Drag Reducing Agent for Water System Using Natural Polymer (Aloe Vera)

By

Ahmad Faheem Bin Md Sani

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Petroleum Engineering)

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CERTIFICATION OF APPROVAL

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Petroleum Engineering Programme
Universiti Teknologi PETRONAS
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BACHELOR OF ENGINEERING (Hons)
(PETROLEUM ENGINEERING)

Approved by,

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(Mazuin Jasamai)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
September 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(Ahmad Faheem Bin Md Sani)

ABSTRACT

Research and development of new chemicals to ensure flow assurance of hydrocarbon in turbulent pipe flow has been done throughout the years since the first introduction of Drag Reducing Agent (DRA) by Tom back in 1948. Drag had caused several problems to the flow line such as power pumping losses, decreasing in production capacity and pipelines corrosion. Thus, the drag reduction applications have brought a lot of improvement in crude oil transportation and water injection for last few decades. Comprehensive research regarding drag reduction in turbulent pipe flow is important which should focus both experimental and theoretical area. However, information on the usage and reliability of natural polymer DRA are still limited compared to synthetic polymers. To make use of these abundant sources of various organic and natural polymers, their effectiveness in reducing frictional drag in pipeline flow must be put into test before it can be introduced and commercialize to the industrial field. Thus, the objective of this project is to determine the effectiveness of new formulated DRA using natural polymer (Aloe Vera).

The 5 different concentrations of Aloe Vera (AV) solutions which are ranging from 800ppm, 900ppm, 1000ppm, 1300ppm, 1500ppm were prepared and pumped in the open flow liquid system of water at the injection point to see the effect on the pressure loss and flow rate. The mixed solution is tested in the 4 meter testing section (1" diameter galvanized pipe) and the pressure reading is observed at two points (P1 and P2) using the pressure gauge. Two pressure gauge is used to monitor the pressure drop obtained along the test section for each concentrations tested. Flow rate of the flow also recorded and compared with each different concentrations of AV solution which will be used to compare the increment of the pipe flow capacity. The drag reduction percentage (DR %) is calculated using the value of pressure loss data obtained in the experiment. The effects of DRA concentration towards the drag reduction and pressure loss were analysed. The result shows that AV solution can increase the drag reduction percentage (%DR) in water flow up to 33% at 1500ppm concentration. The results agree with the theory of DRA polymer reduces the frictional pressure loss in the pipe flow by reducing the degree of turbulence flow, thus increase the transportation flow efficiency.

ACKNOWLEDGEMENT

بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

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CHAPTER 1: INTRODUCTION

PROJECT BACKGROUND

1.1 Project Title

Drag reduction study of natural polymer solution (Aloe Vera) in turbulent pipe flow.

1.2 Background Study

It is important to understand and ensure the flow assurance of the fluids from the wells (upstream) is transported efficiently in the pipeline to the delivery location (downstream). In term of economical aspect, if the flow is not smooth enough and consumes more time than it should be to reach the delivery point, it will cost a lot of money and this is not a preferable situation.

Major concern here is the large pressure losses due to the frictional drag in pipelines can lower the flow rates and affect the pipe capacity. Basic understanding of DRA is that it can assist in reducing the pressure drop when added to the fluid flow in the pipeline. The usage of DRA as describe by Lester (1985) emphasize that the flow improver chemical (DRA) that is introduced into the crude oil production assist in dealing with the pressure loss in turbulent flow regime by reducing the frictional drag between fluid with the inner pipe wall and also by damping the turbulence degree. Thus, it is used to help in reducing the frictional pressure loss during transportation along the pipeline.

Since the famous successful usage of DRA in field application for Trans-Alaska Pipeline during late 1970s, DRA have been improved tremendously, both in reliability and effectiveness [1-3]. Different types of DRA are being introduced to the industry with improved characteristic and suitability to different type of fluid. Over the years, there are three main types of DRA that have been widely used in industry which are polymers, surfactants and suspended solids. Polymers DRA can be divided into two categories: synthetic polymers and natural polymers. However, the availability of natural polymers DRAs is quite limited in industry. To give contribution to the fluid transportation in oil and gas industry, this project is purposely done to explore the usage of natural polymer DRA in the pipeline.

This project is intended to experimentally do the research on the ability of Aloe Vera characteristic as DRA. The effects of 5 different concentrations of Aloe Vera solution ranging from 800ppm, 900ppm, 1000ppm, 1300ppm, and 1500ppm will be tested towards flow rate and pressure loss in turbulent water flow. The experiment is conducted using an open flow piping system which is installed and setup in the lab.

1.3 Feasibility of the project

In pumping operation that operate under similar operating parameter, introducing polymer DRA into the fluid will increase the mobility of the solution causing the flow to require less pressure gradient to maintain the same flow rate. Maintaining the similar pressure gradient (less pressure drop) can result in higher flow rate. This finding has significant value in operation that required the movement of mass such as transportation on crude oil from offshore facilities to onshore facilities. Given the price of oil nowadays, having higher flow rate even under similar pumping operation can save million of money for transportation. There are many literatures available regarding drag reduction study of synthetic polymer DRA in water as the solvent but few on natural polymer DRA. The experiment was started in May 2012 until December 2012. Given that amount of time, numerous areas and finding have been covered by the author.

During the first semester (FYP I), the scope and task that will be covered are:

a) Research on the effects of natural polymer DRA towards the drag reduction in pipeline flow.

b) Learn about Aloe Vera characteristic that is suitable as drag reducing agent.

For the subsequent semester (FYP II), the scope and task that will be covered are:

a) Perform the experiments to verify the theory.

b) Analyzing the findings from the experiment.

c) Preparing academic paper (final report and also the technical paper).

1.4 Problem Statement

In fluid flow in pipeline, the fluid in contact with the inner surface of pipe (pipe wall) tends to stick to the surface due to the viscous effect. This layer of fluid will slow down the movement of the adjacent fluid layer by dragging that fluid layer due to friction. Due to this frictional drag, it will cause pressure drop along the pipeline. With the increasing distance, more pressure will be reduced and directly affect the flow rate of the fluid transportation. In oil and gas industry, to cope with the pressure loss, equipment such as booster pump is installed at specified location. The installing, operating and maintaining this equipment can cost millions or maybe higher. Thus, presence of DRA has proven to reduce the friction and increase the flow rate which can be considered as reliable and economical solution for the problem. The study is intended to explore the degree of effectiveness of natural polymer, Aloe Vera (AV) as the drag reducing agent (DRA). With varied concentration, Aloe Vera solutions will be used in the experiment. Parameters such as Reynolds Number, drag reduction percentage (DR %), flow rate (Q), flow velocity, and flow increment (%FI) are factors are important data to be calculated or observed during the experiment.

1.5 Objectives and Scope of Study

The objectives of this project are:

a) To justify the effectiveness of natural polymer, Aloe Vera (AV), as drag reduction in term reducing transported fluid flow rate in pipeline.
b) The project is to investigate the effect of natural polymer DRA (AV) in reducing the frictional drag and pressure loss along the pipeline. Also to understand about the relationship between reducing turbulent flow can affect the frictional drag and pressure loss in a pipeline.
c) To perform experiments and evaluate the effects of variation concentrations of natural polymer DRA (Aloe Vera) towards the drag reduction percentage in pipeline flow.
d) Compare the effect of AV as DRA in term of drag reduction, flow increment and flow rate with other natural polymer, Hibiscus.

CHAPTER 2: LITERATURE REVIEW

This chapter will deal with the literature research of the type of fluid flow regime and drag reduction along the pipeline. In this project, the experiment will be using natural polymer (Aloe Vera) as the drag reducing agent with 5 different concentrations to see the effects on the drag reduction effectiveness in water system (pipeline).

Turbulent flow is believed can caused increase in frictional drag and pressure loss along the pipeline. Increase in pressure loss will become a major difficulty for the flow assurance of the transported fluid since it can slow down the flow rate. However, by using DRA, it is proven that it can reduce the turbulence degree and further decrease the pressure drop along the pipeline.

2.1 Fluid flow in pipeline

Since the drag reduction phenomenon was first discovered by Tom in 1948, most of the research areas were focused on the synthetic polymer DRA. For this project, the author tried to explore on more specific and less explored side of DRA polymer which is natural polymer. But first, the concept of fluid flow in pipes must be understood. As suggest by Toms, polymer solution flow in a pipe require much lower pressure gradient to maintain the same amount of flow rate compare to the solvent alone. This means, when water flow is mixed with the natural polymer Aloe Vera solution as DRA, with the same pump operating pressure, higher flow rate can be obtained compared to the water flow alone with no natural polymer DRA in the pipe.

