CERTIFICATION OF APPROVAL

DRAG REDUCING AGENT BY WATER INJECTION USING NATURAL POLYMER (Solanum Tuberosum)

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.

AMIRA BINTI ABDUL RASIB

Abstract

This research presents an experimental study of drag reduction performance of natural polymer solution in pipelines. The aim is to prove the effectiveness of using potatoes solution or in scientific called Solanum Tuberosum as Drag Reducing Agent (DRA). DRA is a chemical agent used to optimize the pipeline capacity by reducing drag and lowering pressure drop across the pipeline. As the production continue, the main problem that will be aroused due to the limited pipeline capacity which caused by drag. Drag had caused power pumping losses, decreasing in production capacity and pipelines corrosion. Thus, DRA is rapidly becoming an essential alternative in Oil & Gas industry since it can be applied in short time and does not require a high initial investment. The objectives of this project are to investigate the effect of natural polymer used as DRA in water flowline, to determine the percentage of drag reduction after injecting the DRA and to determine water flow rate due to different concentration of DRA. This polymer has been tested in 1-inch diameter Galvanize Iron steel single pipeline. The pipeline is 12.25 meter long where water is pumped throughout 4 meter long of test section which 2 pressure gauges were located in order to measure the pressure drop. An injection point is created to inject the DRA solutions at the starting point of 6 meter entrance length before the test section. At the beginning of the experiment, 36 liter of water from storage tank is pumped through the test section without injecting the DRA. Readings from both pressure gauges and time taken for water to cater the drainage tank is recorded. Then, the experiment is repeated with the same procedure with injecting the DRA at the injection point. The difference pressure of both pressure drops is calculated in order to get drag reduction percentage (%Dr). In the experiment, 5 different concentrations of DRA are prepared. The result showed that Solanum Tuberosum give potential effect when acts as DRA significantly by recorded 3.03% of Drag Reduction Percentage in the lowest concentration, 600 ppm and 10.91% in the highest concentration which is 1000 ppm. Although it did not present the best performance as DRA, but there are advantages of using the natural polymer as DRA. There are very abundant quantity in Malaysia, thus, it has zero problem in getting them in a big amount to produce as DRA.

Acknowledgment

This Final Year Project involved many parties in order to complete it successfully. At first, I would like to give the highest appreciation to Puan Mazuin Jasamai, whom act as my supervisor for the entire lesson learnt in assisting me and give fully moral support in order to complete this project.

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CHAPTER 1: INTRODUCTION

1.1 Background Study

In the production stage, hydrocarbon is displaced by sufficient pressure provided by natural reservoir drives. After some time, the natural energy is depleted and it affects the capacity of hydrocarbon production rate. Thus, secondary recovery is needed in order to recover the energy depleted from reservoir. One of the methods of secondary recovery is water injection. From a journal entitled The Water Injection Process authored by B. Palson, D.R.Davies, A.C.Todd and J.M.Somerville from Heriot-Watt University, Edinburgh, UK said water injection is an essential part of many modern oilfield development plans. The water used for water injection usually consists of some sort of brine or from other source that already been treated. After water injection well is drilled, water was pumped to the reservoir and then gravity will help to push the liquid into the formation.

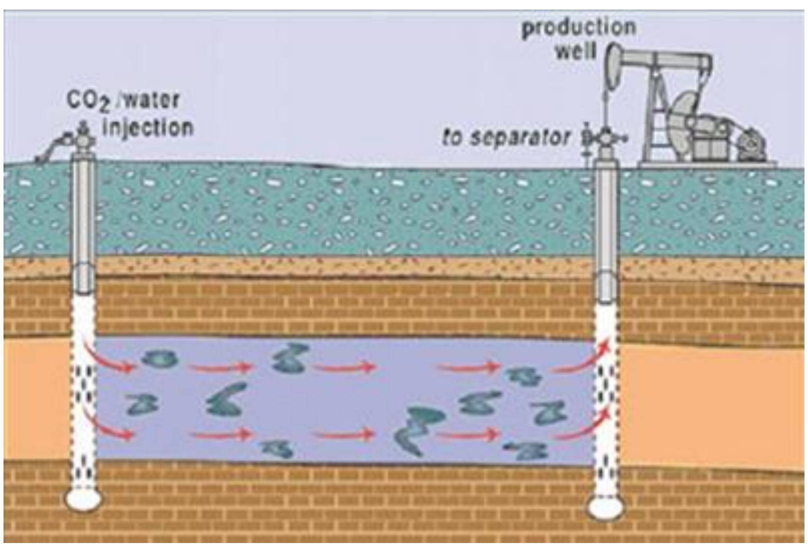


Figure 1: Water Injection
Source: Schlumberger

The main objective of water injection is to maintain the reservoir pressure in order to boost hydrocarbon to the production level. It will maximize the overall recovery and accelerating hydrocarbon production. However, there is some limitation occurred in injection flowline which effect the flow assurance and thus limit the capacity of water injection into the wellbore. The implementation of water injection will reach poor efficiency after times due to drag problem which occurs in pipeline. According to journal entitled Evaluation of Drag Reducing Agent for Seawater Injection System authored by H.A.Al-Anazi from SPE said drag is a result of the resistance encountered by flowing fluid with solid surface, such as pipe wall. It means as friction exists at the near wall region of pipe, the energy of fluid flow will be loss. As the result, it decreases the flow rate of water injected. Basically, the contractor built pipelines with a life expectancy of about 20 years with wall thickness, materials and corrosion rate calculations are taken into account. However, corrosion still occurs although some prevention already held such as regular pigging, cathodic protection, and injecting corrosion inhibitors and so on. As the wall thickness reduces, Maximum Allowable Operating Pressure (MAOP) also get reduces. MAOP is the measurement of how much pressure of the pipe wall may safely hold in normal condition. If the operating still continues in high pressure with the wall thickness has reduced, pipeline rupture will occur. There are 2 alternatives to solve the problems which are renewing the pipelines or inject drag reducer. Clearly, if replacing or renew the lines, the capital expenditures (CAPEX) will be very costly and need time to be developed. However, by injecting drag reducer, the same amount of water injection can be pumped at a lower pressure. The drag of the water on the pipeline is reduced and thus the pressure drop is reduced.

Basically, this project which entitled 'DRA by Water Injection using Natural Polymer' is conducted to study the effectiveness of Natural Polymer in reducing or minimizing the frictional pressure loss in water pipeline. As the result, by using DRA, it will help to increase the flow rate of water and optimize the level of production. DRA is a solution consists of a long chain polymer which will break out then interact with the water phase in the near wall region of the pipeline. In Malaysia, natural polymers are experiencing abundant in its quantity. Besides that, the initial investment cost in getting the natural polymer is cheaper than any chemical substances. This is the reason why natural polymer should be more commercialize in oil & gas industry. The essential thing about natural polymers, it is environmental-friendly, indeed. It has no contribution in world's pollution. For instance, if natural polymer acts as DRA in water treatment process, it will not give any harmful for human's life because it is safe to be used. Instead of it, natural polymers also will not contribute in any damage in a pipeline such as corrosion, erosion, and so on when it was injected because it has no harmful chemical reaction. Previously, in order to increase the flow rate of water, more pumping powers are installed to boost the energy of the flow. However, by installing more pumps, it required higher operational cost and time consuming. Thus, by the application of natural polymer as DRA, it will reduce the operational cost and at the same time it can be quickly-installed at any existing facilities. Depending on how good the flow capacity of water will be achieved, the characteristics of DRA are examined in order to get high efficiency of drag reduction.

1.2 Problem Statement

The intention of this project is to establish the purpose of reducing the friction pressure loss in the water injection flow line. The friction between flowing water and pipe wall occurs because of high flow velocity in the core. Large amount of energy provided by pumping power are lost because of the turbulence structure in flow line. In turbulent flow, the water moves in various motions and it provides eddies to form. Eddies will absorb the energy from the main flow and cause friction pressure loss. As the result, the flow rate of water in the flow line will reduce. Besides that, when the friction get increases, the surface of pipeline will damage. In particular, the expectancy of maximum production capacity of pipeline is never similar with the earlier prediction at design stage. The main reason of this is because of corrosion. Corrosion will decrease the wall thickness of pipeline and will create rupture and roughness inside the pipeline. In order to prevent fracture from occur, Maximum Allowable Operating Pressure need to be reduces, consequently decreases the production capacity in pipeline.

Figure 2: Damage in pipeline surface

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

ρ =density of solution (kg/m³)

v = velocity of solution in pipeline (m/s)

D = pipe diameter (m)

Figure 3: Formula of Reynolds Number

In the turbulent flow, Reynolds number is larger than 4000. In the other words, Reynolds number can be formulated as inertia force (drag) over viscous force. Drag was occurred by the various motions of water molecules in flow line. Some of the molecules are remain at the origin place which influenced by the inertia force. Inertia force is the tendency in resist any changes in its motion. The static molecules will form at the laminar sublayer which near to the pipe wall.

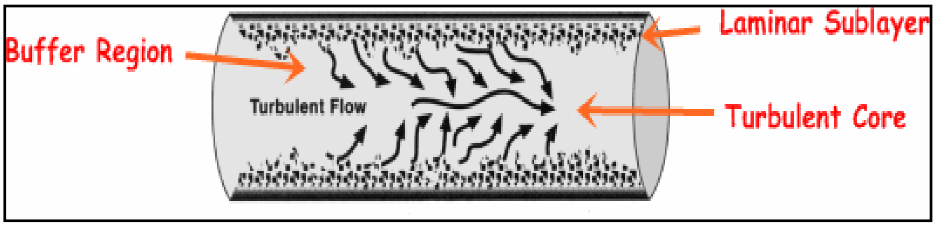


Figure 4: Turbulent Flow in Pipeline

Meanwhile, the molecules of flowing water will move in different direction of inertia existed, thus it provides drag. It leads the water flows slower because the friction holds the molecules at the buffer region. As a result, energy of the molecules at turbulent core become reduces hence, the flow rate of water in flow line get decreases. That is why DRA which consists of a small amount of a long chained polymer, with a very high molecular weight is needed in water flow line.

1.3 Objectives of the Project

The aim of this project is to increase the performance of flowline which been reduced because of friction pressure loss occurred due to turbulent flow. Thus, by injecting DRA inside the flow line, it will disturb the development of turbulence structure and at the same time absorb the energy from eddies in the flow. It will increase the capacity of water injection and reduce the cost of pumping powers.

