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EXTREME GROWTH BEHAVIOUR OF CORROSION PIT IN HYDROCARBON PIPELINE (CASE STUDY OF ∅242.1MM PIPELINE)

ANN SEE PENG

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

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I declare that this thesis entitled "Extreme Growth Behaviour of Corrosion Pit in Hydrocarbon Pipeline (Case Study of ∅242.1MM 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

Inspection data obtained from in-line inspection is useful to assess present integrity as well as to predict future integrity of pipeline by using statistical and probabilistic analyses and simulation process. However, numerical errors arise when all the inspection data are used in the analysis. Numerical error arises because failure probability due to a single extreme corrosion out of huge quantity of corrosion data has been greatly reduced. Thus, in this study, extreme values analysis using extreme value theory, peaks-over-threshold method or combination of both methods is adopted to analyze the inspection data. This aims to eliminate the "low-risk" data in the analysis in order for extreme values to be emphasized. Based on the result, high threshold value will lead to high failure probability. However, the optimum threshold value is limited by the number of remaining data. Meanwhile, extreme value distribution is also efficient in indicating an early failure probability. Instead, combination of both methods results an overestimated failure probability.

ABSTRAK

Data yang diperolehi daripada pemeriksaan dalam talian pipe adalah sangat berguna untuk menilai keadaan kini and meramalkan integriti kelak tailian pipe dengan mnggunakan analisis statistik dan kebarangkalian. Walau bagaimanapun, apabila kesemua data diambilkira dalam analisis, keputusan yang diperolehi sering diiringi kesilapan angka. Kesilapan angka timbul kerana quantiti data yang banyak menyebabkan kebarangkalian kegagalan tailan paip yang disebabkan oleh satu pengaratan yang ekstrem adalah sangat rendah. Maka, dalam kajian ini, analisis nilai ekstrem dengan menggunakan teori nilai ekstrem, cara nilai-atas-batasan atau kedua-duanya sekali untuk menganalisiskan data. Ini adalah bertujuan untuk mengecualikan data-data risiko rendah daripada analisis supaya nilai-nilai ekstrem lebih dititikberatkan. Keputuskan menunjukkan semakin tinggi nilai batasan, semakin tinggi kebarangkalian kegagalan tailian paip. Walau bagaimanapu, nilai batasan dihadkan oleh bilangan data yang masih kekal setelah data-data bawah nilai batasan dihapuskan. Sementara itu, taburan nilai ekstrem adalah juga berkesan dalam menunjukkan kebarangkalian kegagalan yang lebih awal. Di sebaliknya, kombinasi kedua-dua cara ini pula menghasilkan kebarangakalian kegagalan yang terlampau.

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LIST OF SYMBOLS

c	=	Number of classes
n	=	Number of observations
$\sigma^2 = V(x)$	=	Variance
$\mu = E(x)$	=	Mean
β	=	the shape parameter of weibull distribution
θ	=	the scale parameter of weibull distribution
δ	=	the location parameter of weibull distribution
Y	=	dependent variable.
X	=	independent variable.
m	=	slope.
C	=	y-axis intercept
χ^2	=	chi-square value.
E	=	expected value.
O	=	observed value.
dt_n	=	corrosion depth at year t_n
t_n	=	year of inspection t_n
Lt_n	=	corrosion length at year t_n
t_i	=	Year of corrosion initiation
D	=	Outer diameter
d	=	depth of corrosion defect
t	=	pipe wall thickness
l	=	measured length of corrosion defect
$(d/t)_{meas}$	=	measurement of relative corrosion depth
γ_m	=	partial safety factor for prediction model and safety class
γ_d	=	partial safety factor for corrosion depth

ε_d	=	rupture value factor for corrosion depth
P_{mao}	=	maximum allowable operating pressure
Std[d/t]	=	standard deviation for measurement (d/t) ratio
SMTS	=	specified minimum tensile stress
G(x)	=	Limit state function
Pp	=	Allowable pressure
Pa	=	Applied pressure
P_f	=	Failure probability
$n(G(x)\leq 0)$	=	No. of failure attempts
N	=	No. of cycles

CHAPTER 1

INTRODUCTION

1.0 Introduction

Hydrocarbon pipeline in oil and gas industry is mainly used to transport oil and gas. It links the offshore production platform to the onshore facilities. Along the pipeline, it is exposed to various defects mechanisms. Corrosion, erosion and external pressure are among the well-known mechanisms that result significant influence to the integrity of pipelines.

