FLOW IN A PIPELINE WITH LEAKAGE

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A dissertation submitted in partial fulfillment of the
requirement for the award of the degree of
Master of Science (Engineering Mathematics)

Faculty of Science
Universiti Teknologi Malaysia

JANUARY 2013

To my beloved Ma and Abah, my lovely Kak Long; my cute little brothers and sisters and my bestfriend, NurFara Azrin. Thanks for all their love and understanding.

And Thanks to Allah for guiding my ways.

ACKNOWLEDGEMENT

In the name of Allah, the most Beneficent, the most Merciful.

Alhamdulillah, all praises to Allah. Thanks to Allah for giving me the opportunity and the strength to fulfill my dissertation after all the challenges and difficulties.

First and foremost, I am deeply grateful to my supervisor, Dr. Anati Bt Ali for her guidance, advices and motivation in conducting this dissertation. I consider myself very fortunate for being able to work with a very considerate and dedication lecturer like her. I am gratefully thankful for her encouragement. I also indebted grateful to Prof. Norsarahaida Bt S.Amin and Prof Mohd Nor for giving me some suggestions, criticisms and constructive comment.

I would like to extent my gratitude to my supportive family who always support me in my journey of education. Thanks to mum, dad and siblings for your taking care of me in every way possible and for being there for me when I was exhausted to believe in myself. Thanks you for pushing me.

Last but not least, I would like to thank to all my beloved friends for their willingness to support and help me to ensuring the completion of this dissertation.

Once again, thanks to Allah for guiding my ways. Alhamdulillah.

ABSTRACT

Leakage in pipelines has always been one of the main problems in pipelines transportation fluid. This fluid leakage can happened without any warning. The leaking of fluid in pipeline can give effects to the economic loss and environmental risk. Therefore, the early detection of leak is a main role in the fluid transportation pipelines. This paper presents a technique for early detection of leak in single pipe. The fluid pressure and flow rate velocity are considered as two dependent variables. The governing equations of transient flow were proposed. The mathematical formulation describes the solution process and then solved by the Method of Characteristics and Finite Different Method (FDM). The simulation of pipeline leakage with the three different diameters has been carried out by Matlab programming to see the behavior of pressure and flow in the upstream head and downstream head when leakage occurs. The results show; flow rate trends at the incoming fluid flow pipelines is not equal to outgoing fluid pipelines when leaking occurs and pressure trend at the incoming fluid also not equal to pressure trend outgoing fluid. These situations are obtained to indicate the early presence of leakage. This method provided a theoretical basis for early recognizing leakage.

ABSTRAK

Kebocoran paip sentiasa menjadi satu masalah utama dalam bidang pengangkutan bendalir melalui paip. Kebocoran bendalir ini boleh berlaku tanpa sebarang amaran. Kebocoran bendalir di dalam sistem paip ini boleh memberi kesan kepada kerugian besar terhadap ekonomi negara dan juga memberi risiko terhadap alam sekitar. Oleh itu, pengesanan di peringkat awal kebocoran memainkan peranan yang penting dalam bidang pengangkutan bendalir melalui paip ini. Kertas ini membentangkan satu teknik untuk mengesan kebocoran di peringkat awal kebocoran dalam paip tunggal. Tekanan bendalir dan kadar aliran halaju dianggap sebagai dua pembolehubah bersandar. Persamaan asas aliran fana diperkenalkan. formulasi matematik menerangkan teknik penyelesaian dan kemudian diselesaikan oleh kaedah ciri-ciri dan kaedah beza terhingga. Dengan menggunakan pengaturcaraan Matlab, simulasi kebocoran di saluran tiga paip yang berbeza diameter telah diuji untuk melihat bentuk tingkah laku tekanan dan aliran di awal takungan dan di akhir takungan apabila kebocoran paip berlaku. Keputusan menunjukkan apabila wujudnya kebocoran pada sesuatu paip, trend kadar aliran pada awal aliran bendalir masuk tidak sama dengan akhir aliran bendalir keluar dan begitu juga dengan trend tekanan bendalir. Situasi sebegini menunjukkan bahawa kebocoran di dalam paip boleh dikesan pada peringkat awal. Kaedah ini hanya menghasilkan satu asas teori untuk mengesan dan mengenalpasti kebocoran.