The objectives of this project are:

i. To investigate the effect of Solanum Tuberosum used as DRA in water flow line
ii. To determine difference of pressure drops and to calculate drag reduction percentage
iii. To determine water flow rate due to different concentration of DRA

1.4 Scope of Study

This project is limited to research and experiment of a prototype aimed in evaluating the performance of flowline. This project is involved Solanum Tuberosum as the additive of DRA. The rheology sample test is conducted in order to obtain the characteristics of additive which fulfill the minimum requirement of DRA. The value of density and viscosity of additive from rheology test are needed in order to obtain Reynolds number of the flow. The DRA is only tested in turbulent flow. In turbulent flow, friction occurs between flowing fluid and pipe wall and it provides energy loss in main flow. Thus, by using DRA, it will suppress eddies by absorb its energy and at the same time disturb the degree of turbulence. As a result, friction pressure losses in pipeline become reduce and it increases the capacity of water flow rate. The efficiency of DRA is determined by the percentage of drag reduction and the difference of pressure drop at given concentration of DRA and water flow rate.

1.5 The Relevancy of the Project

The Drag Reducing Agent application is successful and working well in Oil & Gas industry. With injecting DRA in pipeline, it optimized pipeline capacity and increase throughput from its baseline. Moreover, it savings on energy and operating costs from adding the booster pump in order to increase the pipeline capacity.

By carry out this project, the effectiveness of natural polymer acts as DRA can be study closely and observe its usefulness in the industry.

1.6 Feasibility of the Project

This project needs an experiment to be carried out in order to gain the result. The entire project needs to be completed within the time given. It started with the objective on determine the type of natural polymer need to be used and then to the phase of proving Solanum Tuberosum can act as DRA in pipeline. The key of success for this project is to follow closely the Gantt Chart and Key Milestone that already discussed earlier.

CHAPTER 2: LITERATURE REVIEW

2.1 Drag Reducing Agent

According to a study featured in journal entitled An Experimental Study of Drag Reduction of Polymer Solutions in Coiled Tubing authored by Subhash N.Shah and Y.Zhou from University of Oklahoma, said “Frictional pressure in turbulent flow can be drastically reduced by adding small quantities of certain long chain polymers to the solvent. This phenomenon is called drag reduction”. Generally, drag reduction was discovered by Toms in 1949. He was investigating the mechanical degradation of high polymer solutions in pipe flow. In turbulent flow, the collisions between water molecules become increase and thus, smaller eddies are formed. It is easier for DRA to suppress smaller eddies rather than larger eddies.

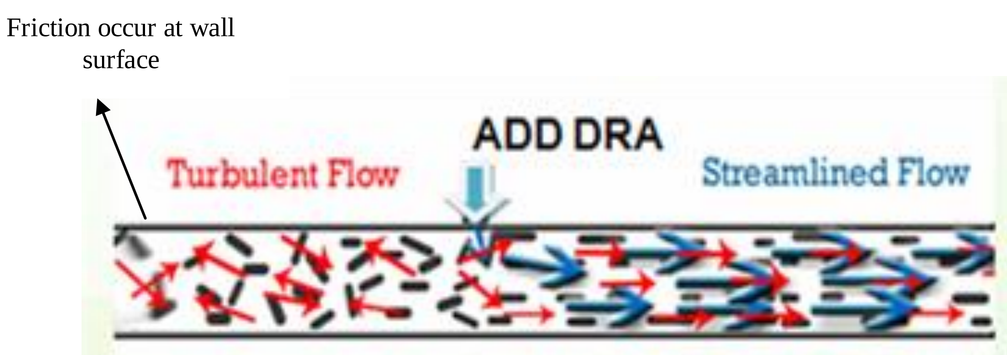


Figure 5: Flow in Pipeline after injecting DRA

Based on Figure 5, after injecting DRA in flow line, turbulent flow was disturbed. DRA absorbed the energy of eddies and reduced degree of turbulence. Hence, friction pressure loss in flow line is decreased and the capacity of water became higher. In this journal, it focused on how polymer concentration effect on drag reduction ratio.

2.2 Characteristics of DRA

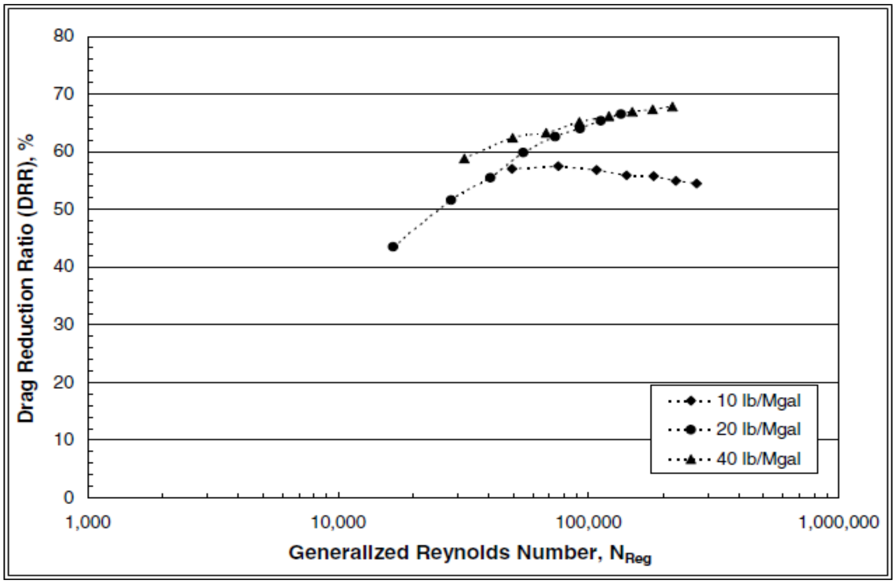


Figure 6: Effect of Polymer Concentration on Drag Reduction Percentage

From Figure 6, it shows polymer concentration of 40lb/Mgal produced highest drag reduction percentage. Meanwhile, the lowest concentration which is 10lb/Mgal produced lowest drag reduction percentage. It happened due to a low ratio between additive concentration and degree of turbulence. For a low ratio, the additive is easy to break or known as degradation. In this stage, the additive is not effective. That is why it shows drastic reduction in drag reduction percentage. The concentrations of polymer give important impact to drag reduction in order to improve capacity of water in flow line. When Reynolds number increases from 10000 to 1000000, the degree of turbulence increases. It can be seen that the drag reduction percentage generally increases with increasing Reynolds number. It also can be seen that for each concentration, the %Dr also increases with increasing Reynolds number until it reach its limitation.

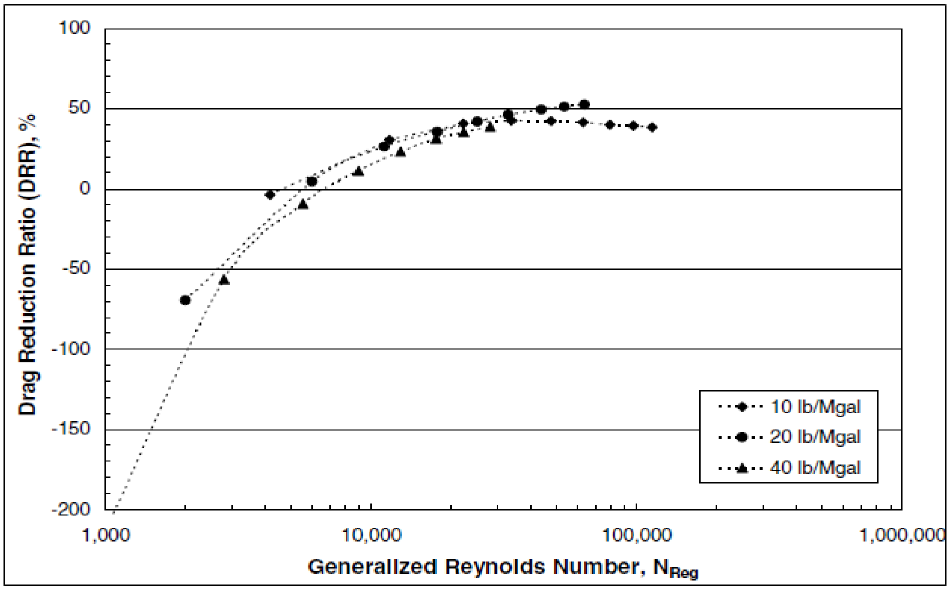


Figure 7: Effect of Polymer Concentration on Drag Reduction Percentage

Based on Figure 7, it clearly shows that at the beginning of concentration 40lb/Mgal, the drag reduction percentage reached negative value. It happened due to low value of Reynolds number and DRA only works in turbulent flow which is Nre>4000. After Reynolds number reached 4000 and above, high drag reduction is obtained which influenced by high concentration. It may be due to the increase in the number of polymeric molecules that influences the strength of the degree of turbulence which will lead to the increase in drag reduction. This was supported by Virk (1975), Japper-Jaafar et al. (2009), Cho et al. (2007) and Bari et al. (2008).

From a study of Evaluation of Drag Reducing Agent (DRA) for Seawater Injection System by H.A.Al-Anazi from Society of Engineers, said that the DRA was found to be sensitive to shear where its effectiveness decreased with high shear due to polymer chains degradation. DRA must be injected at the discharge of the booster pump to avoid polymer degradation. The impact of degradation was studied by repeating the experiment by using a fresh DRA solution and the other using a sheared (broken) DRA. The fresh DRA was prepared by using magnetic stirrer with gentle mixing, while the sheared DRA was prepared by using a blender with high mixing speed. Figure 8 shows that the broken DRA is virtually ineffective compared to fresh DRA. The shear degradation is associated with chain elongation. Chain degradation is observed when shear rate increased to critical point after the drag reduction decreased drastically.

