TRITON-X AMPHOTERIC SURFACTANT AS DRAG REDUCING AGENT IN AQUEOUS MEDIA FLOWING IN PIPELINES WITH DIFFERENT PIPE DIAMETERS

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I declare that this thesis entitled *"Triton-X Amphoteric Surfactant as Drag Reducing Agent in Aqueous Media Flowing in Pipelines with Different Pipe Diameters"* is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : ZAINUR AZIZI BT ZAKARIA

Date : ....

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

Supportive parents;
Zakaria Bin Umat and Asmah Binti Mat

Supportive siblings;
Zainuddin B Zakaria, Zarini Bt Zakaria, Zainur Anida Bt Zakaria, Mohd Zaidi B Zakaria, Zainur Umira Bt Zakaria and Zainur Syafika Bt Zakaria

This is for all of you.

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ABSTRACT

In this study the effect of the presence of a drag reducing agent (DRA) on the pressure drop in co-current horizontal pipes carrying flow of water is investigated. An experimental set-up is erected. The tested fluid was water and aqueous solution of Triton X-100 surfactant with 50 ppm (ppm-part per million), 100 ppm, 200 ppm and 300 ppm weight concentration of Triton X-100. The test section of the experimental set-up is consisted of three different pipe diameter and testing section length. The experimental was doing with 0.5 inch, 1.0 inch, 1.5 inch ID and 0.5 m long, 1.0 m long and 1.5 m long. Water also was pumped with five different fluid flow rates which is for each pipe diameter have a differ values of volumetric flow rate setting. The percent drag reduction (%DR) is calculated using the obtained experimental data, in presence of the DRA. The results show that addition of DRA could be effective up to some doses of DRA. Not only that, with smaller pipe diameter, performances of drag reduction occur is much better than larger pipe diameter. A maximum %DR of about 73 is obtained for 300 ppm concentration of Triton X-100. This is shows that, the energy consumption for pumping system will be decrease about 73%. When the energy consumption is decrease, the costing for installation pumping system also will be decreased.

ABSTRAK

Dalam kajian ini, objektif utama yang ingin ditekankan ialah keberkesanan kehadiran ‘Drag Reducing Agent (DRA)’, terhadap perbezaan tekanan yang berlaku dalam sistem paip melintang. Cecair ujikaji yang digunakan dalam kajian ini ialah air paip dan larutan Triton X-100. Larutan Triton X-100 yang digunakan mempunyai empat nilai kepekatan yang berbeza iaitu 50 ppm (ppm-part per million), 100 ppm, 200 ppm dan 300 ppm. Kajian ini telah dijalankan ke atas tiga diameter paip dan tiga panjang paip yang berbeza-beza ukurannya. Ukuran bagi diameter paip ialah 0.5 inci, 1.0 inci, dan 1.5 inci, manakala untuk ukuran panjang paip ialah, 0.5 meter, 1.0 meter dan 1.5 meter. Air paip juga telah dipam dengan lima nilai halaju yang berbeza-beza bergantung kepada diameter paip yang digunakan. Peratus ‘Drag Reduction (%DR)’, dapat dikira dengan menggunakan data-data perbezaan tekanan yang telah diambil semasa eksperimen dijalankan. Melalui keputusan yang telah diperoleh dari eksperimen, apabila air ditambah dengan sedikit DRA, %DR akan meningkat. Peratus peningkatan ini akan berterusan apabila kepekatan Triton X-100 yang ditambah semakin meningkat. Bukan itu sahaja, apabila ujikaji dijalankan terhadap saiz paip diameter yang lebih kecil, persembahan DR yang terhasil adalah lebih baik berbanding dengan saiz paip diameter yang lebih besar. Nilai maksimum %DR yang dapat dicapai melalui experiment ini adalah mencecah kepada 73% iaitu pada kepekatan 300 ppm Triton X-100. Ini bermakna, sebanyak 73% tenaga pam dapat dijimatkan. Apabila tenaga pam yang digunakan berkurang, kos yang ditanggung juga akan menurun.

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DR	-	Drag reduction
DRA	-	Drag reducing agent
D	-	Diameter
%	-	Percentage
Re	-	Reynolds number
ppm	-	Parts per million
ΔP_a	-	Frictional pressure difference after adding additives
ΔP_b	-	Frictional pressure difference before adding the additives
μ	-	Viscosity
ρ	-	Density
Q	-	Flowrate
V	-	Velocity

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Drag reduction as a phenomenon occurs where adding certain amount of drag reducing agent, such as polymer, surfactant or fibe. From addition of that agent, it causes a dramatic frictional drag reduction (Feng-Chen Li et al., 2008). The drag reduction effects are very important in the industrial application. The application of drag reducers has been in the Trans-Alaska Pipeline, which is a major U.S oil pipeline. They desired discharge of an additional million barrels of crude oil per day was accomplished by the addition of polymers rather than by constructing additional pumping stations (Bo Yu et al., 2004).

