FORMULATION NEW FLOW IMPROVER IN AQUEOUS USING NATURAL MUCILAGE EXTRACTED FROM ALOE VERA

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KUMARAN A/L LETCHMANAN

A thesis submitted in fulfillment
of the requirements for the award of the degree of
Bachelor of Chemical Engineering

Faculty of Chemical & Natural Resources Engineering
University Malaysia Pahang

APRIL 2010

I declare that this thesis entitled "Formulation New Flow Improver in Aqueous Using Natural Mucilage Extracted from Aloe Vera" is the result of my own research except as cited in references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Dedicated especially to my beloved Father, Mother, Siblings, Friends, Lecturers and the ones who give me inspiration and support that made this work possible.

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ABSTRACT

In the present research, natural polymer of aloe Vera tested as drag reducing agent in aqueous media flow in pipelines. After research in the literature dealing with drag reduction phenomena, there was no evidence that aloe Vera was used as flow improver before this in the drag reduction field. Aloe Vera mucilage with concentration from 100 to 400ppm was tested in 2 different internal diameters (0.0254m and 0.0381m) pipes and 5 different flow rate which are represented by Reynolds number. All the experimental work was carried out in a built-up closed loop liquid circulation system with four testing sections of 2m long pipe were investigated. The experimental results showed that the drag reduction increases corresponding with increasing of Re, additive concentration and pipe length and reduction of pipe diameter. The results show, aloe Vera polymer can perform as a good drag reducing agent with maximum percentage drag reduction of 71% obtained at I.D 0.0254m and 15472.694 of Reynolds number for 400ppm of solution.

ABSTRAK

Objektif menjalankan kajian ini adalah mengkaji keupayaan formulasi polimer asli yang bertindak sebagai agen pengurangan seretan yang berlaku di dalam aliran paip. Selepas kajian yang lama dibuktikan bahawa kajian terhadap aloe Vera adalah yang baru dan tidak pernah diuji oleh saintis yang lain.Polimer asli dengan kepekatan 100ppm, 200ppm, 300ppm dan 400ppm akan diuji di dalam kerangka ujian yang mempunyai paip lutsinar berukuran 0.0254 meter D.I, dan 0.0381 meter D.I dengan 1.5 meter panjang dan 5 Nombor Reynolds yang berlainan. Daripada keputusan yang diperolehi, peratusan pengurangan seretan tertinggi adalah 71% pada 0.0254m I.D dan Nombor Reynolds 15472.694 untuk Polimer asli dengan kepekatan 400ppm. Peratusan pengurangan seretan didapati meningkat apabila halaju cecair yang diwakili oleh Nombor Reynolds meningkat, peningkatan kepekatan agen pengurangan seretan dan pengurangan diameter dalaman paip. Keputusan juga menunjukkan peratusan pengurangan seretan pada tahap maksimum sebelum degradasi mekanikal berlaku yang disebabkan rotasi pump semasa eksperimen perbezaan tekanan dijalankan. Berdasrkan keputusan, agen pengurangan seretan memberikan peratusan pengurangan seretan yang tinggi tanpa penambahan pum. Objektif dalam menjalankan kajian ini telah tercapai dengan menentukan kaedah paling berkesan dalam mengekstrak polimer asli yang bergantung kepada kesan halaju cecair, kepekatan agen pengurangan geseran dan diameter dalaman paip terhadap peratusan pengurangan seretan.

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LIST OF SYMBOLS / ABBREVIATIONS

DRA	-	Drag Reducing Agent
DR	-	Drag Reduction, dimensionless
D.I	-	Internal pipe diameter, meter
%DR	-	Percentage Drag Reduction
m	-	Mass, kg
ppm	-	Parts per million
ΔP_a	-	Pressure difference after adding additives, N/m^2
ΔP_b	-	Pressure difference before adding additives, N/m^2
Re	-	Reynolds number, dimensionless
Q	-	Volumetric flow rate, m^3/hr
ρ	-	Density, kg/m^3
μ	-	Viscosity, kg/s.m

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CHAPTER 1

INTRODUCTION

1.1 Study background.

Drag is a mechanical force that generated by the interaction and contact of a solid body with a fluid (liquid or gas). For drag to be generated, the solid body must be in contact with the fluid. Drag is generated by the difference in velocity between the solid object and the fluid which are in motion. If there is no motion, there is no drag occur [1]. The remarkable ability of low concentrations of certain additives to reduce the frictional resistant in turbulent flow of the pure solvent is known as drag reduction. It is well known that polymers are the most effective drag reducers. It is not unusual to see up to 80 percent drag reduction with only a few parts per million of added polymer [2].

Drag reduction agent also known as drag reducer or flow improver is high-molecular-weight polymers that improve the fluid flow characteristics of low-viscosity petroleum products. Drag reduction agent can reduce pumping costs by reducing friction between the flowing fluid (gasoline) and the walls of the pipe [3]. When DRA dissolves in crude oil the polymer molecules begin to uncoil and outspread as they interact with the pipeline flow. This interaction is complex; the long chain molecules dampen turbulent bursts near the pipe wall as if they were acting as tiny shock buffers. This dampening effect reduces frictional pressure loss resulting in a decrease in energy consumption or an increase in flow rate [4].

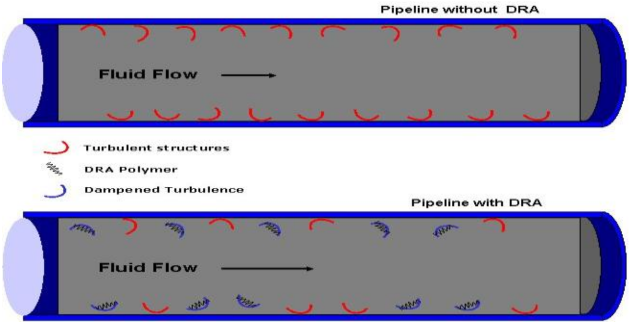


Figure 1.1 Fluid flow through pipelines with and without DRA

In achieving drag reduction efficient, a new material, natural polymers will be study. The natural polymer is aloe Vera mucilage. There are three methods of extracting aloe Vera which are Cold Method, Thermal Method of water and solvent extraction of ethanol. These three methods will be explained in the in methodology in chapter three. These natural polymers then will be used to detect the most optimal drag reducing efficiency in pipeline.

Aloe Vera gel is the commercial name given to the fibre free mucilaginous exudates extracted from the hydro parenchyma of the succulent leaves of aloe Vera. The viscous, pseudo plastic nature of aloe Vera gel, due mainly to the presence of polysaccharides composed of a mixture of acetylated glucomannans is lost shortly after extraction, apparently due to enzymatic degradation. To stabilize aloe Vera gel and delay its degradation by admixture with natural polysaccharides [5].

Toms (1949) was the first to report the existing phenomenon of drag reduction. He obtained friction reduction up to 50% compared with a pure solvent using a 0.25% solution of poly (methylmethacrylate) in monochlorobenzene. He used tubes of various diameter and observed that (i) drag reduction occurs in turbulent flow; (ii) for a given polymer concentration and Reynolds number, it increases as the pipe diameter is reduced and also (iii) the drag reduction occurs when the wall shear stress exceeds a critical value which later came to be known as ‘onset of drag reduction’ [6].

1.2 Problems statement.

Drag reduction or flow improving in pipelines carrying petroleum products or crude oils, was one of the main challenges especially in the last few decades when the term power saving, raised up due to the rapid increase in global power consumption. One of the major sectors that deal with huge amounts of power losses is the liquids transportations through pipelines. It is known that, liquids (water, crude oil and refinery products) are transported in pipelines in a turbulent mode (Reynolds number higher than 2500) and that will lead to huge pumping power losses along the pipelines (especially strategic pipelines). Drag Reducing Agents (DRA`s) were used in the past few decades to improve the flow in pipelines and to increase it without the need for any changes in the geometry of the pipeline system. [7]

1.3 Objectives.

The objectives in this present research are:

1. Identify the most suitable plant or vegetable to use as a raw material which is aloe Vera.
2. Identify the suitable time or age of aloe Vera to use in the experiment so the amount of mucilage is high.
3. Identify the most suitable procedures in extracting natural polymer of aloe Vera.
4. Investigate effect of the drag reduction agent in pipelines.
5. Identify the effect of dried skin of aloe Vera as a fiber in drag reduction.
6. Investigate the most suitable flow rate, pipe diameter and concentration in reducing pressure drop.

1.4 Scope of study.

Survey shows very limited or almost no work on processing of aloe Vera as DRA. High percentage of mucilage in aloe Vera creates a need to do more research and study on this field. Study on extraction of aloe Vera mucilage and drying of aloe Vera skin was, therefore, started in undergraduate research project. In this study, technique of extraction with optimum temperature, preserve the quality of mucilage by antibacterial and antioxidant, solubility and the commercial value of aloe Vera mucilage is investigated. In brief the scope of the study is stated as below;

1. Aloe Vera mucilage used as a Drag Reduction Agent.

2. Extract aloe Vera mucilage using three different suitable methods to find out the method that can save time and cost.

3. Choose the best method of extraction out of three methods to maximize the yield.

4. Dry aloe Vera skin and use as fiber to reduce drag to avoid any waste.

5. To increase shelf life of aloe Vera by using Rosmarinic acid as antibacterial and antioxidant.

6. Following qualities of aloe Vera mucilage is measured; optimum temperature to preserve the best qualities of aloe gel, optimum amount of Rosmarinic acid added, optimum age of aloe Vera to become mature and produce high percentage of mucilage and the solubility.

1.5 Rationale and significant.

This significant of this research is to develop another environmental friendly product to overcome lost of energy in transporting liquid using pipelines especially in long distance transportation such as in an offshore platform and oil rig. This is because, by studying the effects of drag reduction, its can help to reduce pumping pressure or increase flow rate when transporting the liquids from one distance to another [8]. Therefore, the cost and time can be saving by adapting Drag Reducing technology in pipeline system. This research also can determine the most suitable natural polymeric Drag Reducing Agent by identify the most suitable treatment in extracting natural polymer which is aloe Vera mucilage. As a result, environment can be safe because this natural polymer is an environmental friendly (biodegradable) DRA.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Formulation of new flow improvers in aqueous media that extracted from aloe Vera mucilage is a very important research to overcome the pressure and energy loss in pipelines during transport fluid like crude oil and refinery. The important subchapters that will be discussed in this chapter is about flows of fluid in pipeline, types of flow, energy consumption during transport fluids, friction in pipeline, definition of drag reduction, information of drag reduction agent, types of flow improver, definition of mucilage and finally commercial application of DRA.

2.2 Flows in pipeline

2.2.1 Classification of fluid flow

Fluids mechanics is the science that deals with the behavior of fluids at rest or in motion and the interaction of the fluid with the solids or other fluid at the boundaries. There is wide variety of fluid flow problems encountered in practice, and it is usually convenient to classify them on the basis of some common characteristics to make it feasible to study them in groups. There are many ways to classify fluid flow problems, and here we present some general categories [9].

