STUDYING THE EFFECT OF CARBON POWDER ADDITION ON THE PERFORMANCE OF NATURAL MUCILAGE DRA FLOWING IN AQUEOUS MEDIA

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ABSTRACT

In the present studies, effect of carbon powder addition on the performance of natural mucilage DRA flowing in aqueous was identified and the performance of natural mucilage DRA flowing in aqueous media was optimized. Carbon powders were presented as a new effective Drag Reducing Agent to improve the performance of natural mucilage flowing in aqueous media. The effects of using various concentrations of fiber and flow rate on increasing the flow in pipelines were investigated in a fully developed turbulent flow and in various concentration of the natural polymer used. Natural polymer that used in the experiment is in the form of mucilage that extracted from okra, cocoa husk and halba respectively. A built experimental rig of PVC pipes was used in order to investigate the performance of carbon powder fiber as drag reducing agent. The experimental results showed that the carbon powder have a great ability to be a good reducing agent in aqueous media. The addition of carbon powder in the natural polymer in pipelines increase the drag reduction consistently and up to 65% from 35% when using natural polymer only. This reduction certainly improves the performance of DRA in the pipelines effectively and does have ability to be commercialized and marketed.

ABSTRAK

Dalam kajian yang dijalankan, kesan penambahan serbuk karbon ke atas tindakbalas polimer asli di dalam aliran paip di kenalpasti dan dioptimasikan. Serbuk karbon digunakan sebagai agen pengurangan seretan untuk meningkatkan prestasi polimer asli yang digunakan. Kesan penggunaan berbagai-bagai kepekatan serbuk karbon dikenalpasti di dalam aliran gelora di dalam paip yang sediakala mengunakan polimer asli. Polimer asli yang digunakan adalah di dalam keadaan musilage yang diperoleh daripada kulit koko, bendi dan halba. Rig dalam skala eksperiment yang digunakan dalam menyiasat kesan penggunaan serbuk karbon sebagai agen pengurangan seretan. Keputusan ekspeiment menunjukkan serbuk karbon dapat berfungsi sebagai agen pengurangan seretan yang baik dalam aliran paip. Penambahan serbuk karbon member bacaan pengurangan seretan setinggi 65% berbanding bacaan 35% daripada penggunaan polimer asli sahaja. Pengurangan ini membuktikan serbuk karbon meningkatkan prestasi polimer asli di dalam aliran paip secara effektif dan mempunyai prospek untuk dikomersialkan di pasaran.

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ABBREVIATIONS

DRA	-	Drag Reducing Agent
DR	-	Drag Rdeuction, dimensionless
DI	-	Internal pipe diameter, meter
%DR	-	Percentage Drag Reduction
m.	-	Mass, kg
ppm	-	Parts per million
ΔP	-	Pressure difference
^{tm}	-	Trade mark
Re	-	Reynolds number
Q	-	Volumetric flow rate, m^3/hr
ρ	-	Density, kg/m^3
μ	-	Viscosity, kg/m.s

CHAPTER 1

1.1 Background of Studies

Transport is performed by various modes, such as air, rail, road, water, cable, pipeline and space. Pipeline transport is the transportation of goods through a pipe. Most commonly, liquid and gases are sent, but pneumatic tubes that transport solid capsules using compressed air have also been used. As for gases and liquids, any chemically stable substance can be sent through a pipeline [1]. Therefore sewage, slurry, water, or even beer pipelines exist; but arguably the most valuable are those transporting oil and natural gas.

Drag by definition means ‘a heavy, pulling action’. Drag also identifiable as the mechanical force that exist in the pipelines that more suitable to be define, as friction at the near wall region that decreases velocity. In the other hand, in fluids flow, drag reduction means lessen the effects of friction of turbulent flows that occur in pipeline. The drag reduction is achieved using drag reduction agent. Here carbon powder will be studied as new material to improve the drag reduction in the pipelines [2].

1.2 Problem statement

It is a common experience that a body meets some resistance when it is forced to move through a fluid especially a liquid. As we may have noticed, it is very difficult to walk in water because of the much greater resistance it offers to motion compared to air. A fluid may exert forces and moments on a body in and about various directions. The force a flowing fluid exerts on a body in the flow direction is called drag. The drag force can be measured directly by simply attaching the body subjected to a calibrated spring and a measuring the displacement in the flow direction. Drag is usually an undesirable effect that always happens. Due to this drag, shear stresses develop between the liquid and the pipe wall. This shear stress is a result of friction, and its magnitude is dependent upon the properties of the fluid, the speed at which it is moving, the internal roughness of the pipe, the length and diameter of pipe. Friction loss, also known as major loss, is a primary cause of energy loss in a pipeline system.

