USING SODIUM STEARATE AS DRAG REDUCING AGENT IN PIPELINES

By

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Dissertation submitted in partial fulfillment of

the Requirements for the

Bachelor of Engineering (Hons)

(Petroleum Engineering)

SEPTEMBER 2011

Universiti Teknologi Petronas

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Petroleum Engineering Programme

Universiti Teknologi PETRONAS

In partial fulfillment of the requirement for the

BACHELOR OF ENGINEERING (Hons)

(PETROLEUM ENGINEERING)

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TRONOH, PERAK

SEPTEMBER 2011

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.

AHMAD HAFIZI BIN AHMAD ZAINI

ABSTRACT

This research study aims to prove the effectiveness of using Sodium Stearate as Drag Reducing Agent in pipelines. Whilst it is more common to see in Oil and Gas industry to utilize polymer as Drag Reducing Agent, surfactants also show a promising future as Drag Reducing Agent nowadays. When it comes to pipeline, drag had caused severe to production capacity of a line. Drag had caused power pumping loses; decreasing in production capacity and indirectly may caused erosion corrosion to take place. The industries are desperate to find Drag Reducing Agents and still searching for the cheapest yet most effective alternative Drag Reducing Agent. With that in mind, this Final Year Project will be focused more on how the surfactant generally, and specifically Sodium Stearate act as Drag Reducing Agent in pipeline. An experiment setup will be fabricate and conduct to determine the effect of Sodium Stearate use as Drag Reducing Agent in oil pipeline. Unfortunately, due to several circumstances and limitation, the original plan which is to run the experiment using crude oil can not been conducted. Instead of using crude oil, water is been used to replace it. An open loop system are fabricated where water in the storage tank will be pump throughout 4 meter long of testing section of 1 inch diameter Galvanize Iron steel pipeline. An injection mechanism is created to inject the Drag Reducing Agent solutions at the starting point of 4 meter testing section. A total of 7 different concentration of Drag Reducing Agent had been prepared. At the end of testing section, pressure gauge is been placed to monitor the pressure drop and hence examine the percentage drag reduction for each concentration been test. Result from experiment shown that Sodium Stearate prove to have great effect when act as Drag Reducing Agent significantly by recorded highest percentage drag reduction of 33.33% at concentration of 800ppm for low RPM of pump. Therefore, it is concluded that Sodium Stearate, which is surfactant has show the ability to act as Drag Reducing Agent effectively in water-pipeline experiment. Impact of this study can be analysis and to make early hypothesis if the fluid inside pipeline is change from water to crude oil.

ACKNOLEDGEMENT

This Final Year Project involves many parties in order for the student to complete it successfully. First of all, highest appreciation to Mrs. Mazuin Jasamai, whom act as my Final Year Project supervisor for the entire lesson learnt in assisting me, tireless and continuous support given to me to complete this research project.

Next I would like to convey my highest gratitude to 'Drag Reducing Agent' group under Mrs. Mazuin Jasamai, which are Mr. Awang and Ms. Fadilah, for working together with me and keep helping each other in order to complete this research project successfully.

Next a token of appreciation also goes to the lab technologist of Block 15, Mr. Shahrul and Mr. Reduan from Petroleum Engineering Department for the support and kindness in assisting me conducting an experiment in the lab.

Last but not least, I would like to thank Universiti Teknologi Petronas, UTP for providing this lifetime opportunity by providing me the facilities, laboratories and assistant in all aspect. I hope this experience and knowledge I gained while completing my Final Year Project will be a valuable steeping stone in my future career development.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INRODUCTION

1.1 Background of Study

Based on International Energy Agency report (IEA,2008) for oil market report, in the last quarter of the 20^{th} century worlds show that worldwide demand for crude oil had a very stable yearly growth rate averaging 1%. According to IEA, current world oil supply is around 89 million barrels per day. Nevertheless, a lot of serious studies done by IEA forecast that demand for oil alone could rise over 100 million barrels per day within next two decades. In fact, oil still predicted to remain the dominant source of energy for the next half century [1].

Thus the operator company will desperately increase their production capacity in their pipeline to cater the need of crude oil demand from time to time. But unfortunately, overtime will corrode no matter how well it's been taken care of such as injection of corrosion inhibitor, cathodic protection, regular pigging and many more. Corrosion will reduce the wall thickness; hence can reduce the Maximum Allowable Operating Pressure (MAOP) if the corrosion that occurred exceeds the corrosion allowance predicted. If the pipelines continue to operate at high pressure in order to maintain their production capacity target, with the wall thickness had reduced due to corrosion, this will risk pipelines to rupture. Generally, this left a company with several choices as follow: [2]

1. Renew the line: (Capital Expenditure ;CAPEX = very costly)
2. Reduce your pressure and hence flow (Deferment = very costly)
3. Inject Drag Reducer (enables equal flows at lower pressures = low cost)

If the MAOP has been reduced to maintain integrity of one system, the amount of oil can pump through that line must reduce. This can cause deferment in the worst case. However by injecting Drag Reducing Agent (DRA), the same quantity of oil can be pumped even at much lower MAOP. The drag of the pipeline is reduced and thus the pressure drop between the two ends f the node is reduced.

This shows that for a small amount of Operating Expenditure; OPEX each year and careful monitoring of the line, the complete line renewal can be postponed, and the massive Capital Expenditure; CAPEX can be postponed by perhaps several years. It's beneficial to postpone pipeline replacement for as long as possible to enables a company to take new developments into account [2].

Thus, DRA can be seen to be use for in general:

1. To increase the flow of oil through an unchanged MAOP
2. To maintain a flow rate through a line where MAOP has been reduced due to corrosion

DRA are commonly be divided in three main groups; polymers, fibers, and surfactants. Polymer and fiber act as DRA by orient themselves in the main direction of the flow, limiting turbulence eddies appearance which results in drag reduction while surfactants can reduce the surface tension of a liquid [1].

Although, it's more commonly practices to use DRA by polymers, DRA by surfactants also show a promising future. High molecular weight polymers are by far the most efficient drag reducer, but their susceptibility to shear degradation, limit their use. Surfactants show less drag reducing capabilities than polymer, but their advantage is that drag reduction at fluid velocities over the "critical shear stress", shear stress at which surfactant's micelles disappears, is less affected than in the presence of polymers. Indeed, surfactants have the ability to restructure its rod-like microstructure and re-assume its own drag reducing capability when the shear stress in the flow decreases to a certain level [1].

1.2 Problem Statement

1.2.1 Problem identification

Often or not, expectancy of maximum production capacity of pipelines is never the same with the earlier prediction at design stage. The main reason for the declining of production capacity of pipelines over time is mainly because of corrosion. Corrosion is the biggest threat for pipelines all over the world. Corrosion will decrease the wall thickness in pipelines. This will create two major concerns which are rupture and roughness inside pipelines.

Rupture will occur when the wall thickness of pipelines decrease and pressure apply in it is too great for it to operate. So in order to prevent from fracture, maximum allowable operating pressure (MAOP) need to be reduced, hence decrease the production capacity in oil pipeline.

Next, roughness inside pipelines will create or contribute more to occurrence of turbulence eddies. This will increase the friction in the pipelines. When fluid is transported by pipelines, the force that must be overcome to drive the fluid through the pipeline is defined as the force of drag, or simply drag. This drag is the result of stresses at the wall due to fluid shearing and causing a drop in fluid pressure. Due to this pressure drop, the fluid must be transported with sufficient pressure to achieve the desired throughput

When higher flow rate are needed, fluid deformation is higher and shear stresses increase, so more pressure must be applied to maintain the flow at the same average velocity. However, specification of pipeline design may limit the amount of pressure that can be employed or rise substantially the investment cost. The problem associated with pressure drop is more acute such as when oil is transported over long distances [1].

Next, either crude oil or refinery product is transported in pipelines in turbulent mode where Reynolds number higher than 2100. This will lead to huge pumping power losses along the pipelines [3].

1.2.2 Significant of the project

By referring to the problem identification, through this project, we can look into more detail the effect of Sodium Stearate to be use as DRA in pipeline. Nowadays, the industries need a variety of DRA that can be use in the field, but as stated above, polymer have better records than the other type of DRA. Thus, this experiment will explore and examine the effectiveness of surfactants if it is been use as DRA in pipeline. As a conclusion, two objectives are being set for this project.

1.3 Objective

To study effect of Sodium Stearate use as DRA in pipelines

- After decided to use Sodium Stearate as DRA in pipelines, the next step is to prove it that Sodium Stearate can act as DRA and study the effect of Sodium Stearate in pipelines.

1.4 Scope of study

The scope of study is mainly focusing on the effects of Sodium Stearate use as DRA in pipeline. Through this project, the effect of Sodium Stearate as DRA will be observe more thoroughly especially on the effect to the flow velocity in pipeline and reducing of turbulence created by observing the pressure drop along the pipe.

This project will be divided into two stages; the first stage will involves on researching and study thoroughly about DRA and surfactants. Then with the help and assist from supervisor, the most suitable surfactant will be choose to be use as DRA in this project.

The second stage will focus on experimental work in the lab, where using a custom-built apparatus and an experiment will be conducted so the effect of Sodium Stearate as DRA will be monitor closely. Result collected from experiments will be analyzed and discussed.

1.5 The relevancy of the project

Drag Reducing Agent is becoming more and more vital to the Oil and Gas industry. As it is too costly to replace the whole pipelines in order to cater the demand from the consumer, they prefer to spend a small amount of operational expenditure by injecting DRA into pipelines and maximize the production capacity. DRAs can also decrease the cost of pumping fluids, the cost of equipment used to pump fluids, and provide for the use of a smaller pipe diameter for a given flow capacity [4].

By carry out this project, the effectiveness of surfactant use as DRA can be study closely and see the usefulness of it in the industry. The effect of such additives has been widely studied in macro scale in the past years [5]. Consequently, the DRA will reduce the cost for a company to produce a maximum production capacity with the same diameter of pipelines.

1.6 Feasibility of the project

This project will need an experiment carry out in order to complete it. The entire objective set out for this research project within the time given. Starting from objective on determine type of surfactant need to be used in the project, and later on moving into the next phase of objective which is proving Sodium Stearate can act as Drag Reducing Agent in pipeline. The key success of feasibility of the project is to follow closely the Gant chart and Key milestones that been decided early.

CHAPTER 2

THEORY AND LITERATURE REVIEW

2.1 Drag

In fluid dynamics, drag sometimes called air resistance or fluid resistance refers to forces that oppose the relative motion of an object through a fluid.

Drag forces act in a direction opposite to the oncoming flow velocity. Unlike other resistive forces such as dry friction, which is nearly independent of velocity, drag forces depend on velocity [8].

In this study, force of drag or simply drag is defined by the force that must be overcome to drive the fluid through the pipeline. This drag is the result of stresses at the wall due to fluid shearing and causing a drop in fluid pressure.

2.2 Drag Reducing Agent

From history, it stated that DRA were discovered by accident by Toms in 1947. Even at that time, it is well-known that water-coal and water-pulp slurries could produce lower friction factors than those of water alone; Tom's publication was the first to discuss DRA in otherwise Newtonian solution. He discovered DRA can give effect by decrease in pressure gradient, until minimum pressure gradient was reached. The first use of DRA's in oil fields was to reduce pressure loss while pumping fluid downhole into fracture tight formations [7].

A Drag Reducing Agent, also called a flow improver or friction reducer [4], usually is a long chain polymer chemical that is used in crude oil, refined products or non-potable water pipelines. It is injected in small amounts (parts per million) and is used to reduce the frictional pressure drop along the pipeline's length.

The oil and gas producing industries have traditionally used DRA to help lower pressure gradients for the transport of single-phase liquids over long distances [7].