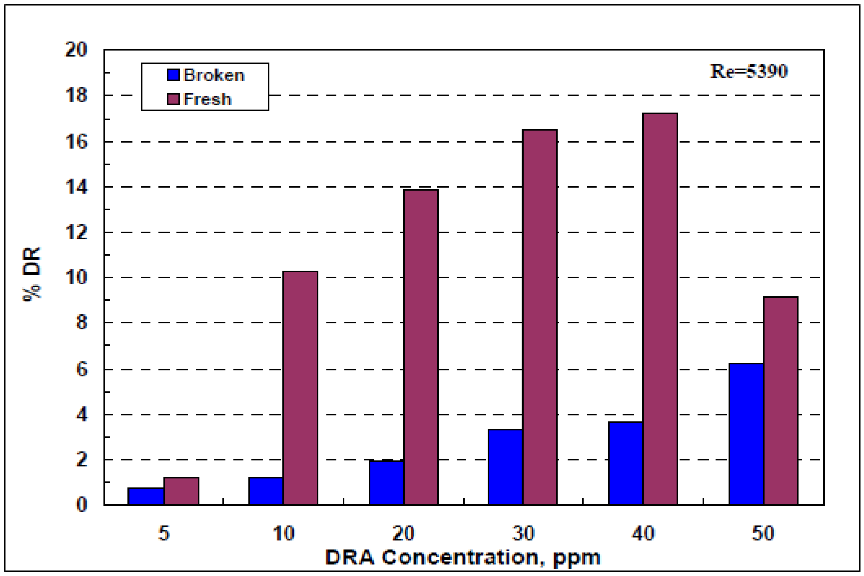


Figure 8: Drag reduction percentage as a function of Concentration for Fresh and Broken DRA

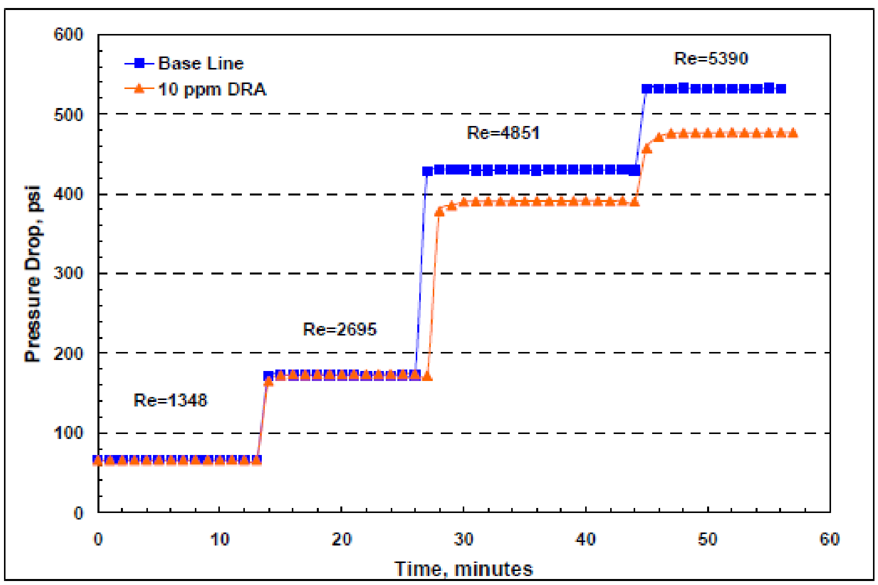


Figure 9: Pressure Drop measured across the tube with various Flow Rate of Water

Figure 9 shows the pressure drop measured across the tube of seawater as 10ppm as a baseline at various Reynolds number. It indicates that the DRA did not reduce the pressure drop in laminar flow (Re<3000). Meanwhile, pressure drop was decreased at turbulent flow. For example, at Re=4851, after adding 10ppm of DRA, the pressure drop reduced from 430 to 390 psi. It confirmed that DRA only works in turbulent flow. It also can be proved based on results in Figure 10 which it shows that by using high concentration of DRA, 40ppm in turbulent flow (Re>4000), percentage of drag reduction increased. Meanwhile, by using high concentration of DRA in laminar flow (Re<3000), the percentage of drag reduction are reached negative values. This is due to increase in seawater viscosity when the DRA is added. As can be see clearly in the figure below, the percentage of drag reduction started to decline when DRA concentration is more than 40ppm for Re 4851 and 5390. It is due to over dosage of the buffer zone that formed at turbulent flow case. It can be said that more drag reduction can be achieved if the flow rate could be increased more.

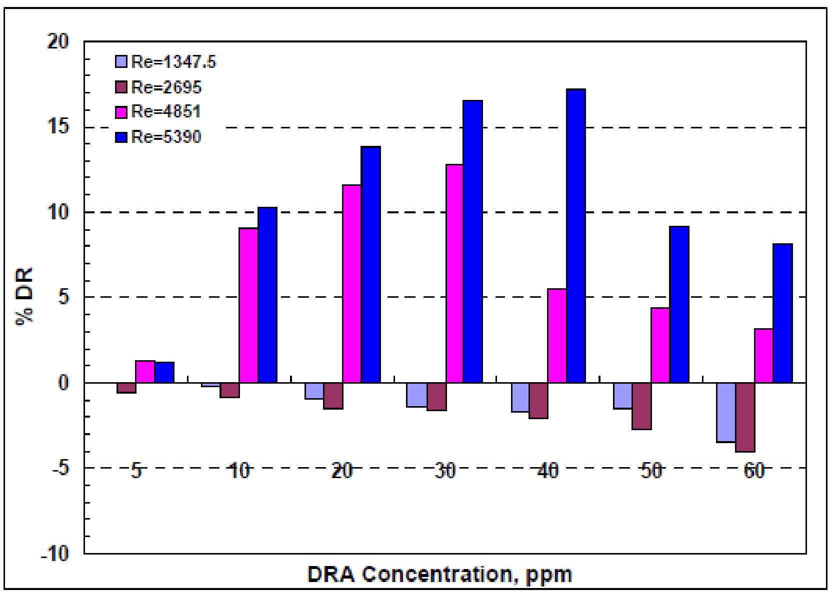


Figure 10: Drag Reduction Percentage as a function of Concentration at various Reynolds number

According to Shao Xueming from Zheijiang University, drag reduction measurements of turbulent flow are conducted by focusing on the effect of injection position of DRA, the Reynolds number as well as the effect of polymer concentration on turbulent structure. In this experiment, DRA was injected in two ways which are from vertically at the wall of pipe and horizontally along the centerline of pipe. In order to measure the flow of water injection, the measurement of flow rate also was conducted by using flow meter. These were performed in a re-circulatory pipe system and screw pump, which avoid strong degradation of polymer was used in order to boost the energy of water. To determine the effect of Reynolds number on DRA, turbulent pipe flow of water and polymer were measured in range of Re= 20000 to 35000. The amounts of drag reduction for different Reynolds number are shown in Table 1, which flow rate of water is increased. By increasing the velocity of water flowing, it will lead to the extended large eddies in the viscous sublayer region to the buffer region. The expended larger eddies produce increased stream wise irregular velocity in buffer region. From table, it shows that the injection of water itself has no effect on DRA, whereas the addition of polymer will increase drag reduction. It also shows that the injecting polymer at the centre of pipeline is more effective rather than at the wall and the amount of drag reduction increases with Reynolds number.

Table 1. The effect of Reynolds number and injecting ways on drag reduction.

	Injecting way	C_p(ppm)	U_m(m/s)	*Re*	ΔQ	f_p	*DR*
1	centre (water)	0	1.379	32131	-	0.0031	-
2	centre	4	1.428	33272	5.9%	0.0019	33.2%
3	centre	6	1.455	33902	7.9%	0.0016	42.4%
4	centre	10	1.471	34274	9.0%	0.0014	49.8%
5	wall (water)	0	1.061	24721	-	0.0031	-
6	wall	6	1.102	25677	5.3%	0.0022	27.9%
7	wall (water)	0	0.864	20131	-	0.0031	-
8	wall	8	0.910	21203	3.7%	0.0023	25.9%

Table 1: The effect of Reynolds number, Concentration and Injecting ways On Drag Reduction

Instead of Reynolds number, concentration of polymer also plays an importance role to drag reduction. As per table above, by injecting DRA at the centre of pipeline, the higher concentration of polymer is, the higher mean velocity is. The total pressure gradient for this experiment is kept constant, so the increase in velocity means that the drag in the pipe is reduced. As stated above, 2 ways of injection position are used. For the same concentration of polymer, injecting DRA horizontally along the centerline of pipe will cause larger drag reduction than at the wall. It happens because the polymer solution diffused quickly and widely when being injected at the centre and at the same time, it can affect the large scale vortex structures which appear in the core region of pipe. Meanwhile, the DRA which injected at wall only can suppress the small scale vortex at sublayer region.

Taken from Japper Jaafar et. Al in 2009, said that, "The efficiency of DRA reaches maximum operating values after a certain distance". Figure 11 show that the length of pipe also effects the percentage of drag reduction. It is clear that the efficiency of DRA reaches optimum drag reduction at length of 1.0m. At that length, DRA reaches its stability against the shear forces and the degree of turbulence. After 1m, the percentage of drag reduction get reduces because of shear degradation. DRA starts to degrade when the distance is longer and the degree of turbulence get higher. Thus, it results a loss in efficiency.

