Effect of Drag Reducing Agent (DRA) In the Injection Well

By

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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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ABSTRACT

The study of drag reducing agent (DRA) is increasing since researcher find on his study of the effect of mechanical degradation of polymer inside the pipe. Throughout the experiment, the studies conducted will assess the effectiveness of long chain polymer with a very high molecular weight DRA to increase the flow rate and reduce the frictional pressure cause by turbulence in the pipeline drop. This is the beginning of using the DRA in the oil and gas pipeline. In the oil and gas industry DRA is commonly used to increase the flow rate inside the pipeline. However, less study has done on the effect of DRA in the injection well. This project will discuss on the application of DRA in the water injection well and focusing on the effect drag reduction for polymers which is Polyacrylamide (PAM) at the standard temperature. In addition, difference injection rate is used to measure the performance of the DRA in the pipeline. Lastly, the correlation to find the optimize point between flow increase in the pipe and the permeability reduction in the reservoir. The results show performance of the DRA in the pipe of injection well. It is found that the best performance of DRA is at 2.5 gram in the 50 liters of water. After the correlation it is found that the optimize performance for DRA in the injection well and reservoir is when flow rate is at 30 liters per second.

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CHAPTER 1

INTRODUCTION

1.1 Background

Drag reducing agent (DRA) is commonly study in the oil and gas industries and the current development have proven that it is very beneficial to these industries especially for drilling and maintenance of pumping application in the pipeline. Basically, the additive can be classified into three groups which are polymer, surfactants and fibbers. When DRA is applied, it will improve pumping power, reducing energy consumption in turbulent flow system. The researcher discovered the effect of DRA around 50 years ago in long oil pipeline and high percentage reduction of the pressure loss in pipe has been achieved. This researcher has studied the mechanical degradation of polymer molecules in a simple flow apparatus.

In the oil and gas industries the liquid flow through the pipe will have the problem when it is in turbulent flow because while transporting the liquid, the frictional pressure loss occurs. The frictional pressure loss will reduce the performance of the liquid flow as a result the flow capacity will reduce. So, drag reducing agent (DRA) is the long chain polymer can overcome this problem to reduce the frictional pressure drop cause by turbulent flow in the pipeline. Addition small amount of polymers to the fluid in the turbulent flow can yield significant increase in the mass flow for particular pressure gradient. By reducing the frictional pressure in the pipeline, it is allow the optimization of the operation of the flowing fluid in the pipeline.

In the large oil and Gas Company for example in the Chevron Texaco, Nigeria evaluated the test on the drag reducing agent in the pipeline because the Inda platform pipeline in the April 1998 was facing deviation in the pipeline pressure drop between the actual and theoretical value. A lot of troubleshooting had been carried out to figure out the problem but the production of the oil was not beyond 18400 bopd. After injecting drag reducing agent into the pipeline, the production increase to 20000 bopd. Economic evaluation was perform and the company decided to use drag reducing agent for as long as it is needed or shut in and wait for new pump.

There are other applications use drag reducing agents (DRA) for example:

1. Medical application
   DRA is used in medical application to protect against Atherogenesis[1].
2. Fire fighting hoses
   DRA is very effective in fire hose streams, providing dramatic increases in hose steam pressure, reach, and volume.

1.2 Problem statement

In the pipeline, the liquid is flowing through it will face the friction between wall of the pipe. The pressure at the outer pipe is less than the theoretical pressure due to the friction. Then, the application of drag reducing agents (DRA) into the pipeline will reduce the pressure loss in pipe flow. However, most of the studies use the application of drag reducing agents (DRA) in transporting oil from platform to the onshore and less study on the effect of drag reducing agents (DRA) in the injection well. Moreover, pressure expected at outlet of the injection well is important to re-pressurise the reservoir.

Since the current literature prefer that drag reducing agents (DRA) concentration will affect the pressure reduction in the injection well. So, the author will carried out the experiment to calculate the performance of drag reducing agents (DRA) in reducing drag using flow through tube. This paper also introduce the effect of the injection rate of drag reducing agents (DRA) toward the pressure loss in the pipe using polymer drag reducing agents (DRA) which isPolyacramide (PAM). At the end of this experiment the author will stimulate the evaluation with the real field situation. Lastly, the author will do the correlation of this experiment with the pressure in the reservoir rock to optimise the oil production.

1.3 Objectives and Scope of Study

1. To Study the effect of pressure drop in the injection well.
    a. Different of injection flow rate
    b. Different concentration of polymer
2. To calculate the pressure different at each parameter change.
3. To correlate and find the point of optimisation between the pressure in the pipe and the pressure in the reservoir

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

2.1 Drag Reducing Agent (DRA) in general

Drag reducing agents (DRA) are commonly used in the pipeline to increase the flowing capacity of the liquid through the pipe. Drag reduction using DRA effect in the turbulent known as Tom phenomenon was discovered by Toms 1948. In his single phase turbulent flow, experiment he noticed that by adding small amount of long chain polymer into the flowing fluid, it will affect to high frictional drag reduction [2]. So, the addition of small concentration of high molecular weight polymer to the fluid, high reduction in frictional pressure drop for turbulent flows and lead to increase flow rate of fluid in the pipe [3]. Usually, most of the DRA is at higher concentration plus when the concentration of DRA solution is increase, the surface tension will decrease and the dynamic surface tension. Moreover, at higher temperature and mechanical degradation most of polymers cannot withstand. Meanwhile, the drag reduction affect give many advantages to the industrial application. In the case of the study the author will limit the study only for two DRA that will use in the experiment which is Polyacrylamide (PAM). Figure 2.1 showsthe photograph of DRA.

Figure 2.1 Polyaccralamide (PAM)

2.2 Application of DRA

Drag reducing agent has a great potential in the industrial applications for example power saving and reduce of power consumption in the pipeline system. In designing piping system, turbulent flow requires a higher input of energy from pump than laminar flow that will lead the company to spend lots of money to build another pumping station. So, to increase the flow capacity the company need to add pumping station at the pipeline systems.

2.2.1 Transportation in pipeline and injection well

The friction between water and inner pipe wall that will occur highly during turbulent flow and this friction will reduce by adding small amount of high molecular weight polymer. (DRA) is high molecular weight and long chain polymer that will reduce the pressure drop in the turbulent flow to increase or maintain the flow rate. In his experiment he had confirmed that the (DRA) reduce frictional pressure drop in the tube and increase the flow capacity and the (DRA) shows very sensitive to shear where the effectiveness decrease with high shear due to polymer chains degradation. (DRA) also decrease the corrosives [2]. The figure below shows that the flowing fluid inside the pipeline there are three layers which are Laminar Sub layer, Buffer region and turbulent core.

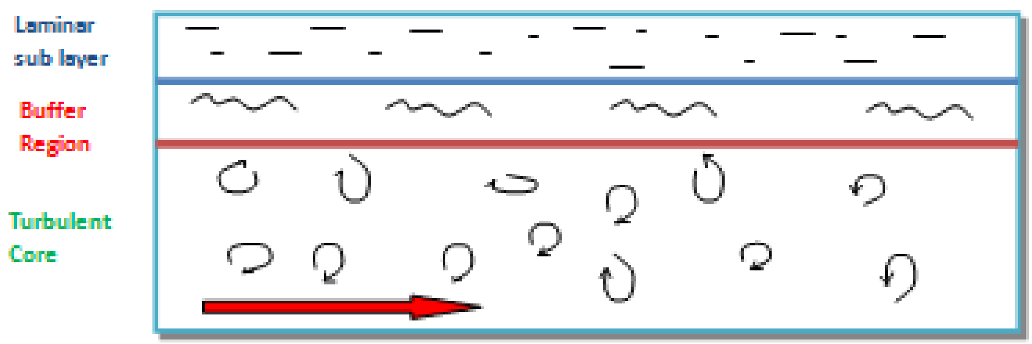

Figure 2.2 Drag Reductions in Pipeline

From the Figure 2.2 it shows that liquids inside the pipeline contain three layers during flowing fluid for Turbulent flow which are laminar sub layer, buffer region, and Turbulent core at the centre [5] whileTurbulent flow can occur in the boundary layer near solid surfaces in the pipeline and the associated fiction increased as the flow velocity increases. The energy losses due to turbulence friction can be a very high magnitude.

