FLOW STUDY OF MEDIUM SIZE PIPELINE TESTING LOOP

By

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LIST OFSYMBOLS

U_{GS}	Gas superficial velocity
F	Front velocity
A_{L1}	Area at station 1
u_1	Velocity
C_B	Velocity
u_3	Liquid velocity at station 3
ϵ	Volume fraction of the gas in the slug
U_3	The gas velocity at station 3
Q_{out}	Volumetric flow rate of the liquid detaching from the slug
U_{mix}	Volumetric balance between the inlet of the pipe and station 3
g	Gravity
D	Diameter
β	Inclination angle
A	Cross sectional area
τ_w	Shear stress acting on the wall wetted by S_w
τ_i	Shear stress acting on oil-water interface S_i
τ_j	Shear stress acting on the oil-gas interface S_j
τ_o	Shear stress acting on the wall wetted by water S_o
μ	Viscosity
σ	Interfacial tension
U_{LS}	Summation of water and oil flow rate
U_{LW}	Water flow rate, m/s
U_{LO}	Oil flow rate, m/s
U_{OW}	Total liquid flow rate
h	Height of Liquid in Pipe

LIST OFABBREVIATIONS

CFD	Computational Fluid Dynamic
PDMS	Plant Design Management System
P	Pressure
W	Water
O	Oil
G	Gas
VOF	Volume of Fluid
H_2S	Hydrogen Sulphide
CO_2	Carbon Dioxide
SWD	Stratified wavy / drops
ODST	Oil-Droplet Stratified Flow
SMW	Stratified mixed / water layer
SMO	Stratified mixed / oil layer
AO	Annular Oil Flow
MMSCFD	Million Metric Standard Cubic Feet per Day
BPD	Barrels of Liquids per Day
cP	Centipoises

KAJIAN PENGALIRAN DALAM LITAR PAIP PERCUBAAN

ABSTRAK

Dalam kajian ini, sebuah litar paip percubaan telah diciptakan untuk pengajian multifasa pengaliran dalam paip. Keseluruhan reka bagi peralatan and paip rangkaian telah ditunjukkan dalam pengajian ini dengan menggunakan perisian PDMS. Pengajian mutifasa pengaliran telah dijalankan dengan menggunakan perisian CFD untuk mengenal pasti jenis trend aliran bagi gas minyak wap, gas minyak cecair dan air yang mempunyai kadar aliran yang tidak sama dalam paip diameter 6 inci. Matlamat utama menjalankan pengajian ini adalah untuk menganalisis aliran multifasa untuk menyelesaikan masalah yang sering dihadapi oleh industri dalam penghantaran campuran dari takungan minyak ke penapisan process. Dengan rekaan litar percubaan paip ini membolehkan pengajian multifasa pengaliran di seksyen percubaan. Litar paip percubaan ini dicipata and direka dengan membina setiap komponen seperti, tangki, penukar haba dan pam. Litar paip telah disambung dengan semua peralatan dengan menggunakan bebibir dan injap. Multifasa simulasi telah dijalankan dengan 6 kadar aliran gas minyak wap dan 4 kadar aliran gas minyak cecair dan air yang tidak sama. VOF model telah dipilih untuk menyelesaikan simulasi pengesaan permukaan.

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ABSTRACT

In this research, a pipeline testing loop was constructed to study on the multiphase flow behavior in pipes. A fully design of equipments and piping network were constructed in this study by using Plant Design Management System (PDMS) software. The multiphase flow study was done by Computational Fluid Dynamic (CFD) software to identify the type of flow trends for different gasoil-vapour flow rate, gasoil-liquid flow rate, and water flow rate in a 6 inches diameter of pipe. The main purpose of this study was to perform the analysis of multiphase flow in order to understand the flow problem that is always encountered in the industry when transporting a mixture from reservoirs to the onshore oil production process. By working on the model fabricated on the pipeline testing loop, the multiphase flow study was able to be studied at the test section in the testing loop. The pipeline testing loop was created by constructing each of the equipments places in the pipeline such as tank, heat exchanger, and pump. The piping network was connected to all the equipments with valves and flanges. The multiphase simulation was carried out by six (6) different gasoil-vapour flow rates and four (4) different gasoil-liquid and water flow rates. Volume of Fluid (VOF) model was selected as the simulation approach to solve the surface tracking simulation.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Nowadays, the demand of crude oil and natural gas by the world's ever increasing population, especially in the developing countries. The use of petroleum products are increasing year by year due to the development of the country and economy. There is a drastic high demand on the production of oil and gas within the industry. The transportation of oil and gas through pipeline is the conventional way of transporting. During the transportation of oil and gas, there are numerous transportation issues that arise, such as Saturated Aromatic Resins and Asphaltenes (SARA) characteristic of crude oil which contains varying amount of wax, or paraffin and corrosive compounds such as hydrogen sulphide (H_2S) and carbon dioxide (CO_2). Other than these compounds, the crude oil also tends to deposit some wax and paraffin residuals on the pipeline walls which will cause the reduction of the cross-sectional area of the pipeline and increase the external pressure. The external pressure will act as a driving force to push the oil from the offshore facility to the oil

production plant. Since the pipeline system plays an important role with the oil and gas industry, it is necessary that regular maintenance be carried out.

