IMPROVING THE GAS OIL FLOW IN PIPELINES BY DESIGNING NEW FLOATING TECHNIQUE

M NERRANJINI A/P MANOHARAN

A thesis submitted in fulfilment of the requirement for the award of the Degree of Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical & Natural Resources Engineering
UNIVERSITI MALAYSIA PAHANG

JANUARY 2012

ABSTRACT

Pipeline transportation is always preferred method to transport crude oil and natural gas due to safety purpose and cost effectiveness. Turbulent flow in pipeline causes friction drag and pressure drag which results in reduction in flow rate and pumping power losses. High operational cost is required in order to overcome these problems. As a result, most of the researchers discovered drag reducing agents like additives, polymers, surfactants and suspended solids to solve the problems. In the present work, floating technique will be introduced to improve the gas oil flow. Butyl rubber (IIR) has been selected as the material for floating device based on their flexibilities and strengths. Three sets of butyl rubber (IIR) with 17 stripes have been fabricated according width and thickness of 0.3cm and 0.1cm respectively with different lengths of 10cm, 15cm and 20cm. The stripes suspended in pipeline by using aluminium made ring. 10 different flow rates of gas oil used to a 1.5 inch sized pipe with testing section lengths of 0.5m, 1.0m, 1.5m and 2.0m. As the floating device suspended in pipeline, it helps to discard the formation of eddies. Among the three lengths of stripes, 15cm achieved the highest drag reduction for most of the Reynolds numbers compared to 10cm and 20cm. The optimum drag reduction that can be achieved by using 15cm stripes at Reynolds number of 18173 is 27.93% at testing section length of 2.0m.

ABSTRAK

Pengangkutan saluran paip sentiasa diutamakan untuk pengangkutan minyak mentah dan gas asli atas tujuan keselamatan dan keberkesanan kos. Aliran gelora di dalam talian paip menyebabkan daya geseran dan tekanan seretan yang menyebabkan pengurangan dalam kadar aliran dan kehilangan kuasa mengepam. Kos operasi yang tinggi diperlukan untuk mengatasi masalah-masalah tersebut. Sejurus dengan itu, kebanyakan penyelidik mendapati ejen pengurangan geseran seperti bahan polimer, surfaktan dan pepejal terampai bagi mengatasi masalah-masalah tersebut. Dalam penyelidikan ini, Butyl Rubber (IIR) telah dipilih sebagai bahan untuk peranti terapung berdasarkan sifat lembut semula jadinya. Tiga set Butyl rubber (IIR) dengan 17 helai jalur telah direka mengikut lebar 0.3cm dan ketebalan 0.1cm dengan panjang 10cm, 15cm dan 20cm. Jalur-jalur tersebut dilekatkan sekitar cincin yang diperbuat daripada aluminium dan digantungkan dalam saluran paip. 10 kadar aliran yang berlainan digunakan dalam pengaliran diesel dimana paip berukuran 1.5 inci dengan panjang seksyen ujian 0.5m, 1.0m, 1.5m dan 2.0m. Peranti terapung yang digunakan dalam paip berjaya menyekat pembetukan pusaran lalu menambah baikan aliran diesel dalam paip. Antara tiga panjang jalur, 15cm mencapai pengurangan tekanan yang paling tinggi bagi kebanyakan nombor Reynolds berbanding 10cm dan 20cm. Pengurangan daya geseran yang optimum yang boleh dicapai dengan menggunakan jalur 15cm pada nombor Reynolds 18173, iaitu 27.93% dengan panjang lebar seksyen ujian 2.0m.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
min	Minute
μm	Micrometer
Re	Reynolds number
cm	Centimeter
W	Waat
Kg	Kilogram
m	Metre
s	Second
ρ	Density of water
V	Velocity of water
d	Diameter of pipe
μ	Viscosity of water
Q	Flow rates of water
Dr %	Drag reduction percentage

LIST OF ABBREVIATIONS

P	Pump
T	Tank
PT	Pressure Transmitter
MV	Valve
PVC	Polyvinyl Chloride

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE RESEARCH

Pipeline transportation is the transporting of goods via pipe. As we know, fluids like crude oil and natural gas are often transported through pipeline because pipeline transportation is the safest and efficient way compare to vehicle transportation (CEPA, 2007). There are three types of flow in pipeline which are laminar flow, transitional flow and turbulence flow. In this research, we will be focussing on turbulence flow in pipeline. Turbulence flow usually occurs at high flow rates where the Reynolds number is more than 4000 (Warhaft, Z. 1997).

