CERTIFICATION OF APPROVAL

Comparison between Two Surfactants (Sodium Oleate and Sodium Stearate) As Drag Reducing Agent in Water System

by

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TRONOH, PERAK
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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 acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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ROSSHAMILA AFIFAH BINTI MUDA

ABSTRACT

This project aim is to study the effectiveness of surfactants which are Sodium Oleate and Sodium Stearate as Drag reducing agents in water injection system. In the life reservoir, there will come to a point where it will be no longer being able to produce for hydrocarbon. At this stage, we usually prefer to use secondary recovery to boost up the performance of the reservoir back. One of the many choices for secondary recovery is by using water injection. In water injection system, it will require a very long pipeline to inject water into reservoir. What the engineers are being concern about is the large pressure drop that might happen along the pipeline. Theoretically explain, the large pressure loss is caused by the frictional forces between the walls of the pipe with the turbulence fluid flowing through it. it is found that the longer the pipeline, the higher the pressure drop will be. So by making two different types of surfactants as DRA, which are Sodium Oleate and Sodium Stearate, we will be able to investigate which one performed better as DRA in water injection system. The experiment is done in a lab consist of 4metre pipeline with two pressure gauges which will measure the pressure drop of liquid. Before that, a total of 8 concentrations of Sodium Oleate and Sodium Stearate are prepared using distilled water and magnetic stirrer. For every concentration, we made two samples so that we can take average measurement of respective concentrations. From the experiment done, it is shown that Sodium Stearate shows a better result performing as DRA compared to Sodium Oleate because at 600ppm, Sodium Stearate gives the lowest average pressure drop which is 7.25psi. While for average flow rate, Sodium Stearate gives the highest at 400ppm which is 37.41gpm. The highest %DR and %FI for Sodium Stearate are 47.22% and 42.66% respectively. So in conclusion, Sodium Stearate shows a better ability as DRA in water pipeline system compared to Sodium Oleate. This shows the study of surfactants DRA is important because it can help to reduce drag problem which is a major problem in our oil industry.

ACKNOWLEDGEMENT

Praise is to be to Allah s.w.t because for His blessings and permission I am able to finish my Final Year Project. There are so many people I would like to thanks for helping me along this process. First of all, I would like to thanks Madam Mazuin for giving a lot of guidance and continuous support for me to finish up this project.

Secondly, I would like to shout many thanks to my group members who are also under DRA team whose are Zetty, Nabil and Faheem for making it together to run every experiment. Next, I would like to thank lab technicians of Block 15 for giving as assistance to me for conducting the experiment successfully.

Last but not least, I would like to thank Universiti Teknologi PETRONAS, UTP for providing the services available to complete the experiment such as 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.

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CHAPTER 1

INTRODUCTION

1. PROJECT BACKGROUND

1.1 Background of Study

The initial production from reservoir is from natural reservoir energy which comes from water drive, gas drives, and gravity drainage. This type of production is termed as primary production. Secondary production came afterwards when the natural energy has depleted. This usually accomplished by the injection of fluids; either fluids or gas. One of the most famous secondary recoveries is by using water injection. The purpose of secondary water injection technique is to re- pressurized the reservoir and to maintain the reservoir pressure at high.

Water injection technique or called waterflooding is a technique where water is injected into the formation using wells that have ceased production. The injected water enters the reservoir and displaces some of the remaining oil toward producing wells in the same reservoir. Water flooding is the least expensive and most widely used secondary recovery method. We can either inject seawater or produced water from the reservoir into the formation.

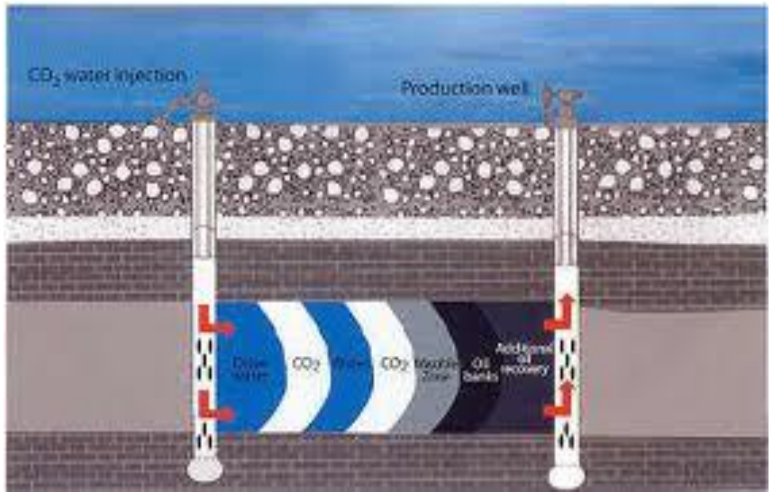


Figure 1: water injection system

To improve the performance of water injection, the use of DRA plays an important role. DRA is defined as a chemical agent use to minimize or decrease the frictional losses in the pipeline cause by turbulence flow of liquid, which is injected along the pipeline to reduce the drag causes by the fluid.

1.2 Problem Statement

Basically, it is important to keep reservoir pressure maintained at high. Reduce in reservoir pressure is an undesirable condition for hydrocarbon production because when the reservoir pressure drops below the bubble point pressure, gas begins to form in the pore spaces. This in turn will cause a gas cap to form inside the reservoir and thus increase the possibility of free gas to be produced. When this happed, the reservoir will lose its energy to push the oil forward since gas expansion is the main energy available to produce the oil. So in order to maximize production, we need to keep the reservoir pressure above the bubble point and all reservoir fluids are in liquid phase. The effect of huge pressure drop will affect the production and later impact our economics. The source of pressure drop in the pipeline is when the interaction between water streak with the walls of pipeline. The turbulence of flowing fluid will cause frictional force between the collisions. This in turn will cause loss of energy and loss of the pressure inside the pipeline. When high pressure drop happened in pipeline, automatically the system will need high pumping energy which means more workforce need to be done to our system. So in order to reduce pumping energy and pressure drop, DRA is injected into the pipeline.

1.3 Objective

The main purpose of this project is to study the effectiveness of two different surfactants, namely Sodium Oleate and Sodium Stearate as drag reducing agent on water injection mechanism. Other than that, this project aim is to;

i. To determine the pressure drop along the flow line and drag reduction percentage by using DRA
ii. To measure flow rate of liquid when mix with DRA
iii. The calculate the %DR of Sodium Oleare and Sodium Stearate as DRA
iv. To measure the %FI of Sodium Oleate and Sodium Stearate

1.4 Scope of Study

Actually the ability of DRA varies in a wide range. Besides reducing the pressure drop of flowing fluid in the pipeline, it can also increase the flow rate of flowing fluid inside the pipeline. According to Hoyt (1990), there are many factors contributing to the effectiveness of DRA. Some of them are molecular structure, temperature, pH, shear rate and many more. Not to forget, the ability of DRA is not only limited to reducing pressure drop and increasing flow rate, it can also reduce corrosion, reduce pumping energy and causes a reduction in heat transfer, which is advantageous in maintaining low oil viscosity. However, in this project, I will only focus on the different concentrations as the manipulated variable while observing on the pressure drop and flow rate as responding variables. And of course I will measure the ability of DRA based on two different types of surfactants which are Sodium Oleate and Sodium Stearate.

1.5 Relevancy Of The Project

Until recently, many oilfield projects have been using surfactant as DRA to help boosting their production because they believed that DRA help to increase oil production while solving pressure drop problem. Hence, this project is developed based on the concern to reducing the cost of operating and maintenance operation of oil transportation system. In Kuwait Oil Company (KOC), the benefits of DRA had prevented them from installing another pipeline as to increase production since the use of DRA in their existing pipeline had proven overcome the problem of pressure drop they had and eventually had increase their oil production. This study is very crucial for industrial practitioners to understand more regarding drag reducing agent for them to produce marginal field with no problems in the future.