2.2.2 Viscous versus viscid regions of flow

When two fluid layers move relatively each other, a friction force develops between them and the slower layer tries to slow down the faster layer. This internal friction to flow is quantified by the fluid properties viscosity, which is the measure of internal stickiness of the fluid. Viscosity is cause by cohesive force between the molecules in liquids and by molecular collisions in gases. There is no fluid with zero viscosity, and thus all fluid flows involve viscous effects to some degree. Flows in which the frictional effects are significant are called viscous flows. However, many flows of practical interest, there are regions (typically region not close to solid surface) where viscous forces are negligibly small compared to inertial or pressure forces. Neglecting the viscous term in such in viscid flow regions greatly simplifies the analysis without much loss in accuracy [9].

2.2.3 Internal versus external flow

A fluid flow is classified as being internal or external, depending on whether the fluid is forced to flow in a confined channel or over a surface. The flow of an unbounded fluid over a surface such as a plate, a wire or a pipe is external flow. The flow in a pipe or duct is internal flow if the fluid is completely bounded by solid surface. Water flow in a pipe, for example, is internal flow, airflow over a ball or over an exposed pipe during a windy day is external flow. The flow of liquids in a duct is called open channel flow if the duct is only partially filled with the fluid and there is a free surface. The flow of water in rivers and irrigation ditches are example of such flows. Internal flows are dominated by the influence of viscosity throughout the flow field. In the external flows the viscous effects are limited to boundary layers near solid surfaces and to wake regions downstream of bodies [9].

2.2.4 Laminar versus turbulent flow

Some flows are smooth and orderly while other are rather chaotic. The highly ordered fluid motion characterized by smooth layer of fluid is called laminar. The word laminar comes from the movement of adjacent such as oils at low velocities and is characterized by velocity fluctuation is called turbulent. The flow of low viscosity fluids such as air at high velocity is typically turbulent. The flow regime greatly influences the required power for pumping. A flow that alternates between being laminar and turbulent is called transitional [9].

2.2.5 Natural flow versus forced flow

The fluid flow is to be natural or forced; depending on the how the fluid motion is initiated. In forced flow, a fluid is forced to flow over a surface or in a pipe by external means such as a pump or a fan. In natural flow, any fluid motion due to natural means such as the buoyancy effect, which manifests itself as the rise of the warmer (and thus lighter) fluids and the fall of cooler (and thus denser) fluid. In solar hot water system, for example, the thermo siphoning effect is commonly used to replace pumps by placing the water tank sufficiently above the solar collectors.

2.2.6 Steady versus unsteady flow

The terms steady and uniform are used frequently in engineering, and thus it is import to have clear understanding of their meanings. The term steady implies no change at the point with time. The opposite of steady is unsteady. The term uniform implies no change with location over a specified region. These meanings are consistent with their everyday use (steady girlfriend, uniform disturbance). The terms unsteady or transient are often used interchangeably, but these terms are not synonyms. In fluid mechanics, unsteady is the most general term that applies to any flow that is not steady, but transient is typically used for developing flows. When a rocket engine is fired up, for example, there are transient effects (the pressure builds up inside the rocket engine, the flow accelerates) until the engine settles down and operates steadily. The term periodic refers to kind of unsteady flow in which the flow oscillates about a steady mean [10].

2.2.7 Compressible versus incompressible flow

A flow is classified as being compressible or incompressible, depending on the level of variation of density during flow. Incompressibility is an approximation, and a flow is said to be incompressible if the density remains nearly constant throughout. Therefore, the volume of every portion of fluid remains unchanged over the course of its motion when the flow or the fluid is incompressible. The densities of liquids are essentially constant, and thus the flow of liquid is typically incompressible. Therefore, liquids are usually referred to as incompressible substances. A pressure of 210 atm, for example, causes the density of liquid water at 1 atm to change by just 1 percentage. Gases, on the other hand, are highly compressible. A pressure change just 0.01 atm, for example, causes a change of 1 percent in the density of atmospheric air [9].

2.3 Types of flow in pipelines

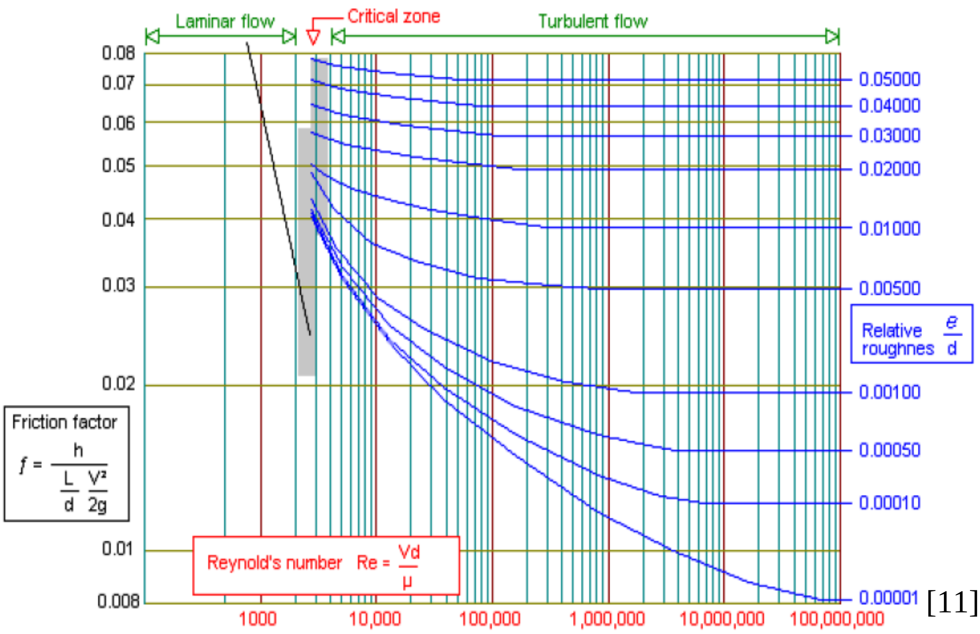
There are in general three types of fluid flow in pipes which are laminar, turbulent, and transient. The type of flow is determine by the Reynolds Number (laminar when $Re < 2300$, transient when $2300 < Re < 4000$, turbulent when $4000 < Re$) which is depend on on the geometry, surface roughness, flow velocity, surface temperature and types of fluid. [10]

2.3.1 Reynolds Number

After exhaustive experiments in the 1880s, Osborne Reynolds discovered that the flow regime depends mainly on the ratio of internal forces to viscous forces in the fluid. The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e. shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force [9]. The Reynolds number (Re) of a flowing fluid is obtained by dividing the kinematic viscosity (viscous force per unit length) into the inertia force of the fluid (velocity x diameter).

$$\text{Kinematic viscosity} = \frac{\text{dynamic viscosity}}{\text{fluid density}} \quad (1)$$

$$\text{Reynolds number} = \frac{\text{Fluid velocity x Internal pipe diameter}}{\text{Kinematic viscosity}} \quad (2)$$



[11]

Figure 2.1 Effect of Reynolds number on Friction Factor

2.3.2 Laminar flow

Laminar flow generally happens when dealing with small pipes and low flow velocities. Laminar flow can be regarded as a series of liquid cylinders in the pipe, where the innermost parts flow the fastest, and the cylinder touching the pipe isn't moving at all [10]. Where the Reynolds number is less than 2300 laminar flow will occur and the resistance to flow will be independent of the pipe wall roughness. The friction factor for laminar flow can be calculated from 64 / Re. Fluids with a high viscosity will flow more slowly and will generally not support eddy currents and therefore the internal roughness of the pipe will have no effect on the frictional resistance [11].

2.3.3 Turbulent Flow

One of the major considerations when designing liquid waste fuel storage and burner supply systems is trying to maintain turbulent flow. The need to maintain turbulent flow is usually associated with the need to keep solids suspended in the fluid, so that the solids do not settle and plug the piping. However, maintaining turbulent flow may not be necessary if the fluid viscosity is sufficiently high enough to impede the settling of the solids. Indeed if the viscosity is too high it may not be possible to achieve turbulent flow without special pumps and high pressure rated piping. In most cases it is worthwhile to try to achieve turbulent flow since it reduces the flow resistance of the fluid and consequently the pressure losses in the piping system due to this flow resistance [12]. In turbulent flow vortices, eddies and wakes make the flow unpredictable. Turbulent flow happens in general at high flow rates and with larger pipes [10]. Turbulent flow occurs when the Reynolds number exceeds 4000. The friction factor for turbulent flow can be calculated from the Colebrook-White equation [11]:

$$1/\sqrt{f} = 1.14 - 2\log_{10}\left(\frac{e}{D} + \frac{9.35}{\mathrm{Re}\sqrt{f}}\right) \quad \text{for Re > 4000} \tag{3}$$

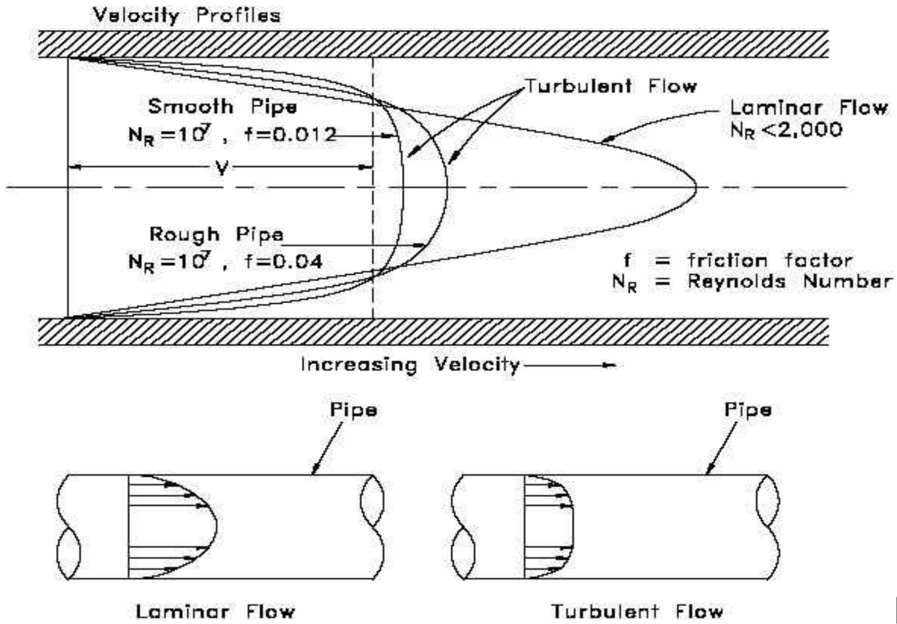
2.3.4 Transitional flow

Between the Laminar and Turbulent flow conditions (Re 2300 to Re 4000) the flow condition is known as critical. The flow is neither wholly laminar nor wholly turbulent. It may be considered as a combination of the two flow conditions [11]. Transitional flow is a mixture of laminar and turbulent flow, with turbulence in the centre of the pipe, and laminar flow near the edges. Each of these flows behaves in different manners in terms of their frictional energy loss while flowing, and have different equations that predict their behavior [10].

