ACOUSTIC INDUCED VIBRATION ANALYSIS (AIV) IN PIPING

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A report submitted
in fulfillment of the requirements of the degree of
Bachelor of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF MECHANICAL ENGINEERING

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(UTeM)

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DECLARATION

I declared that this project entitled "Acoustic Induced Vibration (AIV) Analysis in Piping" is the result of my own work except as cited in the references

Signature : ....

Name : Mu'adz Bin Mohd Sabri

Date : 18th July 2021

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APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature : ....

Name : Prof. Datuk Ir. Ts. Dr. Mohd Jailani Bin Mohd Nor

Date : 18th July 2021

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ABSTRACT

Piping system is widely used in almost all industries around the world. The process of pipe design is the most paramount part where any obstacles need to be considered to avoid unwanted events after installation and operation. Acoustic Induced Vibration (AIV) is one of the pipe failures that should be avoided as it would happen in short period of time without any physical signs and merely can be detected by using specific vibration sensor. This research proposed methods to properly simulate the AIV inside a 90° reducing tee and 90° bend pipe by using Computational Fluid Dynamics (CFD) in ANSYS. The total amplitude of vibration is obtained through Fluid-Structure Interaction (FSI). The possible mitigation methods are recommended for each pipe configurations. In such cases, AIV in 90° reducing tee pipe is shown to be reduced by applying the Wrought-Butt Welding (Fillet) and Gusset. Meanwhile, for 90° bend pipe, additional thickness and contour fitting can be applied and it exhibits its efficiency in reducing the AIV effect.

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ABSTRAK

Sistem paip digunapakai di hampir semua industri di seluruh dunia. Proses reka bentuk paip adalah bahagian yang sangat penting di mana sebarang rintangan mestilah dititikberatkan untuk mengelak kejadian yang tidak diingini berlaku selepas pemasangan dan operasi. *Acoustic Induced Vibration (AIV)* adalah salah satu kegagalan pipe yang mesti dielak kerana ia boleh berlaku dalam jangka masa pendek tanpa tanda fizikal dan hanya boleh dikesan dengan menggunakan alat khas getaran. Kajian ini mengemukakan cara yang tepat untuk menganalisis aliran *AIV* dalam paip 90° segi tiga dan 90° paip selekoh dengan mengunakan pengiraan dinamik cecair *(CFD)* untuk mengesan kelakuannya. Jumlah amplitude getaran diperoleh melalui interaksi cecair-strucktur *(FSI)*. Kaedah pengurangan dicadangkan untuk setiap konfigurasi paip. Dalam kes yang sama, *AIV* dalam paip 90° segi tiga dibuktikan dapat dikurangkan dengan mengaplikasi *Wrought-Butt Welding (Fillet)* dan *Gusset*. Pada masa yang sama, untuk 90° paip selekoh, penambahan ketebalan dan *Contour Fitting* telah diaplikasi dan menunjukkan kecekapannya dalam mengurangkan kesan AIV.

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LIST OF ABBREVIATION

AIV	Acoustic-Induced Vibration
FEA	Finite Element Analysis
EI	Energy Institute
PSV	Pressure Safety Valves
PRV	Pressure Relief Valves
CV	Control Valves
MAWP	Maximum Allowable Working Pressure
FPSO	Floating Production Storage and Off-Loading
PVC	Polyvinylchloride
SBC	Small Bore Connection
CAPEX	Capital Expenses
OPEX	Operation Expenses
HSE	Health, Safety and Environment
PWL	Sound Power Level
LOF	Likelihood of Failure
CAD	Computer-Aided Design
CFD	Computational Fluid Dynamics

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Piping is a system or process to transfer liquid, gas, slurries, or any fine particles from one particular location to another. It is primarily widely being used in most of the industries such as power, gas and air, oil, and gas as well as refrigeration. A piping system is generally considered to include the complete interconnection of pipes, including in-line components such as pipe fittings and flanges. According to Theprocesspiping (2017), pumps, heat exchanges, valves and tanks are also considered part of piping system. These components are usually used to control pressure, flow rate and temperature of the flowing fluid. Figure 1.1(a) shows the arrangement of pipes in chemical process plant. It clearly shows that piping system plays a major role in chemical industry.