Fluid flow can be described into 2 behaviours which is laminar flow and turbulent flow (A. Cengel & John, 2006). In laminar flow, the fluid flow in a uniform manner. Dye streak that is injected into the flow produced a smooth and straight line in laminar region. In contrast, dye streak will form random zig-zag motion in turbulent flow. In turbulent flow, the fluid is flowing in highly disorder or chaotic manner. The transformation between laminar flow into turbulent flow is called transition state.

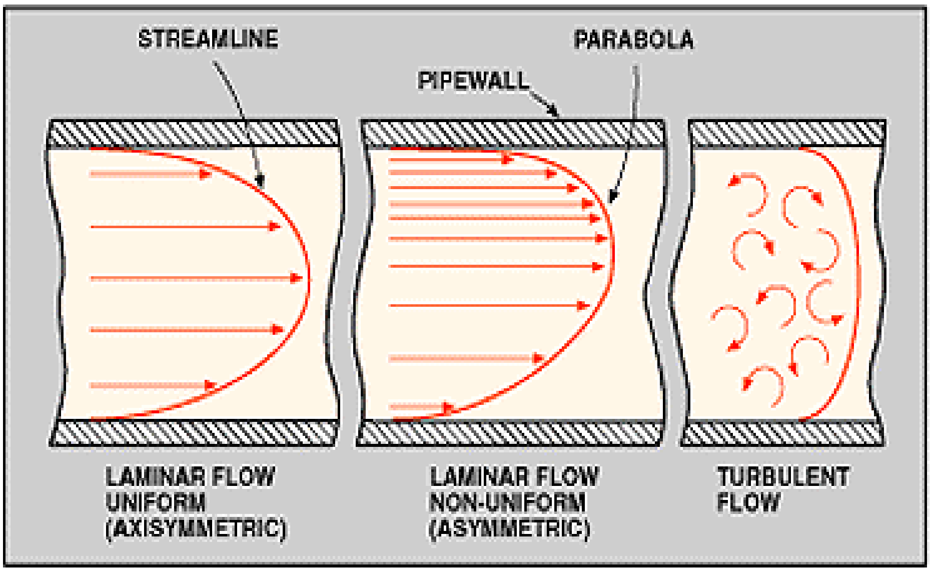

Figure 1: Laminar flow and turbulence flow in a pipeline side view

During the fluid flow, not all fluid particles travel at the same velocity within a pipe. The fluid velocity in a pipe changes from zero at the inner wall surface to maximum at the centre of the pipe. The fluid velocity is zero at the wall due to no-slip condition and the velocity must be highest at the centre to keep mass flow rate.

The shape of the velocity curve, which is represent in the velocity profile across any given section of the pipe, depends upon whether the flow is laminar or turbulent. If the flow in a pipe is laminar, the velocity distribution at a cross section will be parabolic in shape with the maximum velocity at the centre being about twice the average velocity in the pipe. In turbulent flow, a fairly flat velocity distribution exists across the section of pipe, with the result that the entire fluid flows at a given single value. Figure 2 below illustrate the above theory of velocity profile in the pipe. The collision of the fluid particles of the fluid did cause the kinematic energy to be converted into thermal energy but the temperature rise is too small to be considered in calculation. For instance, in the absence of heat transfer, no significant changes in term of the temperature of the fluid that is noticeable.

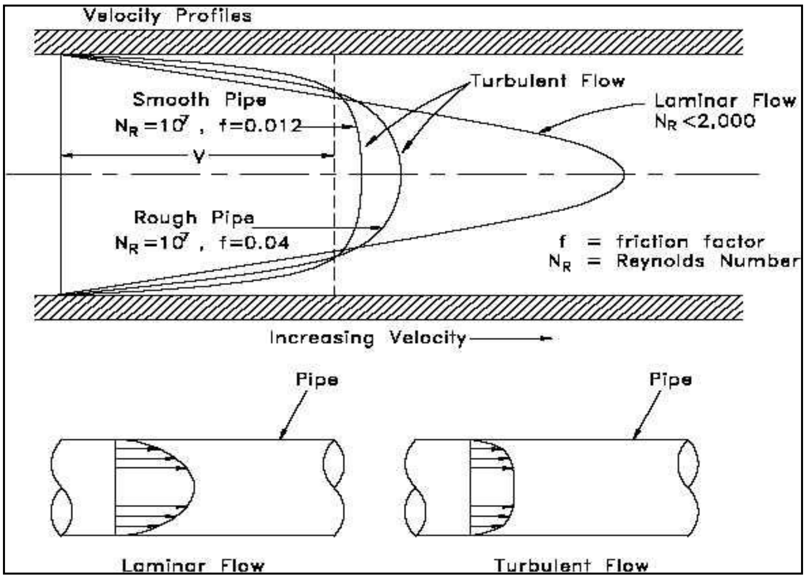

Figure 2 : Laminar and turbulent flow velocity profile

Characterized by the distance to the wall, A. Cengel & John classified velocity profile in turbulent region into a few regions. The very thin layer next to the wall where viscous effect is dominant is the viscous sub layer. Next to the viscous sub layer is buffer layer, in which turbulent effect is significant, but the flow is still dominated by the viscous effect. Above the buffer layer is the overlap layer in which turbulent effect is significant. Above this layer is turbulent layer and the turbulent effect is much more significant compare to the overlap layer. Some literature classified these layers with other names.

The flow behaviour can be distinguished based on the Reynolds number. Reynolds number is given as the ratio between inertial forces and viscous forces and flow behaviour is dependent on which forces are more dominant.

Equation 1: Reynolds Number, $Re = \frac{\textbf{inertial forces}}{\textbf{viscous forces}}$

Dominant inertial force resulting in laminar flow and turbulent if the viscous tend to be dominant. Under most practical condition, fluid behaviours are classified according to following value of Reynolds number.

- $Re < 2300$ laminar flow
- $2300 < Re < 4000$ transitional flow
- $Re > 4000$ turbulent flow

Two regions will be form inside the pipe which is entrance region and fully developed region. In hydrodynamic entrance region, the velocity profile of the fluid is being developed. After a certain distance from the entrance of pipe, the velocity profile will become constant and this region is known as hydrodynamic ally fully developed region. Velocity profile in the fully developed laminar flow has a parabolic shape and somewhat flatter in fully developed turbulent flow. Research area in this paper is focusing in fully developed turbulent region.

Turbulent flow is characterized by random and a rapid fluctuation of swirling region of fluid called eddies, throughout the flow. In turbulent flow, the swirling eddies transport mass, momentum and energy to other region of flow much more rapidly compare to laminar flow (Escudier, M.P., & Smith, 1999). In the study, it is observed that the viscous sub layer plays a passive role in drag reduction effect. However the buffer zone and logarithmic layer are considerably affected. The buffer zone increases in thickness with increasing level of drag reduction. This results in high flow velocity in logarithmic layer, which is responsible for the increase in the flow rate with the introduction of drag reducing polymer.

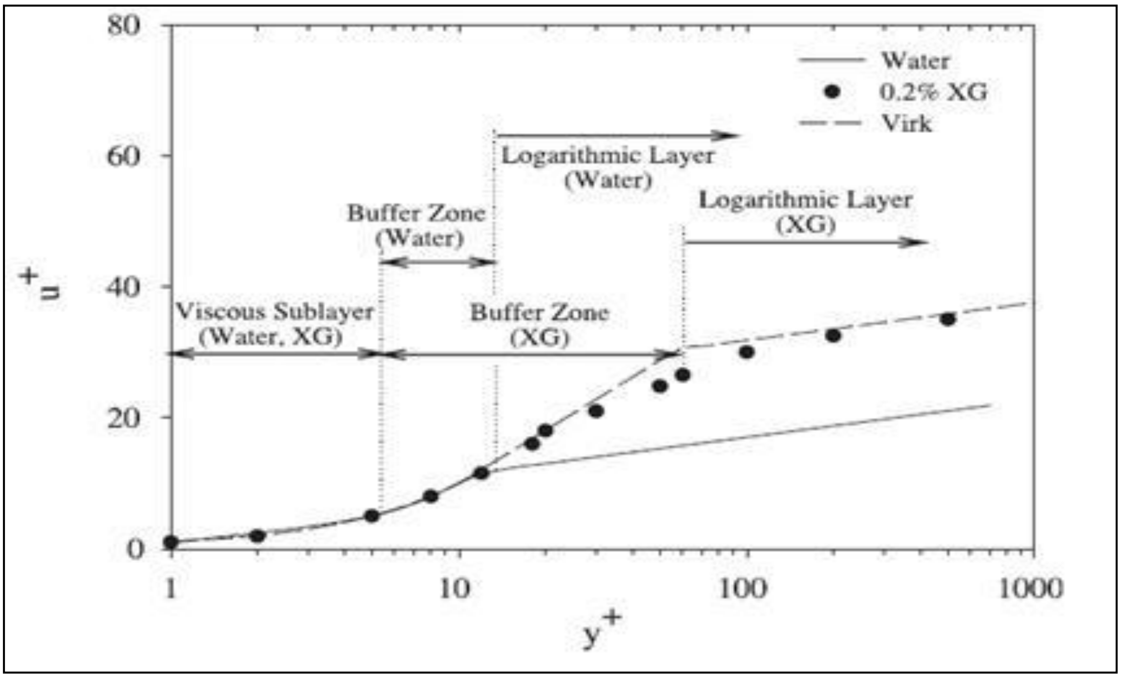

Figure 3: Thickness of buffer layer in water and Xanthan solution (polymer), (Escudier, M.P., & Smith, 1999)

