IMPROVING THE WATER FLOW IN PIPELINES USING FLOATING TECHNIQUE

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Chemical Engineering (Gas technology).

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ABSTRACT

Pipelines transportation is widely used regardless in any industry. Mostly, liquid and gases are sent using the transportation method through a pipe. Turbulent flow in pipeline causes friction drag and pressure drag which results in pressure drop and increases the operational cost by increasing the pumping power losses. Therefore, an effective pipeline flow is needed in order to reduce the pressure drop by improving the drag reduction in the pipeline system. This research is executed to improve water flow by using the floating technique. Natural Rubber (cis-1, 4-polyisoprene) was selected as floating materials by considering its flexible nature and strength. The dimension of the fabricated floating equipment are, 17 stripes of natural rubber (cis-1, 4-polyisoprene) in length of 10cm,15cm and 20cm, width and thickness of 0.3cm and 0.1cm respectively. The rubber stripes suspended in pipeline by using aluminium made ring. 10 different flow rates of water used to a 1.5 inch sized pipe. The variables of length are 10cm, 15cm and 20cm. During the experiment, the pressure drop before and after using floating technique was recorded and used to calculate the percentage of drag reduction. The data was analysed further by plotting graphs of percentage of drag reduction versus Reynolds numbers. The floating technique is proven to reduce the pressure drop, pumping power losses and degree of turbulence by increasing the drag reduction in pipeline transportation. A significant reduction of drag in the turbulent flow of water with the fabrication of floating equipment was appraised with pressure drop reduction. The applied floating technique proved to redirect the turbulence flow to laminar flow by correcting the mechanism of turbulent flow. The maximum drag reduction obtained is from 27.80% to 26.18% which occurs at a pipe length of 1m by using the floating device with the length of 15cm and 20cm. These results were attained for the Reynolds number of 51059.94 and 64985.38.

ABSTRAK

Pengangkutan dalam talian paip digunakan secara meluas dalam pelbagai industri. Kebanyakannya, cecair dan gas akan dihantar menggunakan kaedah pengangkutan melalui talian paip. Aliran yang gelora dalam talian paip menyebabkan daya seretan and tekanan seretan yang mendorong kepada kejatuhan tekanan yang turut meningkatkan kos operasi pengepaman serta meningkatkan kuasan mengepam. Oleh itu, aliran saluran paip yang berkesan diperlukan untuk mengurangkan kejatuhan tekanan dengan memperbaiki pengurangan daya seret dalam sistem pengangkutan talian paip. Kajian ini dilaksanakan untuk memperbaiki aliran air dengan menggunakan teknik pengapungan. Getah asli "cis-1, 4-polyisoprene" telah dipilih sebagai bahan yang digunakan untuk tujuan pengapungan dengan mengambil kita sifat-sifat getah yang fleksibel serta berdaya kekuatan yang tinggi. Dimensi peralatan terapung direka dengan 17 jalur getah asli "cis-1, 4-polyisoprene" yang mempunyai panjang 10cm, 15cm dan 20cm, lebar dan ketebalan masing-masing berukuran 0.3cm dan 0.1cm. Jalur getah yang digunakan dalam kajian ini dipasangkan pada cincin aluminium. 10 kadar aliran air yang berbeza digunakan untuk paip yang berukuran 1.5inci. Pembolehubah dimanipulasi dalam kajian ini adalah panjang alat pengapungan yang digunakan iaitu, 10cm, 15cm, 20cm. Semasa experimen dijalankan, kejatuhan dalam tekanan sebelum dan selepas menggunakan teknik pengapungan dicatatkan dan data diperolehi digunakan untuk tujuan pengiraan peratusan pengurangan daya seretan. Data dianalisis dengan lebih lanjut dengan memplot graf peratusan pengurangan daya seretan melawan nombor Reynolds. Teknik pengapungan terbukti untuk mengurangkan kejatuhan dalam tekanan, kerugian dalam pengunaan pam berkuasa tinggi serta meningkatkan pengurangan daya seret dalam pengangkutan saluran paip. Pengurangan ketara daya seretan dalam aliran turbulen air dengan fabrikasi peralatan terapung ini dinilai dengan pengurangan kejatuhan tekanan dalam paip. Teknik pengapung yang digunakan terbukti untuk mewujudkan peralihan aliran gelora ke aliran lamina dengan membetulkan mekanisme aliran gelora. Pengurangan daya seretan maksimum yang diperoleh dari 27.80% and 26.18% yang berlaku pada jarak paip 1m dengan menggunakan alat pengapungan yang panjangnya 15cm dan 20cm. Keputusan ini telah dicapai untuk nombor Reynolds 51059.94 dan 64985.38.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
°C	Degree Celsius
min	Minute
ppm	Parts per million
µm	Micrometer
Re	Reynolds number
cm	Centimetre
W	Watt
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 STUDY