Generally, all of the additives can be categorized into three groups; they are polymers, surfactants and fibers. Drag reducers have been applied can give a lot of benefits such as in pipeline systems. It can save pumping power, reducing energy consumption, increasing the flow rate, decreasing the size of pumps and many more in turbulent pipe flow systems.

The drag reduction agents solution flows behave viscoelastic characteristics. The most notable elastic property of the viscoelastic polymer or surfactant solutions is that stress does not immediately become zero when the fluid motion stops, but rather decays with some characteristic time that is the relaxation time, which can achieve seconds and even minutes (Feng-Chen Li et al., 2008). The existence of fluid viscoelasticity is known to give rise to unusual secondary flows and to produce anomalous drag reduction in turbulent pipe flow (Lixin Cheng et al., 2007). In this work, the additives are carrying out experimental test to study the mechanism of additive induced drag reduction.

1.2 Problem Statement

During the past few decades, power saving and reduce of power consumption in the pipeline systems are one of the major issues. When designing piping systems, turbulent flow requires a higher input of energy from a pump than laminar flow. This phenomenon cause the company spends much money to construct additional pumping stations. Adding the pumping stations to the pipelines system in order to increase the flow rate of the fluid. This study focuses particularly how to reduce turbulent friction drag in order to save energy consumption, increasing flow rate and decreasing the size of pumps with using Triton X-100 amphoteric surfactant additives.

1.3 Objectives of Study

The objectives of this research are to study the effect of the different values of Triton X-100 concentrations, liquid flow rate, pipe diameter and length of pipes in order to get the pressure difference of the fluid.

1.4 Scopes of Study

In sequence to accomplish the objective, the following scopes have been identified:

i. The effect of the Triton X-100 concentrations

ii. The effect of the liquid flow rates
iii. The effect of the pipe diameters
iv. The effect of the pipe lengths

1.5 Rationale and Significance

This research are to study the effect of the different values of Triton X-100 concentrations, liquid flow rate, pipe diameter and length of pipes in order to get the pressure difference of the fluid. From the pressure difference which gets from doing the experiment, the percent of drag reduction (%DR) in the fluid can be determined. The value %DR which determine can be conclude that how effective the surfactant additives to reduce the turbulent friction factor of the fluid.

If this research is successful, it will give great impact to the industrial application especially in pipeline systems. It is because, when the turbulent friction factor of the fluid decreases, the energy consumption will be saved and the flowrate of the fluid also increase. Others rationale, we also can save our cost because of this drag reduction phenomenon. Why we can say like that because, we do not need to spend much money to construct additional pumping stations in order to increase the flowrate of fluid.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Laminar, Transition and Turbulent flow

Laminar flows also known as streamline flow that occurs when a fluid flows in parallel layers, with no disruption between the layers. The laminar flow in context of nonscientific terms is smooth compared to the turbulent flow is rough. In fluid dynamics, laminar flow is a flow regime characterized by high momentum diffusion, low momentum convection, pressure and velocity independent from time but different compared to the turbulent flow. Turbulent flow or turbulence is a fluid regime characterized by chaotic, stochastic property changes. It has low momentum diffusion, high momentum convection, and rapid variation of pressure and velocity in space and time. The dimensionless Reynolds number is an important parameter in the equations that describe whether flow conditions lead to laminar or turbulent flow. For instance in pipe flow, when a Reynolds number above about 4000 knows as turbulent flow and Reynolds numbers of less than 2000 are generally considered to be of a laminar type. For transition flow, a Reynolds number between 2100 and 4000 and it also have a medium of velocity

When the speed increases, at some point the transition is made to turbulent flow. In turbulent flow, unsteady vortices appear on many scales and interact with each other. Drag due to boundary layer skin friction increases. The structure and location of boundary layer separation often changes, sometimes resulting in a reduction of overall drag. Because laminar-turbulent transition is governed by Reynolds number, the same transition occurs if the size of the object is gradually increased, or the viscosity of the fluid is decreased, or if the density of the fluid is increased. Turbulence causes the formation of eddies of many different length scales. Most of the kinetic energy of the turbulent motion is contained in the large scale structures. The energy "cascades" from these large scale structures to smaller scale structures by an inertial and essentially inviscid mechanism. This process continues, creating smaller and smaller structures which produces a hierarchy of eddies. Eventually this process creates structures that are small enough that molecular diffusion becomes important and viscous dissipation of energy finally takes place. The scale at which this happens is the Kolmogorov length scale.