Drag Reducing Agent can be divided into three main groups:

1. Surfactants
2. Polymer
3. Fibers

The role of these additives is to suppress the growth of turbulent eddies by the absorption of the energy released by the breakdown of lamellar layers, which result in higher flow rate at constant pumping pressure.

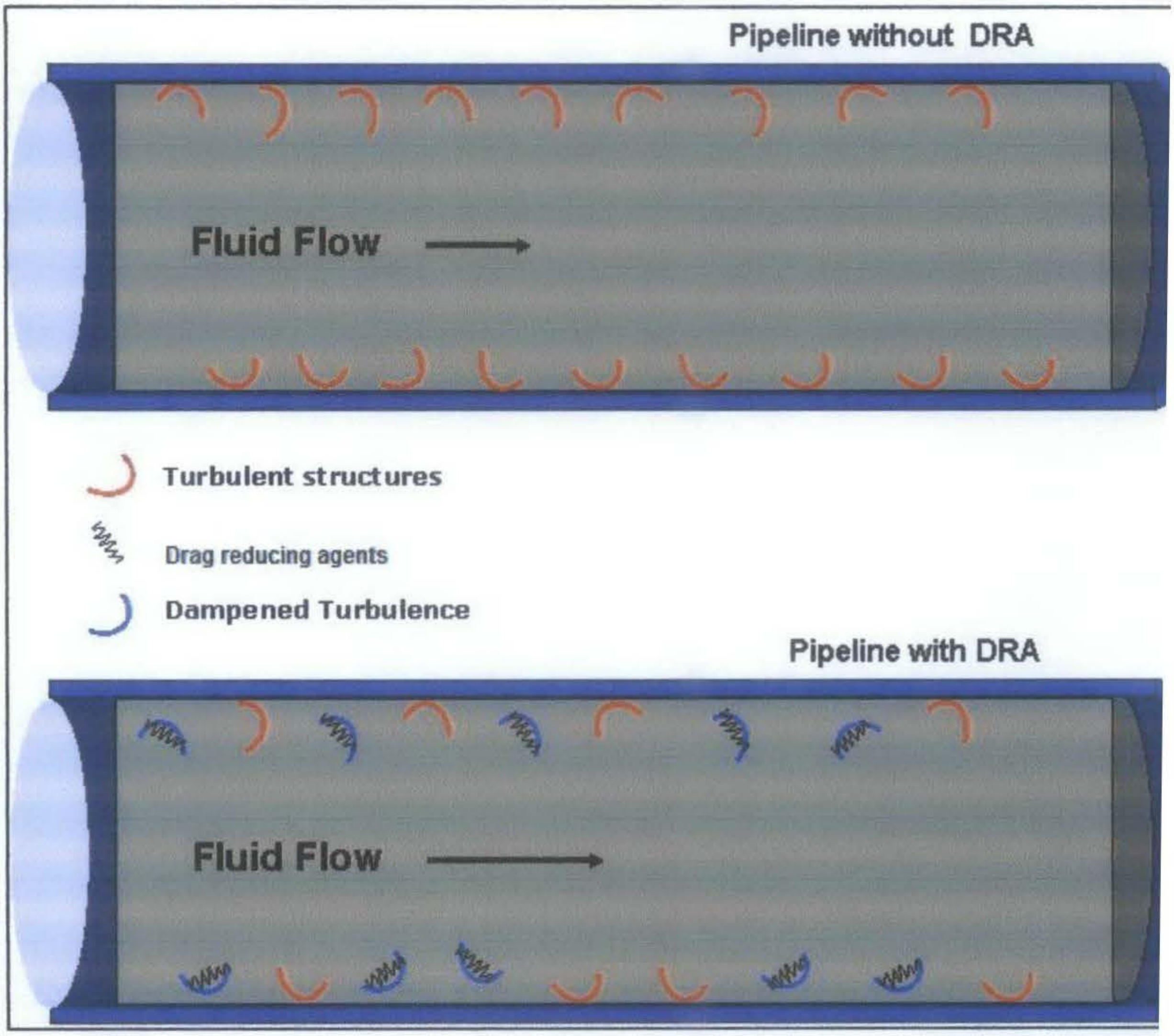

Figure 1: Illustration of the mechanism of Drag Reducing Agent [10].

The effectiveness of DRA always depends on several factors such as fluid viscosity, pipe diameter, and flow velocity which indicate a dependence on the Reynolds Number. Often or not drag reduction is usually only effective in turbulent flow and improves with decreasing viscosity and pipe diameter, or with increasing Reynolds Number. Also the effectiveness of DRA depends on oil structure. A DRA may produce a desirable effect with certain oil, and may not as effective as expect with similar oil [7].

In conclusion, Robert M.Vancko Jr. (1997) in his thesis about the effect of DRA in pressure drop said that the precise mechanism of how the DRA works is not well established. In general there are two theories, which are [7]:

1. DRA act by directly reducing turbulence
2. DRA act by absorbing and returning stream energy which otherwise would have been used to create turbulent cross flows.

Cheolho. K et.al in the paper 'The Effect of Drag Reducing Agents On Corrosion In Multiphase Flow', summarized all previous finding about Drag Reducing Agent such as Virk and Baher (1970) have shown that DRA only act effectively to reduce pressure drop only in turbulent flow, but not in laminar, Lester (1985) had stated that DRA degrade by shear when centrifugal pump are used, David and Darby (1983) point out that DRA degrade by age, losing effectiveness after a few days, and shear [13].

2.3 Surfactant

Surfactant is compounds that lower the surface tension of a liquid, the interfacial tension between two liquids, or that between a liquid and a solid. Surfactants may act as detergents, wetting, emulsifiers, foaming agents, and dispersants.

The term surfactant is a blend of surface active agent. Surfactants are usually organic compounds that are amphiphilic, meaning they contain both groups present in the molecule, one being hydrophobic in nature (their tails) and hydrophilic groups in nature. (their heads). Hydrophilic means water-liking and hydrophobic means water-hating/oil-liking [6]. Therefore, a surfactant molecule contains both a water insoluble (and oil soluble component) and a water soluble component.

Surfactant molecules will migrate to the water surface, where the insoluble hydrophobic group may extend out of the bulk water phase, either into the air or, if water is mixed with oil, into the oil phase, while the water soluble head group remains in the water phase. This alignment and aggregation of surfactant molecules at the surface acts to alter the surface properties of water at the water/air or water/oil interface [9].

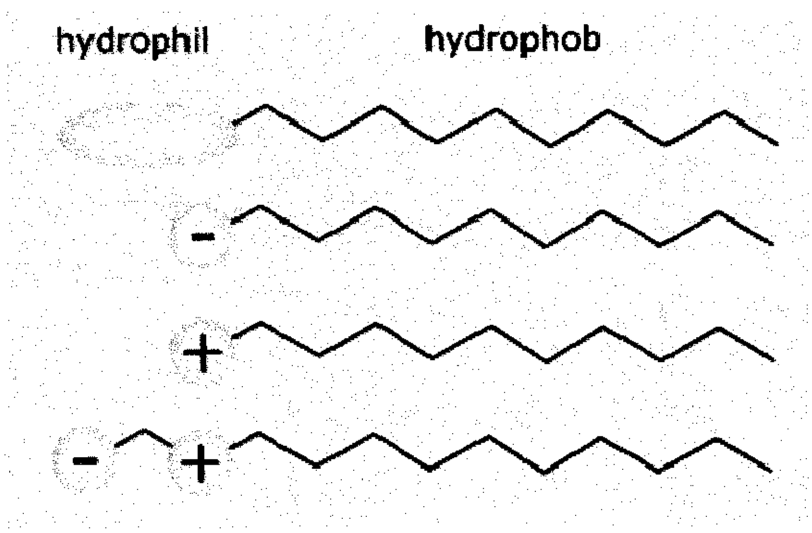

Figure 2: Surfactant classification according to the composition of their head: nonionic, anionic, cationic, amphoteric [9].

2.4 Sodium Stearate

Sodium Stearate (SS) $C_{18}H_{35}NaO_2$ is white crystalline anionic surfactant with a molecular weight of 306.46 g/gmol and active substance of 87%. The synonyms of Sodium Stearate are Octadecanoic acid sodium salt or Stearic acid sodium salt [12]. Sodium Stearate also is an anionic surfactant since it has a negative charge head group.

SS can be found in most animal and vegetable oils and fats. It is used to lubricating mixtures, waters proofing materials and soap manufacturing. SS can be made by reacting glyceryl stearate with water to from stearic acid. Then stearic acid reacts with coastic soda to form Sodium Stearate [3]. In this project, it is 96% mixture of stearic acid and Palmitic Fatty Chain.

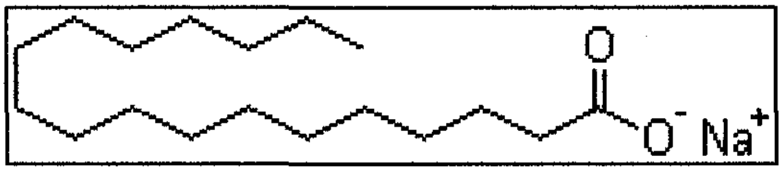

Figure 3: Molecular structure of Sodium Stearate [11].

Below are some other properties of Sodium Stearate [12]:

2.4.1 Physical and Chemical Properties

- **Physical State:** Solid
- **Appearance:** white
- **Odor:** fatty-tallow odor
- **pH:** Not available.
- **Solubility:** soluble in cold and hot water
- **Type of charge**: Anionic.

2.4.2 Stability and Reactivity

- **Chemical Stability:** Stable under normal temperatures and pressures.
- **Conditions to Avoid:** Incompatible materials, light, dust generation
- **Incompatibilities with Other Materials:** Oxidizing agents.
- **Hazardous Decomposition Products:** Carbon monoxide, irritating and toxic fumes and gases, carbon dioxide.
- **Hazardous Polymerization:** Will not occur.

2.5 Theory Calculation

The effectiveness of DRA in oil pipelines will be indicating by the pressure drop observed from the pressure gauge. Drag reduction can be defined as follows:

$$\%\, Drag\ Reduction = \frac{\Delta P_{without\ DRA} - \Delta P_{with\ DRA}}{\Delta P_{without\ DRA}}$$

We can define an efficiency factor for the DRA as follows:

$$E_{DRA} = \frac{\%\, Drag\ reduction}{C_{DRA}}$$

Where: E_{DRA} = Efficiency factor

C_{DRA} = DRA concentration

The DRA concentration is calculated on a total liquid volume basis as follows:

$$V_{DRA} = \frac{C_{DRA} * V_{total}}{1x10^6}$$

Where: V_{DRA} = Volume of DRA to be added

V_{Total} = Total liquid volume of the system

C_{DRA} = Desired DRA concentration (ppm)

