CERTIFICATION OF APPROVAL

Drag Reducing Agents for Water Injection using Natural Polymer (Mung Beans)

By

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11562

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Approved

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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 acknowledgments and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ABSTRACT

Drag is one type of the problem in the flow assurance. Drag is a resistance encountered by the flowing fluid when in contact with solid surface or pipeline. Use of Drag Reducing Agents (DRA) in a liquids pipeline can increase throughput and reduce operating costs, both of which can have a significant impact on the revenue and profit of the pipeline company. The effectiveness of DRA is measured in terms of the percentage drag reduction in the frictional losses in the pipeline. However, this effectiveness varies with the DRA concentration. Presence of DRA will help to reduce frictional pressure drop and increase water flow rate in the pipeline. The present study focused on a new, cheap, natural and environmentally friendly flow improver that was extracted from the natural polymer such as okra fruit, cocoa husk, tapioca and aloe vera. Instead of buying a new pump power which is very costly or install a new pipeline which is more complicated work, by introducing natural polymer as drag reducing agent is more reliable solution and moreover fulfil both demand economically and environmentally. Rheology test is conducted to all candidates of natural polymer in order to select the best type of natural polymer for being tested. The experimental study has been performed in 1 inch galvanized iron steel pipe with a total length of 12.25 meters. In addition, two pressure gauges with scale 0-100 psi have been placed to record pressure readings. The DRA concentrations of 600ppm – 1000ppm were used in this study. This project has specifically focused on Mung Beans as DRA. Result of the project showed that Mung Beans give highest drag reduction percentage which is 11.54% in concentration of 1000ppm. Result of this experiment also showed that water flow rate and velocity of the water has increased with the increment value of concentration.

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First of all, I would like to convey my highest gratitude to my Final Year Project Supervisor, Mdm. Mazuin Bt. Jasamai for her continuous support, knowledge, and words that kept me moving to complete this research project.

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CHAPTER 1: INTRODUCTION

1.1 Background of Study

There is study being examined as flow improver in the pipeline which in turbulent flow by using drags reducing agent (DRA). A new kind of drag reducing agent which is natural, biodegradable and environmentally friendly is preferable. Based on the Wikipedia, the first person apparently to notice that the addition of a small amount of polymer dissolved in a liquid will affect its theology was Tom in a year 1949. Basically, DRA is a long chain polymer chemical that when injected into a pipeline modifies the flow regime of the fluid reducing the frictional pressure drop along the pipeline length

For better understanding, take example function of drag reducing agent in water flooding. At the beginning of an oil field production life, primary recovery reacts as the natural energy of the reservoir to cause hydrocarbon to flow into the well bore. However, the natural energy of the reservoir utilized in primary recovery is depleted after some period of time. To continue further production some secondary recovery method must be implemented. Water flooding is the most common Enhanced Oil Recovery used in real field. As oil fields mature, amount of produced water automatically will be increases. These amount of water production have to be disposed due to oil production is our top priority compared to produced water. Hence, disposal of this produced water needs to be conducted in an economic and environmentally friendly way. Produced water can be disposed in two ways which are by inject excessive water into abandon reservoir or re-inject water into the producing reservoir. Drag reducing will help in both cases by increase in pumpability of a fluid caused by the addition another substance known as DRA such as high molecular weight polymers, Polyvinylpyrrolidone (PVP) or surfactant to the fluid.

Furthermore, DRA is a special polymer that injected into a pipeline transporting fluids such as crude oil or water will reduce frictional losses in the pipeline. In addition, the concentration of DRA needed for injection is very small whereby the unit is ppm. DRA interacts with turbulent flow in the region near the pipeline wall and reduce the turbulence. As such, frictional pressure losses are reduced. For the consequence, DRA will only work effectively in a turbulent flow.

1.2 Problem Statement

In a pipeline there is a resistance encountered by flowing fluid coming into contact with a solid surface. Result of this resistance will create drag or frictional pressure drop. Laminar and turbulent flow regime generally two kinds of fluid flow involved in the pipeline. Drag basically will occur in the turbulent flow whereby molecules of the fluid will move in the random direction. As a result, it will cause much of energy due to eddy currents and other indiscriminate motion. Eddies is a swirling of fluid when fluid flow past an obstacle. DRA can react very well in turbulent flow regime because DRA will not change fluid properties.

In addition mainly liquid will flow through the pipeline in a turbulent flow regime. As in laminar flow, the friction pressures observed cannot be changed unless the physical properties of the fluid are changed. Drag also will encounter a problem during transportation of fluid in the pipeline. Water will be transported under turbulent condition in the pipeline. Power of pump will be reduced due to loss of power due to the turbulence flow in the pipeline. Pumping power loss due to energy absorption from eddies and this can be detected via pressure drop from pressure gauge.

Moreover, in terms of cost also can be reduced by using drag reducing agent. Other alternative rather than using drag agent is by installing booster station. However, due to the high costs associated with installing, maintaining and operating each booster station, economics dictate that the size and number of such station for any particular pipeline is limited even though the actual throughput or flow rate may wind up being substantially less than the pipeline could otherwise carry.

It is important to note that each production field and water injection system has its own characteristics and hence the performance of drag reducing agents will vary from field to field.

1.3 Objectives

Objectives of this project are:

1. To determine effect of different concentration of DRA towards drag reduction.
2. To compare new natural polymer as DRA with commercial DRA.
3. To calculate the percentage of drag reduction and to measure difference of pressure drop.

1.4 Scope of Work

This project is about usage of natural polymer as drag reducing agent. Mung Beans (Kacang Hijau), Tapioca Stem (Batang Ubi), Potato (Ubi Kentang) , Banana Stem (Batang Pisang) and Jicama (Ubi Sengkuang) were among types of natural polymer being analyzed to use as DRA. In order to select the best polymer, additional research has to be carried out to identify their characteristics. All these natural polymers will be tested their rheology parameters by using rheometer. Viscosity, Gel Strength, and Shear Stress are some of the result gained from the rheology test. Afterwards, natural polymer to be used in this project can be finalized. Subsequent to successfully select the best DRA, experiment will be carried out in order to get their effectiveness and reaction towards the flow. This project is focused on DRA concentration of Mung Beans between 600ppm-1000ppm. This project involved several laboratories testing to compare with the reference material. On the other hand, some fabrication works is conducted to the prototype in order to get more accurate and precise data. The scope of the study also focus on the methodology and prototype either it is achievable or not. The result of the experimental is calculated such as water flow rate, Reynold number and drag reduction percentage towards different flow rates and different concentration.

1.5 The Relevancy of the project

These are significance that can be gained from this project :

- Increase capacity of water injection
- Cost reduction instead of install new pumping power
- Improve performance of water flow rate in the pipeline

1.6 Feasibility of the Project within the Scope and Time frame

This project is separated into theoretical studies, fabrication and experimental studies. Theoretical studies consists of research, collect and summarized data from the journal papers and past experimental studies related to fluid flow line, drag process and reaction of drag reducing agent. As for fabrication is dealing with modified the existing prototype with assistance from group members. Lastly is experimental studies which are rheology test in the fluid mechanics laboratory and flowline test. Numerous related researches and articles available for references and natural polymer sources is widely available in the market and easy to get. All the facilities and equipment all available in the campus. Thus, this project is efficiently can be completed within the planning time scope.

CHAPTER 2: LITERATURE REVIEW AND THEORY

2.1 Drag Reducing Agent (DRA) in water injection well

According to the review of technical paper entitled 'Optimize production using DRA in water injection wells' written by Jennifer Nelson[10] from Conoco Philips (2003), one of the methods to maintain reservoir pressure is by injecting water into the reservoir via water injection well. Furthermore, it can maintain or boost oil production levels due to water drive towards the oil. In general, more water that injected into the formation resulted more oil that can be subsequently produced until water breakthrough occurs. The capacity of water injection pump, the capacity of the injection tubing and the reservoir characteristics are among factors that determine amount of water that can be injected. Water injection rate can be increase by reduce the differential pressure drop in the pipeline. DRA injected to the pipeline can reduce the frictional pressure drop hence, increase flow rate of the pipeline. In addition, DRA may also be used to increase the rate of water disposal. In some cases where produced water increases, this water is disposed of by pumping into an abandoned reservoir or aquifer. By treating this water with DRA, the rate at which the water may be disposed of can be substantially increased.

2.2 Factors influenced effectiveness of DRA

Based on previous experiments done by Natural Resource from University Malaysia Pahang (2009) [9][12], articles from Onepetro and Science Direct [1][2], and information from several expertise in fluid pipeline [5][6][20], there are factors that have to be considered before to select the most suitable DRA for certain condition. Here are some of the key factors influenced towards effectiveness of DRA.

- Viscosity
- Diameter of pipeline
- Pipe roughness
- Pipe inclination
- Concentration
- Temperature
- Liquid velocity

2.3 Drag process

C. Kang and W.P. Jepson (2000) [4], Institute for Corrosion and Multiphase Technology explain in his technical paper that drag reduction is a flow phenomenon by which small amounts of additives can greatly reduce the turbulent friction factor of a fluid. The aim for the drag reduction is to improve the fluid-mechanical efficiency using active agents, known as polymers. In a single-phase flow, drag reduction is defined as the reduction of friction below that which would occur for the same flow without the drag reducing additive.