As the mechanism involved, the drag reduction phenomenon is the attribute to the shear waves caused by the elasticity of polymer chain. This shear waves are argued to suppress the turbulent velocity fluctuations at small scales thereby reducing the viscous drag. In recent experimental work, it has been shown that turbulent shear stresses are substantially suppressed by polymer chain. This study revealed that unravelling of polymer chains is indeed an essential ingredient in the ability of a polymer to reduce viscous drag.

2.2 Drag reduction in pipeline using polymer DRA

Liquids in pipeline, especially water, crude oils, product of refinery, are always being transported under turbulent flow in a pipeline. Because of this turbulent structure in flow media, severe amount of drag of flow will be created along the pipeline. As a result, there will be a lot of pressure loss during the transportation and higher pumping power will be needed to make sure liquid can reach the destination (Mashelkar et al., 1975; Quraishi et al., 1976).

Through research over the years, it is found that one of the solutions to pumping power losses during liquid transportation flow is using additive (soluble chemical) to the main flow. Toms (1948) was the first author who described the effect on flow of the addition of a small amount of high molecular weight polymers to a liquid, which phenomenon was called 'drag reduction'.

One of the most impressive successes in polymer applications for drag reduction was the use of 10ppm oil-soluble polymers in the trans-Alaska pipeline system which increased pipeline flow rates significantly (Burger et al., 1982). Actually in oil industry, oil soluble and long-chain polymers had been identified as the effective chemical to reduce the frictional pressure drop caused by turbulence in a pipeline. The operating pressure can be diminished while keeping the same flow rate or the throughput can be increased while applying the same pressure.

To evaluate more about the mechanism of the DRA, Sedahmed et al. (1984) found that polymer molecules are assumed to undergo a dynamic chain elongation that interacts with the eddies in the flow, altering the whole energy balance of the turbulence. This chain stretching occurs under high shear and explains why drag reduction is generally accepted as near-wall phenomenon. As the action of the polymer mainly located at the near-wall region, only a few tens of parts per million by weight of product are required. The low concentrations make polymer chemicals economically attractive. They are all easier to handle and are known to reduce the effect of diffusion controlled corrosion.

2.3 Aloe Vera (AV) as the natural polymer of Drag Reducing Agent (DRA)

Based on the previous research on Aloe Vera, one of the main characteristics of this plant that make it a good drag reduction chemical is pseudoplasticity (shear thinning) properties. These positive effects are thought to be due to the presence of compounds such as polysaccharides. Most of these polysaccharides exhibit interesting and very useful visco-elastic properties when dissolved in water at very low levels and this shear thinning effect can be very useful (i.e. a viscous appearance when stationary, but fluidity when the slightest shear is applied, such as when wiped, poured or brushed) (Hayder 2011). For this project, this Aloe Vera property will be put into test to see what extent of its effectiveness as a drag reducing agent in an open flow piping system using water as the fluid flow.

2.4 Selection of data acquisition and analysis from the experiment

Based on the previously related experiment and research paper, it is found that there are many method of the data selection in order to relate to the effectiveness of the chemical in flow drag reduction.

According to Hayder (2011), different concentrations of the Aloe Vera solution (natural polymer DRA) can affect the amount of pressure drop which can be calculated and presented in term of the flow rate, velocity, drag reduction percentage and flow throughput percentage. It is known that DRA can only works in turbulent flow where the Reynolds number must be greater than 5000.

Drag reduction is defined as:

Equation 2: $$\%DR = \frac{\Delta P1 - \Delta P2}{\Delta P1}$$

$\Delta P1$ is the pressure drop of the flow without addition on DRA. While $\Delta P2$ is the value of pressure loss after DRA was introduced in to the flow.

Next important parameter is the flow rate and the velocity of the flow. Calculation for these two parameters will be using the formula below respectively:

Equation 3: Flow rate, Q (gallon per minutes) = $\frac{Volume}{Time}$

Equation 4: Velocity = $\frac{\text{Flow Rate}}{\text{Area}}$

Where:

Time = time taken for the pump to flow 36L of water to fill up the sump tank
Velocity = average velocity of the flow
Area = cross-sectional area of the pipe (which is set at 0.0254m diameter of pipe)
Reynolds number which is defined as:

Equation 5: *NRe* = $\frac{\rho V D}{\mu}$

From the %DR calculated, the percentage of the increase in flow can be calculated using this formula:

Equation 6: *%FI* = $\{[\frac{100}{100-\%DR}]^{0.556} - 1\}\ x\ 100\%$

In this project, the author will try to use this data to evaluate the effectiveness of Aloe Vera as the drag reducing agent in the water injection flow. This project will be using the open flow piping system with the injection of DRA into the main flow. The injection point of the DRA is decided to be located after the pump to avoid any mechanical degradation of the Aloe Vera polymer by the pump. The Aloe Vera solution will be prepared in the lab with five different concentrations. Drag reduction percentage was calculated from the pressure loss reading, and the effects on the flow rate were analysed and discussed in the next section of this report.

CHAPTER 3: METHODOLOGY

This chapter is going to cover the process and flow through the project. Along with the project activities and Gantt chart, the milestone of the project and equipment used will also discuss in detailed throughout this chapter.

3.1 Research Methodology

Methods to be adopted:

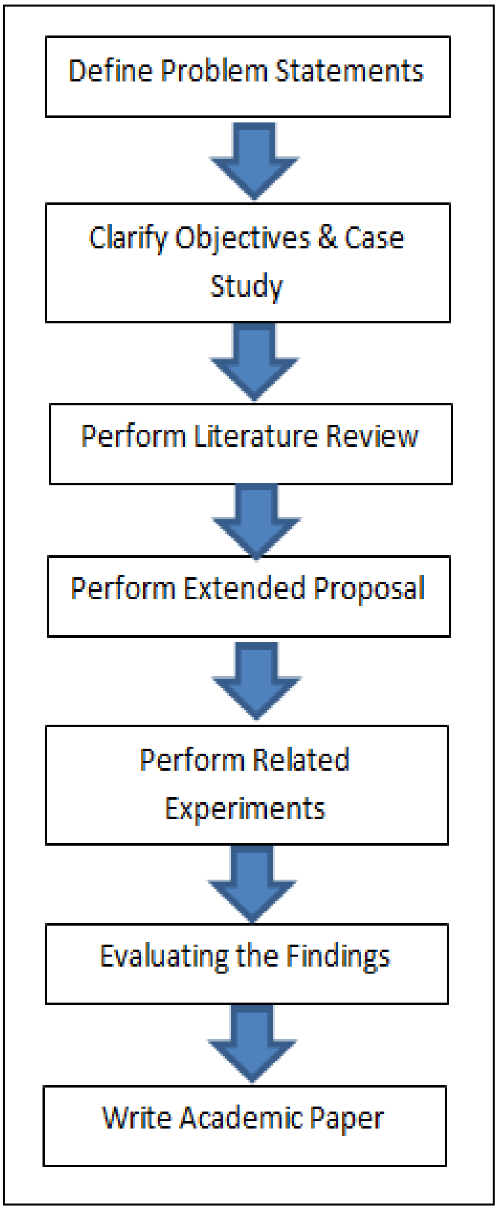

Figure 4: Method and project workflow

During the early stage of the project (FYP 1), research on the natural polymer DRA is made through general reading on article and science journals by researchers on flow assurance drag reducing agent, natural polymer and other related subjects on the topic itself. Through this reading, information of suitable experiment method on how to operate and evaluate DRA in open water flow system have been observed crucially in order to know which data should be utilised. Some of the common DRA mentioned in the past and recent studies are polymer and surfactant. Out of these two type of DRA, the polymer (synthetic and natural) is believed to have more available information most probably polymer DRA is more focused by the researcher compared to others. As the polymers is assumed much more practical and mechanical effective.