For the Reynolds Number, it's defined as follows:

$$Re = \frac{\rho * V * D}{\mu}$$

Where V = average velocity of liquid

ρ = density

D = diameter of pipe

μ = Viscosity

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

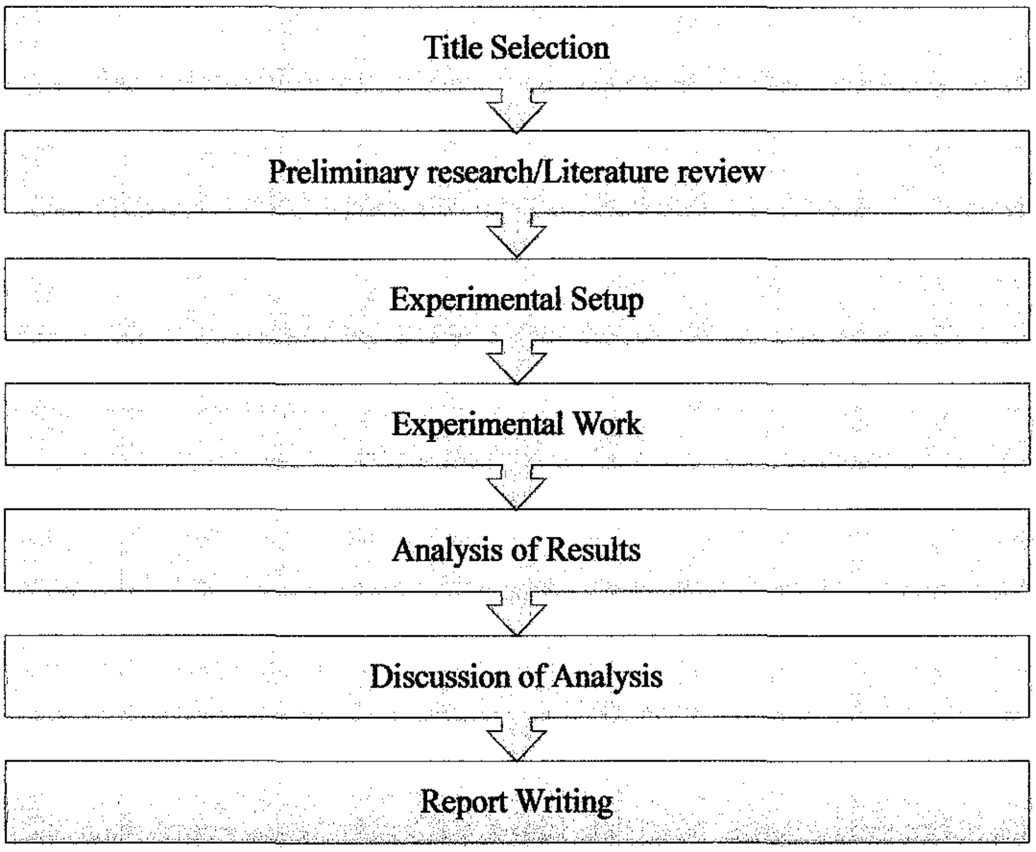

Figure 4: Flow chart of the research methodology

3.1.1 Title Selection

There is needed to be rational and real when it comes to choose the title. Especially when it need to compromise with all the limitation found. The final title that had been chosen is 'Using Sodium Stearate as Drag Reducing Agent in Pipelines'.

3.1.2 Preliminary research/Literature review

Before proceed with the project, there is a need to cover all the basic understanding about surfactant, DRA, pipeline and others related to the project. Knowledge can be extracted from technical paper, journal, and other literature review.

3.1.3 Experimental setup

The experiment will be carried out in built-up liquid circulation system with one inch galvanized iron (G.I) steel pipe.

In general view this system is consisting of two tanks, one for storage tank and another one is for draining tank. Then storage tank will be connected to reciprocal pump. Then the pump will pump the water through the pipeline, and end at drainage tank.

Next, the injection point needs to be fabricated after the reciprocal pump. This is mainly because DRA molecular structure does not generally survive the high shear forces generated by centrifugal or positive displacement pumps. Hence the DRA must be injected after pump [7]. At the end of testing section, there is pressure gauge to monitor pressure drop. Often or not, observable fact of drag reduction is related to pressure drop by reducing the turbulent flow in pipeline [14].

At first stage, the diagram decided for experimental setup is as below from respective angle:

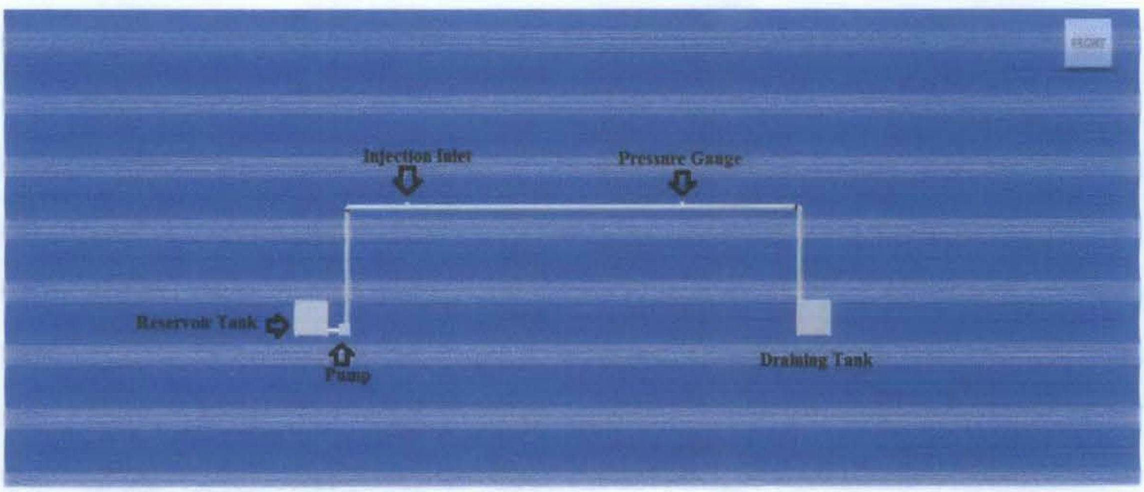

Figure 5: Pipe flow system layout from front view

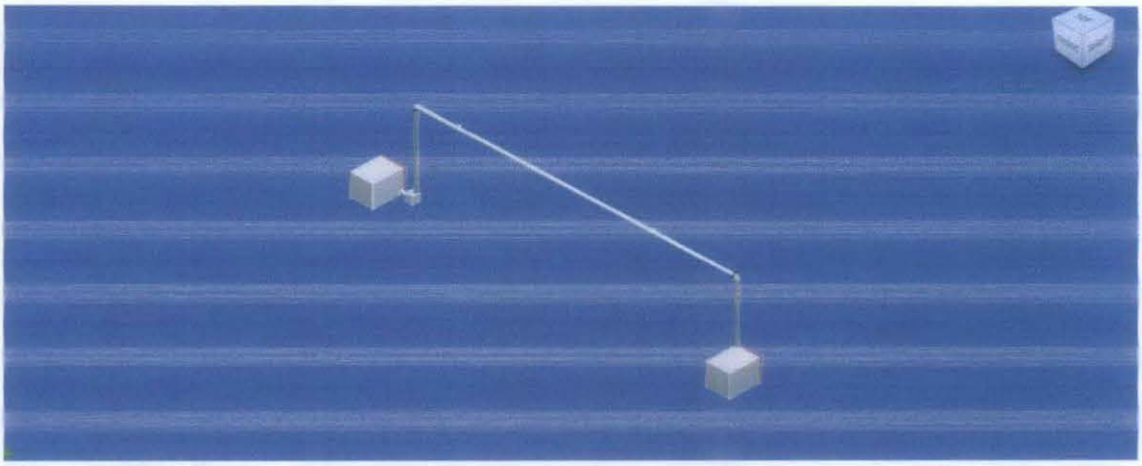

Figure 6: Pipe flow system layout from top right corner view.

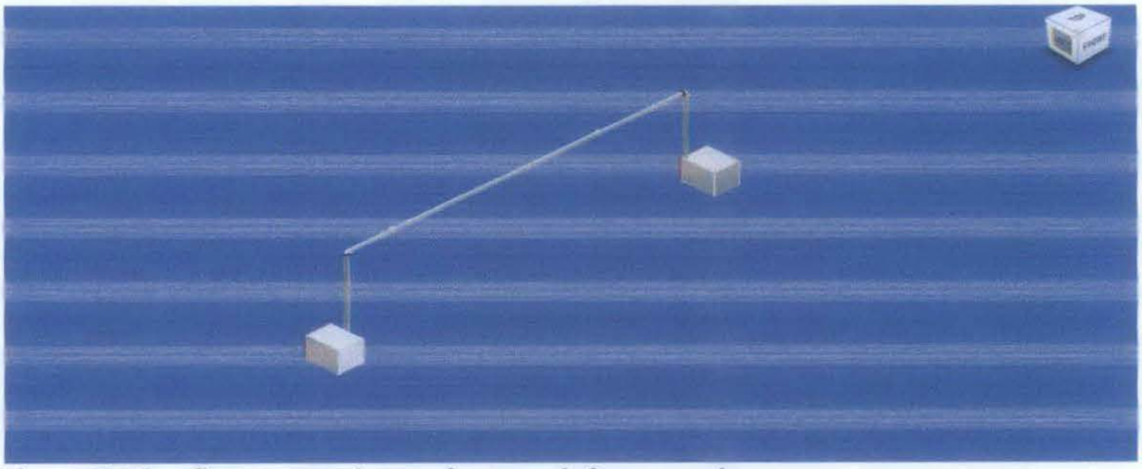

Figure 7: Pipe flow system layout from top left corner view.

For the final stage of this project which is at Final Year Project II, the layout of the setup had been changed slightly. For final design of experiment setup, it is been divided into a few major partition. Below are the partitions divided with the real image:

1. Storage tank to reciprocal pump

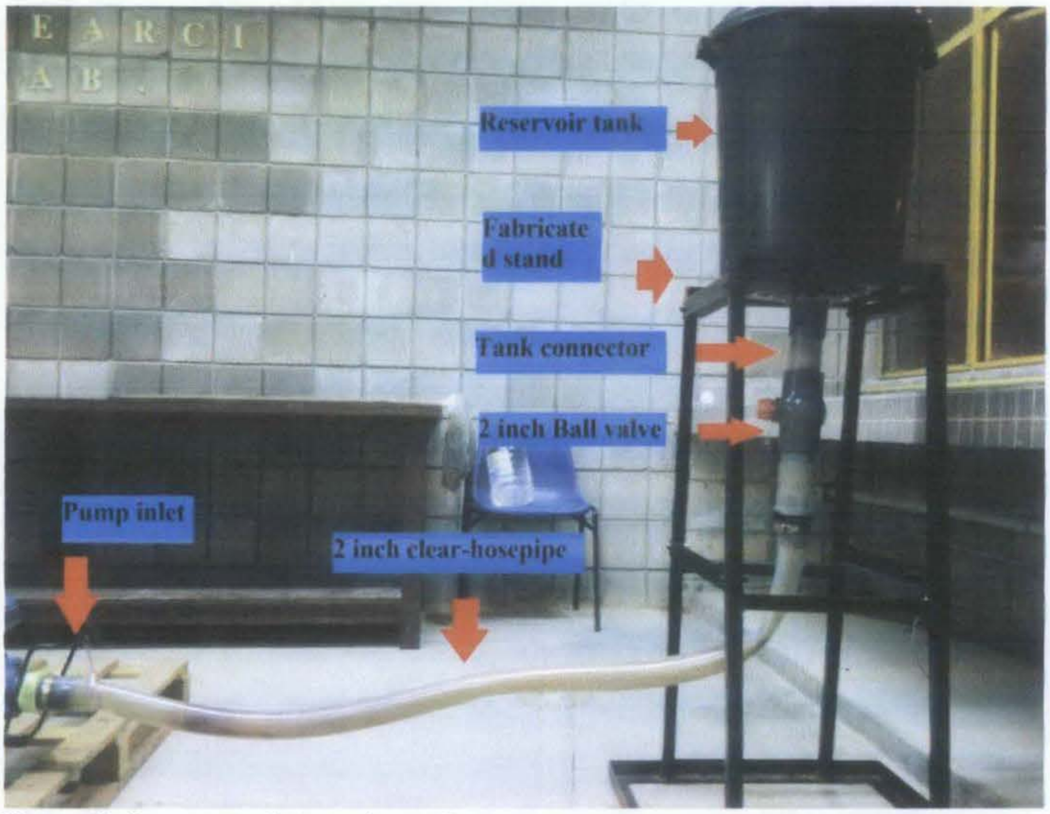

Figure 8: Storage tank to reciprocal pump

The storage tank actually fabricated and modified from pile in order to save the cost. The storage tank can hold up to 45.43 liter of water. The storage tank is positioning at a fabricated-stand with a clearance from ground approximately at 1 meter. The storage tank needs to be at higher place than the inlet point of pump so that water can flow with the mean of potential energy.