1.6 Feasibility Of The Project

This project can be able to be done by this whole semester by follow closely the guidelines and the scheduled activities in the Gantt chart. Furthermore, given the facilities and laboratory of DRA which is already ready in Blok I, UTP, I am able to finish this project on time. According to the guideline, the tasks and scope covered for FYP I during first semester are:

a) Research on the drag reducing agent and its mechanisms
b) Study on the surfactant type of DRA and research on the articles and journals on DRA works.

While for the subsequent FYP II, the scope and task that will be covered are:

a) Doing experiment to prove the theory
b) Analyzing findings from the experiment
c) Preparing academic paper

CHAPTER 2

LITERATURE REVIEW

2.1 Drag

The resistance that the flowing fluid faces along the pipeline is called "Drag". In other word, we can say that it is the pressure loss due to the frictional forces happened in the pipeline due to the collision of water molecules with the walls of pipeline. Drag had become major problem in oil and gas industry because they had to suffering high cost of operations due to the high measure of pumpability which resulted in high energy use, limit the throughput and huge loss of pressure drop which reduce the production of hydrocarbon to the surface.

2.2 Drag Reduction

According to Savins (1964) Drag reduction was defined by as the increase in pumpability of a fluid caused by the addition of small amounts of another substance, such as high molecular weight polymers, to the fluid. While Lumney (1969) suggested that the phenomenon of drag reduction is the reduction of skin friction in turbulent flow below that of that solvent alone. In the late 1940, Toms had accidentally found the idea of drag reduction. Toms (1949) discovered that dissolving a small amount of polymers (usually a few weight parts per million) in water can drastically reduce the pressure drop or known as frictional drag of turbulent pipe flow. Lescarboura (1996) stated that small concentrations of DRA will result in large pressure drop. The first commercial application for high polymer drag reduction was its use in the 48-inch diameter 800 mile long Alaska pipeline carrying crude oil from the North Slope in Alaska to Valdez in the south of Alaska (E. D. Burger, 1982).

Frictional pressure drop (or drag) restricts the flow of liquid in the pipeline. Usually, it will limit the throughput and thus require greater amounts of energy for pumping. In turbulence flow regime, the hydrocarbon molecules move in a random manner causing much of the energy applied to them to be wasted as eddy currents and other motions. Drag reduction occurs by an interaction of the polymer molecules of the drag reduction chemicals with the turbulence of the flowing fluid. (Peace Heaven website). When there is fluid flowing through a pipeline, there exist frictions between the adjacent layer of water and also between water molecule and the wall of the pipe. This friction causes some changes in energy as it convert pressure energy to heat energy. This has cause a substantial amount of energy loss. As the water keep flowing to the end of the pipeline, we can see the decreasing in pressure as the molecules of water had dissipated into heat and other energy.

2.3 Drag Reducing Mechanisms

Drag reduction only works in turbulent flow which the flowing fluid Reynolds number is higher than 2500. The formula used to calculate Reynolds number is;

$$\boldsymbol{Nre} = \frac{\boldsymbol{\rho\, vD}}{\boldsymbol{\mu}} \qquad (1)$$

From what had been mentioned earlier, drag reducer does not work in laminar flow regimes. This is because drag reduction occurs by an interaction of the polymer molecules of the drag reducer with the turbulence formation of the flowing fluid or hydrocarbon. (Lumney, 1977) proposed that the mechanism for drag reduction is an increased viscosity near the wall, caused by elongation deformation of the molecules by the turbulence.

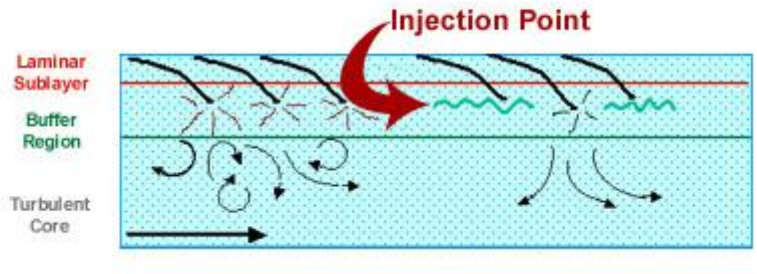


Figure 2: Flow Regime in a Pipeline

In turbulent flow regimes, there are three different zones or layers. Nearest the pipeline wall is a zone called laminar sub layer. There are no cross flows in this zone. In the very center of the pipe is the turbulent core zone. This zone is the largest region and includes most of the fluid in the pipe where eddy currents and random motion of turbulent flow going on. Between the laminar sub layer and turbulent core zones lies the buffer zone. This zone is important because it is here that the turbulence first forms. A portion of the laminar sub layer called 'streak' will occasionally move up to the buffer zone. Once the streak enters the buffer zone, it will begin to vortex and oscillate, moving faster as it gets closer to the turbulence core. Finally the streak become unstable and breaks up as it throws fluid into the core of the flow.

The ejection of fluid in the core is called 'turbulent burst'. The burst creates the turbulence in the core. Energy is wasted in different directions causing the drag and pressure loss. Drag reduction occurs by an interaction of the polymer molecules of the drag reducer with the turbulence of the flowing fluid. Drag reducer polymer interfere with the bursting process or inhibit the formation of turbulent burst and prevent the turbulence from being formed, or at least reduce the degree of turbulence and in turn, reduce the drag or pressure loss. In general, the higher the degrees of turbulence, the higher the performance of drag reducing in the pipeline. Therefore, the drag reducing performance increased as the fluid viscosity and flow rate increase (ConocoPhillips, 2008).

2.4 Surfactant Drag Reducing Agent

Although there are many researches on polymers when talking about DRA, surfactants are also known as effective drag reducers. Even though it degrades by shear when centrifugal pumps are used, however their nanostructures can self-assemble after breakup by high shear (Lester, 1985).

Surfactants are usually organic compounds that are amphiphilic, meaning they contain both hydrophobic groups (their "tails") and hydrophilic groups (their "heads"). Therefore, they are soluble in both organic solvents and water. Surfactant can reduce the surface tension of a liquid thus will reduce the turbulent friction and improve the fluid flow. To reduce the surface tension, however, surfactant molecules have to migrate to the interface, and this takes some finite amount of time. The formulation will eventually reach equilibrium (static) surface tension after certain time. This takes several seconds or even several hours depending on the type of surfactant and the concentration of solutions used. (Lixin Cheng et al., 2007).

Surfactants are surface active agents that have a tendency to absorb at surfaces and interfaces. They lower the free energy of the phase boundary by absorbing at the interface. For example, the surface tension of water is largely reduced when surfactant is added to water as the surfactant covers the water surface in contact with air. The surface density of the surfactant molecules determines the amount of reduction in surface tension of water. There is, however a limit to the reduction of surface tension of the solvent. The lowering of the surface tension of solvent by addition of surfactant stops when surfactant molecules begin to form micelles in the bulk solution. The concentration at which micelles start to form is called critical micelle concentration (cmc). .(Ketan Prajapati,2009)

In normal condition, the molecules of surfactant will form a normal dispersion in liquid. However, as the concentration of surfactant exceed a certain value called Critical Micelle Concentration (CMC), the molecules will gather and form a bulk spherical shape called micelles in turbulent flow. During this micelles formation, they modified the solvent properties and produce viscoelasticity. a large number of researchers believed that viscoleastic effect of surfactant solution could be responsible for the turbulent drag reduction in pipeline. (Lixin Cheng et al., 2007).