Drag Reduction :

$$Drag\ reduction\ (\%) = \frac{\Delta P\ (without\ DRA) - \Delta P\ (with\ DRA)}{\Delta P\ (without\ DRA)} * 100\%$$

$\Delta P\ (without\ DRA)$ denotes the frictional pressure drop without the presence of DRA while $\Delta P\ (with\ DRA)$ stands for the pressure drop with addition of drag reducing additives. Basically there are three types of additives which are polymers, surfactant and fibers. All DRAs aim for the same objective which is to reduce frictional drag force. However, the reaction of the additives towards the fluid is different. As for surfactant, it can reduce the surface tension of a liquid. While Fibers are long cylinder-like objects with high length to width ratio. They orient themselves in the main direction of the flow to reduce drag. In their extended configuration, polymers have a size which is much smaller than the smallest length scale of the turbulence. A well known effect is the increase of the shear viscosity of a fluid due to polymers, which gives reason to suspect that polymers can at the most affect the microscales of the turbulence. Polymers are primarily active on the microscale and macroscales of the turbulence which basically transportation mode of the fluid in the pipeline.

2.3.1 Drag reduction concept

There are basically two types of fluid flow in the pipeline which are turbulence and laminar. The one that we dealt with in the real field is a turbulence flow. Frictional pressure drop, or drag, is a result of the resistance encountered by flowing fluid coming into contact with a solid surface, such as a pipe wall. Surfactant, Fibers and Natural Polymer are among DRA agent that being used to reduce frictional pressure drop. All DRAs do not change fluid properties and will effectively react in turbulence flow only. Therefore, current DRAs can perform very well in most pipelines.

According to Laura Thomas and Tim Burden who is from Conoco Phillips [10] (2001) which is a company specialist in liquid flow improver. DRAs work by an interaction of the polymer molecules with the turbulence of the flowing fluid. Structure of turbulent flow in a pipeline will help in order to understand better how drag reducers decrease the turbulence. The image below shows a typical turbulent flow in a pipeline that has three parts to the flow. Top layer of the pipeline wall is the laminar sub layer. In this zone, the fluid moves laterally in sheets. Between the laminar layer and the turbulent core lies the buffer zone. Bottom zone of the pipe is a turbulent core. It is the largest region and includes most of the fluid in the pipeline. This is the zone of the eddy currents and random motions of turbulent flow.

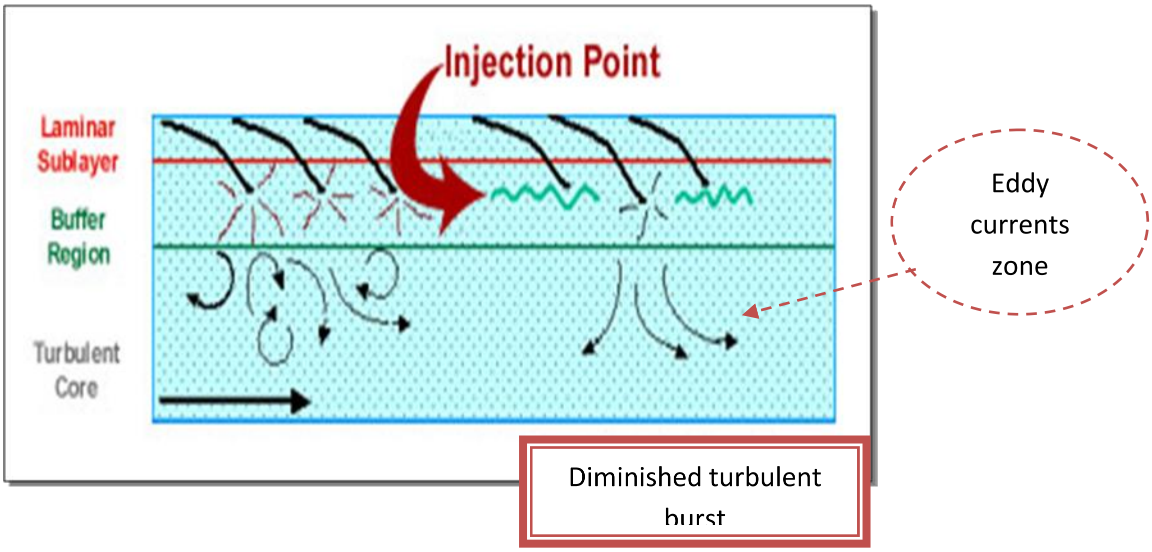

Figure 1 : Drag reduction process

Eddies is a swirling of fluid when fluid flow past an obstacle. Eddy currents zone is a zone where the frictional pressure drop occurred and loss energy due to the turbulence structure. Buffer zone is very important because this is where turbulence formed first and by avoiding this from happening, maximum frictional drop can be achieved. Streak is a piece of laminar sublayer. Streak will become unstable when it moves to the buffer region and moving faster as it closer turbulent core. According to conference paper written by Huey J. Chen and G.E. Kouba from Chevron Petroleum Technology (1998) [6], this is where it will begin to eddy and fluctuate. Finally, the streak becomes unstable and breaks up as it throws fluid into the core of the flow. This is what we called as turbulent burst. As such, drag reducing polymers are most active in the buffer zone because polymer will eventually absorbed the energy in the streak resulting in reduction of turbulence burst. Hence, reduction of turbulence will resulting also in reduction of wasted energy and increase the flow rate of the fluid.

2.3.2 Importance of DRA

According to the article written B.K Berge and O.Solsvik from his field experience (1996) [3] , DRA has typically been used to provide for those occasional occurrence when more oil is produced than can be physically pumped down the line, given the pipeline dimensions and pressure constraints available. However, Drag Reduction is rapidly becoming an essential aspect of cost savings for Petroleum Development Oman (PDO). He mentioned out when PDO first built its pipelines, it built them with a life expectancy of about 20 years after considering all possibilities such as wall thickness, materials and corrosion rate . In order to replace the pipeline, it will taken cost reach to $50 million for 100km. Same goes to alternative for install a new pump power which will take a large amount money has to be invested. Clearly, if these kinds of alternatives can be delay will give massive savings in store for PDO. No matter how well you look after them such as cathode protection or injecting corrosion inhibitors, over the time pipelines will corrode, as the wall thickness reduces, so does the Maximum Allowable Operating Pressure (MAOP). If the MAOP has been reduced to maintain integrity of the system, the amount of oil you can pump through that line must reduce. This can cause deferment in the worst case. However, new alternative is by injecting Drag reducer with the same quantity of oil can be pumped, but at a lower pressure. The drag of the oil on the pipeline is reduced, and thus the pressure drop between the two ends of the node is reduced. Thus, flow rate of the oil and amount of oil production can be increased for a small amount of OPEX each year and careful monitoring of the line and the massive CAPEX investment can be postponed by perhaps several years. It is clear that DRA will play a significant role in this industry in the future. The use of DRA is looking to become increasingly important as an aid to making key pipeline investment decisions

2.3.3 Application of Drag Reduction Agent

Based on Journal of Applied Science written by Hayder A. Abdul Bari and Kumaran Letchmanan, (2011) [9] there are lots of advantages and benefits we could benefit by the implementation natural polymer as DRA agent. Some of the advantages that can be concluding:

- Increase amount of fluids flowing in the pipeline
- Reduce pipeline operating pressure
- Energy and operation cost savings
- Reduction of the waiting time for tanker loading
- Change of flow pattern
- Reduction of corrosion rate

A. E. Abu Nada, Al-Sarkhi and M. Batayneh (2006) [2] from Hashemite University, Zarqa Jordan says one of the major challenges in the power saving field is pumping power losses in the pipeline which carrying water or crude oil in turbulent mode. Pumping power saving by the addition of minute quantities of additives to the main flow was applied in the present study. Turbulent mode will create a result of the resistance encountered by flowing fluid coming into contact with a solid surface. A typical turbulent flow in a pipeline can be divided into three parts of flow. In the very center of the pipe is a turbulent core. It is the largest region and includes most of the fluid in the pipeline. This is the zone of the eddy currents and random motions of turbulent flow. Nearest to the pipeline wall is the laminar sub layer. In this zone, the fluid moves laterally in sheets. By addition of natural polymer as DRA can save up power losses in the pipeline by reduce turbulent burst. A natural polymer has a long chain polymer chemical that will react when injected into pipeline by reduce frictional pressure drop along pipeline length.

2.3.4 Characteristic features of drag reduction

According to Witold Brostow (2001) [21] from his journal in Journal of Industrial and Engineering Chemistry volume 14, he did mention on about Manifestations and characteristic features of drag reduction. These are some of the results of his findings:

- Drag reduction (DR) is directly proportional to the molecular mass M of the polymer regardless of type of the liquid.
- The concentration of DR agent required for a given level of drag reduction is several times higher in a poor solvent. It recalls that solvents can be classified as good and poor.
- Higher drag reduction occurs in a poor solvent under fixed flow conditions than in a good solvent under the same flow conditions. It will stop at some time, so that further flow turbulence does not make the chains which already underwent scission any shorter. It has been proven in experiments that limiting molecular weight values in poor solvents are lower than in good ones.
- Bond scission in flow along chain backbones does not occur exclusively at chain midpoints nor is it random. Shear degradation at a given shear stress is independent of the viscosity of the solvent.
- Kulicke from his books Advance Polymer 1984, have demonstrated that single chains can also cause the drag reduction. This agrees with practical applications of the DR phenomenon which involve sometimes concentrations as low as 10 ppm.
- DR takes place also in laminar flow and injecting a DRA into the centre of the pipe results in practically direct drag reduction performance.