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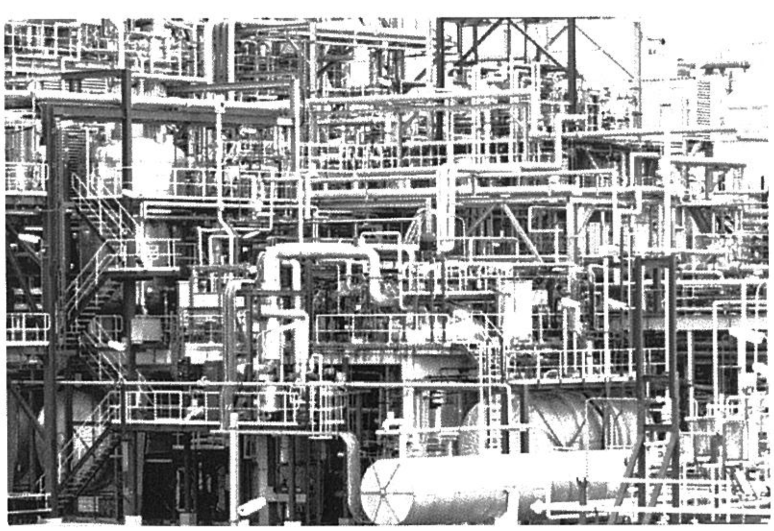

Figure 1.1(a): Piping System in Chemical Process Plant

Pipe fittings are works as adapter in piping whereby its function is to connect a straight pipe with a different sizes or shapes of pipe. There are different varieties of pipe fittings made of various materials and available in various shapes and sizes as shown in Figure 1.1(b) (Sunny Steel Enterprise Ltd, 2011). In addition, to choose the type of pipe fittings is basically depends on some factors for instances type of substances involved, environmental law or building codes as well as rules and regulations. Choosing the most suitable pipe fittings may prevent from any fatigue failure or unexpected events to occur. Pipe fitting is a stress discontinuity that is high susceptible area to get affected by high frequency vibration generated at high pressure drop devices such as Pressure Safety Valves (PSV) or Pressure Relief Valves (PRV).

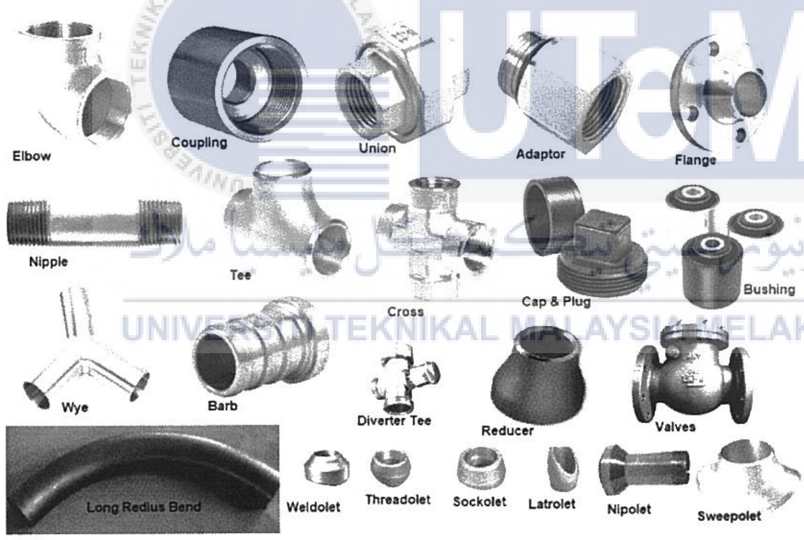

Figure 1.1(b): Type of Pipe Fittings

Besides, depressuring or pressure relief valves are one of the important components in piping system. It is used to prevent massive rise of fluid pressure inside the pipe until it reaches beyond Maximum Allowable Working Pressure (MAWP) that could lead to structural pipe's failure in short period of time (Eisinger & Francis, 1999) . According to Valve (1997), the pressure relief valve must open at a predetermined set pressure, flow a rated capacity at a specified overpressure, and close when the system pressure has returned to a safe level. However, the use of this pressure reducing devices could somehow cause piping fatigue and fretting due to its high pressure drop. It will result in vibrations induced by high frequency acoustic excitation. This phenomenon is called Acoustic Induced Vibration (AIV).