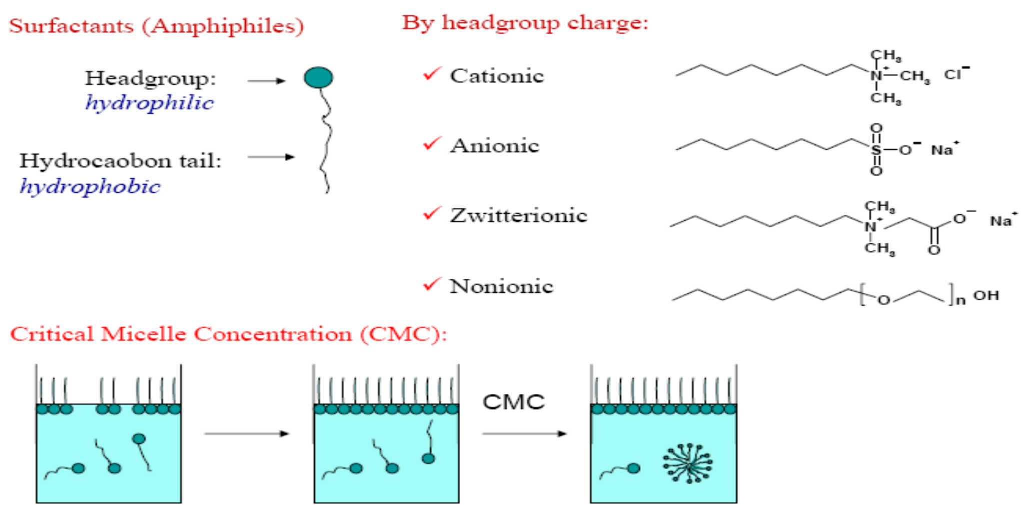


Figure 3: Micelle formation in Surfactant

2.4.1 Sodium Oleate

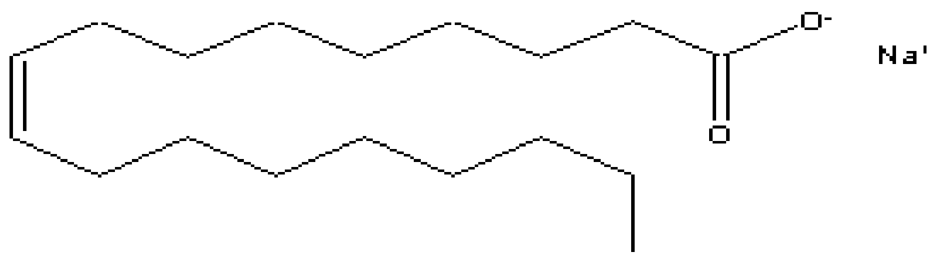


Figure 4: Molecular Structure of $C_{18}H_{33}NaO_2$

Taken from Product information (SIGMA website), they explained that Sodium Oleate is the sodium salt of oleic acid, a monounsaturated fatty acid. This anionic surfactant and emulsifier is a component of commercial soaps. It exists as white powder and has a slight soap-like odor. It is soluble in alcohol and also in water with some decomposition. Other properties of Sodium Oleate are;

Synonyms	Oleic acid, Sodium salt; sodium salt; 9 -Octadecenoic acid sodium salt, Sodium salt of Oleic Fatty acid.
Molecular Wt	304
Physical Form	Powder
Color	Pale White
Moisture	<6%
pH	10-11
Solubility	soluble in water

Table 1: Chemical Properties of $C_{18}H_{33}NaO_2$

2.4.2 Sodium Stearate

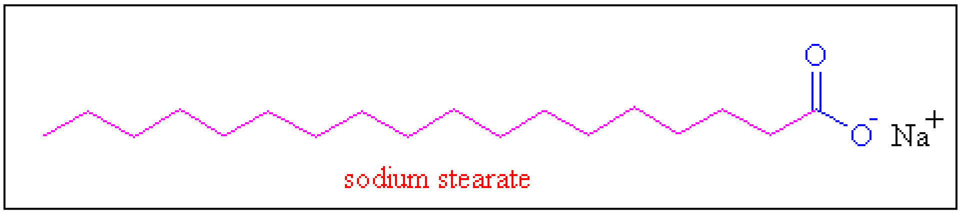


Figure 5: Molecular Structure of $C_{18}H_{36}NaO_2$

From Wikipedia, it says that Sodium Stearate, or Sodium Octadecanoate, is the sodium salt of Stearic Acid. It is the major component of some types of soap, especially those made from animal fat. It is found in many types of solid deodorants, rubbers, latex paints, and inks. It is also a component of some food additives and food flavorings. It is also used in the pharmaceutical industry as a surfactant to aid the solubility of hydrophobic compounds in the production of various mouth foams. Other properties of Sodium Stearate include;

Synonyms	Octadecanoic acid, sodium salt; Stearic acid, sodium salt, mixture of stearic and palmitic fatty chain
Molecular Wt	306
Physical Form	Powder

Color	White
Moisture	<6%
pH	10-11
Solubility	Sparingly soluble in water

Table 2: Chemical Properties of $C_{18}H_{36}NaO_2$

2.5 Calculation Theory

2.5.1 Entrance Length of Turbulent Flow

A fluid need some length to develop the velocity profile after entering the pipe or after passing through components as bends, valves, pumps, turbines or similar.

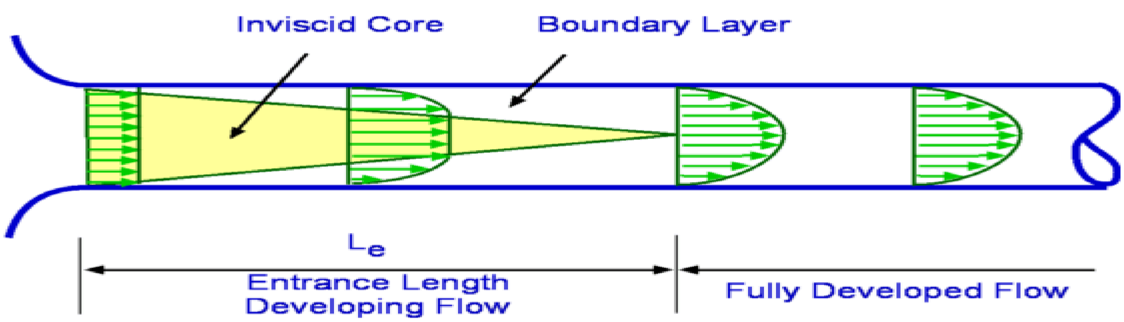


Figure 6: Flow at the entrance to a pipe

Denoted by L_e, the entrance length is a function of the Reynolds Number of the flow. In general,

$$\frac{L_e}{d} \approx 0.06\ Re_d, \quad \text{for a Laminar Flow}$$

$$\frac{L_e}{d} \approx 4.4\ Re_d^{1/6}, \quad \text{for a Turbulent Flow} \qquad (2)$$

Where;

Le = length to fully developed velocity profile (m, ft)

d = tube or duct diameter (m, ft)

Re = Reynolds Number

At critical condition, i.e., Red =2300, the Le/d for a laminar flow is 138. Under turbulent conditions it ranges from 18(at Re_d = 4000) to 95 (at $Re_d=10^8$). This is important to decide whether a long enough entrance length is required or a shorter one is required.

2.5.2 Calculations

The effectiveness of DRA can be assessed by the following formula.