2.4 Chitosan solution as Drag Reducing Agent

Refer to thesis paper done by Nurkhadijah (2009) [12] , 'Chitosan as drag reducing agent in water flowing system', there are two ways of reducing the drag which are passive and active techniques. The passive way is only involved installation and maintenance, while the active way is require certain energy input. With the active techniques, the level of drag reduction can be achieved up to 80% and that makes this method is more efficient compared to passive technique. Mainly, there are three major types of drag reducing agent which is are surfactant, polymers, and suspended solid. In this project, she determine the effect of different concentration of chitosan solution as polymer drag reducing agent to the drag reduction percentage. She also mention about the advantages of using Polymer as drag reducing agent. Firstly. Polymer has higher stability against degradation which means that they are not easier to be degraded when there is a shear forces towars them. Secondly, Polymer also has excellent resistance to heat, light and chemical exposure proven by (D.Mowla et al, 2006).

In addition, Polymer additives also renewable resource commodity and nontoxic material thus the abundant usage of Chitosan will not bring destructive to microorganism. However, the disadvantages of Chitosan are much complicated because it requires particular injection equipment, as well as pressurized delivery systems. Due to the high solution viscosity of these DRAs, they are also limited to about 10% polymer as a maximum concentration in a carrier fluid. Thus, transportation costs of the DRA are considerable, since up to about 90% of the volume being transported and handled is inert material.

Other than that, some polymeric DRAs are also suffer from the problem that the high molecular weight polymer molecules can be irreversibly degraded and this will reduced the size and so the effectiveness of this DRA when it was subjected to conditions of high shear, such as when they pass through a pump. Moreover, some polymeric DRAs can cause undesirable changes in emulsion or fluid quality, or cause foaming problems when used to reduce the drag of multiphase liquids. According to her, there are three ways of introducing a polymer solution in the water flow.

a) The polymer is allowed to mix homogeneously into the solvent before the fluid is pump through the pipeline network.
b) In the second case of heterogeneous drag reduction, a highly concentrated polymer solution is injected in the center of the pipe.
c) In the third case, a concentrated polymer solution is injected into the center line of a turbulent flow at a high enough concentration that a single coherent unbroken polymer thread forms at the injector and continuous downstream for several hundred pipe diameters.

2.5 DRA application seawater injection system

Journal in conference proceedings refer to H.A. Al- Anazi and M.G al-Faifi (2006) [8],'Evaluation of Drag reducing agent in seawater injection system', run experimental studies to assess the effectiveness of a drag reducing agent to increase flow capacity of seawater flowline to power water injection. DRA can reduce frictional pressure drop and increase flow rate in the pipe. Those frictional pressure drop caused by the turbulence flow in the pipe and drag reduction is occurred in near the wall of the pipeline due to the contact fluid flow with the solid surface. They have underlined several factors that affecting performance of the DRA such as molecular weight of the polymer, concentration, flow turbulence and injection location. Experimental result show that DRA has successfully decreased the corrosives of seawater up to 50% and is compatible with currently used biocides in seawater. The DRA was found to be sensitive to shear where its effectiveness decreased with high shear due to polymer chain degradation. This paper summarizes three successful field cases of this DRA in seawater injection systems which are in Brent Alpha offshore field injection rates increased up to 34 %, Gyda oil field in Norway injection of DRA with concentration 80 ppm has increased volume of seawater injection by 65% and Galley offshore field resulted in re-pressurized the reservoir and maintained oil production. Degraded DRA will give less damage compared to the fresh DRA. The extent of damage increased in low permeability cores. However, it caused a permeability reduction at higher concentration. The authors advise for field application, it is recommend for the field to start the concentration of the DRA with 5 ppm then increased gradually the concentration to meet the target flow capacity. In order to avoid polymer degradation, DRA solution must be injected at the discharge of the booster pump and DRA injection must be adjusted if there is fluctuation in flow rate of the transported seawater. A baseline must be created to get a precise data for comparison. This can be achieved by measuring the recording flow rate and pressure drop for several days before DRA injection using pressure gauge or flow meter. DRA should not be stored for longer than time recommend by the supplier because it might damage the DRA thus affect the result of pressure drop. Lastly, DRA neat chemical must be well mixed before being injected into the pipeline.

CHAPTER 3: METHODOLOGY

This section consists of project analysis where at the early of this project as it involves data and information gathering, decide the best method or some modification on the existence methods, some case study analysis and last but not least experimental analysis. Below is overall flow of the project.

3.1 The Work Flow (Execution Chart)

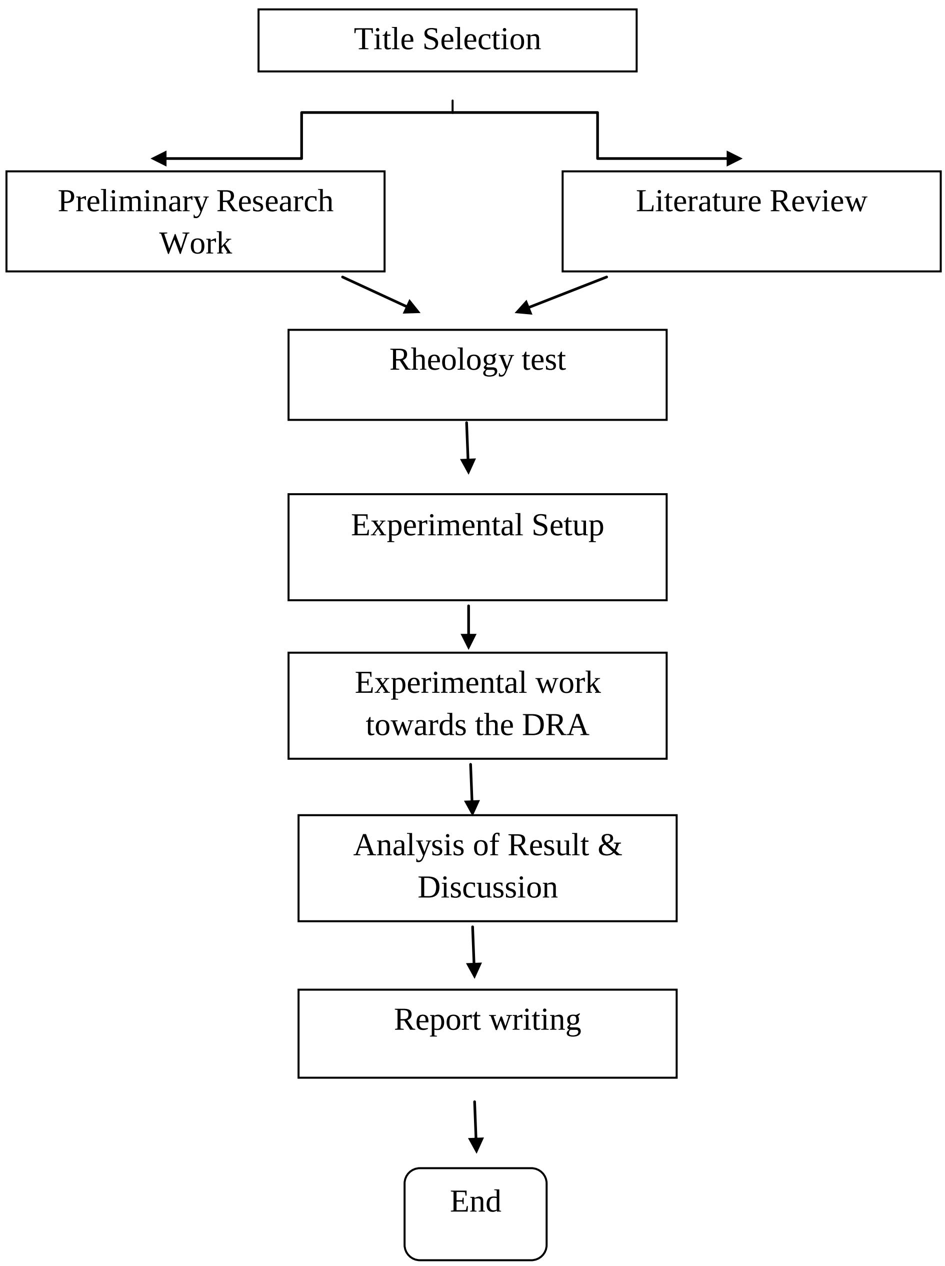

Figure 2: Project Flow Chart

3.1.1 Preliminary research / Literature review

Firstly research, collect and summarized data from the theoretical studies related to fluid flow line, drag process and reaction of drag reducing agent. Literature sources such as experimental studies, journals and reference books regarding concept of drag reducing agent, diagnose the common practice techniques also contribute information to this project. All past experiments about using natural polymer as DRA can be valuable info towards this project. Errors and recommendation from previous can give benefits and advantage for this project. Types of natural polymers available in Malaysia also have to be taken care of in order to know the suitability resource for this project.