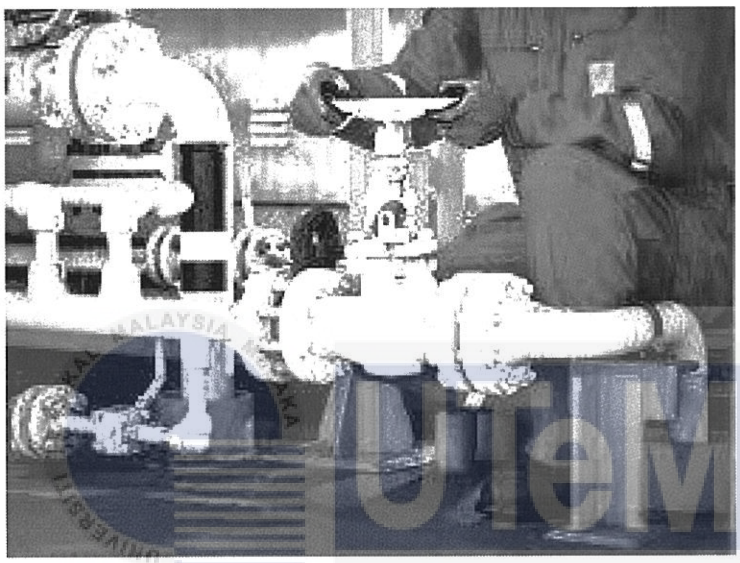

Figure 1.1(c): Pressure Relief Valve in Oil and Gas Industry

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1.2 PROBLEM STATEMENT

AIV phenomenon is one of the failures that can occur during the operation of the piping system. This failure is often associated with fatigue failure and fretting due to high frequency vibration of 500-2500 Hz and low amplitude. According to Coulon et al. (2018), there are two primary factors that can lead to AIV which are high flow rates and high pressure drop at pressure reducing devices such as Pressure Safety Valves (PSV) and Control Valves (CV) where it could result in high frequency acoustic energy. AIV is identified at point of flow restriction by valves resulting in an intense area for turbulent flow pressure shifts at the valves.

The induced high frequency excitation propagates through pipe. It amplifies by transverse acoustic pipe modes thus excites pipe's wall. Eventually, susceptible area as branch connection, welded pipe support and bends will crack in few minutes to hours after it reaches its dynamic stress limit (Misra et al, 2002). However, according to Jiang Hai Wu et al. (2018), had the failure occurred at the Floating Production Storage and Off-Loading (FPSO), the effect should become extremely catastrophic. Therefore, it is paramount to study the effect of uncontrollable AIV as well as the effective mitigation to prevent from triggering AIV in future.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To study the effect of AIV using ANSYS
2. To simulate the methods of AIV mitigation using ANSYS

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1.4 SCOPE OF PROJECT

The scopes of this project are:

1. Various shapes of pipe will be simulated using ANSYS
2. Mitigation methods to reduce the impact of AIV will be compared and simulated using ANSYS

1.5 GENERAL METHODOLOGY

The actions that need to be carried out to achieve the objectives in this project are listed below.

1. Literature review

   Journals, articles, books, or any materials regarding the project will be reviewed.

2. Identification Problem

The location source of the vibration will be identified based on research being made and affected areas could be detected.

3. Simulation

Simulation of the vibration flow in internal pipe will be analysed based on the data input from the measurement.

4. Analysis and proposed solution

Analysis on how AIV is generated, its effects on the piping system as well as the root cause of the problem. Solutions and mitigations will be proposed based on the analysis.

5. Report writing

A report on this study will be written and compiled at the end of the project.

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The methodology of this study is summarized in the flow chart as shown in Figure 1.3

