

DETERMINATION OF LEAKAGE IN AN OIL AND GAS PIPELINE

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Especially to my beloved father and mother who inspired me a lot throughout the
journey of my life;

Hj Mohideen Abdul Kadir Bin Hamim Marikar

&

Hajjah Zaleha Bt. Othman

And special dedication to my beloved husband and sons

Mohd Syafiz Bin Zakaria

&

Muhammad Adam Bin Mohd Syafiz and Muhammad Ammar Bin Mohd Syafiz

And for those who are always believe and appreciate in the richness of learning.

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ABSTRACT

Leaking pipes for oil and gas channel is a situation that can lead to a large problems. Among them, a massive explosion which could result in property damage, death or injury and thus involve high costs for repairing activities. Therefore, the first step in identifying any leaks is very important. This has implications on the development of a mathematical model to identify the leakage of pipelines for oil and gas. This dissertation will focus on determining the position and size of leaks in oil and gas pipelines in various circumstances, especially when operating on a pipe in a partially shut down condition. By using an observer in the production system model, simulation will be performed. Finite difference method used to solve the equations of the model next in the simulation will be made using MATLAB software. The graph resulting from these simulations will be read and discussed. The results of the simulations carried out with time varying boundary conditions, show that the observer is able to detect leaks in cases such as shut down and with sinusoidal varying boundary conditions.

ABSTRAK

Kebocoran paip bagi saluran minyak dan gas merupakan satu situasi yang boleh mengundang pelbagai masalah besar. Antaranya, letupan besar yang boleh mengakibatkan kemusnahan harta benda, kematian atau kecederaan dan seterusnya membabitkan kos yang tinggi untuk aktiviti baikpulih. Oleh itu, langkah awal dalam mengenalpasti sebarang kebocoran adalah amat penting. Ini memberi implikasi kepada penghasilan model matematik dalam mengenalpasti kebocoran saluran paip bagi minyak dan gas. Disertasi ini akan memberi fokus kepada penentuan kedudukan dan juga saiz kebocoran pada saluran paip minyak dan gas dalam pelbagai keadaan terutamanya semasa operasi pada paip tersebut dalam keadaan separa terhenti. Dengan menggunakan sistem pemerhati dalam penghasilan model, simulasi akan dilakukan. Kaedah Beza Terhingga akan digunakan untuk menyelesaikan persamaan model tersebut seterusnya simulasi akan dibuat menggunakan perisian MATLAB. Graf yang terhasil daripada simulasi ini akan ditafsir dan dibincangkan. Keputusan bagi simulasi dijalankan dengan masa yang berbeza-beza keadaan sempadan, menunjukkan bahawa pemerhati mampu untuk mengesan kebocoran dalam kes-kes seperti ditutup dan dengan bentuk sinus syarat sempadan yang berbeza-beza.

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LIST OF SYMBOLS

t	-	Time
x	-	Position
u	-	Flow velocity
ρ	-	Density of the fluid
ρ_{ref}	-	Reference density
p	-	Pressure of the fluid
p_{ref}	-	Reference pressure
\hat{p}	-	Pressure in the observer
p_{amb}	-	Ambient pressure
c	-	Speed of sound in fluid
k_0	-	Tuning constant for output injection at the outlet
k_L	-	Tuning constant for output injection at the inlet
L	-	Length of pipeline
D	-	Diameter of the pipeline

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CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter will briefly discuss on the dissertation flow from study of research background, problem statement and objective of the study. Hence, it follows by the scope of study, significant of the study and study overview. Each subtopic is related to each other in order to make the readers understand the process of the dissertation is conducted.

1.1 Research Background

Oil and natural gas are two item that mix together and form a petroleum. Petroleum in Latin means “rock oil” is a fossil fuel, that was made naturally from decaying prehistoric plants and animals. It is a mixture of hundred of different hydrocarbons molecules containing hydrogen and carbon that exist in two conditions sometimes as a liquid (crude oil) and sometimes as a vapour (gas).

Crude oil and natural gas are found throughout the world, beneath both land and sea, as follows:

- Western Hemisphere Intercontinental Basin (US Gulf Coast, Mexico, Venezuela)
- Middle East (Arabian Peninsula, Persian Gulf, Black and Caspian Seas)
- Indonesia and South China Sea
- North and West Africa (Sahara and Nigeria)
- North America (Alaska, Newfoundland, California and Mid-continent United States and Canada)
- Far East (Siberia and China)
- North Sea.

Natural gas is most probably can be found near petroleum field. The oil is then being transported to refineries and distilled into fuel or any base chemical products. While for natural gas, it is pumped from below ground and travels in pipelines. It is difficult to transport the natural gas across long distances. In most countries, the best action to be taken is to consume the natural gas within the country or exported to a neighbouring country by pipeline. Another alternative is by using the technology for liquefying natural gas so that it can be transported in tankers (like oil) is improving, but the volume of natural gas exported in this manner is still limited. As technology expands the options for gas transportation, demand for natural gas is expected to grow.

