STUDYING THE EFFECT OF CHITOSAN AS DRAG REDUING AGENT IN WATER FLOWING SYSTEM WITH DIFFERENT CONCENTRATION AND PREPARATION USING DIFFERENT ACID TYPES

NUR KHADIJAH BINTI MOHAMAD NAJIB

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
Universiti Malaysia Pahang

MAY 2009

I declare that this thesis entitled “Studying the effects of Chitosan as Drag Reducing Agent in Water Flowing System with Different Concentration and Preparation with Different Acid Types.” 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.

Signature	:	
Name	:	Nur Khadijah Binti Mohamad Najib
Date	:	2 May 2009

I dedicate this thesis especially to my family, without whom none of this would have been worth the challenge…

Supportive Parents;
Mohamad Najib Bin Othman & Salmiah Binti Shaari

Not-so-little Siblings;
Nur Mashitah, Nur Shatila, Mohd Ridzuan, Nur Aishah, Mohd Firdaus

My True Friends;

This is for all of you.
.

ACKNOWLEDGEMENT

Praise is to God for His help and guidance that we finally able to complete this design project.

Predominantly I would like to extend my sincerest gratitude to Dr Hayder A.Abdul Bari, my Undergraduate Research Project supervisor, for his willingness in overseeing the progress of my research project from its initial phases till the completion of it. Without his supports, I would not be able complete this research successfully. Secondly, I would like to extend our words of appreciation to the encouraging lecturers, and also my research team, for the roles they had played in giving me guideline and valuable advices during the progress of this research and this thesis as well.

The experiences and knowledge I have gained throughout the process of completing this project will be the invaluable experience to better equip me for the challenges which lie ahead. In particular, my truthful thankful is also extends to all my colleagues and others who have provided assistance to me without anticipate any return for it. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space.

Last but definitely not least to my family members and our closest acquaintance, Azie, Finnie, Adda, Amy, and not forgotten for my love one, Mohd Hafiz your worships, and for the audaciousness, as well as supporting me throughout carrying out my studies in Universiti Malaysia Pahang (UMP).

ABSTRACT

The investigation of turbulent drag reduction, which is caused by the addition of a small amount of polymer or some other substances to the liquids flowing systems has been the focus of attention of many scientists for the last decades. Due to the reduction of the drag, pumping power for the pipeline will significantly reduced and thus will decrease the cost of electricity in total production cost. It also has great impending in the industrial applications, such as in liquid pipeline transportation. In the present work, a new drag reducing agent has been devised from natural occurring polymer based which is Chitosan. The polymer additive prepared is tremendously cheaper compared to other commercial drag reducing agents and nevertheless offering the comparable performance in reducing drag. The method of preparation the additive is uncomplicated, not time consuming and most of the compound used are fulfilling natural need. Two types of chitosan solution is prepared using different types of acid and three different proportion of volume in the solution and each solution are measured in term of viscosity The turbulent drag reductions are measured by reading the value of pressure drop along the pipeline re-circulatory flow system of approximately 400 kg tap water. A drastic reduction of drag in the turbulent flow of solutions as appraised with pressure drop reduction in comparison to the pure solvent can be observed, even when only minute amounts of the additives are added. The % of drag reduction is relatively increases as the increases concentration of polymer DRA. Approximately 80.842% of maximum drag reductions for solution prepared with hydrochloric acid are obtained before no more reductions can be achieved as it reached concentration limits. the drag maximum drag reduction point for this type of solution are slightly higher than solution prepared with acetic acid but shows the drastic reduction in %DR.

ABSTRAK

Kajian tentang penguragan geseran dalam pengolakan cecair ini,yang mana dengan penambahan sedikit campuran polimer asli atau sesuatu bahan pejal ke dalam sistem pengaliran cecair telah menjadi tumpuan bannyak ahli sains dalam dekad ini. Dengan pengurangan geseran ini, kuasa pam yang diperlukan untuk mengangkut cecair telah berjaya dikurangkan dan juga turut megurangkan kos janakuasa elektrik yang diperlukan. Dalam kajian ini, satu polimer ejen baru telah yang berasal dari bahan semulajadi yang murah dan mudah didapati telah diformulasikan Cara penyediaan ejen ini adalah sangat mudah dan murah tetapi dalam masa yang sama berupaya mengurangkan geseran diantara cecair dan dinding paip setanding dengan ejen komersial yang lain. Dua jenis ejen telah dihasilkan mengunakan dua jenis asid yang berlainan untuk mengkaji kesan penggunaan asid lain terhadap campuran yang dihasilkan. Alat untuk menguji pengurangan geseran didalam paip ini direka khas untuk menunjukkan kadar perubahan tekanan yang terjadi pada suatu titik yang ditentukan. Bedasarkan hasil yang didapati dari kajian ini, hampir 80.842% kadar pengurangan geseran berjaya dihasilkan untuk penggunaan ejen yang diperbuat dengan menggunakan asid hidroklorik berbanding 80.5% kadar maksimum yang direkodkan untuk ejen yang diperbuat dari asid asetik pada nisbah 6% kadar asid didalam larutan ejen. Akan tetapi, corak pengurangan yang dihasilkan dengan penggunaan asid hidroklorik adalah tidak stabil berbanding corak yang ditunjukkan oleh ejen sebaliknya. % pengurangan oleh ejen dari hidroklorik asid ini menurun dengan mendadak apabila mencapai kadar maksimum penurunannya dan ia berbeza berbanding larutan lain yang menunjukkan penurunan yang stabil. Ia mungkin terjadi hasil daripada pemecahan molekul polimer ejen apabila melalui pam dan injap didalam sistem aliran cecair itu. Oleh itu, dapat disimpulkan bahawa kaedah penghasilan menggunakan asid asetik adalah lebih berkesan berbanding kaedah penghasilan menggunakan asik hidroklorik.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

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
Dp		Diameter Pipe
PDRA		Polymer Drag Reduction Agent
MDR		Maximum Drag Reduction