The formation of eddies in turbulence flow often affect the flow in pipeline (Warhaft, Z. 1997) where the output flow rate is lower than the input flow rate. Besides that, the friction between the fluid and pipe wall causes pressure drop, called as 'drag' (Hadri et al., 2010). Therefore, by discarding the formation of eddies, we may improve the flow behaviour. Researches are being carried out to improve the fluid flow in pipeline. Some of the researches they applied polymers (Motozawa, M. et al., 2011), additives (Wei, J. et al., 2011), surfactants (Drappier, J. et al., 2006), and solid particles (Bari, H.A. et al., 2011).

Although those methods are successfully improve the flow behaviour, but, they are not the perfect solution since at the end we have to remove those additives, polymers, surfactants and solid particles through several process which involve the cost and energy consumption. Apart from that, the most recent invention to improve the pipeline flow is by using the chain assembly (Bari, H.A. et al., 2010). According to them, the number of chains can be added according to the desired drag reduction which is cost effective and environmental friendly.

In this research, floating technique has been introduced to improve the gas oil flow in pipeline. As for this technique, a mechanical device with flexible butyl rubber (IIR) stripes has been fabricated and suspended in pipeline to improve the turbulent flow of gas oil.

1.2 PROBLEM STATEMENT

During the transportation process, pump is being used to transmit the fluids for a long distance from one place to another place. However, a huge part of the pumping energy is lost due to the friction between the fluid and the wall (Hadri et al., 2010). This results in higher cost and high amount of electricity consumption. There are so many researches being done to improve the turbulence flow such as by addition of drag reduction agent, polymers, surfactants and suspended solid particles so that these problems may overcome. However, these methods require separation processes at the end which consume energy and money. In addition, some of the chemical additives used are toxic and expensive. Therefore, new inventions are coming up to overcome this problem and find a method which is more cost effective and environmental friendly. As for this research, floating technique is introduced to improve the gas oil flow and at the same time save energy consumptions and money.

1.3 RESEARCH OBJECTIVES

- To design a new technique (floating technique) to improve the flow in pipelines replacing the usage of chemical additives.
- To study the effect of
  a) Design parameters (dimensions of floating object)
  b) Liquid circulation parameters (liquid flow rate and testing section lengths)

1.4 Scope of Study

Some restriction factors have been manipulated for this research. Those variables are as listed below:

1.4.1 Study the effect of design parameters

a) Length of floating device stripes (10cm, 15cm and 20cm)

1.4.2 Study the effect of liquid circulation parameters

a) Gas oil flow rates ($4.5m^3/hr$ – $9.0m^3/hr$)
b) Testing Section Length (0.5m, 1.0m, 1.5m and 2.0m)

1.5 Rationale & Significance

This research has been carried out based on the concern of pumping power consumption, cost and environmental friendly. Since there are no additives, polymers, surfactants or solid particles that will be added to the fluid, therefore, the cost for the recovery of fluid can be saved. Besides, the increase in volumetric flow rate by floating material leads to the reduction in the consumption of electricity. In addition, butyl rubber (IIR) as floating device is environmental friendly and cost effective. Since this is a novel research and this technique is able to improve significantly, therefore, it will have high commercial value not only in national level but also in international level.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will cover up the basic and fundamental of turbulent flow, causes of imperfect flow in turbulent flow such as friction, viscosity, pressure drop and drag reduction, and researches that has been carried out so far to improve the flow.

2.2 TYPES OF FLOW

Flows behaviours can be categorized as laminar flow, transitional flow and turbulent flow. Laminar flow produces smooth streamline and highly ordered motion. Meanwhile, turbulent flow is characterized by its velocity fluctuations and highly disordered formation. The existence of those flows can be verified by injecting some dye streaks into the flow in a glass pipe as done by Osborne Reynold during 19^{th} century (Yunus, 2006, pg323).

According to Osborne Reynold, the flow behaviour is depends on velocity of the fluid, density of fluid, diameter of pipe and viscosity of the fluid. He came out with his own formula which is known as dimensionless Reynolds number.

$$\mathrm{Re} = \frac{\rho . V . D}{\mu} \tag{2.1}$$

Where;

ρ = Density of fluid, kg/m^3

V = Average velocity of fluid, m/s

D = Diameter of pipe, m

μ = Viscosity of fluid, kg/m.s

Based on his research, flows with Reynolds number less than 2300 are known as laminar flow while flows with Reynolds number more than 4000 are known as turbulent flow. At the same time, flows with Reynolds number in between of 2300 and 4000 are known as transitional flow (Yunus, 2006, pg324).

