MODELLING SLUG AND SURGE ON PIPING VIBRATION

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This report is submitted as
fulfilling some of the terms for the award of
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DECLARATION

I hereby declare that this thesis entitled “Modelling Slug and Surge on Piping Vibration” is the outcome of my own, except it is stated and cited with reliable reference.

Signature : ……

Name : SITI ELYA BINTI HASSAN

Date : ……

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 : ……

Supervisor's Name : PROF. MADYA IR. DR. AZMA PUTRA

Date : ……

DEDICATION

To my beloved mother and father

ABSTRACT

The piping system is the most crucial in the oil and gas industry, and ensuring the smoothness of the system is the target for all engineers involved in this industry. Piping vibration becomes the most crucial problem in the piping system. Among the causes contributing to piping vibration are slug and surge. In this study, slug and surge are modelled by using computational fluid dynamic (CFD) in ANSYS and their effects in piping vibration are simulated through fluid structure interaction (FSI). In order to reduce the piping vibration, the formation of slug flow is mitigated by increasing the velocity of gas and enlarging the diameter of the pipe. It is found that by increasing the gas velocity, the possibility of gas bubbles coalescing and forming a gas pocket at the ceiling of the pipe can be reduced. The vibration of the piping structure is also reduced by enlarging the size of pipe diameter where it helps prevent the mixed-fluid from bridging the pipe as the height of the ceiling increases. The velocity of gas shall not be increased in the larger pipe diameter to avoid the production of unstable and excessive waves that can lead to slug flow.

ABSTRAK

Sistem perpaipan adalah yang paling penting dalam industri minyak dan gas. Untuk memastikan kelancaran sistem adalah menjadi sasaran semua jurutera yang terlibat dalam industri ini. Getaran paip telah menjadi masalah paling penting dalam sistem perpaipan. Antara penyebab yang menyumbang kepada getaran paip adalah slug dan tekanan lonjakan. Dalam kajian ini, slug dan tekanan lonjakan dimodelkan dengan menggunakan Computational Fluid Dynamic (CFD) di dalam ANSYS dan kesannya terhadap getaran paip disimulasikan menggunakan Fluid Solid Interaction (FSI). Untuk mengurangkan getaran paip, pembentukan aliran slug dikurangi dengan meningkatkan kelajuan gas dan memperbesarkan diameter paip. Didapati bahawa dengan meningkatkan halaju gas, kemungkinan gelembung gas untuk bersatu dan membentuk poket gas di siling paip dapat dikurangkan. Getaran struktur paip juga dikurangkan dengan memperbesar ukuran diameter paip di mana ia membantu mengelakkan cecair campuran menjembatani paip ketika ketinggian siling meningkat. Halaju gas tidak boleh ditingkatkan pada diameter paip yang lebih besar untuk mengelakkan pengeluaran gelombang tidak stabil dan berlebihan yang boleh menyebabkan aliran slug.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

FEM	Finite Element Method
FEA	Finite Element Analysis
CFD	Computational Fluid Dynamic
VOF	Volume of Fluid
FSI	Fluid-Structure Interaction

LIST OF SYMBOLS

G	=	mass flux of gas
L	=	Mass flux of liquid
α_k	=	Volume fraction of fluid
ρ	=	Density of fluid
a	=	propagation of speed
K	=	Modulus of liquid
E	=	Youngs Modulus of pipe
D	=	Diameter of pipe
$\mathcal{C}$	=	speed of sound in unconfined fluid
μ	=	Poisson's ratio
s	=	Wall thickness of pipe

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Slug is a type of multiphase or two-phased flow that occurs in piping system. It has become a serious issue and caught a huge attention from the engineers in various engineering fields such as power and processing plant, nuclear power plant, heat exchanger and the most focusing sector is petroleum pipeline (Miwa et al., 2015). Slug is caused by the formation of bubbles during the flow in the pipeline, which then consolidates into gas pockets. These gas pockets separate the series of liquid plugs or also known as slugs. The formation of these bubbles and gas pockets are generally more extensive and moves in high velocity than the liquid in the pipeline, especially in the mixture flow of gas and liquid. The example of slug flow characteristic is shown in Figure 1.1.

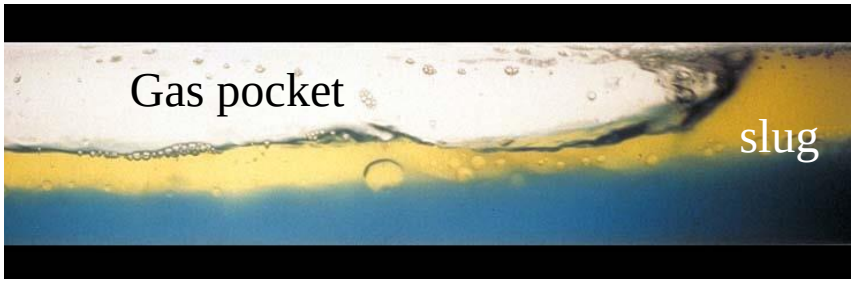


Figure 1.1 Slug flow in Horizontal Pipe

During the flow, liquid usually trapped at the low point of the pipe but still flow continuously. The gas phase that is occurred in the flow may be incredibly unevenly dispersed due to the influence of the buoyancy forces (Abdulkadir et al., 2020). The unsteady flow structure gave a huge contribution in excessive vibration on the structure of the pipe that results in fluctuation of pressure and also leads to the fluctuation of stresses (Bamidele et al., 2019). Due to the excessive and great vibration occurred in the piping structure, it is commonly causing failures to the piping structure. These tragedy is due to the harsh environmental exposure and operational loads experienced by the pipeline (Mohmmed et al., 2019).