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LIST OF SYMBOLS

Room Letters

A	Cross-sectional area of pipe
a	Wave speed
C^+	Positive characteristic equation
C^-	Negative characteristic equation
D	Diameter of the pipe
D/D_t	Total Derivative
e	Pipe wall thickness
E	Young Modulus of the pipe
f	Darcy-Weisbach Friction forces
g_x	Axial component of the gravity acceleration or body force
H	Hydraulic Head
k	Minor Loss Coefficient
P	Pressure
Q	Flow Rate
R	Pipe Friction Constant
r	Radial pipe position
u	Fluid Velocity
u_r	Radial of the fluid velocity
u_θ	Rotational of the fluid velocity
u_x	Axial component of the fluid velocity

Greek Letters

V	Fluid velocity
z	Elevation of Pipe
β	Bulk modulus of elasticity
ε_T	Circumferential strain
ρ	Fluid Density
τ	Shear stress
τ_w	Shear stress at the wall
μ	Fluid Viscosity
ν	Poisson's Ratio
x	Distance along length of pipe
η	Unknown multiplier used in Method of Characteristic derivation
σ_θ	Circumferential pipe stress
σ_z	Axial pipe stress

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In general, transportation in pipelines is among the biggest infrastructure projects in developing countries in recent years. Transportation in pipelines is the transportation of good through a pipe. There is much type of fluid or sources that can be transported by pipeline such as refineries, oil or natural gas, biofuel, ammonia, hydrogen, coal, beverage and the common one is water. Commonly, an industry provided a pipeline that comprises steel pipes that are always buried in land. The line (pipe) comprises pumping station to propel the liquid and terminal at both ends for the product or source being carried.

In this pipeline transportation, the fluid flow is considerable importance in process for homes and city (water), for country and transport in daily life (oil or natural gas) and many more. Generally, the fluid could be a single phase, liquid phase or gases phases. It also could be the mixture of gas, liquids or may be solid.

Pipelines transporting fluids requires to a great extent in the world nowadays. As the study mention above, the pipelines can be classified in three categories depending on purpose which is gathering pipelines, transportation pipelines and distribution pipelines.

Transmissions pipelines flow model are one of the larger pipeline which is they are the main arteries of the oil and gas transportation systems (in certain case).

Generally, the public will not normally see these as they are either under the sea or buried on land. In order to support high transportation rates, the transmissions pipelines usually large diameter and operate at high pressures. Also, the transmission pipelines have a good safety record since the combination of good design, materials and operating practices has been developed.

During the construction and operation, the pipelines must be able to withstand a variety of loads and ranging from the high loads because the major cases in most pipelines is that cause by the internal pressure. Generally, there exist four main categories of pipeline failure in this industry such as the pipeline corrosion and wear which it is possible damages that can be happen because of the product used itself.

Hence, the operation outside design limits whereas the operators seek to use the line for as many fluids as possible. Unintentional third party damage and intentional damage also included in pipelines failures categories that will cause a big implication to industry.

Generally, there are many factors that will give a big impact to the pipelines transportation. Any possibility could be happen in the pipelines flow since the naked eyes also cannot notice the problem occurs. For example, in oil and gas industry, heat exchangers and fouling in oil refineries, inhomogeneous mixture, corrosion and also leakage problems could be happened in pipeline. Typically, heat exchanger is commonly used a chemical process in order to transfer heat from hot fluid to a cool fluid through a solid wall (Khare, 2010). Most of the industries used heat exchanger system since there exist many different types of heat exchanger in the industry. Meanwhile in oil refineries, fouling is the major cause of energy loses since through the years, the oil industries need to face this problem.