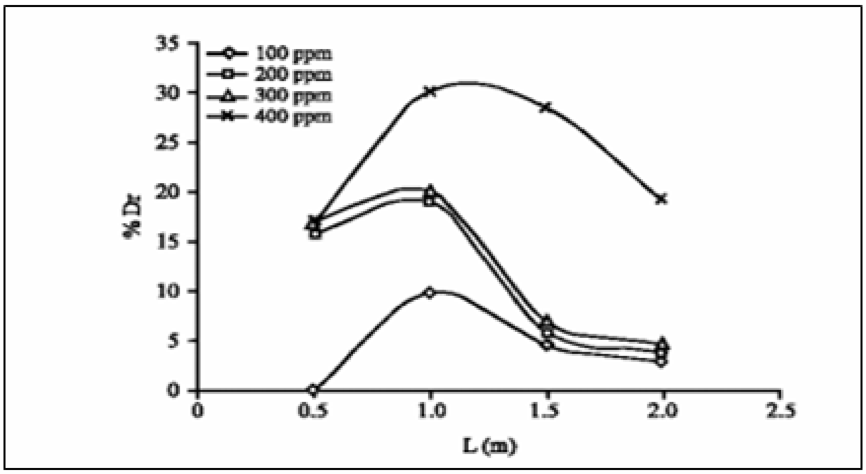


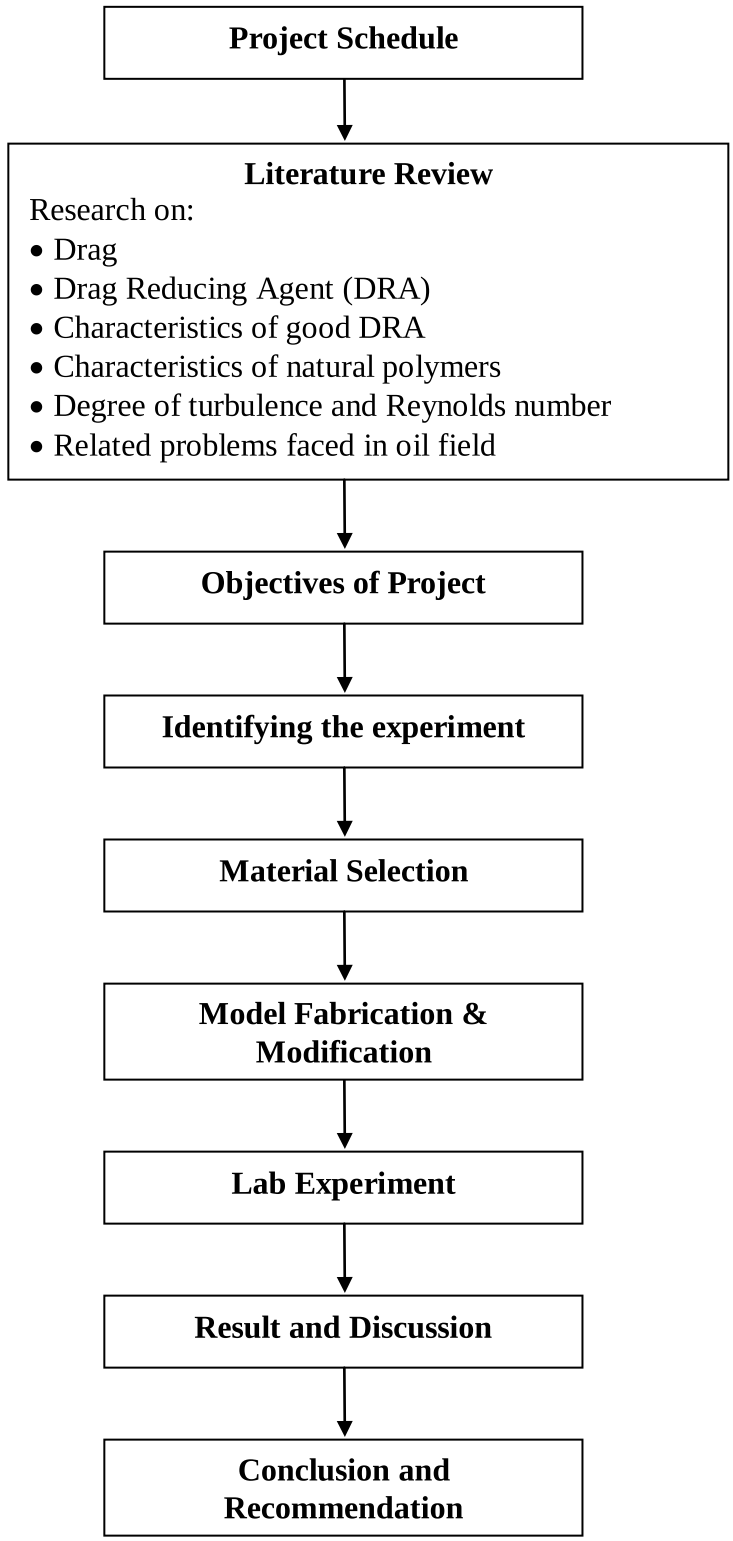
Figure 11: Effect of Pipe Length to Drag Reduction Percentage

It is very important to know the relation between the degree of turbulence, pipe length and the concentration of DRA. The degree of turbulence increase by increasing the length of pipe due to the collision of eddies inside the pipe. Thus, it will lead to increase the effectiveness of the DRA. DRA will disturb eddies from develop more and at the same time can reduce the drag friction inside the pipe. Hence, percentage of drag reduction become increase and improves the flow in pipeline.

According to Indra Prasetyo from PT Exspan Nusantara, DRA are used to reduce the frictional friction pressure loss caused by turbulence in pipeline. DRA does not work in laminar flow regimes. This is because drag reduction occurs by an interaction of the polymer molecules of DRA with the turbulence formation of the flowing fluid. In turbulent flow regimes, there are 3 different layers. Laminar sub-layer is the layer which located at the nearest pipeline wall. In this zone, the fluid follows the pipeline flow in laminar regime. In the center of the pipeline is the turbulent core layer. This is the largest layer which includes eddies in random motion and also carries variation of molecules velocity. In between of those layers lies the buffer layer. This layer is very important because it is here where turbulence first forms. When a part of laminar sublayer which called streak moves to the buffer region, it will begin to oscillate and moving faster in different directions and gets closer to the turbulence core. Then, the streak becomes unstable and creates turbulence in the core. When the streak moves randomly, it wastes the energy and causing the drag and pressure loss. After injecting the DRA to the turbulence of flowing fluid, it will interfere or inhibit the formation of turbulent burst and prevent the turbulence from being formed, or reduce the degree of turbulence. DRA works by absorb the energy of the streak and in turn, reduce the drag and pressure loss.

CHAPTER 3: METHODOLOGY

3.1 The Work Flow



3.2 Experimental Setup

The purpose of this experiment is to investigate the effect of variety concentration of natural polymer used as DRA. In order to determine the effectiveness of DRA, pressure drop along the pipeline and flow rate of water is evaluated. This experiment is conducted in 2 ways which run the water without the DRA (acts as base case) and with the DRA. For this experiment, the previous prototype is modified to cater the requirement of this project. Two pressure gauges will be installed at inlet of test section (which located at discharge of the pump) and at the outlet of flowline in order to measure the pressure drop of water before and after adding the DRA.

The test section consists of constant diameter of single flow system which is 1-inch. This system consists of two tanks which are storage tank and drainage tank. Storage tank will be connected with centrifugal pump which will boost the water pass through the test section until end at drainage tank. The injection point of DRA needs to be located after the discharge pump because DRA cannot survive in high shear force generated by centrifugal pump. DRA will be degraded and it will reduce its efficiency and as a result, drag reduction will be reduced.

<u>Without inject DRA:</u>

After water was pump by centrifugal pump into the test section, pressure gauge at the inlet will measure the pressure of water and same goes to pressure gauge at the outlet of the flowline. Then, the difference of those pressures will be calculated and be as delta P1.

<u>With inject DRA</u>

The procedure for this experiment is the same with the experiment of without injecting the DRA. DRA will be injected at the discharge of pump (at injection point) after water flow through the test section. Pressure gauges will measure the pressure of water at inlet and outlet of the pipe. The difference of pressures will be as delta P2.

Below are the equipments used with the real image :

a) Storage tank to centrifugal pump

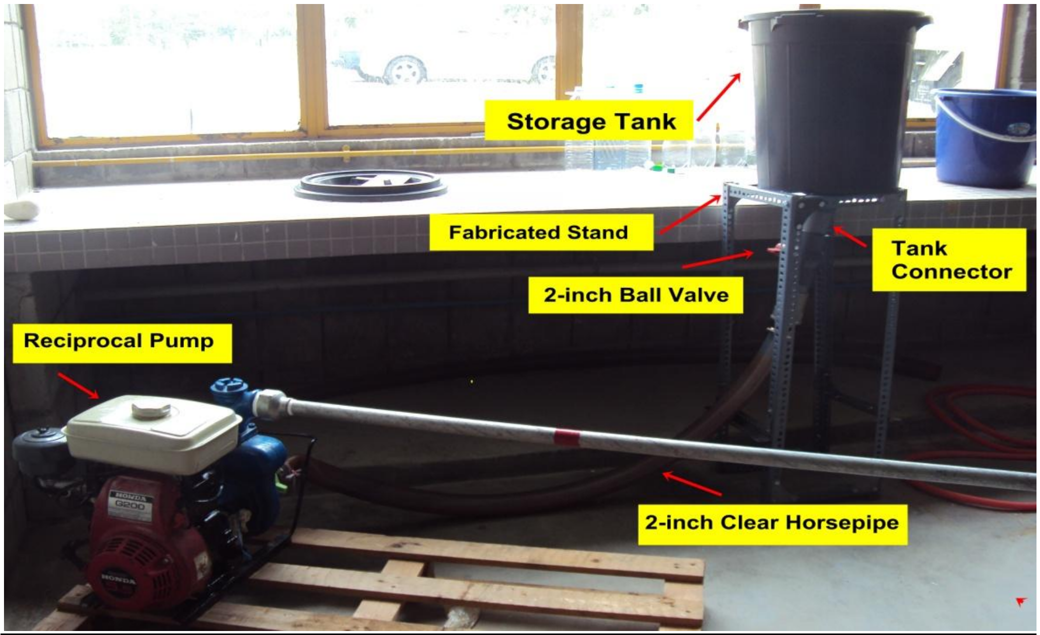


Figure 12: Storage tank to centrifugal pump

Storage tank is located on the fabricated stand with approximately at 1 meter from the ground. The purpose is to ensure the water can flow with the mean of potential energy by putting it higher than the inlet point of centrifugal pump. Tank connector is connected between the storage tank and 2-inch ball valve in order to make sure the water flow from tank to the pump. Then, ball valve is used to control the flow of water from the tank to the pump through the clear hosepipe.