For a practical demonstration of laminar and turbulent flow, one can observe the smoke rising off a cigarette in a place where there is no breeze. The smoke from the cigarette will rise vertically and smoothly for some distance (laminar flow) and then will start undulating into a turbulent, non-laminar flow. The figure shows about laminar, transition and turbulent flows shown in Figure 2.1.

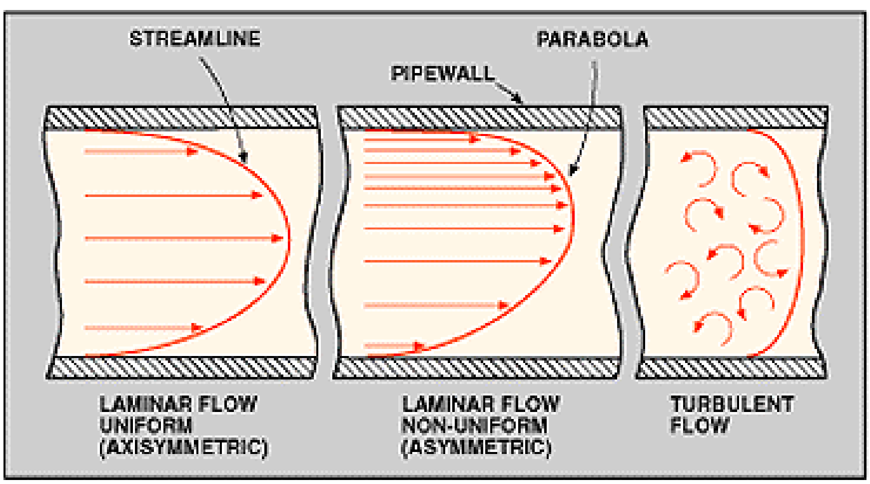

Figure 2.1: Laminar Flow, Transition Flow and Turbulent Flow

2.2 Drag Reduction

Drag reduction can defined is a flow phenomenon by which small amount of an additives, for instance a few parts per million (ppm), can greatly reduce the turbulent friction of a fluid. Aim of the drag reduction is to develop the fluid mechanical efficiency using active agents that known as drag reducing agent (DRA). In multiphase flow, percent drag reduction (%DR) 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. (1) (D.Mowla et al., 2006).

$$\% \, DR = (\Delta P_b - \Delta P_a) / \Delta P_b \times 100 \qquad \textbf{(1)}$$

In this equation ΔP_b is the frictional pressure difference before adding the additives, N/m^2 and ΔP_a is the frictional pressure difference after adding additives, N/m^2.

The drag reduction effect have multiple mechanisms such as isolated polymer molecules extend in elongation flow fields present in turbulence, thereby increasing the thickness of the elastic sublayer. The other mechanisms are polymer aggregates may exist to form large hydrodynamic domains which could suppress small scale turbulence by resisting rapid changes in alignment. Not only that, in heterogeneous drag reduction, for example injection of a concentrated polymer solution in the center of a pipe, a long thread of the polymer solution interact with the larger turbulent disturbances or eddies in the center of the pipe.

2.3 Drag Reduction Mechanism

In a review of the literature of Yasuo Kawaguchi et al. (2004) the mechanism of additive induced drag reduction has not been clearly described. For polymer solutions, two theoretical explanations are given. One was proposed by Lumley (1969, 1973), who postulated that the increased extensional viscosity due to the stretching of randomly coiled polymers tends to dampen the small eddies in the buffer layer and thickens the buffer layer, to give rise to the drag reduction. Lumley emphasized that drag-reduction occurs only when the relaxation time of the solution is larger than the characteristic time scale of the turbulent flow. The other important theory was proposed by De Gennes (1990), who criticized the earlier scenario that used extensional viscosity, and argued that the elastic energy stored in the macromolecules causes drag-reduction. For surfactant solutions, generally, the super-order network structures made up of rod-like micelles show elasticity, and cause drag-reduction. Nevertheless, these explanations are qualitative.