The percent drag reduction calculation;

$$DR\,\% = \frac{\Delta P - \Delta P^\circ}{\Delta P} \times 100 \qquad (3)$$

While the percent flow rate increase (%FI) can be known using this equation:

$$\%FI = \left\{ \left[\frac{100}{100 - \%DR} \right]^{0.556} - 1 \right\} \times 100 \qquad (4)$$

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

$$VDRA = \frac{CDRA \text{ X } Vtotal}{1 \text{ X } 10^6} \qquad (5)$$

V = Volume of the DRA t o be added

C= Desired DRA concentration (ppm)

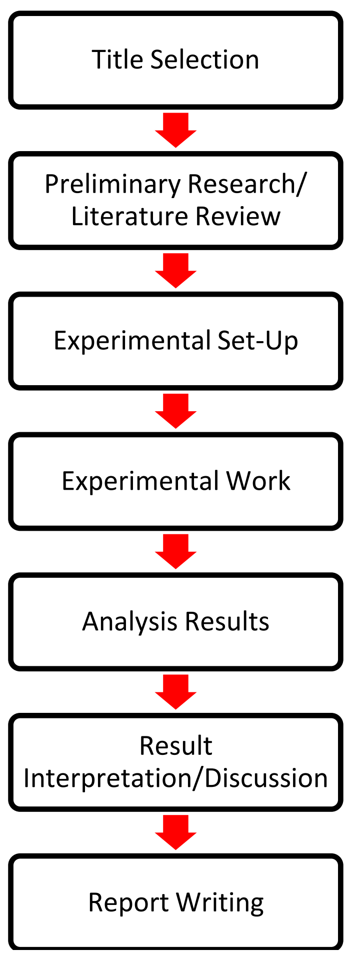
V= Total liquid volume of the system

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

Methods to be adopted:



3.1.1 Title selection

This is the most important part of FYP. We as a group member had a discussion with our supervisor, Pn Mazuin to determine and select topic which will be entitled as our project. There are four people in DRA group, so we divide the project based on our liking and concern. Hence, I had chosen the topic of DRA which is by using surfactants. The title for my project is ‘The Comparison between Two Surfactants (Sodium Oleate and Sodium Stearate) as Drag Reducing Agent in Water System’.

3.1.2 Preliminary Research/ Literature Review

after had been assigned each other topic for DRA, students have to make research what is actually DRA to get the idea of what we will be working on. a lot of articles reading is done based on previous work by many researchers. Then, from that we have to make summary and extract what are the important mechanism in DRA and also surfactants.

3.1.3 Experimental Set-Up

The experimental set-up of this experiment is by using the open flow prototype is used to mimic the condition in real life condition in oilfield. The set-up consists twp of large water tanks as water container, 4 meter pipelines with two pressure gauges being installed at the centre and another one is at the end of the pipeline to measure the pressure drop of the flowing fluid inside, a centrifugal pump used to boost the flow of fluid inside the pipeline. There is also one injection point located after the pump act as the point for DRA injection. It is installed after the pump to avoid from shear degradation since molecular structure of surfactants undergone degradation when flowing through moving section such as pump. To install the injection point, we need to calculate the turbulence entrance of the pipeline using the equation 2 stated in the literature review.

However for this time, we just used the prototype which had been set-up by the senior previously who was working on this project too. So some check up has been made such as repairing the pump and replace its lubricant oil. The actual design is shown below;

a) Water Container And As Storage Tank

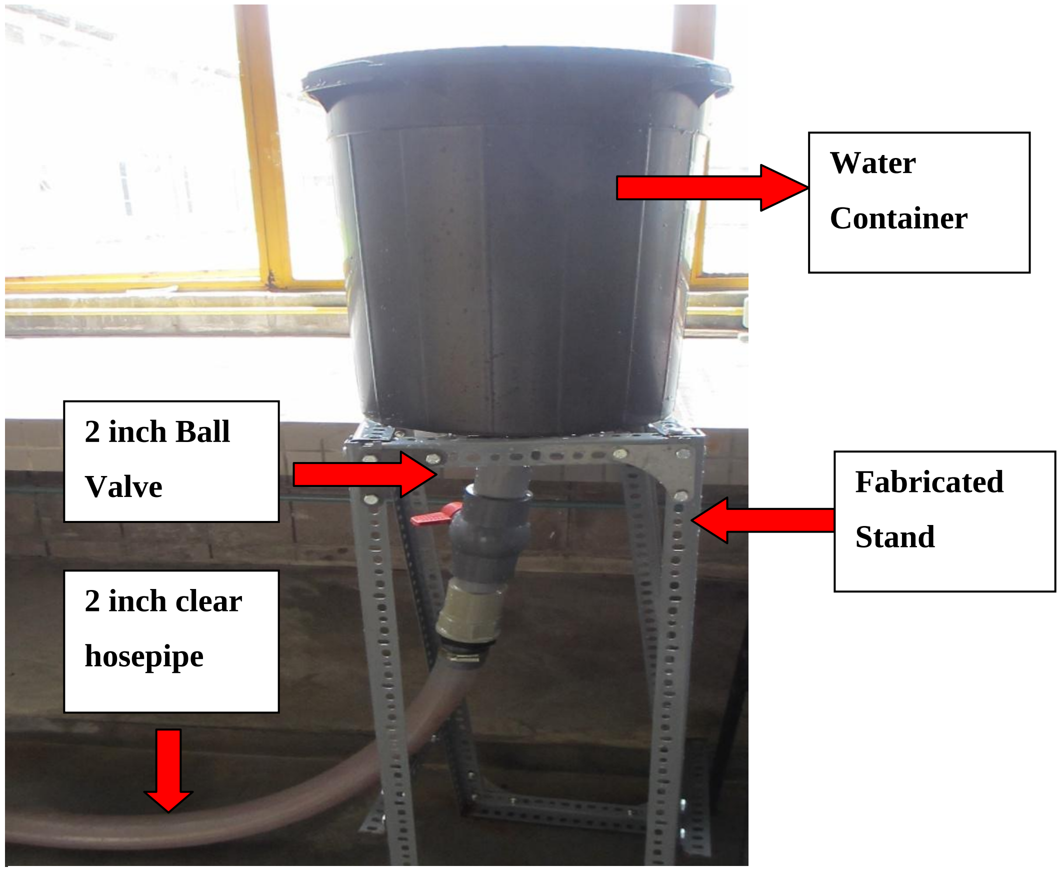


Figure 7: Storage Tank to Pump inlet

Storage water container is can hold up about 36 liters of fluid inside it. It is positioned 1 meter from ground so that it may flow with the force of gravitational direction. The container is located on a fabricated stand so that it can be positioned approximately 1 meter from ground and also to ensure its stability. The 2 inch ball valve is to open/close the flow from water container to the pump inlet through 2inch clear hose pipeline.