Tank connector is been use to connect between the tank and ball valve with a size of 2 inch. Then ball valve used to control the flow from a storage tank to the pump. Lastly, a 2 inch clear-hosepipe connected the ball valve to pump inlet

2. Reciprocal pump

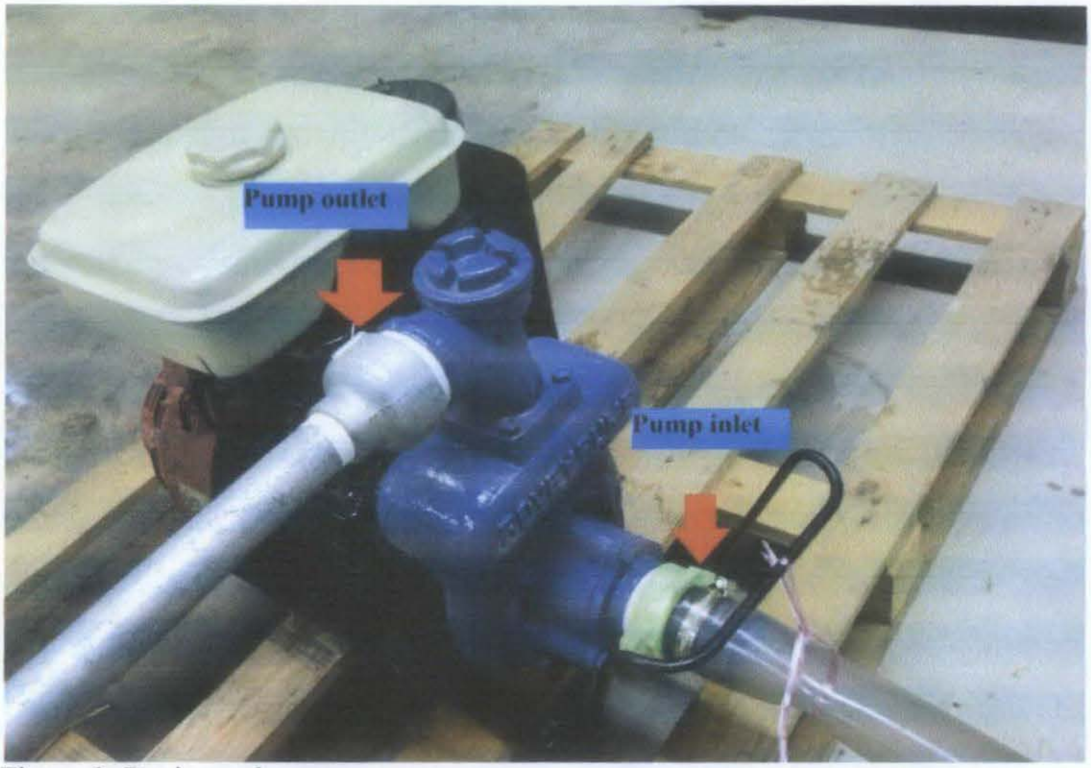

Figure 9: Reciprocal pump

Figure 10: RPM control lever

The inlet and outlet of the pump has 2 inch size of diameter of factory made. The pump also had a control-mechanism lever to adjust the revolution per minute (RPM) of the pump. Unfortunately, the lever doesn't have scale, thus the RPM only can be adjust to the highest point or to the lowest point of lever.

3. Reciprocal pump to injection section

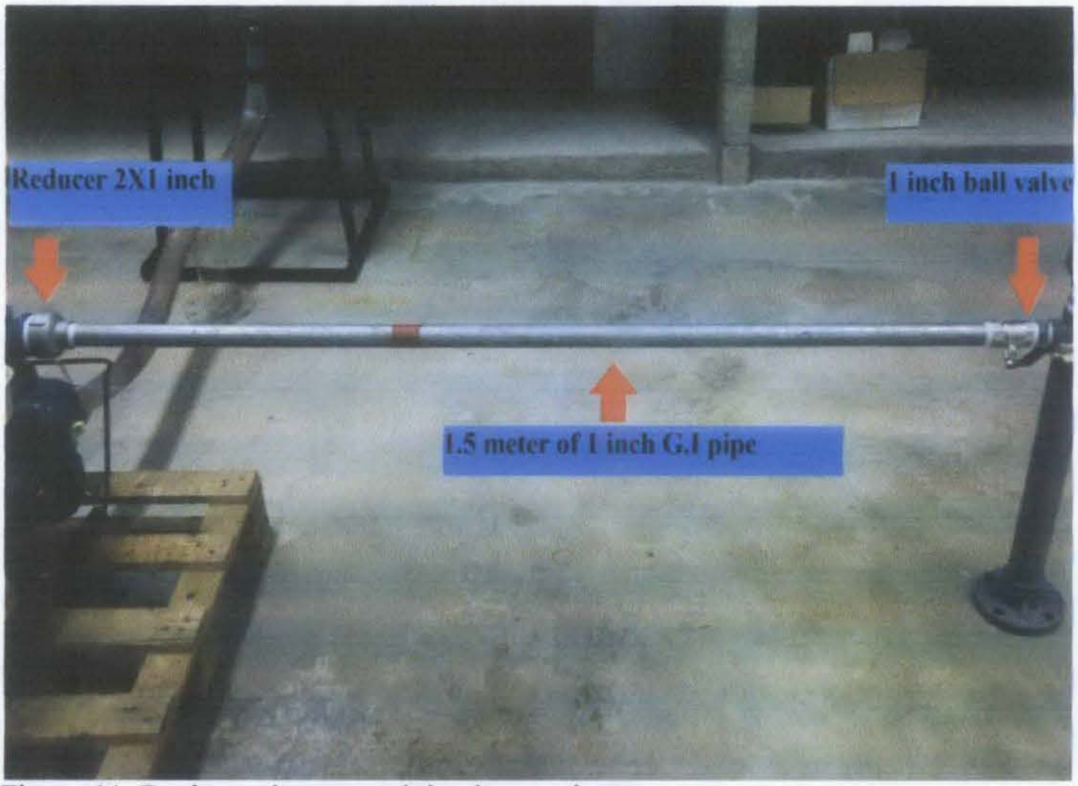

Figure 11: Reciprocal pump to injection section

Since the outlet of the pump is factory made with a 2 inch diameter, hence a reducer fitting of 2'x1' is installed to decrease the diameter from a two inch to one inch. The length of this section is determined based on the paper produced by H.A Abdul Bari et.al (2008): *"Sodium Stearate as Drag Reducing Agent in non-aqueous media"*, saying that before the mixture of fluid and DRA flow into the test section, it needs the minimum entrance length required in order to fully develop velocity profile in turbulent flow. This been calculated from the formula suggested by Desissler (1950) in that paper:

$$Le = 50(D)$$

Where D is diameter in 'cm', so

$$Le=50(2.54)$$

$$= 127cm \text{ or } 1.27meter$$

Thus, to make it easy to purchase the galvanized iron pipe, 1.5 meter is chosen instead of 1.27 meter. At the end of this 1.5 meter section of entrance, a 1 inch ball valve had been installed to manipulate the flow for DRA been drop into the pipeline.

4. Injection section

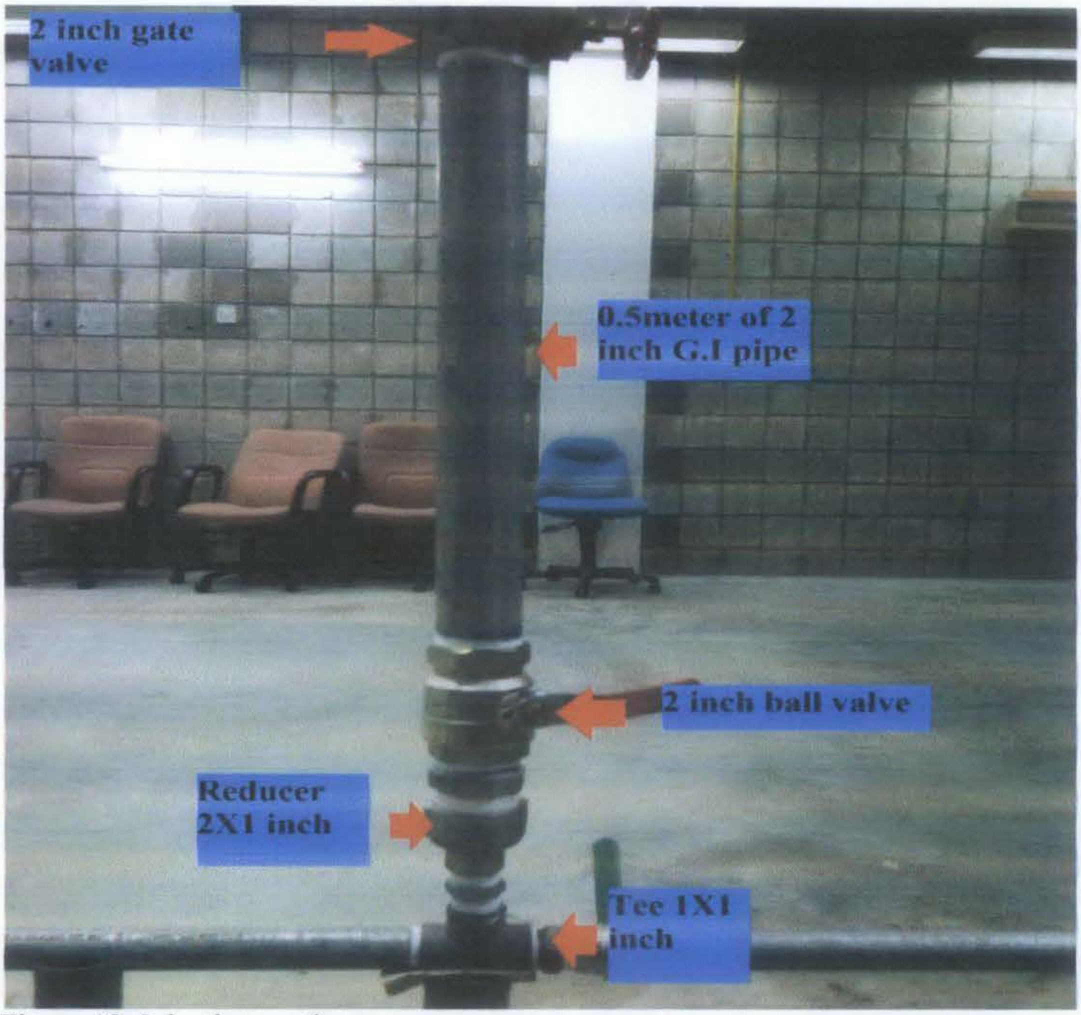

Figure 12: Injection section

The injection inlet is made by tee-fitting of a pipe. Robert M.Vancko Jr. (1997) mention that in his thesis that Lester (1985) suggests a nozzle to be use to inject DRA directly into the turbulent core of the flow [7]. But this has a main drawback which is nozzle is too costly. Hence limiting by budget resources, a Tee-fitting will be use. Robert M. Vancko Jr. (1997) also stated that the DRA molecular structure does not generally survive the high shear forces generated by centrifugal or any positive displacement pumps. As a result of that, DRA must be injected after pumping station.

