INVESTIGATION OF TURBULENCE SLAPPING TECHNIQUE EFFECT ON THE FLOW BEHAVIOR IN PIPELINES

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ABSTRACT

Cost is a very famous topic that always is the most significant factor to be concern in order to build up a piping system. Pumping power needed to pump fluid along the pipelines is increase to overcome the pressure drop of the fluid inside the pipeline. In this investigation, a fins is introduce to overcome the pumping power loses and increase the percentage of drag reduction (DR%). This investigation had undergo with a liquid circulation system where a smooth PVC pipe with 0.00381m I.D to rough galvanized iron with 5 pressure sensor which located 0.5m distance each pressure sensor. Fins model is an object where a stainless steel ring connected with 4 chains with few plastic plates. It is installing inside the 0.00381m I.D PVC pipe. The experiment was run for 2 minutes at several fluid velocities. The highest Dr% from the experiment is 78.51%. The investigation had successful to prove the blending fins are high potential to replace chemical drag reducer in pipelines to reduce pumping power losses.

ABSTRAK

Kos adalah topik terkenal yang selalu merupakan faktor yang paling penting untuk menjadi perhatian dalam rangka membangun sistem paip. Kuasa mengepam yang diperlukan untuk mengepam cecair di sepanjang paip meningkat untuk mengatasi penurunan tekanan cecair di dalam paip. Dalam kajian ini, sebuah model sirip memperkenalkan untuk mengatasi kehilangan kuasa mengepam dan meningkatkan peratusan “drag reduction” (DR%). Penyelidikan ini telah menjalani dengan sistem peredaran cecair di mana paip PVC dengan 0.00381m ID bersambung dengan paip besi Galvanis dengan 5 sensor tekanan yang terletak 0.5m setiap jarak sensor tekanan. Model sirip adalah sebuah objek di mana sebuah bulatan stainless steel dihubungkan dengan 4 rantai sambungan beberapa pinggan plastik. Model sirip adalah memasang di dalam paip PVC I.D 0.00381m. Percubaan dijalan selama 2 minit pada beberapa kelajuan cecair. Dr% tertinggi dari percubaan adalah 78,51%. Penyelidikan telah berjaya membuktikan bahawa model sirip adalah berpotensi tinggi untuk menggantikan drag reducer kimia dalam paip untuk mengurangkan kehilangan kuasa mengepam.

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LIST OF SYMBOLS

ρ	Density
V	Average velocity
D	Diameter
μ	Viscosity
f	Fanning Friction Factor
L	Length
Q	Flow rate
A	Area
P	Pressure
ΔP	Pressure drop
t	Time

LIST OF ABBREVIATIONS

Re	Reynolds' Number
SLES	Sodium Lauyl Ether Sulphate
Dr%	Drag reduction
PVC	Polyvinyl chloride
ID	Internal Diameter

CHAPTER 1

INTRODUCTION

1.1 Introduction

The first chapter will introduce the overview of the research. It's give the basic knowledge about the research. The subtopics of the first chapter includes background of the study, problem statement, research objective, scope of research, limitation of research, rationale, and expected outcome from the research.

1.2 Background of Study

Fluid such as natural gas and crude oil is transported via pipelines from one location to another location. The transportation distance between two locations is usually very far. Drag or friction occurs along the pipelines and eventually will cause the pressure drop along the pipelines. To overcome the pressure drop problem, compressor and pump are added. As a result, extra cost needed to install the pump and compressor (Lowther, 1990). Therefore, to reduce the cost of install the device, alternative methods to overcome the pressure drop should be introduced.

At presence industry, polymer drag reducer is introduced to add into the fluid to improve the flowabiliy in the pipelines. As the different type of fluid in the pipeline, different types of polymers are required to add to reduce the turbulent flow. This is because the composition, structure and content of both fluid and polymer drag reducers are different, only the suitable type of polymer drag reducer would perform well in the fluid. (Qian et al, 1995) To enhance the flowability, another alternative method is to add a device, turbulence blending fins into the pipelines.

1.3 Problem Statement

Turbulent flows in the pipelines always cause the pressure drop inside the pipelines. The pressure drop may affect the flow of the fluid. As the result, there is more power required to move the fluid along the pipeline. The pressure drop inside the pipeline are caused by the formation of the eddies. At presence industries, there are method overcome this problem which is added chemical components into the fluid to stop the formation of eddies. The study of this research is to reduce the formation in the pipeline by added a device instead of chemical component which require more cost and technique to inject the drag reducer. The turbulence slapping technique is a technique use to decrease the pumping power losses by using a device.