Pipelines transportation is widely used regardless in any industry. Most commonly, liquid and gases are sent using the transportation method through a pipe (Herberg et. al, 2000). In industry, pipelines are one of the most important tools among the many utilities. Pipelines are widely needed in water supply, sewer, telephone lines, oil pipelines and natural gas pipelines which tucked under our streets, through neighbourhoods and communities, stretched across farms, forests, and deserts. These pipelines also provide fuel to generate electricity and fertilizers to increase crop production (A. Basu, 2010). Pipelines also collect crude oil from many rural areas and deliver that crude oil to refineries and chemical plants to create all the products that come from petroleum and petrochemicals (L.Mansingh, 2007). Therefore, an effective pipeline flow is needed in order to reduce the pressure drop and drag reduction for better and improved flow in the pipeline system.

There are three types of flow in pipeline systems, laminar flow, transitional and turbulent flow. This research will be on the turbulence flow in pipeline systems. Turbulent flow has a Reynolds number above 4000 which is type of fluid regime characterized by stochastic property changes (J. Mathieu.2000). Turbulence in pipeline causes the formation of eddies of many different length scales. These eddies which enhance the unsteady vortices appearance in pipe flow on many scales and interact with each other. In this case, the drag due to boundary layer skin friction increases thus resulting in a reduction of overall drag (W. Cabot et. al. 1999). Drag Reduction is the difference in fictional pressure drop along a segment of pipeline at a constant flow rate. If the high drag reduction is obtained then the pipeline flow can be improved.

Pressure drop is the major problems that need to be catered in pipeline system. In pipeline, pressure drop is a term used to describe the decrease in pressure from one point in a pipe or tube to another point downstream (Britannia Enclylopedia.2002). The occurrence of pressure drop results in frictional forces on the fluid as it flows through the tube. The frictional forces are caused by a resistance to flow during a fluid transportation. Pressure drop is an important factor which affects the flow behaviour and pipeline efficiency. When designing piping systems, turbulent flow requires a higher input of energy from a pump (Gasso, 2003). Even high pressure is given at the initial stage, the pressure drop in the pipeline transportation proved to be a major problem.

Many researches have been done to improve the flow in the pipeline system and there are always room for betterment and new implementation. Previously, research has been done to improve the flow in the pipeline by adding polymers, fibers or amphilic solutes (known as surfactants). The previous surfactant research results in more than 70% of drag reduction (G. Albert. 2002). White and Savins reported that when surfactant solutions flow through hydraulically smooth pipes of different diameters, the drag reduction loss occurs at the constant critical wall shear stress τ,w,c, independent of the pipe diameter. Their drag reduction has reached 73.7% (J. Rozanski.2010). This research has its flaws as well when considering the recovery of the transported fluid. The addition of surfactants needs fluid recovery in order to remove the added polymers. In short, purification of the transported fluid will be the last process of the fluid before it can be used. This will result in addition to operational cost. Application of a drag reducing surfactant in the heating circuit also results up to 90% of drag reduction at surfactants temperature of 70°C (J.Myska.2002). Yet, this system needs external heating device to enhance the drag reduction. This research introduces new method by using the floating technique without any added external force. Floating technique requires a set of material which is elastic in nature and easy to float in water. Therefore, rubber material is chosen to execute this research. This research is able to produce positive results thus give huge impact in the industry of pipeline flow.