3.1.2 Rheology test

Rheology is the science of the deformation and flow of matter, normally relating to fluids and semi-solids. Next will be the discussion of type of polymer to be used as drag reducing agent. The using of natural polymer to the water pipeline will be the major part of the discussion. A number of natural polymers will be tested in rheology test in order to select as DRA for this project. The more sophisticated rheological techniques often apply to medical and academic, as well as industrial research. Interests for this project include shear stress, shear rate, apparent viscosity, plastic viscosity and gel strength. These are some of the input that has to be considering being a good DRA. Fann Viscometer is the instrument used to measure viscosity and gel strength of natural polymer. Natural polymers will be converting to liquid first before being run for rheology test. The direct-indicating viscometer is a rotational cylinder and bob instrument, also known as a V-G meter. Two speeds of rotation, 300 and 600 rpm are available in the instruments. It is called "direct-indicating" because at a given speed, the dial reading is a true centipoise viscosity. These are list of natural polymers that have been used for rheology test :-

- Jicama (sengkuang)
- Corn Leaf (daun jagung)
- Potato (Ubi kentang)
- Mung Beans (kacang hijau)
- Banana stem (batang pisang)
- Tapioca stem (Batang ubi)

All these six natural polymers being selected as candidates based on several factors. Among factors been overlooked are liquid availability from the natural polymers itself, viscosity of the liquid, simplicity of the process and ease of the source to be obtain. Briefly these are some of the pre-selection criteria to be analyzing before select the natural polymers to be used as the DRA in the project. All the kind of natural polymers will be test their viscosity, gel strength and shear factor of the liquid from the rheology test using Fann Viscometer 35A. All there six natural polymers been chosen due to their availability to obtain and ease of liquid to be taken out from the natural polymer.

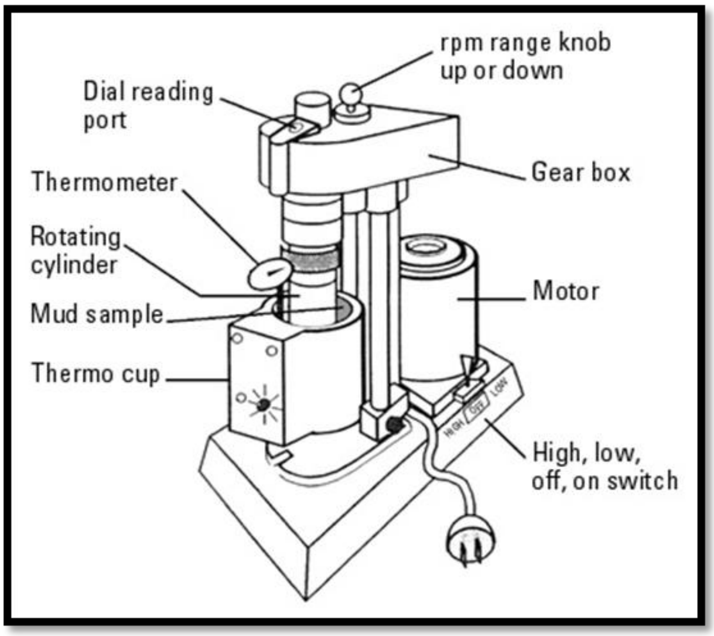

Figure 3: Fann Viscometer 35A

3.1.3 Experimental Setup

With the aid of theories, several experiments will be undergone towards the pipeline to obtain the result of the percentage of frictional pressure drop after injecting natural polymer. Fabrication work on the pipeline has to be done first before jump into experimental work. Overall length of the pipeline will be extending up to 12.25 metres. Next, several experimental will be run on the water flow in the pipeline. This experiment can be divided into three parts which are water flow base case without using DRA, water flow with DRA, and water flow with commercial DRA.

The main purpose of this work is studying the drag reduction in the pipeline systems. This experiment doing is to investigate the effect of the different values of drag reducing agent concentrations and liquid flow rate in order to get the pressure drop of the fluid. This experiment will be run in galvanized iron steel pipe with 1-inch diameter. Generally, this prototype consists of two tanks which are drainage tank at the exit of the pipeline and storage tank at the early part of the prototype. Storage tank will be connected to reciprocal pump. Then the reciprocal pump will provide force for water through the pipeline, and end at drainage tank.

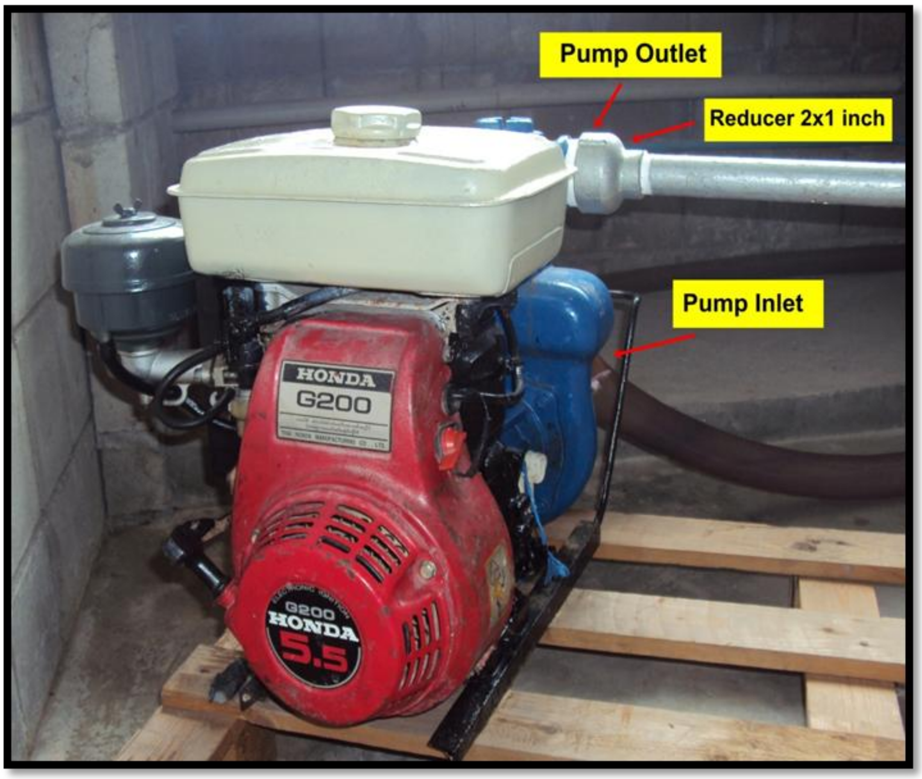

Figure 4: Reciprocal pump

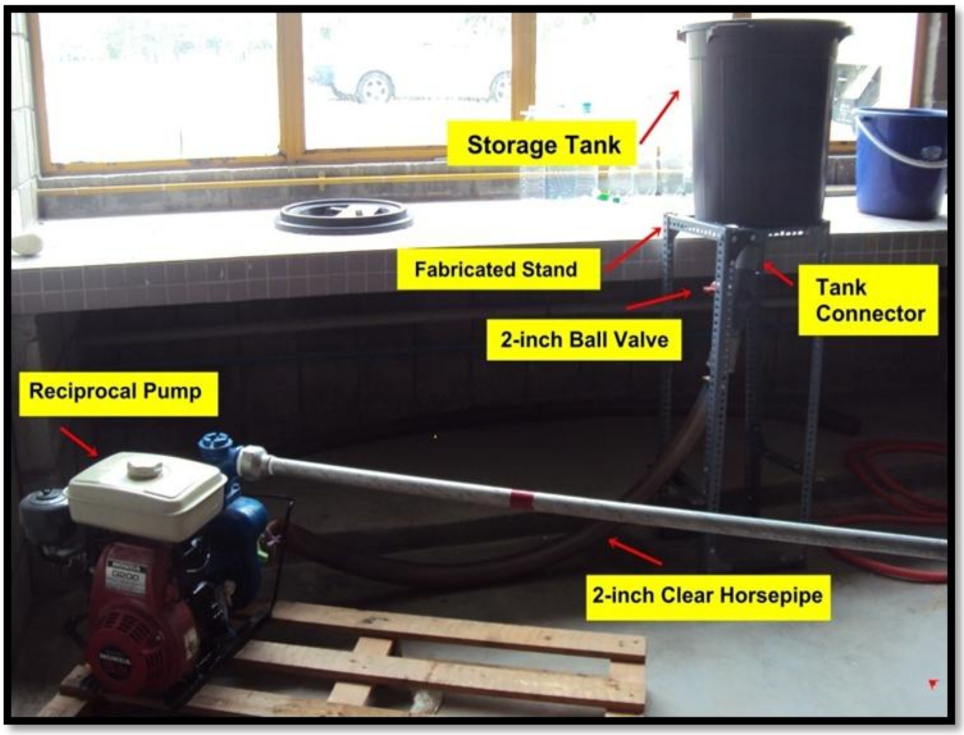

Figure 5 : Reciprocal Pump to injection point

The storage tank is being stand at fabricated-stand with clearance from the ground almost 1metre and water being filled manually in the storage tank. 2-inch Ball valve placed just below the storage tank to control water in and out from the storage tank. A 2-inch clear hosepipe connected the ball valve to the reciprocal pump. This is for route of water flow from the storage tank to the reciprocal pump. The reason put storage tank on the fabricated stand for ease of water to flow in the hosepipe without any blockage or obstacles.