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the Research

The study of turbulent drag reduction, which is caused by the addition of a small amount of polymer or some other substances to the liquids flowing systems has been the focus of attention of many scientists for the last decades. A reduction in energy loss in turbulent pipe flow in water/solid transportation was reported more than 65 years ago and since the first reports of drag reduction by Tom (1948), a large number of researchers have worked in this area in order to find the most effectives additives in reducing drag. Nadolink and Haigh (1995) have compiled a bibliography on drag reduction phenomenon by polymers and other additives and there are more than 4900 references revolves about the drag reducing dating from 1931 to 1994. (K. Gasljevic et.al 1999)

The addition of small amount of drag-reducing materials such as polymers, surfactants or fibers, a percentage of drag reduction up to 80% can easily be achieved. This technique is considered to be the most convenient method of reducing turbulent frictional drag in pipeline during transportation of fluids (Jiri Myska, 1997). Due to the reduction of the drag, pumping power for the pipeline can be greatly reduced and thus will decrease the cost of electricity in production cost. It also has great potentials in the industrial applications, such as in saving pumping power in a water-circulating device like a district heating/cooling system. Due to its importance, the phenomenon has been the subject of much revise in the past, in both theoretical and experimental field.

The basic definition of drag reduction is the reduction of the fluid mechanical force in order to improve the efficiency of the engineering system. There are two ways of reducing the drag, which are passive and active techniques. The passive way is only involved installation and maintenance, while the active way is require certain energy input. With the active techniques, the level of drag reduction can be achieved up to 80% and that makes this method is more efficient compared to passive technique. Mainly, there are three major types of drag reducing agent which is are surfactant, polymers, and suspended solid.

The types of the additives can be differentiating based on the extensive dissimilarity between their flow behaviors and their way of reducing the pressure drop in the flowing system once they were introduced in the liquid. These include the influence of preshearing, the effect of mechanical shear on degradation, and the influence of tube diameter, maximum drag-reduction effectiveness, and the shape of their mean velocity profiles. The differences suggest that the mechanisms for causing drag reduction may be different for the two types of additives. (Jiri Myska, 1997)

In the present investigation, Chitosan is used as a polymeric additives solution to reduce the drag of liquid flow in a pipeline and require a lower pressure gradient to maintain the same flow rate. A higher flow rate would be obtained for the same pressure gradient if such an additive was used. The various parameters such as polymer concentration, polymer molecular weight, temperature, Reynolds number, and solvent quality are known to be the important factors of drag reduction (DR).

1.2 Problem Statement

In the chemical process industries, it is usually a requirement to transport fluid using pump over long distances from storage to another processing unit or to another plant sites. During the process of pumping the liquids, there may be substantial frictional pressure drop in the pipeline and also in the individual units themselves. Thus, it is important to consider the problems of calculating the power requirement for pumping through the pipe network, selection of optimum pipe diameter, control of liquid flow rate and the number of pump station should be install along the network.

The frictional pressure loss in the pipeline is due to the resistance encountered by flowing fluid coming into contact with solid surface, such as pipe wall. Resulting from that, fluid molecule will move randomly and will cause lots of energy loss as eddy current and other indiscriminate motion. By reduction of the drag or the fluid mechanical forces in the pipeline system, it may deduct a significant part of the plant cost.

1.3 Objective of Study

The proposed research was studied to achieve the following objectives:

1. To investigate the effect of addition of different concentration of polymer drag reducing agent to the drag reduction efficiency

2. To explore the other alternative of more economical and low potential of toxicity polymer that can be used to reduce the drag reduction which is Chitosan.

3. To study on the most efficient Chitosan preparation as drag reduction agent.

4. To determine the most suitable acid types in chitosan preparation and to the evaluate the optimum proportion of acid percentage in preparation of chitosan

5. To predict the effective viscosity value in producing high drag reduction

1.4 Scope of Study

In order to investigate the effect of chitosan solution as drag reducing agent in water pipeline system, we have manipulated some restriction factor that involve in limits the effect of drag reducer and also pressure drop effect. The restrictions that involve in this research are listed like below:

1) Effect of different addition of Chitosan concentration in the solvent solution which is based on weight basis (100,300,500 and 700 ppm)

2) Effect of different values of water flow rate in the pipeline system

3) Effect of different pipe diameter in water flowing system. (0.5,1.0 and 1.5 inch inside diameter)

4) Usage of different types of acid in Chitosan preparation and this involves sing Hydrochloric Acid and Acetic Acid

5) Consequence of adding different proportion of acid in Chitosan solution for both acid types. This proportion varied from value 2%, 4% and 6% based on volume ratios.

1.2 Rationale and Significance

This research is developed based on the concern of power consumption despite of mechanical drag in pipeline system and to improve the efficiency of liquid transportation. The reduction of the frictional pressure during flow can greatly reduce the cost of pumping power and cost of pumping station units. In addition, by using Chitosan as natural occurring polymer drag reducer which can degradable and environmental friendly is a healthy way to preserve the earth.

CHAPTER 2

LITERATURE REVIEW

Drag or also known as fractional pressure drop is an effect from the flowing fluid or solution contacting with a solid surface, such as pipe wall. By adding of drag-reducing polymer or surfactant additives may cause a spectacular frictional drag reduction in the flow in the pipeline and thus reduce fluid mechanical force which is exerted on an engineering system to improve its efficiency. By addition of these Drag Reducing Agent, pressure losses in the pipeline can be reduce and in the meanwhile the operating cost of the transportation can be save.

2.1 Types of Flow

Essentially, there are two types of flow exist which is laminar and turbulent flow. The friction pressures experimental in laminar flow cannot be changed unless the physical properties of the fluid are changed. In this research, the addition of drag reducing agent in the flowing fluid is supposedly does not change fluid properties and for this reason, they are effective only in turbulent flow. These two flow regimes are defined by Reynold's number, the ratio of the fluid body forces viscous forces ($Re = VL\rho/\mu$).