Another frequent problem that also occurred in pipeline is surging. Surging is a phenomenon which the fluid or liquid in the pipe experienced a sudden change in velocity and sudden change of pressure. It is always been said that surge is also known as water hammer, but it actually has a different on the motion between those two. According to Stephenson, (1976), surge is referred to a slow-motion mass oscillation fluid flow while water hammer is referred to a rapid change in flow by elastic strain of the fluid. Nevertheless, both of these theories give the same results and therefore, they are both considered as same.

Surge occurs in every pipeline that have pumps and valves which may causes a sudden closure or start-up. These lead to the positive and negative movement of the fluid flow. A sudden closure of valves and rapid start-up of pumps will generates transient pressure excessively of the steady state pressure (Lokesh Kumar Mylapilli & Phanindra Vital Reddy Gogula, 2015). All these pressure surges are undesirable because it has a long-term effect to the performance of the pipe. It may cause a physical movement of the piping system which is a repetitive shock waves that leads to pipeline fatigue and pipeline failure such as rupture in pipes and fitting, leaks, collapse of pipe wall and much more costly damages.

1.2 Problem Statement

One of the most terrifying cases that frequently happen in a piping system is piping vibration. Since piping is the most crucial system in every oil and gas transportation activity, it has been a prior focus for engineers. One of the crucial factors causing the problem is that slug flow in the pipe leads to the formation of surge pressure. This factor has caught a serious intention to all engineers in engineering fields since it leads to excessive vibration to the piping structure and causes piping failure.

Figure 1.2 shows the failure of buckling happened to the pipe due to slug and Figure 1.3 shows the pipe damages that happened due to surge pressure such as pipe burst, leaking, failure of the pipeline fittings, and deformation of valves and supports. All of these failures will cost a tremendous amount of money to restore or replace the components, cost of workforce, and maintenance. In addition, the safety and health aspects also need to be considered since the problem may lead to severe injuries to the workforce and the workplace environment.

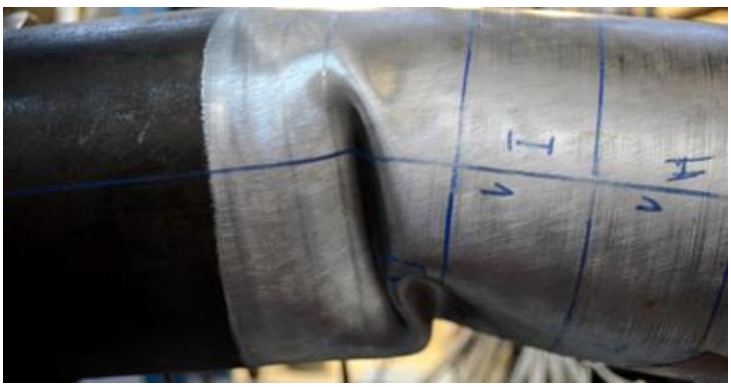


Figure 1.2 Buckling due to slug (Pournara A. E, 2013)

Figure 1.3 Effects of surge in pipeline (Dey K. P, 2020)

Details on piping vibration analysis due to slug and surge also lack in the works of literature, especially on the mitigation of slug flow and the relationship between slug flow and surge pressure. Therefore, this report will provide a detailed analysis of the cause and the effect of these two phenomena in piping and various ways to solve the issues.

1.3 Research Objectives

There are several objectives to be achieved in this study which are:

a) To simulate slug flow in piping using ANSYS (Fluent) software.

b) To investigate the vibration effects of slug flow and surge and to simulate the solutions.

1.4 Scope of Study

The main focusses of this study are as stated below.

a) The analysis of slug flow in pipeline using ANSYS CFD (Fluent) simulation.

b) The piping vibration occurred due to slug formation.