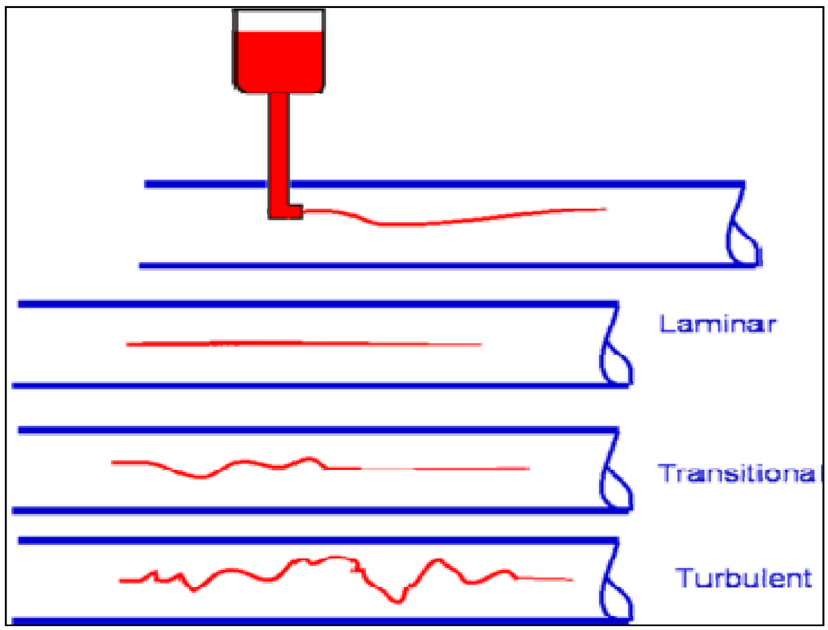

Figure 2.1.1: Reynolds Experiment

Source: Aerospace, Mechanical & Mechatronic Engg. 2005

2.3 TURBULENT FLOW IN PIPELINES

According to Yunus, (2006, pg335) "turbulent flow is characterized by random and rapid fluctuations of swirling regions of fluid, called eddies,...". The eddy (the size of the largest scales of fluid motion) is set by the overall geometry of the flow (Jermy, 2005). As the Reynolds number increases, smaller scales of the flow are visible in thus to large bulky eddies appears. Yunus added that although so many researches have been done, yet the turbulent flow remains largely undeveloped. Turbulent flow is associated with higher friction values compare to other flows because of the swirling eddies that transport mass, momentum and energy to other regions of flow more rapidly.

2.3.1 Friction Drag and Pressure Drag

Drag force can be classified as the net force exerted by fluids as a result of combined effect of wall shear and pressure forces. Drag force results in pressure drop. The drag due to shear stress is known as skin friction drag while drag due to pressure is known as pressure drag. According to Osborne Reynold, Reynolds number is inversely proportional to viscosity of the fluid. Therefore, the friction drag at very high Reynolds numbers is negligible. Pressure drag is directly proportional to the surface area and to the difference between the pressures acting at the beginning and end of fluid (Yunus, 2006, pg567). Higher velocity of fluid results in higher pressure drag. Formula that used to calculate the percentage of pressure drag is as below:

$$\%\ \mathrm{Dr} = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \times 100 \tag{2.2}$$

Where;

ΔP_b = Initial pressure drop

ΔP_a = Final pressure drop

2.4 IMPROVING THE TURBULENT FLOW

Researches are being carried to improve the turbulent flow in pipeline since past few decades. Most of the researches used drag reducing agents like additives, polymers, surfactants and suspended solids. These agents will be mixed out evenly in the fluid before pass through the pipeline. In other transportation industries, methods like dimples walls (ZhenSheng, S. et al., 2010), micro bubbles injection (Mohanarangam, K. et al., 2007) and riblets (Mayoral, R.G. et al., 2011) are being used to improve the turbulent flow by reducing the skin friction drag.