For the value of Reynold's number less than 2000 define laminar flow regime for pipes. With the increases of Re number, pipe flow are transitions from laminar to turbulent over a range of values from 2,000 to 10,500 and is fully turbulent above 10,500 (Stanford P. Seto, 2005). Reynold's number less than 2000 define laminar flow regime for pipes. With the increases of Re number, pipe flow are transitions from laminar to turbulent over a range of values from 2,000 to 10,500 and is fully turbulent above 10,500 (Stanford P. Seto, 2005).

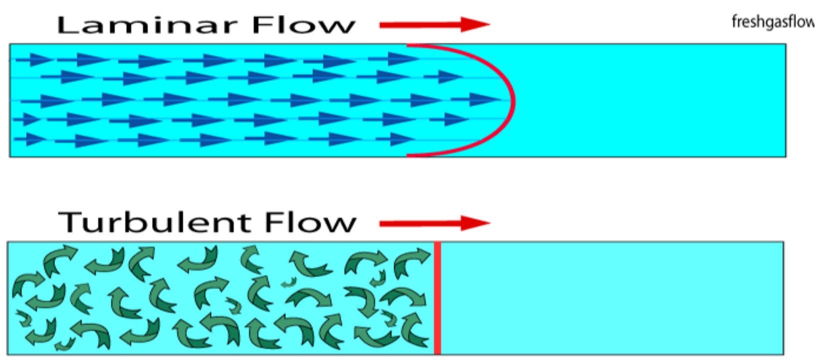

Figure 2.1: Diagram of Laminar and Turbulent Flow in Pipeline

2.1.1 Laminar Flow

Laminar flow is defined as steady state flow in which the liquid flows through the pipe smoothly in laminations (E.Shashi Menon et.al, 2005). Hoener (1965) has defined Laminar flow as 'state of flow where the various fluid sheets do not mix with each other'. It also is described as a uniform stable streamline flow without any mixing between layers. It can be consider as a smooth motion of the fluid as the objects goes through it. This type of flow is also known as low friction or viscous flow in which no eddies or turbulence exist. As the flow rate increases, more and more disturbance or eddies are formed due to friction between the adjacent layers of the liquid as well as friction between the pipe wall and the liquid (E.Shashi Menon et.al, 2005).

Laminar flow becomes turbulent flow (at a velocity which is dependent on the geometry of the medium surrounding it) when the fluid begins to have a highly irregular and random motion.

2.1.2 Turbulent Flow

Turbulent flow defined by Hoerner, (1965) as a state of "...a more or less irregular "eddying" motion, a state of commotion and agitation, consisting of velocity fluctuations superimposed to the main flow, within boundary layers..., and within the wake behind solid bodies."Turbulence is a result of certain factors including surface roughness, high velocities, and sound/mechanical waves. Surface roughness and imperfections of a body in motion can cause the boundary layer (the layers of fluid directly in contact with the object) of the fluid in which it is moving to become turbulent more easily than if the surface were more smooth.

In this case, surface roughness will be considered negligible (Hoerner, 1965). Turbulence as a result of high velocities is disregarded here as well. Friction factor of the pipe wall represent an important factor to the degree of turbulences and thus the amount of pressure drop along the pipeline. With the increase of friction in the pipeline, the pressure in the liquid will decreases from the along the pipeline until the outlet. This is called pressure loss due to friction in pipe flow.

The image below shows a characteristic 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.

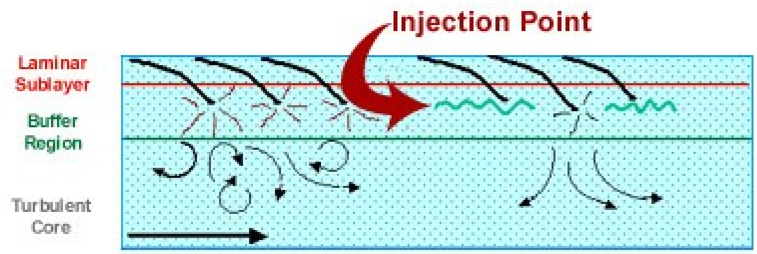

Figure 2.2: Drag Reduction occurs due to suppression of the energy wickedness by Turbulent eddy currents near the pipe wall during turbulent flow.

Latest researches made into this area tell us that the buffer zone is really important because this is where the first formation of turbulence. A section of the laminar sub layer, called a “streak”, will occasionally move to the buffer region. At there, the streaks begin 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 turbulence core is called turbulent burst. The bursting motion and development of the burst in the turbulent core will result wasted energy

2.2 Pressure Drop Due to Friction

As the water flows through the pipeline, there is friction exist between the adjacent layers of water and contiguous layer of water and between the water molecule and wall of pipe. The friction causes the lost energy that will convert from the pressure energy to the heat.

The pressure is continuously decreases as the water flow down the pipe to the downstream end of the pipeline. The amount of pressure loss due to the friction or also known as head losses due to the friction are depends on the flow rate, properties of the water (water specific gravity and viscosity), pipe diameter, pipe length, and internal friction factor or roughness effect of the wall.

2.2.1 Principles and Theory

Friction drag behavior is typically correlated as friction factor vs. Reynolds number. Recall that the relationship between pressure drop in a pipe and the fanning friction factor is:

$$\Delta P = \frac{2 f \rho U_{av}^2 L}{d} \tag{2.1}$$

Where:

ρ = fluid density,

ΔP = pressure drop across the pipe,

f = fanning friction factor

d = diameter of the pipe.

U_{av} = mean fluid velocity in the flow direction averaged across the pipe's cross section.

L = length of pipe used.

Another useful correlation quantity is the wall shear stress:

$$\tau_w = \frac{\Delta P d}{4L} \qquad (2.2)$$

Where

τ_w = wall shear stress.

The Reynolds number is:

$$\mathrm{Re} = \frac{dU_{av}}{\nu_s} \qquad (2.3)$$

Where:

ν_s = kinematic viscosity of the fluid.