2.3.5 Comparison between laminar and turbulent flow

2.3.5.1 Flow Velocity Profiles

Not all fluid particles travel at the same velocity within a pipe. The shape of the velocity curve (the velocity profile across any given section of the pipe) depends upon whether the flow is laminar or turbulent. If the flow in a pipe is laminar, the velocity distribution at a cross section will be parabolic in shape with the maximum velocity at the centre being about twice the average velocity in the pipe. In turbulent flow, a fairly flat velocity distribution exists across the section of pipe, with the result that the entire fluid flows at a given single value. Figure 5 helps illustrate the above ideas. The velocity of the fluid in contact with the pipe wall is essentially zero and increases the further away from the wall. The velocity profile depends upon the surface condition of the pipe wall. A smoother wall results in a more uniform velocity profile than a rough pipe wall [13].



[13]

Figure 2.2: Velocity profiles of laminar and turbulent flow in pipeline.

2.4 Energy consumption

The rapid increase in oil and gas prices during the 1970s brought emphasis on reducing the use of energy in all petroleum operations, including pipeline system. Efficiency became an important part of the design of a new system.

In general, many decision on designing for energy efficiency or for increasing the efficiency of existing systems hinge on the tradeoffs between larger lines sizes and greater pumping or compression horsepower. Engine fuel is typically the largest use of energy in a pipeline system. In the case of natural gas pipeline systems, for example, studies in the late 1970s showed that beyond a certain operating pressure the use of larger pipe-or looping portions of existing pipelines-to increase system capacity was less expensive than additional compression horsepower and saved significant amounts of fuel. As prices fluctuate, of course, these cost relationships change [14]. There are three types of energy losses in pipeline, which are losses due to friction in a pipeline or during laminar and turbulent flow in a pipe.

2.5 The Force of Friction

Friction is a force that is created whenever two surfaces move or try to move across each other.

- Friction always opposes the motion or attempted motion of one surface across another surface.
- Friction is dependent on the texture of both surfaces.
- Friction is also dependant on the amount of contact force pushing the two surfaces together [17].

2.5.1 Flow of fluid through a pipe

The flow of liquid through a pipe is resisted by viscous shear stresses within the liquid and the turbulence that occurs along the internal walls of the pipe, created by the roughness of the pipe material. This resistance is usually known as pipe friction and is measured is feet or metres head of the fluid, thus the term head loss is also used to express the resistance to flow.

Many factors affect the head loss in pipes, the viscosity of the fluid being handled, the size of the pipes, the roughness of the internal surface of the pipes, the changes in elevations within the system and the length of travel of the fluid. The resistance through various valves and fittings will also contribute to the overall head loss. A method to model the resistances for valves and fittings is described elsewhere [18].

In a well designed system the resistance through valves and fittings will be of minor significance to the overall head loss, many designers choose to ignore the head loss for valves and fittings at least in the initial stages of a design. Much research has been carried out over many years and various formulae to calculate head loss have been developed based on experimental data [18].

2.5.2 Resistance to flow in a pipe

When a fluid flows through a pipe the internal roughness of the pipe wall can create local eddy currents within the fluid adding a resistance to flow of the fluid. Pipes with smooth walls such as glass, copper, brass and polyethylene have only a small effect on the frictional resistance. Pipes with less smooth walls such as concrete, cast iron and steel will create larger eddy currents which will sometimes have a significant effect on the frictional resistance. The velocity profile in a pipe will show that the fluid at the centre of the stream will move more quickly than the fluid towards the edge of the stream. Therefore friction will occur between layers within the fluid. Fluids with a high viscosity will flow more slowly and will generally not support eddy currents and therefore the internal roughness of the pipe will have no effect on the frictional resistance [18].

2.6 Drag Reduction

The remarkable ability of low concentrations of certain additives to reduce the frictional resistant in turbulent flow is known as drag reduction. It is well known that polymers are the most effective drag reducers [19]. The phenomenon of drag reduction, reported for the first time by the British chemist Toms in 1949, is probably the effect produced by polymer addiction in fluids which has attracted the most attention, because of its relevance for applications. While performing experiments on the degradation of polymers, Toms observed that the addition of few parts per million of long chain polymers in turbulent flow produces a dramatic reduction of the friction drag [20].

Despite the extensive research in the area of drag reduction over the past four decades, there is no universally accepted model that explains the mechanism by which macromolecules act to bring about frictional reduction. A comprehensive mechanism would have to address the role of the polymer structure, composition and microstructure as well as polymer-solvent interactions in the drag reduction phenomena. A comprehensive mechanism will also have to explain the differences observed for flexible versus rigid rod polymers. Even though a comprehensive mechanism does not exist, several theories have been presented. One school of thought believes that there are multiple mechanisms must exist to bring about the drag reduction effect. Isolated polymer molecules extend in elongation flow fields present in turbulence, thereby increasing the thickness of the elastic sub layer. Polymer aggregates may exist to form large hydrodynamic domains which could suppress small scale turbulence by resisting rapid changes in alignment. In heterogeneous drag reduction, e.g. injection of a concentrated polymer solution in the centre of a pipe, a long thread of the polymer solution interacts with the larger turbulent disturbances or eddies in the centre of the pipe.

Hydrophobically modified polyacrylamide polymers, anionic and cationic polyelectrolytes, and polyampholytes. It was discovered that all copolymers were found to conform to a universal curve for drag reduction, when normalized for hydrodynamic volume fraction of polymer in solution. This method of plotting allows the facile comparison of drag reduction efficiencies of polymers of widely differing structures, compositions and molecular weights. The most efficient drag reducers are the polymers which yield the greatest values of %DR at a particular volume fraction. The drag reduction efficiency seems to be related to the efficiency with which the polymer hydrodynamic coil interacts with and disrupts the eddies and micro vortices present in turbulent flow. Current work is continuing in this area by utilizing a rotating disk rheometer to determine drag reduction efficiencies of novel water soluble polymers [19].

2.6.1 Theory of Drag Reduction

Frictional pressure drop, or drag, is a result of the resistance encountered by flowing fluid coming into contact with a solid surface, such as a pipe wall. There are generally two types of flow; laminar and turbulent. The friction pressures observed in laminar flow cannot be changed unless the physical properties of the fluid are changed. The current class of DRAs does not change fluid properties and hence they are effective only in turbulent flow. In most petroleum pipelines, the liquid flows through the pipeline in a turbulent regime. Therefore, current DRAs can perform very well in most pipelines.

In a turbulent flow regime, the fluid molecules move in a random manner, causing much of the energy applied to them to be wasted as eddy currents and other indiscriminate motion. DRAs work by an interaction of the polymer molecules with the turbulence of the flowing fluid.

In order to understand how drag reducers decrease the turbulence, it is necessary to describe the structure of turbulent flow in a pipeline. The image below shows a typical turbulent flow in a pipeline that has three parts to the flow. In the very center of the pipe is a turbulent core. It is the largest region and includes most of the fluid in the pipeline. This is the zone of the eddy currents and random motions of turbulent flow. Nearest to the pipeline wall is the laminar sub layer. In this zone, the fluid moves laterally in sheets. Between the laminar layer and the turbulent core lies the buffer zone.

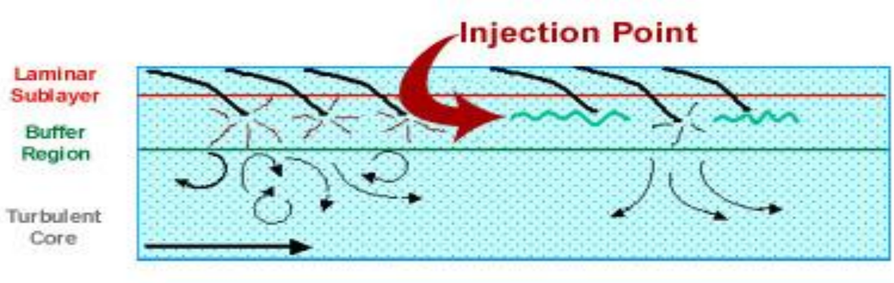


Figure 2.3 Drag Reduction occurs due to suppression of the energy dissipation by turbulent eddy currents near the pipe wall during turbulent flow.

There still is much to be learned about polymeric drag reduction, as there still is much to be learned about the complex phenomenon of turbulence. Recent research into this area tells us that the buffer zone is very important because this is where turbulence is formed first. A portion of the laminar sub layer, called a “streak”, will occasionally move to the buffer region. There, the streak begins to vortex and oscillate, moving faster as it gets closer to the turbulent core. Finally, the streak becomes unstable and breaks up as it throws fluid into the core of the flow. This ejection of fluid into the turbulent core is called a turbulent burst. This bursting motion and growth of the bursts in the turbulence core results in wasted energy.

Drag reducing polymers interfere with the bursting process and reduce the turbulence in the core. The polymers absorb the energy in the streak, like a shock absorber, thereby reducing subsequent turbulent bursts. As such, drag reducing polymers are most active in the buffer zone [21].

2.7 Drag Reduction Agent

Drag reducer also known as Drag Reducing Agents, DRAs or Flow Improvers are high–molecular-weight polymers that improve the fluid flow characteristics of low viscosity petroleum products. As enery cost have incresed, pipelines have sought more efficient way to ship products. Drag reducer lower pumping costs by reducing friction between the flowing gasoline and the wall of the pipe.

When inject into pipeline these long chain polymers interact with small scale flow disturbances that develop into large scale turbulent structures. These interactions interfere with the development of large scale turbulent flow structures resulting in a reduction the amount of turbulent flow in the pipe. This reduction results reduction in the frictional pressure loss for a given flow rate.

The long chain of polymer are broken up in regions of flow where high shear is present such as pumps or through pipe sections with numerous elbows. Once broken up this types of DRA no longer exhibit any significant drag reduction. There are also other types that able to reform after passing through regions of high shear [3].

2.7.1 Use of Drag Reduction Agents

DRA has typically been used to cater for those occasional instances when more oil is produced than can be physically pumped down the line, given the pipeline dimensions and pressure constraints available. However, Drag Reduction is rapidly becoming an essential aspect of cost savings for petroleum industries. Pipelines were usually built with a life expectancy of about 20 years (wall thickness, materials and corrosion rate calculations all taken into account). But replacing pipelines is a very expensive pastime (up to $50 million for 100 km). Clearly, if replacing pipelines can be postponed for as long as possible, there are enormous savings in store for industries. Over time pipelines corrode, no matter how well you look after them (regular pigging, cathodic protection, injecting corrosion inhibitors, etc.). As the wall thickness reduces, so does the Maximum Allowable Operating Pressure (MAOP). If you continue to operate a line at high pressures but the wall thickness has reduced, you risk a pipeline rupture. Hence, you have 3 choices:

• Renew the line (very costly)

• Reduce your pressure and hence flow (very costly)

• Inject Drag Reducer (enables equal flows at lower pressures = low cost)

If the Maximum Allowable Operating Pressure (MAOP) has been reduced to maintain integrity of the system, the amount of oil you can pump through that line must reduce. This can cause deferment in the worst case. However, by injecting Drag Reducer, the same quantity of oil can be pumped, but at a lower pressure. The drag of the oil on the pipeline is reduced, and thus the pressure drop between the two ends of the node is reduced [22].

