INVESTIGATING THE EFFECT OF NONIONIC SURFACTANT MOLECULAR WEIGHT ON ITS DRAG REDUCTION PERFORMANCE

by

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ABSTRACT

The major problems in transportation by pipeline are about pumping power losses due to the turbulent mode of transportation. This research is proposed to improve oil flow by using nonionic surfactant as drag reducing agent. Triton X series, one of nonionic surfactant group was selected for this study. By using three types of surfactant, Triton X-15, Triton X-45 and Triton X-114, the effect of molecular weight between Triton X was investigated. Other variable studied are concentration (300ppm, 800ppm, 1200ppm and 1800ppm) and Reynolds number. Rotation speed of RDA used is 50rpm- 3000rpm. During the experiment, the torque reading for additive- free oil and oil with additive was recorded and used to calculate percentage of drag reduction. The data was analyzed further by plotting drag reduction versus Reynolds numbers, drag reduction versus concentration and torque versus speed. The maximum drag reduction obtained is almost 29% which occurs for oil with Triton -15 at concentration 1500ppm. As conclusion, when the concentration increases, the drag reduction increase and decreasing the molecular weight will result the increasing of drag reduction. Lastly, for all the experimental cases, the percentage of drag reduction values decreases by increasing the Reynolds number.

ABSTRAK

Masalah utama dalam pengangkutan melalui talian paip adalah disebabkan kerugian kuasa yang berlaku apabila aliran bendalir dalam keadaan bergelora. Kajian ini dijalankan adalah untuk memperbaiki aliran minyak dengan menggunakan “nonionic surfactant” sebagai ejen pengurangan seretan. Triton X siri, salah satu kumpulan dari “nonionic surfactant” yang telah digunakan untuk kajian ini. Dengan menggunakan tiga jenis “surfactant”, Triton X-15, Triton X-45 dan Triton X-114,perbezaan jisim molekul antara Triton X telah dikaji. Pembolehubah lain yang dikaji ialah kepekatan (300ppm, 800ppm, 1200ppm dan 1800ppm) dan nombor Reynolds. Kelajuan putaran “RDA” yang digunakan adalah 50rpm-3000rpm. Semasa eksperimen dijalankan, bacaan untuk minyak tanpa aditif dan minyak dengan tambahan aditif telah direkodkan dan digunakan untuk mengira peratusan pengurangan seretan. Data telah dianalisis dengan lebih lanjut dengan memplot pengurangan seretan melawan nombor Reynolds, pengurangan seretan melawan kepekatan dan “torque” melawan kelajuan. Pengurangan daya seretan maksimum yang diperoleh adalah hampir 29% yang berlaku pada minyak dengan Triton -15 pada kepekatan 1500ppm. Sebagai kesimpulan, apabila kepekatan meningkat, daya seretan akan berkurang dan apabila jisim molekul berkurang akan menyebabkan pengurangan daya seretan. Akhir sekali, bagi semua kes eksperimen, peratusan nilai pengurangan seretan berkurangan apabila nombor Reynolds meningkat.

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LIST OF SYMBOLS

%	Percentage
℃	Degree Celsius
ppm	Parts per million
rpm	Revolution per minute
Re	Reynolds number
Kg	Kilogram
m	Meter
s	Second
ρ	Density
d	Diameter
ω	Angular velocity
μ	Viscosity of cooking oil
τ	Torque
DR%	Drag reduction percentage

LIST OF ABBREVIATIONS

RDA	Rotating Disk Apparatus
A/D	Analogue/Digital Transmitter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUNG STUDY

Increasing of world energy demand for conventional oil becomes a very big issue in pipeline transportation system. High viscosity of oil or every high viscosity fluid gives major difficulties in transportation through pipeline where the mobility of transportation is low and not economically feasibility (Y.Al-Roomi et al., 2004). There are several factors that can influence the fluid flow in pipeline and in this case drag is the major issue which can resists the fluid flow. The friction between the fluid and the inner surface of the pipeline can form a turbulent flow. This turbulent flow can cause mechanical forces within the pipeline and which in turn lead to the formation of eddies.

The formation of eddies will heavily affected the fluid flow because it will affect the pressure drop within the pipeline. This drop in pressure actually reduces the fluid flow rate; eventually cause the production rate to become slower. In economical perspective, the reduction in the production rate is very bad for the company because the output of the fluid flow is lesser than the input fluid flow. In other words, the production is not at its best because the fluid flow rate in the pipeline is not efficient. This inefficiency is mainly caused by the factors stated above in which case these factors cause the drag reduction of the fluid flow in pipelines.