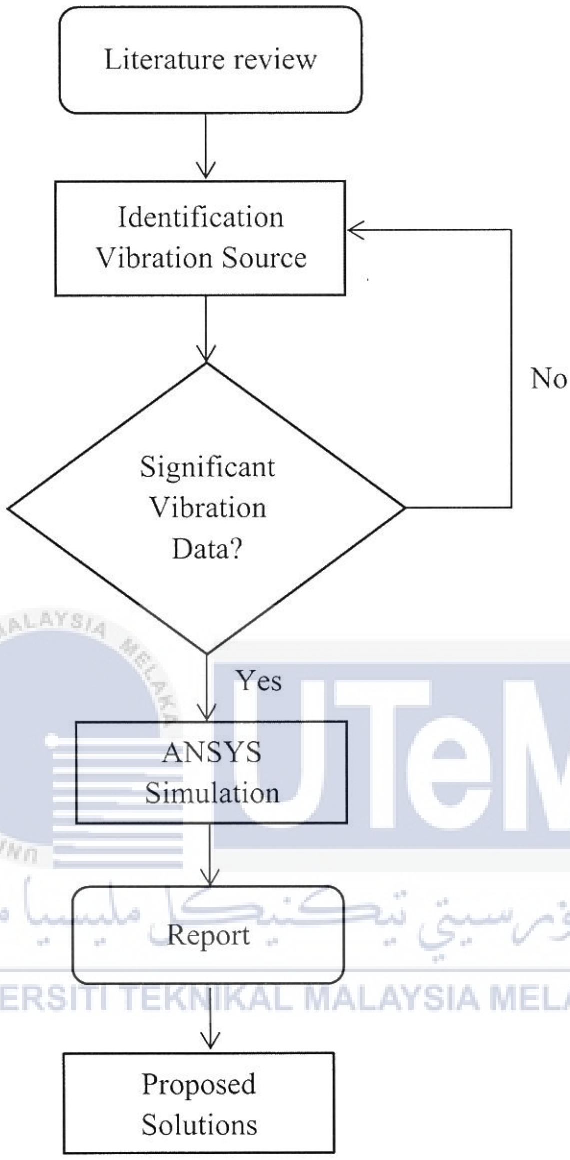

Figure 1.5: Flow Chart of The Methodology

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1.6 PROJECT TIMELINE

To achieve the main objective of this research, Gantt chart for *Projek Sarjana Muda (PSM 1)* and *Projek Sarjana Muda (PSM 2)* are provided in Figure 1.2 and Figure 1.3 respectively to show the project timeline to complete this project research paper.

Activity	October			November				December				January				
	Weeks															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Title Selection																
Project Briefing																
Run Basic Ansys Simulation																
Jurnal Research																
Discussion																
Simulation Data Analysis																
Submission Progress Report																
Consultation																
Improve Progress Report																
Submission Draft Final Report																
Seminar PSM 1																

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Figure 1.6(a): Gantt Chart for *Project Sarjana Muda 1 (PSM 1)*

Activity	March			April				May					June				July			
	Weeks																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Refining Acoustic Induced Vibration																				
Simulation of 90° Tee Pipe and 90° Bend Pipe																				
Simulation of Mitigation Methods for 90° Tee Pipe																				
Simulation of Mitigation Methods for 90° Bend Pipe																				
Comparing Frequency and Total Deformation																				
Chapter 4 - Result and Discussion																				
Chapter 5 - Conclusion																				
Submission Progress Report																				
Improve Progress Report																				
Submission Draft Final Report																				
Seminar PSM 2																				
Submission of Correction Thesis PSM 2																				
Submission Thesis PSM 2 Hard Bound																				

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Figure 1.6(b): Gantt Chart for *Projek Sarjana Muda II (PSM II)*

CHAPTER 2

LITERATURE REVIEW

2.1 Pipe Application and AIV Effect

Pipe is a paramount connection component in most of the industrial plant sectors such as oil and gas, manufacturing, nuclear and chemical in order to transfer liquid and gases from one place to another (Smith P, 2005). It is usually involves high frequency and pressure depends on fluid properties and design of the pipelines as well as the material being used. Figure 2.1 shows, pipes generally made from various materials, for instances, carbon steel or black steel, cast iron, galvanised steel, stainless steel, and Polyvinylchloride (PVC) depends on the application related. Somehow, carbon steel has been widely being used when involving steam or gas substance especially in oil and gas sector. High temperature and heat resistance are the main reason on why carbon steel is the best choice.

Designing a pipeline system is utmost complex and risky. In order for an engineer to design it, variables of pipe such as cross-sectional area, diameter, selection of valves and pipe support to be used as well as sound power level in the pipe need to be determined. Failure in designing a proper pipeline will lead to failure within short amount of time. As mentioned before, the pressure, frequency and temperature are likely to be very high in pipe. Despite selecting the best pipe's material, the design of the pipe undeniably could also affect the flowing fluid characteristics. The main component that will be discussed on is high pressure drop devices. The differences of cross-sectional area, number of bends, geometrical complexity of each component, pipe fitting, and also relief valves in pipeline somehow give impact towards overall piping system condition (Central States Industrial, 2020).

Bends, pipe fitting and pipe support are among the stress discontinuity parts. Most of the time, AIV is more triggered by the energy of pressure waves at pressure reducing devices compared to heat. It occurs at the frequency of 500-2500 Hz and due to high pressure drops and mass flow rate. This broadband excitation will generate resonant at some locations in pipe, amplified by transverse acoustic pipe modes, excites the pipe's shell vibration mode and lead to crack (Energy Institute, 2008). The condition of piping shell mode is shown in Figure 2.1(a). Figure 2.1(b) indicates that AIV happens at pipe discontinuities after it is generated from high pressure drops devices (Harper & Eng, 2016). Unfortunately, high pressure drops devices especially small-bore connection, and 90° tee are unavoidable not to be used in pipelines as it is a main component to connect from one pipe to another with different size and shape. Pressure drops is commonly occur in pipe but sometimes it could lead to adverse effect on some components when the pressure drops excessively resulting to high sound levels of high frequency acoustic energy.