a) Centrifugal Pump

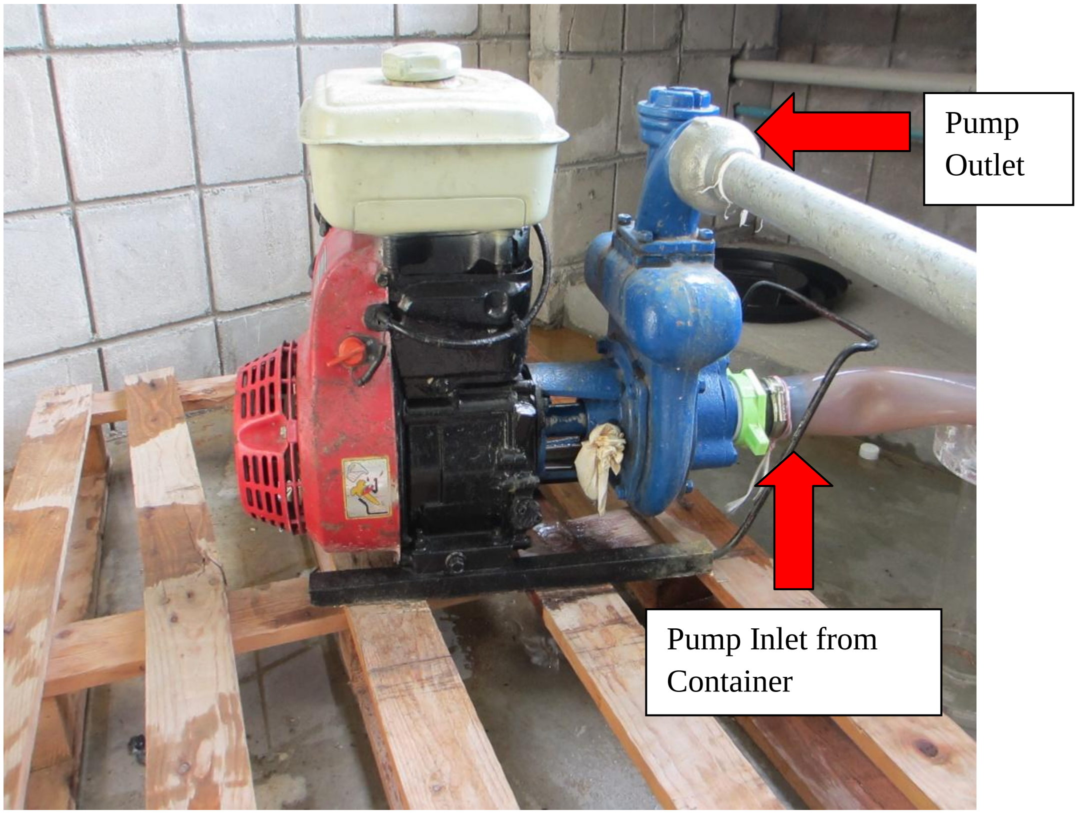


Figure 8: Centrifugal Pump

Centrifugal pump functions to increase flow of fluid flowing through it from water container. It has been designed to have 2 inch of inlet and outlet diameter. It also has the RPM adjustor to set it to higher or slow rate of pumping. The function of the pump is to give kinetic energy to the incoming fluid. When the fast rotating impeller work, it will produce a centrifugal force that draws in liquid and increasing kinetic energy of the liquid causing it move out fast from the pump.

b) Injection Section

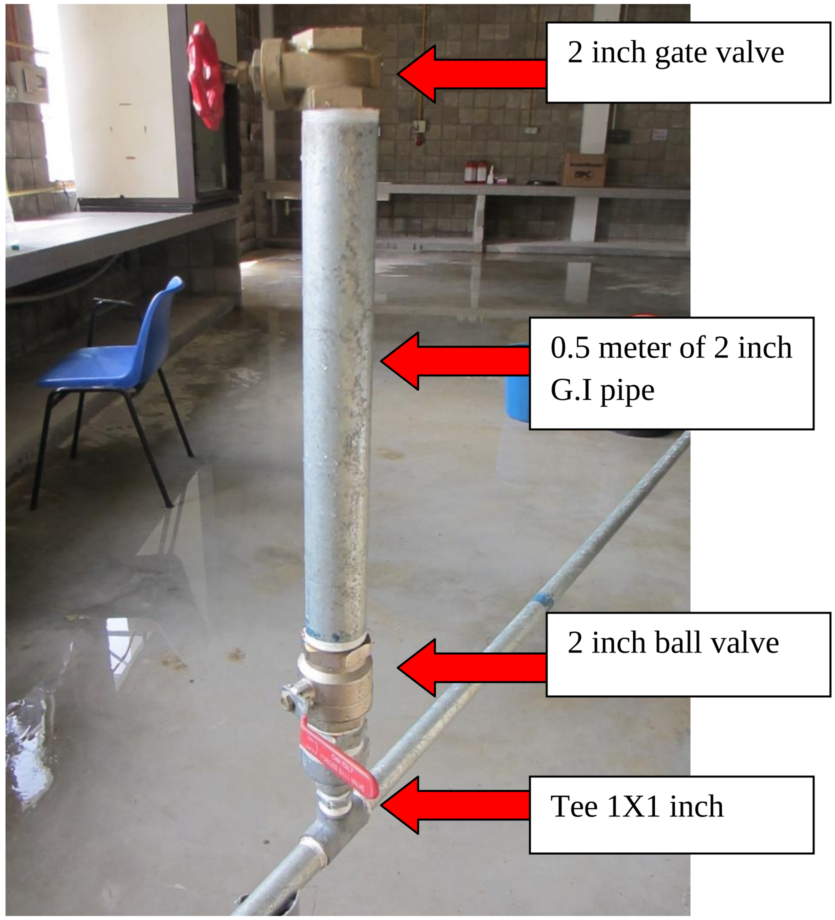


Figure 9 : Injection Header

This injection point consists of 2 inch gate valve as an entrainment section of DRA into injection point. the 2 inch ball valve located lower must be closed whenever the upper valve is open as to avoid DRA goes directly into pipeline. The 0.5 meter of 2 inch pipe purposes it to hold amount of DRA that has been prepare earlier in the lab, it is indicated that DRA only works in turbulence flow so this injection point is calculated as the section where turbulence flow is in motion.

c) Flowing Section of Fluid

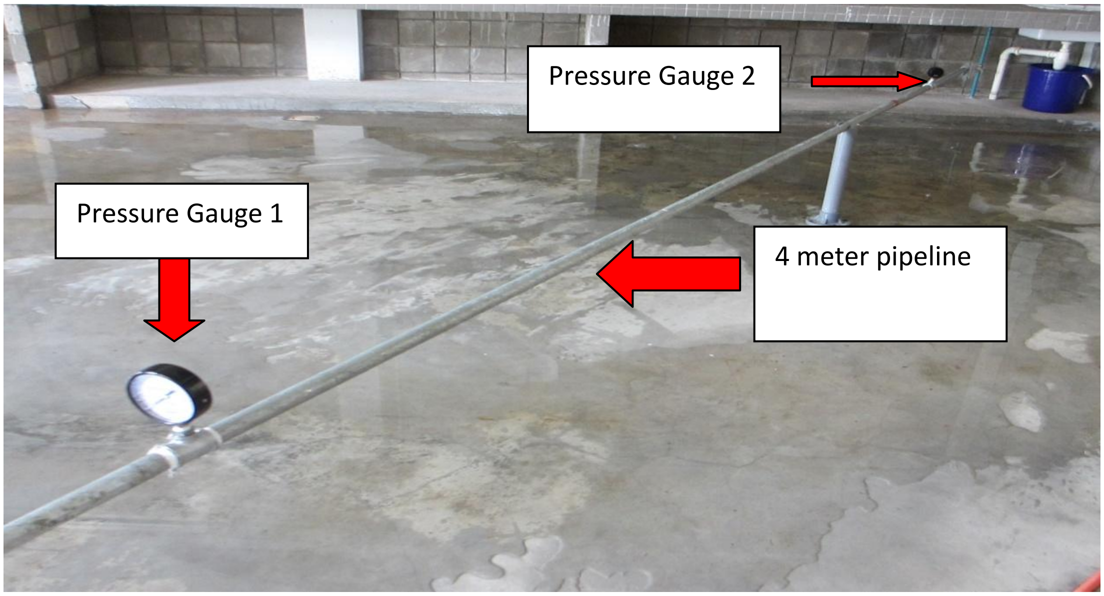


Figure 10 : 4 meter testing section

Figure 12: Pressure Gauge 1

Figure 11: Pressure Gauge 2

This testing section consists of 4 meter pipeline together with the first pressure gauge located where the turbulent flow is fully developed. While pressure gauge 2, is located at the end of the pipeline to measure end pressure of flowing fluid inside the pipeline.

d) Drainage Tank

Figure 13: Drainage Tank

This is the area where the flowing fluid is collected after had been mixed with DRA. The capacity this drainage tank can hold up is the same as the storage tank which is about 36litres of fluid. Time taken for the fluid to fully contain this tank is recorded to calculate the flow rate of fluid.