Drag reducers are believed to work by stabilizing the pipe wall sub layer by reducing the frequency of turbulent eddy bursts from this region [6]. So, the frictional drag and hence pressure drop in the pipeline is reduced due to the rate of energy dissipation within the eddy flow. By injecting small amount of drag reducing agent at the outlet of the pump stations the reduction in rate of energy dissipation due to fluid friction could be achieved. On other hands, a drag reducer will shift the transition from laminar flow to a turbulent flow to higher flow velocity. Furthermore the main purpose of drag reduction is to delay the onset of turbulent flows and reduced in size as the intermediate sub layer expands. When injected continuously into a pipeline at concentrations of typical 40-100ppm of formulated product, turbulence and resulting frictional pressure drop can be reduced by as much as 60% and also acts on the formation to increase flowing fluid capacity of the system [10].

In addition, Drag reducing agents(DRA) also used for the reducing friction pressure during pumping and therefore boosting the efficiency of pumping rock forstimulating treatment of tight gas reservoir. High molecular weight is typically expected more effective friction reduction because it can cause friction reduction by interacting with eddies of turbulent flow. Commercially, friction reducing polymers are come from many forms, ionic emulsion polymer and lately friction reducers are the choices of many applications. From a number of studies, there are relationships between the performance of friction reducing polymer with their rheological behaviour in extensional flow field to reach an extended conformation and resist degradation of molecular weight due to action of shear force. Although friction reducing polymer may come in many forms, ionic emulsion is mostly choice in many application [4].

Drag Reducing Agent (DRA) is deal with the state if drag reduction in pipeline for liquid transportation. When a liquid flow through the pipeline, shear stresses developed between liquid and pipe inner wall and this shear stress will result of friction. At the same time, turbulent flow occur during the flowing fluid hence the higher the degree of turbulent flow of liquid.

Therefore, turbulent and drag reducing increase when the flow rate increase while diameter of the pipe decrease according to the Reynolds number formula below [3].

$$Re = \frac{\rho V D}{\mu} \tag{2.2}$$

ρ = fluid density

V = mean fluid velocity

D = pipe diameter

μ= fluid viscosity

Moreover, it is a wide potential application for oil industry because high pressure drops reductions can be achieved. Drag reducing agent is flow improvers inside the pipeline because, small amount of polymers (10ppm-30ppm) injected into the flowing system will increase the pressure drop and the transported volume of oil will be increasing [6].

Most of the country use drag reducing agent (DRA) achieved very good impact to their companies in the recent years for example in the Chevron Texaco. John U. Ibrahim wrote that a type of (DRA) is used as flow improvers at the Chevron Texaco's Inda platform in Nigeria. The (DRA) injected to the downstream based on the principle of the effect the performance by the shear point in the pipeline, being a suspension polymer, once dissolve in the crude oil [8]. In addition, the used of (DRA) was contributed to yield grater benefits to the company. Effectiveness of friction reduction of polymers depends on compatibility between friction reducing polymer and liquid. In the other hand performances of friction reducer are highly influenced by presence of salts, pH value, corrosion, etc [9].

2.2.2 Effect of DRA in formation

In formation, in most cases DRA is used in water flooding and water injection system. The water injection system is specifically to maintain the reservoir pressure. Using water flooding system is to reduce the mobility ratio of working fluid and the mobility ratio of water is higher to increase the efficiency of water and push the oil toward the productions system. In the formation, the viscosity is very important in order to sweep the oil. So, DRA will increase the viscosity in the water injection system to sweep the oil to the production system. The picture below shows the DRA work in formation [12].

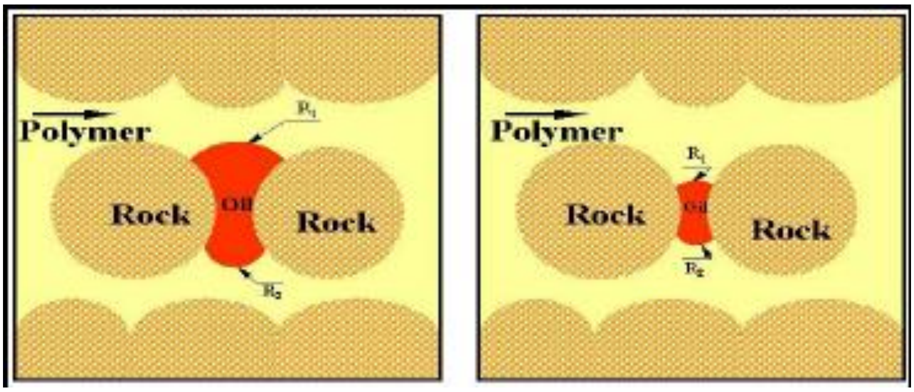

Figure 1.3 Application of DRA in Reservoir [12]

2.2.3 Effect of temperature

Effect of temperature on drag reduction characteristics of polymers in fresh water is shows that the percent drag reduction as a function of solvent Reynolds number. It can be seen from this that the highest drag reduction is achieved at ambient temperature and it decreases with increasing temperature. Itcan also be seen that the effect of temperature is more severe at lowerReynolds numbers. As Reynolds number increases, turbulence intensityincreases and the effect of temperature is minimized. Also, the decrease in drag reduction because of increasing temperature ismore pronounced. For all practical purposes, polymers can be considered to exhibit excellent drag reduction characteristics in fresh water at ambient and elevated temperatures.It is known that water is a good solvent but its solvent power is drastically decreased by increasing temperature due to a decrease in hydrogen bonding ability. This reduces the interactions between the polymer and the bulk solvent which translates to a decrease in drag reduction. Another consequence of decreased polymer and solvent interaction is the decrease in the radius of rotation of the molecule. Therefore, viscosity decreases as temperature increases. As a result, drag reduction decreases [11] and [12].

Another parameter is the decrease in solution viscosity at higher temperature which results in decreasing the elongation viscosity. As a result, turbulent fluctuations and eddies will increase which increases drag [13]

2.3 Performance of DRA

The polymer destroys the turbulent disturbance waves, which are the cause of drop formation and which help the water film to spread upward around the pipe circumference. At maximum drag reduction almost all of liquid flows along the bottom wall. The interface is relatively smooth and the friction is higher. So, Pressure reduction in pipeline can be analysed using percentage drag reduction formula [7].

$$\%DR = \frac{\Delta P - \Delta P_{DRA}}{\Delta P} \tag{2.2}$$

%DR = percent of drag reduction

ΔP = different between pressure drops

ΔP_{DRA} = pressure with DRA

Thus, percent flow (or throughput) increase (%FI) can be calculate using the following equation [6].

$$\%FI = \left\{\left[\frac{100}{100 - \%DR}\right]^{0.556} - 1\right\} \times 100 \tag{2.3}$$

Friction reduction can be calculated using friction reduction (%FR) formula.Formula below is use to find the drag reduction [3]. For a given flow rate, the percent friction reduction (%FR) is calculated as follow

$$\%FR = \frac{f_0 - f}{f_0} \times 100\% \tag{2.4}$$

Where f is Fanning friction factor for system with drag-reducing polymer, and f_0 is the Fanning friction factor for base Newtonian fluid without any drag reduction. The value of f is calculated from the measured values of differential pressure, ΔP, fluid and tubing characteristic as

$$f = \frac{\Delta P \times D}{2L \times \rho \times v^2} \tag{2.5}$$

Where D is inner tubing diameter, ρ is fluid density, L is the length of test section, and v is linear fluid velocity.