Recently, direct numerical simulation (DNS) has been used to quantitatively analyze the turbulence transport mechanism. With DNS, the instantaneous flow structures near the wall can be calculated accurately, which are difficult to measure precisely in experiments. The instantaneous extra stress associated with the deformation of macromolecules/network structures can be calculated which has not yet been directly measured in experimental conditions. The quantitative data obtained by DNS are helpful in analyzing the mechanism of drag-reduction. Moreover, in contrast to experiments, the effects of various physical properties can be easily isolated and studied by numerical simulations. Main conclusions drawn from previous DNSs on the drag-reducing flow caused by additives are summarized below. Orlandi (1995) and DenToonder et al. (1997) carried out DNS using extensional viscosity models for a channel, and a pipe flow, respectively. Their results qualitatively agree with most experimental observations.

On the other hand, the inelastic characteristic of such extensional models cannot examine the onset phenomenon, an important feature of drag-reducing flow caused by additives. Sureshkumar et al. (1997) and Dimitropoulos et al. (1998) performed direct numerical simulations for a fully developed turbulence channel flow by using viscoelastic models (the FENE-P and the Giesekus models), and verified Lumley’s hypothesis that drag reduction is primarily an effect of the extension of the polymer chains where the increase in the extensional viscosity leads to the inhibition of turbulence-generating events. They also proposed a criterion for the onset of the drag-reduction. Angelis et al. (2002) further confirmed the ability of the FENE-P model to reproduce most of the essential effects of polymers in dilute solutions on the wall turbulence. Min et al. (2001) studied the role of elastic energy in turbulence drag-reduction caused by polymer additives using an elastic Oldroyd-B model. Yu and Kawaguchi (2003) studied the effect of the Weissenberg number on the turbulence flow structure using a Giesekus model.

2.4 Drag Reducing Agent

The effect of drag reduction in turbulent flows by additives was apparently discovered by Toms in 1948, and has been known since then as the Toms phenomenon. It is the effect of reduced drag in turbulent flow of a low concentration fibrous additive suspension, in comparison to the drag in turbulent flow of the pure solvent (I. Sher and G. Hetsroni, 2008). The additives which cause drag reduction, can be classified into three groups, they are polymers, surfactants and fibers.

2.4.1 Polymers

It has been known since the late 1940s (Toms, 1948) that the addition of small concentrations of high molecular weight polymer to water or other solvent can produce large reductions in frictional pressure drop for turbulent flows past a surface, leading to the possibility of increased pipeline capacities and faster ships. Two-phase gas–liquid flow is frequently encountered in many industrial units such as distillation columns, pipelines, boiler tubes, condensers, evaporators, and chemical reactors.

An experimental was done before to prove that polymers act as drag reducing agents. A. Al-Sarkhi and T.J.Hanratty (2001) was used of a partially hydrolyzed solution of polyacrylamide (HPAM) into a horizontal flow of air and water causes a change from an annular flow to a stratified flow by destroying the disturbance waves on the liquid film. Drag reductions of 48% were realized for a 9.53 cm pipe and 63%, for a 2.54 cm pipe. The polymer destroys the turbulent disturbance waves, which are the cause of drop formation and which help the water film to spread upward around the pipe circumference. At maximum drag reduction almost all of liquid flows along the bottom wall. The interface is relatively smooth and the friction factor is roughly equal to that which would characterize gas flowing alone in the pipe.

Used of polymer as an additive also have their advantages and disadvantages. The mixing of the polymer in the liquid prior to contacting the water solution with the air reduces the effectiveness, in that larger amounts of polymer are needed and the maximum drag reduction could be reduced. These disadvantages are emphasized if dilute mater solution are used. This result is influenced by work of (Warholic et al., 1999). The degradation could occur in two ways, which is one involves the breakup of aggregates of polymers and the other one which requires more severe hydrodynamic forces. The hydrodynamic force is the mechanical breakup of high molecular weight molecules in the solutions. However the advantages of injecting the polymer solution into wall film of an annular flow could also result from a type of preconditioning has been identified by (Vissman and Bewerdorff, 1989). The injection of polymers through a narrow passage in the wall could cause them elongate.

2.4.2 Fibers

Fibers are long cylinder like objects with high length to width ratio. They oriented themselves in the main direction of the flow to reduce the drag (D.Mowla et al., 2006). (J.Z. Lin et al., 2006) says that fiber suspension occurs in a wide variety of natural and man-made materials. The investigation of microstructure of fiber suspension has received much attention because the mechanical, thermal and electrical properties of the corresponding fiber composite are highly sensitive to the orientation distribution and spatial configuration of fibers. Such suspension has complicated rheological properties that are different from those of the suspending fluid, even at very low concentrations. In the experiment that (J.Z Lin et al., 2006)