b) Centrifugal Pump to Injection Point

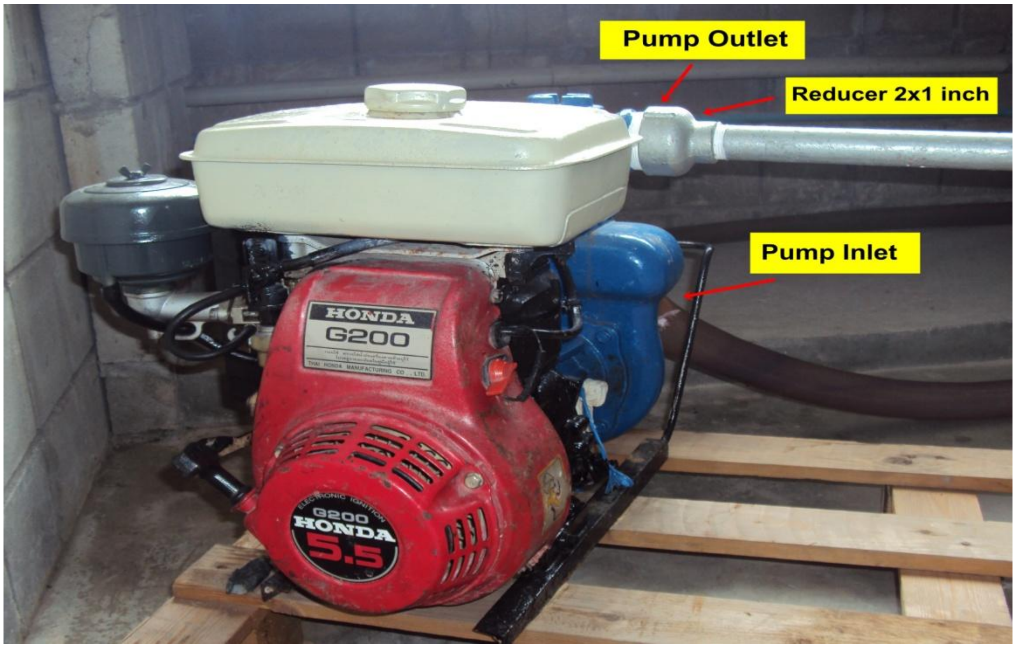


Figure 13: Centrifugal Pump

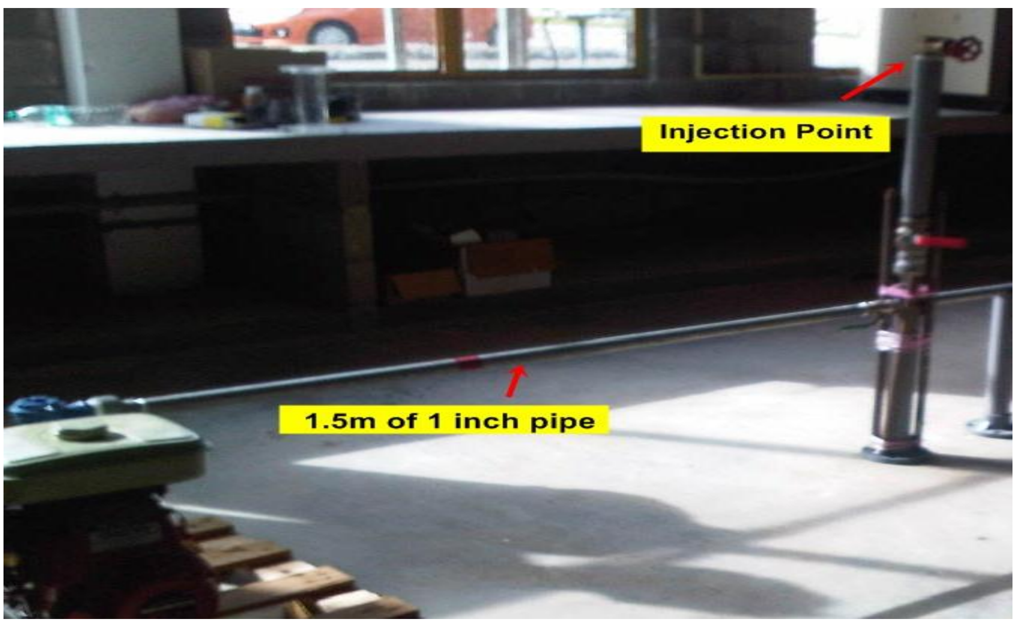


Figure 14: Centrifugal pump to injection point

The pump has 2-inch diameter of inlet and outlet, thus, reducer 2x1 inch is installed at the outlet of the pump to connect the pipe section since 1-inch of pipe diameter is used. Besides that, the pump only has RPM (revolution per minutes) for the speed which includes low and high RPM instead of scale in order to adjust the speed of pump to pump the water through the pipe section. Meanwhile, 1.5 meter of 1 inch pipe is installed before the injection point as an entrance length in order to fully develop velocity profile in turbulent flow. According to journal by Int. J.Chem Technol entrance length is the length of the pipe between the start and the point where the fully develop flow begins. It denoted by L_e and is a function of Reynolds number. As for turbulent flow, the entrance length is estimated by the equation :

$$L_e = 50\,(D)$$

Where pipe diameter used = 0.0254m. Thus,

$L_e = 50(0.0254) = 1.27\text{m} \cong \underline{1.5\text{m}}$ (minimum entrance length)

c) Injection Section

Injection point is installed after the discharge of the pump. It is because, DRA cannot survive the high shear force condition which generated by pump. DRA is very shear sensitive and drag reducing performance could be affected when it passing through high shear force region in pipeline system and its effectiveness reduced with high shear due to polymer chain degradation.

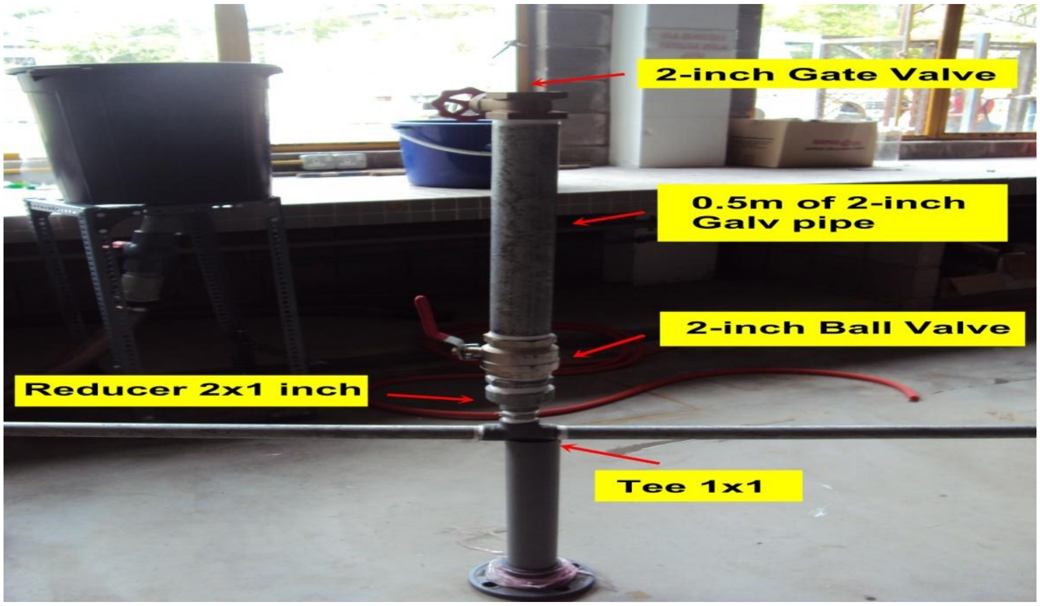


Figure 15: Injection point

Gate valve is installed at the top of injection section in order to avoid the DRA solution from bursting out when the pump is pumping the water in high speed. Meanwhile, ball valve is installed to control the flow of DRA solution to enter through the test section.

d) Test Section

Test section is consists of 4 meter long straight pipe and 2 pressure gauge are installed at the beginning and at the end of section in order to monitor the pressure drop. After the last pressure gauge, drainage tank is located to collect the output of water and measure the volume of it. The drainage tank can hold up approximately up to 45 liter same as storage tank but for this experiment, the volume of water needed is 36 liter.

Figure 16: Pressure Gauge

Figure 17: Drainage Tank

3.3 Experimental Work

3.3.1 Viscosity & Density Reading

Before choosing the suitable DRA to be used, several types of polymers are evaluated. After done some research about the characteristics of natural polymer to be a good DRA, 5 types of natural polymers are selected. Those polymers are been selected based on their gel strength. Then, rheology test are conducted to analyze the content of gel strength and viscosity of each polymer.

Sample	Viscosity					Gel Strenght (lb/100ft2)
	Ө 600 (RPM)	Ө 300 (RPM)	µa (cp)	µp (cp)	YP (lb/100ft2)	
Solanum Tuberosum	25	14	12.5	11	3	4
Mung Beans	33	17	16.5	16	1	5
Turnip	12	7	6	5	2	2
Tuber stem	8	5	4	3	2	0
Banana stem	10	5	5	5	0	0

Table 2: Viscosity of Natural Polymers

From Table 2, Solanum Tuberosum is selected to be as drag reducer because it has high value of gel strength. In fact, high gel strength can avoid poor protein degradation.

3.3.2 Concentration Preparation

Before conducting the experiment, several concentrations of Solanum Tuberosum solution are prepared. At first, Solanum Tuberosum fruits are blended and filtered in order to get its puree. The puree was prepared from 0.5kg of Solanum Tuberosum, concentrated into 1 litre of distilled water solution. Then, to prepare each concentration, the weight of Solanum Tuberosum is measure accordingly based on :

$$V_{DRA} = \frac{C_{DRA} \times V_{total}}{1 \times 10^{6}}$$

V_{DRA} = volume of DRA (gram)

C_{DRA} = concentration of DRA

V_{total} = volume of water (constant) = 1L

Concentration (ppm)	600	700	800	900	1000
Weight of Solanum Tuberosum (g)	0.6	0.7	0.8	0.9	1.0

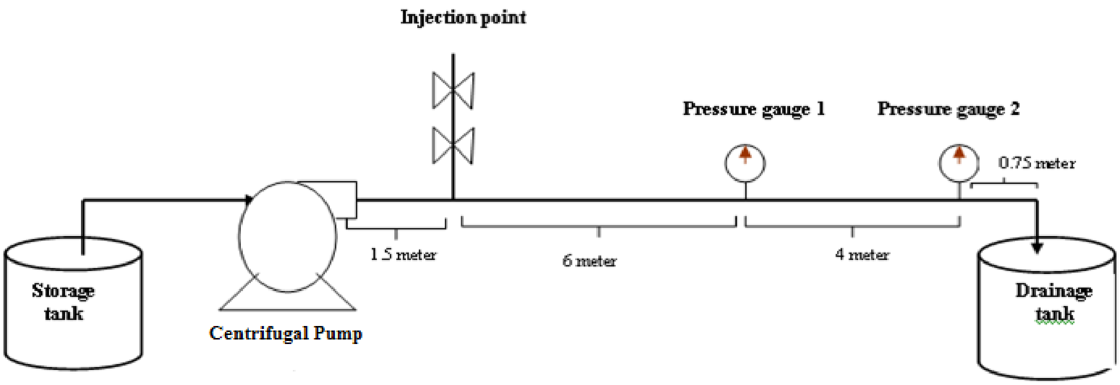
Table 3: Concentrations of DRA

After prepare the solution, magnetic stirrer is used to stir the solution. It is to ensure the solution is fully mixed and completely dilute. The mixing time for each solution is 1 hour. Then, density and viscosity of each concentration is measured in order to calculate the Reynolds number which is used in tabulating all data.

Magnetic Stirrer

3.3.3 Conducting the experiment

Procedure:



Schematic diagram of prototype

<u>Without injecting DRA (base case)</u>

1. In running the experiment, the storage tank was filled with water and must ensure it equals 36 liter. The ball valve under the storage tank was closed to avoid the water from exit through the hosepipe.
2. After the tank reached requires volume, the pump was started and the ball valve under the tank was opened to permit the water to flow through the test section. Time was monitored right after water started to exit the tank.
3. Pressure at the inlet and outlet of the test section was measured by the pressure gauge
4. Time was recorded when water filled the drainage tank until reached 36 liter.
5. The pump was turned off.
6. All data were tabulated and acts as the base case for the experiment.