Right after the 1 inch ball valve, a tee of 1'x1' inch fitting is been installed. The upper part is been chosen as 0.5 meter of 2 inch of galvanized iron pipe instead of using 1 inch because to avoid having a longer testing section going upward to hold up the DRA solution in it. As a result, a reducer of 2'x1' inch is been installed to connect the tee section with the 2 inch pipe. At the 2 inch section, there is 2 type of valve where at the top is 2 inch gate valve and at the bottom is 2 inch ball valve.

5. Testing section

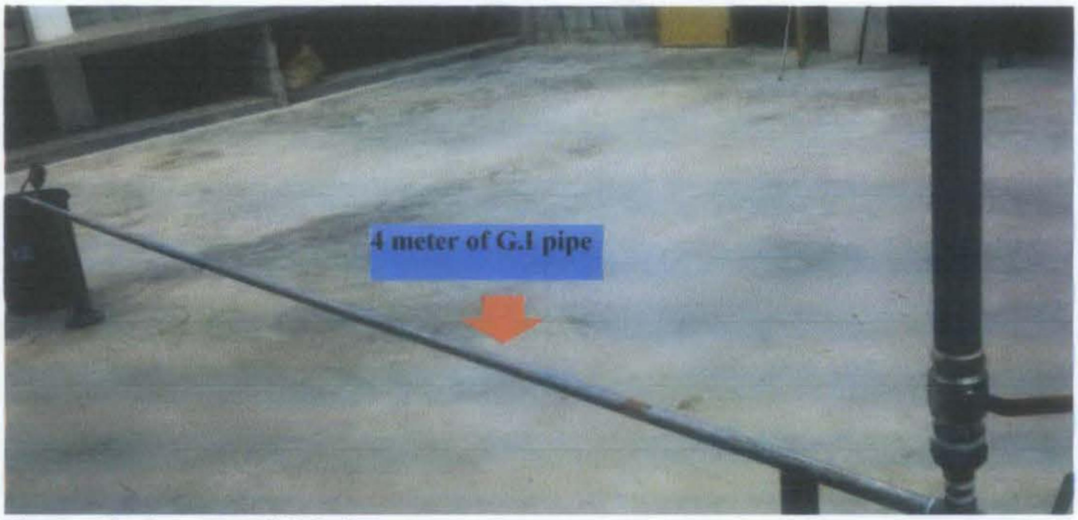

Figure 13: 4 meter of G.I pipe

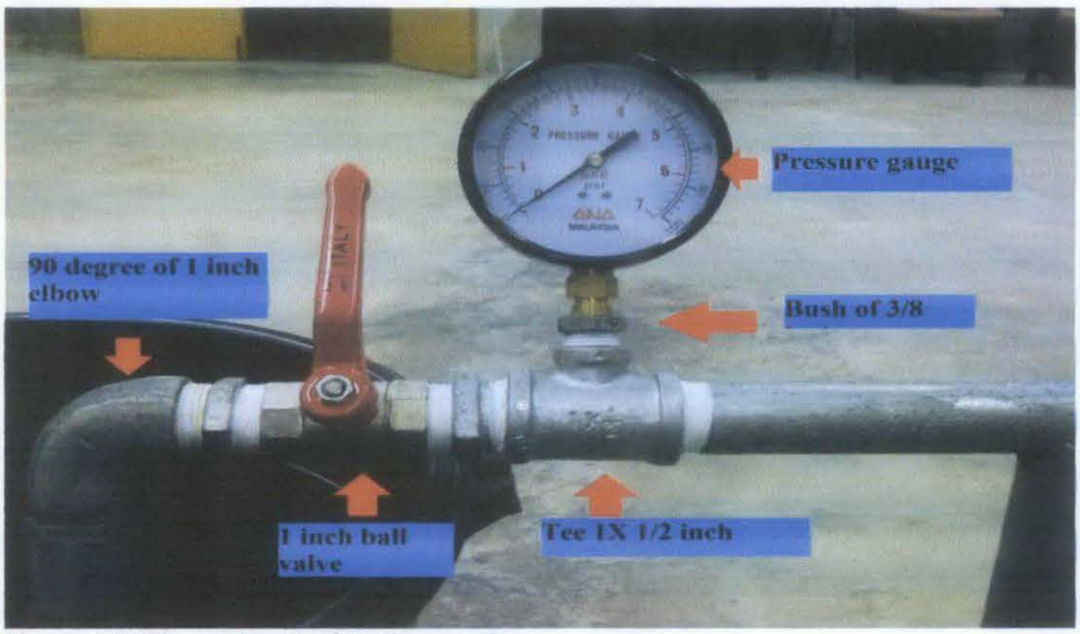

Figure 14: The end part of testing section

Testing section is consisting a 4 meter of straight pipe with at the end of it is the pressure gauge use for monitor the pressure drop. Coming right after pressure gauge is another 1 inch ball valve for safety reason in order to stop the flow at the drainage tank. Finally a 90 degree of elbow with size of 1 inch been fitted after the ball valve and facing downward to drainage tank

6. Drainage tank

Figure 15: Drainage tank

Basically drainage tank also using the same concept of storage tank. A pile been used as drainage tank ant the capacity it can hold up is up to 45.43 liter same as the storage tank.

3.1.4 Experimental work

Each set of experiment will deal with sodium stearate as DRA in water flowing in pipeline with different in additive concentration. First, there is need to set a control experiment. The control experiment should be water run into the pipeline without any DRA in it, and the pressure is recorded.

Next, the experiment will be conduct by running with several different concentration of Sodium Stearate injected into the pipeline. For each set of experiment, the pressure is recorded and the result of pressure will be compare with the control experiment to see the pressure drop. The result of the experiment should be the pressure decrease before and after addition of DRA, and be representative by percentage of drag reducing

1. Concentration preparation

Before conducting the experiment, several different concentrations are prepared in lab at Block 15. Below is the table of Concentration prepared with weight of Sodium Stearate diluted respectively.

Table 1: Concentration solutions of DRA

Concentration (ppm)	100	200	400	500	600	700	800
Weight of Sodium Stearate (gram)	0.1	0.2	0.4	0.5	0.6	0.7	0.8

Preparation of concentration had been done at laboratory using a magnetic stirrer. Since none of the technical paper in the references, and any info searched had stated for how long it need to be stir for the Sodium Stearate to dilute completely, it is assume that the solution already well-mix using eye-judgment only. Below is the picture of magnetic stirrer.

Figure 16: Magnetic Stirrer.

2. Conducting the experiment

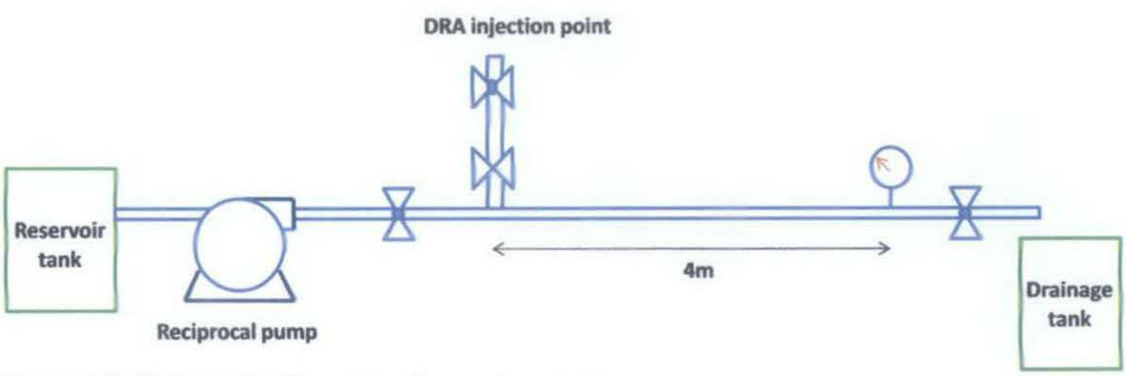

Figure 17: Schematic diagram of experiment setup

Experimental procedure:

1. Before the pump starts, valve 1 and valve 4 are need to be opened while valve 2 and valve 3 are closed.
2. The operation begins when the pump is started. The solution will be delivered through the testing section. Pressure reading is taken to this flow rate.
3. Then, valve 1 and valve 4 are closed. The pump will be turned off.

4. Valve 3 is opened to add the DRAs solution into the flowing fluid inside the pipe. The volume added is 500ml.
5. Then, valve 2 will be opened while valve 3 is closed to let the DRAs solution mix with the flowing fluid.
6. The pump is started again.
7. Valve 1 and valve 4 will be opened slowly to flow the fluid mixed with the DRAs solution.
8. Pressure drop readings are taken and compared with the readings for pure water without DRAs.
9. At the tank, there already scale to measure fluid filled in it. Time were taken to determine the flow rate.
10. This procedure is repeated for each DRAs concentration to test its effect on the drag reduction operation.
11. The pump is turned off after getting the pressure drop readings. All data are tabulated and plotted on the graph.

3. Density and Viscosity reading

All the samples need to be taken to the lab to determine the density and viscosity of each run of experiment. It is vital in order to find out Reynolds Number. Digital density meter and Viscometer are used. Below are the picture of Digital density meter and Viscometer.

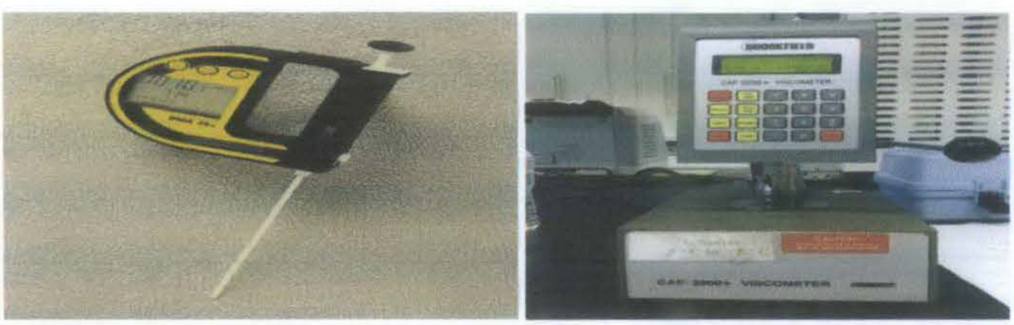

Figure 18: Digital density meter and Viscometer

3.1.5 Analysis of result

From this experiment, the results that will get are in term of pressure reading from pressure gauge and flow rate. From this data, it need to be analyzed and extract to determine the effect of Sodium Stearate. Using the formula list down at the theory calculation section, the effectiveness of one's DRA can be conclude.

3.2 Gant Chart

Table 2: Gant Chart

Activity	FYP1				FYP2			
	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG
Early stage documentation		■						
Research literature review related to DRA and surfactant		■	■					
Studies on related theories to apply			■	■				
Prepare the experiment					■	■		
Conduct the experiment						■		
Analysis of result						■	■	
End stage documentation								■

4. 3 Key Milestones

Table 3: Key milestone

Key Milestones	FYP1				FYP2			
	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUG
FYP 1 completion				■				
Experiment completion						■	■	
Analysis of result							■	■
Project Dissertation						■	■	■

3.4 Tools, Equipments and materials

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

1. Total of 5.5 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. One pressure gauge with scale 0-100 psi and thread of 3/8 inch
14. 1 kg of Sodium Stearate with MW= 306.46

CHAPTER 4

RESULT AND DISCUSSION

4.1 Variables

In any research, the entire variables need to be identified first before starting with the experiment. The variables are listed as follow:

1. Manipulated variable

It is basically what is changed during the experiment intentionally. In this case, the manipulated variable is concentration and RPM of centrifugal pump.

2. Responding variable

It is outcome result of one experiment. In this project, responding variable is reading of pressure and flow rate.