There are a lot of pipeline testing loops such as 6'' High Pressure Large-Diameter Pipeline, 6'' Low Liquid Large-Diameter Pipeline, 3'' Hilly-Terrain Multiphase Pipeline, 3'' Gas/Oil/Water Flow Loop, 2'' High Viscosity Oil/Gas Two-phase Flow Loop (James, 1973). These facilities are used to test the flow in the pipeline with different conditions. In addition, there are some problems like pressure drop or multiphase flow frequently occurring in pipeline during the transportation of oil and gas or other chemical compounds. Therefore, the pipeline testing loop is also used to test the pressure drop for gas and liquid especially for the multiphase flow situation.

The pipeline testing loop is also important to determine the friction mechanism governing the flow for multiphase flow. The main focus in this research is to conceptual build a medium size (6'') pipeline testing rig and analyzes the multiphase fluid flow in the pipeline. By performing this testing loop, there is more information that would lead to further understanding about the pipe flow that is governing the multiphase flow.

1.2 Problem Statement

The oil and gas industry always encounter multiphase flow problems such as the presence of slug, solid particles, natural gas, oil and water. The oil and gas that

are produced from the reservoirs always contain sea water and sand. This formed a mixture flow called slug flow. Slug flow creates a potential problem for the transportation of crude oil from offshore to onshore production process. It is unfavorable to the processing equipments downstream due to the intermittent flow of crude inside the pipe. The flow is highly complex, unstable and hard to handle and will create a large pressure drop and accumulation inside the pipeline which clogs the pipeline and produces an unfriendly flow trend. This formation will definitely affect the separation unit for oil and gas. Hence, the multiphase flow model using Computational Fluid Dynamic (CFD) and Plant Design Management System (PDMS) are needed to model pipeline testing loop. There are some mathematical assumptions made and reviewed in order to form a good multiphase flow in a pipeline.

1.3 Research Objectives

The research objectives must be able to achieve the designing, simulation and understanding of the pipeline testing loop and flow trends. Therefore, three research objectives have been determined to achieve the goal of this research, and that are

i. To construct a testing rig for the multiphase system by using PDMS
ii. To determine the multiphase flow trend along the pipe by using CFD
iii. To determine the liquid level over diameter at the pipe outlet by using CFD

1.4 Scope of Research

The scope of research covers the types of flow such as slug flow, stratified flow, plug flow, and bubbles flow. In addition, the pipeline testing rigs from different researches are studied in order to get a suitable pipeline section and parameters for this work. The simulation models formulation in FLUENT simulator such as Eulerian, Volume of Fluid (VOF), and Mixture are the models that need to be studied. PDMS software is used to design the pipeline testing loop. Slug flow stabilities analysis is to understand the stability of slug and its structure. The behavior of slug will affect the stability and this is the most common flow problem occur in multiphase pipe flow. The slug length is to study the average slug length inside the pipe with varying pipe diameters. This scope also provides the information about the entrance conditions, flow rates of gas and liquid, and the pipe inclination affecting on the slug length. Transition to slug flow studies is about the transition flow formation. It also covers about the instability of a stratified flow to long wavelength disturbances and instability of stratified flow. Pipeline testing rig for multiphase system is the main item in this study. The testing rig is very important in order to generate the analysis of multiphase flow by using CFD. This scope provides the information about different testing rig with different rig structures. The main focus in the testing rig is to understand the behaviors of the oil, gas and water flow trend of this multiphase flow inside the test section. CFD multiphase flow model is to understand the past researcher's work on the multiphase flow by using CFD. The study gives some knowledge about the model of CFD analysis and the results. Mathematical model to simulate the multiphase flow in CFD is to study about the velocity of the moving bubble by considering and the rate of the liquid adjoining and

detaching from a slug at is front and rear. This mathematical model can provide the volumetric flow rate of the liquid detaching from the slug. Multiphase simulation model is very important to be determined in order to obtain a better result. There are few models such as Eulerian, VOF, and Mixture. Each of these models has different limitation and specification. Thus, it is necessary to choose the best model among them. Type of flow motions either lamina or turbulent flow of fluid is common types of flow motion. In the simulation, the lamina and turbulent also need to be determined for choosing the correct turbulent model. Either steady state or unsteady state flow will be considered in this work. It depends on the change of properties, velocity and temperature for the flow. If there is change in properties, velocity, and temperature the unsteady state flow must be chosen. Boundary condition such as wall condition, interfacial tension between the fluids, flow rate, and phases need to be defined in the simulator. The interfacial tension is the attractive forces between molecules in a fluid. When two fluids come into contact to each others, there must be force acting between them. The flow rate for every phase can affect the flow trend in the pipe. Plant Design Management System (PDMS) is classified as design software which user can used to design chemical plant. This software is able to construct equipments and piping network.