2.7.2 Advantages of DRA

Capacity may be increased by installing more pumping power on the pipeline system, by installing paralle pipe sections or by incresing the diameter of the mainline pipe. The installation of new pumping facilities or additional pipe is abig investment and is a time consuming process. A DRA injection installation, in its simplest form, consists of an injection tap, and injection pump, and a DRA storage tank as in this picture taken from Aramco field.

This typically requires a much smaller investment and can be quickly installed at almost any existing facility. The Dar injection equipment can also be easily relocated to other locations should operational needs change in the future. Since DRA injection equipment can be deployed quickly, it can be used to provide short term increases in capacity if required. So, it can be injected into specific commodities and at specific rates to meet the required goals of increased capacity and improved operating costs [3].

2.8 Types of drag Reduction Agent

- Polymer (long-chain or macromolecule)
    1. natural
    2. synthetic
- Oligimer (short-chain or soap)
- Fibre (pulp)
    1. natural
    2. synthetic
- Particle (sediment)
- Surfactant
- Bubble (micro diameter gas)
- Mixture (fibre and polymer) [23]

2.8.1 Surfactant

There are generally four types of surfactants: cationic, anionic, non-ionic, and zwitterionic. Cationic surfactants are positively charged and typically are effective drag reducers, but are not very biodegradable. Anionic surfactants are negatively charged, which allows them to interact with any positive ions present in solution (such as calcium and magnesium ions in tap water). Non-ionic surfactants do not have a net charge, and are typically biodegradable. Zwitterionic surfactants also do not have a net charge, but they are different in that they have a positive and negative charge both present on the molecule in different regions.

Surfactants, or surface-active agents, are characterized by the coexistence of a hydrophobic tail and hydrophilic head group in one molecule, making them amphiphilic compounds. The hydrophobic tail is typically a long alkyl chain and the hydrophilic head is ionisable, polar, polarisable, or suitable for forming hydrogen bridges. In a polar solvent, the hydrophobic groups cluster together, leaving the polar groups to surround them and contact the solvent. In a non-polar solvent, the hydrophilic groups cluster together while the hydrophobic groups are exposed to the solvent. These structures are held together by hydrophobic interactions, while if head groups are charged, electrostatic interactions play a role. Steric factors also have significant effects on micelle structures.

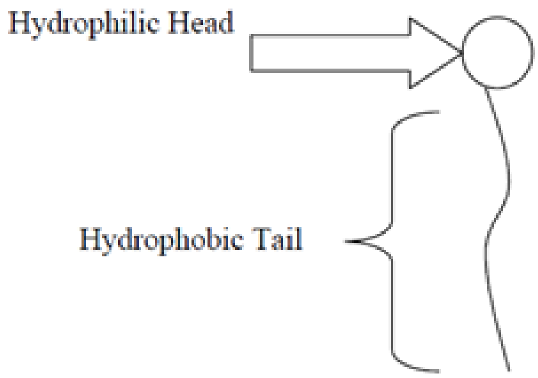


Figure 2.4 Surfactant structure diagram

Surfactants have the ability to reassemble into micelles quickly after being degraded by mechanical stress such as in a pump. Introducing surfactants into polar solvents causes interactions between the surfactant and solvent. The hydrophobic tail of the surfactant repulses the solvent, and forms micelles in order to effectively avoid contact with the solvent. Micelles take three general forms: spheres, elongated cylinders known as threads, or vesicles. It should be noted that threadlike micelles are generally accepted to be necessary for drag reducing behavior to occur. Therefore, through the addition of surfactants into polar solvents, the drag can be reduced in the turbulent flow through the pipes due to micelle formation, thus reducing the pumping energy required to circulate the fluid and saving energy and money [24].

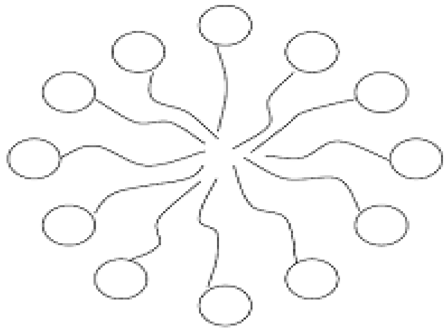


Figure 2.5 Spherical micelle diagram

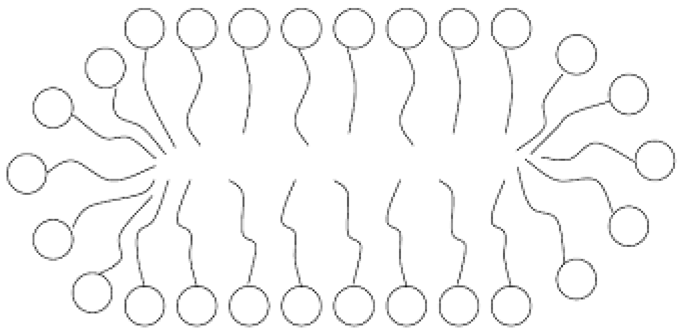


Figure 2.6 Threads like micelle diagram

2.8.2 Polymer

The frictional resistance in turbulent flow can be drastically reduced by the injection of minute amounts of polymeric additive. This phenomenon implies that polymer solutions undergoing flow in a pipe require a lower pressure drop to maintain the same flow rate [25].

One of the most impressive successes in polymer applications for drag reduction was the use of 10ppm oil-soluble polymers in the trans-Alaska pipeline system which increased pipeline flow rates significantly. This important finding has prompted a number of investigations to study the influence of polymers on gas–liquid flow. Drag reduction was reported but the most interesting aspect of these works is that the configuration of the phases can be changed. Found that the injection of a concentrated solution of a co-polymer of polyacrylamide and sodium acrylate into air–water flow in 1 in.ID and 4 in. ID pipe changed annular and slug flow patterns to a stratified wavy flow pattern by eliminating the disturbance waves in the liquid film. Concluded that, drag reducing polymer is damping small wavelength waves on the interface between gas and liquid in stratified flow and this results in a lower interfacial friction factor [26].

In turbulent flow, polymeric additives are exposed to elongation strain as well as to strong shear stresses, and this mechanical energy cause's scission of the polymer chains occurs, decreasing the drag reduction effectiveness. This mechanical degradation in turbulent flow is known to be affected by various properties, including polymer molecular weight (MW), molecular weight distribution (MWD), temperature, polymer–solvent interactions, polymer concentration, and turbulent intensity, method of preparation and storage, and flow geometry [25].

Following properties influence the performance of the polymer:

• High molecular weight. (M>1000000 g/mol)

• Shear degradation resistance.

• Quick solubility in the pipeline fluid.

• Heat, light, chemical, biological degradation resistant [27].

2.8.3 Suspended solid (Fibre)

Fibre suspensions have more and more applications in industry, such as composite manufacturing, paper making and fibre spinning. The characterization of the flow or the fibre orientation in a suspension is of particular interest in the industrial processing research. When fibres form a flow-induced orientation state, fibre suspension exhibits anisotropy. Therefore, the addition of fibres to a Newtonian fluid can drastically change the flow kinematics, even at very low concentrations. Besides, the flow can induce a preferred orientation of the fibres which, upon solidification, influences the mechanical properties of the resulting fibre-reinforced composite. The composite is stiffer and stronger in the direction of greatest orientation, and weaker and more compliant in the direction of least orientation. Drag reduction in turbulent flow, affected by suspending a very small concentration of fibres, is another application [28].

2.9 Mucilage

Mucilage is a thick gluey substance produced by most plants and some microorganisms. It is a polar glycoprotein and an exopolysaccharide. It occurs in various parts of nearly all classes of plant, usually in relatively small percentages, and is frequently associated with other substances, such as tannins and alkaloids. Mucilage in plants is thought to aid in water storage and seed germination, and to act as a membrane thickener and food reserve. Among the richest sources are cacti (and other succulents) and flax seeds. Mucilage has a unique purpose in some carnivorous plants. The plant genera *Drosera* (Sundews), *Pinguicula*, and others have leaves studded with mucilage-secreting glands, and use a "flypaper trap" to capture insects. Exopolysaccharides are the most stabilising factor for microaggregates and are widely distributed in soils. Therefore exopolysaccharide-producing "soil algae" play a vital role in the ecology of the world's soils. The substance covers the outside of, for example, unicellular or filamentous green algae and cyanobacteria. Amongst the green algae especially, the group Volvocales are known to produce exopolysaccharides in a certain part of their life cycle [31].

2.10 Commercial application of DRA

There has been number of attempts on drag reducing polymers for possible applications in fire extinguishing operations, crude oil transport, oil well operation, sewers and slurry transport. The positive results obtained in drag reducing phenomenon in above fields of technology have led the research work to try its possible application in sprinkler irrigation system. In sprinkler irrigation system, there are multiple outlets and frictional losses are quite high. The sprinkler and drip are the two most efficient methods of irrigation. Sprinkler method can be applied to all major crops especially closed spaced crops such as cereals, pulses, oil seeds, etc. Among the various factors limiting the extensive use of sprinkler irrigation system, is the high energy requirement. The sprinkler irrigation is operated in turbulent flow condition in the distribution pipes, risers and ejected water jet. Hence, application of turbulent drag reduction phenomenon can be useful in reducing the energy requirement and thereby saving power and fuel requirement. The first experiment demonstrating the application of this phenomenon was performed by Union Carbide Corporation (1969). The addition of the polymer increased crop coverage by 215% [6].

Drag reduction in pipelines carrying petroleum products or crude oils, was one of the main challenges face by oil companies when the term power saving, raised up due to the rapid increase in global power consumption. Sectors that transport liquids through pipelines have to deal with huge amounts of power losses. It is known that, liquids are transported in pipelines in a turbulent mode and that will lead to huge pumping power losses along the pipelines. Drag Reducing Agents were used in the past few decades to improve the flow in pipelines and to increase it without the need for any changes in the geometry of the pipeline system [7].

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this research, aloe Vera mucilage which is natural polymer of aloe Vera will be used as drag reduction agents (DRA). In this research methodology, specification and the properties of aloe Vera mucilage, procedures of extraction, procedures of drying, experimental rig design, and pressure drops determination will be explained.

3.2 Material and Method

Raw material in this research is aloe Vera gel. Aloe Vera gel is the colorless mucilaginous gel obtained from the parenchymatous cells in the fresh leaves of Aloe Vera which is succulent, almost sessile perennial herb; leaves 30–50 cm long and 10cm broad at the base; color pea-green (when young spotted with white); bright yellow tubular flowers 25–35 cm in length arranged in a slender loose spike [32]. About 3 years old plant will became mature and produce high amount of mucilage [5].