<u>With injecting DRA</u>

1. Step 1 (base case) was repeated accordingly.
2. The solution of DRA was filled inside the injection section and ball valve below the injection section was closed to avoid the solution enter the test section.

3. Step 2 (base case) was repeated.
4. The ball valve was opened to permit the DRA solution mix with flowing water.
5. Step 3, 4 and 5 (base case) were repeated accordingly.
6. All data were tabulated.

For this experiment, 5 different concentrations of DRA solution were used which are 600, 700, 800, 900 and 1000 ppm. Each run was repeated 5 times, and results with the best repeatability was used in the analysis.

3.4 Equations

There are some equation involves for this experiment.

i. To calculate concentration of DRA

$$V_{DRA} = \frac{C_{DRA} \times V_{total}}{1 \times 10^6}$$

ii. To calculate flow rate of water

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

iii. To calculate Reynolds number

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

iv. To calculate entrance length

$$L_e = 50(D)$$

v. To calculate drag reduction percentage

$$\%Drag\,\mathrm{Re}\,duction = \left[\frac{\Delta P_{withoutDRA} - \Delta P_{withDRA}}{\Delta P_{withoutDRA}}\right] \times 100$$

vi. To calculate DRA efficiency

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

vii. To calculate flow increase

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

3.5 Tools, Equipments and Materials

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

1. Total of 12.25 meter of 1 inch galvanized iron steel pipe
2. 0.5 meter of 2 inch galvanized iron steel pipe
3. Two ball valve of 1 inch
4. Two ball valve of 2 inch
5. One gate valve of 2 inch
6. One 90 degree of elbow of 1 inch
7. One tank connector
8. One tee of 1X1 inch
9. One tee of 1X ½ inch
10. Two reducer of 2X1 inch
11. Two pail of 45.43 liter capacity
12. One centrifugal pump
13. Two pressure gauge with scale 0-100 psi and thread of 3/8 inch
14. 5 concentrations of DRA (Solanum Tuberosum)

CHAPTER 4: RESULT & DISCUSSION

4.1 Assumptions

In this project, there are several assumptions had been made because of limitations and errors occurred during conducting the experiment. Those assumptions are made in order to get good and accurate result.

1. Turbulent profile is fully developed.

Since the type of pipe used is galvanized iron steel, which is not transparent, thus it is assumed that turbulent profile is developed for the first section of pipe, at 1.5 meter long. This assumption is made based on the calculation of entrance length which is:

$$L_e = 50(D)$$

Where pipe diameter used = 0.0254m. Thus,

L_e = 50(0.0254) = 1.27m ≅ 1.5m (minimum entrance length).

2. DRA substance is 100% dissolved in distilled water.

In preparation of DRA concentration, DRA substance is mixed with 1000ml of distilled water and stirrer using magnetic stirrer. The mixing rate is 1 hour for each concentration. It is assumed that by that rate, DRA solution is well mixed and no precipitation occurred.

3. DRA solutions are totally mixed with water inside pipeline.

It is difficult to determine either DRA solution is mix well enough with water in pipeline after injection when using galvanized pipe. Thus, it is better to assume that DRA solution is well mixed with water right after DRA flow through the test section.

4.2 Graph & Discussion

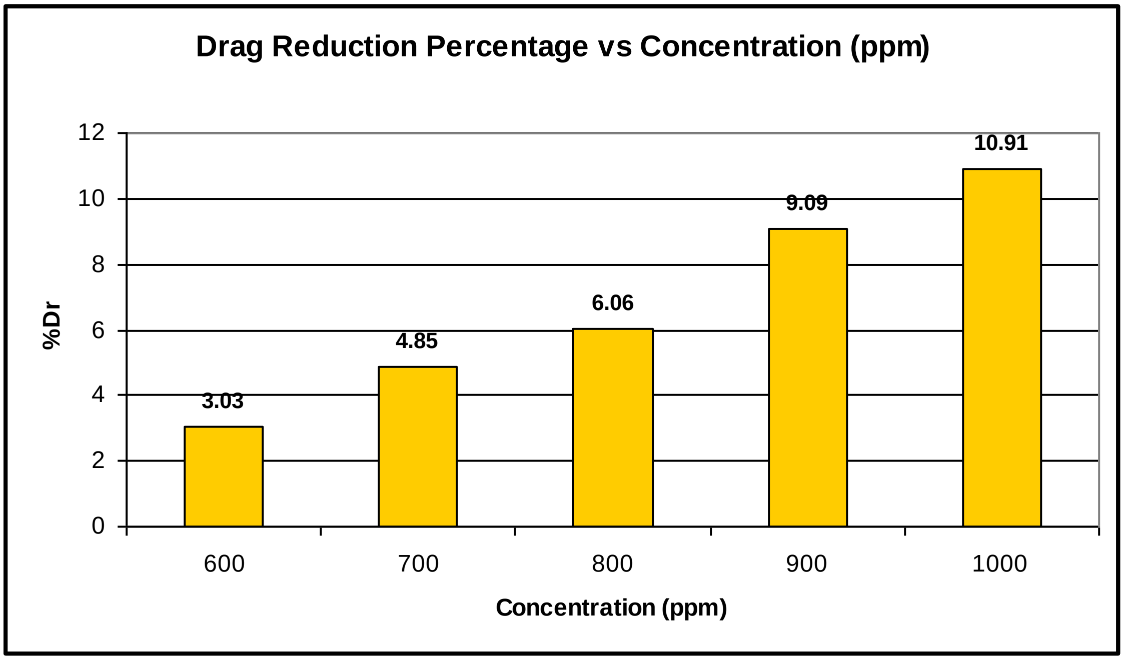


Figure 18: Drag Reduction Percentage vs Concentration (ppm)

From Figure 18, it is clearly showed that percentage of drag reduction is keep increasing from the lowest DRA concentration to the highest concentration. For 600 ppm, the value of drag reduction percentage is reflected to 3.03% and 700 ppm of DRA concentration is reflected to 4.85%. Meanwhile, for concentration of 800 ppm, 900 ppm and 1000 ppm are used, the percentage of drag reduction inclined to 6.06%, 9.09% and up to 10.91%. This occurred because when high concentration of DRA is injected to the test section, it increased the ratio between DRA molecule and the degree of turbulence. In fact, more DRA molecules are reacted with turbulent structure. It disturbed and reduced the degree of turbulence and at the same time reduced the energy loss and friction pressure loss. Thus, the drag reduction is increased due to high concentration of DRA. Meanwhile, for a low concentration of DRA, the chain of polymer is easy to break or known as degradation. It is due to low ratio between DRA molecules and degree of turbulence. Thus, it reduced the performance of DRA to reduce friction pressure loss and as a result, the percentage of drag reduction is reduced.

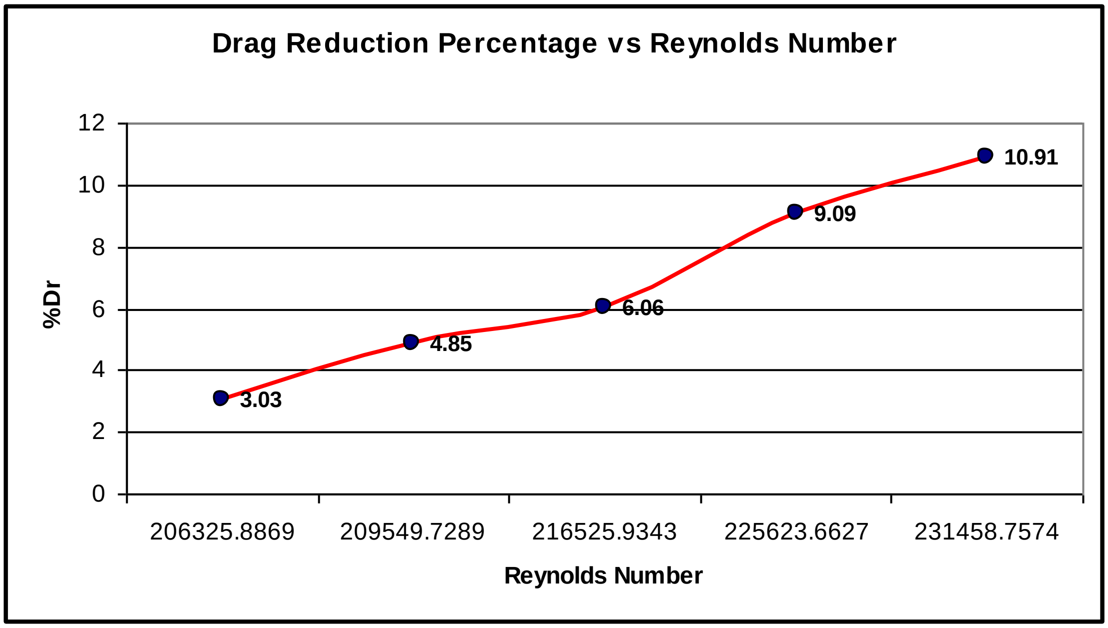


Figure 19: Drag Reduction Percentage vs Reynolds Number

Refer to Figure 19, it showed that the percentage of drag reduction is increased when Reynolds Number is increased. When the Reynolds number is increased, the percentage of drag reduction is increased from 3.03% up to 10.91%. DRA only works in turbulent flow which is Re > 5000. When Reynolds number is increased, the degree of turbulence also increased. The molecules of water moved in random motion and unstable. It wasted the energy and causing drag and pressure loss. By injecting the DRA to the flowing water, it disturbed the formation of turbulence and absorbed the energy of it. As a result, it reduced the friction pressure loss and increased the percentage of drag reduction.