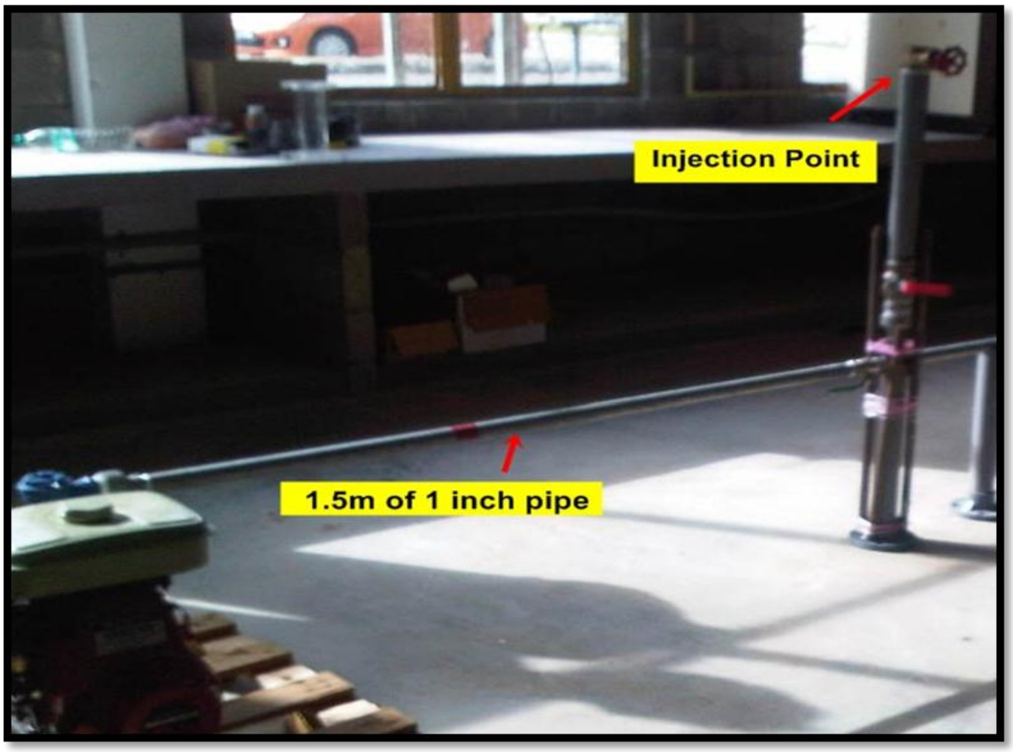

Figure 6 : Reciprocal pump to injection point

According to H.A Abdul Bari et.al (2008), he said that entrance length which is from pump to the injection point must be measure according to the diameter of the pipeline in order to have fully developed velocity profile in turbulent flow. This been calculated from formula suggested by Desissler (1950) :

Entrance Length (Le) = 50(Dia) : Diameter in 'cm' unit

1inch = 2.54 cm, Le = 50 (2.54)

= 127 cm or 1.27 meter

Therefore, minimum entrance length must be in this prototype is 1.27 meter. Thus, this project chooses to use 6 meters of 1-inch galvanized iron steel pipe as entrance length.

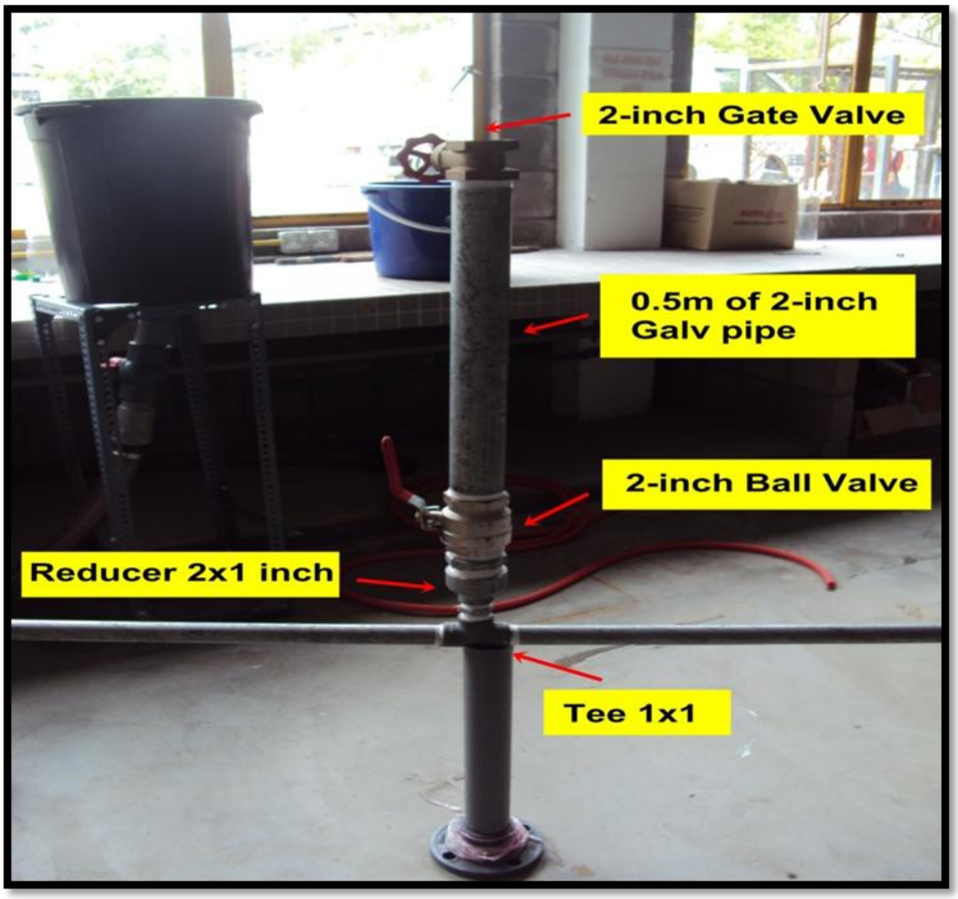

Figure 7: Injection Point section

The injection inlet is made by tee-fitting of a pipe. 2-inch Gate valve will be used as route for DRA to be placed on while 2-inch Ball valve will be functioning as valve to control flow of DRA to the pipeline. 2-inch Gate valve must be closed right after fill DRA into the 0.5m of 2-inch Galvanized iron steel pipe. This is to avoid from water and DRA blow out from pipeline to the upward direction which will make our pressure reading is less accurate. Next section is called entrance length which is from injection section to pressure gauge 1 with the distance is 6metres.

Figure 8 : Test section from Pressure gauge 1 to Pressure gauge 2 (4 metres)

Figure above show test section where the process of drag reduction occurs. This is the place where both pressure gauges been placed on. First pressure gauge been placed 6-meters further ahead after the injection point. This means that entrance length for this prototype is 6-meters. This is because to ensure pressure reading is after fully development of turbulence structure between water and DRA completely occurred. Bush of 3/8 and tee 1x1/2 inch going to be used to hold pressure gauge and connect pressure gauge with the pipeline. Next, second pressure gauge been placed on next 4 meters distance ahead of first pressure gauge. The subtraction between two pressure readings will yield pressure difference along the test section. This so called pressure drop is vital in determine the efficiency of DRA.

Figure 9 : Drainage tank

Lastly, a 90 degree of elbow with size of 1-inch been fitted at the end of the pipeline and facing downward to the drainage tank. This tank has been marked constant volume which is 36 centimetres. Thus, when water exit to the drainage tank reach to 36 centimetres, time reading will be stop and this data can be used to calculate velocity and water flow rate.

3.1.4 Experimental work

a) Mung Beans Concentration preparation

Mung Beans being selected as DRA for this project. Before execute DRA to the experimental run, DRA must be prepared in several concentration which are 600ppm, 700ppm, 800ppm, 900ppm, and 1000ppm. This is to measure effect of varies concentration towards the drag reduction. Preparation of concentration had been done in laboratory using a magnetic stirrer (figure 11) for one hour. This is to ensure DRA and distilled water has completely mixed up and DRA has been totally dilute in the distilled water.

$$Volume\ of\ DRA\ (g) = \frac{Concentration\ of\ DRA * Volume\ distilled\ water\ \text{(L)}}{1 * x10^6}$$

Equation 1 : Concentration solution of DRA

Figure 10 : Magnetic stirrer

Equation above show methods to prepare varies concentration of DRA. As example:

Distilled water (mL)	1000	1000	1000	1000	1000
Mung Beans Weight (gram)	0.6	0.7	0.8	0.9	1.0
Concentration (ppm)	600	700	800	900	1000

Table1 : Concentration solutions of DRA

b) Density and Viscosity reading

All the samples must be taken to lab for viscosity and density reading. It is vital in order to find out Reynolds number for calculation part later on. Density of the liquid can be determine by Digital density meter while viscosity of the fluid is by Fann viscometer.

Figure 11: Fann Viscometer

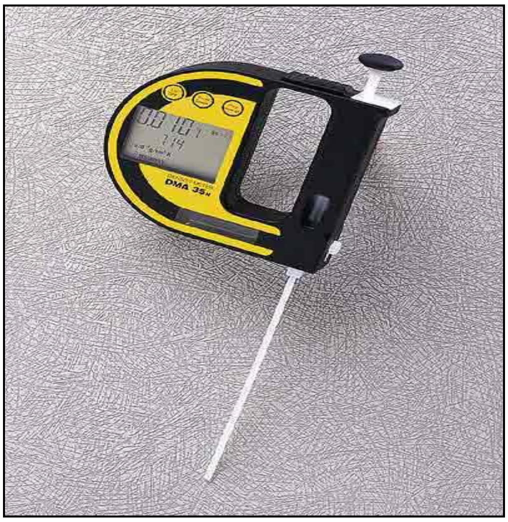

Figure 12: Digital density meter

c) Perform the experiment

1. Fill up water in the storage tank until full.
2. Pour DRA solution into the injection point. However, please ensure 2-inch Gate valve and 2-inch Ball valve closed right after finished fill up DRA solution into it.
3. Operation begins when pump is started. Time start when valve at the storage tank been open up.
4. Open up valve below the storage tank will let water start to flow through the hosepipe and reciprocal pump.
5. When water reach up to the entrance length, Ball valve in the intersection point must be open up. This is to ensure DRA solution to mix up with the water flow during development of turbulence structure.
6. Water flow through the pipeline and test section. Pressure reading from pressure gauge at the early test section will be taken.
7. Pressure reading from the pressure gauge at the end of test section will be taken.
8. Time recorded stop when water at the drainage tank reached the constant volume.
9. Step 1 to 9 repeated with new concentration of DRA solution.
10. Calculate pressure drop and all data will be taken for further analysis and being plotted into graph.
11. Each run was repeated two times and results with best pressure reading was used in the analysis.