3.2.1 Additional chemicals

1. Rosmarinic acid as antioxidant and antibacterial.
2. Water as extraction solvent.

3.2.1.1 Rosmarinic acid as antioxidant and antibacterial

Rosmarinic acid, $C_{18}H_{16}O_8$, is a natural polyphenol antioxidant carboxylic acid found in many *Lamiaceae* herbs used commonly as culinary herbs such as lemon balm, rosemary, oregano, sage, thyme and peppermint. Chemically, rosmarinic acid is an ester of caffeic acid with 3,4-dihydroxyphenyl lactic acid. It is a red-orange powder that is slightly soluble in water, but well soluble in most organic solvents. [33].

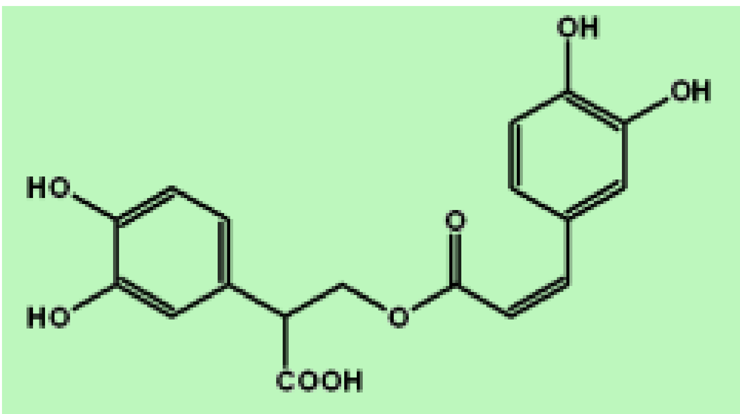


Figure 3.1 Structural Formula of Rosmarinic acid

Rosmarinic acid has antioxidant, anti-inflammatory and antimicrobial activities. The antioxidant activity of rosmarinic acid is stronger than that of vitamin E. Rosmarinic acid helps to prevent cell damage caused by free radicals, thereby reducing the risk for cancer and atherosclerosis. Rosmarinic acid has anti-inflammatory properties. Perilla, rich in rosmarinic acid, is used for its anti-allergic activity. A study by Sanbongi C and colleagues (Clinical and Experimental Allergy, June 2004) have shown that the oral administration of rosmarinic acid is an effective intervention for allergic asthma. Another study by Youn J and colleagues (Journal of Rheumatology, June 2003) demonstrated that rosmarinic acid suppressed synovitis in mice and that it may be beneficial for the treatment of rheumatoid arthritis. Unlike antihistamines, rosmarinic acid prevents the activation of immune responder cells, which cause swelling and fluid formation. Rosmarinic acid is also used for food preservation. In Japan the perilla extracts, rich in rosmarinic acid, is used the garnish and improve the shelf life of fresh seafood. Rosmarinic acid is used to treat peptic ulcers, arthritis, cataract, cancer, rheumatoid arthritis and bronchial asthma.

3.2.1.2 Extraction using water

Water (H_2O) is often perceived to be ordinary as it is transparent, odorless, tasteless and ubiquitous. It is the simplest compound of the two most common reactive elements, consisting of just two hydrogen atoms attached to a single oxygen atom. Indeed, very few molecules are smaller or lighter. Liquid water, however, is the most extraordinary substance.

Droughts cause famines and floods cause death and disease. It makes up over about half of us and, without it, we die within a few days. Liquid water has importance as a solvent, a solute, a reactant and a biomolecule, structuring proteins, nucleic acids and cells and controlling our consciousness. H_2O is the second most common molecule in the Universe (behind hydrogen, H_2), the most abundant solid material and fundamental to star formation. Life cannot evolve or continue without liquid water, which is why there is so much excitement about finding it on Mars and other planets and moons. It is unsurprising that water plays a central role in many of the World's religions. This web site discusses many aspects of water science with the exception of availability, agricultural and environmental issues.

A number of explanations of the complex behavior of liquid water have been published, many quite recently, with several stirring up great controversy. In this web site, I have attempted to present these ideas in a self-consistent and balanced manner, which I hope will encourage both its understanding and further work. [34].

Table 3.1 Properties of Rosmarinic acid and Water

Chemicals	Rosmarinic acid	Water
Molecular formula	$C_{18}H_{16}O_8$	H_2O
Molecular weight	360.31g/mole	18.01528 g/mole
Appearance	red to brown powder	white solid or almost colorless, transparent, with a slight hint of blue, crystalline solid or liquid
Density		1000 kg/m^3, liquid (4 °C) 917 kg/m^3, solid
Melting point	171-175 °C	0 °C, 32 F (273.15 K)
Boiling point	694.7 °C	100 °C, 212 °F (373.15 K)
Solubility	Soluble in water and organic solvents	Miscible with water

[33], [35]

3.2.2 Closed loop circulation system

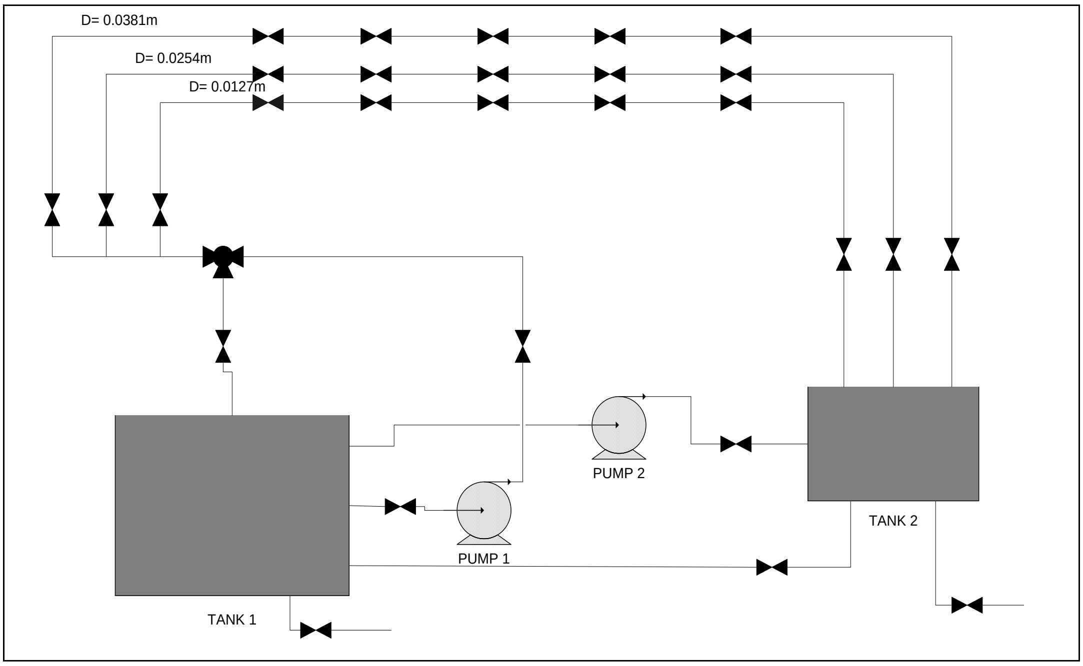


Figure 3.2 Schematic diagram of experiment setup

The built up or rig that used during the experiment of testing the effect of drag reduction agent was shown in detail in the schematic diagram above. It consists of pipes with 3 different diameters and valves, 2 reservoir tanks of different volume, centrifugal pumps, flow-meters and manometer. A build up system consist of horizontal test section and instrumentations was used to fulfil the investigation requirements.

The reservoir tank 1 was supported with two exit pipes connected to centrifugal pumps. The first exit pipe with 0 0.0381 m I.D was connected to the main centrifugal pump which delivers the fluid to the testing sections. The other exit is of 0.0381 m I.D was connected to the other centrifugal pump for deliver excess solvent to reservoir tank. Reservoir tank 1 volume will be 420 liter. The volume of reservoir tank 1 is important because to measure the concentration of DRA. The volume of reservoir tank 2 is not important since this is used to collected solution and returned to the reservoir tank 1.

The pump 2 is required for suction of the overload solution in tank 2 to be back into reservoir tank 1 and pump 1 is for suction from reservoir tank 1 to testing section pipelines. The power or the pumps are 6-horse power for each with model CPM-158.

The system consist pipes with 0.0127, 0.0254 and 0.0381 m inside diameter and the length of 2 m made from transparent PVC pipe to permit visual observation of flow pattern. The PVC pipes are used for relating it to the roughness of pipes that assume near to zero. Each pipe divided into four pressure testing sections with a distance equal to 0.5 m. The first pressure testing point for each pipe was located about 50 times pipe diameter (50D.) of the testing pipe as shown in figure. This is to ensure the turbulent flows are fully developed before the testing point.

Table 3.2 Minimum entrance length for the pies used

Pipe internal diameter (m)	Minimum entrance length (Le) (m)
0.0127	0.635
0.0254	1.270
0.0381	1.905

Baumer Differential Pressure Gauges were used to detect the pressure drop in pipelines with maximum differential pressure readings up to 0.16 bar. To determine the pressure drop at certain length, only valves that connected to two flexible tubes will be opened and the rest are fully closed. Then the portable tube was used to connect the pressure gauges based on selected ratio of pipe length to pipe diameter (L/D). The pressure gauge was positioned in the centre of testing point to obtain the accurate reading of pressure drop.

The flow rate of fluid in pipelines was measures by Ultraflux Portable Flow meter Minisonic P in which this ultrasonic flow measurement was sensitive with small changes in flow rate as low as 0.001 ms^{-1}. The purpose of using this exterior portable ultrasonic measurement is to avoid any disturbance might happen in the flow pattern.

3.2.3 Solvent Extraction of aloe Vera mucilage using water

The aloe Vera extraction will be held in room temperature (25°C). 100 gram of aloe Vera will be cut into pieces. Then, aloe Vera will be soaked with 800 ml of distilled water and stirring process will be done in five hours. Stirring process is required so that more water molecules to have contact with mucilage molecules thus pulled mucilage molecules from its pods. By stirring process, dispersion of mucilage will evenly disperse. The reasons limiting time is because to unvarying mucilage extraction process time consumed from aloe Vera pod. The soaked aloe Vera will produce mucilage that change clear water into very thick viscous. Then, aloe Vera will be filtrate by muslin cloth to prevent any big colloidal and suspended solid to get trough. This also to ensure there are no foreign substance or contaminant in mucilage so that chemical degradation will be slow down. This filtration process will be leaved about 1 hour to be done. Rapidly heat the Aloe Vera gel to a temperature in the range of from about 35° C to about 80°. Adding to the heated Aloe Vera gel one or more stabilizing antioxidants. Rapidly cool the heated Aloe Vera gel to a temperature in the range of from about 20° C to about 30°C.