2.4 Field case study

2.4.1 Ukpokiti Field, Niger Delta

The first discovery well drilled was found in Western Niger Delta offshore, Ukpokiti to have around 500 MMSTB recoverable oil reserve. It was first drilled in late 1992. It has one gas bearing zone, and two oil bearing formation. In the field development project, the field was supposed to flood the reservoir with 40,000 bbl/day, however during the initiation of the project, the facilities installed could only deliver up to 31,000 bbl/day. So, they decided to use the Conoco Drag Reducer (CDR) after Looking through all aspect of the problem. The picture below shows that the place where the oil is drilled.

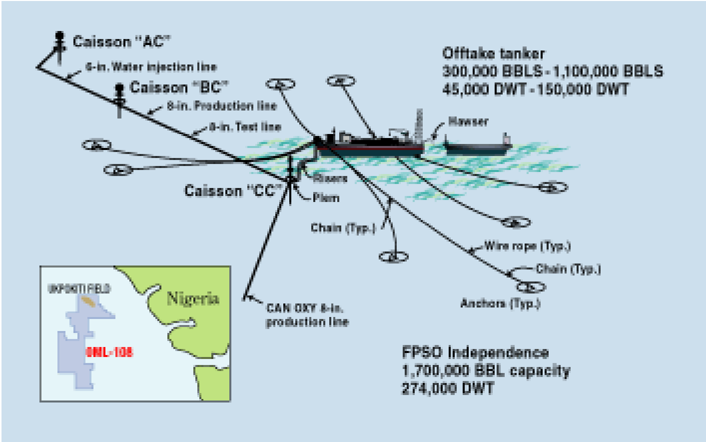

Figure 2.4 Ukpokiti, Niger Delta Offshore [12]

Before the CDR was applied, several tests were done to evaluate the solution. The first test was the fluid incompatibility test to determine the reason behind loss of injectivity. Some of the water from the injection water treatment system was taken, and they found several factor causing the lower injection rate. They found that acid which they had been used in the previous treatment to restore the injectivity produces solid mixture when added to the emulsion, and they decided not to use acid in further treatment. Salinity from the injection water and the formation aquifer was also found to be different, eliminating the possibility of water breakthrough. Using the Watson test, the company concluded that, the CDR is compatible with other chemicals used in this project, and shows no negative impact on both the operation, and the environment [14].

2.4.2 Apiay, South America country of Colombia

In the South America country of Colombia, ECOPETROL SA (Ecopetrol) produces heavy crude oil. The Apiay Pipeline (Apiay) is wholly owned and operated by Ecopetrol and runs through rural Colombia. The pipeline delivers from the Apiay, La Reforma,Chichimene, Castilla and Suria reserves. The baseline flow of theuntreated system yielded an approximate rate of 94,000 barrels per day (BOPD) and approximately rate of the pipeline is 103,000 BOPD. The test involves a given volumeof DRA, an injection skid and a pipeline flowing in transition/turbulent flow. A typical test involves rigorous measurement of the pipeline baseline prior to injecting DRA, followed by the injection of two to three different concentrations of DRA. Economic evaluation principles show that it is capable of producing more crude than could be delivered to market via an existing pipeline. The economic model evaluated multiple options, including capital investment in new pipelines, installing more or larger pumps or incurring a variable cost to inject a DRA to eliminate the constraint. Their interim solution is to apply a DRA to provide an economic benefit, allowing production levels to increase prior to the completion of the pipeline project in one year’s time. This latest frontier of increased delivery of produced heavy crude oil to market. For more than 25 years, increasing operational flexibility and throughput capacity while substantially increasing bottom line profit potentials [15].

2.5Project relevance and Feasibility

Relevance

- DRA is very potential cost efficient
- DRA is widely used in oil and gas industry

Feasibility

- Equipments are available in the lab
- Project can be finished within timeframe

CHAPTER 3

METHODOLOGY/PROJECT WORK

3.1 Research Methodology

Start

↓

a) Literature Review

- Study online journals on polymers, and their effect towards drag reducer.
- Read the fluid mechanic book for flowing fluid
- Learn on basic polymer action

↓

b) Preparation on Lab Work

- Identify the availability of equipment
- Prepare solution of brine, treated brine with DRA, and pipeline mechanism.
- Prepare methodology to run experiment

↓

c) Lab Work

- Measure the equipment used (diameter tube, Efficiency of the pump)
- Run experiment (Flowing fluid trough tube)
- Collect final data

↓

d) Data Analysis

- Calculate drag reduction and determine the performance of each concentration
- Run calculation to find the optimization point of the tube and the reservoir.

↓

e) Discussion

- Analysis and compare results.
- Objective achievement

↓

Conclusion and final documentation

3.2 Summary of Key Milestone and Gantt chart

Table 3.1: Summary of Timeline of Project

	2012								
Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Selection of FYP title	■	■							
Literature Review		■	■						
Submission of Peliminary Report			■						
Lab Work Preparation			■						
Submission of Interim Report				■	■				
Experimental Work					■	■	■		
Submission of Progress Report						■	■	■	
Discussion and Calculation on the outcomes						■	■	■	
Oral Presentation									■
Report Documentation									■

	2012								
Milestone	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Completion of Interim Report (FYP 1)					■				
Experiment with polyaccrylamide					■	■			
Experiment with difference concentration						■	■		
Report Documentation								■	■

3.3 Summary of project activities

Table 3.2: Summary of Project Activities

Task	Objective	Expected Result
Effect of flow rate	To measure optimum injection rate for DRA	Flow rate increase by increasing injection rate
Effect of different concentration of polyaccrylamide(PAM)	To study the different DRA concentration effect in the pipe of injection well.	At best concentration of DRAs will have the good result for water flowing in the pipe
Measure the percentage pressure reduction	To assess the percentage of the pressure reduction in pipeline	Justify and evaluate the above expected results
Correlation between pressure in the pipe and pressure in the reservoir	To calculate the optimise pressure in the pipeline and in the reservoir	Optimise pressure between in the pipeline and reservoir will increase the production oil

3.4 Key Milestone and Gantt chart FYP 1 and FYP 2

Table 3.3: Timeline for FYP 1

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic	■	■						Mid-semester break							
2	Preliminary Research Work		■	■	■	■										
3	Submission of Extended Proposal Defence						●									
4	Proposal Defence									■	■					
5	Project work continues											■	■	■		
6	Submission of Interim Draft Report														●	
10	Submission of Interim Report															●

● Suggested milestone

■ Process

Table 3.4: Timeline for FYP 2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									●							
3	Project Work Continues									■	■	■	■	■			
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone

■ Process

3.5 Equipments and Consumables

In this experiment there are two main equipments used in the experiment which are Pressure Transducer, Flow Meter and three type of consumables needed for the testing which are, polyacrylamides (PAM), polysaccharide (Xanthan Gum), and brine. These equipments and consumables will be discussed further in this chapter.

3.5.1 Brine

The brine is prepared by diluting 2500g of normal salt (NaCl) into 50 litre of distilled water, and mixed inside the tank. This would result in 2500000 ppm of brine, which considered being low salinity brine. In this experiment, the salinity of the brine will be fixed at 2500000 ppm at each run.