3.2 Project Activities

There are quite a number of activities to be done in this project, such as:

a) Doing research by reading related materials regarding natural polymer DRA and Aloe Vera pseudo plasticity properties.
b) Determine the suitable method to be executed in this project.
c) Prepare for the experiments by having training session in using the equipment.
d) Perform experiments based on the knowledge acquired.
e) Analysing the findings from the experiments.

The main part of this project is the DRA preparation with five different concentrations. Solution of DRA is prepared by adding Aloe Vera gel that is extracted from the Aloe Vera leaves with distilled water. With different mass of Aloe Vera can create different concentrations of solution. This mixture will be stirred slowly using the magnetic stirrer to avoid any mechanical degradation to the structure of natural polymer. All mucilage is prepared with the same method. Repeat the same procedure by changing mass of Aloe Vera in order to create different concentrations. This entire preparation works will be done in laboratory with official authorisation. Fluid flow must also exist in single phase. In order to remove any air bubble inside the equipment, one of the important steps is to bleed small amount of fluid from the pressure tapping.

3.3 Tools and Equipment

This project will be using an open flow piping system. Which will be included all the important components of piping system.

a) Pump
b) Natural polymer DRA solution (with different concentrations). This solution will be prepared by the author with different concentrations.
c) Flow rate meter
d) PVC pipe (the size ID will be determined by the help of supervisor later during the experiment period)
e) Water tank
f) Sump tank
g) Viscometer
h) Formaldehydes

3.4 Design and Setup

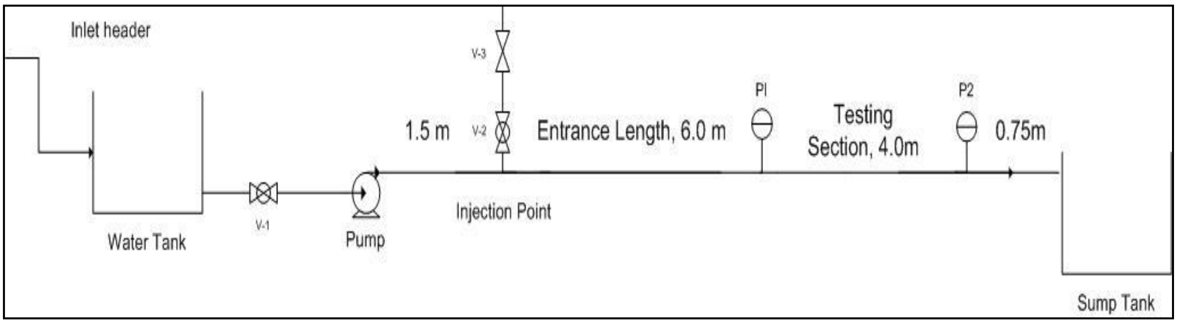

Figure 5: Project equipment setup

This project will be using the open flow piping system with the injection of DRA into the main flow at the water tank before go through a pump. The Aloe Vera solution will be prepared in the lab with different concentration. Next, it will be injected in the flow loop. Drag reduction percentage will be calculated, and the effect on the flow rate will be analysed and discussed throughout the project. The procedures of the experiment will be explained in details in the experiment details section below.

The pictures of the equipments used in this project are included in the **Appendix**

The entrance length where the turbulent flow in a pipe is fully developed is another factor to be considered before proceeding with the experiment as the drag reducer work at its best performance in turbulent flow. The entrance length for turbulent flow is given by;

Equation 7: $\mathrm{El}_{\mathrm{turbulent}} = 4.4\ \mathrm{Re}^{1/6}$

After calculated the length, given that the pipe diameter is 0.0254m, the testing section is decided to be after 7 meters of pipe length. The length of the testing section will be 4 meters long.

3.5 Experimental Details

Preparations of Aloe Vera (AV) mucilage:

1. The AV leaf is rinsed under warm water to remove dirt, debris and any insects that may have found their way onto the leaf.
2. Set the AV leaf on a clean cutting board. Fillet the AV leaf lengthwise; slice from tip to base, using the sharp knife.
3. Turn each half of the filleted AV leaf inside facing up on the cutting board, exposing a layer of gel. Scoop the gel from the leaf using a teaspoon or kitchen butter knife.
4. 1000ml of distilled water is poured in a beaker to prepare 800ppm DRA solution.
5. Then, 0.8g of AV gel is weighted using the digital electronic weight scale. Next, the gel is mixed with the 1000ml of distilled water together with the formaldehyde as the anti oxidation agent to avoid the natural polymer of AV being oxidize.
6. The mixture is stirred slowly for 30 minutes using the magnetic stirrer with low speed of stirring to avoid any mechanical degradation of AV polymer.
7. Then mucilage will be filtrated using filter paper to prevent any suspended solid to get through
8. Step 4-7 are repeated by changing the weight of the AV gel to 0.9g, 1.0g, 1.3g, and 1.5g to create series of DRA solution with concentration of 900ppm, 1000ppm, 1300ppm, and 1500ppm.

Eight concentrations Aloe Vera need to be prepared by dissolving few grams of the Aloe Vera gel extract from the leaves in 1000ml of distilled water. Below is the table of concentration with weight of polymer. Calculation for solution concentration is shown in the appendix B.

Table 1: Aloe Vera solution concentration

Weight of AV (gram)	0.8	0.9	1.0	1.3	1.5
Concentration of solution (ppm)	800	900	1000	1300	1500

Before the addition of DRA in flow system, pressure drop was measured as a function of flow rate. DRA with various concentrations were tested and the pressure reading is taken at two points which is at the start and end point of the 4 meter testing section of the galvanize pipe. These readings were compared with the pressure reading of the flow system without the DRA and purely water flow (dry run).

Experimental procedures are as below:

1. Before the pump starts, all valves must be closed while fill in the water tank until full.
2. Valve 2 is opened and the 1L of DRA is being filled at the injection point, while the valve 3 is left closed.
3. The operation begins when the pump is started. Valve 1 will be opened and valve 3 is opened to make sure the DRA being introduce into the flow and mixed with the water flow.
4. Pressure drop readings are taken at two pressure gauges which is located within the 4 meter testing section.
5. Readings obtained are compared to the reading for water flow without DRAs.
6. This procedure is repeated for each DRA concentrations to test its effect on the flow rate, %DR and %FI.
7. The pump is turned off after getting the pressure drop readings. All data are tabulated and plotted on the graph.

3.5 Gantt Chart and Key Milestone

Table 2: Final Year Project I (FYP1) Gantt chart

No	Detail/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	**Topic Selection / Proposal**	■	■												
2	**Preliminary Research Work**		■	■	■	■									
3	**Submission of Proposal Defense Report**						●								
4	**Proposal Defense (Oral Presentation)**							**Sem break**	■	■					
5	**Project Work Continues**										■	■	■		
6	**Submission of Interim Draft Report**												●		
7	**Submission of Interim Report**													●	

● Suggested Milestone

■ Process

Table 3: Final Year Project II (FYP2) Gantt chart

No.	Activities	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1.	**Lab work**	■	■	■	■	■	■	■	**MID SEMESTER BREAK**							
2.	**Submission of Progress Report**							●								
3.	**Lab work continues**									■	■	■	■	■		
4.	**Pre-Sedex**											●				
5.	**Submission of Draft Report**												●			
6.	**Submission of Dissertation**													●		
7.	**Submission of Technical Paper**													●		
8.	**Oral Presentation**															●

Legend:

■ Process ● Milestone

CHAPTER 4: RESULT AND DISCUSSION

4.1 Experimental calculation

Pressure drop reading through testing sections before and after DRA addition were needed to calculate the percentage drag reduction %DR as follows:

$$\%DR = \frac{\Delta P - \Delta P_{DRA}}{\Delta P} \text{ x } 100 \qquad \textbf{(1)}$$

The average pressure drop at the testing section is observed ($\Delta P2$) and used in the formula above with the value of flow without DRA ($\Delta P1$) and the percentage of drag reduction can be obtained. The pressure loss reduction is expected to be reducing as the concentration of DRA increasing.

The base case experiment for this project is data recorded after flowing 36 litre or 9.501 gallon of pipe water into the pipeline without injecting any additive and pressure drop is recorded. This value of pressure drop is essential in calculating %DR.