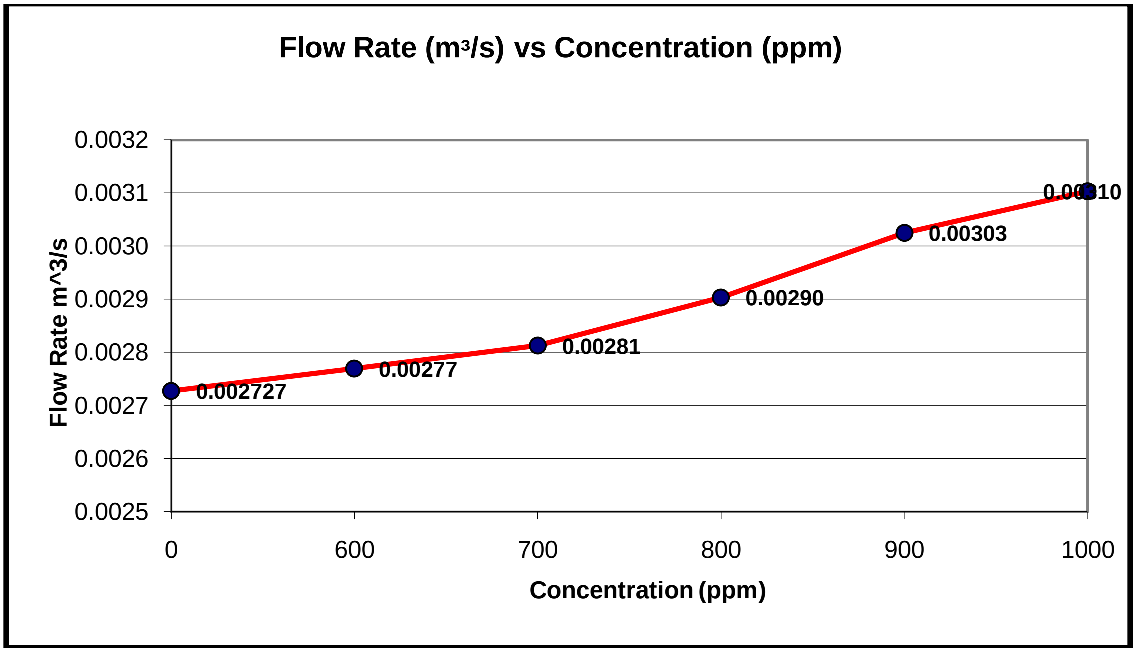


Figure 20: Flow Rate vs Concentration

According to Figure 20, the capacity of flowing water is increased with high concentration of DRA. Before injecting the DRA, the flow rate of water flowing from storage tank to drainage tank is 0.002727m³/s. Meanwhile, after injecting the DRA, the flow rate of water in increased and based on the graph, it stated that from the lowest concentration, 600 ppm, the flow rate is 0.00277m³/s and for the highest concentration, 1000 ppm, the flow rate is 0.00310m³/s. It proved that the water flowed in short time after injecting the DRA (in increasing concentration) at the test section. It occurred because after DRA is injected, it inhibited the formation of turbulent burst and absorbed the energy of the streak. Thus, it reduced drag and friction pressure loss in the pipeline. As a result, the capacity of water is increased with the concentration of DRA.

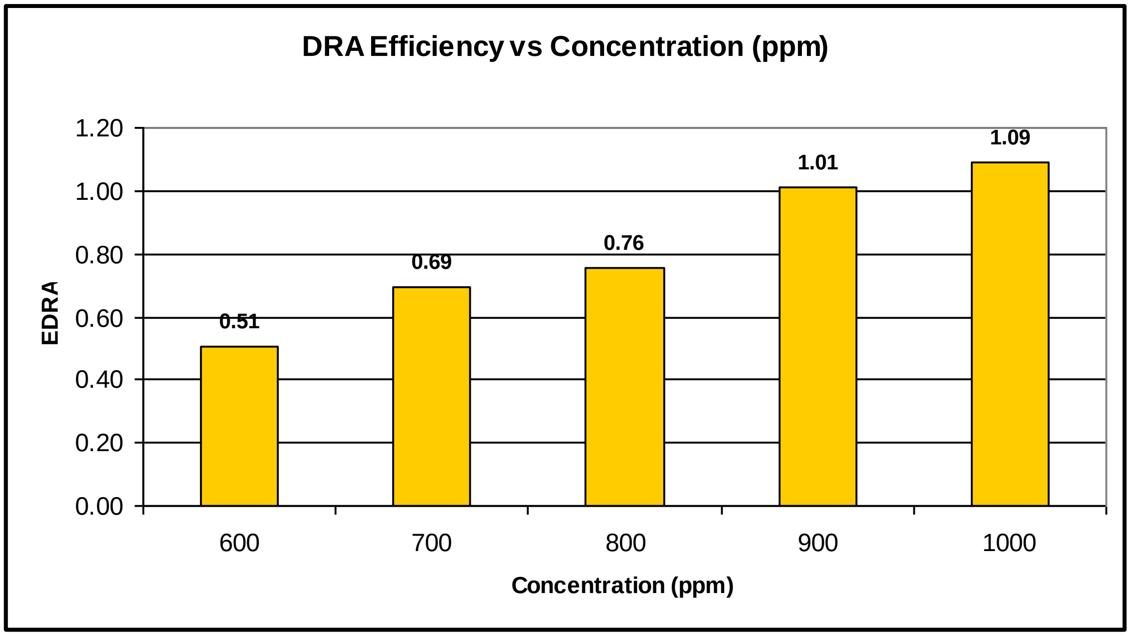


Figure 21: DRA Efficiency vs Concentration

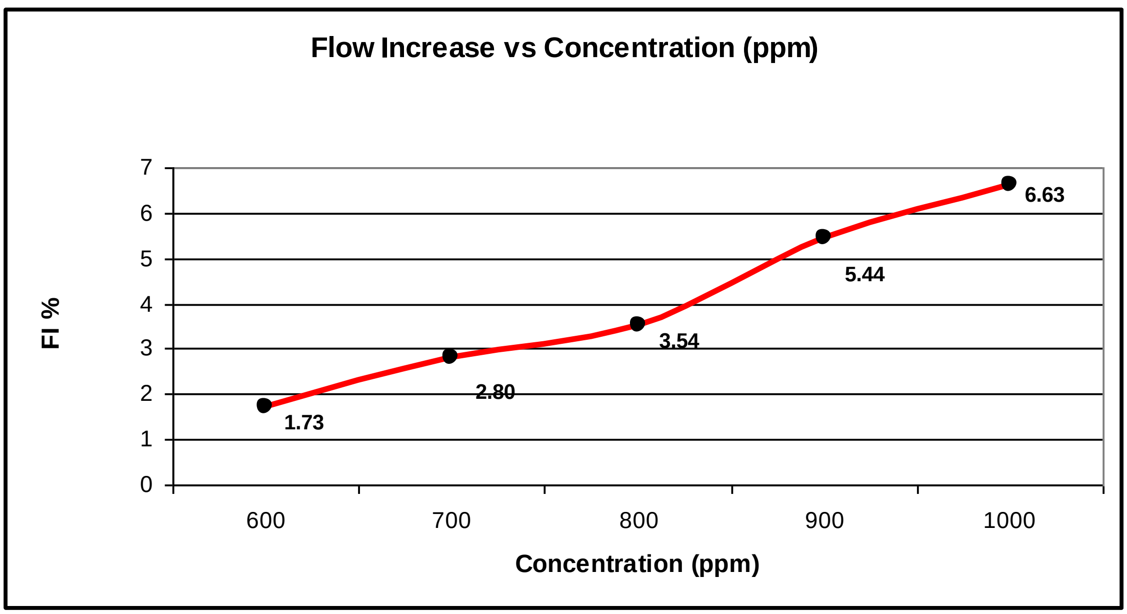


Figure 22: Flow Increase vs Concentration

From Figure 21, the highest DRA efficiency is referred to 1000 ppm which is 1.09 meanwhile the lowest DRA efficiency is goes to 600 ppm of DRA concentration which is 0.51. According to the result, it proved that DRA with 1000 ppm is the ideal concentration for this experiment. It is because as refer to Figure 18, it stated that 1000 ppm gives the highest value of drag reduction percentage which is 10.91%. In addition,

Figure 22 which showed the relationship between flow increase and concentration of DRA also proved that 1000 ppm is an ideal concentration of DRA and has potential to be good DRA. It increased in pump ability of water from 1.73% up to 6.63%.

Comparison of Results

In this experiment, there are 2 types of natural polymer used as DRA are evaluated. This evaluation is held in order to measure the performance of DRA in reducing the pressure drop in pipeline and at the same time, increased the capacity of water. Basically, there are Solanum Tuberosum and Mung Beans.

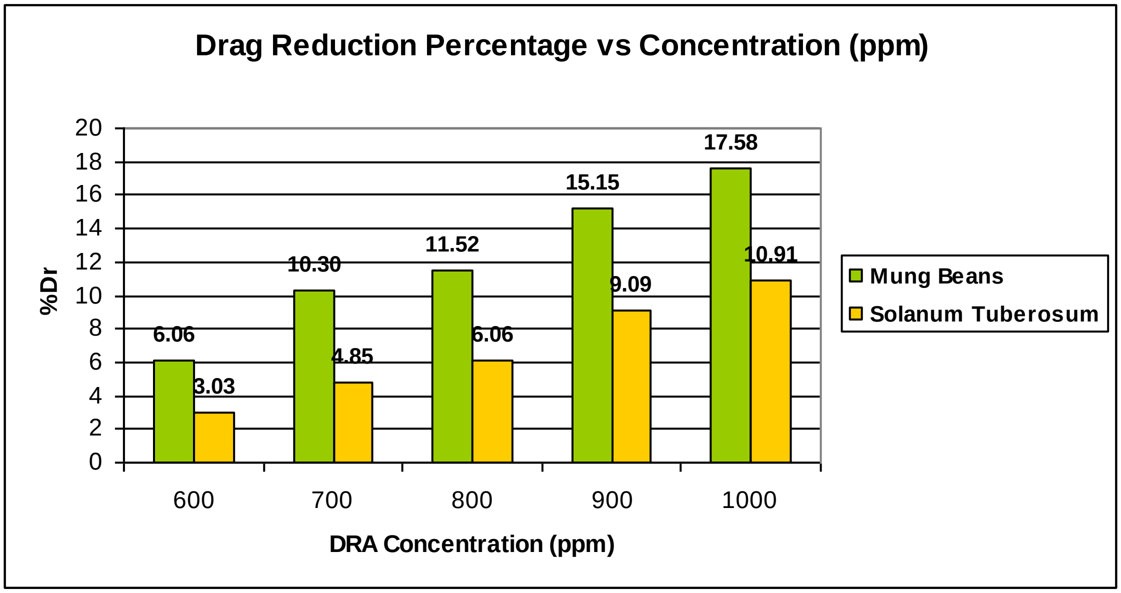


Figure 23: Drag Reduction Percentage from Comparison of Natural Polymers

According to Figure 23, the highest percentage of drag reduction is provided by Mung Beans at 1000 ppm. It increased up to 17.58% compared to Solanum Tuberosum which only has 10.91% as the highest percentage of drag reduction.