3.1.4 Experimental Work

a) Samples Preparation

Before we can run the experiment in the set-up mentioned above, we must first prepare different concentration of both surfactants. Concentrations ranging from 400pm to 1000ppm is prepared in the lab 15 using the distilled water and magnetic stirrer. For every concentration, 2 samples is prepared so that it is easier to take average of its properties measured later.

Table 3: Concentration of DRA

<table>
<tr><td rowspan="2">Sodium Oleate/ Sodium Stearate</td><td>Concentration (ppm)</td><td>400 (1)</td><td>400 (2)</td><td>600 (1)</td><td>600 (2)</td><td>800 (1)</td><td>800 (2)</td><td>1000 (1)</td><td>1000 (2)</td></tr>
<tr><td>Weight of Surfactant (gram)</td><td colspan="2">0.4</td><td colspan="2">0.6</td><td colspan="2">0.8</td><td colspan="2">1.0</td></tr>
</table>

Figure 14: Weighing process of Surfactants

Figure 15: Solution Stir for 30 min using magnetic stirrer

b) Conducting the Experiment

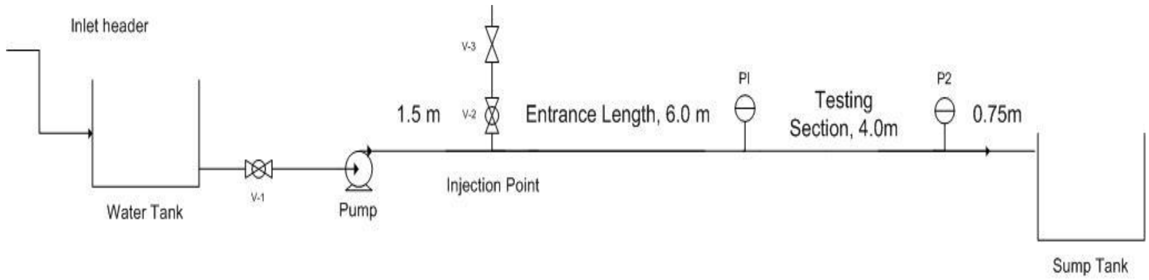


Figure 16: Schematic Figure of Set-up

1) Before start the experiment, make sure valve 2 and 3 are in closed condition while Valve 1 opened.

2) The operation begins when the pump started. The solution with no DRA will be delivered through the injection point.

3) Pressure reading is recorded at pressure gauge 1 and marked as initial pressure while pressure gauge 2 as end pressure.

4) Then, run 400ppm of Sodium Oleate first. The pump is off and Valve 3 is opened to add DRA solution prepared earlier into the pipeline. Make sure Valve 1 and 2 are in closed position.

5) Valve 1 is opened and pump is run. At the same time, open valve 2 so that the earlier DRA can enter the pipeline.

6) Pressure at P1 and P2 is recorded using a video camera.

7) The pump is off when the sump tank is full up to 36 liters.

8) The time for the sump tank to full was recorded.

9) Repeat step 3-7 for other concentrations of DRA. All data collected is recorded and tabulated as follows;

Type Of Chemical	Concentration (Ppm)	P1 (Psi)	P2 (Psi)	P1-P2 (Psi)	Time, T (S)
Sodium Oleate/ Sodium Stearate	dry run				
	400				
	600				
	800				
	1000				

10) Repeat steps 4-9 using another type of surfactant, Sodium Searate.

11) The average pressure drop, average flow rate, %DR and %FI are calculated

12) The graphs for average pressure drop, average flow rate, %DR, %FI against concentration are plotted.

3.1.5 Tools, Equipments and Materials

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

a) 2 pile of 36 litter capacity
b) 2" hosepipe
c) 1 tank connector
d) 2 ball valve of 2"
e) 1 centrifugal pump
f) 2 reducer of 2x1"
g) 12.25m of 1" galvanized pipe

h) 0.5m of 2” galvanized pipe

i) 1 tee of 1x1”

j) 2 tee of 1x1/2”

k) 2 bush of 3/8

l) 1 gate valve of 2”

m) 2 pressure gauge with scale of 0-100 psi

n) Sodium Oleate

o) Sodium Stearate

3.2 Gantt Chart

No	Semester	FYP 1																FYP 2															
	Week	1	2	3	4	5	6	7	mid-sem break	8	9	10	11	12	13	14	sem break	1	2	3	4	5	6	7	mid-sem break	8	9	10	11	12	13	14	15
1	Selection of project topic	■	■																														
2	Preliminary research work		■	■	■	■																											
3	Project Understanding		■	■	■	■																											
4	Literature review				■	■	■	■																									
5	Submission of extended proposal						■																										
6	Proposal defence									■	■																						
7	Experimental work											■	■	■	■	■		■	■	■	■	■	■	■		■	■	■	■	■			
8	Submission of interim draft report														■																		
9	Submission of interim report															■																	
10	Submission of progress report																									■							
11	Interpretation data and parametric analysis																									■	■	■	■	■			
12	Pre-SEDEX																												■				
13	Report writing											■	■	■	■	■		■	■	■	■	■	■	■		■	■	■	■	■			
14	Submission of draft report																													■			
15	Submission of dissertation (soft bound)																														■		
16	Submission of technical paper																														■		
17	Oral presentation																															■	
18	Submission of dissertation (hard bound)																																■

CHAPTER 4

RESULTS AND DISCUSSION

Type Of Chemical	Concentration (Ppm)	P1 (Psi)	P2 (Psi)	P1-P2 (Psi)	Avg Pressure Drop	Time, T (S)	Avg Time, S	Avg Time (Min)	Avg Flow Rate, Gpm
Sodium Oleate	dry run	16	2.5	13.5	13.5	20	20	0.333	28.53
	400	10	2.5	7.5	7.5	29.06	25.26	0.421	22.58
		10	2.5	7.5		21.47			
	600	14	7.5	6.5	6.5	15.57	15.28	0.254	37.33
		14	7.5	6.5		15			
	800	16	7.5	8.5	9.375	14.75	14.82	0.247	38.48
		14	3.75	10.25		14.9			
	1000	20	5	15	13	15.4	15.65	0.260	36.46
		16	5	11		15.9			
Sodium Stearate	400	14	3.75	10.25	10.375	15.7	15.25	0.254	37.41
		13	2.5	10.5		14.8			
	600	11	3.75	7.25	7.125	16.3	16.45	0.274	34.68
		12	5	7		16.6			
	800	13	5	8	8	15.8	15.65	0.260	36.46
		13	5	8		15.5			
	1000	13	3.75	9.25	9.75	15.9	15.55	0.259	36.69
		14	3.75	10.25		15.2			

Table 4: Result of Experiment

4.1 Average Pressure Drop

Concentration (ppm)	Average Pressure Drop (psi)	
	Sodium Oleate	Sodium Stearate
0	13.5	13.5
400	7.5	10.375
600	6.5	7.125
800	9.375	8
1000	13	9.75