This research is conducted by designing an experimental work using the fabricated floating equipment. The length of the floating material used in this technique and the testing pipe length was the variable in this research. The effect of these two variables was carefully investigated and the best length was selected. The best length was further analysed with different variables such as flow rates and the pipe length. In conclusion this research is novel and requires theoretical studies and experimental work to strengthen the research outcome.

1.2 PROBLEM STATEMENT

Drag reduction and pressure drop are the major problem in turbulent flow in pipeline systems. Pressure drop is the result of frictional forces and formation of eddies on the fluid as it flows through the tube. The frictional forces are caused by a resistance to flow. Formation of eddies results in pressure drop in turbulence flow. These parameters reduce the efficiency and the performance of pipeline systems. In order to improve flow in pipeline systems, these two parameters needs to be look after. The previous studies on the drag reduction by using the additives such as polymer were sufficient up to 70%. But, the cost of fluid recovery after the fluid transportation needs to be taken into consideration. Addition in operational cost as well as pump failure due to accumulation of these particles results in maintenance cost. Therefore, a new technique of pipeline improvisation is needed in order to cater these problems. In this research, floating technique does not require any fluid recovery process. There will be no pump failure and there is no need for external power added to this technique. The effect of floating technique has the potential breakthrough in pipeline industry by competing with the previous research. Usage of the floating technique in turbulence flow is easy to fabricate and handle. There is huge commercial value for this technique, since it is applicable for any pipeline.

1.3 RESEARCH OBJECTIVES

i. To design a new technique to improve the water flow in pipelines replacing the usage of chemical additives
ii. To study the effect of the design parameters (dimensions of the floating object)
iii. To study the effect of the liquid circulation parameters (liquid flow rate, and testing section lengths)

1.4 RESEARCH QUESTIONS

i. How to improve the water flow in pipeline?
ii. What are the effects of the design parameters on the water flow?
iii. What are the effects of the liquid circulation parameters on the water flow?

1.5 SCOPE OF STUDY

The scope of study of this research is focused on improving the water flow by using floating technique. The flow improvement of the water was analysed by calculating the performance of drag reduction. Improving the pipeline flow means increase the flow and directly reduce the pressure as well as reduce the degree of the turbulence. The drag reduction needs to be improved in order to obtain an optimum performance of the pipe flow. In this research, the floating technique was introduced with three different length of rubber. Fabrication of rubber inside the pipeline is the cost effective technique. The research scope was involved in turbulence flow by using the floating technique without any external forces to the fabricated floating material. The variables of this research are the length of rubbers, the testing pipe length. Other parameters such as the flow rate, type of fluid, type of pipe, the size (diameter) of the pipe, and related pipe specification was set to be constant in order to analyse the variables in this research. The selection of the best rubber length (10cm, 15cm, and 20cm) on the different pipe length is the major scope of this research. The result of this research satisfies the main objective which is to improve drag reduction, pumping power saving and improving flow inside pipelines.

1.6 SIGNIFICANCE OF STUDY

This research enables the new implementation in pipeline system. The method of fabricating the floating equipment with rubber material is cheap and save way to improve the turbulent flow. There is no research have been done on pipe flow improvisation by using floating technique. Costing is the major problem in previous drag reduction studies. This research is geared up with cost effective and applicable technique in industry. The ability of this study to produce positive result with more than 20% on the drag reduction in turbulent flow is proved to be applicable in pipeline industry. The implementation of this technique in piping industry with set a benchmark in the fluid transportation industry. This research has high commercial value in the industry of pipeline transportation system. The novelty of this research enables us to pattern the research for further publication and commercialisation. A series of investigation is proposed to be followed after the execution of this novel research.