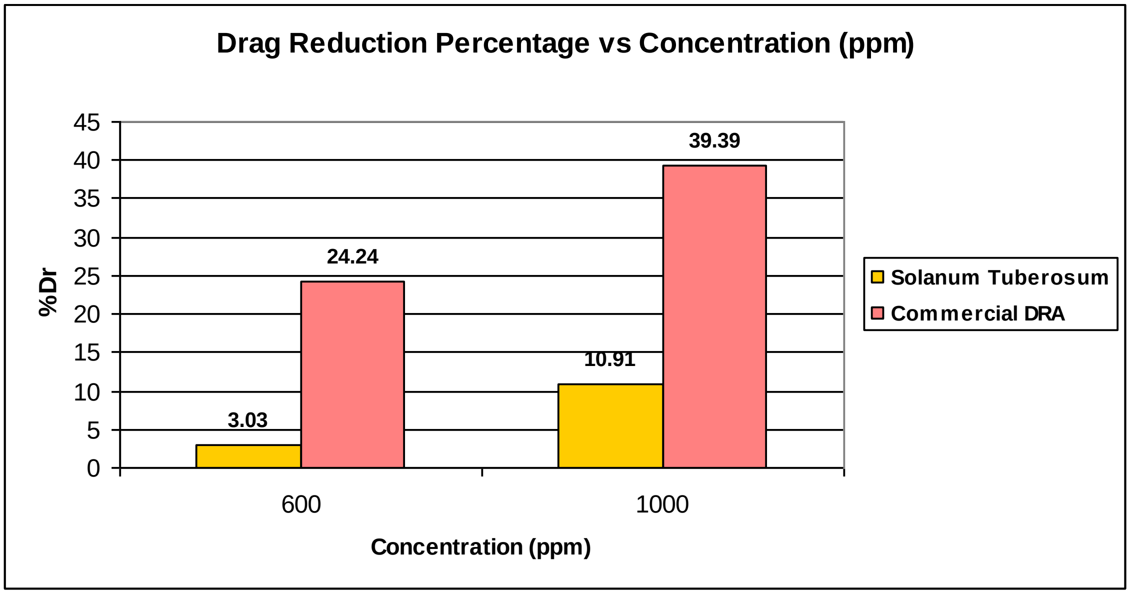


Figure 24: Comparison of Drag Reduction Percentage with commercial DRA

Besides that, comparison between Solanum Tuberosum and commercial DRA is also conducted and the result is based on Figure 24. Although the result showed that Solanum Tuberosum is lower than commercial DRA , but it still has potential to be as a good drag reducer in industries after considers some adjustments and minimize the limitations which needs more time to expand this research. Despite the DRA is raw, it is still comparable to commercial DRA.

4.3 Calculations

a) <u>Sample calculation for concentration preparation</u>

$$V_{DRA} = \frac{C_{DRA} \times V_{total}}{1 \times 10^6}$$

V_{DRA} = Volume of DRA needed (g)

V_{Total} = Total volume of distilled water (ml)

C_{DRA} = DRA concentration

To prepare 600 ppm:

$$V_{DRA} = \frac{600\,ppm \times 1000ml}{1 \times 10^6}$$

= <u>0.6 gram</u> of DRA needed

b) <u>Sample calculation for drag reduction percentage</u>

$$\%Drag\,\mathrm{Re}\,duction = \left[\frac{\Delta P_{withoutDRA} - \Delta P_{withDRA}}{\Delta P_{withoutDRA}}\right] \times 100$$

To calculate drag reduction percentage for 600ppm:

$$\%Dr = \left[\frac{16.5 - 16}{16.5}\right] \times 100 = \underline{3.03\%}$$

c) <u>Sample calculation for Efficiency Factor for DRA</u>

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

E_{DRA} = Efficiency factor for DRA

C_{DRA} = DRA Concentration

To calculate efficiency factor for 600 ppm:

$$E_{DRA} = \left[\frac{3.03\%}{600}\right] \times 100$$

$$= \underline{0.51\%}$$

d) Sample calculation for Flow Increase

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

FI = Flow Increase

%Dr = Percentage of Drag Reduction

To calculate FI for 600 ppm:

$$FI = \left(\left[\frac{100}{100 - 3.03} \right]^{0.556} - 1 \right) \times 100$$

$$= \underline{1.73\%}$$

4.4 Limitations

In completing the experiment, there are several limitations that had influenced possible outcome. There are:

i. Time is of the essence

It is very time constraint in order to complete the experiment especially in preparing the samples in different concentrations. There are limited magnetic stirrers provided in lab for all students. Thus, everyone needs to take turn in using that equipment. Besides, after the solutions already prepared, each of it must be stirred around 1 hour to get well mixed and dilute totally in distill water.

ii. Pump ability

The centrifugal pump consists of two different speeds which are low and high RPM. But, when low RPM is used in pumping the water through the test section, it did not give any reading at the outlet of test section (pressure gauge 2). It might happened because of the length of test section already added which is from 4m to 6m. The pump is not able to pump the water in low speed through the longer pipe. Thus, for this experiment, only high RPM is used.

4.4 Errors

There are errors occurred during the experiment.

1. Systematic error

Systematic error cannot be estimated even by repeating the experiment with same equipment. For this project, systematic error occurred when the readings of pressure gauge is measured. It is difficult to get the readings since the needle of pressure gauge is moved upwards and downwards repeatedly and fast. Besides that, viscometer used to measure DRA's viscosity and gel strength also has difficulty to read. The reading is not at the constant value hence, to reduce the error, the reading is measured for several times and averaged value is taken. In running the experiment, centrifugal pump is used to boost water through the pipeline. But, the centrifugal pump only has 'low' and 'high' reading for its revolution per minute (RPM).Thus, the level of energy that is delivered from the pump is not the same for each run because the value of RPM is unknown.

2. Parallax error

Parallax error is error in reading the instrument employing a scale and pointer because the observer's eye and pointer are not in a line perpendicular to the plane of the scale. For this project, this error happened when the readings of pressure gauge are measured. To minimize the effect of error, the averaged reading is taken.

3. Human error

This error occurred when time is taken to determine time needed to fill the tank with water in order to get its flow rate. The stop watch is stopped when water reached 36 liter. But, for the time being, the stop watch cannot be stopped at the same time because of the human limitation which cannot give same reaction between brain and hand.

CHAPTER 5: CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

After the experiment is conducted, the objective to study the performance and effect of Solanum Tuberosum used in DRA is achieved. Although this type of natural polymer did not shown the best performance in the percentage of drag reduction, but it can be potential drag reducer after considering some adjustments. As mention in background study, using DRA in water injection is a vital concept of displace the oil in reservoir when natural energy is depleted. It will help to maintain or re-pressurized reservoir pressure by reduce the drag friction in pipeline. Thus, friction pressure losses inside the pipe will reduce and as a result, the capacity of water injection will increase.

Besides that, the initial investment cost in getting Solanum Tuberosum is cheaper than any chemical substances. Thus, natural polymer should be more commercialize in oil & gas industry. The essential thing about natural polymers, it is environmental-friendly, indeed. It has no contribution in world's pollution

Overall, to accomplish this project, the significant of DRA in oil & gas industry need to be learned and the concept of how DRA will only react in turbulence flow also how to increase the performance of DRA in the easiest and cheapest way must be discovered.

5.2 Recommendations

For future continuation on this research, there have a lot of improvements need to be done in order to minimize the errors and limitations encountered during the experiment.

Below are the recommendations for next reference:

1) Change galvanized steel pipe to transparent pipe as easier to observe condition inside the pipeline.
2) Use more stable centrifugal pump in delivering its power which has values of its RPM instead of 'low' and 'high' only.
3) Use digital scale of pressure gauge which has 'average, min, max' reading function in order to get accurate values.
4) Use suitable tank which has divisions as to measure volume of water inside storage and drainage tank
5) Use more accurate injector mechanism to inject DRA right to the core of pipeline such as nozzle with check valve rather than use tee section as injector mechanism.
6) To ensure centrifugal pump is in good condition. No leaking occurs.
7) Add on some dye or stain in DRA solution as easier to observe either DRA is mix well enough with water in pipeline or not.
8) Provide more options in pipe diameter instead of one diameter only.
9) Get as much as possible all the knowledge and information about this project.

FYP 2 GANTT CHART

Activities/ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Continue the work • Continue modify the prototype • Commence Rheology test for natural polymer • Drafting progress report • Prepare DRA concentrations														
Commence the experiment • Measure pressure drop for base case (water only) • Measure pressure drop for each concentration of natural polymer (water + DRA) • Prepare progress report														
Submission of progress report														
Submission of poster														
Submission of final report														
Submission of technical paper														
Final oral presentation														
Submission of Hard Bound Copies														

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APPENDIX A

EXPERIMENTAL DATA SHEET RESULT

A.1 Result of Experiment

PIPE	
Length (m)	12.25
Pipe D (m)	0.0254
Volume Pipe (m^3)	0.006207167
Area Pipe (m^2)	0.000506773
Constant	1000000
DRAINAGE TANK	
Volume (l)	36
Volume (m^3)	0.036

Table 4: Data of Pipeline & Drainage Tank

BASE CASE					
DRA Conc. (ppm)	Time (s)	P1 (psi)	P2 (psi)	∆P	%DR
NONE	13.2	22.5	6	16.5	NONE

Table 5: Pressure Drop of Base Case (without DRA)

DRA Conc. (ppm)	Time (s)	P1 (psi)	P2 (psi)	∆P	%DR (without DRA-with DRA)/without DRA
600	13	22.5	6.5	16	3.03
700	12.8	22.5	6.8	15.7	4.85
800	12.4	22.5	7	15.5	6.06
900	11.9	22.5	7.5	15	9.09
1000	11.6	22.5	7.8	14.7	10.91

Table 6: Pressure Drop with DRA

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

Table 7: Pressure Drop with Commercial DRA

Tabulated Data

HIGH RPM														
DRA Vol. (g)	**DRA Conc. (ppm)**	**μ (cp)**	**μ (kg/m³)**	**ρ (kg/m³)**	**t**	**Q (m³/s)**	**V (m/s)**	**N_{RE}**	**P (1)**	**P (2)**	**ΔP**	**%DR**	**E_{DRA}**	**FI**
0.6	600	1.0	0.00067	998.95	13	0.00277	5.4644	206325.9	22.5	6.5	16	3.03	0.51	1.73
0.7	700	1.0	0.00067	998.95	12.8	0.00281	5.5498	209549.7	22.5	6.8	15.7	4.85	0.69	2.80
0.8	800	1.0	0.00067	999.95	12.4	0.00290	5.7288	216525.9	22.5	7	15.5	6.06	0.76	3.54
0.9	900	1.0	0.00067	999.95	11.9	0.00303	5.9696	225623.7	22.5	7.5	15	9.09	1.01	5.44
1.0	1000	1.0	0.00067	999.95	11.6	0.00310	6.1239	231458.8	22.5	7.8	14.7	10.91	1.09	6.63