2.4.1 Drag Reducing Agents

Any substance that reduces the drag is known as drag reducing agent (DRA) (Wilski et al., 1980). Drag reducing agents can be classified as additives, polymers, surfactants and suspended solids. DRA comes in both liquid and gel form (Greasby, 2011). Those DRA reduce the friction by changing the flow profile from turbulent to laminar (Surface Chemistry, 2010). However, the performance of DRA still could not explain briefly although researchers carried out so many investigations. It is due to the effectiveness of DRA that depends on a few parameters such as oil viscosity, pipe diameter, liquid and gas velocities, composition of oil, pipe roughness, water cut, pipeline inclination, DRA concentration, types of DRA, and shear degradation of DRA (Kang et al., 2000). Researchers have proved that low viscosity and high concentrated drag reducing agent improve the turbulent flow up to 71% (Bari, H.A. et al., 2010). Those DRAs able to increase the flow rate of fluid in a pipeline at same pressure drop by reducing the friction drag.

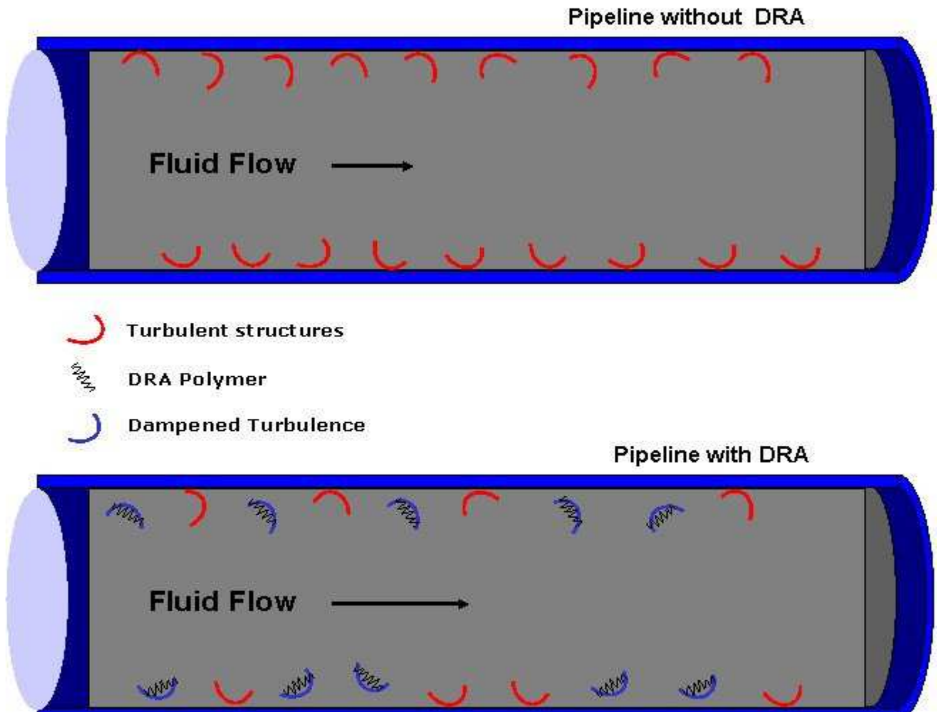

Figure 2.4.1: Effect of Drag Reducing Agents on Turbulent Flow Behaviours

Source: Flo-Quest, 2011

2.4.2 Dimples Walls

Russian scientists, Alekseev et al., 1998 discovered that dimples might be useful for drag reduction apart from heat transfer enhancement. They found out a decrease of the skin friction drag of a turbulent flow up to 20% based on experimental measurements of turbulent flows over surfaces with regular arrangements of shallow dimples (Alekseev, V.V. et al., 1998). Zhensheng, S. et al., observed drag reduction up to 15% with active dimples as the wall-deformation actuators (Zhensheng, S. et al., 2010). Since the drag reduction by dimples would give a significant economical influence, therefore, Lienhart, H. et al., clarified whether dimples causes reduction of the skin friction drag or not which has been answered in negative. They did not observe a significant increase of pressure loss. They have concluded that present arrangement of dimples does not lead to drag reduction but rather to a slight increase of the total drag (Lienhart, H. et al., 2010).