3. Constant variable

It is things or factors that need to keep the same for the entire experiment process so that it will not affect the result. In this experiment, there are many example of constant variable such as temperature of the room, density of water, and volume of DRA injected into pipe.

4.2 Assumptions

In this research, there are few assumptions that had been made in order to get a good and accurate result. These assumptions are made simply because of several limitations or errors that occurred when conducting this research project.

1. Turbulent current profile is fully developed.

Since no acrylic pipe are used in the experimental setup to determine the current profile in pipe, for the first section, at 1.5meter long of pipe, it is assumed that turbulent profile is developed and created inside it. The same thing also happened after the injection point.

2. All DRAs' solutions are injected right into the pipe.

Since the injection mechanism is not good enough especially when just using Tee-section as the mechanism for it, it is assumed that all DRAs' solutions are flow downward right into the pipeline.

3. DRAs' substances are 100% dissolve in distilled water.

As mention earlier, it is assume that in the process of making DRAs' solutions, it is assume that all DRA substance dissolve completely and well mix in distilled water when stir it using magnetic stirrer. This assumption is made due to lack of literature review and information on how long it takes for Sodim Stearate to dissolve completely in distilled water.

4. DRAs' solutions are totally well mix with fluid inside pipeline.

Again, without the aid of acrylic pipe, it's hard to determine whether DRAs' solutions are mix well enough with fluid inside pipeline. So it's best to assume that DRAs' solutions do totally well mix and with that, all of DRAs' substance react as it should be together with fluid inside pipeline.

4.3 Graphs and Discussions

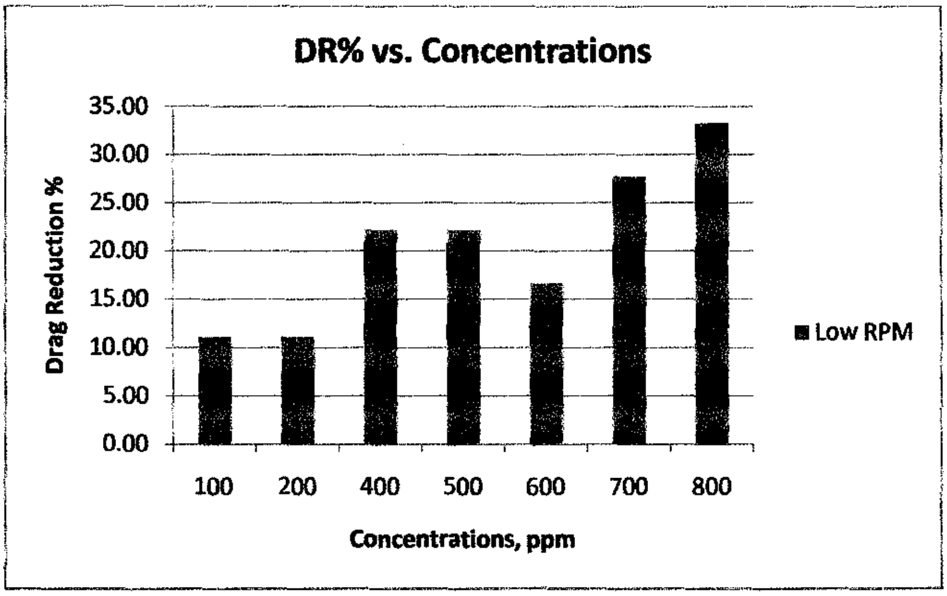

Figure 19: Drag Reduction % vs. Concentrations for Low RPM

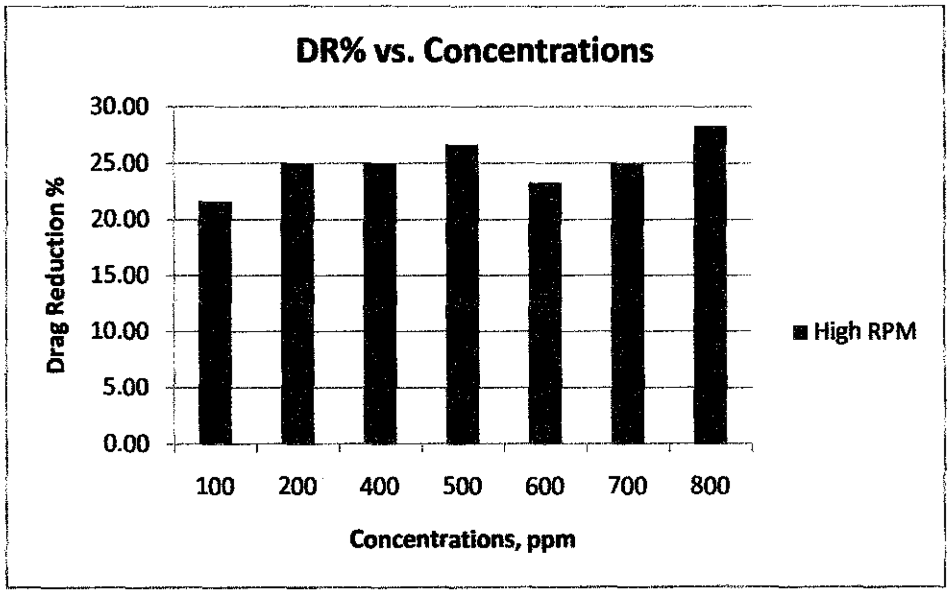

Figure 20: Drag Reduction % vs. Concentrations for High RPM

From both of the graph, it is clearly showed that Drag Reduction % is increasing with increasing of concentration. This happened because with higher concentration, there will be more DRA molecule in a pipe. Hence, more DRA molecule can react with turbulence structure and affect the percentage drag reduction. But then if it is closely observe there are several data when the drag reduction % does not produce result that reflect to the theory discuss earlier. Even with higher concentration, the drag reduction is decreasing. It is believed due to errors encounter during experiment run.

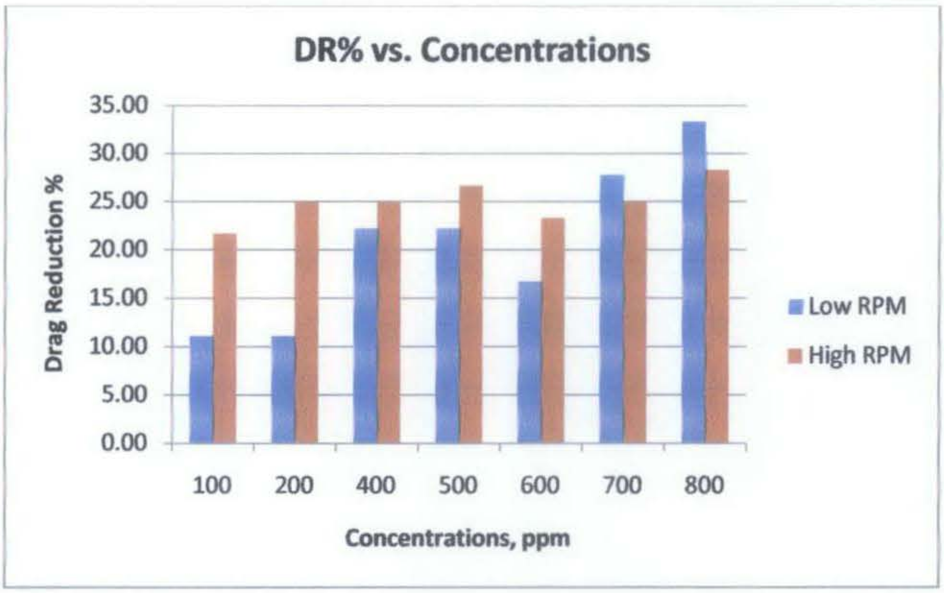

Figure 21: Drag Reduction % vs. Concentrations for Low and High RPM

When the Drag Reduction % vs. Concentration in ppm had been compared side by side for Low RPM and High RPM, it can be observed that High RPM contribute to higher percentage of Drag Reduction. Higher RPM create higher pressure when fluid is transport. With higher pressure, it will create higher flow rate. Turbulence eddies structure are more created when fluid is transport rapidly and fast. Hence, the effect of DRA is much clear when it is observe at high pressure. Thus, when the high RPM is applied, the effect of DRA at drag reduction is more obvious. But as expected, there also a few undesirable result such as at concentration 700ppm and 800ppm where Low RPM had higher Drag Reduction % compare to High RPM, due to errors occurred when experiment was conducted.

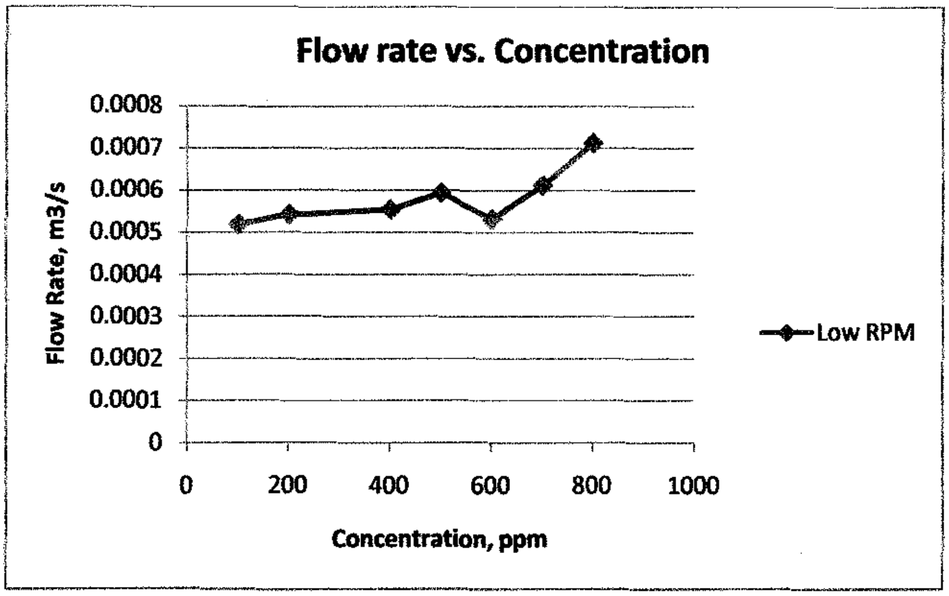

Figure 22: Flow rate vs. Concentrations for Low RPM

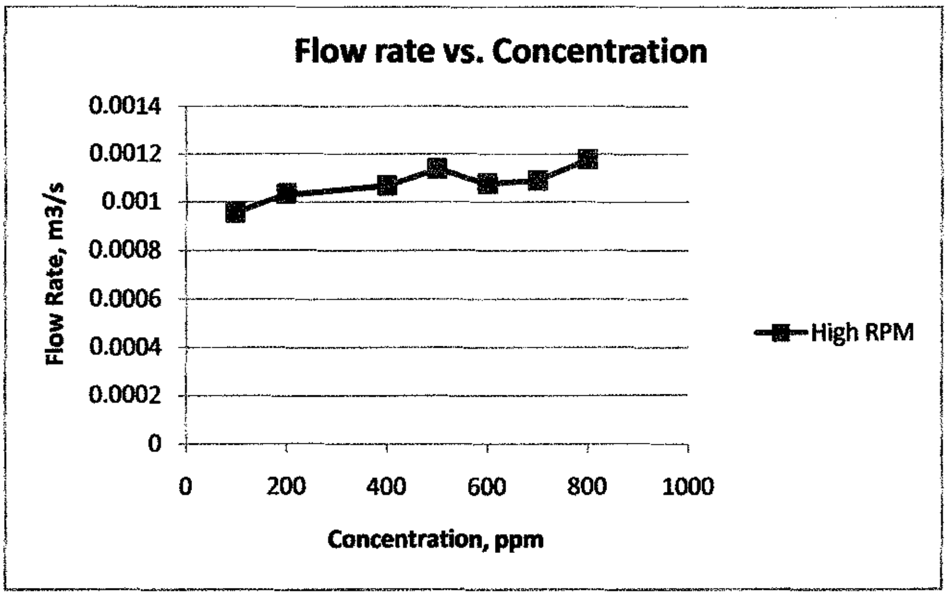

Figure 23: Flow rate vs. Concentrations for High RPM

Flow rate are as expected to increase if the concentration of solution also increase. This is because the higher DRA in the concentration, it will result in higher drag reduction. Hence, this will increase the volume of fluid transport. There is some case when running the experiment where flow rate calculated are lower even with higher concentration like at 600ppm. It is consider a result of errors occurred in the experiment and especially when preparing the solution. Perhaps the solution is not well mix and Sodium Stearate not mix completely in distilled water.