1.5 Significance of Study

One of major difficulties faced when transporting oil and gas through a pipeline is the unsteady flow of the fluid in pipeline. The oil and gas production industries have faced a lot of issues due to this unsteady flow regime inside the pipe.

If left uncontrolled, it will reduce the quality composition of the product greatly which causes unwanted losses in the production process in oil and gas plant. Therefore is it important to solve these issues by understanding the flow trending of multiphase flow inside the pipeline in order to increase the quality of the production of oil and gas. In order to perform this study, CFD is used to analyze the multiphase flow in the testing rig to create a computer simulation model to solve the multiphase flow problem. The result obtain is comparable with the real experimental results measured with minimal errors.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Overview

There are seventeen main sections in this chapter. In the first section, stratified flow patterns have been discussed to explain about the different models of stratified flow which can be formed under different conditions. In the second section, the annular flow is being discussed in relation to the annular formation superficial velocity and its characteristics. The third section discusses about slug flow behavior by looking of the slug formation condition. Next, the slug length is also an important scope to study the effect of pipe diameter on the slug length. Then, transitions to slug flow and its definition have been discussed. Furthermore, the slug stability theory with the equation related to the slug flow is being discussed. After that, comparison also been made for the researchers use different pipeline testing rig to study about the multiphase flow trend. Then, in the section 2.7 and 2.8 some useful mathematic models that can link to this study have been discussed. From section 2.9 to 2.16 mainly discuss about the parameters and models need to use in the simulation. The

comparisons and definitions for all the parameters and models have been stated and selected clearly and understanding.

2.2 Stratified Flow Pattern

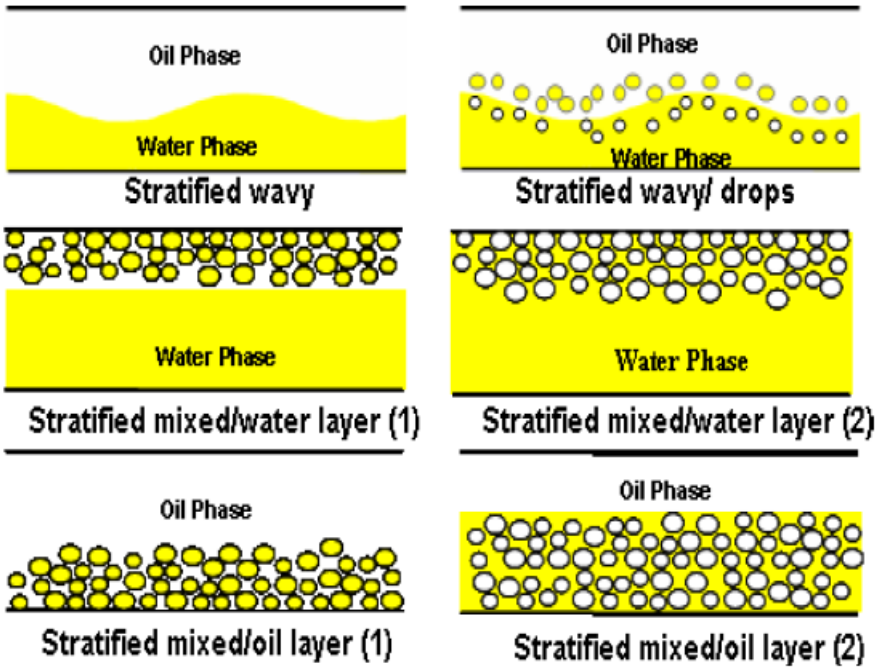

Figure 2.1 Difference Types of Stratified Flow in Pipeline

(**Source:** Al-Yaaris & Abu-Sharkh, 2011)

The stratified wavy flow occurs when the phases are completely segregated with the interface between them showing a characteristic wavy nature (Al-Yaaris & Abu-Sharkh, 2011). The Stratified wavy / drops (SWD). On the other hand, Oil-Droplet Stratified Flow (ODST), which is similar to the mixed flow pattern defined by Arirachakaran et al. (1989) occurs at the higher water fraction conditions. The entrainment of one or both phases as drops in the other has begun, the droplets being concentrated near the interface zone (stratified wavy with mixing interface).