1.7 DEFINITION OF TERMS

1.7.1 Floating technique

- Floating technique is term used to describe the suspension of the selected material (rubber) in the turbulence flow. The floating technique is carried out by fabricating the floating equipment in the pipeline. The fabrication of rubber on a ring of aluminium holder is secured in pipeline. This term is specially defined in order to describe the method used in this research.

1.7.2 Turbulence flow

- Type of fluid (gas or liquid) flow in which the fluid undergoes irregular fluctuations, or mixing, in contrast to laminar flow, in which the fluid moves in smooth paths or layers. In turbulent flow the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction. The flow of wind and rivers is generally turbulent in this sense, even if the currents are gentle. The air or water swirls and eddies while its overall bulk moves along a specific direction. (Britannia Encyclopaedia. 2002)

1.8 CONCLUSION

This chapter explains the detailed information of research restrictions and topic background. The introduction begins with the background of studies which filled with compact content concerning the field of research and the research impact towards the industry. The field of the research and the aims to fulfil were set in research objectives and research questions. The research flow of content and its boundary has been set in a frame under the scope of research. The significant of this study which involves in pipeline system have high commercial value in the industry not only nationally but internationally it is very important. The continuation of this research will be followed by chapter two which is known as the literature review.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The pipelines transport is broadly used in various industries. Any form of liquid and gases are sent using the transportation method through a pipeline system. As discussed in previous chapter, the pipeline system is the heart for transportation field. An effective pipeline system is needed in order to save the pumping power and increase the efficiency of pipeline systems.

In this research, the turbulent flow in pipeline system was studied. The major factors which affect the turbulent flow are the pressure drop and drag reduction. Therefore, both parameters need to be improved in order to obtain maximum flow in pipeline system. In this study, the water flow in pipeline was improvised by using floating technique. This novel idea need to be further analysed to improve the efficiency of floating technique phenomena in turbulence flow.

2.2 TYPES OF FLOW

When a fluid flows through a pipe, different parts flow at different speeds. Fluid flow can be laminar, transitional or turbulent. Reynolds number used to characterize different flow regimes, such as laminar or turbulent flow (Streeter, 1962). Reynolds number is a dimensionless number that gives a measure of the ratio of inertial forces to viscous forces and thus quantifies the relative significance of these three types of forces for given pipe flow conditions (Wiggins and Goldstein, 1998). In this research, the floating technique is involved with turbulence flow.