Table 4 : Base case information

DRA Concentration (ppm)	Time (s)	P1 (psi)	P2 (psi)	ΔP (psi)	%DR
Pipe Water	20	16.0	2.5	13.5	-

The relationship between the percent drag reduction and percent flow (or throughput) increase (% FI) can be estimated using the following equation:

$$\%FI = \left\{\left[\frac{100}{100-\%DR}\right]^{0.556} - 1\right\} \text{ x } 100 \qquad \textbf{(2)}$$

For every different concentration, the time taken for the pump to fully fill the 36 litre (9.501 gallons) of water tank (sump tank) is recorded and the flow rate can be calculated using equation below:

$$Q\ (\text{gpm}) = \frac{\text{Volume of fluid past a section (gallon)}}{\text{Time taken (min)}}$$

4.2 Experiment result

Table 5: Results obtained from the experiment

	Concentration (ppm)	P1 (psi)	P2 (psi)	P1-P2 (psi)	Average pressure drop, (psi)	Time, t (s)	Average time, (s)	Average time (min)	Average flow rate, (gpm)
Dry run (water flow without DRA)		16.00	2.50	13.50	13.50	20.00	20.00	0.33	28.530
Aloe Vera	800	15.00	2.50	12.50	12.50	16.42	16.42	0.27	34.751
		15.00	2.50	12.50		16.42			
	900	15.00	3.75	11.25	11.63	15.50	15.75	0.26	36.229
		15.00	3.00	12.00		16.00			
	1000	16.00	5.00	11.00	10.25	14.60	14.50	0.24	39.352
		12.00	2.50	9.50		14.40			
	1300	14.00	5.00	9.00	9.25	14.30	14.40	0.24	39.625
		12.00	2.50	9.50		14.50			
	1500	14.00	5.00	9.00	9.00	15.20	15.20	0.25	37.539
		14.00	5.00	9.00		15.20			

Table 6: Calculated Drag Reduction (%DR) and Flow Increment (%FI)

Concentration (ppm)	Average Pressure Drop, (psi)	Cumulative Pressure Drop, (psi)	Average Flow Rate, (gpm)	%DR	%FI
800	12.500	12.500	34.751	7.407	4.372
900	11.625	24.125	36.229	13.889	8.669
1000	10.250	34.375	39.352	24.074	16.548
1300	9.250	43.625	39.625	31.481	23.393
1500	9.000	52.625	37.539	33.333	25.287

Table 1 and table 2 shows the reading obtained from the experiment which are pressure reading from the gauge 1 and gauge 2. The flow rate of the water flow to fill up the 36L of the sump tank can be calculated from the average time taken for the pump to fill up the sump tank with the water. The average time taken to run the pump is 14 seconds. Based from the flow rate data and pressure drop data taken from the table, figure 6, figure 7, figure 8 and figure 9 shown below were able to be generated and the results were analysed.

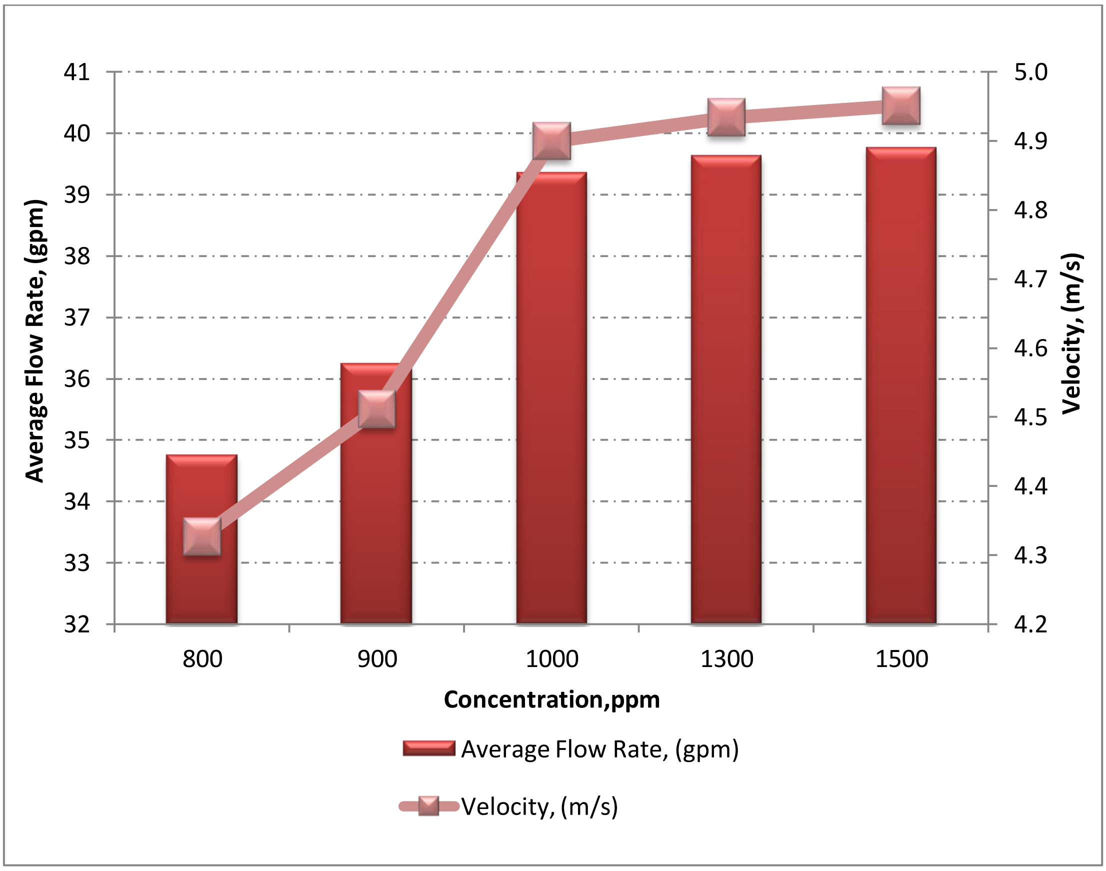

Figure 6: Graph for Average Flow Rate (gpm) and calculated Flow Velocity (m/s)

Figure 6 shows the average flow rate vs. the different concentration of Aloe Vera solution graph. The values of the flow rate increase together with the increase in AV solution concentration. As the concentration increase from 800ppm to 1000ppm, the rate of increment of flow rate is high with the graph's steep gradient. Flow rate slowly increase from 1000ppm to 1500ppm. The highest flow rate is at 1500ppm concentration of DRA with a value of approximately 39.8gpm. Velocity is also proportional with the flow rate.

