UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Microstructural Characterization of Corrosion Product for Natural Gas Pipelines in Malaysia

Thesis submitted in accordance with the requirements of the Universiti Teknikal Malaysia Melaka for the Bachelor of Manufacturing Engineering with Honours in Engineering Materials

By

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March 2008

APPENDIX D

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ABSTRACT

Malaysia is among the largest producer of gas industry which 12th largest gas reserves in the world. In 2004 Malaysia had 7,281 kilometers of pipelines and 5,047 kilometers for gas transporter. In this project, I study the characterization of corrosion product by using potentiostat and SEM as the core equipments. In this case, seawater at Terengganu (Kerteh, Marang) and Melaka (Klebang) can be uses as the solution and carbon steel pipelines API 5L X65 grade as the sample product. This product sample will be cut by using horizontal bandsaw machine follow dimension required. The next step is to perform continuous study on the sample subject by using EDX machine to confirm the composition of the sample subject.

Experiment between the sample product and seawater will proceed by immerse sample product into the seawater solution, than the observation of polarization curve and corrosion rate will be analyze. The last step for this project, the corrosion of the sample product would be analyzed with SEM and the microstructure, types of corrosion chemical can be identified.

ABSTRAK

Malaysia adalah diantara pengeluar terbesar industri gas dimana mempunyai simpanan gas ke-12 terbesar didunia. Pada tahun 2004, Malaysia telah mempunyai 7,281 kilometer saluran paip dan 5,047 kilometer adalah untuk penyaluran gas. Dalam projek kajian ini, saya mengkaji krateria pengaratan pada produk dengan menggunakan potentiostat dan SEM sebagai peralatan utama. Dalam kes ini, air laut di Negeri Terengganu (Kerteh, Marang) dan Melaka (Klebang) akan digunakan sebagai larutan dan besi karbon gred API 5L X65 sebagai produk kajian. Produk kajian akan dipotong dengan menggunakan mesin gergaji jenis melintang mengikut ukuran yang diperlukan. Langkah seterusnya adalah untuk menjalankan kajian berterusan keatas sampel subjek dengan menggunakan EDX bagi mengesahkan komposisi bahan subjek.

Kajian diantara sampel produk dan air laut akan diteruskan dengan merendam sampel produk ke dalam larutan air laut, kemudian pemerhatian pada lengkuk pertambahan dan kadar pengaratan akan dianalisis. Langkah terakhir untuk kajian ini, pengaratan pada sampel produk akan dianalisis dengan menggunakan SEM dan struktur mikro, jenis bahan kimia pada karat akan diketahui.

DEDICATION

"Special to my parents, my family and all my friends that helps me in finishing this research".

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In the Name of Allah, the Most Gracious, the Most Merciful.
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Lastly, I'm happy to present the following cumulative list of all those individuals who, in one way or another, made various contributions to this research.

APPROVAL

This thesis submitted to the senate of UTeM and has been accepted as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Material Engineering)
The members of the supervisory committee are follow:

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Main Supervisor

(Mr. Mohd Asyadi' Azam Bin Mohd Abid)

28th March 2008

DECLARATION

I hereby, declared this thesis entitled "Microstructural Characterization of Corrosion Product for Natural Gas Pipeline in Malaysia" is the results of my own research except as cited in references.

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SIGN AND SYMBOLS

API	-	American Petroleum Institute
ASTM	-	America Society for testing and Materials
A	-	Ampere
Ag/AgCl	-	Silver/silver chloride
AWD	-	Analytical Working Distance
BSD	-	Berkeley Software Distribution
Cl^-	-	Chloride
C_3H_8	-	Propane
C_4H_{10}	-	Butane
CH_4	-	Methane
C_2H_6	-	Ethane
CO_2	-	Carbon Dioxide
CECER	-	Construction Engineering Research Laboratories
cm	-	Centimeter
Cu	-	Copper
C	-	Carbon
CE	-	Counter electrode
daN	-	force display (Newton)
E	-	Electron
Et al	-	et alli (and others)
Ec	-	Current electrochemical parameter
EDX	-	Energy Dispersive X-ray Spectroscopy
Eq	-	Equation
Ep	-	Editional photographers
EW	-	Equivalent Weight
FKM	-	Fakulti Kejuruteraan Mekanikal