3.1.5 Analysis of result

From this experiment, results are in term of pressure reading from the pressure gauge and time for water to reach the constant volume. From here value of the difference pressure drop will be used to calculate flow rate, drag reduction percentage, Reynolds number and effectiveness of DRA.

3.2 Gantt Chart

Activities	Week														
	1	2	3	4	5	6	7		8	9	10	11	12	13	14
FYP briefing								S							
Selection of Project Topic								E							
Preliminary Research Work								M							
Submission of Extended Proposal Defense															
Proposal Defense								B							
Project work continues								E							
Submission of Interim Draft Report								A							
Submission of Interim Report Final Draft								K							

Table 2: Gantt chart – FYP I

Activities	Week															
	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
Project Work Continues - **Rheology test** - **Selection of DRA** - **Prototype fabrication** - **Experimental run**								S								
Submission of Progress Report								E								
Project Work Continues - **Comparison with commercial DRA**								M								
Pre-EDX																
Submission of Draft Report								B								
Submission of Dissertation (Soft Bound)								E								
Submission of Technical Paper								A								
Oral Presentation								K								
Submission of Project Dissertation (Hard Bound)																

Table 3: Gantt chart – FYP II

3.3 Tools, Equipments and Materials

The material, tool and equipments needed specifically for the experiments which are listed below:

1. Total of 12.25 meter of 1 inch galvanized iron steel pipe
2. 0.5 meter of 2 inch galvanized iron steel pipe
3. Two ball valve of 1 inch
4. Two ball valve of 2 inch
5. One gate valve of 2 inch
6. One 90 degree of elbow of 1 inch
7. One tank connector
8. One tee of 1X1 inch
9. One tee of 1X ½ inch
10. Two reducer of 2X1 inch
11. Two pail of 45.43 liter capacity
12. One reciprocal pump
13. Two pressure gauge with scale 0-100 psi and thread of 3/8 inch

CHAPTER 4 : RESULTS AND DISCUSSION

4.1 Calculation part

There are few calculations needed for result analysis. The effectiveness of Mung Beans as DRA can be measure from this equation. This equation shows percentage of drag reduction by taken differential pressure drop value of base case which is water flow run without interfere of DRA and subtract it with differential pressure drop value of water flow with DRA.

$$Drag\ reduction\,(\%) = \frac{\Delta P\ (without\ DRA) - \Delta P\ (with\ DRA)}{\Delta P\ (without\ DRA)} * 100\%$$

Equation 2 : Percentage of drag reduction

ΔPf = Differential pressure drop

% DR = Drag reduction percentage

We can prepare concentration of DRA form this equation:

$$Volume\ of\ DRA\,(g) = \frac{Concentration\ of\ DRA * Volume\ distilled\ water\ (\mathrm{L})}{1 * x10^{6}}$$

Equation 3 : Concentration of DRA

Flow rate of the fluid can measure from this formula :

$$FlowRate, Q = \frac{Volume, V}{Time, t}$$

Equation 4 : Water flow rate

Efficiency of DRA can be calculated from this equation:

$$E_{DRA} = \frac{\%Drag\,\mathrm{Re}\,duction}{C_{DRA}}$$

Equation 5 : Efficiency of DRA

Measure entrance length from this equation:

$$L_e = 50(D)$$

Equation 6 : Entrance length

D = diameter in cm

Le = Entrance length in meter

Reynolds number can be calculated from this formula

$$\mathrm{Re} = \frac{\rho v D}{\mu}$$

Equation 7 : Reynolds number

Re = Reynolds number

ρ = Density

μ = Viscosity

D = Diameter

4.2 Result analysis

This project is separated in two phases which firstly is to deal with viscosity test of all the alternatives of natural polymers available consists of Jicama (sengkuang), potato (Ubi) , mung beans (kacang hijau), Banana stem (batang pisang), and Tapioca stem(batang ubi). In order to select the best drag reducing agent among all, viscosity test have to be conducted using Fann Viscometer 35A in order to compare the rheology parameters among these entire natural polymer. Hence, Figure 14 below shows the result of the viscosity test for all the alternatives.

Sample	**Viscosity**					**Gel Strength** (lb/100ft2)
	ϴ 600 (RPM)	ϴ 300 (RPM)	μa (cp)	μp (cp)	YP (lb/100ft2)	
Ubi kentang (Potato)	25	14	12.5	11	3	4
Kacang Hijau (Mung beans)	**33**	**17**	**16.5**	**16**	**1**	**5**
Ubi Sengkuang (Jicama)	12	7	6	5	2	2
Batang Ubi (Tapioca stem)	8	5	4	3	2	0
Batang Pisang (Banana stem)	10	5	5	5	0	0

Figure 13 : Viscosity test chart

All these kind of natural polymers never being used in the commercial usage as drag reducing agent. So, this is might be a new discovery and environmental friendly of natural polymer. Based on the result above, it can be clearly seen that Mung beans (kacang hijau) is the highest natural polymer that having higher viscosity compared to other natural polymers. In addition, it also has higher gel strength compared to other sample which lead to be a good drag reducing agent as we know a good drag reducing agent must having a high gel strength with the purpose of improve the water flow. All the solution is a mixture of 1Litre distilled water and natural polymer. Weight of natural polymer will be depends on the concentration itself. As example for concentration DRA solution of 700ppm, the puree was prepared from 0.7gram of natural polymer and poured into 1Litre of distilled water. Next, the solution will be stir for one hour using Magnetic stirrer as shown in figure 10.

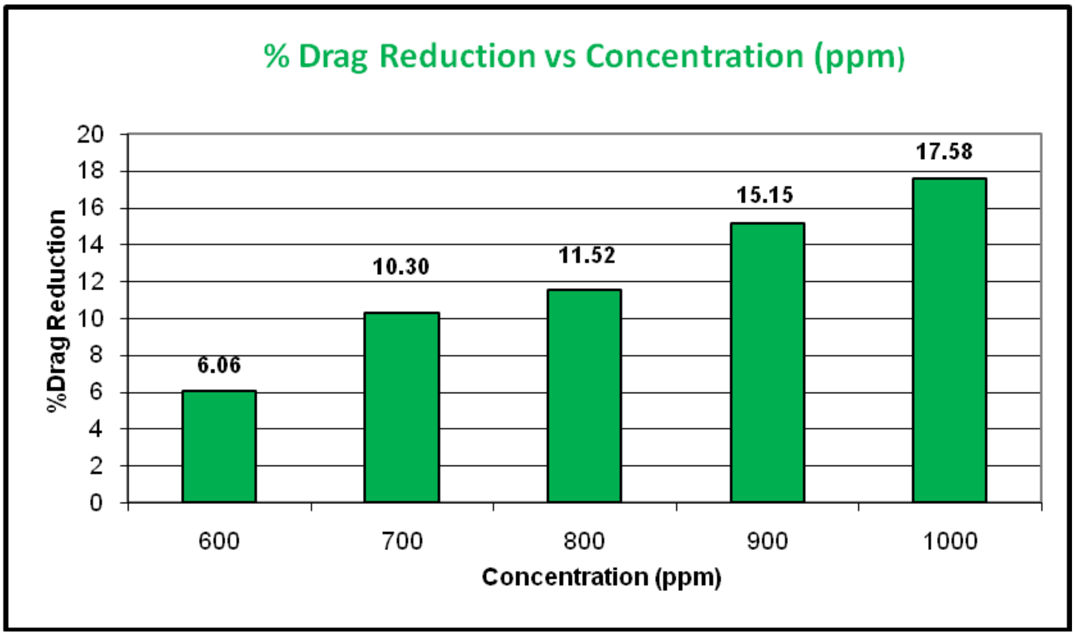

Figure 14: Percentage of Drag Reduction vs Concentration

The result of experimental work showed that percentage of drag reduction increases by increasing the concentration of drag reducing agent. Figure 14 above show relationship result of percentage of drag reduction towards concentration of drag reducing agent. It shows that drag reduction will be increasing with increasing value of concentration. This is due to high concentration will be more effective in tackling drag problem because increase of the number of natural polymer molecules involved in the drag reduction process. It will keep on increasing until they reached their limitation which is when the mixture of water and natural polymer achieve stability.

