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EXTREME GROWTH BEHAVIOUR OF CORROSION PIT IN HYDROCARBON PIPELINE (CASE STUDY OF ∅914.4MM PIPELINE)

CHUAH CHONG KEAT

A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil - Structure)

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JUNE 2008

I declare that this thesis entitled "Extreme Growth Behaviour of Corrosion Pit in Hydrocarbon Pipeline (Case Study of ∅914.4MM Pipeline)" 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.

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To my beloved family

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ABSTRACT

The prediction of pipeline integrity in the early stage is important in order to provide assessment for future inspection, repair and replacement activities since the failure of hydrocarbon pipelines contributes to economic implications and cause serious hazards to the environment. The main objective of this research is to study the effects of extreme growth behaviour of corrosion pit in hydrocarbon pipeline using statistical and probability methods. The linear model is deployed due to its simplicity and flexibility to project the corrosion dimension in the future. The research methodology consists of three main stages, which are statistical analysis, probabilistic analysis and reliability analysis using Monte Carlo simulation. The information of pipeline internal condition provided by the in-line inspection tools called pig has numerous uncertainties. It is more realistic to concern a group of data that has already exceeded a certain level of corrosion severity rather than considering the large volume of detected data provided by the intelligent pig inspections. Instead, the peak depth of corrosion defects is most likely to cause the failure of hydrocarbon pipeline. Thus, peaks-over-threshold method and extreme value statistics have been adopted. Based on the result, higher threshold value will lead to earlier time to failure. Both peaks-over-threshold method and extreme value statistics can be combined to produce a reliable prediction. With the results from both methods, we can compare and make a reliable prediction. The results are important for pipeline operators to assist their planning program of inspection, repairing and replacement activities in the future.

ABSTRAK

Ramalan keupayaan semasa pada peringkat awalan struktur talian paip minyak adalah penting untuk menyediakan penilaian awal bagi tujuan pemeriksaan, penyelenggaraan dan penggantian pada masa hadapan kerana kegagalan struktur talian paip minyak akan menyebabkan implikasi kepada ekonomi dan mendatangkan bahaya kepada alam sekitar. Objektif utama bagi penyelidikan ini adalah untuk mengkaji kesan-kesan daripada sifat pertumbuhan pengaratan dalaman yang ekstrem dalam paip minyak menggunakan pendekatan statistik dan kebarangkalian. Model linear digunakan kerana sifatnya yang ringkas dan fleksibel untuk meramal dimensi karat pada masa hadapan. Metodologi penyelidikan mengandungi tiga bahagian utama iaitu analisis statistik, analisis kebarangkalian dan simulasi keboleharapan struktur dengan menggunakan prosedur Monte Carlo. Maklumat keadaan dalaman paip diperolehi melalui peralatan pemeriksaan yang dikenali sebagai *pig* mengandungi banyak ketaktentuan. Adalah lebih realistik untuk mempertimbangkan sekumpulan data yang telah melebihi sesuatu tahap pengaratan daripada mempertimbangkan data yang banyak yang diperolehi daripada pemeriksaan I*pig*. Biasanya, pengaratan yang dalam sekali akan menyebabkan kegagalan paip minyak. Oleh itu, metode nilai atas batasan dan statistic nilai ekstrem telah digunakan. Keputusan menunjukkan semakin tinggi nilai batasan, semakin cepat paip minyak akan gagal. Kedua-dua metode nilai atas batasan dan statistic nilai ekstrem boleh digabungkan untuk menghasilkan ramalan yang dapat dipercayai. Dengan adanya keputusan daripada kedua-dua metode, kita boleh berbanding sesama metode lalu membuat ramalan yang dapat dipercayai. Keputusan kajian sangat penting bagi pengendali paip minyak untuk merancang aktiviti pemeriksaan, penyelenggaraan dan penggantian pada masa hadapan.

