# FLUID STRUCTURAL INTERFACE OF FORCE EXCITATION ON PIPELINE ELBOW JOINT

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## ABSTRACT

Piping systems are one of the most reliable and safest means of transfer of matter and energy. The length of the piping system can archieve hundreds of kilometers and belong the piping system can occur mechanism failure modes including cracking, lage deformation, buckling, fracture, local damage, corrosion and clogging of piping systems. Piping system has a lot of connector along its connection. For example equal elbow, T-Joint, Pipe nipple and Pipe Offset. The connectors has their own problem and that problems can cause accident. So, it is a responsibility for engineers to make researches in other to improve the piping system.

## ABSTRAK

Sistem perpaipan adalah antara salah satu yang sangat berguna dan selamat bagi menyalurkan jirim dan tenaga. Panjang system paip boleh mencapai sehingga berates-ratus kilometer dan kemungkinan untuk berlaku kegagalan mechanism untuk berfungsi dengan baik seperti retak, perubahan bentuk, bengkok, kerosakan, dan karat. Sistem perpaipan mengandungi bayak penyambung sepanjang perhubungannya. Sebagai contoh, sesiku, penyambung T, dan paip lurus. Setiap penyambung mempunyai masalah yang memungkinkan berlaku kemalangan. Jadi, sangat penting untuk jurutera mereka system yang selamat untuk mengelakkan kemalangan. Tanggungjawab jurutera untuk membuat kajian bagi menambah baik system perpaipan.

# **TABLE OF CONTENTS**

	Page
EXAMINER'S DECLARATION	ii
SUPERVISOR'S DECLARATION	iii
STUDENT'S DECLARATION	iv
ACKNOWLEDGEMENTS	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	Х
LIST OF FIGURES	xi
LIST OF SYMBOLS	xiii

# CHAPTER 1 INTRODUCTION

1.1	Introduction	1
1.2	Objective	1
1.3	Scope of study	2
1.4	Project background	2

# CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	3
2.2	Fluid Structural interface of force excitation	3
2.3	Pipeline elbow joint	5
2.4	Modal Analysis	9
2.5	Operatinal Deflection Shape	10
2.6	Mode Shape	11
2.7	Ansys Software	12

viii

# CHAPTER 3 METHODOLOGY

3.1	Introduction	14
3.2	Flow chart methodology	14
3.2.1	Flow chart 1	15
		vii
3.2.2	Flow chart 2	16
3.3	Gantt chart	17
3.4	Test rig and tools preparation	19
3.5	Procedure	27

# CHAPTER 4 RESULTS AND ANALYSIS

4.1	Introduction	28
4.2	Experiment result	29
4.3	Result of Simulation	36
4.4	Comparison Between Experiment and Simulation	39

# CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Conclusion	40
5.2	Suggestion	40
REF	ERENCES	41
APP	ENDICES	
А	Gantt chart for FYP 1 and FYP 2	43
В	Dassy Lab Layout	45
С	The example of the test data gain	46

# LIST OF TABLES

Table No.	Title	Page
4.1	Table of frequency, maximum and minimum deformation of structure.	39
4.2	Table of comparison of frequencies	39

# LIST OF FIGURES

Figure No.	Title	Page
2.1	Tacoma Bridge Breakdown	4
2.2	Example of Fluid Structural Interaction analysis	5
2.3	Piping system	6
2.4	Equal Elbow	8
2.5	Elbow 45	9
2.6	Phase of a modal testing	10
2.7	An FRF measurement	11
2.8	lissajous pattern indicating a pure mode.	12
2.9	Ansys workbench	13
3.1	Flow Chart for FYP 1	15
3.2	Flow Chart for FYP 2	16
3.3	Gant Chart for FYP 1	17
3.4	Gant Chart for FYP 2	18
3.5	One whole system of pipeline.	19
3.6	Elbow-Joint Part 1	20
3.7	Elbow-Joint Part 2	21
3.8	Elbow-Joint Part 3	21
3.9	Elbow-Joint Part 4	22
3.10	Support for test rig.	22
3.11	Impact hammer.	23
3.12	Accelerometer sensor	24

xi

3.13	Data acquisition sensor.	24
3.14	Modal testing layout.	25
3.15	Dassy lab layout.	26
4.1	Structure of test rig in mescope	29
4.2	Mode shape and frequency at x axis.	30
4.3	Mode shape on elbow joint for x-axis.	31
4.4	Mode shape and natural frequency of y-axis.	32
4.5	Mode shape on elbow joint for y-axis.	33
4.6	Mode shape and natural frequency of z-axis.	34
4.7	Mode shape on elbow joint for z-axis.	35
4.8	Elbow-Joint Dimension in Ansys Software	36
4.9	The characteristics of pipe	37
4.10	Mode shape 1 at frequency 26.849 hertz.	38
4.11	Mode shape 2 at frequency of 31.56 hertz.	39