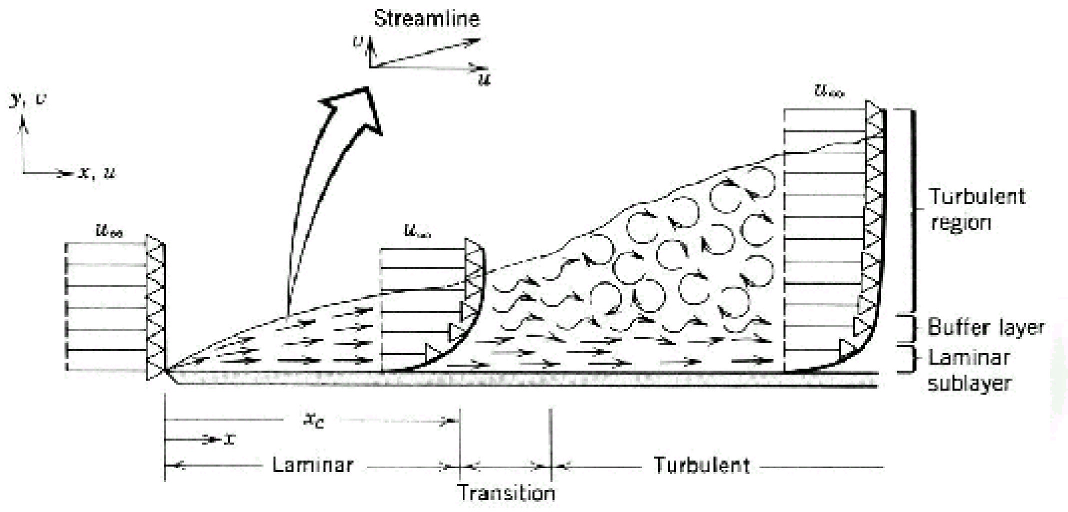

Figure 2.1: Types of flow

Source: Krohne Australia Pty Ltd.2009

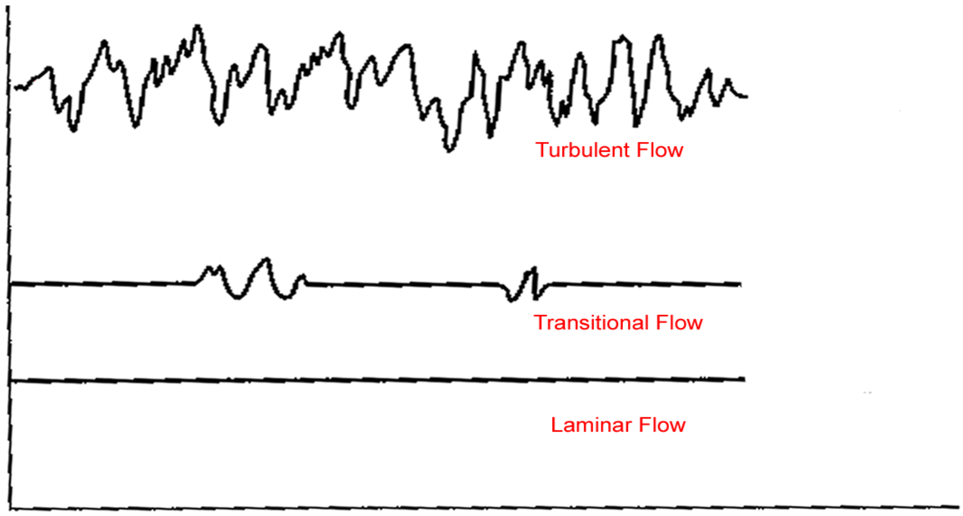

Figure 2.2: Three types of flow

Source: Warhaft, Z. Cambridge University Press.1997

2.2.1 Turbulent flow

There is a range of scales of the time-varying motion in a turbulent flow. 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. Eddy is the swirling of a fluid and the reverse current created when the fluid flows past an obstacle (Patel.et al, 1985). Therefore, Reynolds number is an indicator of the range of scales in the flow. The flow is completely turbulent when the Reynolds Number is above 4000. Turbulence is a very complex physical phenomenon and even today we do not fully understand how turbulence works. Richard Feynman, a Nobel Prize-winning physicist, once said that turbulence is the most important unsolved problem of classical physics.

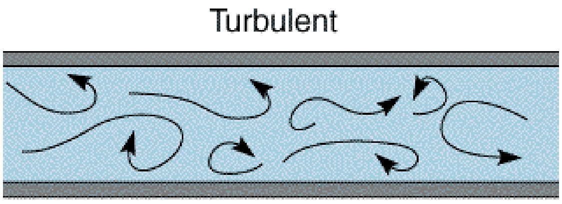

Figure 2.3: Turbulent Flow

Source: University of Cambridge.2010

Turbulence increases the energy required to fluid flow because turbulence increases the loss of energy in the form of friction, which generates heat. When plotting a pressure-flow relationship, turbulence increases the perfusion pressure required to drive a given flow. Alternatively, at a given pressure gradient, turbulence leads to a decrease in flow (E.Richard,2007).