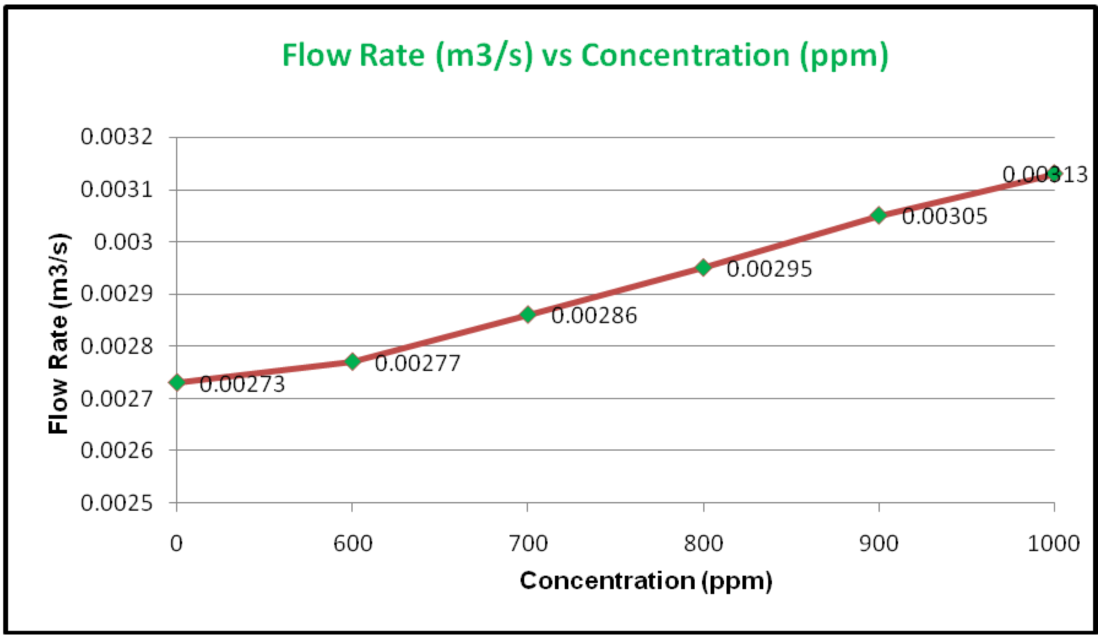

Figure 15 : Flow rate vs Concentration

As in Figure 15, it gives more details on fluid flow rate which concern on the relationship between water flow rates with concentration. Higher concentration of drag reducing agent simultaneously affect to the higher water flow rate. Water flow rate will increase when time for the water reaching the constant volume is decreasing.

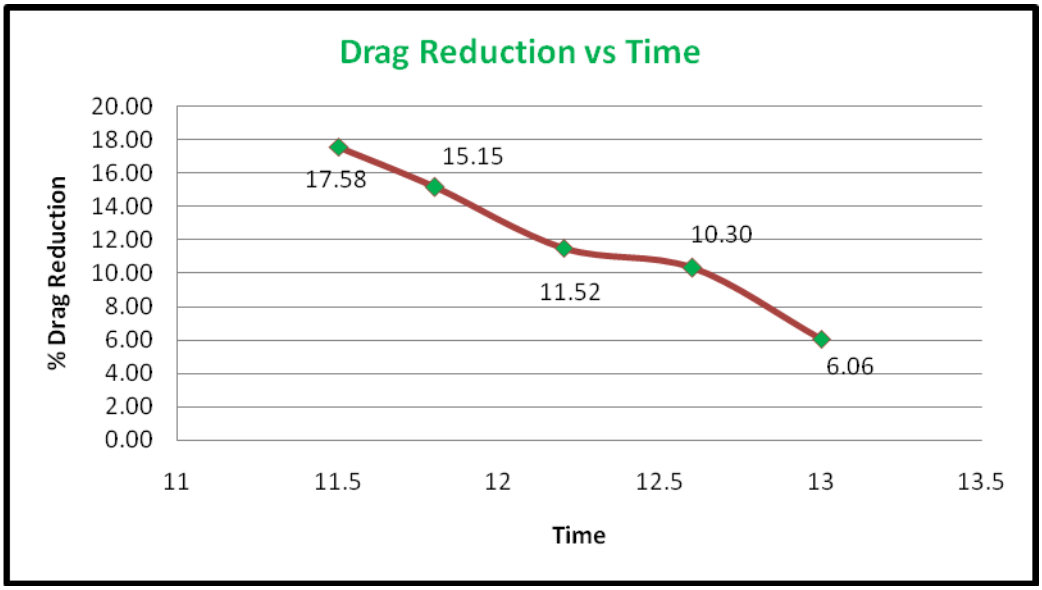

Figure 16 : Percentage of Drag Reduction vs Time

Figure 16 shows the drag reduction percentage obtained for different concentrations of Mung beans as a function of time to reach constant volume in drainage tank. As a result, it means velocity of the water will also increase. Generally, the higher the drag reduction, the greater water flow rate may be achieved and time for water to reach constant volume is faster. Concentration is also a major factor affecting drag reduction performance in a pipeline. As the concentration of polymer increases, so the resulting drag reduction performance increases simultaneously will shorten time for water to reach constant volume in the drainage tank.

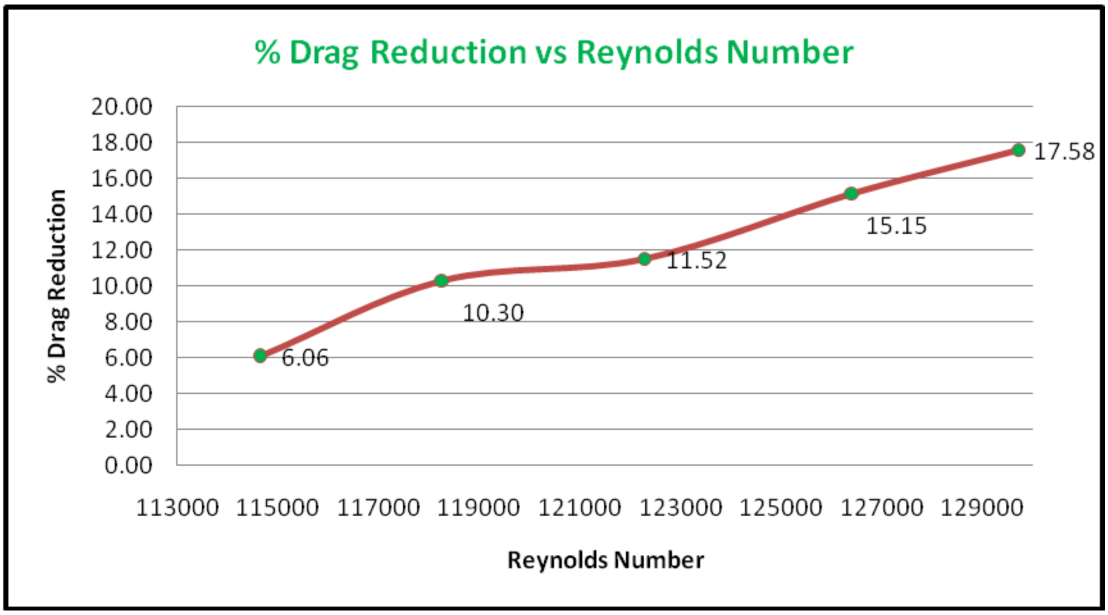

Figure 17 : Percentage of Drag Reduction vs Reynolds Number

Figure 17 shows the relationship between percentage of drag reductions obtained for different concentrations of Mung beans towards Reynolds number. This behavior is due to increase degree of turbulence provides suitable media for drag reducing agent to act efficiently by suppressing the turbulence structure. High degree of turbulence means increasing number of eddies absorb energies. By the existence of molecules Mung beans, it will be part of eddies and make it difficult for these eddies to form by disturb development of the turbulence structure. Thus, existence of Mung Beans as DRA will help in improve degree of turbulence resulted in increasing percentage of drag reduction.

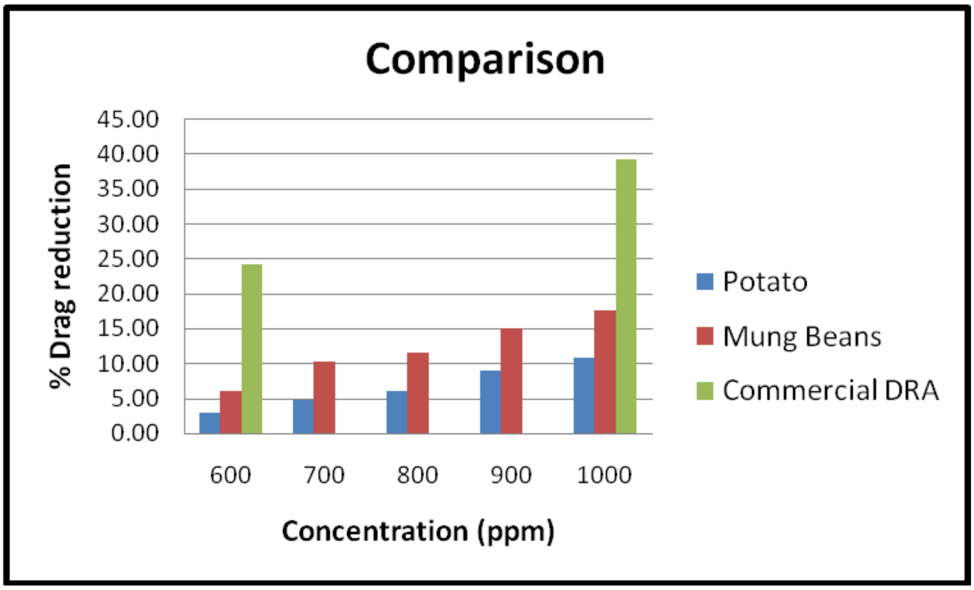

Figure 18 : Comparison Percentage of Drag Reduction vs Concentration

Figure 18 shows result of comparison between two kinds of natural polymer as drag reducing agent which are Potato and Mung beans with Commercial DRA. Both of these drag agent used same concentration value from 600ppm, 700 ppm, 800ppm, 900ppm, and 1000ppm to be tested except for commercial DRA which is only used 600 ppm and 1000ppm due to limitation of sources. From the figure 19, it can be conclude that Mung beans is more applicable and effective drag reducing agent compared to Potato. This might be due to the quality of the gel strength and viscosity in Mung beans which is much more higher than Potato. However, both natural polymer could not reached percentage of drag reduction more than 20%. However, it still gives a good and encouraging result for the applicable of Mung beans and Potato as drag reducing agent as long as percentage of the drug reduction is positive. In addition, the commercial DRA is a refined product which is after going through treatment and modification while the Mung Beans is a natural DRA without any refined product and purely natural. Thus, performance of natural polymer as DRA can possibly be improved if further refined applied.