FKP	-	Fakulti Kejuruteraan Pembuatan
Fe	-	Iron
GPP	-	Gas Processing Plants
g/l	-	gram per liter
H_2S	-	Hydrogen Sulphide
He	-	Helium
Hz	-	Hertz
HT	-	High tension generator
IAPSO	-	International Association for the Physical Sciences of the Ocean
KM	-	Kilometer
K	-	Kelvin
Kw	-	Kilowatts
Kg	-	kilograms
L	-	Liter
M	-	Metal
m/s	-	meter per second
max	-	Maximum
Mpa	-	Mega Pascal
Mn	-	Manganese
mm	-	Millimeters
m/min	-	meter per minute
MHz	-	Megahertz
NaCl	-	Sodium Chloride
N_2	-	Nitrogen
NS_4	-	Synthetic electrolytic solution
NG	-	Not Good
N	-	Newton
PRSB	-	Petronas Research Sdn. Bhd
PGU	-	Peninsular Gas utilization
pH	-	Potential of hydrogen

PSL 1	-	Products Specification Level 1
Psi	-	Pounds Per Square Inch
P	-	Phosphorus
Rpm	-	Rotation per minute
Rp	-	Polarization resistance
RE	-	Reference electrode
SEM	-	Scanning Electron Microscope
Sdn. Bhd	-	Sendirian Berhad
SCC	-	Stress corrosion cracking
S	-	Sulfur
SAXS	-	Small Angle X-ray Scattering
Tcf	-	Trillion cubic feet
UTeM	-	Universiti Teknikal Malaysia Melaka
V	-	volt
Wt %	-	Weight Percentages
WE	-	Working Electrode
XRD	-	X-ray diffraction
XVGA	-	Extended Video Graphes Array
XVP	-	X-View Package
Zn	-	Zinc
^{o}C	-	Degree Celsius
%	-	Percentage
^{o}F	-	Degrees Fahrenheit
μm	-	micron meter
pA	-	picoAmpere (10^{-12})
aA	-	attoAmpere (10^{-18})
ρ	-	Density
nm	-	nanometer

CHAPTER 1
INTODUCTION

1.1 Background

Malaysia is placed in Southeast Asia with alienated by about 530 kilometers of the South China Sea. Malaysian have two regions are Peninsular Malaysia and East Malaysia or also known as island of Borneo which collected of two states Sabah and Serawak (Appendix C). Malaysia's total land area is 329,758 square kilometers: 131,598 square kilometers in Peninsular Malaysia and 198,160 square kilometers in Sabah and Sarawak *(library of congress, 2006).* Based on library of congress information, the coastline in Peninsular Malaysia is 2,068 kilometers and for East Malaysia is 2,608 kilometers. Malaysian annual average temperatures between 23 ^{o}C to 34 ^{o}C and the economics generally from natural resources such as tin, bauxite, copper, gold, iron ore, timber, petroleum and natural gas. In 2004, Malaysia had 7,281 kilometers of pipelines: 5,047 kilometers for gas, 1,841 kilometers for oil, 279 kilometers for condensate, and 114 kilometers for refined products *(library of congress, 2006).*

Natural gas is one type of gas fuel and it's very important to global and Malaysian economy. Normally, large amount of natural gas from the main source usually need effective transportation. So, pipeline is great method to solve this problem. But, any failure to ensure the safe and continuous operation on natural gas pipelines can be effects to economic, environmental and life-safety implications. The observations and

consideration of natural gas pipeline at initial stages during fabrication, installation, selection of material and operation are good criteria to avoid bigger defects on pipelines in further. However, the observations and consideration on natural gas pipeline it is not practical to prevent all defects from occurring because not all defects are destructive to pipeline integrity; it is essential to be able to differentiate defects that can be tolerated from those that cannot. The understandings about characterization and corrosion behavior in natural gas pipeline that good method can be avoid problems in natural gas pipeline.