Pioneer method introduce by Toms (1949) known as Tom's Phenomenon, addition of a small amount of additives can greatly reduce the turbulent frictional pressure drop of a fluid is known as drag reducing agent (DRA). A few techniques were applied by using DRA; one of them is injection or DRA into pipe or mix up the DRA with the fluid in storage tank before transporting the fluid. DRA can be classified into three major categories: polymers, surfactants and suspended solids. Surfactants are known as surface active agents who capable in reducing surface tension of a liquid have be classified as anionic, cationic, nonionic or zwitterionic (Zhang, 2005). Basically, all the surfactant is differ on their charge. Cationic surfactant has positively charged head whereas non-ionic surfactant does not carry any net charges while zwitterionic surfactant has two oppositely charged groups. There are several types of non-ionic surfactant used in industry such as trioexethylene monododecyl ether and poly (oxyethylene) cholestryl ether (Varade et al., 2007) and Triton-X (Cheng et al., 2007). The presence in fluids of very small amounts of high molecular weight polymers produces high levels of drag reduction in the fluid flow (R.C.R.Figueredo & E.Sabadini, 2003) Other study state that, Increase of alkyl chain length and decrease of the number of ethoxylate both decrease the cloud point close to measurement temperature and enhance drag reducing ability. It was found that non-ionic surfactants with straight chain alkyl groups are effective while alkyl phenyl surfactants were not (Y.Jiang, 2002).

This research is executed by designing an experimental work using the chemical additive, non-ionic surfactant. The different molecular weight of surfactant from the same group and varies concentration of samples was the variable in this research. The RDA is used to analyze the samples and testing. In conclusion, the novelty of this study requires theoretical research and experimental work to strengthen the research outcomes.

1.2 PROBLEM STATEMENT

The major problems in transportation by pipeline are about pumping power losses due to the turbulent mode of transportation. The industry is more concerned about the cost for transportation through pipelines. The transportation cost is considerably higher at this level when pump and treat method is applied to increase drag reduction (Lee, Kang, & Do, 2004). The formation of eddies and frictional forces of the fluid result the pressure drop phenomena.

The frictional force usually happened when there are resistance occurs during the fluid flow. Frictional force and formation of eddies phenomena can cause of low efficiency and performance of fluid flow through the pipelines. In order to upgrade the performance of flow in pipeline system, both causes need to be focus more.

In the present work, the potential of non-ionic surfactant act as drag reducing agent is going to be study in order to cater this problem. Nonionic surfactant behaviors are investigated to improve drag reduction of oil in pipeline system. The different of molecular weight present in nonionic surfactant from the same group will be analyzed the percentage of drag reduction. Varies concentration of samples also will be study in order to distinguish the nonionic surfactant characteristic as reducing agents. To makes this work more relevant, the rotation speed of the system was considerable.

1.3 RESEARCH OBJECTIVES

i. To investigate the potential of nonionic surface active agents to improve the oil flow in pipelines.
ii. To test the effect of the design parameters (different molecular weight with same group of surfactant and samples concentration).
iii. To study the effect of the liquid circulation parameters (speeds, rpm).

1.4 RESEARCH QUESTIONS

i. How to work up the oil flow in pipeline system?
ii. What are the results obtained by manipulating the design parameters?
iii. What are the effects of the liquid circulation parameter on the oil flow in the pipelines?

1.5 SCOPE OF STUDY

The scope of this research is focused on improving the oil flow by using chemical additive technique. The improvement performance can be express by calculating the performance of drag reduction. The drag reduction needs to be look up in order to fulfill the demand in pipeline industries. In this study, Triton X series from nonionic surfactant group is used as reducing agent. Three types of Triton X are introduced after screening up the requirement needed for this study. Triton X-15, Triton X-45 and Triton X-114 are soluble in oil and have different molecular weights which are 294 g/mol, 426 g/mol and 558 g/mol respectively. The research is involved in turbulent flow fluid by dissolved Triton X to create varies concentration. Other parameters involved such as speeds act as constant variables in this research. The major selection on the scope of research is same group with molecular weight different and ability for soluble in oil was stress more. The result given from this research meet the main objective which is to improve flow inside pipelines thus improves economically feasible.