The next example for fluid that is transported by pipelines is water. Water is the most important sources that are very potentially useful to humans, animals, plants and many others. The uses of water are also useful for agriculture, recreational uses

and industrial part. The entire user needs clean water and fresh water to live in this world and due to that the clean water is in high demand. Same as in oil and gas industry, any possibility could be happen to the groundwater flow in pipelines. One of the possibility is the groundwater can become polluted in the pipelines flow when toxic are dissolved into water. Otherwise, the most famous problem in pipeline flow is the leakage problems can happened. Surely, all of these problems will give a drastic impact to economic of the country.

There exists too many methods and techniques to reduce the risk due to ensure the pipelines are not damaged, or that damage is detected before it poses a problem. Here are the examples of the methods used to detect damage to the pipelines such as, patrol, internal inspection, above ground inspections, leak surveys, specialized surveys, on-line quality monitoring, hydro testing and public awareness.

Mathematically, the inspection can be done by solving its governing equations analytically or numerically. Here, we interested to consider the Finite Different Method (FDM) to describe the solution process. Finite Different Method was proposed by Zixuan *et. al* (2010) and was used to carry out a qualitative analysis on the negative pressure wave transmissions process and reflection in the closed pipeline. In fact, the finite difference method is a technique suitable for recognition of pipeline leakage.

Thus, in this dissertation a Matlab programming will be developed to solve the finite difference equation to analyze the variations trend of pressure and flow after leakage.

1.2 Problem Statement

Transportation of fluids in pipelines is very common in chemical and petrochemical industries. In this case, leaks in pipelines are the most serious problem

and whereas it has the potential to cause significant environmental damage and economic loss. The flow and pressure in a pipeline having leakage can be seen by using numerical or mathematical approach. These flow and pressure are affected by the external factors such as diameter of pipelines or types of a pipeline.

1.3 Objective

The objectives of this project are:

1) To formulate a mathematical model due to leakage problem in a pipeline.
2) To construct a numerical descritization of the governing equations problem.
3) To analyze the result from simulation for a leakage problem for different diameter of pipe.

1.4 Scope of the Project

Scope of this project is focusing on the basic assumption from a mathematical modeling. The flow transient analysis model of pipeline is built on the following assumption such as the flow is one dimensional, the flow is non-stationary and the flow is incompressible. As model of pipeline has the basic assumption, we construct the numerical calculation of transient flow theory to pipeline leakage.

1.5 Significance of the Study

The positive result of this study will has a great impact for economical, time needed and safety operation in this industry. This also will give some ideas to other researcher due to solve the real life problems out there by using the mathematical

modeling. Hence, the application of mathematical modeling will be introduce to the world which may be used as a reference to other related areas.

1.6 Introduction to Chapters

This report contains six chapters including introduction chapter. Section 1.1 presents the research background on the development of research in this area. Section 1.2 described the problem statement; Section 1.3 listed the objectives of the study while Section 1.4 is state about scope of the study and Section 1.5 elaborate about significance of the study.

In Chapter 2, we discuss about the literature review. We are looking for related publication of research, papers, journals, books or any discussion related to this study. This reference will support our study with strong evidence from the result published.

The main objective in Chapter 3 is to understand about transient pipe flow equation. The transient pipe flow equation was introduced in this chapter. The derivation of momentum and continuity equation is shown where the study needs to reduce the partial differential equation to ordinary differential equation.

The next chapter describe about method use in this study named Method of Characteristics. The method of characteristics is introduced after the momentum and continuity equations are derived. Then, we introduced the Finite Difference Method and there are several steps that we have go through using this method, called discretization shown in Section 4.2.1. The rest are discussing about the notation for flow and pressure in a pipeline.

Majority parts of Chapter 5 are describing the application result obtained in Chapter 3 and Chapter 4. We will use the equation from both chapters and apply them to the mathematical programming; Matlab. We have used the existing

algorithm to use in the program in solving a mathematical model given in chapter three. Next, the chapter also describes the analysis of results which elaborate about the behavior of pressure and flow rate trend with different diameter.

Finally, the summary of this study will be included in Chapter 6. This chapter also contains some suggestions for future studies.

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