Table 5: Ave Pressure Drop

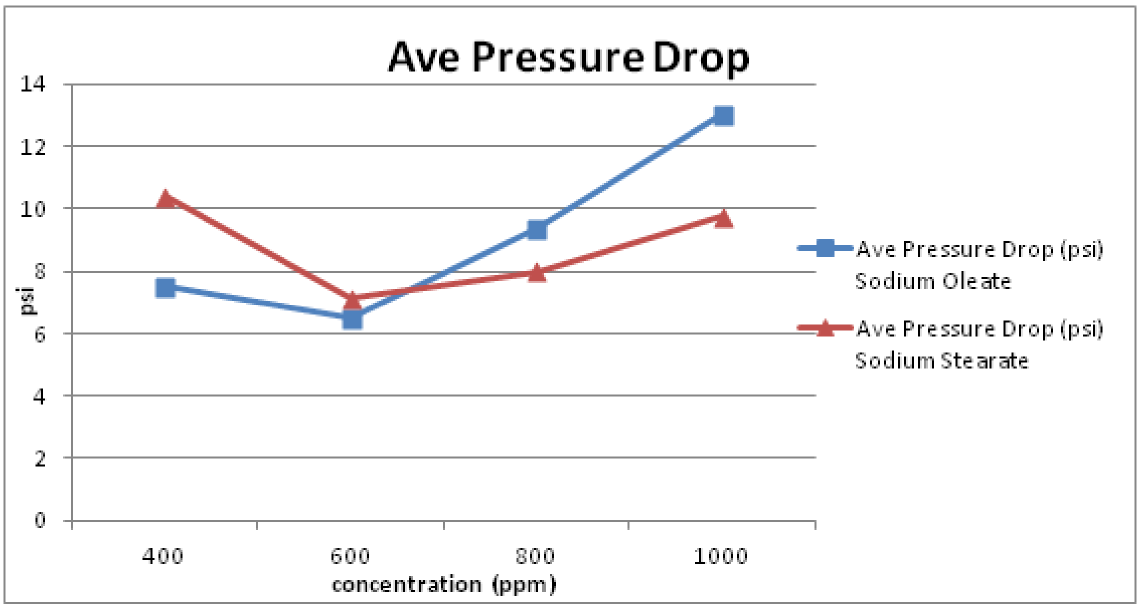


Figure 17: Average Pressure Drop

According to figure 17, we can see that initially, Sodium Oleate gives a lower pressure drop while Sodium Stearate gives a higher pressure drop until 600ppm. However, starting from 600ppm, Sodium Oleate exhibit higher pressure drop while Sodium Stearate produced a lower pressure drop eventhough both of them are slowly increasing until 1000ppm. The lowest pressure drop of Sodium Stearate is at 600ppm which is 7.125psi while for Sodium Oleate, the lowest pressure drop is at 600ppm which is 6.5psi.

4.2 Average Flow Rate

Concentration (ppm)	Average Flow Rate (gpm)	
	Sodium Oleate	Sodium Stearate
0	28.53	28.53
400	22.58	37.41
600	37.33	34.68
800	38.48	36.46
1000	36.46	36.69

Table 6: Ave Flow rate

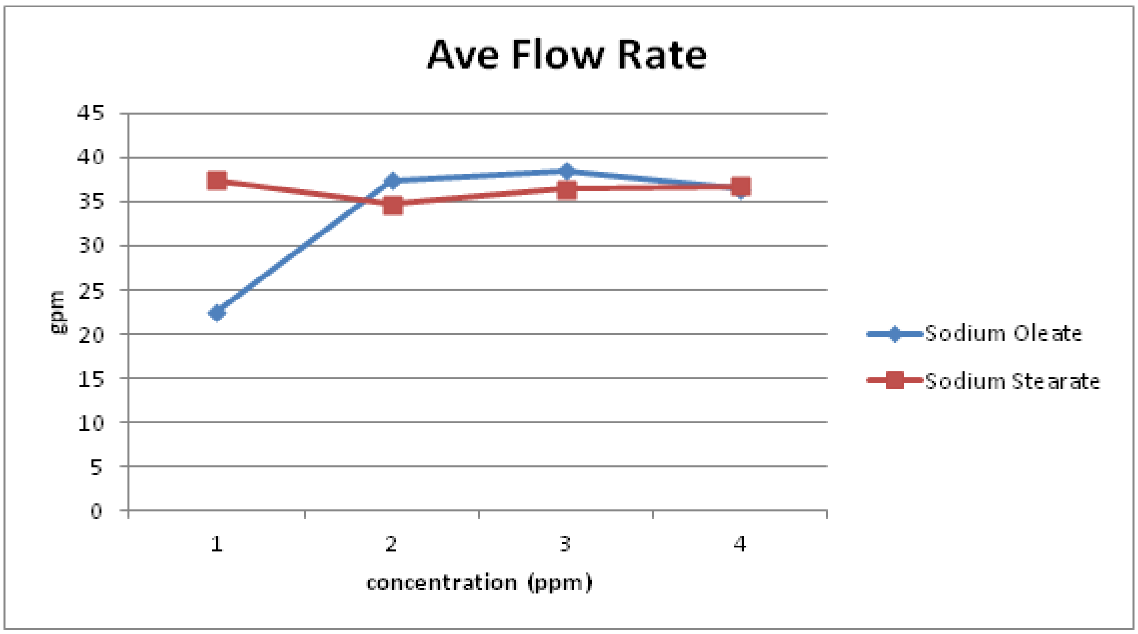


Figure 18: Average Pressure Rate

From this graph, we can see that Sodium Oleate showing a rapid increase at flow rate initially differently from Sodium Stearate which shows a slight decrease at initial concentration. this once again proof that Sodium Oleate is better DRA compared to Sodium Stearate since the former increase flow rate rapidly until it reaches its optimum state; where it starts to decline slowly. The pattern that we can see in Sodium Stearate is that the flow rate starts to increase at 600ppm however at a very small amount. But in the end, we noticed that both of the surfactants come to a very close point at 1000ppm. The highest pressure drop for Sodium Oleate is at 800ppm which is 38.48gpm while Sodium Stearate is at 400ppm which is 37.41gpm.

4.3 Percent Drag Reduction

Concentration (ppm)	%DR	
	Sodium Oleate	Sodium Stearate
400	44.44	23.14
600	51.85	47.22
800	30.556	40.74
1000	3.70	27.77

Table 7: % Drag Reduction

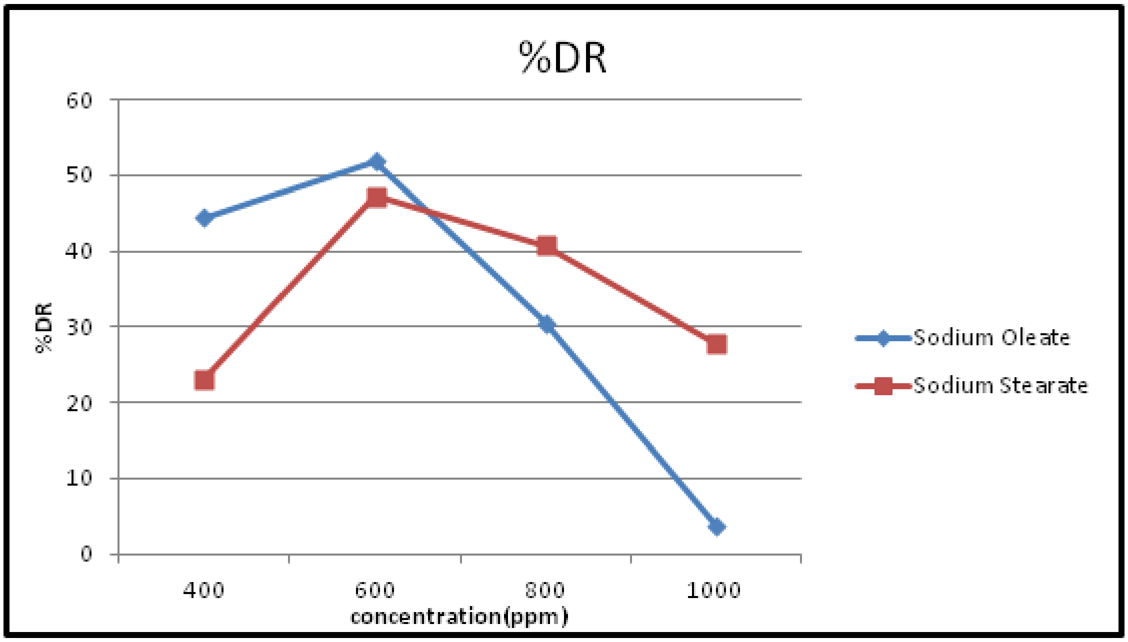


Figure 19: % Drag Reduction

For this plot, we see that the percent drag reduction of Sodium Oleate initially increase from 400ppm to 600ppm. But, after that, it starts to decrease drastically until it reaches 1000ppm. Quite the same pattern is produced for Sodium Stearate which at 400ppm, it shows a drastically increase until 600ppm. Soon after that, it shows a declination. However, Sodium Stearate shows a lower rate of reduction compared to Sodium Oleate. The highest %DR for both of the surfactants is at 600ppm which are 51.85% and 47.22% respectively.