1.6 SIGNIFICANCE OF STUDY

These studies allow the new idea and innovation for improving the performance of fluid in the pipeline system. Even though there are many studies on improving pipe flow by using chemical additive but there is no research have been done focusing in different molecular weight for Triton X series. This research has high values in the industry focusing in oil industry of pipelines transport system. Further investigation is proposed to continue and explore the novelty of this research.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The transportation of liquid through pipeline is widely used by most of industries. While transporting liquid via pipeline can cause the frictional pressure drop along pipelines will result to increasing the power consumptions. An effective pipeline system is needed due to minimize power consumption and improve the efficiency in turbulent flow. Drag reduction technique is one of effective way to minimize the problems. Three reducing agents were introduce; polymer, surfactant and suspended solid. The novelty of each agent makes it different from others.

2.2 TYPES OF FLOW

Fluid flows via pipeline basically have three types and patterns depend on speeds of flow. Each flow has its own characteristic thus possesses different drag effect. Flow can be laminar, transition or turbulent depend on unique characteristic that can be determine by Reynolds number calculation. Reynolds number is a dimensionless number that gives a measure of ratio of inertial forces to viscous forces and thus quantifies the relative significance of these three types of forces for given pipe flow conditions (Wigging and Goldstein, 1998). Reynolds number is a way to predict under ide conditions when turbulence will occur (E.Richard, 2007). In this research, the rotational Reynolds number (N_{Re}) is used to describe the flow characteristic in RDA (J.I. Sohn et al., 2000).

$$N_{Re} = \frac{\rho R^2 \omega}{\mu} \qquad (2.1)$$

Where

ρ = fluid density

μ = fluid viscosity

R = radius of the disk

ω = angular velocity

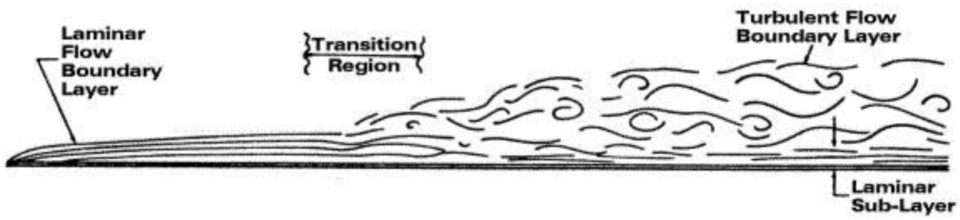

Figure 2.1: Illustration of three types of flow

2.2.1 Laminar flow

Laminar or streamline flow occurs when the fluid flows in smooth line or parallel layer in Figure 2.2. There is no disruption between the layers, and the flow's velocity is constant. The laminar flow is to be stable up to Reynolds number less than 2300 in absence of any particular effort to minimize the disturbance (Yunus and Cimbala, 2006)

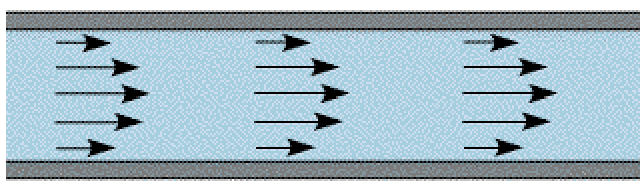

Figure 2.2: Illustration of smooth streamline in laminar flow

2.2.2 Transition flow

Transition flow is the process of laminar boundary layer becoming turbulent. The ranges from 2000-4000 considered as transition flow. The amplitude of the disturbance creates non-linearity effects. However, transition flow rarely happened because it's only a small region.

2.2.3 Turbulent flow

Turbulence is an instability phenomenon caused in most cases types in the industrial applications. In turbulent flow, the inertia stresses dominate over the viscous stress, leading to small-scale chaotic behavior in the fluid motion. This chaotic motion is often described as being made up of ‘eddies'. Eddy is the swirling of a fluid and the reverse current created when the fluid flows past an obstacle (Patel et al., 1985). Turbulent flow occurs when the velocity made is enough to develop a random and chaotic component of motion (Davidson, 2004). Figure 2.3 illustrate the random and chaotic component occur in turbulent flow.