1.5 Gantt Chart

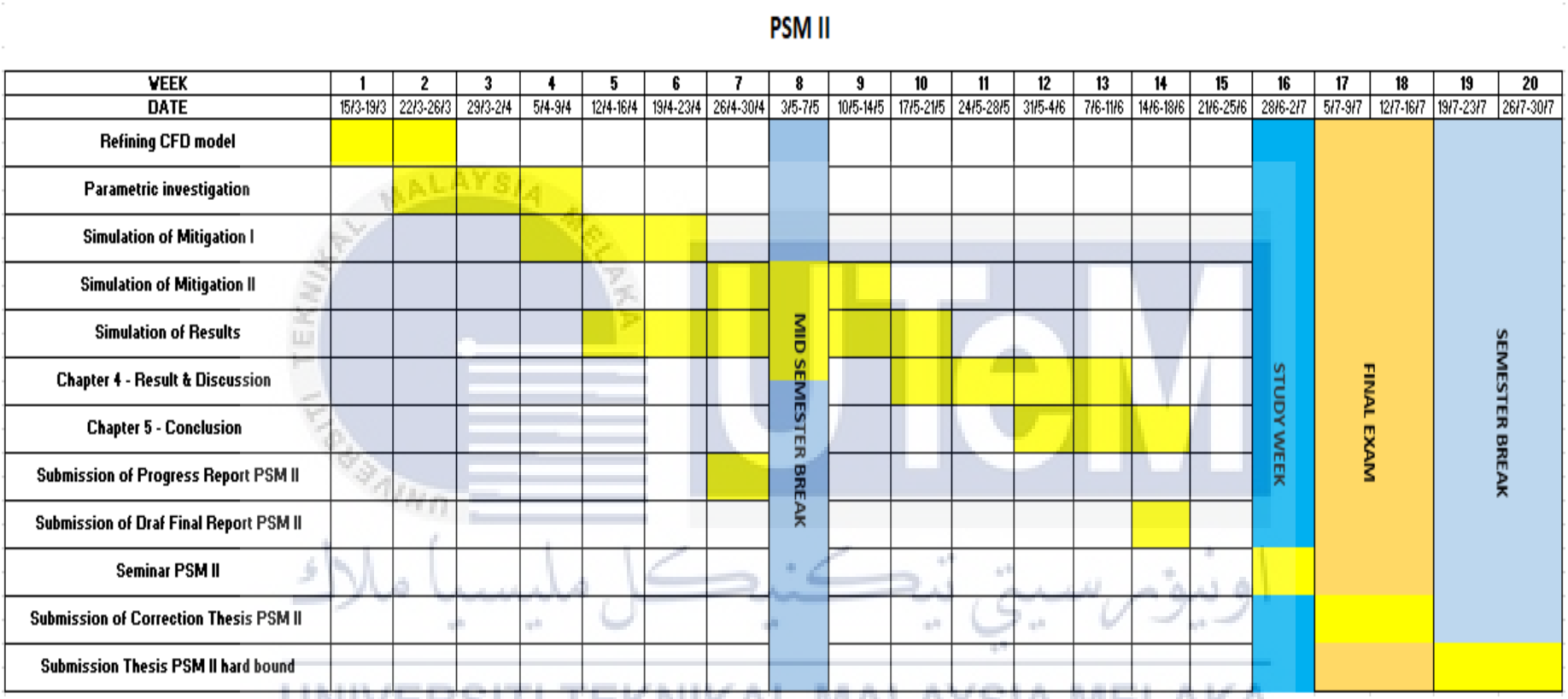
The Gantt chart for Projek Sarjana Muda 1 is shown in the Table 1.1 and the Gantt chart for Projek Sarjana Muda 2 is shown in Table 1.2 below. The Gantt chart shows the details of every part completed with their due dates according to each week from last semester until the end of this semester. This chart is created to ensure the steps and requirements of this study went smoothly. It is included the works from week 1 started with Chapter 1 until the last week of semester 1, which within week 16, where the seminar of PSM 1 ended and week 1 for semester 2 began with continuing with the progress of this project until the submission of the bounded report at the end of the semester.

Table 1.1 Gantt Chart for PSM 1

PSM I

WEEK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
DATE	12-16/10	19-23/10	26-30/10	2-6/11	9-13/11	16-20/11	23-27/11	30/11-4/12	7-11/12	14-18/12	21-25/12	28/12-1/1	4-8/1	11-15/1	18-22/1	25-29/1
Chapter 1 - Introduction								MID SEMESTER BREAK								STUDY WEEK
Chapter 2 - Literature Riview																
Chapter 3 - Methodology																
Solidwork																
ANSYS Fluent/ CFD																
Chapter 4 - Result & Discussion (Primary Result)																
Submission of Progress Report PSM I																
Submission of Draf Final Report PSM I																
Seminar PSM I																

Table 1.2 Gantt Chart for PSM 2



CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter provides the details of slug and surge in the piping system and previous research, including experiments and observations. The types of slug and the process of slugging and surging are explained point by point to ensure a clear understanding of slug. In addition, the explanation of methods and ways to prevent or reduce the effect of slug and surge is included.

Slug and surge have become a crucial problem in a pipeline system which has been a primary and most important system in every engineering plant. These problems are focused on due to its existence and behavior that has caused a severe vibration to the piping system. Both slug and surge are undesired by all engineers as it leads not only to vibration but also to the structure of the pipe such and causes corrosion that will affect the durability of the pipe.

2.1 Types of Slug

There are several types of slug that cause the piping vibration. These types of slug depend on the shape of the piping system itself, leading to the flow of the fluid inside the pipe. Therefore, different shape of the piping produces different types of slug.