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Δ	-	Interval width
r	-	Range of the data
N	-	Number of data points
μ_x	-	Mean
σ_x	-	Standard deviation
λ_x	-	Lognormal parameter
ξ_x	-	Lognormal parameter
λ	-	Exponential parameter or known as failure rate
x_o	-	An offset, which is assumed to be known a priori (the smallest value)
β	-	Shape parameter ($0<\beta<\infty$)
θ	-	Scale parameter ($0<\theta<\infty$)
δ	-	Location parameter ($-\infty<\delta<\infty$)
$\hat{x}$	-	Independent variable
m	-	Slope
c	-	y-axis intercept
O	-	Observed frequency
E	-	Expected frequency
χ^2	-	Chi-square
d	-	Degree of freedom
k	-	Number of classes
r^2	-	Determination coefficient
CR	-	Corrosion rate
SMTS	-	Specified minimum yield stress

d	-	Corrosion depth
t	-	Pipe thickness
D	-	Pipe diameter
P_p	-	Applied fluid pressure
P_a	-	Calculated allowable pressure using failure model equation

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Hydrocarbon pipelines are one of the important elements in oil and gas industry. They are mainly used to transport oil and gas. When pipelines aged, it is necessary that their safety, environmental and economical interests are preserved.

The internal environments of hydrocarbon pipelines can be extremely corrosive. Corrosion has become a major cause of the loss of strength in hydrocarbon pipelines resulting in failures. Due to leakage, the failure of hydrocarbon pipelines contributes to economic implications and cause serious hazards to the environment. Therefore, the prediction of pipeline integrity in the early stage is important in order to provide assessment for future inspection, repair and replacement activities.

This study is solely focused on the effects of extreme growth behaviour of corrosion pit in hydrocarbon pipeline using statistical and probability methods.

1.2 Problem Statement

An intelligent pig inspection will provide a huge amount of defects on pipeline even very shallow defects. It is more realistic to concern a group of data that has already exceeded a certain level of corrosion severity. Instead, the peak depth of corrosion defects is most likely to cause the failure of hydrocarbon pipeline. In this case, peaks-over-threshold method and extreme value statistics have been adopted.

1.3 Objectives of Study

The main goal of the research is to study the effects of extreme growth behaviour of corrosion pit in hydrocarbon pipeline using statistical and probability methods. To achieve this goal, the following plans were identified:

a) To analyse real inspection data using statistical and probability methods.

b) To model extreme growth behaviour of corrosion pit base on the metal loss volume of the hydrocarbon pipeline obtained from inspection data.

c) To determine the most suitable peaks-over-threshold range of corrosion data.

d) To predict the probability distribution of extreme growth behaviour of corrosion pit and the remaining life of corroding pipeline at the time of inspection and in the future using Monte Carlo simulation.

1.4 Scope of Study

The scope of study will include the statistical study on the inspection data gathered from oil and gas producer and inspection vendor. In this study, there are no dependency on the weather, environmental properties, material properties and operation conditions. The extreme growth behaviour of corrosion pit is modelled base on solely the metal loss volume of the hydrocarbon pipeline obtained from the inspection data. The summary of the inspection data is presented in Table 1.1 below. All parameters are presented as the statistical probability distributions. With different peaks-over-threshold value, the probability distribution of the extreme growth behaviour of corrosion pit will be predicted. To calculate the probability of failure, Monte Carlo simulation procedure will be used.

Table 1.1 : Summary of the inspection data

INFORMATION	**PIPELINE B**
Diameter (mm)	914.4
Inspected Distance (km)	150
Wall Thickness (mm)	22.2
Year of Inspection	1990,1992,1995
Year of Installation	1967
No. of Data (All Sets)	7009

1.5 Importance of Study

The study shows the systematic procedure in modeling the extreme growth behaviour of corrosion pit in hydrocarbon pipeline based on the in-line inspection data. Statistical and probability methods used in this study increase the accuracy in analyzing the data. The peak depth of corrosion defects is most likely to cause the failure of hydrocarbon pipeline. Therefore, the findings of this study are able to assist the pipeline operator in providing assessment for future inspection, repair and replacement activities.