1.4 Research Objective

i. To introduce a new technique to improve the effect on the flow behavior in pipelines.

ii. To identify the effect of Turbulence Slapping Technique on flow behavior in pipelines.

iii. To identify the effect of fluid flow rate to the flow behavior

1.5 Scope of The Project

i. Turbulence slapping technique considered are the additional of fins in pipelines

ii. The fins were designed by using the SOLIDWORKS software

iii. The fins were fabricated using plastic and stainless steel

iv. The flow behaviour studied includes Reynold number, percentage of drag reduction, and pressure drop in recorded time.

v. The turbulence flow of the fluid inside the pipeline were then analyzed.

1.6 Limitation of The Research

This research is undergoing inside a 1.5 inches pipelines. The flow rate of the fluid is 4 m^3/ hour (minimum) and 8.0 m^3/ hour (maximum). The turbulence slapping technique only can be tested at 4, 4.5, 5, 5.5, 6, 6.5, 7, 7.5 and 8 m^3/ hour. Flow rate at 4 and 4.5 m^3/ hour are eliminated due the data is out of range. There are no data on higher flow rate than 8 m^3/ hour.

1.7 Significant of Study

As mentioned earlier, the formation of the eddies in pipelines will caused the pressure drop of the fluid and energy losses. Therefore, to decrease the energy required to move the fluid along the pipelines, the formation of the eddies must be reduced. (AltunbaImage et al. , 2002). The idea of the investigation is by added the slapping fan in the pipeline, the formation of the eddies can be stopped. This investigation used to replace the formal polymer drag reducers.

The investigation is to establish another alternative method to control the pressure drop of the fluid along the pipelines. The successful of the investigation can provide a new approach in the related field. The usage of the polymer can be replaced and thus cost reduced. The device have long lifetime and as efficient as the polymer improver.

1.8 Rationale

Pressure drops in pipelines always an issue in pipeline transportation industries. Pressure drops in pipeline caused extra cost needed to run the transportation of fluid in pipeline. Turbulence flows of the fluid increase the cost. Even out there are solutions to solve this problem; however there should be another new technique to implement to reduce the turbulence flows. This is a very interesting topic where the concept of the device is never done by others. This investigation might give the new implementation of method into pipeline industries in order to reduce pumping power loses in permanent solution.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, there are some significant components and elements will be discussed and explained in details. At the early stage, drag reducers source as poly-isobutylene or higher molecular weight poly-alphaolefins are used. These drag reducers will dissolve in the hydrocarbon fluid inside the pipelines (Royer, 1987).

Meanwhile, to move the polymer drag reducers along the pipeline over long distances will be cost expensive and required special transportation and also the pumping equipment (Royer, 1987). The device introduce in this research can overcome the problem stated above as it does not needed special transportation and pumping equipment for the installation. The cost is lower and more convenient than the polymer drag reducers.

2.2 Fluid

The most different between fluid and solid is fluid does not have a fixed shape while solid does not change the shape when withdrawn it to different shape of container without any external force. For example, fluid is drawn into a rectangular jar; the shape of the fluid is rectangular. After that, the fluid is withdrawn to a round bowl; the shape of the fluid will follow the shape of the bowl (Kundu and Cohen, 2004).

Fluids of any liquid or gas that cannot sustain a shearing force when at rest and that undergoes a continuous change in shape when subjected to such a stress. Compressed fluids exert an outward pressure that is perpendicular to the walls of their containers. A perfect fluid lacks viscosity, but real fluids do not.

Fluid is divided into two which are liquids and gases. Gas are very compressible due to the distance of gas molecules are much farther apart then liquid. Figure 2.1 below shows the example of the gas and liquid where the gas molecules stay much farther apart then liquid.