# LIST OF SYMBOLS

- *⁰* Degree
- μ Micro
- % Percentage
- c Celsius

## **CHAPTER 1**

### INTRODUCTION

#### **1.1 INTRODUCTION**

Piping Vibration failures have been one of the major causes of downtime, fires and explotions in industrial plants over the past 30 years. For example, one piping failure at a petrochemical plant in 1974 caused over \$114,000,000 in property damage. In nuclear pressurized water reactor power plants, over 80 cases of cracks or leaks occured in the piping systems of charging pumps over a two-year period (A.S Tijsseling, 2001).

Therefore, it is important to study in order to determine the level that acceptable for piping vibration. If the vibration level is excessive, the piping configuration, support structure, and material may have to modified to make the system in balance (A.S Tijsseling, 2001).

Vibration problem areas of typical piping systems include the excitation of the following:

i.Piping span natural frequencies

ii.Valves and valve compo

iii.Piping shell axial natural frequencies.

Piping system is developed early since a few centuries back. No wonder the development and research will keep running to improve the system time to time.

In this project, a simulation and an experiment has been conducted to determine the mode shape and the natural frequency of the structure.

#### **1.2 OBJECTIVES**

For this project, two main objectives are listed:

- 1. To find the mode shapes and natural frequency of piping system focusly on elbow joint
- 2. To compare the result of Modal Analysis experiment with the actual result from Ansys Sofeware.

#### **1.3 PROBLEM STATEMENT**

Piping systems are one of the most reliable and safest means of transfer of matter and energy. The length of the piping system can archieve hundreds of kilometers and belong the piping system can occur mechanism failure modes including cracking, lage deformation, buckling, fracture, local damage, corrosion and clogging of piping systems. Piping system has a lot of connector along its connection. For example equal elbow, T-Joint, Pipe nipple and Pipe Offset. The connectors has their own problem and that problems can cause accident. So, it is important for engineer to design the systems safely in order to prevent accident. So, it is a responsibility for engineers to make researches in other to improve the piping system.

## **1.3 SCOPE OF STUDY**

The scope of study is to conduct an experiment on Fluid Structural Interaction of force excitation on pipelines elbow joint by using Modal Analysis experiment. The aim of this experiment is to define the mode shape and natural frequency on elbow joint. The elbow-joint has been placed at four differences partin piping system. Therefore, we will know the difference result at difference pressure and height. After the experiment is done, the result of experiment will be compared with the exact data from ANSYS Software.

#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 INTRODUCTION

This chapter is briefly explain on piping system, elbow joint, modal analysis, and Operational Deflection Shape. In has been studied by using a few journals that been made by researchers. Besides, the information about software for experiment will be explain in this chapter.

## 2.2 FLUID STRUCTURAL INTERFACE OF FORCE EXCITATION

Fluid-structure interaction (FSI) occurs when a fluid interacts with a solid structure, exerting pressure on it which may cause deformation in the structure and thus alter the flow of the fluid itself.

Fluid-structure interaction in piping systems (FSI) consists of the transfer of momentum and forces between piping and the contained liquid during unsteady flow.

Such interactions may be stable or oscillatory, and are a crucial consideration in the design of many engineering systems, especially aircraft. Failing to consider the effects of FSI can be catastrophic, especially in large scale structures and those comprising materials susceptible to fatigue

The first Tacoma Narrows Bridge, is probably one of the most infamous examples of large-scale failure (A.S Tijsseling, 2001).