Turbulence does not begin to occur until the velocity of flow becomes high enough till lamina flow break apart. Turbulence occurs when a critical Reynolds number (Re) is exceeded. Reynolds number is a way to predict under idea conditions when turbulence will occur (E.Richard,2007). The equation for Reynolds number is:

$$\boldsymbol{Re} = \frac{\boldsymbol{v}\times\boldsymbol{D}\times\boldsymbol{p}}{\boldsymbol{\mu}} \tag{2.1}$$

Where;
v = mean velocity,
D = pipe diameter,
ρ = fluid density, and
μ= fluid viscosity

Based on this equation, it can be concluded that Re increases as velocity increases. In contrast velocity decreases as viscosity increases. Therefore, high velocities and low fluid viscosity are more likely to cause turbulence. An increase in diameter without a change in velocity also increases Re and this induces the presence of turbulence. However, the velocity in pipe ordinarily decreases disproportionately as diameter increases. The reason for this is that flow (Q) equals the product of mean velocity (V) times cross-sectional area (A), and area is proportionate to radius squared. Therefore, the velocity at constant flow is inversely related to radius (or diameter) squared (E.Richard,2007). For example, if radius (or diameter) is doubled, the velocity decreases to one-fourth its normal value, and Re decreases by one-half (E.Richard,2007).

2.3 PRESSURE DROP

Pressure drop occurs when there is a decrease in pressure from one point in a pipe to another point downstream. Pressure drop is due to frictional forces on the fluid as it flows through the pipe. The frictional forces are caused by a resistance to flow. The main factors contributes resistance to fluid flow are fluid velocity through the pipe and fluid viscosity (Gudmundsson, 1996). Tube convergence, divergence, surface roughness and other physical properties will also affect the pressure drop (Gudmundsson, 1996). High flow velocities or high fluid viscosities result in a larger pressure drop across a section of pipe. Low velocity will result in lower or no pressure drop (Gudmundsson, 1996). In turbulence flow, high velocity fluid is involved therefore the pressure drop is greater than the pressure drop in laminar or transitional flow.

2.4 DRAG REDUCTION

The remarkable ability of low concentrations of certain additives to reduce the frictional resistant in turbulent flow to as low as one-quarter that of the pure solvent is known as drag reduction (McCormick.1995). The phenomenon of drag reduction has been studied experimentally mainly in channels and pipes. In that case the reduction in drag manifests itself as a change in the relation between the mean pressure drop P over the channel/pipe and the flow rate Q the flow rate is increased if the pressure drop is kept constant, or the pressure drop goes down if the flow rate is kept constant (K.F. Wakker,1996). The phenomenon of drag reduction, reported for the first time by the British chemist Toms in 1949, is probably the effect produced by polymer addiction in fluids which has attracted the most attention, because of its relevance for applications. This implies the determining drag reduction by using the formula below:

$$\%\ \text{Drag Reduction} = \frac{\Delta P_{Normal} - \Delta P_{Floating\ Technique}}{\Delta P_{Normal}} \tag{2.2}$$

The pressure drop at normal condition and the pressure drop occurrence after the fabrication of floating equipment in the pipeline will be measured. The percentage of drag reduction of the pipeline will be analysed using the drag reduction equation. The positive result can be obtained when the drag reduction percentage is above 20%.

2.5 PRESSURE DRAG AND FRICTION 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 (Cengel, 2006). The drag due to shear stress is known as skin friction drag while drag due to pressure is known as pressure drag (Cengel, 2006). 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 (Cengel, 2006). Therefore the drag reduction in this research is categorized as drag reduction due to pressure drag.

2.6 IMPROVING THE TURBULENT FLOW

Many researches had been done to improve the turbulent flow in pipelines. A series of investigation by adding additives, surfactants, polymers and even natural mucilage were used as drag reducing agent in turbulent flow. These researches were success with more than 70% of drag reduction. Apart from that, suspended solids such as metal powder were also used in order to improve the turbulent flow. Recently, assembled chain was fabricated in pipeline and the effect of the suspended chain on the drag reduction were analysed.