3.2.4 Dilution Process

The aloe Vera mucilage must be undergoing dilution process before being added into reservoir tank 1 so the fix amount or concentration can added. Since the density of okra mucilage cannot be identified, dilution of mucilage in tap water will used weight percent technique.

$$\text{Weight of water (kg)} = \text{volumetric tank} \times \frac{1\ m^3}{1000L} \times \rho_{water@25°C} \quad (4)$$

$$= 420L \times \frac{1\ m^3}{1000L} \times 99708\ \frac{kg}{m^3} = 418.7736\ kg$$

Add (1) into concentration equation

$$\text{Concentration (ppm)} = \frac{\text{mg mucilage}}{\text{kg water}}$$

$$\text{Concentration (ppm)} = \frac{\text{mg mucilage}}{418.7736 \text{ kg water}} \quad (5)$$

$$\text{Concentration (ppm)} = \frac{\text{g mucilage}}{418.7736 \text{ kg water}} \times 1000$$

Table 3.3 Corresponding weights for different concentration of mucilage

concentration(ppm)	weight of mucilage (g)
0	0
50	20.93868
100	41.87736
200	83.75472
300	125.63208
400	167.50944
500	209.3868

3.2.5 Drag reduction testing experiment

Make sure all the valves are fully closed and fill tank 1 with 420L pipe water. Pump 1 and all the valves of 0.0127 m I.D pipe are fully open and allow the water flow in the pipe for a few minutes. Fix ULTRAFLUX ultrasonic flow meter in pipe 0.0127m I.D after apply the flow meter gel on the pipe. Take the maximum flow rate in the pipe and record it. Adjust the main valve of 0.0127m I.D to set the flow rate of water at $0.5m^3/s$. Connect the flexible tubes to the valves at testing point of 0.5 m length and connect to the pressure gauge. Fix the pressure gauge at the centre of those 2 valves. Record the pressure drop for the particular flow rate. Repeat all the above steps by change the flow rate at the interval $0.5m^3/s$ until reach the max flow rate.

Repeat the experiment by change the length of testing point at 1.0m, 1.5m and 2.0m. Repeat the experiment by adding different concentration of aloe Vera mucilage that is 50, 100, 200, 300, 400, 500 ppm.

Warning: Open pump 2 if the water level in tank 2 in reach ¾ of the tank so the water in tank 2 can recycle back to tank 1.

3.2.6 Experimental calculations

There are two major calculations in this experiment, which is calculation to find out Reynolds number and percentage of drag reduction.

3.2.6.1 Velocity and Reynolds number calculations

$$Re = \frac{\rho \, V.D}{\mu} \tag{6}$$

Average velocity (V),
Reynolds number (Re),
Density (ρ),
Viscosity (μ)
Pipe internal diameter (D)

3.2.6.2 Percentage Drag Reduction calculations

Pressure drop readings through testing sections before and after drag reducer addition were used to calculate the percentage drag reduction %Dr as follows

$$\%Dr = \frac{\Delta P2 - \Delta P_1}{\Delta P_2} \qquad (7)$$

Δp_1 = Pressure drop after drag reducer addition

Δp_2 = Pressure drop before drag reducer addition

CHAPTER 4

RESULT & DISCUSSION

4.1 Effect of Fluid Velocity (Re) on Percentage of Drag Reduction

After the the experimental method, all the collected data were tabulated in a graphical form to have a clearer picture upon the results of the research to obtain a more understanding on the relationships between the manipulated variables.

Figure 4.1 shows the performance of drag reduction as a function of Re (Reynolds Number) and concentrations with D=0.0245m of internal diameter and 1.0m of pipe length. The results of the experiment showed that the percentage Drag reduction increases by increasing the Reynolds number (Re).

Based on the experimental work, the drag reduction (%Dr) values ranged between 0% and 73% when the Reynolds number was between 10000 and 40000. As shown in figure 3, the highest %Dr for each of the concentration was obtained at 10000 to 20000 of Re with maximum %Dr values of 71% at 400ppm of additive concentration. All concentration showed a drastic reduction of %Dr after 15472.694 of Re until the reading reach 11%.

When the Re increase from 10000 to 40000 the degree of turbulence will increase. This will increase the collisions between eddies which will produce smaller eddies. Overcoming smaller eddies is easier to polymer additives compare to larger eddies, because of the amount of energy absorbed by smaller eddies is lower. The decrease in %Dr after it reached a max value at 15472.694 of Re is due to low ratio of additive concentration to degree of turbulence. At lower additive concentration to degree of turbulence ratio the micelles structure of polysaccharides is easy to break which will create a drastic reduction in %Dr value [17,18].

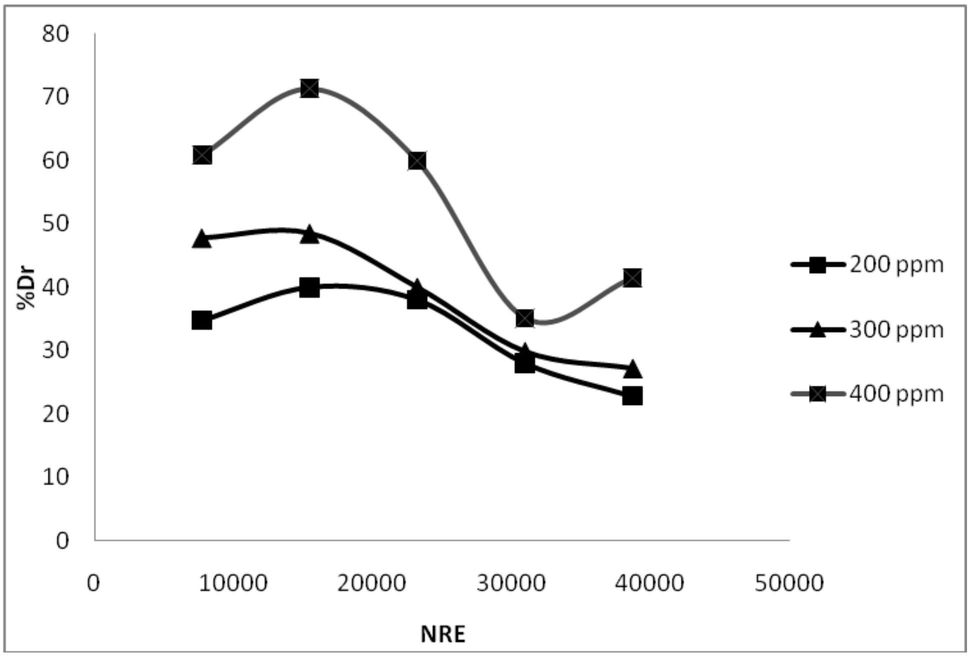


Figure 4.1 Effect of Reynolds number on percentage drags reduction at different additive concentration, with D=0.0245m and L=1.0m

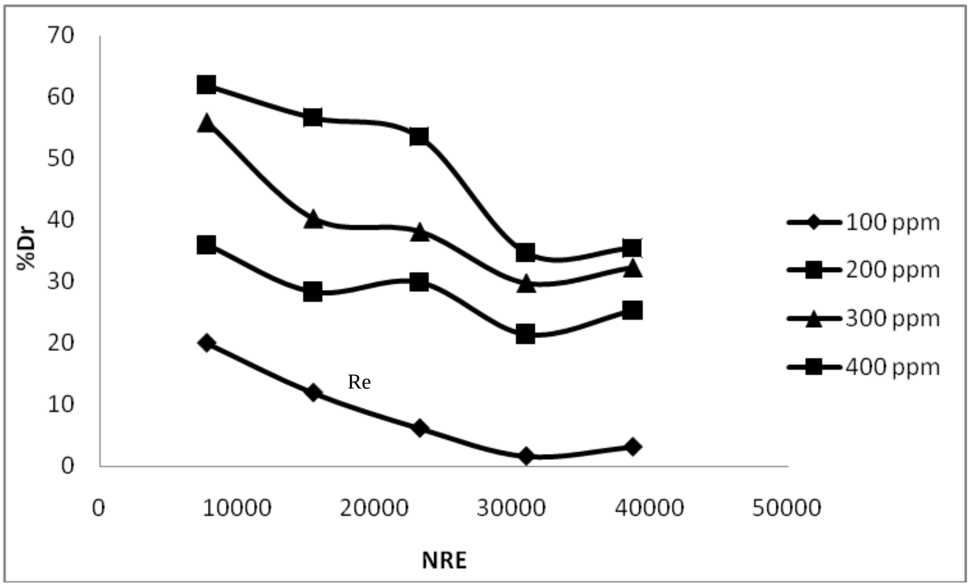


Figure 4.2 Effect of Reynolds number on percentage drags reduction at different additive concentration, with D=0.0245m and L=2.0m

Figure 4.2 is presented in order to compare the profile of drag reduction. This figure shows the performance of drag reduction as a function of concentrations and Re which has the same function as Figure 4.1 by means of using a different length that is 2.0m. The profile pattern of each concentration of this figure is similar as Figure 3 but is different in values of %Dr. From the comparison of these 2 figures (figure 4.1 and figure 4.2) it was clearly observed that there were large deviations between both figures for the value of drag reduction ranged between 10000 and 40000 of Re. The max value of %Dr which is obtained in figure 4 is achieved at Re range of 20000 to 30000, which is higher than figure 4.1. (10000 to 20000). This shows when the pipe length increases, higher degree of turbulence is needed during the liquid transportation which then requires the system to supply a high amount of energy so the drag reducer being used can perform effectively [17,18].

4.2 Effect of Additive Concentration on Percentage of Drag Reduction

The result of drag reduction experiment of aloe Vera polymer with function of additive concentration and Re are shown in figure 4.3. Based on the experiments conducted, the drag reduction values increases from 3% to 62% by increasing the additive concentration due to the increase of number of polymer molecules that were involve in the drag reduction process during the research. The highest drag reduction for each Re was obtained at 400ppm with maximum %Dr values achieved is 62% at 7736.347222 of Re. Higher concentration of aloe Vera polymer makes it more capable to form threadlike micelles in water and makes water more viscous with low shear stress. The water solution with low shear stress will produce smaller eddies which is easy to overcome [17, 18].