Fanning Friction Factor can be calculated using below equation:

$$f = \frac{\Delta P.D/4L}{\rho V^2/2}$$

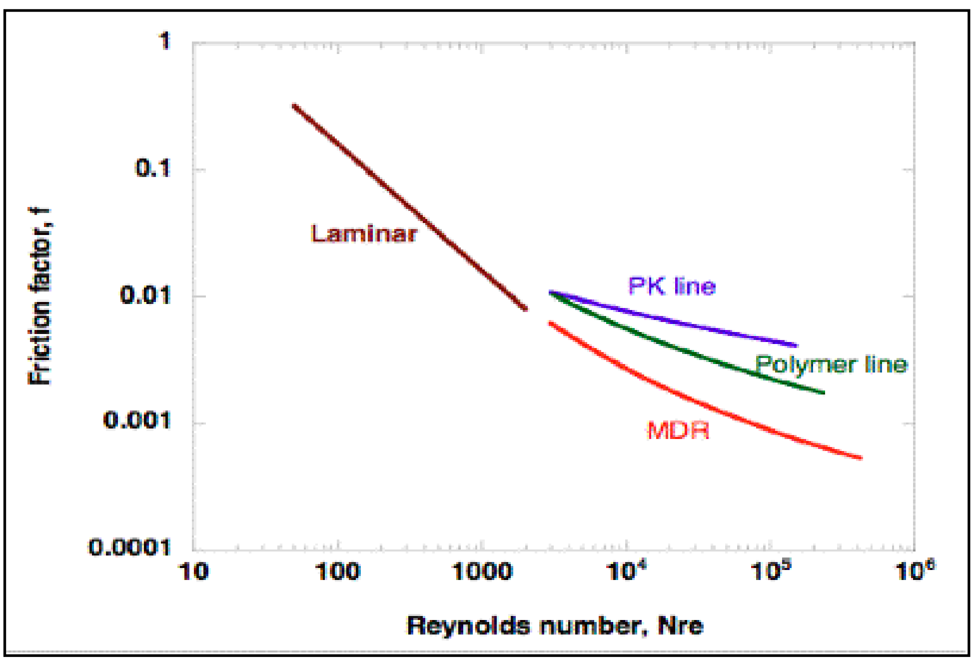

Figure 2.3: f vs Re plot depicting drag reduction. The polymer line is for some particular polymer, molar mass and concentration. Different concentrations, The line labeled "PK" is for behavior of a Newtonian fluid.

Figure 2.3 shows characteristic behavior in turbulent flow for friction factor vs Reynolds number correlations. The behavior of a Newtonian fluid, such as water is shown. Two curves for polymers are given. One is for a polymer of a certain concentration and molar mass. The other is the maximum achievable drag reduction. This limit is called the maximum drag reduction asymptote (MDR).

Prandtl-Karman plots are an excellent way to analyze polymer turbulent drag reduction data. In 1975 Virk collected all data available in literature pertaining to drag reduction and explained them in terms of simple phenomenological equations. These relationships were then used to create Prandtl-Karman plots. Prandtl-Karman plots are generally used to depict drag reduction studies. These plots relate drag reduction phenomena to flow and other polymer related variables. The axes of the plot are 1/ as the ordinate and Re as their abscissa.

Newtonian and polymer solutions exhibit distinct flow regimes based on Re. In the laminar flow regime solutions obey the Poiseuille law given by:

$$\frac{1}{\sqrt{f}} = \frac{\mathrm{Re}\sqrt{f}}{16} \tag{2.4}$$

With further increase in flowrate, when fully developed turbulent flow is attained (Re>3000), different behaviors are obtained if the fluid is Newtonian or polymeric.

When the wall shear stress τ_w is below a critical value, τ_w^*, there is no drag reduction and the Prandtl-Karman (PK) coordinates follow the PK law for Newtonian solvents in turbulent flows which is given by:

$$\frac{1}{\sqrt{f}} = 4.0\log_{10}\left(\mathrm{Re}\sqrt{f}\right) - 0.4 \tag{2.5}$$

It is easy to show that this function form is nearly equivalent to friction factor Reynolds number equations given in fluid mechanics textbooks for Newtonian fluids.

However, once the critical shear stress τ_w^* is exceeded for the polymer solution, it will not obey equation (2.5). Instead, the friction factor will decrease at any particular Reynolds number relative to a Newtonian fluid. Virk (1975) shows that this decrease is well correlated by the equation:

$$\frac{1}{\sqrt{f}} = (4.0+\Delta)\log_{10}\left(\mathrm{Re}\sqrt{f}\right) - 0.4 - \Delta\log_{10}\left(\left(\mathrm{Re}\sqrt{f}\right)^*\right) \qquad (2.6)$$

Equation (2.6) contains two empirical constants that depend on the material properties of the polymer solution (such as the identity of the polymer, its concentration and its molar mass).

Note that $\left(\mathrm{Re}\sqrt{f}\right)^*$ is simply related to the material property τ_w^* through the following equations:

$$\left(\mathrm{Re}\sqrt{f}\right)^* = \frac{\sqrt{2}u_\tau^* d}{\nu_s} \qquad \text{Where } u_\tau^* = \sqrt{\frac{\tau_w^*}{\rho}} \qquad (2.7)$$

Since τ_w^* and Δ are material properties of the polymer solution, they are very useful for engineering design, they can be measured on a small-scale system and applied to a large-scale system.

The amount of drag reduction that can be achieved does not increase without bound. At some concentration and molar mass no further increase is possible. Virk has found that the maximum is well described by the equation:

$$\frac{1}{\sqrt{f}} = (19.0)\log_{10}\left(\mathrm{Re}\sqrt{f}\right) - 32.4\,. \qquad (2.8)$$

This equation is called the maximum drag reduction asymptote (MDR).

Figure 2.4 below shows that main physical features of polymer drag reduction on a friction factor Reynolds number plot.

The same data can be plotted in terms of the Prandtl-Karman coordinates (Figure 2.4.). Here the green line is MDR and the blue line shows data for a particular onset condition and slope increment. The orange line is the Prandtl-Karman (PK) line for a Newtonian fluid.