2.6.1 Drag Reducing Agents (DRAs)

Drag reduction is due to boundary layer skin friction. The structure and location of boundary layer separation often changes, sometimes resulting in a reduction of overall drag (Joline.et al, 2006). The flow can be driven by pumps providing a pressure head that overcomes the wall friction or the drag in the flow. The drag reduction is a major problem even though maximum pumping power is consumed. To save the pumping power a drag reducing agent is vital. Many researches have been done to overcome this problem as well to improve the existing flow system. A drag reducing agent, also called a flow improver, is a long chain polymer chemical that is used in crude oil, refined products or non-potable water pipelines (Havard, 2006). It is injected in small amounts (parts per million) and is used to reduce the frictional pressure drop along the pipeline's length (Havard, 2006). “Drag reduction for liquid flow in a pipe or channel flow is commonly achieved by adding chemicals such as surfactants or polymers to the liquid. Through the formation of surfactant micelles or polymer chains in the bulk liquid, the frequency of formation and size of the turbulence eddies can be dampened. This results in the boundary layer in the pipe wall becoming less turbulent, resulting in less drag in the liquid flow.” (Joline,et al,2006). By dissolving a minute amount of long-chained polymer molecules in water, the frictional drag of turbulent flow could be reduced dramatically. In pipe flows, for example, the drag could be reduced up to 70 % by adding just a few parts per million (ppm) of polymer (Tom,1977). In years time, drag reducing agent were used to improvise the pipe flow. After considering the pros and cons of the previous studies, new design is created in

The application of floating device caused significance reduction in the degree of turbulence. Similar trend of graph was achieved for the comparison of tested different pipe length. There is a pulse of drag reduction in the initial flow rate of the water and steadily reduces the fluctuation of the pressure drop in the water flow. There is definite degree of compatibility achieved by altering the length of the floating device. The turbulence instability is corrected by the aid of mechanical device to generate effective drag reduction on the pipeline system.

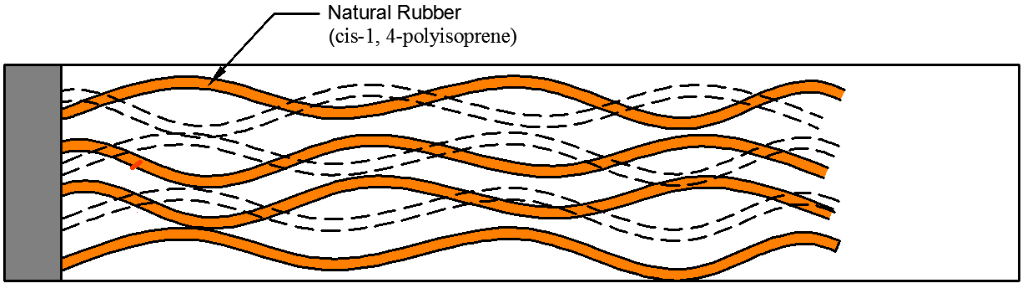

Figure 4.17: Illustration of Floating Device

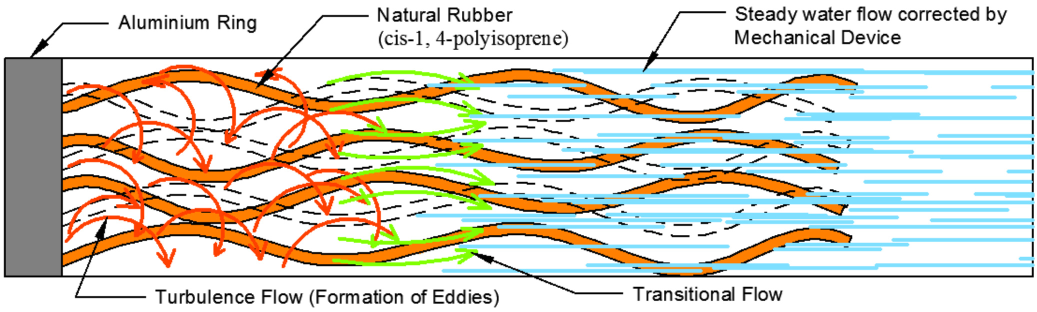

Figure 4.18: Floating Device in Turbulence Flow