2.4.3 Microbubbles

Micro bubbles have been studied by many researches in sequence to the pioneering work of McCormick and Bhattacharyya (Mohanarangam, K. et al., 2007). Merkle and Deutsch injected bubbles at the top flat wall and discovered as the amount of injected air increases, skin friction reduction effect increases up to 80% (Madavan, N.K. et al., 1984). The reduction in drag seems to be more effective if the micro bubbles are located in buffer layer. Likewise, Madavan, N.K. et al. added that the drag reduction increases only to a certain point since the effect of additional bubbles decreases as the fraction of bubbles in the boundary layer increases (Madavan, N.K. et al., 1984). The role of the micro bubbles in drag reduction has been numerically investigated by Mohanarangam, K. et al. They investigated the effect of stream wise velocity modulation due to the presence of micro bubbles along the boundary layer where the presence of micro bubbles caused turbulence attenuation for some distance along the boundary layer and later an augmentation was felt due to the shedding of the vortices behind the bubbles (Mohanarangam, K. et al., 2007).

2.4.4 Riblets

Riblets that aligned with the direction of flow are one of the few techniques that have been successfully reducing the skin friction in turbulent boundary layers (Mayoral, R.G. et al., 2011). Mayoral, R.G. et al. proved that drag reduction is proportional to the riblet size. However, the proportionality breaks down for larger riblets. Meanwhile, Walsh, M.J. et al. investigated effect of shapes of riblets to drag reduction, obtaining maximum drag reduction of 8% for riblet spacings of approximately 15 wall units (Walsh, M.J. et al., 1984). At the same time, Peet, Y. et al. invented sinusoidal riblets with triangular cross section which can increase the drag reduction by at least 50% (Peet, Y. et al., 2008).

2.5 CONCLUSION

In the present research, floating device will be introduced to improve the turbulent flow in pipeline. The flexible floating device that will be suspended in pipeline reduces the friction that occurs during transmission of fluids through pipes. This research uses a new technique where it is able to give a huge impact to the pipeline transportation system in term of marketability and effective tool in saving operational cost.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter will cover up on methodology that will be used for this research. It includes the type of material selected, design of the equipment and experimental procedures.

3.2 MATERIALS

As for this research, the medium will be used in pipeline is gas oil which is known as diesel. Since rubber is tough and elastic in nature, therefore, it has been the choice for the floating material for this research. The selected type of rubber chosen is butyl rubber (IIR). The characteristic of butyl rubber (IIR) has been listed in Table 3.2.1. In addition, rings made of aluminium will be used during the fabrication of floating device.

Table 3.2.1: Characteristic of Butyl Rubber (IIR)

Butyl rubber (IIR)
(Synthetic Rubber)

Operating Temperature:

- -40 - 150°C

Advantages:

- Flexible
- Low glass transition temperature
- Resistant to ozone
- Displays high damping at ambient temperatures
- Good ozone resistance
- Good weathering, heat, and chemical resistance
- Good vibration damper

Disadvantages:

- Does not perform well at high temperature.

Source: Lanxess Butyl Rubber

3.3 FABRICATION OF FLOATING DEVICE

First of all, rings with a diameter of 1.5inch will be fabricated. Then, butyl rubber (IIR) and elastic rubber will be cut into strips according to the desired size and length. The width and thickness of the strips will be 0.3cm and 0.1cm respectively. Each and every strip will be sticked around the ring by using Hyper Glue. The Figure 3.3.1 illustrates the fabrication of floating material and Figure 3.3.2 shows the fabricated floating material.