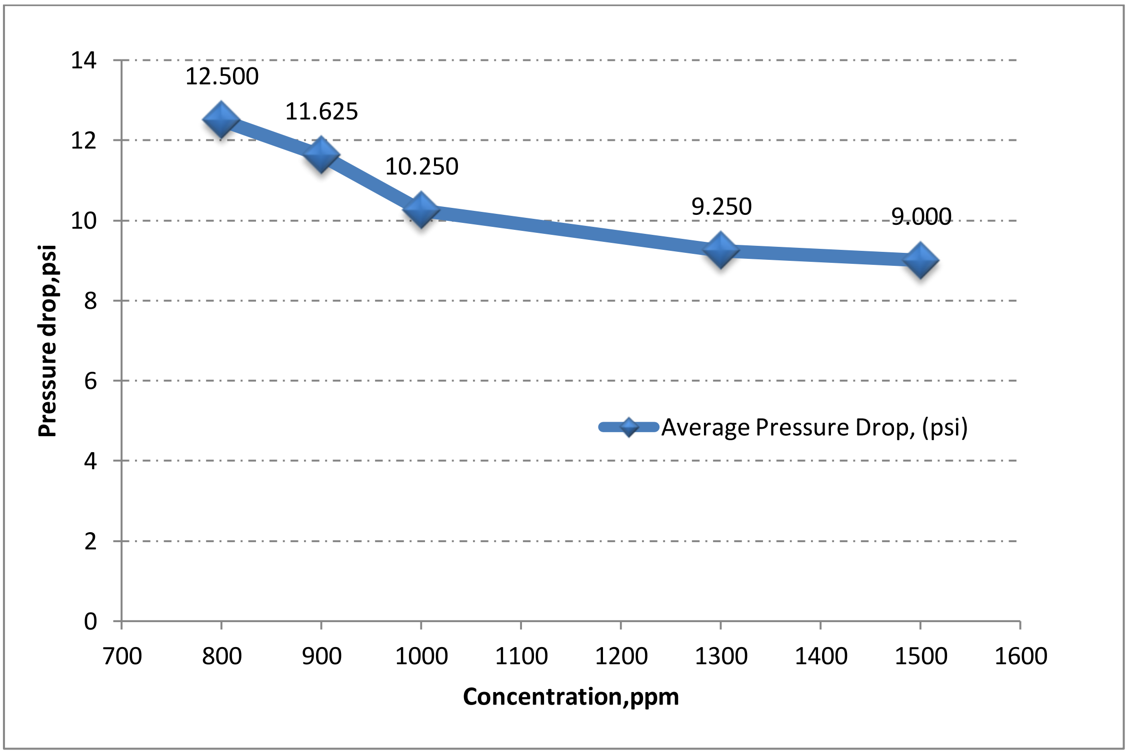

Figure 7: Average Pressure Drop for Different Concentration

Figure 7 shows graph of average pressure drop vs. the concentration of DRA. From the trend, this graph shows that the average pressure drop is decreasing as the concentration of DRA is increase. Reduction in pressure drop is good for the flow in the pipe. If the pressure drop can be reduce, the required installation of equipment to maintain the flow pressure (i.e. Booster pump station) is less likely needed. This is the main purpose of DRA which is to reduce pressure drop along the pipeline. Relationship between the pressure drops with drag reduction is when the pressure drop is decrease; it means the frictional drag reduction of the flow in pipe is increase. From the graph also shows that the highest pressure drop is obtained at 1500ppm at 9psi. Clearly, the AV solution already reduces the frictional drag in the pipe and pressure is more stable and less reduced from the drag force.

Figure 8 below plot the drag reduction percentage (%DR) against the DRA concentration. This is the important parameter to prove the effectiveness of Aloe Vera as the drag reduction agent. The drag reduction percentage (%DR) is calculated using equation (1). In all this experiment, drag reduction is observed to be increasing as the concentration is increased. This is because the pressure drop is decreased across the pipelines; indicating that the frictional drag which cause pressure drop is reduced. The highest drag reduction calculated is around 33.33 % by adding 1500ppm Aloe Vera solution into the flow.

Figure 9 shows the percentage flow throughput increase (%FI) versus the concentration. %FI is calculated using equation (2) mentioned above. The graph trends for flow throughput shows similar pattern to the %DR graph plot which the value increase in steady manner. The highest %FI is when 1500ppm of Aloe Vera solution is injected into the system; which reached value of 25.29%. The flow throughput showing the proportional relationship %DR where the values will increase as the drag reduction is increased.

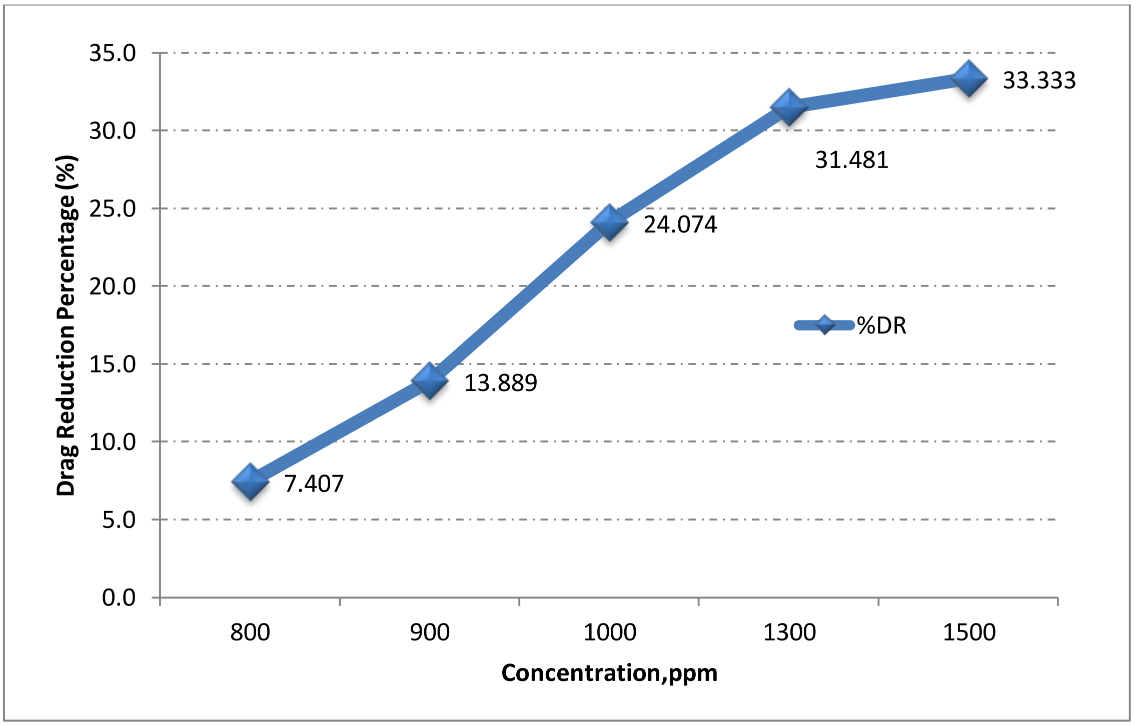

Figure 8: Drag reduction vs. concentration graph

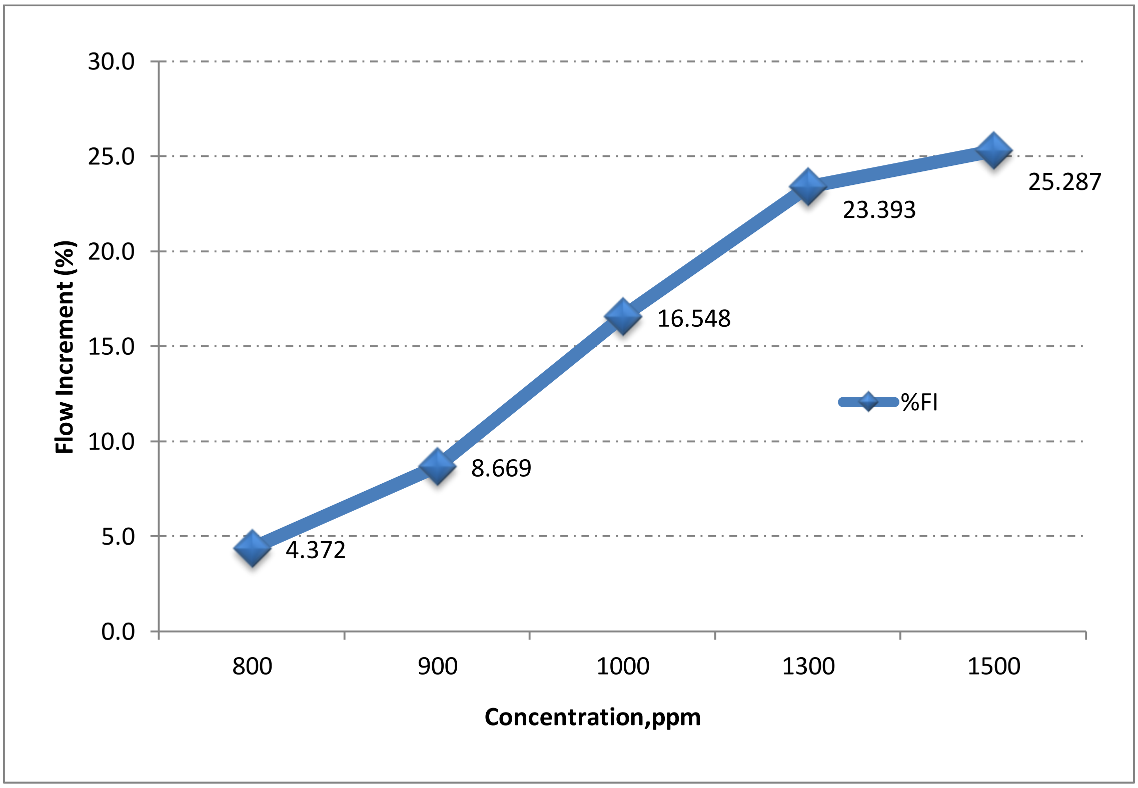

Figure 9: Throughput increase percentage vs. concentration graph

Figure 10, Figure 11, Figure 12 and Figure 13 below show the comparison between Aloe Vera with one of the natural polymer which is Hibiscus. The experiment is executed using the same equipment that is used in this project. The results that will be used to evaluate the effectiveness of natural polymer DRA are in terms of pressure drop, drag reduction and flow rate is compare the performance of Hibiscus with Aloe Vera as DRA in fluid transport in a pipeline. The lowest pressure drop using Hibiscus is 7.8psi at 1300ppm concentration. Using the value of pressure drop, highest drag reduction that Hibiscus solution managed to get is 43% at 1300ppm which is higher than AV solution at the same value of concentration which is 32%. In term flow increment, highest value from Hibiscus at 1300ppm is more than AV about 13% higher. For flow rate value, both solutions having almost similar pattern with increasing flow rate at increasing concentration. Maximum flow rate is at 1300ppm with value of 39gpm for both solutions.