3.5.2 Polyacrylamide (PAM)

The solution is prepared according to the methods [2]; the fresh DRA was prepared by mixing 2.5 g polyacrylamide (powder form) into 50 litre of prepared brine, and mixed gently pump flowing through the pipe for 1 hour. Then, each time before each run, the fresh DRA will be broken at high shear rate after the DRA going through the pump and the pipe to simulate the real condition of DRA in the field use. All run will be conducted at the same concentration of 50 ppm polyacrylamide, with the broken condition.

3.6 Experiment procedure

In this project the experiment is divided into two categories, difference concentration of Polyaccralamide (PAM) and difference flow rate using same experiment method. Figure 3.2 shows that the schematic diagram of the experiment. 50 liters of brine solution/water is filled in the tank. After opening valve the water moves to the positive displacement pump. Then the positive displacement pumps moved the water throughout the pipe and the water is flowing through the flow meter, pipe and through the pressure transducer and lastly to the tank.

3.6.1 The difference concentration with difference flow rate test.

For difference of concentration test, there are three concentration of PAM at the same quantity of water will be tested.

The procedures are as follows;

1. Clean the tank and pipe from any contaminant and check leakage through the water flow.
2. Set up the main component equipments for example pump, pipe, flow meter, and pressure transducer throughout the 6 meters length of pipe.
3. Make the brine solution and polyaccralamide (PAM) solution.
4. Fill 50 liters of brine solution into the tank.
5. Switch on flow meter, pressure transducer, and pump. Then start the pump and observe the water flow for 15 minutes.
6. Set the flow rate at 20 liters/s and see the pressure drop.
7. Repeat the experiment with 25 liters/s, 30 liters/s, 35 liters/s and 40 liters/s.
8. Then, insert the solution of polyaccralamide (PAM) into the tank and observed the flow of the fluid through the pipe.
9. Repeat step 4 until 6 with 2.0gram, 2.5 gram, 3.0 gram.
10. Record all the data’s in the excel sheet.
11. Correlate the data with the data from the reservoir to find the optimum point between pipe and reservoir.

The summary of the difference concentration with difference flow rate test is as follow;