Transportation pipelines, mainly long pipes with large diameters, moving products (oil, gas, refined products) between cities, countries and even continents. These transportation networks include several compressor stations in gas lines or pump stations for crude and multi-products pipelines. Usually, oil pipelines are made from steel or plastic tubes with inner diameter typically from 4 to 48 inches (100 to 1,220 mm). Most pipelines are typically buried at a depth of about 3 to 6 feet (0.91 to 1.83 m). To protect pipes from impact, abrasion, and corrosion, a variety of methods are used. These can include wood lagging (wood slats), concrete coating,

rock shield, high-density polyethylene, imported sand padding, and padding machines. For natural gas, pipelines are constructed of carbon steel and vary in size from 2 to 60 inches (51 to 1,524 mm) in diameter, depending on the type of pipeline.

There are many factors that will give a big impact to the pipelines transportation. In oil and gas industry, some of the problem that could occur in the pipeline is heat exchangers and fouling in oil refineries, corrosion, inhomogeneous mixture and also leakage. Leaks in pipelines (Figure 1.1) and major accidents can occur, but are extremely rare situation. Leakage is a process in which material is gradually lost, intentionally or accidentally, through the holes or defects of their containers.

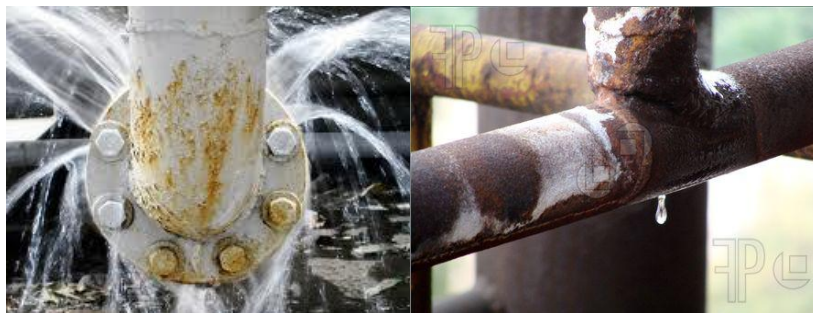


Figure 1.1 : Examples of leakage occurring through the pipeline.

The cause of leakage of fluid especially in pipelines occurs in a number of reasons such as fatigue crack. Fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. They manifest themselves as internal or external surface cracks that usually occur in the vicinity of longitudinal welds. Stress of corrosion is an external tension crack causes localised damage to the cathodic corrosion protection, resulting in corrosion in the area. Corrosion is the gradual destruction of material, usually metals, by chemical reaction with its environment. Another reason that can causes leakage is hydrogen induction. In this case, atomic hydrogen diffuses in to the metal matrix of the pipeline, resulting in the embrittlement of the metal. Material failure, for example the rolling in of

cavities during manufacture and internal influences that include earthwork and subsidence caused by mining activities also can cause leaks.

1.2 Problem Statement

Leakage in oil and gas pipelines can potentially cause of the losses of production, environment pollution and human safety, as well as economic loss. The effects of the damage that cause by oil and gas leaks to necessitates the development of efficient leak detection systems. However, it is difficult to detect any problem that could occur in the pipeline flow with the naked eyes. Therefore, to overcome this situations, there are many methods and techniques are being proposed. Several methods have been developed to detect the leakage of oil and gas in pipeline such as hardware based methods, non-technical methods and software based method.

The software-based methods that work for cases with limited instrumentation being considered as the motivations for this study. The leak detection model will be governed by a mathematical model. Based on the situation when once the leak is detected, the plant is start to shutting down the pipelines. At this moment the major problem of oil and gas production is to monitor the leakage of the fluid in pipeline.

Therefore this study will explore the following question:

- Can the leak detection system be improved under time-varying boundary conditions.

1.3 Objectives Of The Study

The objective of this study are :

1. To formulate the model of leak with friction
2. To formulate the observer model of leak with friction
3. To discretize the governing equation of the model using Finite Difference Method
4. To develop the algorithm for leak detection method

1.4 Scope Of The Study

The scope of this research are stated as the following :

1. Worked is based on the paper written by Espen Hauge et. al (2007) entitled “Model Based Pipeline Monitoring With Leak Detection”.
2. One-dimensional compressible flow described by time dependent continuity and momentum equations.

1.5 Significance Of The Study

This study should help the oil and gas productions to detect and locate the leakage more precisely and efficiently. Hence, it could give a great impact for economical and safety operation in this industry.