Figure 2.1 : Tacoma Bridge Breakdown

Fluid structure interaction in liquid filled system comprise two separate analysis that undertaken sequentially. Usually a fluid transient code is use to defined the pressure and flow velocities of the liquid, that are used as a input in a structure dynamic code that is call uncoupled. The dynamic code has some limitation because it neglected the crucial interaction between the liquid and the pipe. Pressure pulsation and mechanical vibration in liquid transporting pipe system had an effect that affects the performance and the safety of the pipeline system. The pipe motion contributes to the dynamic pressure to the less restrained system. It will because the analyses of the fluid structure interaction cannot be properly consider independent. When we compared the conventional analyses, it may lead to higher or lower extreme pressure and stress in fluid structure interaction analyses. Due to the change of natural frequencies more damping and dispersion in the pressure and in the stress. There are many factor that need to be consider when do fluid structure interaction, the factors that need to be consider is sources of excitation or on possible responses to an citation. Excitation can be categorized into single larger event or repetitive excitation. The factor that can be neglected liquid pipe coupling, there are three type of liquid pipe coupling; friction, Poisson and junction coupling. Friction and junction coupling happen along entire pipe also call as distributed force. Junction coupling happens at the specific point (local forces) in the network. Poisson coupling relate pressure in the liquid to axial stresses in the pipe through the radial contraction and lead to precursors waves. Friction coupling is happen when there are interaction between the pipe wall and the fluid(D.J Leslie, 2001)



Figure 2.2 : Example of Fluid Structural Interaction analysis

## 2.3 PIPELINES ELBOW JOINT

#### 2.3.1 Piping System

A system can be described as a collection of related elements. The elements of a systems consist of their own subsystem. A subsystem is a element or functional component of a larger system and it fulfills the requirement of a systemic entity which has been integrated into large system and as a constituting part, plays a role in the existence and behavior of the large system

Pipeline is like any other technical installation are not only assemble of elements, but the structural systems interacting with their environment (Farshad,2006)



Figure 2.3: Piping system

Source: http://www.thecenturionco.com/upvc-piping-system-216345.html

## 2.3.2 Type Of Connector Of Piping System

There are several types of connector in piping system. The function of connector is to connect pipes with different materials or different type of pipes that required different joining methods. Types of Connectors:

a)Tee – Bullhead

When a branch is larger than the other two run openings, it is referred to as a bullhead tee. On a "bullhead tee" the side outlet is the largest socket on the tee and the side outlet is referred to as the "Bullhead". Thus, Bullhead Tees are the tees in which the ports of the run are smaller than the port of the branch.

## b)Pipe Nipple

A pipe Nipple is a short pipe, with small opening which provides way for liquids or gases to pass through the pipe. It has a male thread on end and is used for extension from a fitting.

#### c)Wye – Standard

As the name implies, this fitting device is "Y" shaped. The branch runs out from the run port at an angle other than 90 degree. It is a fitting with three openings and is used to create branch lines.

#### d) Pipe Offset

An Offset means a combination of pipes and/or fitting that brings one section of the pipe out of line but into a line, parallel with the other section. Apart from different materials, these offset pipe fittings are manufactured in awide range of dimensions as per the specific requirements of the applications.

e) Equal Elbow

f) Elbow – 45

#### 2.3.3 Elbow Joint

There are two types of elbow joint which are Equal Elbow and Elbow 45. It is commonly used to connect pipes in a junction area.

#### 2.3.3.1 Equal Elbow

Equal elbow is a quick-connect fittings that are extremely helpful in routing water lines that are laid in confined areas. They are known as 'elbow fittings' because they display an angular bent so that two pipes can be easily fixed an the same manner. An elbow fitting has hard poly-ethylene tubinfg that prevents kinking in tight conners. It basiccally has M# and M% threated ends which are designed to be hand tightened.



Figure 2.4 : Equal Elbow

Source: http://www.plasticpipe.com.cn/fittings\_pvcpipe.htm

#### 2.3.3.2 Elbow 45

45 degree elbow, also called "45 bends or 45 ells" are typically made as Long Radius elbows. Available in various sizes( in mm or inches), 45 degree pipe elbow is available with different male to female BSP thread connections. Providing a wide choice of colours, these elbows csan be manufacted to meet different specifications, in term of size and diameter.



Figure 2.5 : Elbow 45

Source: http://www.plasticpipe.com.cn/fittings\_pvcpipe.html

#### 2.4 MODAL ANALYSIS

Modal analysis is defined as the study of the dynamic characteristics of a mechanical structure. This application note emphasizes experimental modal techniques, specifically the method known as frequency response function testing. A basic understanding of structural dynamics is necessary for successful modal testing. Specifically, it is important to have a good grasp of the relationships between frequency response functions and their individual modal parameters (R. J. Allemang 1982).