4.4 Percent Flow Increase

Concentration (ppm)	%FI	
	Sodium Oleate	Sodium Stearate
400	38.65	15.76
600	50.14	42.66
800	22.48	33.76
1000	2.12	19.83

Table 8: % Flow Efficiency

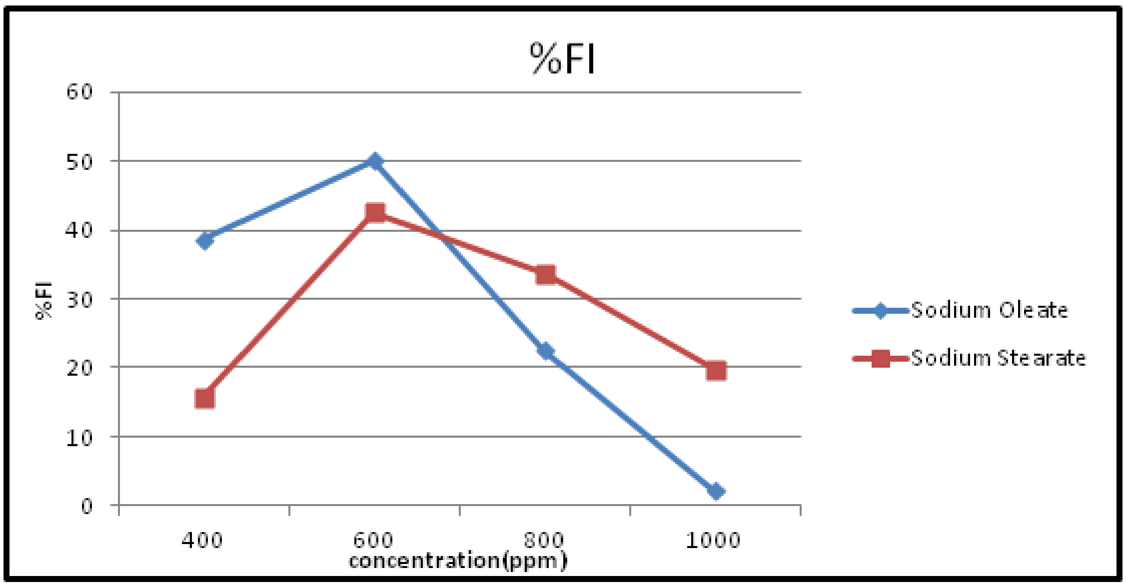


Figure 20: % FLow Efficiency

This graph does not distinct so much from the previous graph. Both of them show quite same pattern which is initially both of them were increasing however after that, they show a declination. As for Sodium Oleate, from 400ppm to 600ppm, it shows a big increment of %FI compared to Sodium Stearate. However, starting from 600ppm to 1000ppm, Sodium Oleate shows a decreasing pattern much lower that Sodium Stearate. At last point, the %FI of Sodium Stearate is much higher than Sodium Oleate. The highest %FI for Sodium Oleate and Sodium Stearate is at 600ppm which is 50.14% and 42.66% respectively.

4.5 Limitations

When doing this experiment, actually several limitations had been identified that affected the outcome of the project which are;

a) Time is of the essence

   Tight schedule on run the experiment to get a result and also time consuming on fabricating and assembling experiment setup is very demanding. Besides, preparing Sodium Stearate solution needs much time as every solution of those surfactant solutions has to be stirred for one hour. Mathematically, 8 eight hours need to be consumed to get eight different Sodium Stearate solutions.

b) Experiment room problems

   Regards this Final Year Project, experiment room is situated at Foundation Academic Blocks. Due to some reasons, there is a party which accommodates tons of chemical inside the experiment room. Because of those chemicals, it makes spaces to setup 15 meter experiment setup gets smaller.

c) Unable to use equipment at lab

   As student, it is quite hard for us to get permission to use several equipments especially when dealing with other department other than Petroleum Engineering. As a result, we did not get to measure fluids rheology which is could be another parameter to be analyzed.

4.6 Errors

Some errors could not be avoided when doing experimental work. Thus, we have to compromise these factors when evaluating the results;

a) 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. Throughout the experiment, there are some aspects which lead to this error.

As for examples, it is difficult to read the pressure reading at the pressure gauge as its needle moves upward and downward repeatedly and fast. Taking an average of that repeated reading is the only solution to overcome this type of error.

b) 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. For this project, this type of error happened at the time of read the reading at pressure gauge. Position of observer's is difficult to perpendicular to the plane of scale as the gauge is just about 25 cm above the floor. In order to minimize the effect of this error, the pressure reading were taken by its average reading of pressure.

c) 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

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion and Recommendations

As a conclusion, in this comparison between two surfactants as DRA, we can see that Sodium Stearate has shown a better result compare to Sodium Oleate. We choose Sodium Stearate as better DRA is because the pattern on the every graphs show that Sodium Stearate gives a smaller rate of increasing or decreasing and very consistent. While for Sodium Oleate, from all the graphs, we can see that it shows a drastically change of value and unsteady in decreasing or increasing. Eventhough both of them show quite the same pattern, but Sodium Stearate is much better than Sodium Oleate. Sodium Sterate at 600ppm gives the lowest average pressure drop which is 7.25psi. While for average flow rate, Sodium Stearate gives the highest at 400ppm which is 37.41gpm. The highest %DR and %FI for Sodium Stearate are 47.22% and 42.66% respectively. So we can choose the most optimum concentration of Sodium Stearate on concentration ranging from 400 to 1000ppm is between 400ppm and 600ppm because at this rate, it shows the average lowest pressure drop and highest average flow rate.

According to Ahmad Darabi(2009), by reducing pressure loss, we can optimize pipeline operation in several ways, such as increasing flow rate in the existing pipeline system whilst maintaining the operating pressure, reducing pipeline operating pressure whilst maintaining total throughput or flow rate, reducing energy and operating costs by lowering pumping energy along the pipeline system, and many other applications.

However, in order to achieve a more concrete result, there are several improvements being recommended in this project;

i. Try to change the orientation of the pipeline from horizontal to vertical so that we can know which way DRA works best. This will measure the effect of gravity to the performance of DRA.

ii. To investigate the effect of DRA to the reservoir rocks; how DRA works in formation that make it able to improve flow capacity.

iii. Performing maintenance on the equipment used such as pump so that our data will be rigid in integrity.

iv. Adding injection skid into pipeline because it will help DRA to flow in one direction thus no backflow will happen.

v. To test DRA on oil so that we know both effect of DRA on water and oil.

vi. To measure the corrosion inhibitor ability of DRA because many journals/papers had shown that DRA is also able to reduce corrosion on their transport line.

vii. To test on the rheological properties of DRA by investigating their elasticity and shear degradation property of DRA so we can know the effect of these properties on drag reduction.

In oilfield application, we can say DRA help in energy saving of the system thus reduce the cost of operating of pipeline. It will also increase the oil production and increase overall recoverable reserves.

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