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Figure 2.1(a): Shell Mode Piping Vibration

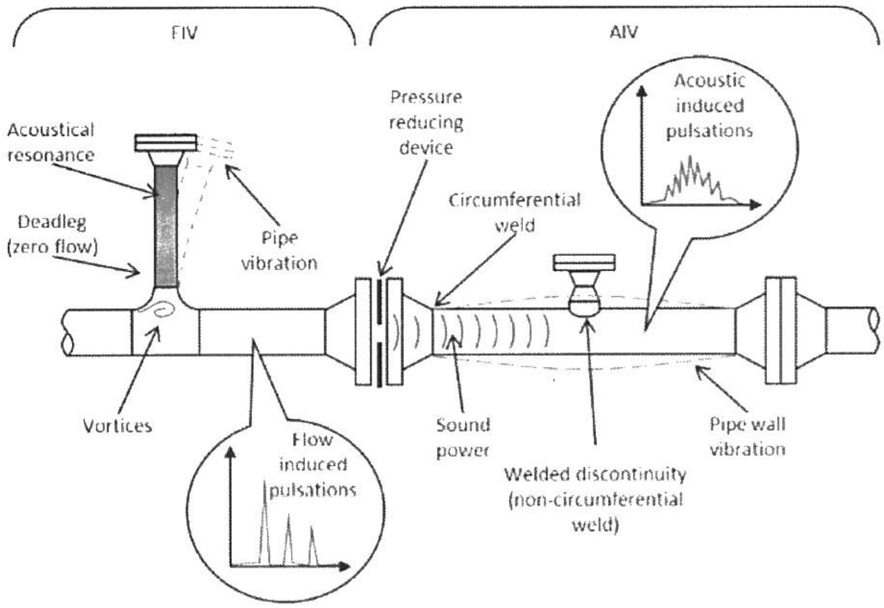

Figure 2.1(b): AIV Impact on Piping System

Small bore connection (SBC) is defined as branched connection that connected to the mainline piping as shown in Figure 2.1(b). DN50 of 2" nominal diameter or smaller is primarily being used in industries. It is believed that piping fatigue could lead to 20% of hydrocarbon releases and major cause is due to SBC failure (Energy Institute, 2008). Cracked vessel due to SBC as shown in Figure 2.1(c) remains unpredictable as low amplitude vibration at the mainline piping system may also be the main factor. SBC has a local resonance that has a possibility of rising the vibration 20 to 30 times from the original mainline piping's vibration (Small-Bore Connections (SBC) Assessment | Vibration, dynamics, and noise, 2012*)*. Therefore, some mitigation methods needed in order to prevent crack or fatigue in pipelines.

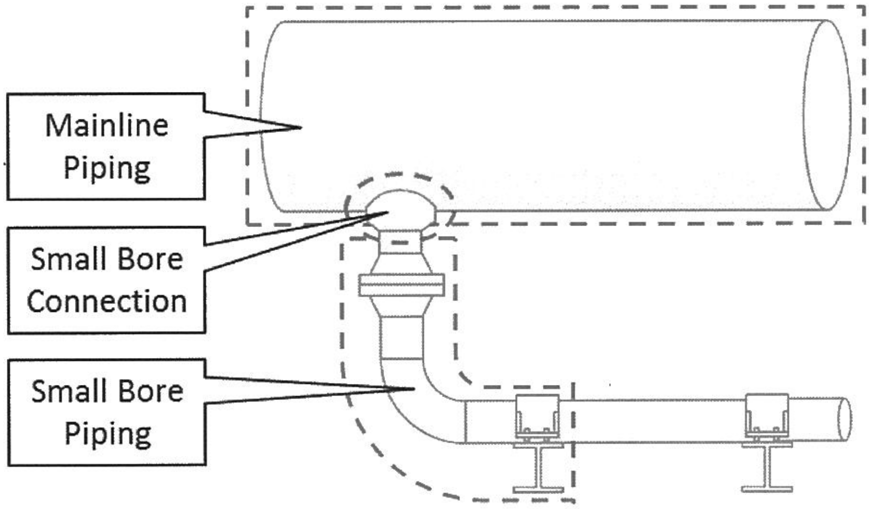

Figure 2.1(c): SBC Location in Pipeline

Figure 2.1(d): Cracked Vessel due to SBC

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