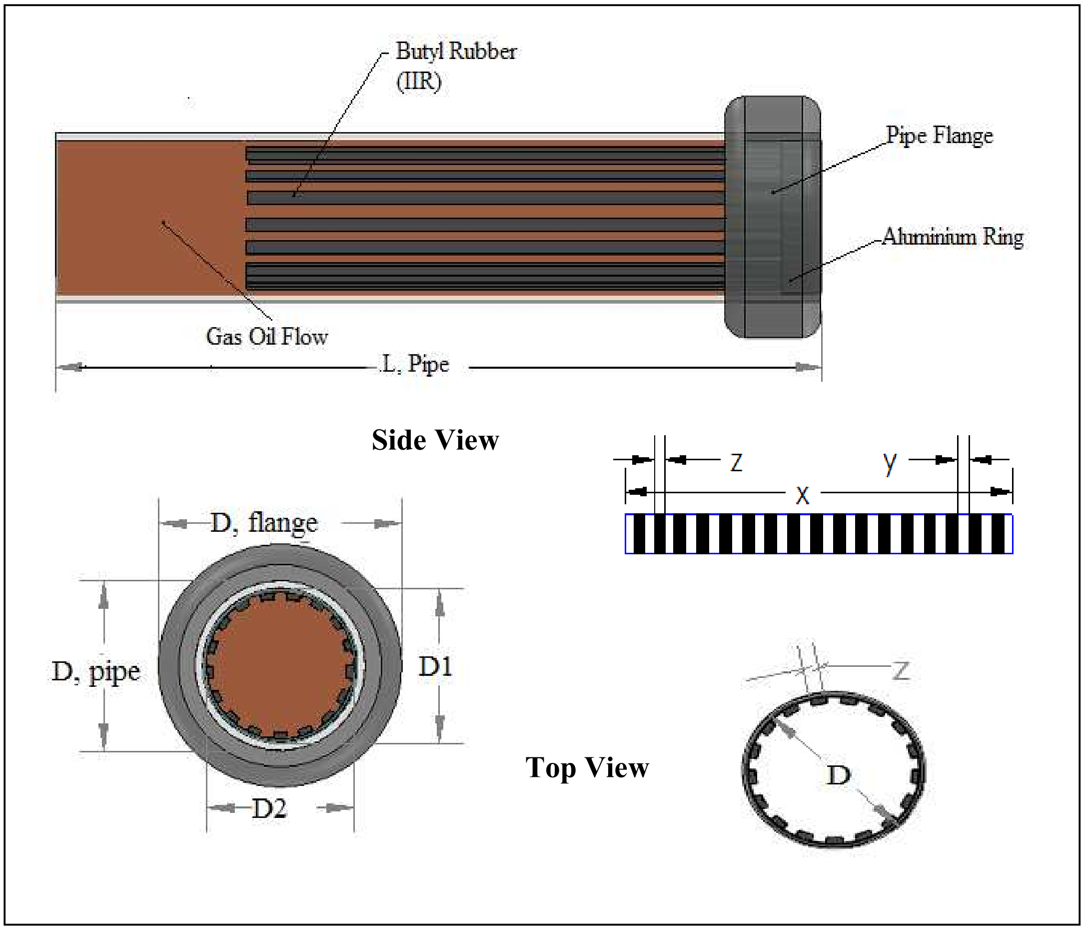

Figure 3.3.1: Fabrication of Floating Device

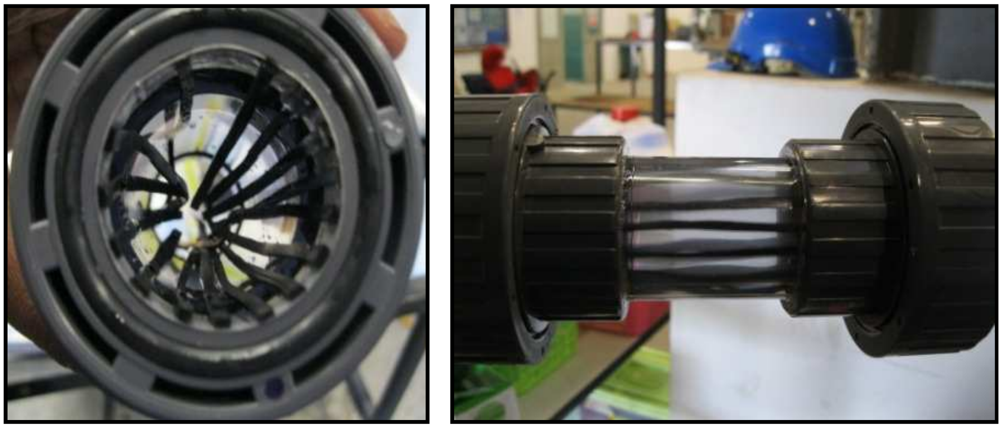

Figure 3.3.2: Fabricated Floating Device

3.4 EXPERIMENTAL RIG DESIGN

The experimental rig design has been shown in Figure 3.4.1. This rig was designed by Assoc. Prof. Dr. Hayder Abdul Bari. The system is closed loop system and consists of reservoir tank, pump, pipes, valves, flow meter and pressure transducers. Gas oil from tank (101) flows through a centrifugal pump (102) where the pump uses a rotating impeller to increase the pressure and flow rate of gas oil. Then, the gas oil from pump (102) flows through pipe 3 (107). This pipe is made of DN40 type PVC plastic. The static flow meter (103) in pipe 3 (107) is used to read the flow rate of gas oil. The model of the flow meter is Burkert 8035. Then, the gas oil will flow through the 1.5 inch pipe 1 (105). The floating material suspended inside pipe (104). Along the pipe 1 (105) there are five pressure transducers labelled PT-101, PT-102, PT-103, PT-104 and PT-105. These transducers are located at a distance of 0.5m with one another respectively. The data from pressure transducers recorded at monitor (108) automatically once record button is clicked on monitor. Finally, the gas oil will flows to tank (101) through pipe 1 (105) and this cycle repeated throughout the experiment. Pipe 2 (106) is the bypass while pipe 3 (108) is the drain.