Furthermore, usage of natural polymer is easier to get and has plenty of sources without limitation. In addition, it is more effective in terms of cost compared to install new pipeline or but a new pump power. But yet both of these natural polymer still cannot reach to the performance of Commercial drag which is proven been more effective in tackling drag problems. Commercial DRA can reach about 40% drag reduction with concentration 1000ppm compared to both natural polymer with the same concentration value only reach below than 20%.

Assumption taken

1. Zero roughness of the pipeline
2. Concentration of the DRA solution is 1.8 (centipoise) or 0.00120968 (kg/m^3)
3. Constant diameter of the pipeline throughout the experiment (1-inch) .
4. Room temperature been applied during the experimental run.
5. Zero inclination because using horizontal flowline.

4.3 Errors

1. Random error

Random error occurs because no measurement can be made with infinite precision. Random errors will cause a series of measurements to be sometimes too large and sometimes too small. An example of random error could be when making timings with a stopwatch. Sometimes it may stop the watch too soon, sometimes too late. Either case introduces random error in the measurements. Human error happened when time is taken to determine time needed to fill in the drainage tank so that time can be stop. Reaction time between brain and hand to stop the stop watch will play an effect when it involves matter of seconds. Velocity would be affected by the error in recorded time.

2. Systematic error

Systematic errors in experimental observations usually come from the measuring instruments. They may occur because of there is something wrong with the instrument or its data handling system. It may also due to the instrument is wrongly used by the experimenter. For example during the rheology test, a viscometer might show a reading of 5centipoise (cp) to 6centipoise and it is continuously keep on changing. It might stop to 5 (cp) and this is value that taken into account. There is possibility that actual value of viscosity is 5.5 cp. This means the systematic error is 0.5 (cp) and all measurements shown by this viscometer will be a half higher than the true value. Other than that, systematic error might be found during the experimental run when reciprocal pump is started. There is water leaking coming from small hole in the reciprocal pump which means loss of pressure and this means pressure reading taken is not totally accurate. The best way to overcome these errors are by do the experiment or measurement several times and take the average value.

2. Parallax error

Parallax error or more accurately motion parallax, is the change of angular position of two observations of a single object relative to each other as seen by an observer, caused by the motion of the observer. Simply put, it is the apparent shift of an object against a fixed background that is caused by a change in the observer's position. In this project, this type of error happened when to get the reading of pressure at pressure gauge. Thus, it may give errors in drag reduction calculation. Besides that, it also occurred during DRA solution preparation which is when to measure volume of 1Litre distilled water into beaker. In order to minimize the effect of this error, the pressure reading and volume measurement were taken several times and choose it by its average reading of pressure.

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 Conclusion

This project has successfully observed Mung Beans as DRA in the water pipeline. Experiments have been carried out to examine the effectiveness of DRA in a different concentration of DRA solution. The DRA concentration of 1000 ppm was more effective than 600 ppm solutions of DRA for all conditions studied. Objectives of this project are achievable where Mung Beans are reacting towards the drag reduction and drag reduction percentage will increase with higher concentration of DRA solution. Same result and performance of Solanum Tuberosum used as DRA is also achieved. For 1000ppm of Mung Beans solutions, percentage of drag reduction reached to 17.58% while for Solanum solutions, percentage of drag reduction is much lower which is 10.91%. However, both consequences indicate that natural polymer even in a raw material could give positive result.

All in all, the objective to compare Natural Polymers with commercial DRA also achievable which clearly showed that drag reduction is higher with the commercial DRA. This is due to commercial DRA is a refined product compared to natural polymer which is purely without any chemical addition. Natural polymer used in this project possibly can be improved by further refined. The objectives to get an improved flow rate and reduction in frictional pressure drop also accomplished. Higher reduction in frictional in pressure drop will affect higher water flow rate.

5.2 Recommendation

Several recommendations can be made as to how this project can be conducted more efficiently. For future continuation and expansion of this research, a lot of improvements need to be done. Especially in term of trying minimizing the errors encountered in this research project and try to reduce the limitation face while carry out the project. Below are the recommendations for future reference:

1. Replaces Galvanized iron pipeline to be transparent pipeline. It can give clear view to the observer how DRA react towards the reduction.
2. Discover new kind of natural polymer other that Mung Beans as the DRA And fully follow the selection criteria such as the gel strength, viscosity and shear factor.
3. Use different size of pipeline and see the difference. Drag reduction may varies with different size of pipeline.
4. Inclination of pipeline may be applied towards the project.
5. Use Centrifugal pump that can will solve pressure pulsation thus give more accurate result.
6. Utilize more accurate injector mechanism to inject DRA right to the core of pipe such as nozzle with check valve rather than using a tee-section as injector mechanism.
7. Apply extra difference in concentration and see the difference in drag reduction percentage.

All of these recommendations can improve result of experiment by minimizing the errors occurred. Moreover, by applying this recommendation it can provide more accurate and precise data.

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CHAPTER 7 : APPENDICES

Experiment datasheet result

BASE CASE					
DRA Conc. (ppm)	Time (s)	P1 (psi)	P2 (psi)	∆P	%DR
**	13.2	22.5	6	16.5	**

Base case run without injection of DRA.

DRA Conc. (ppm)	Time (s)	P1 (psi)	P2 (psi)	∆P	%DR (without DRA-with DRA)/without DRA
600	13	22	6.5	15.5	6.06
700	12.6	21.5	6.7	14.8	10.30
800	12.2	22	7.4	14.6	11.52
900	11.8	22	8	14	15.15
1000	11.5	21.5	7.9	13.6	17.58

Result of experiment with the injection of Mung Beans solution into the pipeline.

PIPE	
Length (m)	12.25
Pipe D (m)	0.0254
Volume Pipe (m^3)	0.006207
Area Pipe (m^2)	0.000507
Constant	1000000

Pipeline details

COMMERCIAL DRA					
DRA Conc. (ppm)	**Time (s)**	**P1 (psi)**	**P2 (psi)**	**∆P**	**%DR**
600	10.5	22.5	10	12.5	24.24
1000	10.2	22.5	12.5	10	39.39

Result of experiment with the injection of Commercial DRA into the pipeline.

HIGH RPM														
DRA Vol. (g)	Water Vol. (ml)	DRA Conc. (ppm)	μ (cp)	μ (kg/m³)	ρ (kg/m³)	t	Q (m³/s)	V (m/s)	N_{RE}	P (1)	P (2)	ΔP	%DR	E_{DRA}
0.6	1000	600	1.8	0.00120968	998.95	13	0.00277	5.4651	114632.4	22	6.5	15.5	6.06	1.01
0.7	1000	700	1.8	0.00120968	998.95	12.6	0.00286	5.6386	118271.6	21.5	6.7	14.8	10.30	1.47
0.8	1000	800	1.8	0.00120968	999.95	12.2	0.00295	5.8235	122271.6	22	7.4	14.6	11.52	1.44
0.9	1000	900	1.8	0.00120968	999.95	11.8	0.00305	6.0209	126416.4	22	8	14	15.15	1.68
1.0	1000	1000	1.8	0.00120968	999.95	11.5	0.00313	6.1780	129714.2	21.5	7.9	13.6	17.58	1.76

Spreadsheet result

Sample calculation :

Take data from concentration of DRA 600 ppm :

- <u>Drag reduction</u>

$$Drag\ reduction\ (\%) = \frac{\Delta P\ (without\ DRA) - \Delta P\ (with\ DRA)}{\Delta P\ (without\ DRA)} * 100\%$$

% DR = [(16.5 – 15.5) / 16.5]* 100%

= 6.06%

- Concentration of DRA

$$Volume\ of\ DRA\ (g) = \frac{Concentration\ of\ DRA * Volume\ distilled\ water\ (L)}{1 * x10^6}$$

Concentration of DRA = (0.6 * 1x10^6) / (1000)

= 600ppm

- Water flow rate

$$FlowRate, Q = \frac{Volume, V}{Time, t}$$

Flow rate = 0.036 / 13

= 0.00277 m3/s

- Efficiency of DRA

$$E_{DRA} = \frac{\%Drag\ Reduction}{C_{DRA}}$$

Efficiency of DRA = 6.06% / 600ppm

= 0.01

- <u>Reynolds number</u>

$$Re = \frac{\rho v D}{\mu}$$

Re = (998.95 * 5.4651 * 0.0254) / 0.00120968

= 114631.79