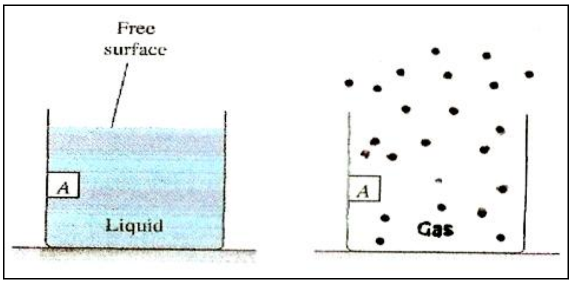

Figure 2.1: Example of gas and liquid (White, 2008)

Density is defined as an object mass per unit volume. The density of fluid or mass density, ρ can be determined by the following equation:

$$\rho = \frac{mass\ (kg)}{volume\ (m^2)}$$

Since ρ is dependent on mass of fluid thus the ρ is independent of the location. The higher the density, the tighter the particles are packed inside the substance. Density is a physical property constant at a given temperature and density can help to identify a substance.

TABLE A.4 Physical properties of common liquids at standard sea-level atmospheric pressure[a]

Liquid	Temperature, T	Density, ρ	Specific gravity,[b] s	Absolute viscosity,[c] μ	Surface tension, σ	Vapor pressure, p_v	Bulk modulus of elasticity, E_v	Specific heat, c
	°F	slug/ft³	—	10^{-6} lb·sec/ft²	lb/ft	psia	psi	ft·lb/(slug·°R) = ft²/(sec²·°R)
Benzene	68°F	1.70	0.88	14.37	0.0020	1.45	150,000	10,290
Carbon tetrachloride	68°F	3.08	1.594	20.35	0.0018	1.90	160,000	5,035
Crude oil	68°F	1.66	0.86	150	0.002	—	—	—
Gasoline	68°F	1.32	0.68	6.1	—	8.0	—	12,500
Glycerin	68°F	2.44	1.26	31,200	0.0043	0.000002	630,000	14,270
Hydrogen	−430°F	0.143	0.074	0.435	0.0002	3.1	—	—
Kerosene	68°F	1.57	0.81	40	0.0017	0.46	—	12,000
Mercury	68°F	26.3	13.56	33	0.032	0.000025	3,800,000	834
Oxygen	−320°F	2.34	1.21	5.8	0.001	3.1	—	~5,760
SAE 10 oil	68°F	1.78	0.92	1,700	0.0025	—	—	—
SAE 30 oil	68°F	1.78	0.92	9,200	0.0024	—	—	—
Fresh water	68°F	1.936	0.999	21.0	0.0050	0.34	318,000	25,000
Seawater	68°F	1.985	1.024	22.5	0.0050	0.34	336,000	23,500
	°C	kg/m³	—	10^{-3} N·s/m²	N/m	kN/m² abs	10^6 N/m²	N·m/(kg·K) = m²/(s²·K)
Benzene	20°C	876	0.88	0.65	0.029	10.0	1030	1720
Carbon tetrachloride	20°C	1588	1.594	0.97	0.026	13.1	1100	842
Crude oil	20°C	856	0.86	7.2	0.03	—	—	—
Gasoline	20°C	680	0.68	0.29	—	55.2	—	2100
Glycerin	20°C	1258	1.26	1494	0.063	0.000014	4344	2386
Hydrogen	−257°C	73.7	0.074	0.021	0.0029	21.4	—	—
Kerosene	20°C	808	0.81	1.92	0.025	3.20	—	2000
Mercury	20°C	13550	13.56	1.56	0.51	0.00017	26200	139.4
Oxygen	−195°C	1206	1.21	0.278	0.015	21.4	—	~964
SAE 10 oil	20°C	918	0.92	82	0.037	—	—	—
SAE 30 oil	20°C	918	0.92	440	0.036	—	—	—
Fresh water	20°C	998	0.999	1.00	0.073	2.34	2171	4187
Seawater	20°C	1023	1.024	1.07	0.073	2.34	2300	3933

[a] In these tables, if (for example, for benzene at 68°F) μ is given as 1.437 and the units are 10^{-6} lb·sec/ft² then $\mu = 1.437 \times 10^{-6}$ lb·sec/ft².
[b] Relative to pure water at 60°F.
[c] For viscosity, see also Figs. A.1 and A.2.

Figure 2.2: The properties of common liquids at standard sea-level atmospheric pressure.(Finnemore, 2002)

2.3 Turbulent Flow Behaviour

In previous last fifty years, there were researches done to study the behaviour of turbulent flow. Turbulence flow is unpredictable and un-uniform. Reynolds, Taylor, Prandtl, Von karman and Kolmogorom had done the research at these fields and made the equations related to the turbulent flow (Mathieu et al. , 2000).