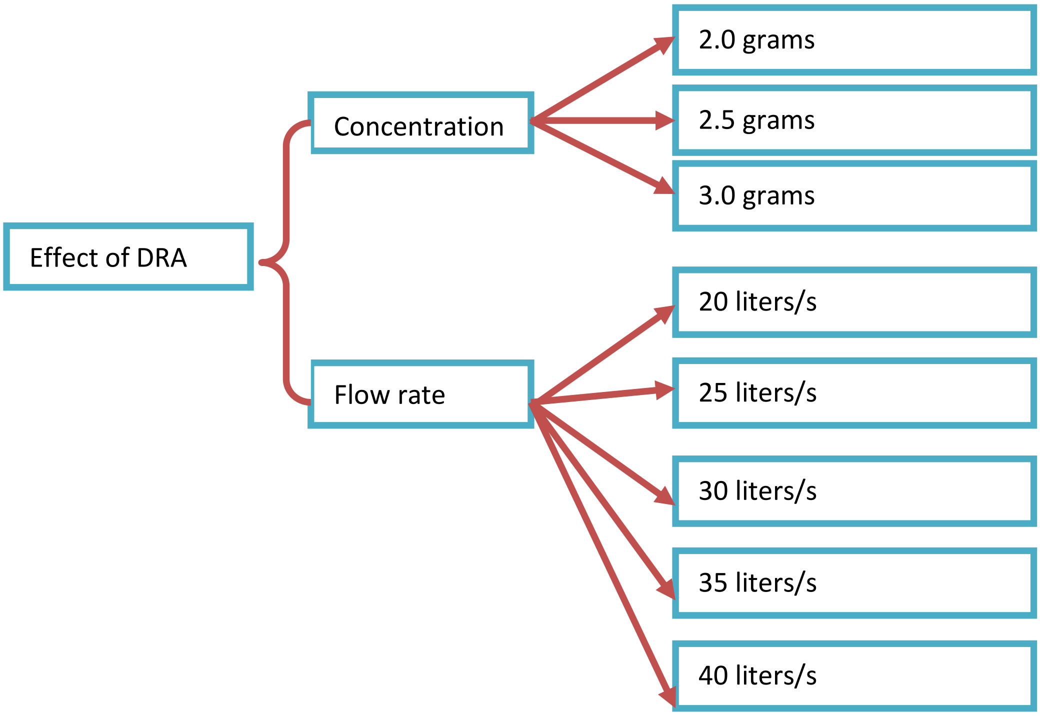

Figure 2.1: Summary of difference concentration and difference flow rate test

Schematic Diagram

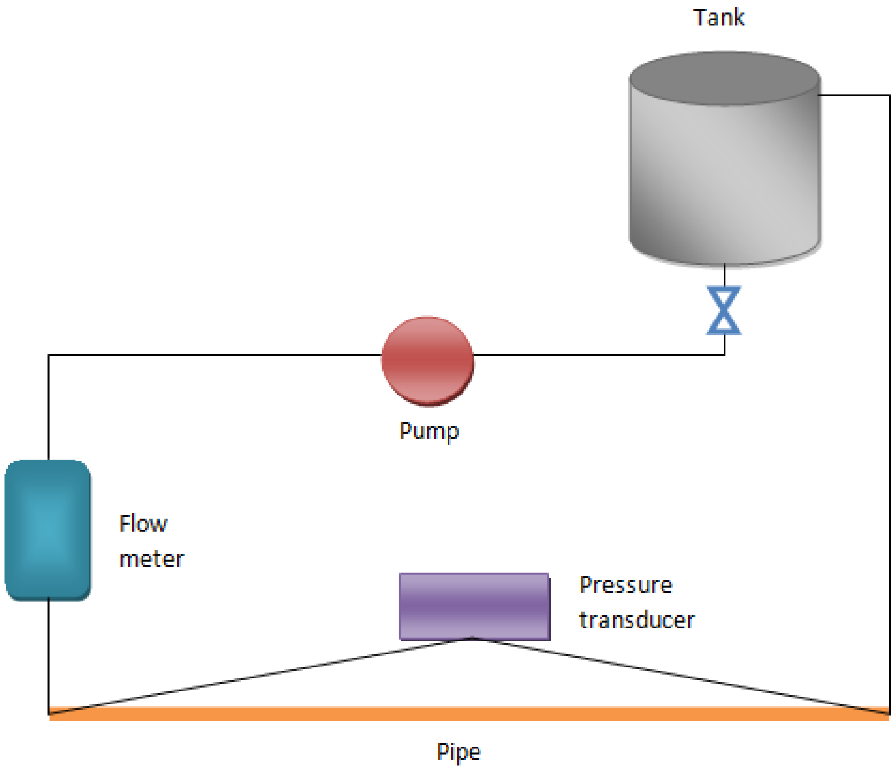

Figure 3.2: Schematic diagram of the experiment

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Effect of flow rate

4.1.1 Effect of flow rate without DRA

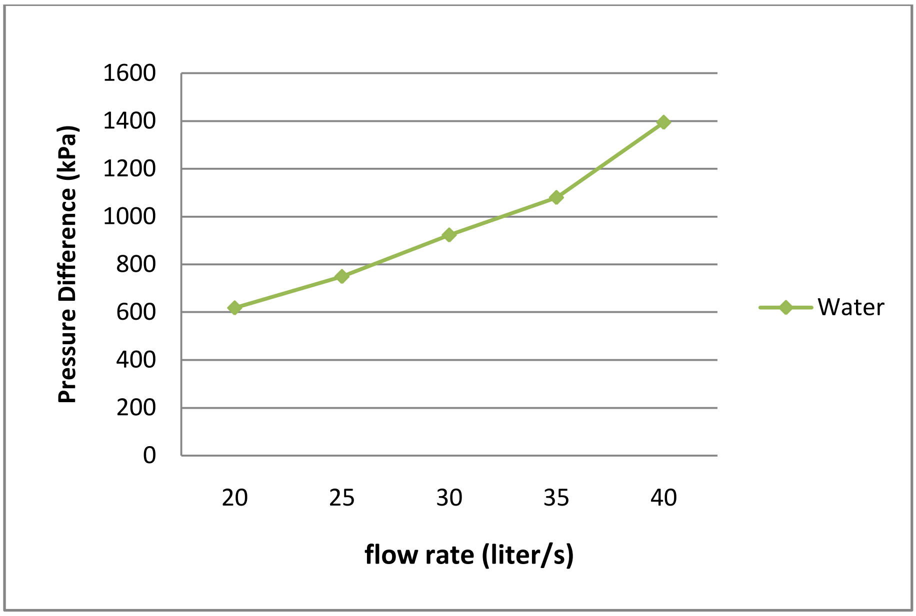

Figure 4.1: Pressure Reduction versus Flow Rate of water without DRA

Based on the Figure 4.1, it shows that the increasing of the pressure difference from 20 liters per second until the end 40 liters per second. The increasing of the pressure difference is not consistence. It is because when the flow rate increase, the turbulence flow increase. Then, the pressure difference will be increase because the turbulence flow will increase the resistance of water with the inner pipe wall. It is showsthat the pressure drop is highest at the flow rate at 40 liters per second. Figure 4.1 show pressure reduction increases when the flow rate increase. Initially at least flow rate which is 20 liters per second the pressure shows 617.675 kPa. At maximum flow rate which is 40 liters per second the pressure reduction is liters per second the 1393.975 kPa.

4.1.2 Effect of flow rate in the DRA solution

Figure 4.2, Figure 4.3, and Figure 4.4 below show the comparison of pressure reduction of DRA and no DRAs.After adding 2.0 grams of DRA in 50 liters of water, the pressure reduction is decrease from 20 liters per second until 40 liters per second. Figure 4.2 shows that the after adding 2.0 grams of DRA the pressure reduction of DRA is lower than the pressure reduction of no DRA.

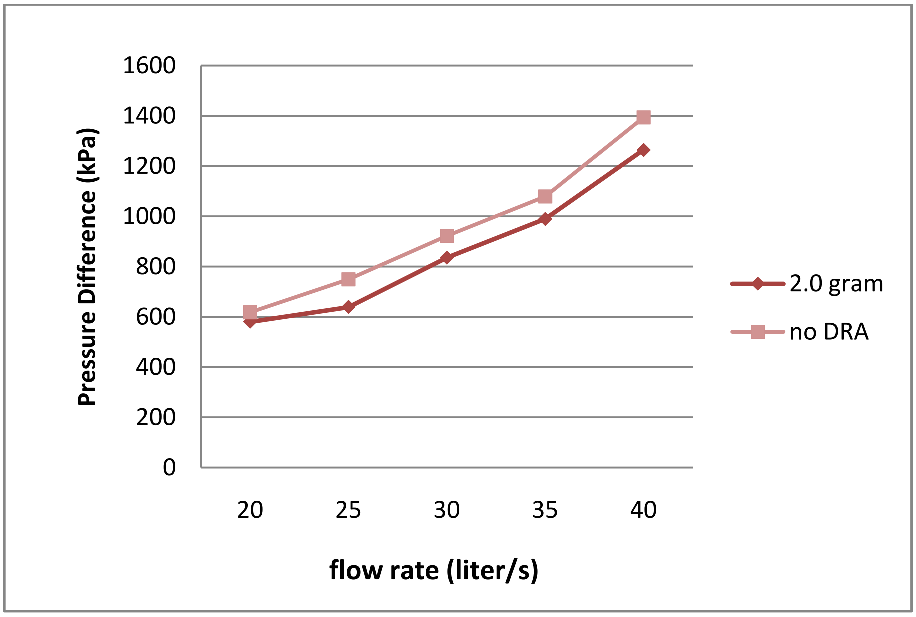

Figure 4.2: Pressure Reduction versus Flow Rate of 2.0 grams of DRA

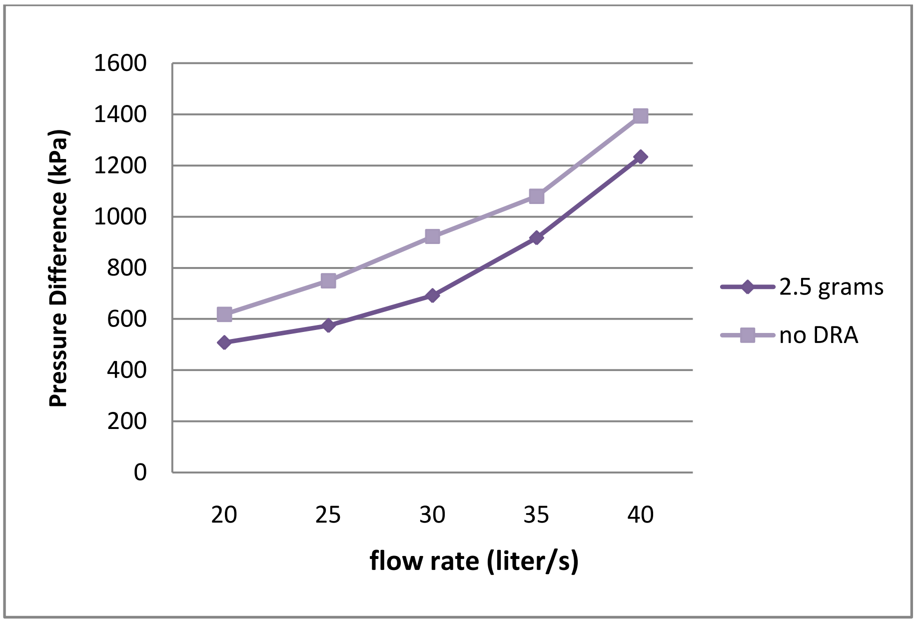

Figure 4.3: Pressure reduction versus flow rate for 2.5 grams of DRA

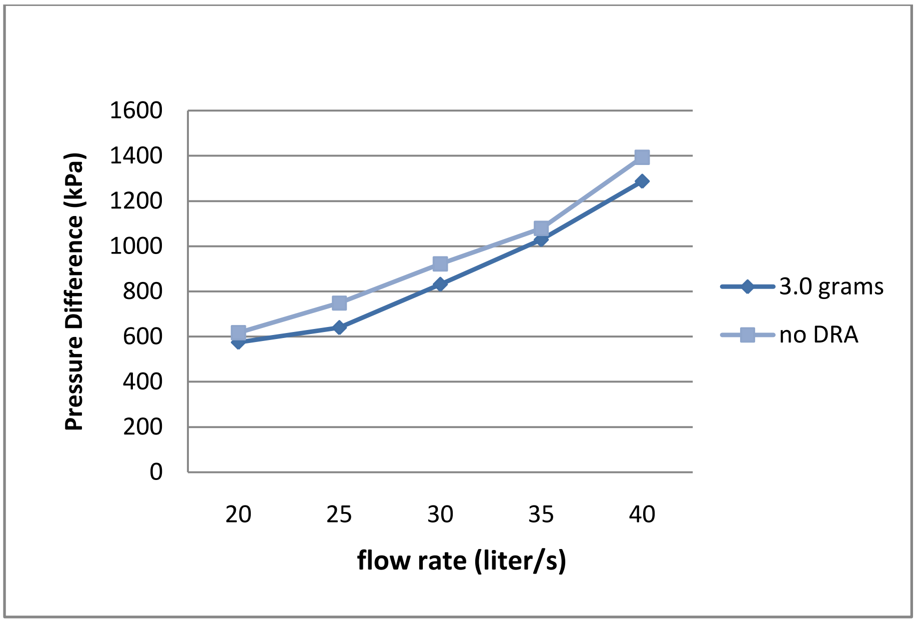

Figure 4.4: Pressure reduction versus Flow rate for 3.0 grams of DRA

Figure 4.5 shows the summary of pressure reduction versus flow rate for 2.0 grams DRA, 2.5 grams of DRA, 3.0 grams of DRA, and no DRA. It is shows pressure reduction between the DRA and the most effective quantity DRA to be added to 50 liters of water. Figure 4.5 shows the lowest pressure reduction is when DRA at 2.5 grams.