Turbulence is usually occurred by increase in friction and pressure drop as a result of generated eddies in the transverse and horizontal direction as the fluid flows along its boundaries. According to Davidson (2004), turbulent spots occur where boundary layer particles rotate. Other theory say a careful inspection of flow in pipe reveals that the fluid flow is streamlined at low velocity but turns chaotic as the velocity increase above a critical value (Yunus and Cimbala, 2006).The flow is completely turbulent at Re above 4000 and is dominated by inertial forces. The presence of such flow can modify the behavior of important parameter such as Reynolds stress, turbulent kinetic energy and dissipation rate.

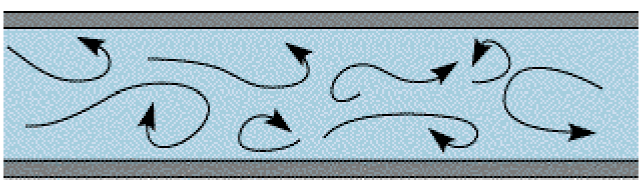

Figure 2.3: Illustration of the random and chaotic component in turbulent flow.

2.3 DRAG FORMATION IN PIPE

Yunus and Cimbala (2006) defined drag as the force component exerted on the body form a moving fluid in the direction of free stream of fluid far from the body in liquids transportation through pipelines. Drag also can be known as physical forces that resist the movement of fluid. Formation of drag in pipeline can low the flowrate and directly increase the pressure drop in the pipeline.

2.4 EDDIES FORMATION

The region where fluctuating random movement of fluids known as eddies. Eddies generally occur in turbulent flows in pipeline. As the Reynolds number increases, smaller scales of the flow are visible in thus to large bulky eddies appears. These fluctuations provide additional mechanism for momentum and energy transfer (Yunus and Cimbala, 2006).When turbulent flow occurs, eddies are generated due to the velocity differences between the fluid moving layers. Eddies tend to collide between each other causes sudden exchange of momentum (Warhaft, 1997). Eddies form a wide range of size in pipeline. The various sizes of eddy also have different characteristic speeds and lifetimes (Holland and Bragg, 1995).These formations slow down the fluid particles and this phenomenon is known as frictional drag.

2.5 PRESSURE DROP

Skin friction is the main cause for energy loss in pipelines. The friction depends on the properties of pipe and flow type. The frictional forces are caused by a resistance to flow. As fluid flows along the pipe, part of its energy dissipated in overcoming this resistance, with the result that the energy of fluid decreases continuously in the flow direction (Rashidi and Baner Jee, 1990). The friction factor occurs in fully turbulent flow. In turbulent flow, high viscosity fluid is involved therefore the pressure drop is highest. The friction is a result of the resistance encountered by flowing fluid into contact with a solid surface, in this case is pipe wall. The resistances cause the pressure drop in pipeline. Tube convergence, divergence, surface roughness and other physical properties will also affect the pressure drop (Gudmundsson, 1996).

2.6 DRAG REDUCTION

Drag reduction occurs by an interaction of the chemical additive of DRA with the turbulence of the flowing fluid. Drag reduction can reduce the flow resistance especially in pipelines, in order to improve the fluid flow efficiency. Pioneer method introduce by Toms (1949) known as Tom's Phenomenon, addition of a small amount of additives can greatly reduce the turbulent frictional pressure drop of a fluid is known as drag reducing agent (DRA). While RDA is used in this study, torque reading is considered for calculating percentage drag reduction. . The percentage drag reduction (%DR) to quantify the drag reduction efficiency was calculated via the torque on the disk in the solvent and that in the polymer solution by (Kim, Kim, Lee, Choi & Jhon, 2000).

$$\%DR = \frac{\tau_S - \tau_P}{\tau_S} \times 100 \qquad (2.2)$$

Where,

τ_S = initial torque

τ_P= final torque

2.6.1 Drag Reducing Agents (DRAs)

Additional of small amount of chemical additive in liquid can cause slightly increase flow rate in the transportation of fluid via pipeline. A drag reducing agent, also called a flow improver, is a long chain polymer chemical that is used in crude oil, refined products or non-potable water pipelines (Havard, 2006). The additives are known as drag reducing agent (DRA). DRA can be classified into three major categories which are polymers, suspended solids and surfactants. The earlier DRA was in the form of gel, and nowadays can be found in the form of slurries and powders (Daas, 2001). The effect of DRA as drag reduction generally depends on their properties and novelty. Each of DRA has pros and cons characteristic.