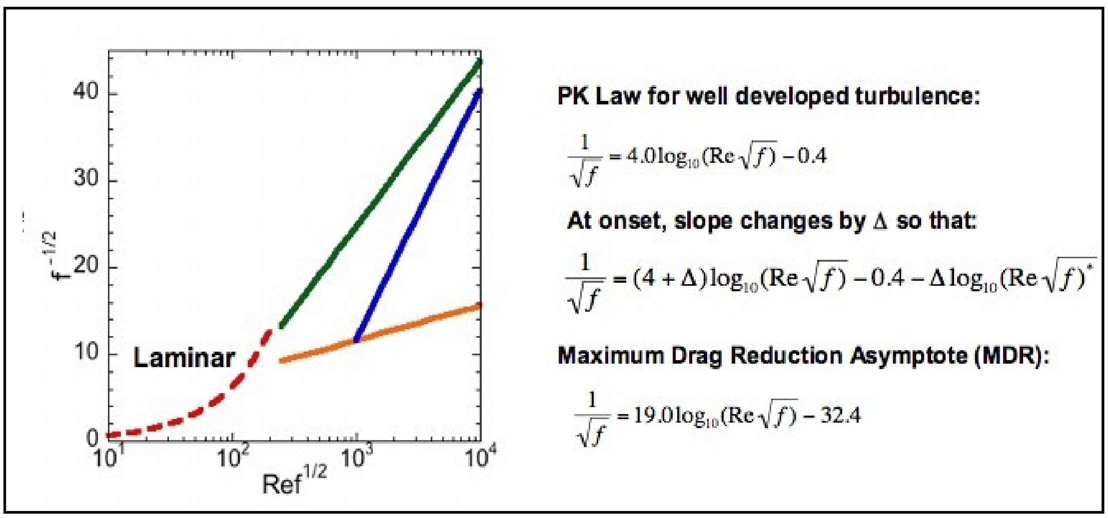

Figure 2.4: Prandtl-Karman plot for representing polymer drag reduction.

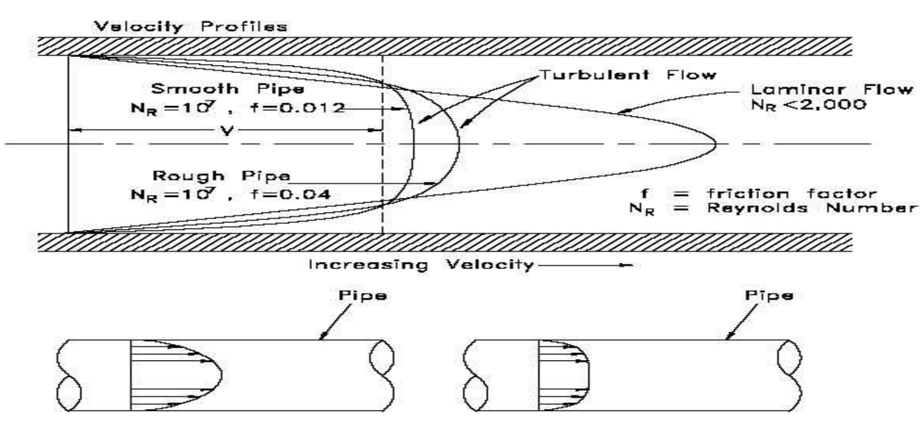

Figure 2.5: Characteristic of turbulent and laminar flow in the rough and smooth pipe with correlates to friction factor of pipe

2.3 Drag Reduction

Drag reduction is a phenomenon which by small addition of a small amount of additives (e.g a few part per million, ppm) can greatly reduce the turbulent friction of a fluid. The main aims for drag reduction are to improve fluid-mechanical efficiency by using active agent known as drag reducing agents and to increase the flow performance by using the same amount of energy supplied (D.Mowla, A.Naderi, 2006). Percent of drag reduction (%DR) or the effectiveness of the DRA can defined as the ratio of reduction in the frictional pressure difference when the flow rates are held constant to the frictional pressure difference without DRA, and then multiplied by 100, as shown in Eq. (2.9) (D.Mowla et al., 2006).

$$\% \, DR = (\Delta P_b - \Delta P_a) / \Delta P_b \times 100\% \qquad (2.9)$$

Drag reduction are applicable in both oil and water phase system and the reducers used in oil phase are typically ultra-high molecular weight poly (alpha-olefins), while water soluble drag reducers are typically polyacryl amide polymers. For two-phase and multiphase slug or bubble flow applications, the continuous liquid phase is the phase which can be drag-reduced. Water soluble drag reducers are used in water flooding operations, high water-cut production lines, spent water disposal, and transport of oily water. In recent times, the application of drag reduction has been taken a step further into the offshore environment and multiphase applications. The application of drag reduction also extent in managing and increase production; significantly lower discharge pressure, and in some instances, change the flow regime, and improve operations.

2.3.1 Mechanism of Drag Reduction

In spite of the extensive research in the area of drag reduction over the past four decades, there is no universally accepted model that explains the exact mechanism bring to the about pressure drop reduction. A complete mechanism would have to address the role of the additives structure, the composition and additives-solvent interactions in the drag reduction phenomena. Even though a comprehensive mechanism does not exist, several postulates that explain on the mechanism of the drag reduction have been presented (Mc Cormick, 1973)

Two theoretical concepts have been put forward by Hannu Eloranta et.al (2006) in order to explain the drag reduction mechanism by polymers. The first concept proposes a mechanism based on the extension of polymers. It postulates that stretching of randomly coiled polymers, primarily in regions with strong deformations such as the buffer layer, increases the effective (extensional) viscosity. The second theory claims is that drag reduction is caused by the elastic rather than the viscous properties of polymers.

