Gas industry has been contributing as a largest government income and Petronas is the role player in this industry and it is evolving from year to year due to world population growth. Malaysia has the 25th largest oil reserve and 14th largest gas reserve in the world (Razalli, 2005). Downstream have different players, and a more diverse range of interests. In oil refining, there are Petronas Penapisan (with plants in Terengganu and Melaka), Shell, ExxonMobil and Conoco. Petronas Gas and Manufacturers of Liquidized Natural Gas (MLNG) are involved in gas processing and transmission. Gas distribution is handled by Gas Malaysia. Oil and Gas sector is expected to generate RM 131.4 billion in Gross National Income by 2020 (5% annual growth) in the period from 2010 to 2020.Twelve entry points projects (EPPs) have been identified under the oil, gas and energy sector.

Due to its unique requirements, the industry has developed standards and practices in order to make sure this industry remain competitive and sustainable. Many of these standards and practices such as the selection of materials, quality assurance and control in construction, non-destructive testing, corrosion and welding practices will probably find their way and tries to meet the ever demanding public expectations. This study is focusing on corrosion as one of the standards that gives a huge impact in company's cost and profit. Corrosion represents a tremendous economic loss and much can be done to reduce it. As the 14th largest gas reserve

in the world, gas industry has also grown significantly. Globalize all over the world, pipelines are the most common and feasible medium in transporting natural gas because of the volume that can be transported. Pipeline normally is constructed by metal which is related to defect such as corrosion. Figure 1.1 shows the corrosion impact of internal pipeline.

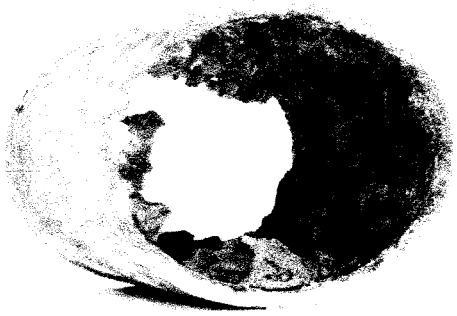

Figure 1.1 : Corrosion in the internal pipeline

Corrosion may appear in different forms, such as general corrosion with the uniform loss of the wall thickness or pitting corrosion, which corresponds to the local wall thickness reduction. To avoid failures and meet the safety requirement standard, corrosion must be detected, measured and the remaining strength of the corroded area has to be determined.

1.2 Problem statement

Pipeline systems are the most effective medium to transport Oil and Gas (O&G) product such as natural gas from one location to another location, offshore to onshore and from transmission to the distribution until it meets the consumer in a mass scale. Pipelines ability and reliability are based on their material properties and its composition may reach the weakness point due to certain factors such as condition and environment of the internal pipelines surface. In order to maintain the life span of a pipeline, such a big amount of money should be invested in maintenance and preventive area. External surface of pipeline is not a

major issue during maintenance process as compared to the internal surface of the pipelines. The hard it goes the more it costs.

In the mix scenario of the world economy environment force the reduction of cost and eliminate unnecessary expenses. Oil and gas sector also is no exception influenced by the economy crisis and most of the cost is involved in corrosion. The total annual cost of corrosion in the oil and gas production industry alone is estimated to be $1.3 billion, including $589 million in surface pipeline and facility costs, $463 million in downhole tubing expenses and $320 million in capital expenditure related to corrosion. (Storck, 2012). Corrosion is the main threat to the petroleum industry depending on the depth, length, orientation and possible future growth of the defect.

As the infrastructure of industrialized countries continues to age, more and more failures due to corrosion are occurring. Replacing all the bridges and pipelines (gas, oil, water) would be prohibitively expensive, and unnecessary as most are in good condition and can provide many more years of service. Figuring out which ones are failing and how long they can last is the function of service life prediction. (Kelly, 2006). In order to restructure the cost, an understanding of how the pipeline will corrode is important and preventive action can be taken. Corrosion attacks almost every component, as all metals and alloys are subjected to it. Carbon steel is a material that widely used in Oil and Gas (O & G) industrial units because of its low cost and excellent mechanical properties and it also faces severe attack from corrosion failure.

However, to fully understand this phenomenon a detailed study of chemical, physical and mechanical properties of material is required. The internal corrosion is preferred to be concerned in this project because the sulphur contain in the natural gas is one of the corrosive agent that can attack the pipeline surface. The internal corrosion rate of carbon steel pipelines

varies in a complex way with the gas composition specifically carbon dioxide (CO_2), O_2 and hydrogen sulphide (H_2S) with presence of condensed water chemistry. The effect of the corrosion process which produce a corrosion product which deposited on the internal pipeline gas. Corrosion product forms a scales layer and act as a protective barrier to prevent the corrosion on the pipeline surface. This scales layer will grown at the certain thickness and become brittle. This characteristic will exposed this layer for easily removed by a mechanical force from the gases flow.

The area of the removed scales layer will expose to the corrosion process and can develops localized pits due to the pitting corrosion. This process of corrosion wills week mechanical properties the area of exposing until the final failure. The understanding of this phenomenon can be demonstrated by testing the internal natural gas pipeline corrosion sample with simulated solution as identified as a major contributor to corrosion failuere and the data can be used to predict the corrosion behaviour in oil and gas industries.

