UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical and Manufacturing Engineering Technology

INVESTIGATION OF THE LENGTH OVER DIAMETER RATIO OF TANDEM PIPE BY COMPUTATIONAL FLUID DYNAMICS METHOD

Dolly Po Jin Ming

Bachelor's Degree in Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours

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TAJUK: **Investigation of Length Over Diameter Ratio of Tandem Pipe By Computational Fluid Dynamics (CFD) Method**

SESI PENGAJIAN: **2019/20 Semester 2**

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I at this moment declare that I have read this project report. In my opinion, this report is enough in term of scope and quality for the award of bachelor's degree in Mechanical Engineering Technology.

Signature :______________________________

Name : Dr Abdul Munir Hidayat Syah Lubis

Date :______________________________

DEDICATION

To my beloved mother and father

ABSTRACT

The aim of this research was to study the effect of the length over diameter ratio in tandem pipe to the fluid pressure and fluid vortex characteristic. Failure due to vibration was the primary concern in oil and gas plant either in offshore or onshore plant. When vortex was shed, a force was produced and act to the inner pipe wall which can cause a vibration named as Flow-induced vibration (FIV). This study was performed using ANSYS FLUENT. A main pipe (MP) inlet with diameter of 0.7112m and two branch pipes which were Remote Controlled Valve (RCV) and Automatically Controlled Valve (ASV) with diameter of 0.6069m were used as parameter. Fluid with the speed of 30m/s were flowed from MP to inlet elbow, then pass through RCV continues with ASV then meet outlet elbow. Valve at both RCV and ASV were assumed fully closed. The initial case of study of the length over diameter ratio was 2. Modification will apply to the length of the pipe where the ratio become 2.5 and ratio 3. According to the result obtained, it was found that tandem branches can cause velocity and pressure drag. Besides, vortex mainly shed at the bending corner and tandem branches mouth. The vorticity increase when increasing the distance between branches. The velocity and dynamic pressure increase as the length over diameter ratio increase.

ABSTRAK

Tujuan kajian ini adalah untuk mengaji kesan nisbah panjang ke atas garis pusat dalam paip tandem pada tekanan cecair dan ciri-ciri vorteks bendalir. Kegagalan akibat getaran adalah persetujuan utama dalam loji minyak dan gas sama ada di loji luar pesisir atau di darat. Apabila vorteks ditumpahkan, daya yang dihasilkan akan bertindak ke dinding paip dalaman yang boleh menyebabkan getaran yang dinamakan sebagai getaran disebabkan vorteks. Kajian ini dilakukan dengan mengunakan ANSYS FLUENT. Satu paip utama dengan garis pusat 0.7112m dan dua paip cawangan dengan garis pusat 0.6096m yang dinamakan injap kawalan jauh (RCV) dan injap kawalan secara automattik (ASV) dibentukan. Cecair dengan kelajuan 20m/s, 30m/s, 40m/s daripada MP akan mengalir RCV, ASV dan akhir sekali mengeluar daripada outlet. Kedua-dua injap di RCV dan ASV diangkap tutup. Kes awal mengajikan nisbah panjang ke atas garis pusat adalah 2. Pengubahsuaian akan digunakan dengan nisbah panjang ke atas garis pusat mencapai 2.5 dan 3. Berdasarkan keputusan yang didapati bahawa cawangan tandem boleh menyebabkan halangan dan tekanan seret. Selain itu, vortex terutamanya susut lenturan dan persimpangan cawangan tandem. Vorticity akan tinggi apabila jarak antara cawangan paip meningkat. Apabila peningkatan nisbah halaju dan tekanan dinamik juga meningkat.