Lumley (1969, 1973) has suggested that stretching of polymer chains in regions with strong deformations (e.g., the buffer layer) will increases the extensional viscosity of the base fluid. Resulting from that, small eddies near the wall are damped out with a subsequent reduction in the viscous drag. De Gennes (1990) postulated that the characteristic of the drag reduction phenomenon to the shear waves caused by the elasticity of polymer chains. These waves are argued to suppress turbulent velocity fluctuations at small-scales thereby reducing the viscous drag.

In the Ptasinki et.al (2001) experimental work, it has been proved that the turbulent shear stresses are substantially suppressed by polymer chains respective of the fact the polymer chains themselves contribute to the extra stress tensor in the momentum equation. These studies exposed that disentanglement of polymer chains is indeed an essential element in the ability of a polymer to reduce viscous drag.

Other interesting work of Vreman, (2007) showed that polymers dissipate these energies through a relaxation process with the highest dissipation taking place in the buffer layer. These studies suggest that the drag reduction is maximum when there is strong shear covering in the buffer layer (i.e., when small-scale eddies dominating turbulence near the wall are separated from large-scale eddies so that large eddies cannot penetrate into the near wall region).

Landahl (1977) developed a two-scale mechanistic model of turbulence based on the classical hydrodynamic stability concept. He did not agree on the postulate that state the shearing of large scale eddies by the mean flow can cause an inflection in the local velocity profile, leading to small scale instability, which in turn can further extend into a bursting occurrence. According to his model, additive drag reduction is mainly due to inhibition (stabilization) of this instability mechanism by aligned elongated molecules, which lowers the formation of turbulent. Based on constitutive rheological relations of fiber suspensions, the model offers explanations for onset and maximum drag reduction (MDR) conditions.

Recently, the direct stimulation system (DNS) model has been developing to quantitatively analyze the turbulence transport mechanism. Den Toonder (1995) has proposed the that the polymers become extended by the flow at a certain Reynolds number, depending on the time scale of the polymer molecules in relation to the time scale of the turbulence. Hence, this “onset” phenomenon is determined by elastic properties of the fluid. When the polymers are extended, viscous anisotropic effects introduced by the extended polymers in the relation between the stress and the deformation cause a change in turbulent structure and the anisotropy production leading to a reduction in drag. At this stage, elasticity plays a counterproductive role in the drag-reduction process

The illustrations below show the effect on the mechanism of polymeric drag reduction. When DRA dissolves in water, the polymer molecules is then begin to uncoil and outspread as they interact with the pipeline flow. This interaction is complex since the long chain molecules of polymer will dampen turbulent bursts near the pipe wall as if they were acting as tiny shock buffers. The dampening effect will reduces frictional pressure loss resulting in a decrease in energy consumption or an increase in flow rate.

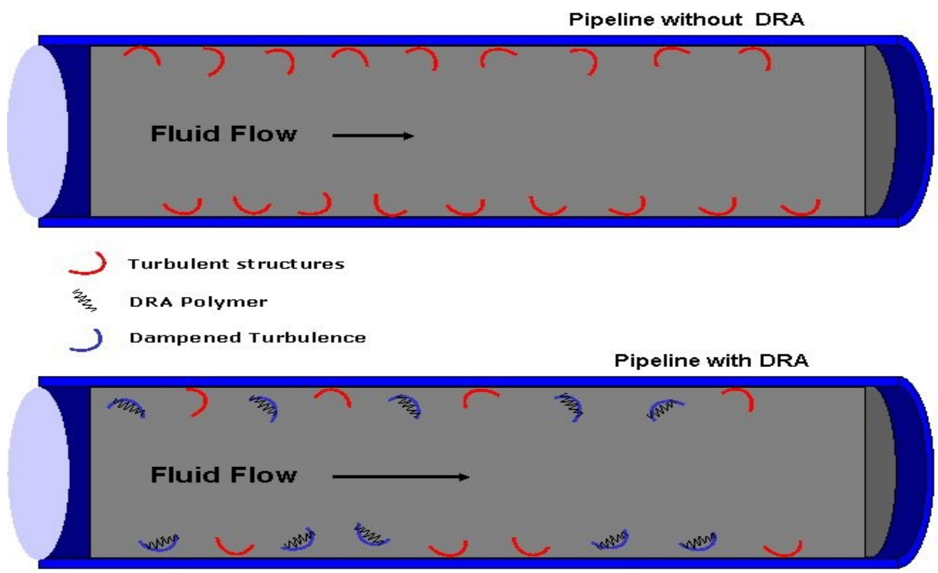

Figure 2.6: Illustration for the Mechanism of Polymeric Drag Reduction.

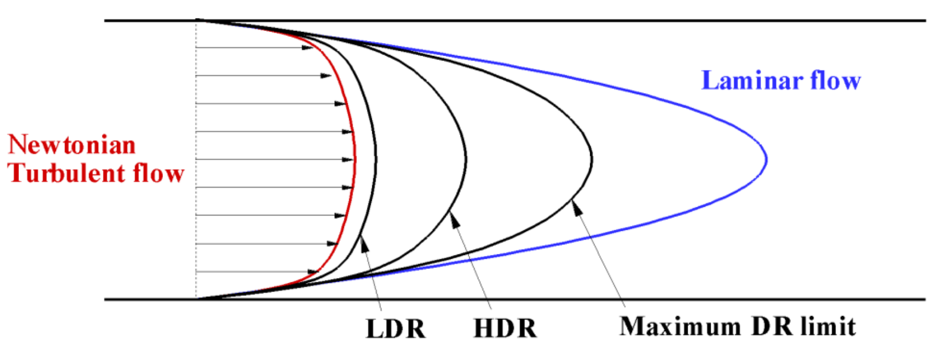

Figure 2.6: The diagram of the effect of drag reduction on the Newtonian Turbulent flow

2.4 Drag Reducing Agents (DRAs)

Drag reducing agents are defined as any material that reduces frictional pressure during fluid flow in a conduit or pipeline. Where fluid is transported over long distance, these friction losses result in inefficiency that increases equipment and operations cost. DRA can be divided into three main groups based on their characteristic. The main divisions of the additives are polymer, surfactants, and fibers drag reducing agents. It has been observed that with the small addition of the additives, will reduce a great number of pressure drops in the pipeline and thus will improve fluid flow.