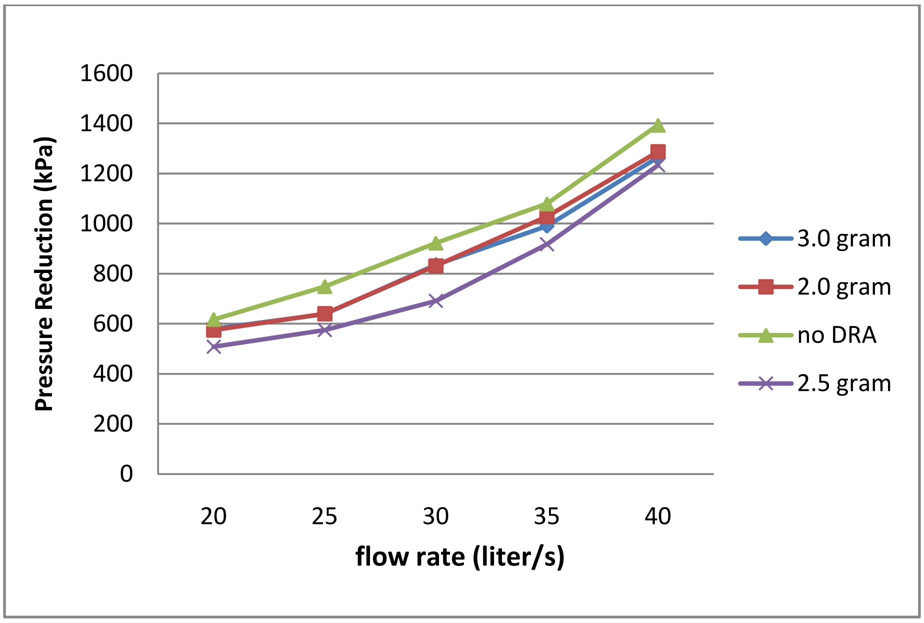

Figure 4.5: Summary of Pressure reduction versus Flow Rate

From the results, it is clearly stated that, when the flow rate increase the reduction pressure increase. When the flow rate increase it will increase the turbulence flow causes the higher shear force between the water and the inner pipe wall. For difference concentration of DRA also give difference performance for pressure reduction. Figure 4.5 shows the difference graph behaviour when the DRA is at difference state of concentration. The result showed that DRA at 2.5 grams give the lowest pressure reduction for difference flow rate comparing to 2.0 grams and 3.0 grams. From the Figure 4.5 it is proved that the DRA reduce the drag pressure drop however it is not significant with the increasing of the DRA concentration.

4.2 Performance of DRA

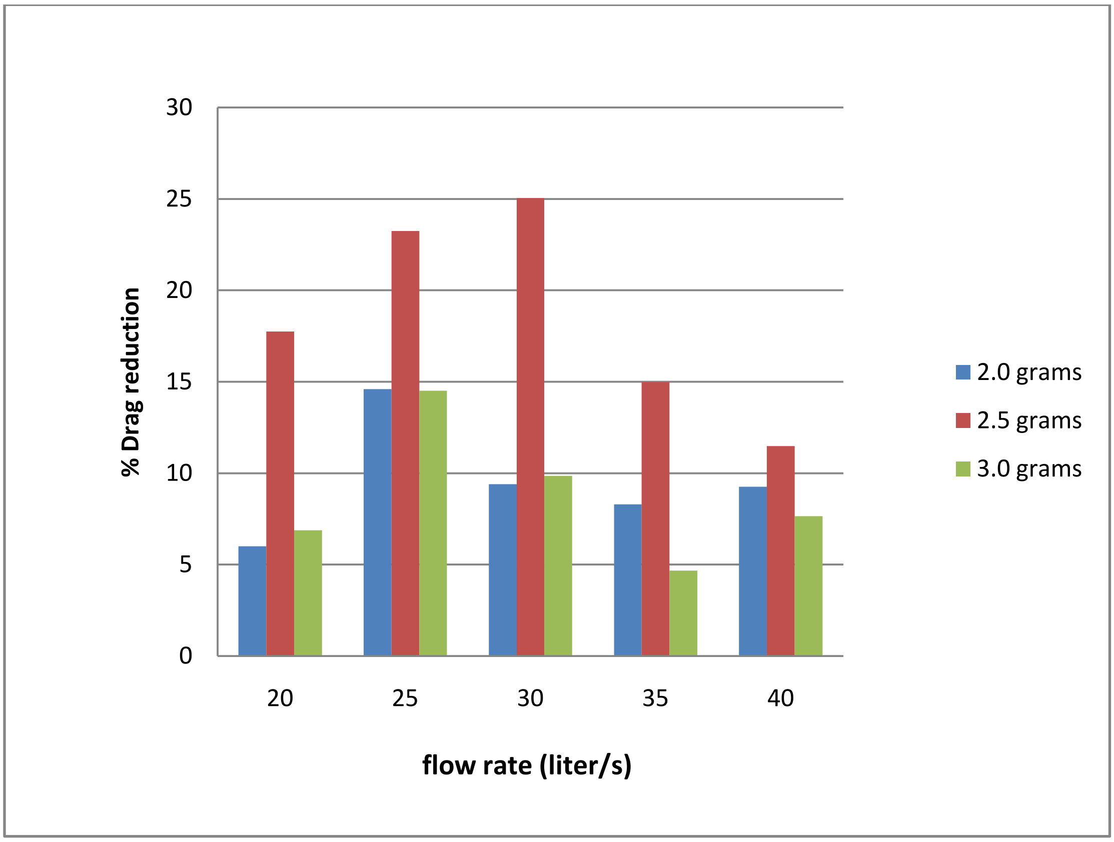

Figure 4.6: Percentage Drag Reduction versus Flow Rate

Figure 4.6 shows the percentage of drag reduction versus flow rate. From the graph, the performance of 2.5 grams of DRA is increasing from 20 liters per second until 30 liters per second, and then it is decreasing until 40 liters per seconds. The highest percentage of drag reduction is at 2.5 grams compare to 2.0 grams and 3.0 grams. At 30 liters per second the flow rate the 25.039% of drag reduction is highest for 2.5 grams of DRA. For 2.0 grams and 3.0 grams, the highest percentage of drag reduction is when the flow rate is at 25 liters per second which are 14.598% and 14.504%.Based on Figure 4.6 percentage of drag reduction is always higher for the DRA is at 2.5 grams. The highest drag reduction is when the flow rate is at 30 liters per second which is 25.039% because it is drastically increasing until flow rate 30 liters per second then the drag reduction is decrease. Concentration of DRA at 2.0 grams and 3.0 grams is no consistently increasing and decreasing. This is approved that the concentration give and effect to the flow rate because it is not proportional to the concentration because when the concentration of DRA is higher, it will cause the viscosity of the fluid increase. The higher viscosity will lead to need higher power to move the fluid.