Figure 1.2 : View of the fire in San Bruno, California

There are several cases that involved pipelines and one of it, is San Bruno pipeline explosion in 9 September 2010 (Figure 1.2). San Bruno, California is a suburb of San Francisco, when a 30 inch (76 cm) diameter steel natural gas pipeline owned by Pacific Gas & Electric exploded in flames in the Crestmoor residential neighbourhood, 2 miles west of San Francisco International Airport near Skyline Boulevard and San Bruno Avenue. The explosion excavated an asymmetric crater 167 feet (51 m) long, 26 feet (7.9 m) wide and 40 feet (12 m) deep along the sidewalk of Glenview Drive.



Figure 1.3: Destruction after fire and explosion in San Bruno

The effect of the explosion is 38 of the houses damaged and 8 people death (Figure 1.3). Throughout the investigation that had been done by the National Transportation Safety Board, they found that the cause of the explosion is leakage on the pipeline. This disaster gave the great impact to the country.

Malaysia is one of the country that produce petroleum and natural gas (Figure 1.4). Based on the official website of Malaysian Investment Development Authority, Malaysia has the world's 14th largest natural gas reserves and the 23rd largest crude oil reserves. Currently, Malaysia produced 2000 million standard cubic feet per day of natural gas and 730000 barrels of oil equivalent per day of crude oil. Malaysia also has the world largest production facility at a single location of liquefied natural gas with production capacity of 24.2 million metric tonne per year.

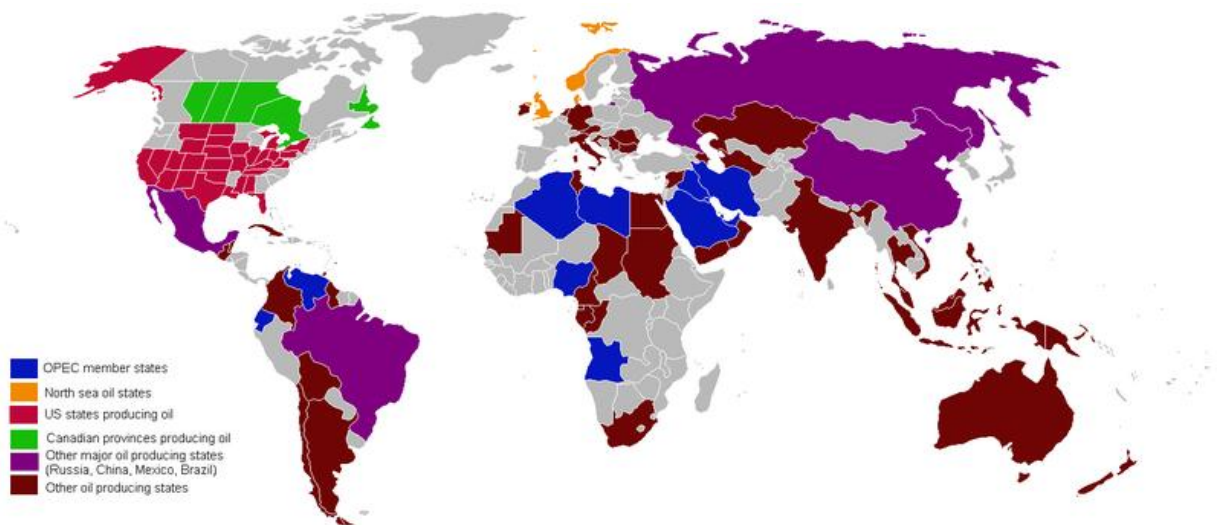


Figure1. 4: Map of countries that produce oil and gas in the world

In the petroleum and natural gas industries, a lots of pipelines are used here to transfer oil and gas from one place to another. Therefore, Malaysia should prepare for a variety of possibilities, particularly related to the leakage of the oil and gas pipelines. The management of leakage problem should get more attention and

prioritized by the player in the industries to prevent from the high impact explosions caused by pipeline leakage. Thus, early detection of pipelines leakage will help to save the whole country from disaster and also prevent from economic loss.

1.6 Outline Of Dissertation

This report contains six chapters including an introduction chapter in Chapter 1. The research background, problem statement, objective of the study, the scope of the study and the significance of the study will be discussed in this chapter.

The literature review of this study is discussed in the next chapter, Chapter 2. All previous studies or research that has been done and related with the current project is assembled in this chapter, including the theories, models, methods and figures that may support this project.

The dissertation's methodology that describes the method or approach that is used to solve the problem given will be discussed in Chapter 3. The derivation of the governing equations for the leak in pipelines is shown in this chapter.

Chapter 4 is to discuss the solution procedure. The procedure that will be used to analyze and to get the solutions for the model proposed in the previous chapter will be shown and used to obtain results in the next chapter using the appropriate mathematical package.

Chapter 5 is to discuss the result and discussion. The solutions from previous chapter will be used to analyze the problem proposed. All results and graph will be shown and attached in this chapter.

The last chapter is Chapter 6 the conclusion and recommendations. This chapter will be concluded with a summary after the whole project is completed. It also contains some suggestions for future studies.

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