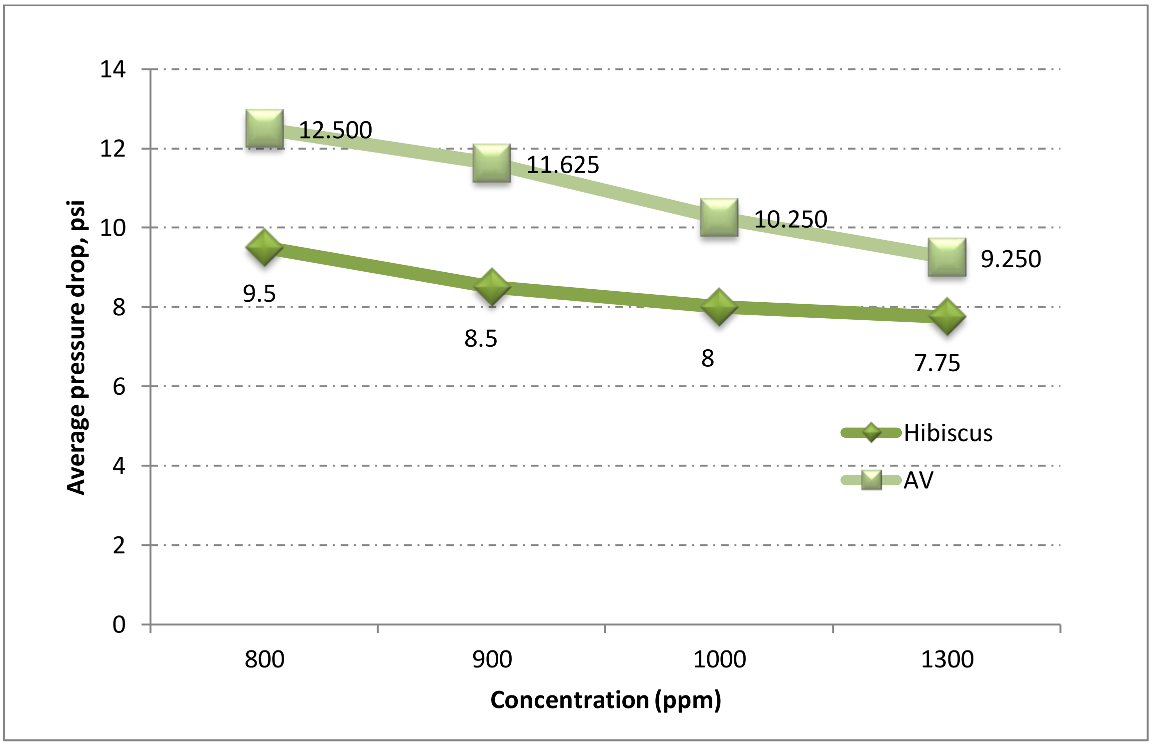

Figure 10: Comparison of average pressure drop vs. concentration

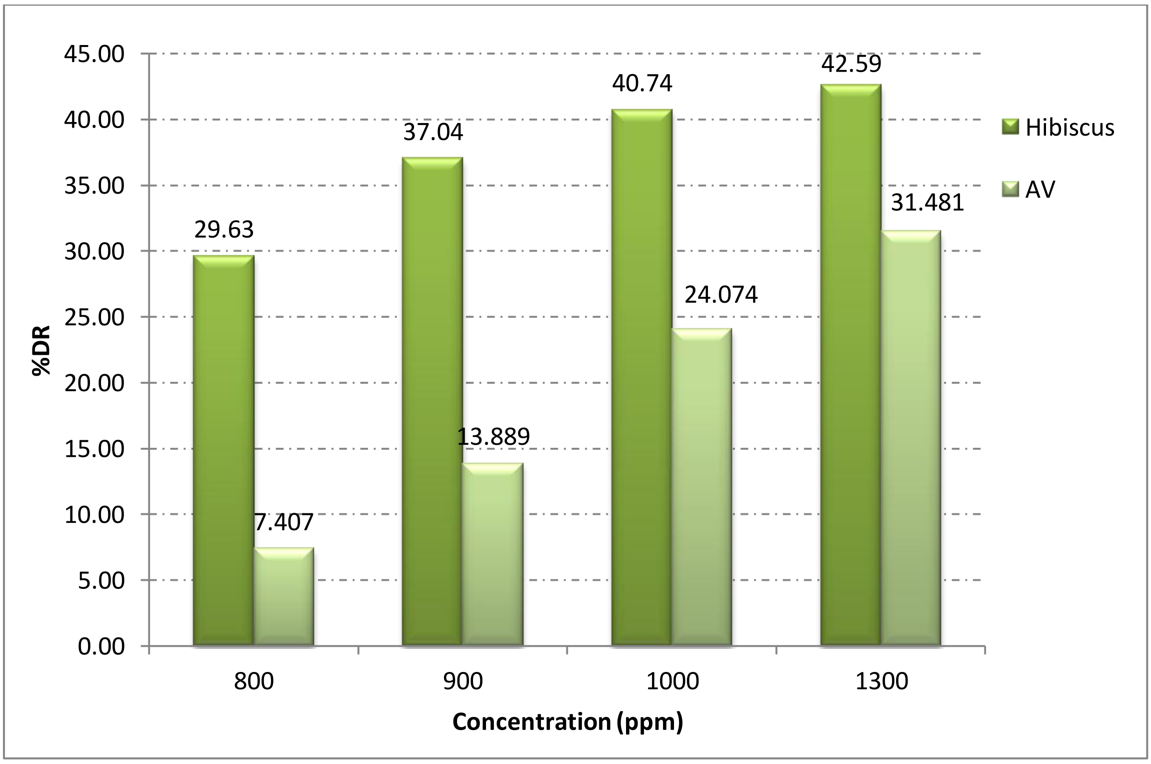

Figure 11: Comparison of drag reduction vs. concentration

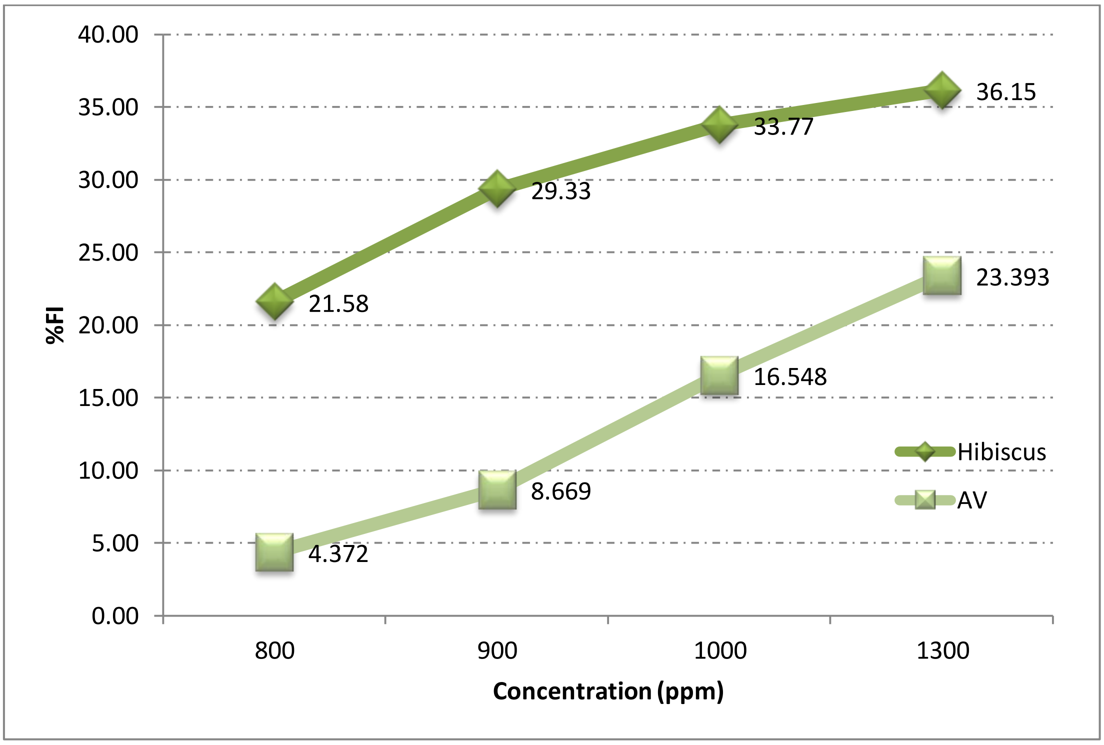

Figure 12 : Comparison flow increment vs. concentration

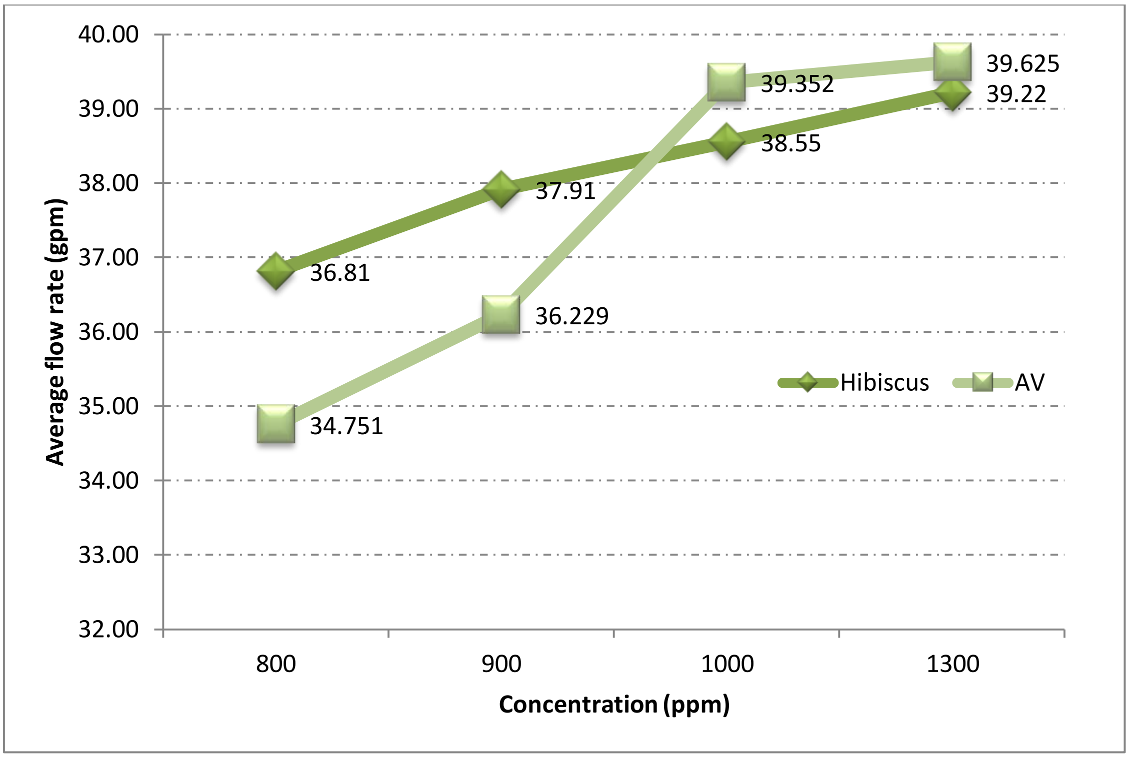

Figure 13: Comparison flow rate vs. concentration

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The usage of polymer DRA in the transportation, there are a lot of proven cases where DRA can improve the pipeline capacity. After properly understand the concept and theory of the DRA mechanism, the experimental phase clearly important in order to test the theory on the DRA and determine the effectiveness of the natural polymer (AV) as the agent to reduce the drag in the turbulent flow along the pipeline. This project is to evaluate use of natural polymer DRA in the pipe flow carrying water in turbulent flow.

Parameters obtained and calculate from the experiment such as pressure drop, drag reduction (%DR), flow throughput increase (%FI) and flow rate were use to evaluate the experiment result. AV solution with concentration of 800ppm, 900ppm, 1000ppm, 1300ppm and 1500ppm has been put into test.

As mention in the report earlier, the purpose of this project is to study the effectiveness of Aloe Vera as DRA in turbulent water flow in pipeline. The effect of the DRA concentration and flow rate will be investigate using the open flow system and pressure drop (ΔP) of every test and time will be taken to see the outcome of drag reducing efficiency (DR%). Based on the result obtained, the project's objectives have achieved successfully. As an increase of Aloe Vera solution concentrations had shown an increment of drag reduction percentage. The flow increment percentage has reached up 25.3% for 1500ppm concentration Aloe Vera solution which indicates positive impact for the flow capacity in pipe.

The effectiveness of DRA increased at higher concentration as compared to lower concentration of DRA. This is proven by the decrease in pressure drop and increase in drag reduction and flow throughput, as shown in Figure 6, 7, 8 and 9. From this experiment, it is concluded that AV solution is able to reduce the frictional drag in the pipeline flow and further reduce the pressure drop along the process to deliver fluid to the destination. From this experiment, the highest %DR can be achieved is 33.33% at 1500ppm of concentration. From the comparison of Aloe Vera with Hibiscus, both natural polymers have the good potential to develop as Drag Reduction Agent (DRA)

5.2 Recommendations

There are a few recommendations to improve the output of this project in the future.

1) This project is using natural polymer as the DRA. Since polymer can be affected by the mechanical degradation, this parameter should be well observed to avoid any undesired effect.