Turbulent flow can be chactecarized as random and occurs of the eddy is a phenomena where when the fluid flow along the pipeline, there are swirling and reverse current formed by the fluid itself or can say as the fluid flow perpendicular to each other. These phenomena will add extra mechanism and energy transfer to the piping systems (Cengel et al. , 2006). Figure 1 below shows the turbulent flow in pipeline.

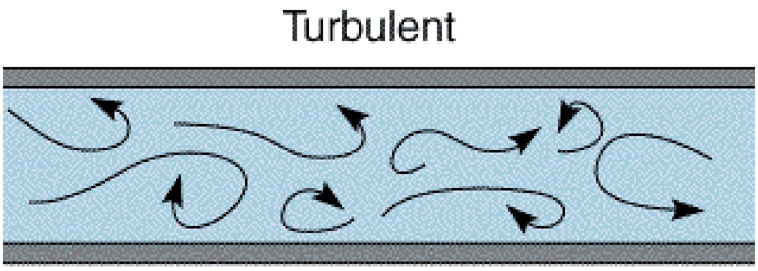

Figure 2.3: Turbulent flow in pipeline (Department of Chemical Engineering and Biotechnology, 2010)

This investigation will study the effect of the Reynolds number to the flow behaviour. It means the turbulent flow gives higher value of Reynolds' Number(Re) which is more than 4000 (Spurk et al. , 2008). Figure2.4 below is the value range of turbulent flow according to Re :

$0 < Re < 1$	**Highly viscous laminar motion**
$1 < Re < 100$	**Laminar, strong Re dependence**
$100 < Re < 10^3$	**Laminar, boundary layer theory useful**
$10^3 < Re < 10^4$	**Transition to turbulence**
$10^6 < Re < 10^6$	**Turbulent, moderate Re dependence**
$10^6 < Re < \infty$	**Turbulent, slight Re dependence**

Figure 2.4: Value range of turbulent flow according to Reynolds' Number (Re) (White, 2008)

The Reynolds' Number (Re) in pipe can be determined by using the equation:

$$Re = \frac{\rho V D}{\mu} \qquad \textbf{(1)}$$

By determining the average velocity V, the Pressure testing section before and after solids and surfactant addition are needed to calculate the percentage drag reduction, Dr% as follows (Virk, 1975):

$$\boldsymbol{Dr}(\%) = \frac{\Delta P_2 - \Delta P_1}{\Delta P_2} \times 100 \qquad \textbf{(2)}$$

Fanning friction factor can be calculated using the following equation:

$$\boldsymbol{f} = \frac{\Delta P D / 4L}{\rho V^2 / 2} \qquad \textbf{(3)}$$

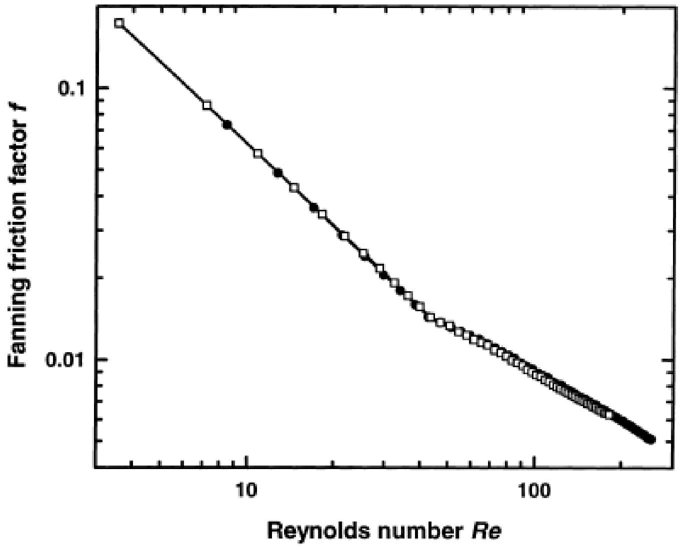

Figure 2.5: Friction factor versus function of Reynolds' Number (Torgeir Nakken et al., 2000)

Figure 2.5 shows the relations of friction factor function and Reynolds' Number. The friction factor function decreases as the Reynolds number decreases as well. The resistance to flow is affected in two ways, either by damping of the turbulence which causes reduction in resistance and by increasing the viscous resistance. Over rough boundaries, the resistance decreases due to damping of turbulence and over smooth boundary, no drag reduction takes place as the two effecrs compensate each other (Wang et al., 1998). The turbulent flow fields with different inlet velocity can be seen in figure 2.6.