As compared to other defect mechanisms, internal corrosion has been proven to be more difficult in terms of monitoring and evaluating. Not similar to external corrosion which can be easily seen and measured using simple tools, internal corrosion occurs inside the pipeline. It can not be easily seen and required more complicated tools to map, locate and measure the corrosion. This leads to various inspection tools invented. The inspection tools will be further discussed in latter chapter.

When more complicated tools are employed for the inspection, huge quantities of inspection data are produced. Usually, probabilistic method is adopted to transform these data into outcome in term of failure probability. With the great variety of distribution models and analysis approaches, different outcomes could be produced. This study concerns the effects of Peaks-Over-Threshold (POT) and extreme value statistics on the outcomes of analysis of inspection data.

1.1 Problem Statement

In oil and gas industry, the first failure is usually of the most concern. First failure always generated by the deepest corrosion pit in pipeline. Thus in order to evaluate or assess the reliability of pipeline, the deepest corrosion sites are of the most interest as these locations are the most likely locations for failure to initiate.

Each pigging inspection carried on a pipeline could produce a vast quantity of data, covering from the shallowest to the deepest corrosion defects. By considering all the data as independent source of potential failure, the analyses are subjected to numerical errors and subsequently lead to unrealistic estimated probability of pipeline failure. This is because of the failure probability of each single defect is very small among the huge quantities of data. Thus, it is more realistic to consider only the data that have exceeded certain extent (depth) of corrosion into the analyses. As these data are the most likely location for failure to initiate.

The research questions of this study include:

i. How significant the effect of extreme defects on the pipeline failure probability?

ii. What is the optimum truncation value to cut-off the low-risk data out of the huge quantities of inspection data?

1.2 Objectives of Study

The major aim to conduct this research is to study the extreme growth behaviour of corrosion pit in hydrocarbon pipeline. In order to achieve such aim, a few objectives are established to support the research. The associate objectives are listed below:

i. To model the normal growth and extreme growth of internal corrosion pit in hydrocarbon pipeline

ii. To determine the most optimum range of POT values for pipeline corrosion data.

iii. To compare pipeline failure probability between normal growth and extreme growth of corrosion pit in hydrocarbon pipeline using Monte Carlo Simulation process.

1.3 Scope of Study

The scope of this study covers the analysis of two sets of real in-line inspection data obtained from in-line inspection carried out on a pipeline located in North Sea by using magnetic flux leakage devices (MFL). The properties of the pipeline are shown in table.

Table 1.1 Properties of the inspected Pipeline

Length	Diameter	Wall thickness	Year of Installation	Year of Inspection
22km	242.1mm	9.53mm	1967	1998, 2000

Statistical, probabilistic analysis and simulation process are adopted in this study. They are used to analysis the inspection data. These inspection data concerns solely on the metal loss volume regardless the causes of loss. Thus none of material properties, environmental properties, operational condition and etc. are taken into account.

The analysis in this study involves conventional analysis method in combination with Peaks-Over-Threshold approach (POT) and extreme values statistic (EV) are to tackle the problem as mentioned in previous section.

1.4 Importance of Study

This study demonstrates the extreme analysis of pipeline inspection data using two approaches; peaks over threshold method and extreme value theory. Te applicability of both methods in pipeline assessment is investigated. By using both methods to emphasize the extreme corrosion pits in pipeline reliability assessment, an earlier failure probability can be foreseen. It might not be the precise failure time; however, it serves as precaution in planning the next inspection, maintenance or even replacement.