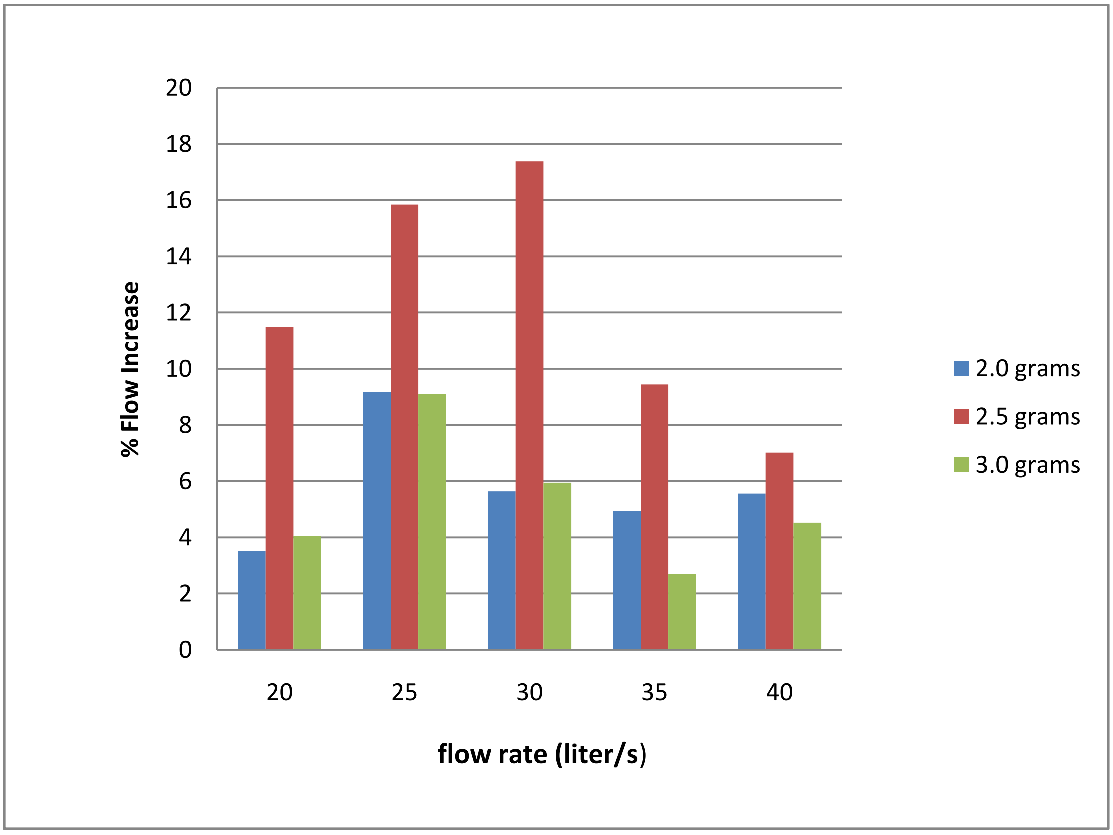

Figure 4.7: Percentage of Flow Increase versus Flow Rate

In addition, Figure 4.7 shows the percentage of flow increase. For 2.5 grams, the percentage of flow increase is increasing until 30 liters per second and it is reducing until 40 liters per second. The highest percentage of flow increase for 2.5 grams is

17.380. Based on the Figure 4.7, concentration of 2.0 grams and 3.0 grams gave highest percentage flow increase at 25 liters per second which are 9.170% and 9.103%. Moreover, Figure 4.7 indicate that the percentage of flow increase when the DRA is 2.5 grams at 30 liters per second. Based on this data, it is indicated that the DRA will reduce shear stress that is occurs during the turbulence flow and friction can be encountered. DRA will reduce the turbulence flow by reducing eddies between the wall of the pipe at the same time it will reduce the pressure difference between the pipe.

4.3 Optimization point between pipeline and reservoir

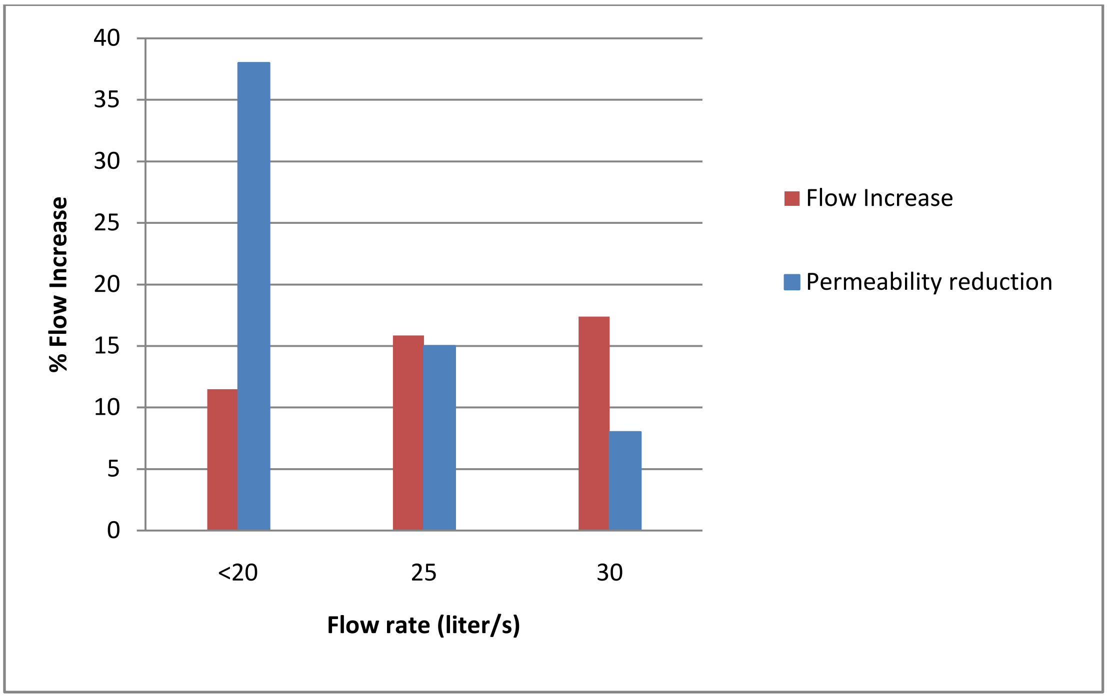

Figure 4.8: Permeability reduction and flow increase versus flow rate

Figure 4.8 shows that the performance of 50ppm of Polyacrylamide (PAM) DRA in 1 liter of water [16] and flow increase of 2.5 grams of Polyacrylamide (PAM) in 50 liters of water. For flow increase three initial flow rate is taken which are 20 liters per second, 25 liters per second and 30 liters per second. For the permeability reduction,the experiment was conducted at difference flow rate and the results shows permeability reduction of 36.89% for 1cc/min injectionrate, 7.93 % for 3cc/min injection rate, and 7.08% for 5 cc/min injection rate[16].