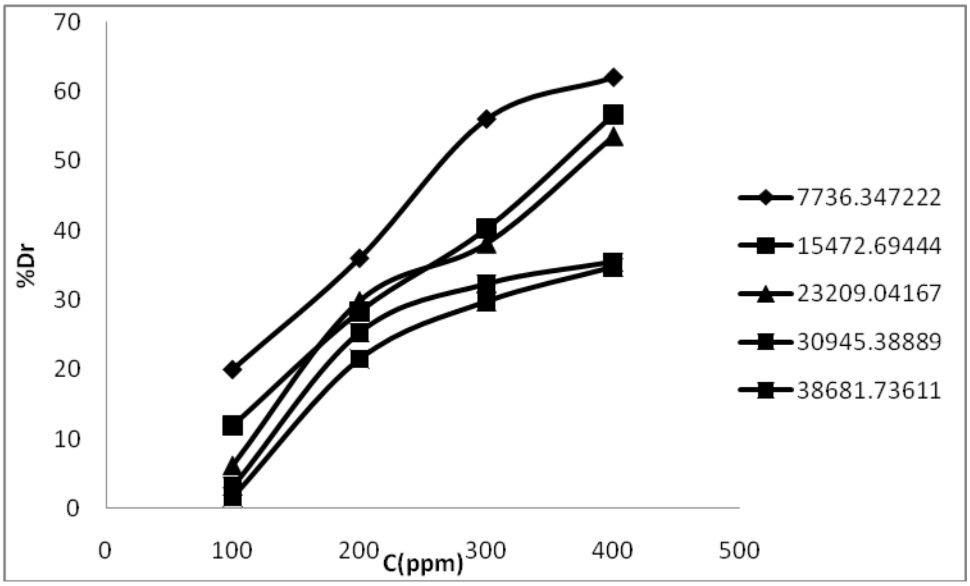


Figure 4.3: Effect of additive concentration on percentage drags reduction at different Reynolds number, with D=0.0245m and L=2.0m

4.3 Effect of Pipe Internal Diameter on Percentage of Drag Reduction

Two different internal diameters were investigated during the present research. These results clearly shows that the %Dr of the pipe with I.D =0.0245m is larger compared to the pipe with I.D=0.0381m. This result statement can be observed from figure 4.4 and figure 4.5. This phenomenon has already been stated in other research in which it is found out that drag reduction is larger in the narrow tubes and it is usually known as ‘diameter effect’ or ‘wall effect’ [16].

Figure 4.4 shows the profile of drag reduction at various internal diameters and pipe length at concentration 300ppm. Maximum drag reduction (40%) occurred at I.D 0.0254m and flow rate 1.5m^3/s. Meanwhile, figure 4.5 shows the profile of drag reduction at various internal diameters and pipe length at concentration 200ppm. Maximum %Dr which is 38% occurred at same I.D and length as figure 6. Basically, the graphical data pattern of drag reduction relation with the diameter of pipe used of figure 4.4. and figure 4.5 are similar. On the other hand, the max and min value of %Dr varies for the set of collected data within both figures.

The polymeric additive will have a better media to work in smaller pipes. Decreasing the pipe diameter means increasing the velocity inside the pipe which will increase the turbulence. For smaller pipe, the energy absorbed by the turbulence (eddies) from the main flow will be higher than that for larger pipes. That, whenever the degree of turbulence becomes higher, the number of collisions between eddies will be higher, which will produce smaller eddies. These collisions provide extra number of eddies absorbing energy from the main flow to complete their shape. Overcoming smaller eddies is easier by polymer additives than larger once, because of the amount of energy absorbed by smaller eddies is lower [17,18].

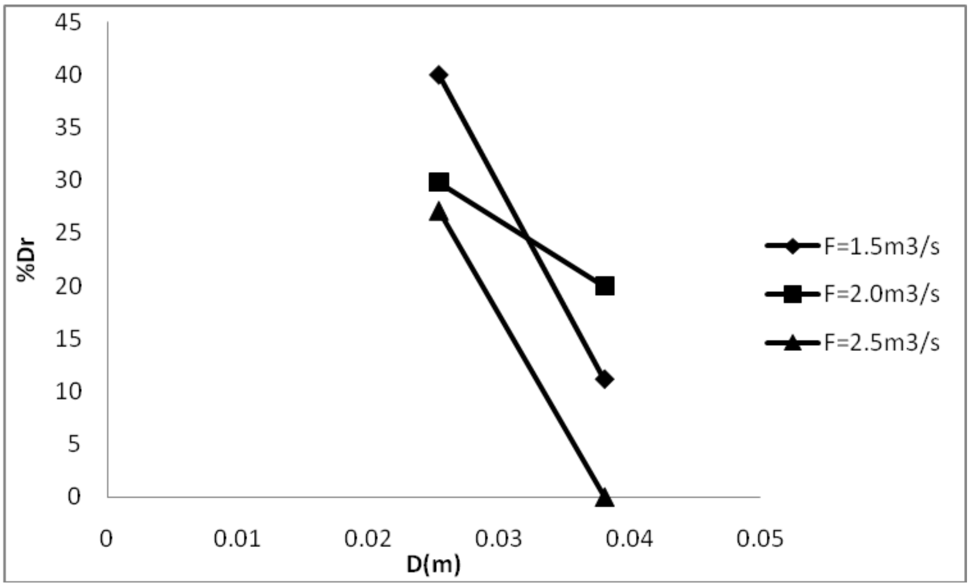


Figure 4.4 Effect of Internal diameter on percentage drags reduction at different fluid flow rate, with L=1.0 m and 300ppm

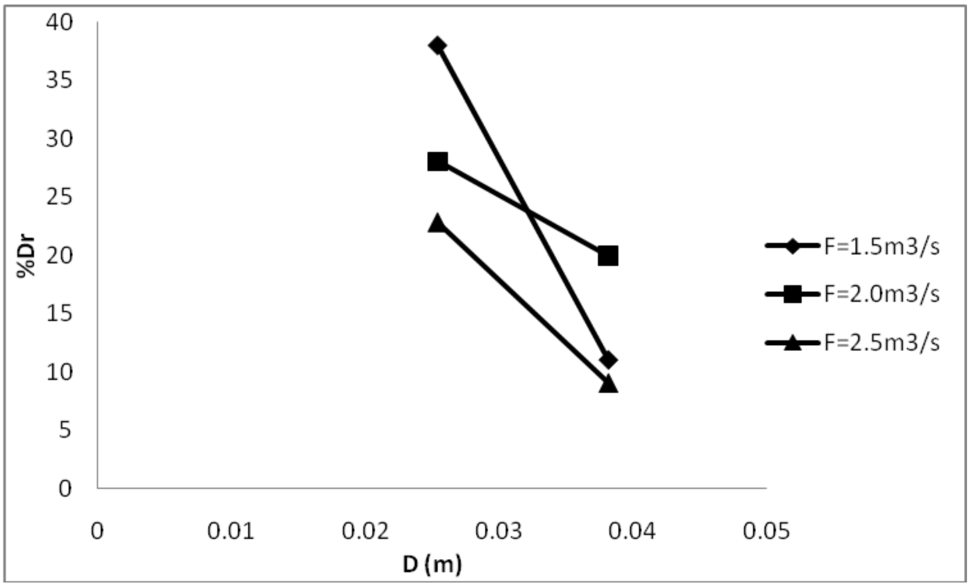


Figure 4.5 Effect of Internal diameter on percentage drags reduction at different fluid flow rate, with L=1.0 m and 200ppm

4.4 Effect of Pipe Testing Length on Percentage of Drag Reduction

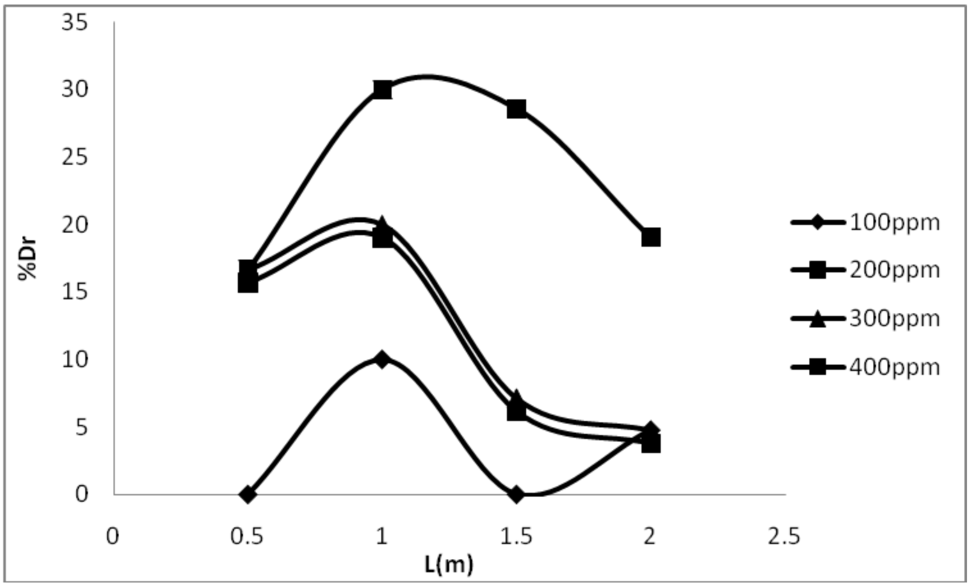


Figure 4.6 Effect of pipe testing length on percentage drags reduction at different additive concentration, with D = 0.0381m and NRE = 41260.546

The results of analysis drag reduction as a function of pipe length and additive concentration are shown in figure 4.6 The highest %Dr for each of the concentration was obtained at L=1.0 with maximum drags reduction values of 30% in 400ppm of concentration.

After the %Dr reaches a certain max value, the %Dr will show a decreasing characteristic where this occurrence has already been explain in figure 4.1 and figure 4.2 in the previous section of this research. This situation happens because as the pipe length increases, the flow rate (degree of turbulence) will decrease. This will cause a decrease of the additive concentration to degree of turbulence ratio which limits the performance of the drag reducer used [17, 18].

CHAPTER 5

CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

From experiment it was found that aloe Vera mucilage acts as a good drag reducing agent in aqueous media flowing through pipelines. Aloe Vera has a high market value and it can be commercialized as a new flow improver.

There were 4 main factors observed that effected the value of %Dr in this experiment. %Dr showed an increase when; pipe diameters used were reducing; by increasing the Reynolds Number (Re), amount of concentration for the mucilage used increases and the length of the pipelines increases.

The additives concentration showed great effect on drag reduction in pipes and %Dr can be reached up to 70% by using only 400ppm of aloe Vera mucilage.

5.2 Recommendation

In order to attain clearer picture on performance of aloe Vera mucilage as a drag reducing agent, it is recommended to continue these research with bigger range of parameters such as concentration and flow rate. It also recommended by using different testing length and repeats the same procedures for five times to get the average reading. It also recommended having further research of grafting mucilage polymer with synthetic polymer or other natural polymer to obtain higher stability in chemical and mechanical degradation.