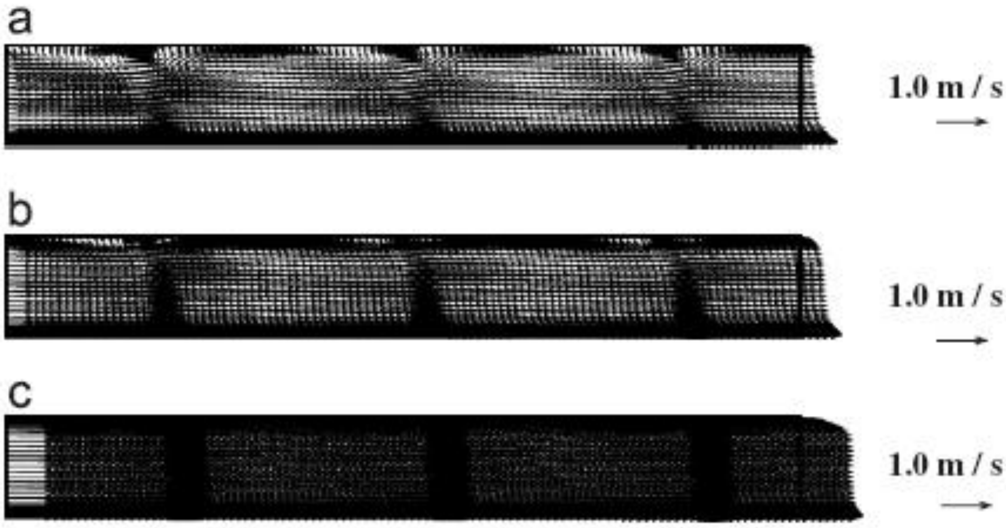

Figure 2.6: Turbulent flow fields with different inlet velocity of (a) 0.3 m/s, (b) 0.5m/s and (c) 1.0m/s. (Hong Lei et al., 2007)

Fom the research paper done by Lim et al., they derived a modified Reynolds mean motion equation of turbulent fiber suspension and the equation of probability distribution function for mean fiber orientation. Their derived equations and successive iteration method were verified by comparing the computational results with the experimental ones. Their ontained results showed that, the flow rate of the fiber suspension is large under the same pressure drop in comparison with the rate of Newtinian fluid in the absence of fiber suspension. The relative turbulent intensity and the Reynolds stress in the fiber suspension are small than those in the Newtonian flow, which illustrates that the fiber have an effect in suppressing the turbulence. The velocity vectors for different Reynolds numbers can be seen in figure 2.7. The velocity vector are greatly influence by the Reynolds number.

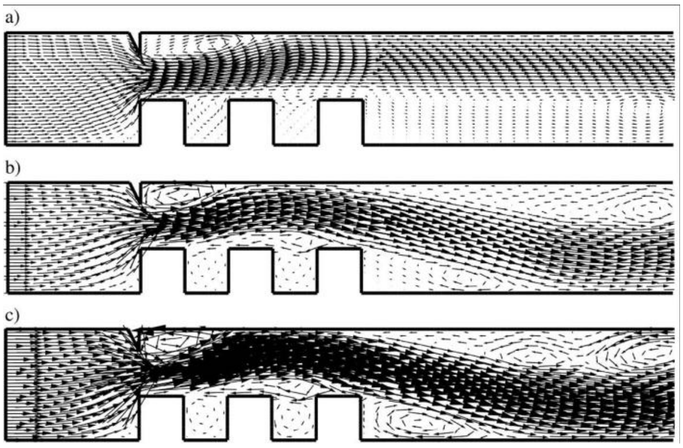

Figure 2.7: Velocity vectors for different Reynolds numbers (Re) at (a) 400, (b) 800 a and (c) 1300 (Hakan F. Oztop et al., 2009)

2.4 Power Losses

One of major problems faced in current industries is the losses of pumping power in pipelines carrying liquid, especially the pipeline that deal with crude oil and refinery products (Hayder, 2009), We discussed about the turbulent flow and the formation of eddies. The formation of eddies increased the energy mechanism of fluid. As a result, the energy needed for the fluid to flow through the pipeline had also increased. Power losses is the pumping power in the piping systems needed to move the fluid through the pipeline in certain distance increase. Thus, more power should be added to the piping system in order to let the fluid reach the desired destination.