Figure 2.6 : Phase of a modal testing

#### 2.5 OPERATIONAL DEFLECTION SHAPE

An ODS has been defined as the deflection of a structure at a particular frequency. However, an ODS can be defined more generally as any forced motion of two or more points on a structure. Specifying the motion of two or more points defines a shape. Stated differently, a shape is the motion of one point relative to all others. Motion is a vector quantity, which means that it has location and direction associated with it. This is also called a Degree Of Freedom, or DOF.

Measuring ODS's can help answer the following vibration related questions, 1)Where is it moving the most, and in what direction? 2)What is the motion of one point relative to another (Operating Deflection Shape)? 3)Is a resonance being excited? What does its mode shape look like?

Operating deflection shape and mode shape only induced in the resonant vibration that has two degree off freedom vibration. Resonant vibration is the factor that vibration problem occur in the structure. Vibration that happens in the structure is the combination of two or more two degree of freedom force and resonant vibration force. If we want to understand the vibration structure problem that happen, we need to defined the resonant. The resonant that has in the structure that induced vibration is natural frequency, modal damping and mode shape. The resonant vibration is induced when there is interaction between the inertial and elastic properties in the structure, B.J. Schwarz and Mark H Richardson, October 1999, *Introduction to operating deflection shape*, Vibrant Technology, Inc, Jamestown, California.



Figure 2.7: An FRF measurement

Sources: Patrick L. McHargue (1993)

#### 2.6 MODE SHAPES

Mode shapes and operational deflection is related to each other. Modes are related with the resonance structure. Mode shape is induced when there is vibration in the structure. The interface between the inertial and elastic properties of material induced resonant vibration in the structure. The vibration in the structure can caused many problems such as failure to maintain tolerance, noisy operation, uncontrollability, material failure, premature fatigue and shortened product life. Modes of the structure are defined by the modal frequency, modal damping and mode shape. Besides that, we can define modes by doing experiment on operational deflection shape. Modes shape does not depend on forces or load that acting on the structure. Besides that, if the material properties and boundary condition change the modes will also change. Modes do not have unit that related, but the modes shape is unique, it related to other point in the resonance, Mark H. Richardson, March 1997, *is it a mode shape, or an operating deflection shape*, Vibrant Technology, Inc Jamestow, California.



Figure 2.8: lissajous pattern indicating a pure mode.

Source: Sound and vibration magazine March 1997.

#### 2.7 ANSYS SOFTWARE

Fluid structure interaction is the force on the structure and deforms the structure. The software that will be use in this study is ansyy. In the fluid structural interaction there are several type of model of modes such as rigid body, 1 way and 2 ways. Rigid body can be defining as no deformations occur in the solid structure, but there is only motion in the solid structure and it can be done by itself. The 1 way fluid structure interaction can be define as there very small deformation in the structure in the solid structure, in 1 way we just need to calculate the pass flow and thermal field from computational fluid dynamic to the structure and do analysis by using finite element analysis code. 2 ways fluid structure interaction is define as large structure deformation in the solid structure. 2 ways fluid structure interaction is the interaction between

computational fluid dynamic and finite element analysis. First step we must install ansyy software to the laptop. The software is easily to install and can be install to the personal laptop.

# 2.7.1 Ansys Procedure

- 1. Open the ansyy workbench and choose the analysis that we want to do.
- 2. Built the geometry shape that we want to analysis.
- 3. Choose the material of the structure, force and constraint of the structure.
- 4. Set up the flow properties and flow boundary condition of the structure, and then identify the fluid solid interface of the structure and meshing the model.
- 5. Do the analysis.



FIGURE 2.9: Ansys workbench

# **CHAPTER 3**

# METHODOLOGY

## **3.1 INTRODUCTION**

This project was mainly about to analysis the effect of fluid structure interaction on pipeline elbow joint. In general, the experiment is called Modal Analysis. The software that been used for this experiment is Dasy Lab and the sensor used is accelerometer.

## **3.2 FLOW CHART METHODOLOGY**

To achieve the objectives of the project, a methodology were construct base on the scope of product as a guiding principal to formulate this project successfully. The important of this project is to determine the mode shape and natural frequency of elbowjoint in pipeline system.

The terminology of the work and planning of this projects shown in the flow chart below. This is very important to make sure that the experiment in the right direction.

# 3.2.1 Flow Chart 1



Figure 3.1 : Flow Chart for FYP 1