Polymer drag reducer also proved to reduce transverse flow gradient, and then effectively creating laminar flow in the pipe. This phenomenon is usually occurring close to the pipe wall where axial flow velocity profile has a very steep gradient in which significant pressure losses happen (Stanford P. Seto, 2005).Therefore, by lowering these internal fluid losses will increase the bulk throughout of the pipeline for a given pumping energy and will significantly reduce the operating cost for the transportation. The selection of the type of drag reducing agent are depends on the fluid type and the general use of the fluid.

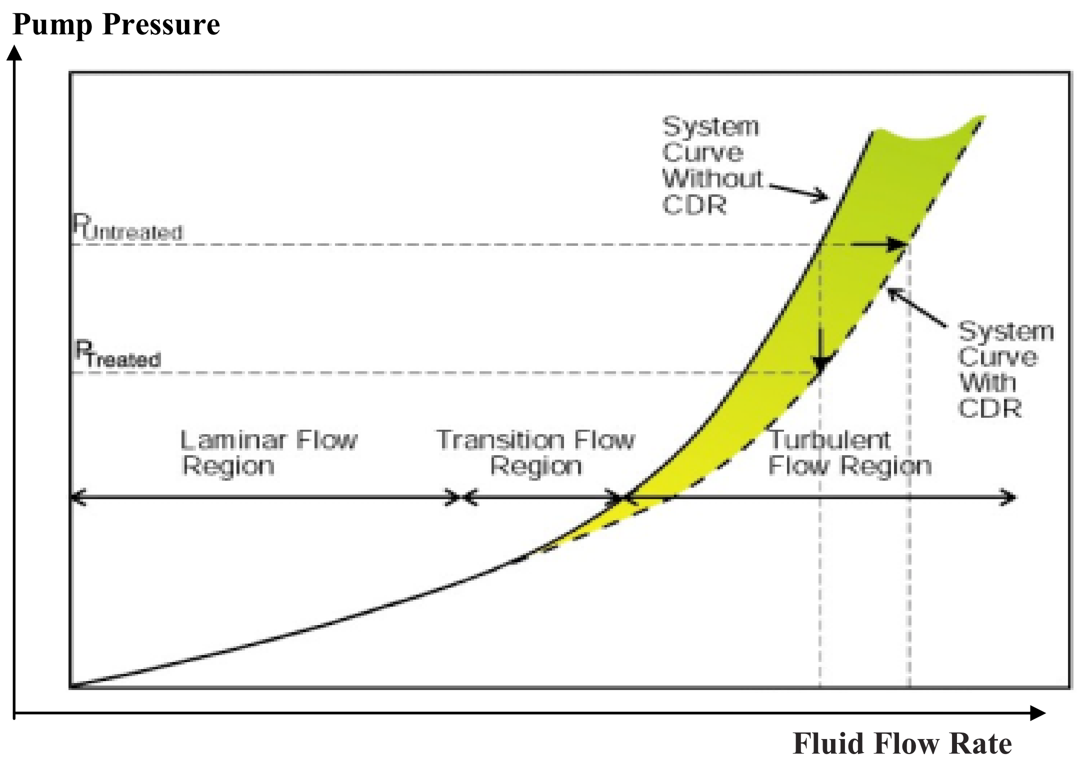

Figure 2.7: Effect of Chemical Drag Reducers (CDR) on Pipeline Pump Pressure of Flow Rate

Figure 2.6 above shown the effect of addition the drag reducing agent in the pipeline to the reduce pressure drop. Pressure drop per unit length in the pipeline are increase with the increase of fluid flow rate due to the friction exist between the wall and the liquid. As the flow begin to tumble due to shearing, it will create transverse flow in which faster moving particle are transported into region of lower velocity and vice versa.

This formation of turbulent flow will causes a greater drag in the pipeline and demands higher pumping energy into the flow to maintain the velocity of the flow. With the addition of DRA in the turbulent region, the result that will be obtain are a reduced pumping pressure compare to the system without the addition of the DRA. The system with DRA will reduces the fluid turbulence, especially right next to the pipe wall, downstream of valves in the pipeline and at the junction points. By decreasing the fluid turbulence, pipeline drag is reduced and higher product all through the system can be achieved at the same lower pumping power.

2.4.1 Polymer Drag Reducing Agent

Polymer drag reduction agents is one of the most potential additives because, as Tom's reported that by addition only a few tens of ppm by weight in a particular solvent can result drag reduction of up to 80%. Drag reducing polymers have been successfully applied for potential benefits in various industrial processes and operations, such as long-distance transportation of liquids, oil-well operations, sewage and flood water disposal, fire fighting, transport of suspensions and slurries, irrigation, water-heating, cooling circuits, jet cutting, and marine and biomedical operations.

The most successful application of drag-reduction phenomenon has been in reducing the drag in crude oil transport through Trans Alaskan Pipelines (TAPS) and other pipelines in several countries (J. W. Hoyt, 1972). Within 10 years, effectiveness of the additives has increased up to 12 times from the earlier accomplishment in 1979.

Basically, there are three ways of introducing a polymer solution in the water flow. Firstly, in homogeneous drag reduction, the polymer is allowed to mix homogeneously into the solvent before the fluid is pump through the pipeline network. In the second case of heterogeneous drag reduction, a highly concentrated polymer solution is injected in the center or at the wall of the pipe, then disperses completely by turbulent diffusion to result a homogenous solution some distance downstream the injector. In the third case, a concentrated polymer solution is injected into the center line of a turbulent flow at a high enough concentration that a single coherent unbroken polymer thread forms at the injector and continuous downstream for several hundred pipe diameters. Polymer drag reducing agent are really effective in high molecular weight polymers ($>10^5$) unfortunately, it will get degraded in turbulent flows and lose their effectiveness after a short interval of time or flow.