Quantitative understanding of the corrosion rate of steel under these conditions will be a key point to an accurate risk assessment of pipelines from internal corrosion. The finding of the study helps in constructing pipelines with higher resistance to corrosion using suitable methods such as coating and etc. Yet, according to NACE, the international corrosion society, if oil and gas production firms manage corrosion effectively, they can improve compliance with safety, health and environmental policies, increase plant availability, and reduce leaks, deferment costs and the amount of unplanned maintenance. (Storck, 2012)

1.3 Objective

The aims of this research are:

i. To study on the effect of solution concentration of H_2SO_4 electrolyte to corrosion behaviour of internal surface of natural gas pipeline using Tafel Extrapolation Method.

ii. To investigate morphology of corroded piping sample of the different solution concentration of H_2SO_4.

1.4 Scope

In order to achieve the objectives, this research is focusing on the following scopes:

For objective i:

i. Tested the natural gas piping samples with 1 M, 0.5 M, 0.1 M and 0.01 M of H_2SO_4 solution.

ii. Immersed the sample in H_2SO_4 solution and tested using Gamry Instrument.

iii. Collected the data of corrosion rate, corrosion potential (E_{corr}) and corrosion current (I_{corr}) from sample of natural gas corrosion surface with different effects of H_2SO_4 solution of electrolyte using Tafel Extrapolation Method.

For objective ii:

i. Observe and magnify the surface morphology of untested sample and tested sample using Optical Microscopy (OM).

ii. Representative SEM analysis of plane view and cross sectional view of the tested sample.

iii. Compare the finding from OM and SEM of the different concentration of H_2SO_4.

iv. Conclude the corrosion behaviour of the natural gas piping samples from the result analysis.

Chapter 2

Literature Review

2.1 Introduction

There are so many studies on corrosion and it has a similar definition that describes the meaning of corrosion. Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment (Fontana, 1986). Corrosion is the degradation of materials' properties due to interactions with their environments, and corrosion of most metals (and many materials for that matter) is inevitable. (Kelly, 2006).

Corrosion of metals could be considered as extractive metallurgy in reverse where it is concerned primarily with the winning of the metal from the ore and refining or alloying the metal for use. (Fontana,1986). Thus from the definition of corrosion, corrosion processes are the process where the metal atoms are removed from the surface and it leads to weakening of the structure, meet the resistance limits and finally causes failures to the metal. Figure 2.1 expresses simple process in sample of corroding cell.

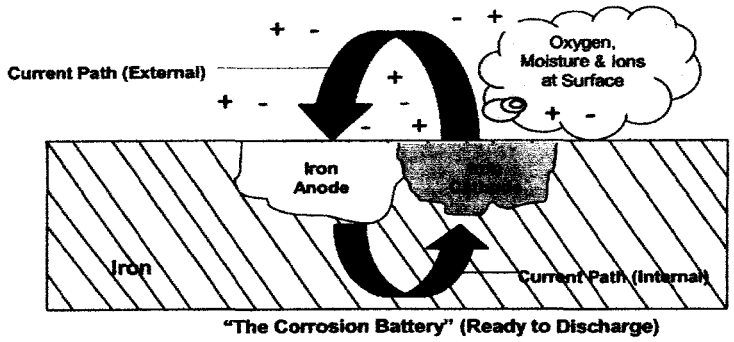

Figure 2.1: Simple corrosion cell

Most corrosion processes involve at least two electrochemical reactions (one anodic and one cathodic). A corroding surface as shown in figure 2.1 can be thought of as a short-circuited battery; the dissolution reaction at the anode supplies electrons for the reduction reaction at the cathode. A short circuit is the electrical connection made by a conductor between the two physical sites, which are often separated by very small distances. (Kelly,2006).

2.2 Corrosion in Oil and Gas industry

According to (Papavinasam, 2006), the oil and gas industry uses large quantities of carbon and low-alloy steels in the construction of pipelines, offshore rigs and structures Global energy needs led to extend searches for oil in offshore environments. Since then offshore pipelines have become the unique means of efficiently transporting hydrocarbons from offshore installations. As mentioned in problem statement, carbon steel is and still remains the primary member in the construction of oil and gas transport pipelines owing to economic reasons, availability and well developed technology (L.Fosbol, 2009).

However, its downside is the fact that it easily corrodes, changing to its more thermodynamically stable form (iron ore) thus becoming mechanically unreliable. Corrosion protection is therefore very important because of the large sums of money spent on corrosion mitigation designs, repair of corroded pipes, refurbishment and cleaning of polluted environments. During this process the metal atoms are removed from the surface, which leads to structure weakening and finally failures. Corrosion attacks almost every component, as all metals and alloys are subjected to it. It can appear down hole or above the ground, on internal and external surfaces, destroying the equipment and interrupting the processes.

Corrosion is the main threat to the petroleum industry. Its enormous impact is shown in Table 2.1. The values in the table may be assumed as average ones, because they vary regarding to the country and region e.g. in Western Europe corrosion-related failures come to 25%, in the Gulf of Mexico and Poland about 50%, while in India they reach 80% (Samant,2003).

Table 2.1 : Failures in oil and gas industry (from Kermanl and Harrop,2003)

Type of failure	Frequency [%]
Corrosion (all types)	33
Fatigue	18
Mechanical damage/overload	14
Brittle fracture	9
Fabrication defects (excluding welding defects)	9
Welding defects	7
Others	10

On the other hand, the study of corrosion in the oil and gas industry usually involved the sweet (CO_2) and sour (H_2S) corrosion. These types of corrosion are famous in oil and gas pipelines. But these corrosions caused by gas during the transportation of crude oil in the pipelines. However, a very few studies mention that the corrosion is caused by crude oil. This study is carried out to determined whether the corrosion in the pipelines also affected by the crude oil.