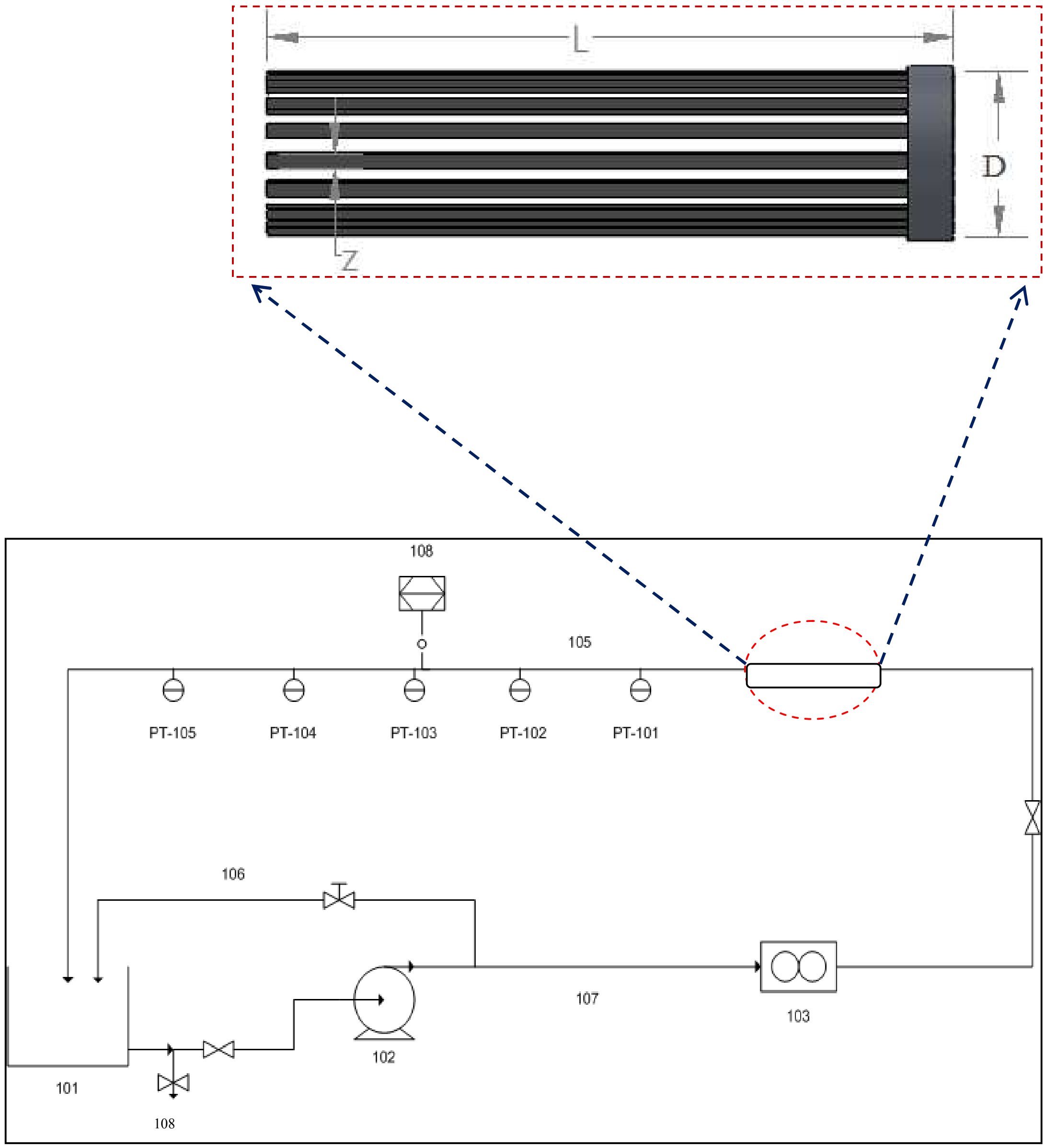

Figure 3.4.1: Experimental Rig