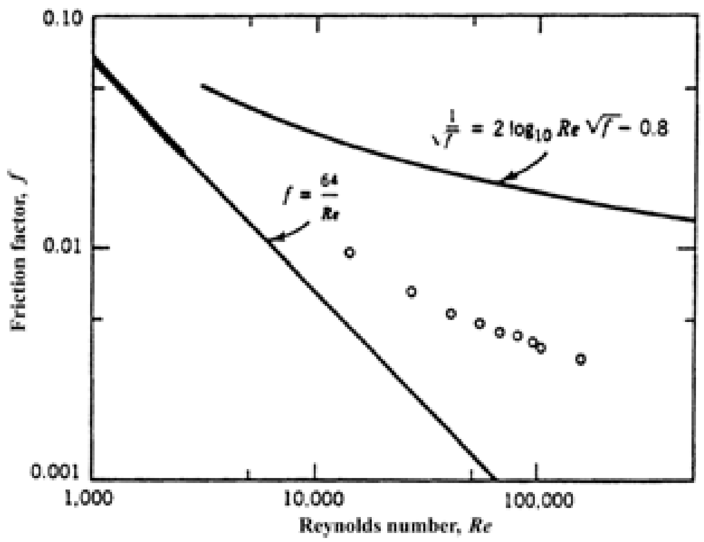

Figure 2.8: Typical data for drag reducing polymer solutions fall between the turbulent friction line for pipe flow, and the laminar line,

.

2.4.1.1 Advantages of Polymer DRA

The advantage of polysaccharide polymers is their high mechanical stability against degradation when compared to flexible synthetic polymers with similar molecular weights. Besides, polymer DRA are also has excellent resistance to heat, light and chemical exposure (D.Mowla et al, 2006). Graft copolymerization methods have been introduced (Deshmukh) in order resist the biological degradation. This method will enhance both drag-reduction effectiveness and shear stability.
Polymer additives also nontoxic material and renewable resource commodity thus the abundant usage of Chitosan will not bring destructive to microorganism.

2.4.1.2 Disadvantages of Polymer DRA

Beside the advantages given below, there also disadvantages using these types of DRA. Polymer drag reducers are requires particular injection equipment, as well as pressurized delivery systems. Due to the high solution viscosity of these DRAs, they are also limited to about 10% polymer as a maximum concentration in a carrier fluid. Thus, transportation costs of the DRA are considerable, since up to about 90% of the volume being transported and handled is inert material.

In additional, some polymeric DRAs are also suffer from the problem that the high molecular weight polymer molecules can be irreversibly degraded and this will reduced the size and so the effectiveness of this DRA when it was subjected to conditions of high shear, such as when they pass through a pump. Moreover, some polymeric DRAs can cause undesirable changes in emulsion or fluid quality, or cause foaming problems when used to reduce the drag of multiphase liquids.

2.4.2 Surfactant Drag Reducing Agent

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

The surfactants can be classified into two groups depends on their nature of the polar group, which are nonionic and anionic, amphoteric or zwitterionic nature. Nonionic surfactants have no charge, anionic surfactants have a negative molecular charge, cationic surfactants have a positive molecule charge, and amphoteric or zwitterrionic surfactants have both positive and negative charges. Anionic and nonionic surfactants provide most of industrial surfactant requirements and are the most common (Lixin Cheng et al., 2007).

With the increasing of surfactant concentration, surface tension will decrease asymptotically and the asymptotic limit is usually referred to as the critical micelle concentration (cmc) of the surfactants. Critical micelle concentration (cmc) is decribed by micelle formation, or micellization, which is the property of surface-active solutes that lends to the formation of colloid-sized clusters, i.e. at a particular concentration, additives form aggregates in the bulk phase or a surfactant cluster in solution that are termed micelles.

The types of micelles are depends on the type and surfactants concentration, solution temperature, presence of other ions and water-soluble organic compounds in the solutions. Unfortunately, most of the surfactants at higher concentrations can cause a change to the physical properties of the solution and also cause strong surface films between adjacent molecules. Some of the surfactant solution are not biodegradable and with abundantly used, it can bring harm to environment.

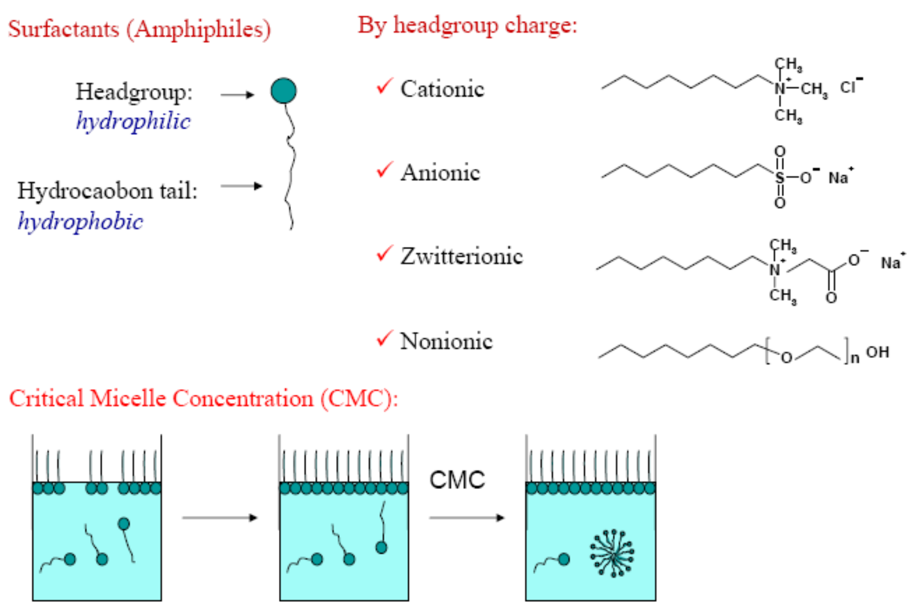

Figure 2.9: Schematics on the Surfactants classifications, and their Applications