On the other hand, from Figure 4.8, it can be concluded that the optimize point of injection rate is at 30 liters per second. Concentration of 2.5 grams meets the specification because 2.5 grams gave the same value as 50ppm in 1 liter of water. Figure 4.8 also shows that theperformance of DRA is optimum when the flow rate is at 30 liters per second. Even though the flow increase at 25 liters per second is almost same as 30 liters per second, but to find the optimize point is at 30 liters per second. It is because the permeability reduction is lower at 30 liters per second. Lower permeability reduction is better for the fluid to flow. This is due to the fact that at lower injection rate, the shear rate of the fluid flowing at the inlet of the core is small. Small shear rate tends to make the polymer molecules plug at the inlet face of the core. However at higher shear rate, more polymer chain is broken, thus easing the fluid flow through inlet and the permeability channel inside the core [16]. Lastly, point of optimization between flow in pipe and reservoir is at and 30 liters per second.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 Conclusion

Drag reducing agent give a good effect of applying in the pipeline and reservoir. From the correlation to find the point of optimization between the flow in the pipe and in the formation, it can be seen that the concentration of 2.5 grams of Polyacrylamide (PAM) gave the highest percentage of flow increase in the pipe at the same time; the best concentration is at 2.5 grams in 50 liters of water. The concentration higher may cause higher viscosity that will resist the flow and it needs more power for the pump to move the fluid. Moreover, after analysing the graph, the flow rate gave the effect on percentage of increasing flow in the pipe because increasing flow rate may increase the pressure difference. This can be seen in the Figure 4.7 showing that at 30 liters per second give the highest flow increase. Lastly, DRA do give good and harm to the injection wells, however some precaution have been made from time to time to ensure that the performance of DRA is at maximum point.

5.2 Recommendation

The studies on DRA give the big impact to the oil and gas production. Moreover, it needs lots of experimental study to compare the performance of DRA. The main focus for this project is to determine the performance of DRA and to correlate the performance in the pipe and in the reservoir with two variables which are flow rate and concentration. The author would like to recommend further studies to be conducted at difference temperature to see the performance of DRA because the author only manage to do experiment at standard temperature. In Addition, further studies can include the injection well flow rate to see the flow increase and comparison between flow increases in the injection well and in the reservoir. Lastly, further experiment and evaluation should be done in order to increase the performance of DRA in the injection well.

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APPENDICES

Reynolds Number

To calculate the Reynolds numbers as below and it used the lowest flow rate to prove the flow rate at the turbulence flow.

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

The velocity of the flow is.

$$Q = 20 \ \frac{l}{min} \times 0.001 \frac{m^3}{l} \ \times \frac{1min}{60s} = 3.33 \times 10^{-4} \ \frac{m^3}{s}$$

$$A = \pi r^2 L = 2\pi r = 0.08$$

$$r = \frac{0.008}{2\pi} = 0.0127$$

$$A = \pi \times 0.0127^2 = 5.093 \times 10^{-4}$$

$$V = \ \frac{Q}{A} = \frac{3.33 \times 10^{-4}}{5.093 \times 10^{-4}} = 0.6538$$

So, the Reynolds number is as follow

$$Re = \ \frac{\rho V D}{\mu} = \frac{\left(1030 \frac{kg}{m^3}\right) \left(0.6538 \frac{m^3}{s}\right) (0.08m)}{(1.20 \times 10^{-3} \ N.s/m^2)} = 44896.11$$

It is clearly proved that the flow of the fluid is in turbulence flow.

DRA

The DRA used is Polyacrylamide(PAM) used in 50 liters of water.

Table A1: DRA quantity

	50 liters
40ppm/liter	2.0 gram
50ppm/liter	2.5 gram
60ppm/liter	3.0 gram

<u>Pressure Difference</u>

Pressure difference is taken from pressure transducer connecting between ends of pipe.

Table A2: Pressure difference

	Pressure Difference (kPa)				
gram in 50 liters of water	20 (l/s)	25 (l/s)	30 (l/s)	35 (l/s)	40 (l/s)
no DRA	617.675	748.925	922.550	1079.500	1393.975
2.0	580.550	639.600	835.875	990.025	1264.800
2.5	508.025	574.825	691.550	917.725	1233.950
3.0	575.225	640.300	831.575	1029.075	1287.275

<u>Percentage of drag reduction</u>

The formula used to calculate the percentage of drag reduction is as below.

$$\%DR = \frac{\Delta P - \Delta P_{DRA}}{\Delta P}$$

1. *2 Grams in 20 l/s*

$$\%DR = \frac{617.68 - 580.55}{617.68} \times 100 = 6\%$$

2. *2.5 Grams in 20 l/s*

$$\%DR = \frac{617.68 - 508.03}{617.68} \times 100 = 17.8\%$$

3. *<u>3.0 Grams in 20 l/s</u>*

$$\%DR = \frac{617.68 - 575.23}{617.68} \times 100 = 7.0\%$$

The data's of the drag reduction in 50 liters of water.

Table A3: Percentage of Pressure reduction

	Pressure Reduction (%)				
gram in 50 liters of water	20 (l/s)	25 (l/s)	30 (l/s)	35 (l/s)	40 (l/s)
2.0	6.010	14.598	9.395	8.289	9.267
2.5	17.752	23.247	25.039	14.986	11.480
3.0	6.873	14.504	9.861	4.671	7.654

<u>Percentage of flow increase</u>

The formula used is as below.

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

1. *2 grams in 20 l/s*

$$\%FI = \left[\left(\frac{100}{100 - 6.0}\right)^{0.556} - 1\right] \times 100 = 3.51\%$$

2. *2.5 grams in 20 l/s*

$$\%FI = \left[\left(\frac{100}{100 - 17.8}\right)^{0.556} - 1\right] \times 100 = 11.48\%$$

3. *3 grams in 20 l/s*

$$\%FI = \left[\left(\frac{100}{100 - 7.0}\right)^{0.556} - 1\right] \times 100 = 4.04\%$$

The data's of the flow increase in 50 liters of water.

Table A4: Percentage of flow increase

	Flow Increase (%)				
gram in 50 liters of water	20 (l/s)	25 (l/s)	30 (l/s)	35 (l/s)	40 (l/s)
2.0	3.507	9.170	5.639	4.928	5.556
2.5	11.478	15.847	17.380	9.447	7.015
3.0	4.038	9.103	5.942	2.695	4.527

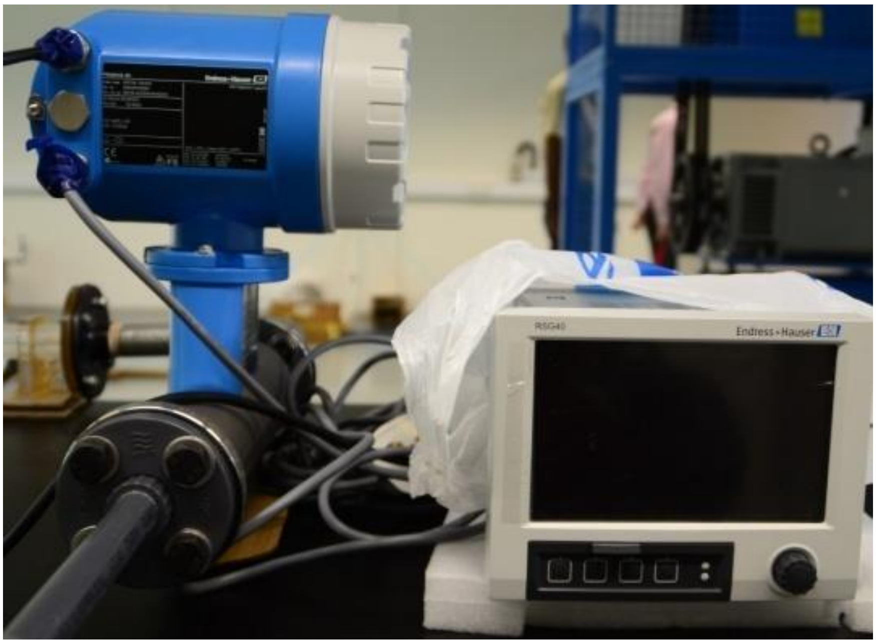

Figure A1 : Flow Meter

Figure A2 :Positive displacement Pump