So, this project is very importance to known the phenomena of initial stage of corrosion behavior for natural gas pipeline in artificial groundwater condition with specify to observe the microstructural of natural gas pipeline. Normally, natural gas pipeline used carbon steel to transports natural gas at main source. This pipeline not just received damaged by earth rust fluctuation and corrosion, but also suffered from the corrosion caused by anions that were dissolved in sea and groundwater. Based on this situation, the applications of an anodic polarization curve measurement with potentiostat and observation analysis through Scanning Electron Microscope (SEM), the microstructure and corrosion rate can be look at in a laboratory experiments. By using this system, formation and dissolution process of corrosion product in artificial groundwater could be examined.

To complete my study in microstructural characterization of corrosion product for natural gas pipeline in Malaysia, the exact samples of API 5L X65 pipe grade was taken from PETRONAS RESEARCH SDN.BHD (PRSB) as main sample laboratory test to realize objective in this study.

1.2 Problem statement

Natural gas transport reliability depends on environment factors and exact choice of pipeline material. The life of a potentially corrosive pipeline structure depends on the choice of material or a method of surface treatment which will avoid damage by corrosion. Carbon steel pipeline usually used in gas transmission is manufactured according to the specified chemical composition and mechanical parameters. It's commonly manufactured to the API 5L specification grade X65 and others grades. All of API 5L pipeline grades is already set of mechanical parameters such as tensile strength, yield strength, elongation and toughness. So, carbon steel pipe is very suitable use in natural gas transportation applications because of its low coast, high strength and the ease of field makeup by welding.

However, the presence of chemical elements in seawater similar to sodium ion (Na^{+}), chloride ion (Cl^{-}), sulfate (SO_4^{2+}), magnesium ion (Mg^{2+}), calcium (Ca^{2+}) and potassium (K^{+}) on carbon steel can cause several corrosion problems in oil and gas pipeline transmissions. So, this project is importance in order to get knowledge of how seawater can be effect specified to microstructure and corrosion behavior on carbon steel pipeline API 5L X65 grade toward to seawater.

1.2.1 Basic Concept of Corrosion

Corrosion is a common problems around us where is involves many factors how do the corrosion behavior happens in engineering field. In order to perform corrosion behavior in the general practices and principle of corrosion, *Mars G. Fontana, (1986)* mentions that, the chemical, metallurgical, physical, and mechanical properties of materials; corrosion testing; the natural of corrosion environments; the availability and fabrication of materials; computer; and design *(p. 3)* must be considers before an engineer produce their product, design the materials, build the building and others to prevent causes producing corrosion layer in engineering applications.

1.2.2 Economic Consideration

Cost is an important aspect in engineering study and corrosion is a main problem in gas field especially in transporting gas by using pipeline. In this case, *Thompson (2001)* has write down in his journal that, a "find it and fix it" strategy utilizing in-line inspection at the expense of corrosion prevention may save money in the short term, but will greatly increase capital expenditures for pipeline replacement and major rehabilitation in the long-term. So, the best strategy in the practices corrosion prevention is give more concerned for before and after constructions of pipelines transmission in every aspect can cause corrosion on the product using. Hence, the costing to repairing and replacement of the damaged product cause by corrosion is capable of avoided.

1.3 Objectives

The objectives of this study were:

1.2.1 To develop a test technology for the in-situ analyses of corrosion under wet condition, including the characterization of the electrolyte chemistry and the redox reactions occurring in the corrosion product.

1.2.2 To observe the microstructural characterization of corrosion product by using SEM and EDX equipments.

1.2.3 To study polarization curve measurement for API 5L X65 pipeline grade by using potentiostat.

1.2.4 To study the effect of Malaysia countries seawater specified at Terengganu (Kerteh, Marang) and Melaka (Klebang) on API 5L X65 pipelines grade.

1.4 Scope

This project focus on the corrosion behavior for pipeline steel API 5L X65 grade in artificial groundwater especially under wet condition and electrolyte chemistry specified for seawater at Terengganu and Melaka under 25 ^{o}C average temperature in Malaysia. In this study, the utilizing of equipment like SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive X-ray Spectroscopy) machine as main software to see the external corrosion microstructural characterization and checking types of corrosion product elements on carbon steel samples is important. Otherwise, the potentiostat machine is uses to search out the corrosion rate, anodic polarization curve and Tafel graph between carbon steel API 5L X65 pipeline grade and seawater. Meanwhile, this study not covers the coating selection, mechanical testing and seawaters as the matter during experimentation.