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LIST OF SYMBOLS AND ABBREVATION

FIV	-	Flow Induced Vibration
CFD	-	Computational Fluid Dynamics
HVAC	-	Heating Ventilation Air-Conditioning
Re	-	Reynolds number
FEM	-	Finite Element Method
FVM	-	Finite Volume Method
RCV	-	Remote Controlled Valve
ASV	-	Automatically Shut-Off Valve
MP	-	Main Pipe
ID	-	Inner Diameter
ρ	-	Density
V	-	Velocity
D	-	Diameter
A	-	Area
μ	-	Viscosity
V	-	Kinematic Viscosity
τ	-	Shear Stress
$\frac{du}{dy}$	-	Velocity Gradient
f	-	Friction Force
C_D	-	Drag Coefficient

F_D	-	Drag Force
C_L	-	Lift Coefficient
F_L	-	Lift Force
k	-	Thermal Conductivity
E_p	-	Potential Energy
E_k	-	Kinetic Energy
U	-	Internal Energy
F	-	Force
m	-	Mass
a	-	Acceleration
g	-	Acceleration due to gravity
h	-	Elevation
L	-	Length
f_h	-	Frictional Loss
Pa	-	Pascal
Ss	-	Second

CHAPTER 1

INTRODUCTION

1.1. Introduction

In recent decade, piping systems are widely used for fluid distribution system in various industry fields. Based on the geometry, there are two types of fluid conductor employed in most industries, circular and non-circular pipe. When fluid conveys through a round conductor, it is named as pipe, tube or hose, whereas when fluid pass through a non-circular cross-section conductor, it is named as duct (Schirber, 2015). Normally, a circular pipe is used in fluid transportation purpose whereas non-circular pipe is usually used in application which involved heating and cooling process (Ziada & Buhlmannt, 1992). Fluid not only flow in straight line but also flow in direction via different pipe fittings such as tee, elbow, Y-shape and T-shape (Liestyarini, 2016). Often, the existence of such fittings will produce hydraulic loses to the fluid flow. the loses produce velocity and pressure drop in the piping or pipeline system which relate to friction factor (Mormanto, 2014). Friction factor is a quantity used to descript frictional losses in a pipeline where the factors are pipe material, Reynold number, viscosity and fitting size.

Flow-induced vibration (FIV) is a vibration or vortex shedding due to internal flow of fluid in a piping system (Siemens,2017). Velocity, density, length of pipe and pressure of fluid are the hydrodynamic quantity that will influence the FIV (Luo et al., 2015). However, the main cause of FIV is the shed vortex generated during the fluid flow. Vibration will occur when a body is exposed to fluid that produce vortex shedding. Bai (2005) stated that vortex shedding frequency that approximate or same as natural frequency of an object will cause FIV to happen. Vortex can easily be shed when the fluid velocity is high or when the inlet is disturbed. Years after years, this phenomenon can bring damages to the pipe component in a piping system such as breaking and leaking (Duan et al., 2018).

1.2. Problem of Statement

Addition of branched joint is common method to change the direction of fluid flow in pipeline. A tandem branched pipe is commonly installed to control the fluid flow direction. Fluid can be distributed or accumulated by installing the tandem pipe. However, since additional of pipe fitting known to be related to friction loses, the existing of fittings should be taken into account in design of piping and pipeline.

Cole (1999) stated that friction losses can happen in any pipe fitting such as tandem pipe and elbow. Vibration such as flow-induced vibration (FIV) will happen when fluid passed through these pipe fitting. These pipe fitting interrupt the smooth fluid flow thus cause additional losses because of the flow separation (Cengel & Combala, 2014). When fluid pass through pipe fitting, separation region will be created. These fluid separations can lead the internal fluid flow become unsteady due to the formation of vortex and usually can cause a large drag force (Snoorri, 2014). Furthermore, vortex shedding can create an oscillatory force which cause vibration to the piping system.

Fatigue damage caused by vibration is a serious challenge faced by most oil and gas industry. Bruce (2013) mentioned that more than twenty percent of pipe failures were because of vibration. A piping system might be broken due to strong shear force (Li et al., 2017). Once the piping structure is broken, the replacement cost will be very high. This phenomenon always happens in a turbulent flow where high Reynolds number occurs (Lim, 2003), low-pressure area (Giosan, 2006), slender structure (Fu, 2018) and non-straight-line piping.