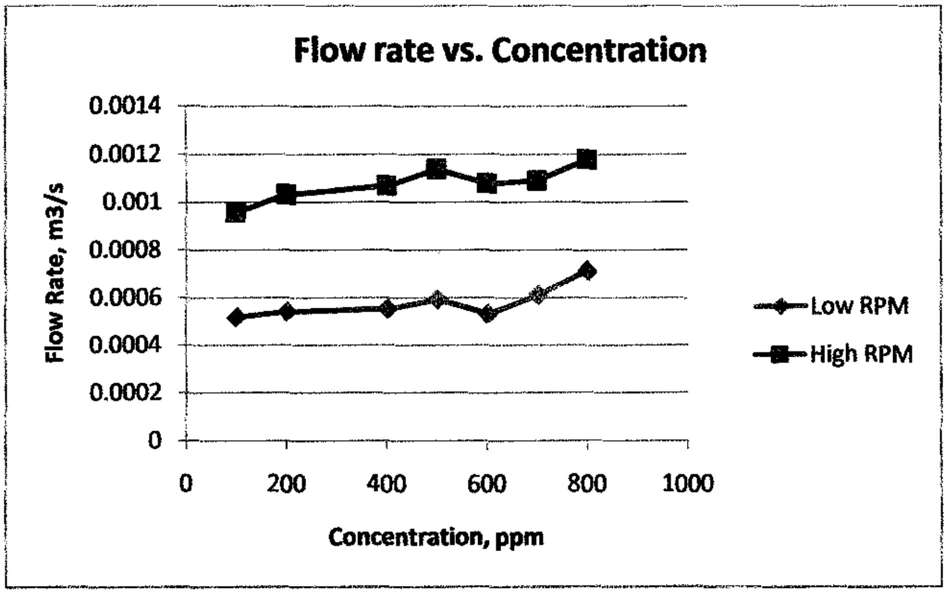

Figure 24: Flow rate vs. Concentrations for Low and High RPM

If Flow rate vs. Concentration graph for both Low and High RPM are combined together to see study carefully the effect of RPM of pump to flowrate, it show that flow rate will increase with increasing of RPM of pump. This is aligned with the theory that with higher RPM of pumps; more fluid can be transfer as the pump is much faster and rapid at its revolution per minute it completed.

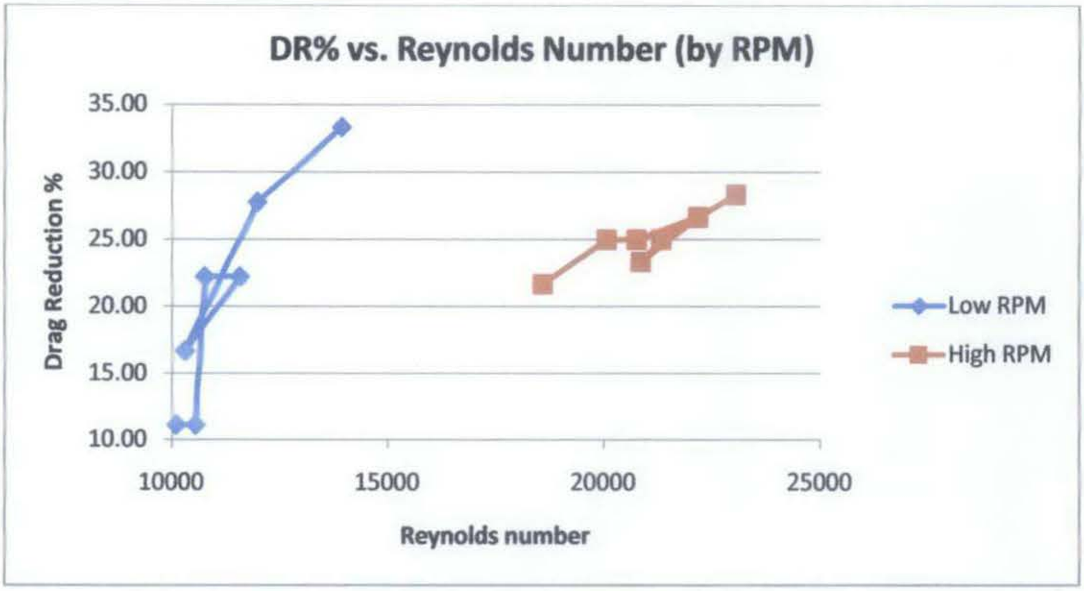

Figure 25: Drag Reduction % vs. Reynolds Number (by RPM)

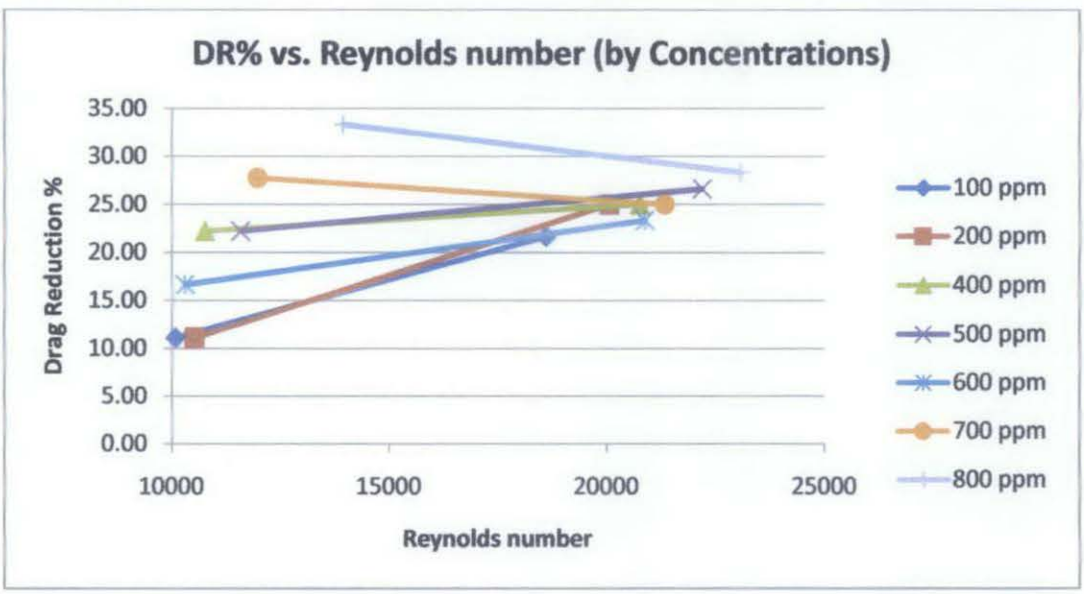

Figure 26: Drag Reduction % vs. Reynolds Number (by Concentrations)

From the theory predicted, percentage of drag reduction will increase with increasing of the transported fluid rate presented by Reynolds Number (Re). It is because the increasing of the degree of turbulence that provides an appropriate medium for DRA to react. But from the graph, it is not so clear to see for the effect of DRA in Drag Reduction% in term of Reynolds Number. All uncertainties occurred during the experiment test may contribute to this trend.

Using formulate stated in theory calculation section, efficiency factor of DRA are tabulate below:

Table 4: Efficiency factor of DRA for all concentrations.

Concentration	100	200	400	500	600	700	800
Low RPM	0.11	0.06	0.06	0.04	0.03	0.04	0.04
High RPM	0.22	0.13	0.06	0.05	0.04	0.04	0.04

It shows that for Low and High RPM, DRA with concentration of 100ppm set the highest efficiency factor over the others with efficiency of 0.11 and 0.22 respectively.

4.4 Limitations

Along the way to complete this Final Year Project, there are several limitations that had influenced every possible outcome for this project. These limitation are been categorized as below.

1. Budget allocate for Final Year Project

Budget is the main concern when doing any research or finding. In this scenario, the budget is RM500. Thus, it is challenging to manage the amount of money allocate to assemble or fabricate the experiment setup and to buy chemical use as DRA.

As consequences of this limitation, many improvement need to be done to compromise this limitation. Firstly, the experiment setup was changed such as from using carbon-steel pipe to galvanized-iron steel pipe and from two inch diameter of pipe to one inch diameter of pipe. Secondly, the medium for the DRA to react also been changed from crude oil to water.

2. Knowledge on assembling or fabricating the experiment setup

Since the experiment for DRA need to be assembling or fabricate by one's self, it is quite difficult for a person who not only had a limitation on budget but also on knowledge. A lot of try and error process had been done to improve the experiment setup so that it will be as perfect as possible to run the experiment.

3. Time is of the essence

Given a tight schedule to complete not only run the experiment and get a result but also fabricate and assembling the experiment setup is very demanding. Most of the times were spent on fabricating and assembling the experiment setup. Other than that, preparation of solution also consume much time. For instant, for 100ppm concentration, assumingly it needs around 4 hour to get well-mix and dilute totally in distilled water.

4.5 Errors

There are a number of errors occurred along the way to completed this research project. These errors are classify as follow

1. Systematic error

Systematic errors are always associated with a flaw in the equipment or in the design of the experiment. This type of errors cannot be estimated even by repeating the experiment with same equipment. Like in this Final Year Project, there are several systematic errors like the DRA supposedly been injected into the pipe, but since it is very complicated to create the injection mechanism, it had been improvised by letting DRA flow into the core of pipe by using gravity or potential energy mean. For that, it is assumed that all DRA went down into the core of pipe and well mix with water.

Another example is the centrifugal pump can't give the exact value reading of its 'revolution per minute' and the reading at pressure gauge quite hard to read as its needle move upward and downward repeatedly and fast. Next is viscometer used to measure the viscosity of the solutions. The viscometer is not constant when given the reading of viscosity. Thus, to minimize the error, viscosity readings are taken several times and try to get the average reading. Systematic errors often shift the result in one direction.

2. Parallax error

Parallax error is error in reading an instrument employing a scale and pointer because the observer's eye and the pointer are not perpendicular to the plane of the scale. In this research project, this type of error happened when to get the reading of pressure at pressure gauge. In order to minimize the effect of this error, the pressure reading were taken by its average reading of pressure.

3. Human error

Human error happened when time is taken to determine time needed to fill in the drainage tank so that flow rate can be determined. Reaction time between brain and hand to stop the stop watch will play an effect when it involves matter of seconds.

CHAPTER 5

CONCLUSIONS AND RECOMENDATIONS

5.1 Conclusions

As mention previously, the only objective set at the early stage of the project is to study effect of Sodium Stearate use as DRA in pipeline. For this objective, it is not totally hundred percent achieved successfully. First, instead of observe the effect of Sodium Stearate in oil pipeline, adjustment are made where the effect of Sodium Stearate are monitored in water pipeline. Thus, it can be concluded that for the second objective, in term of seeing the effect of Sodium Stearate use as DRA is successfully, but on the other hand, in term of using DRA in oil pipelines is not achieved.