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APPENDIX A

METHODOLOGY

Appendix A-1: Calculation for Additive Dilution.

$$\text{Concentration (ppm)} = \frac{\text{x mg mucilage}}{420\ \text{L}\ H_2O}$$

$$\text{x g mucilage} = \frac{\text{Concentration (ppm)} \times 420\ \text{L}\ H_2O}{1000}$$

Table A-1.1: Mass of aloe Vera mucilage for corresponding concentration

No	Concentration (ppm)	x g mucilage
1	100	42
2	200	84
3	300	126
4	400	168

Appendix A-2: Calculation for Reynolds Number

Viscosity ($\mu_{\text{water @ 25°C}}$) : 0.8973×10^{-3} Pa.s

Density ($\rho_{\text{water @ 25°C}}$) : 997.08 kg/$m^3$

$$Re = \frac{\rho . V . D}{\mu} \tag{6}$$

$$V = \frac{\text{Q (fluid flow rate)}}{\text{Area of pipe}} \tag{8}$$

$$\text{Area of pipe} = \frac{\pi D^2}{4} \tag{9}$$

Add equation (8) and (9) into (6):

$$Re = \frac{\left(997.08\ \frac{kg}{m^3}\right)\left(\frac{1h}{3600s}\right)\left(Q\ \frac{m^3}{h}\right)\left(\frac{4}{\pi D^2}\ m^2\right)(D\ m)}{0.8973 \times 10^{-3}\ \frac{kg}{m.s}}$$

Simplify the equation

$$Re = \frac{(Q)(394.5898)}{D}$$

Table A-2.1: Reynolds no. at different pipe internal diameter and flow rate

D (m)	Q (m^3/h)	Nre	D (m)	Q (m^3/h)	Nre
0.0254			0.0381		
	0.5	7736.347		0.5	10315.14
	1	15472.69		1	20630.27
	1.5	23209.04		1.5	30945.41
	2	30945.39		2	41260.55
	2.5	38681.74		2.5	51575.68
				3	61890.82

Appendix A-3: Calculation for Percentage Drag Reduction

$$\%DR = \frac{(\Delta P\ before) - (\Delta P\ after)}{\Delta P\ before}\ X\ 100\%$$

For instance:

ΔP water = 0.01 bar

ΔP additive solution: 0.005 bar

$$\%DR = \frac{(0.01bar) - (0.005bar)}{0.01bar}\ X\ 100\%$$

= 50%

APPENDIX B

RESULT & DISCUSSION

Appendix B-1: Pressure Drop Data of pipe 0.0254m I.D

Table B-1.1: Pressure drop of water flowing trough pipe of 0.0254m I.D and 100ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0254	0.5			0	100	
		0.5	7736.347	6	5.5	8.333333
		1	15472.69	8	7	12.5
		1.5	23209.04	11.5	10	13.04348
		2	30945.39	13.5	12.5	7.407407
		2.5	38681.74	17	16.5	2.941176
	1					
		0.5	7736.347	11.5	9.5	17.3913
		1	15472.69	17.5	17.5	0
		1.5	23209.04	25	23.5	6
		2	30945.39	28.5	28	1.754386
		2.5	38681.74	35	31	11.42857
	1.5					
		0.5	7736.347	18.5	14	24.32432
		1	15472.69	25	20.5	18
		1.5	23209.04	36.5	35.5	2.739726
		2	30945.39	42.5	39	8.235294
		2.5	38681.74	56	55.5	0.892857
	2					
		0.5	7736.347	25	20	20
		1	15472.69	33.5	29.5	11.9403
		1.5	23209.04	48.5	45.5	6.185567
		2	30945.39	60.5	59.5	1.652893
		2.5	38681.74	79	76.5	3.164557

Table B-1.2: Pressure drop of water flowing trough pipe of 0.0254m I.D and 200ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0254	0.5			0	200	
		0.5	7736.347	6	5	16.66667
		1	15472.69	8	6.5	18.75
		1.5	23209.04	11.5	7	39.13043
		2	30945.39	13.5	9.5	29.62963
		2.5	38681.74	17	12	29.41176
	1					
		0.5	7736.347	11.5	7.5	34.78261
		1	15472.69	17.5	10.5	40
		1.5	23209.04	25	15.5	38
		2	30945.39	28.5	20.5	28.07018
		2.5	38681.74	35	27	22.85714
	1.5					
		0.5	7736.347	18.5	12.5	32.43243
		1	15472.69	25	17.5	30
		1.5	23209.04	36.5	24.5	32.87671
		2	30945.39	42.5	33.5	21.17647
		2.5	38681.74	56	42.5	24.10714
	2					
		0.5	7736.347	25	16	36
		1	15472.69	33.5	24	28.35821
		1.5	23209.04	48.5	34	29.89691
		2	30945.39	60.5	47.5	21.4876
		2.5	38681.74	79	59	25.31646

Table B-1.3: Pressure drop of water flowing trough pipe of 0.0254m I.D and 300ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0254	0.5			0	300	
		0.5	7736.347	6	5	16.66667
		1	15472.69	8	5.5	31.25
		1.5	23209.04	11.5	7.5	34.78261
		2	30945.39	13.5	10	25.92593
		2.5	38681.74	17	11.5	32.35294
	1					
		0.5	7736.347	11.5	6	47.82609
		1	15472.69	17.5	9	48.57143
		1.5	23209.04	25	15	40
		2	30945.39	28.5	20	29.82456
		2.5	38681.74	35	25.5	27.14286
	1.5					
		0.5	7736.347	18.5	11.5	37.83784
		1	15472.69	25	15	40
		1.5	23209.04	36.5	22.5	38.35616
		2	30945.39	42.5	30	29.41176
		2.5	38681.74	56	39	30.35714
	2					
		0.5	7736.347	25	11	56
		1	15472.69	33.5	20	40.29851
		1.5	23209.04	48.5	30	38.14433
		2	30945.39	60.5	42.5	29.75207
		2.5	38681.74	79	53.5	32.27848

Table B-1.4: Pressure drop of water flowing trough pipe of 0.0254m I.D and 400ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0254	0.5			0	400	
		0.5	7736.347	6	3.5	41.66667
		1	15472.69	8	4.5	43.75
		1.5	23209.04	11.5	5	56.52174
		2	30945.39	13.5	8	40.74074
		2.5	38681.74	17	11	35.29412
	1					
		0.5	7736.347	11.5	4.5	60.86957
		1	15472.69	17.5	5	71.42857
		1.5	23209.04	25	10	60
		2	30945.39	28.5	18.5	35.08772
		2.5	38681.74	35	20.5	41.42857
	1.5					
		0.5	7736.347	18.5	10	45.94595
		1	15472.69	25	10	60
		1.5	23209.04	36.5	16.5	54.79452
		2	30945.39	42.5	27	36.47059
		2.5	38681.74	56	35.5	36.60714
	2					
		0.5	7736.347	25	9.5	62
		1	15472.69	33.5	14.5	56.71642
		1.5	23209.04	48.5	22.5	53.60825
		2	30945.39	60.5	39.5	34.71074
		2.5	38681.74	79	51	35.44304

Appendix B-2: Pressure Drop Data of pipe 0.0381m I.D

Table B-2.1: Pressure drop of water flowing trough pipe of 0.0381m I.D and 100ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0381	0.5			0	100	
		0.5	10315.14	1	0.5	50
		1	20630.27	2	2	0
		1.5	30945.41	2	2	0
		2	41260.55	3	3	0
		2.5	51575.68	3.5	3	14.28571
		3	61890.82	5.5	5	9.090909
	1					
		0.5	10315.14	3	2.5	16.66667
		1	20630.27	4	3	25
		1.5	30945.41	4.5	4.5	0
		2	41260.55	5	4.5	10
		2.5	51575.68	5.5	5	9.090909
		3	61890.82	5.5	6.5	-18.1818
	1.5					
		0.5	10315.14	4	4	0
		1	20630.27	5	5	0
		1.5	30945.41	6	5.5	8.333333
		2	41260.55	7	7	0
		2.5	51575.68	9	8	11.11111
		3	61890.82	10	9.5	5
	2					
		0.5	10315.14	5.5	5.5	0
		1	20630.27	9	7	22.22222
		1.5	30945.41	10	9	10
		2	41260.55	10.5	10	4.761905
		2.5	51575.68	14	13	7.142857
		3	61890.82	14.5	14.5	0

Table B-2.2: Pressure drop of water flowing trough pipe of 0.0381m I.D and 200ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0381	0.5			0	100	
		0.5	10315.14	1	0.5	50
		1	20630.27	2	1.5	25
		1.5	30945.41	2	2	0
		2	41260.55	3	2.5	16.66667
		2.5	51575.68	3.5	2.5	28.57143
		3	61890.82	5.5	4	27.27273
	1					
		0.5	10315.14	3	2	33.33333
		1	20630.27	4	2.5	37.5
		1.5	30945.41	4.5	4	11.11111
		2	41260.55	5	4	20
		2.5	51575.68	5.5	5	9.090909
		3	61890.82	5.5	6.5	-18.1818
	1.5					
		0.5	10315.14	4	3.5	12.5
		1	20630.27	5	5	0
		1.5	30945.41	6	5.5	8.333333
		2	41260.55	7	6.5	7.142857
		2.5	51575.68	9	8.5	5.555556
		3	61890.82	10	9	10
	2					
		0.5	10315.14	5.5	5.5	0
		1	20630.27	9	5	44.44444
		1.5	30945.41	10	8.5	15
		2	41260.55	10.5	10	4.761905
		2.5	51575.68	14	12	14.28571
		3	61890.82	14.5	14.5	0

Table B-2.3: Pressure drop of water flowing trough pipe of 0.0381m I.D and 300ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0381	0.5			0	100	
		0.5	10315.14	1	0.5	50
		1	20630.27	2	1.5	25
		1.5	30945.41	2	2	0
		2	41260.55	3	2.5	16.66667
		2.5	51575.68	3.5	2	42.85714
		3	61890.82	5.5	4	27.27273
	1					
		0.5	10315.14	3	1.5	50
		1	20630.27	4	1.5	62.5
		1.5	30945.41	4.5	4	11.11111
		2	41260.55	5	4	20
		2.5	51575.68	5.5	5.5	0
		3	61890.82	5.5	6.5	-18.1818
	1.5					
		0.5	10315.14	4	3.5	12.5
		1	20630.27	5	4	20
		1.5	30945.41	6	5	16.66667
		2	41260.55	7	6.5	7.142857
		2.5	51575.68	9	8	11.11111
		3	61890.82	10	9	10
	2					
		0.5	10315.14	5.5	5	9.090909
		1	20630.27	9	6	33.33333
		1.5	30945.41	10	7.5	25
		2	41260.55	10.5	10	4.761905
		2.5	51575.68	14	11	21.42857
		3	61890.82	14.5	14	3.448276

Table B-2.4: Pressure drop of water flowing trough pipe of 0.0381m I.D and 400ppm mucilage concentration

D (m)	L (m)	F (m^3/s)	NRe	concentration (ppm)		%DR
0.0381	0.5			0	100	
		0.5	10315.14	1	0	100
		1	20630.27	2	0	100
		1.5	30945.41	2	0.5	75
		2	41260.55	3	2.5	16.66667
		2.5	51575.68	3.5	1.5	57.14286
		3	61890.82	5.5	3	45.45455
	1					
		0.5	10315.14	3	0	100
		1	20630.27	4	0	100
		1.5	30945.41	4.5	3.5	22.22222
		2	41260.55	5	3.5	30
		2.5	51575.68	5.5	4	27.27273
		3	61890.82	5.5	6	-9.09091
	1.5					
		0.5	10315.14	4	0	100
		1	20630.27	5	1	80
		1.5	30945.41	6	5	16.66667
		2	41260.55	7	5	28.57143
		2.5	51575.68	9	7	22.22222
		3	61890.82	10	7	30
	2					
		0.5	10315.14	5.5	1	81.81818
		1	20630.27	9	4	55.55556
		1.5	30945.41	10	6.5	35
		2	41260.55	10.5	8.5	19.04762
		2.5	51575.68	14	10.5	25
		3	61890.82	14.5	10	31.03448