In the past, most existing studies concentrated on the FIV of straight cylinders with different parameters. In a study conducted by (Wu et al, 2012) found that the vibration behavior for long slender cylinder and short rigid cylinder are significantly different. Keshtkar (2017) examined that by increasing fluid velocity, the inflicted vibration will increase in frequency. Although there are numerous researches or study about FIV are carried out in the past, however the research on the relationship between branches distance over the main pipe diameter ratio ($\frac{L}{D}$) in the tandem pipe is still limited. Therefore, such study is still required.

1.3 Objective

II. To investigate the effects of the pipe's length and diameter ratio of tandem pipe to the fluid flow characteristic.

III. To observe the effects of the pipe's length and diameter ratio of tandem pipe to the fluid pressure.

1.4. Scope of study

I. This study only performed simulation and analyses to the internal fluid flow in tandem pipe arrangement.

II. The analysis on the effect of fluid force to structural vibration is exclude in this project.

III. The study performed based on simulation through ANSYS FLUENT CFD software.

IV. Fluid used in the simulation is gases, other fluid's is not considered in this project.

V. The study performed for length over diameter ratios ($\frac{L}{D}$) of 2, 2.5 and 3. Other ratio are excluded from the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Pipe

A pipe is a hollow cylinder which is usually used to transport fluid from a place to another. Industry always uses different pipe of sizes and material depending on the fluid that conveys. Piping with various shapes and size can be joined together by using pipe fittings. Sometimes, several pipes joined in a system in an industry can be very complex as shown in figure 2.1. The piping system not always constructed in a straight line but also in a non-straight or crossing line so it can transport the fluids to a different direction.

Figure 2.1 A complex piping system (Walter, 2015)

2.1.1 Circular pipe

Industry often use circular pipe to transport fluid. This is because circular pipe has a small cross-sectional area compared to the non-circular pipe with the same diameter. As the cross-sectional area of the internal pipe is smaller, the friction between the internal wall and the fluid is smaller as well. A circular pipe can withstand higher fluid pressure than the non-circular pipe (Cengel & Combala, 2014). Besides, a round circular does not consist any sharp edge such as triangular and rectangular pipe. The sharp edge can cause high friction loss in a fluid flow. As the friction losses are high, the energy loss also high. To reduce high energy losses, a round pipe is usually being selected.

Figure 2.2 Circular pipe (Rodriguez, 2018)

2.1.2 Non-circular pipe

Non-circular pipe such as rectangular usually called duct, is typically used in heating, ventilation and air conditioning (HVAC) system. The friction between fluid flow and internal wall is high in rectangular duct because of the large cross-sectional area. High cross-sectional area will cause high energy loss or pressure drop in the system. However, square or cylinder duct is easier to manufacture compared to the round duct.

2.1.3 Pipe fittings

Several pipes can be connected or joined together in a piping system by using pipe fitting such as elbow, tee, reducer and end cap. The purpose of using these fittings are to change the direction of the fluid flow, change the pipe size and stop the flow. The material of pipes can either be metallic or plastic, whereas the pipe fittings vary depending on the type of pipe installed.

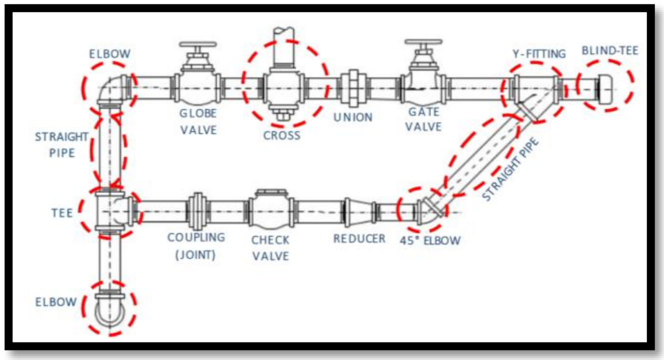

Figure 2.3 Pipe fittings (Shearer, 2014)