This project had lead me to learn and study on how turbulence flow can affect the flow capacity of one pipeline, and most importantly discover the significance of DRA in the industry.

5.2 Recommendations

Limitation is stated for reasoning and rationalizing but not for excuses. But it is believed if the limitation can be reduce in one research, the result of the research will be more satisfy and accurate.

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. Using crude oil instead of water as medium for DRA to react.
2. Change galvanized iron steel pipe to Carbon steel pipe.
3. Create and improve the experimental setup such as closed-loop system.
4. Add on more variety of surfactant to act as DRA.
5. Get as much as possible all the knowledge and info related to project.
6. Provide more option for pipe diameter instead of only one diameter.
7. Use more stable pump in term of power deliver such as centrifugal pump.
8. Use pump that can give more variety to RPM variable and can be set accurately.
9. Use 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.
10. Use digital-scale pressure gauge with 'average, max, min' reading function.
11. Use digital-scale flow rate gauge with 'average, max, min. reading function.

All of this recommendation hope can improve the result of experiment and give more accurate data.

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APPENDIX A

EXPERIMENT DATASHEET RESULT

A.1 Result of Experiment

Below are the Experiment data sheet and table of data recorded and calculated for every run in the experiment.

Table 5: Experiment data sheet

UNIVERSITI TEKNOLOGI PETRONAS

Final Year Project II
Experiment Data Sheet

Name	Ahmad Hafizi Bin Ahmad Zaini	
Project Title	Using Sodium Stearate As Drag Reducing Agent In Oil Pipeline	
Date of Experiment	23-Jul-11	
Time of Experiment	8.30 p.m	
Experiment No.	1	
DRA used	Sodium Stearate (surfactant)	
Pipe Diameter, D	0.0254	meter
Flow Area, A	0.00050671	meter2

Table 6: Data recorded and calculated for every set of run in the experiment

RPM of Pump	Low								
Concentration Ppm	Volumetric Flow Rate, Q m^3/s	Velocity, V m/s	Density, ρ kg/m^3	Dynamic Viscosity, μ kg/m.s	Reynolds Number, Re	Initial Pressure, P_1 psi	Final Pressure, P_2 psi	Pressure Drop, ΔP psi	Drag Reduction %
100	0.000518783	1.023825548	999.89	0.00258	10078.41409	18	16	2	11.11
200	0.000542314	1.070265346	999	0.00258	10526.18413	18	16	2	11.11
400	0.000554185	1.093691755	999	0.00258	10756.58559	18	14	4	22.22
500	0.000593815	1.17190241	999	0.00257	11570.64392	18	14	4	22.22
600	0.000532145	1.050196493	998.7	0.00259	10285.8353	18	15	3	16.67
700	0.000612257	1.20829862	999.1	0.00256	11977.79814	18	13	5	27.78
800	0.000712414	1.405959608	999	0.00256	13935.80573	18	12	6	33.33

RPM of Pump	High								
Concentration Ppm	Volumetric Flow Rate, Q m^3/s	Velocity, V m/s	Density, ρ kg/m^3	Dynamic Viscosity, μ kg/m.s	Reynolds Number, Re	Initial Pressure, P_1 psi	Final Pressure, P_2 psi	Pressure Drop, ΔP psi	Drag Reduction %
100	0.000957191	1.889030237	999.89	0.00258	18595.38375	60	47	13	21.67
200	0.001033	2.038641432	999.8	0.00258	20066.33181	60	45	15	25.00
400	0.001069801	2.111269089	999	0.00258	20764.57698	60	45	15	25.00
500	0.001138668	2.247179709	999	0.00257	22187.27091	60	44	16	26.67
600	0.001078739	2.128907093	999	0.00259	20857.20692	60	46	14	23.33
700	0.001090583	2.152281917	999.1	0.00256	21335.45294	60	45	15	25.00
800	0.001177611	2.32403264	999.89	0.00256	23056.22489	60	43	17	28.33

APPENDIX B

FLOW RATE DATA FOR EACH SET OF RUN IN THE EXPERIMENT

The method used is quite basic since limitation on equipment to measure flow rate accurately such as digital-reading flow rate gauge. At the drainage tank, a mark is created to mark the scale at that particular point the volume of water fill is 0.025825m^3. Then with using stop watch, times are taken for water need to be filling up till that mark. Time 1 is for the Low RPM run while Time 2 is for High RPM.

Table 7: Flow rate data for each set of run in the experiment

Concentration (ppm)	Time 1 (s)	Time 2(s)	Flow rate 1 ($m^{3/}s$)	Flow rate 2 ($m^{3/}s$)
100	49.78	26.98	0.000518783	0.000957191
200	47.62	25	0.000542314	0.001033
400	46.6	24.14	0.000554185	0.001069801
500	43.49	22.68	0.000593815	0.001138668
600	48.53	23.94	0.000532145	0.001078739
700	42.18	23.68	0.000612257	0.001090583
800	36.25	21.93	0.000712414	0.001177611

To calculate Flow rate, simply divided time taken with volume of water. For example, at 100ppm for Low RPM run,

Flow Rate = 0.025825 m^3 / 49.78s

= 0.000518783 $m^{3/}s$

APPENDIX C

DENSITY DATA WITH TEMPERATURE

After each set of run of experiment, the samples are taken back to the lab to measure the density of the solution using Digital density meter. Additionally, the Digital density meter also gives a reading of temperature of solution at that time.

Table 8: Density data with temperature

Concentration (ppm)	Density for Low RPM (kg/m^3)	Temperature	Density for High RPM (kg/m^3)	Temperature
100	999.89	25.9	999.89	26
200	999	26	999.8	25.9
400	999	26	999	25.9
500	999	25.9	999	26
600	998.7	26	999	26
700	999.1	25.7	999.1	26
800	999	26	999.89	26

APPENDIX D

SAMPLE OF CALCULATION FOR RESULT

D.1 Sample of Calculation for Result

Taking of one sample on how to calculate Reynolds Number, Pressure Drop and Drag reduction. Bear in mind that, volumetric flow rate, Q, Initial pressure, P_1, final Pressure, P_2 are getting straight from experiment conducted. While Density and Dynamic Viscosity are getting from sample of solution been analysis in the Lab using Digital density meter and Viscometer. Below are the examples of 100ppm at Low RPM of pump taken at Table 5: Data recorded and calculated for every set of run in the experiment.

RPM of Pump	Low								
Concentration	Volumetric Flow Rate, Q	Velocity, V	Density, ρ	Dynamic Viscosity, μ	Reynolds Number, Re	Initial Pressure, P_1	Final Pressure, P_2	Pressure Drop, ΔP	Drag Reduction
ppm	m^3/s	m/s	kg/m^3	kg/m.s		psi	psi	psi	%
100	0.000518783	1.023825548	999.89	0.00258	10078.41409	18	16	2	11.11

Pressure Drop, ΔP = Initial pressure P_1 - Final Pressure P_2

= 18 -16 = 2 psi

$$\% \, \boldsymbol{Drag\ Reduction} = \frac{\Delta P_{without\ DRA} - \Delta P_{with\ DRA}}{\Delta P_{without\ DRA}}$$

$$= \frac{2\ psi}{18\ psi} = \quad = 0.1111 = 11.11\%$$

Reynolds Number, Re = $Re = \frac{\rho * V * D}{\mu}$

Knowing that diameter of pipe = 1inch =0.0254

Re = (999.89* 1.023825548*0.0254)/0.00254

= 10078.41409

APPENDIX E

SAMPLE OF CALCULATION FOR SOLUTION PREPARATION

Using formula below:

$$V_{DRA} = \frac{C_{DRA} * V_{total}}{1x10^6}$$

Where: V_{DRA} = Volume of DRA to be added (gram)

V_{Total} = Total liquid volume of the system (mL)

C_{DRA} = Desired DRA concentration (ppm)

For 100ppm:

V_{DRA}= (100ppm* 1000mL of Distilled water)/ $1x10^6$

= 0.1 gram

For other concentration, it been tabulated in Table 1: Concentration solutions of DRA

APPENDIX F

SAMPLE OF CALCULATION FOR EFFICIENCY FACTOR FOR DRA

Using formula below:

$$E_{DRA} = \frac{\%\, Drag\ reduction}{C_{DRA}}$$

Where: E_{DRA} = Efficiency factor

C_{DRA} = DRA concentration

For instant, at 100ppm Low RPM, the Drag reduction is 11.11%

Hence,

E_{DRA} = 11.11/ 100

= 0.111

For other efficiency factor for each concentration, it been tabulated in Table 6: Efficiency factor of DRA for all concentrations.

APPENDIX G

SAMPLE OF CALCULATION FOR EXPERIMENTAL SETUP

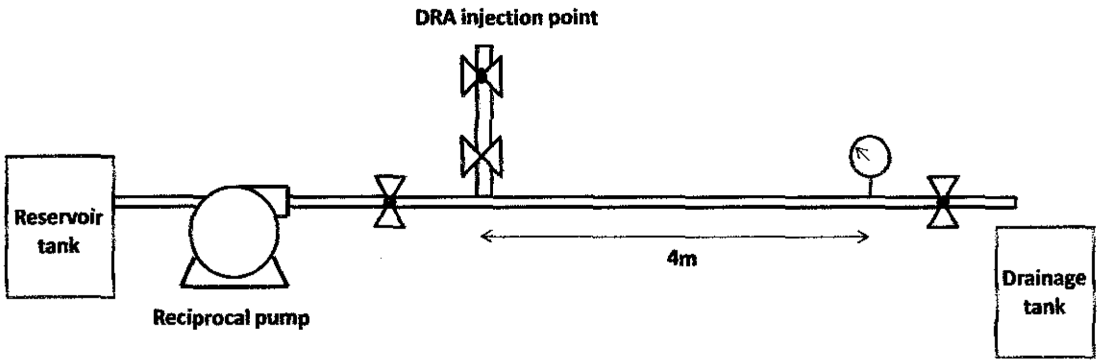

Figure 17: Schematic diagram of experiment setup

From figure 17, the total length of Galvanized Iron pipe starting from outlet of Reciprocal Pump to the Drainage tank is 5.5meter. Knowing that inner diameter of pipe is 1 inch or 2.54cm. Total volume of water need to be in the pipe at one time is calculated as follow:

$$\text{Volume} = \pi * (\text{radius})^2 * \text{Length}$$

$$= \pi *(0.0254/2)^2 * 5.5$$

$$= 0.00279 \text{ m}^3 = 2.79 \text{ Liter}$$

This mean, at one time, water need to be in the pipeline is around 2.79Liter.

Next, for the injection point, 2 inch pipe are used with length of 0.5meter. Thus, total volume of DRA solution can be fill up in the Injection point is calculated as follow:

$$\text{Volume} = \pi * (\text{radius})^2 * \text{Length}$$

$$= \pi *(0.0254)^2 * 0.5$$

$$= 0.00101 \text{ m}^3 = 1.01 \text{ Liter}$$

This mean, at one time, the injection section can fill up to 1.01Liter of DRA solution.

APPENDIX H

SUGGESTED MILESTONE FOR THE SECOND SEMESTER OF 2-SEMESTER FINAL YEAR PROJECT –FYP2 BY UTP GUIDELINE

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project Work Continue	■	■	■					Mid-Semester Break							
2	Submission of Progress Report 1				●											
3	Project Work Continue				■	■	■	■								
4	Submission of Progress Report 2									●						
5	Seminar (compulsory)										■	■	■			
5	Project work continue									■	■	■	■			
6	Poster Exhibition											●				
7	Submission of Dissertation (soft bound)												●			
8	Oral Presentation														●	
9	Submission of Project Dissertation (Hard Bound)															●

● Suggested milestone

■ Process