2) To make sure the injection direction is always in the right direction, injection skid should be added up to the equipment at the injection point to avoid any back flow of the DRA.

3) To improve in understanding the properties of natural polymer as DRA, it is better to fabricate tools to observe the elasticity of the DRA properties.

4) Using the core flood concept to replace the open flow loop can give the opportunity to explore the effect of DRA towards the pores in the reservoir.

5) Use digital-scale pressure gauge with “average, max, min” reading function.

6) Use digital-scale flow rate gauge with “average, max, min” reading function

7) Change the static pressure gauge to dynamic pressure gauge; which can measure pressure at the centre of the pipe.

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APPENDIX

Appendix A: Equipment and tools used in the project

Figure 14: Water tank

Figure 15: Engine pump

Figure 16: Injection point

Figure 17 : Test section

Figure 18 : Pressure gauge 1

Figure 19: Pressure gauge 2

Figure 20: 36 litre sump tank

Figure 21: Aloe Vera leaf

Appendix B: Example calculation for the experiment result

1) Solution preparation

$$\frac{100mg}{1000ml} = 1ppm$$

Thus, 0.1 gram of PVP will be used to dissolve with 1000ml of distilled water to obtain 100ppm. The result of other concentration was shown in Table 1

2) Calculation of flow rate and velocity

Equation: Flow rate

$$\text{Flow rate, Q} = \frac{\text{Volume of Water, m}^3}{\text{Time taken, } s}$$

Example:

At 800 ppm, the time taken during the flow is 16.42 second. The volume of water is taken from the pile volume which is as control volume of 36 litters.

36 litre = $0.036m^3$ = 9.51019 gallon

1 minute = 60 second

16.42 second = 0.27 minute

Flow rate, Q (gallon per minutes) = $\frac{Volume}{Time}$

$= \frac{9.51019\ gallon}{0.27\ minute}$

= 35.22 gpm

Equation: Velocity

$$Q = \text{Velocity}, \frac{\text{m}}{\text{s}} \times \text{Area m}^2$$

Thus the equation of pipe area is below:

$$\text{Area m}^2 = \pi r^2$$

Example:

$$\text{Area m}^2 = \pi\left(\frac{0.0254\text{m}}{2}\right)^2 = 0.00051$$

For 800ppm,

Velocity, v = $\frac{Flow\ rate}{Area}$

= $\frac{0.00219\ \text{m3/s}}{0.00051\ m2}$

= 4.3 m/s

3) <u>Calculation for DRA performance</u>

Drag reduction (%DR) and flow increment (%FI)

<u>Drag reduction</u>

Equation:

$$\%\text{DR} = \frac{\Delta\text{P} - \Delta\text{P}_{\text{DRA}}}{\Delta\text{P}} \text{ x } 100$$

Example:

The pressure drop for base case is about 13.5 psi and for 800 ppm is about 12.5 psi, thus the DR% obtained is

$= \frac{13.5 - 12.5}{13.5} \text{ x } 100\%$

= 7.41%

Flow increment

Equation:

$$\%\text{FI} = \left\{\left[\frac{100}{100 - \%\text{DR}}\right]^{0.556} - 1\right\} \text{ x } 100$$

Example:

From the DR% measured, the value is inserted into FI% equation

$$\%\text{FI} = \left\{\left[\frac{100}{100 - 7.41}\right]^{0.556} - 1\right\} \text{ x } 100$$

= 4.37%