Additional power station is very costly and it need source to generate the power. When there is a will there is a way, so there is a solution to reduce the power losses. Polymer drag reducer is then invented to reduce the formation of eddies, less turbulent flow in pipelines and reduce power losses.

In liquid trasportation through pipelines, the addition of small amounts of chemcal addition in pressure drop which is a clue to power saving made in the system. The eficienct of these additves was proven in many investigations carried out by many authors (Hayder, 2009)

2.5 Drag Reducers

The turbulent drag reduction by polymer additives was discovered by Toms in 1949. A minute amount of long-chain polymer molecules dissolved in water or organic solvents reduced the frictional drag of turbulent flow rapidly along the pipes. Toms discovered this fact when he was investigating the mechanical degradation of polymer molecules using a simple pipe apparatus. Another discovery of additional aluminium soap in gasoline lowered the resistance of the fluid to turbulent flow in pipeline in 1948. (Toonder, 1995).

Turbulent drag reduction (DR) is defined as the very striking phenomenon in which turbulent drag of flowing medium is drastically reduced by even minute amounts of suitable additives. It has been extensively investigated not only due to its wide range of applications but also due to its scientific interests. While a satisfactory explanation of DR still eludes fundamental and general interpretation on it due to a coupled mechanism of both turbulence and polymer dynamics. It is well known that the DR is governed by various parameters such as polymer concentration, polymer molecular weight, temperature, Reynolds number (Re) and solvent quality. In addition, various intrinsic structural characteristics are also playing crucial roles in controlling and evaluating the fundamental features of DR phenomena (Brasseur et al., 2005). The relationship between drag reduction and different liquid velocity can be seen in figure 2.8. The drag reduction increases as the liquid velocity increases.

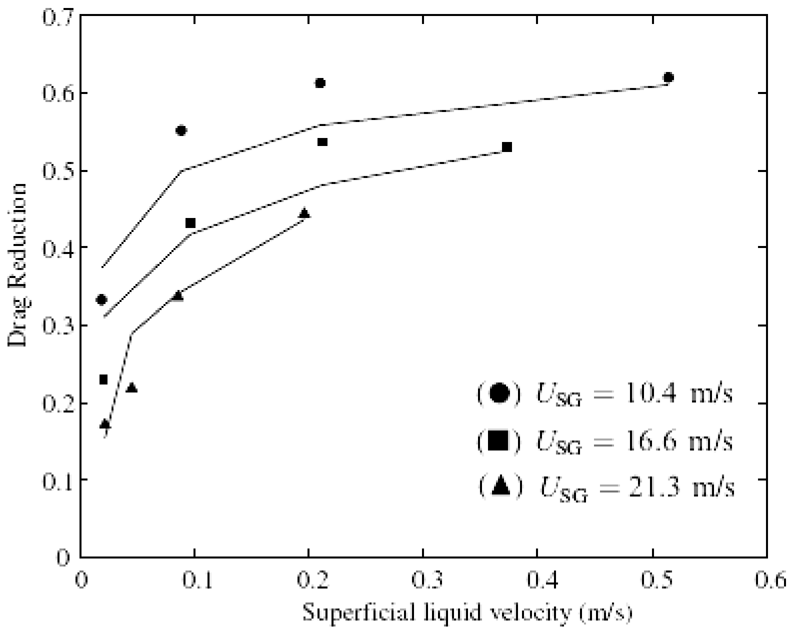

Figure 2.8: Relations between drag reduction and different liquid velocity (R.L.J. Fernandes et al., 2004)

The additional of particles showed excellent ability of improving the flow in pipelines and vanished one of the major assertions in the drag reduction technique. It was assumed before that the drag reducer must be solible or at leasr has the ability to penetrate its molecules reorient in the transportad luquid to be affected. This behavior suggest new and merely independent mechanism to explain the drag reduction phenomena (Fossa, 1995)

2.5.1 Polymer Drag Reducer Agent

The drag reducer agent is important in petroleum industry. The use of guar in oil well fracturing was the first application of the drag reducer agent. Meanwhile, large quantities of the drag reducer agent are needed on this application. The drag reducer agent was successfully reducing the friction drag in pipelines and thus it is highly used in pipeline transportation field. The drag reducer agent has been lowered