1.3 Objectives

The objectives of the research are:

1 To identify the effect of carbon powder addition on the performance of natural mucilage DRA flowing in aqueous.
2. To optimize the performance of natural mucilage DRA flowing in aqueous media.
3. To reduce the drag in the pipelines effectively.

1.4 Scope of project

The scopes for this project are:

1. Identifying the drag problems that occur in the aqueous pipelines system.
2. Usage of the natural mucilage DRA flowing in aqueous media which is okra (*Abelmoschus esculentus), halba (*Fenugreek) and cocoa husk.
3. Add carbon powder on this natural mucilage to improve the performance in reducing drag in the flowing.
4. Replace the usage of the natural mucilage with the combination of the carbon powder and the natural mucilage in order to maximize the performance.

1.5 Rationale and Significance

Oil and Gas from field production plants are transported to petroleum refineries; petrochemical and chemical plants; power plants and terminals by cross country pipelines. Pipelines have been the backbone energy transport infrastructure in many regions of the world for many decades now and this situation will most likely to continue in the future. Hence the drag problem that we encounter during the transportation process here making it as the major setback in this field. As we alert of, this problem required more pumping energy to overcome it. As a result, more energy is allocates for this making money and man power are wasted for this particular problem. So the natural mucilage that functioning as drag reduction agent (DRA) will reduce the friction and drag as well. The addition of carbon powder into this natural mucilage hence will maximize the performance of this natural mucilage as DRA. So this will lead developer to save cost and man power working on this problem.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In order to achieve constant flow rates and installments, DRA been used as an alternative to minimize pressure drop in pipelines. DRA is an additive that disperses in pipelines to help reducing friction pressure losses. In economical perspective cost of the production can be minimize by reducing energy consumption in pumping system and installments of pipelines. In this chapter, we discussed the literature review on turbulent flow as it is the cost of the drag occurs in pipelines. Besides, it also discussed about DRA that has been used in the experiment which are polymers and carbon fibers.

2.2 Fluid flows

There are few types of flow in the pipelines which is laminar, transitional and turbulent flow. Laminar flow generally happens when dealing with small pipes and low flow velocities. Laminar flow can be regarded as a series of liquid cylinders in the pipe, where the innermost parts flows the fastest, and the cylinder touching the pipe isn't moving at all. Shear stress depends almost only on the viscosity – μ, and is independent of density – ρ [3].

Transitional flow is a mixture of laminar and turbulent flow, with turbulence in the center of the pipe, and laminar flow near the edges. Each of these flows behaves in different manners in terms of their frictional energy loss while flowing, and have different equations that predict their behavior.

In turbulent flow vortices, eddies and wakes make the flow unpredictable. Turbulent flow happens in general at high flow rates and with larger pipes. Shear stress for turbulent flow is a function of the density – ρ [3]. The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e. shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force. The flow is laminar when $Re < 2300$, transient when $2300 < Re < 4000$ and turbulent when $4000<Re$. The force a flowing fluid exerts on a body in the flow direction is called drag which is usually an undesirable effect, like friction [4], [5].

2.3 Drag Reducing Agent

In 1948 Toms discovered by experiments that the addition of a small amount of polymer into a turbulent Newtonian solvent (parts per million by weight), which results in a Non-Newtonian fluid solution, can reduce the skin fictional drag on a stationary surface by up to 80% . This technology has been successfully implemented to reduce pumping cost for oil pipelines, to increase the flow rate in fire fighting equipments and to help irrigation and drainage [6], [7].

Drag reducing agent (DRA) is a very important innovation in enhancing the flow in pipelines. To avoid the pumping power from being wasted DRA's usage in pipeline becomes essential nowadays. DRA allows higher throughput without additional pumps, and allows earlier ramp down of pump stations as throughput

decline. As known, drag usually an undesirable effect, like friction which will decrease the velocity of flow in pipelines. And increase the vortices as well. DRA can bursts the buffer zone, increase streaks in pipelines, decrease vorticity force and increase velocity of flow.

DRA can be classified into three which are polymers, fibers and surfactant. Each does have its own advantage and disadvantage in performing as DRA.

2.3.1 Polymeric DRA

Toms (1949) discovered that adding small quantities of high molecular weight polymers known as drag reducers to a fluid flowing in pipes in the turbulent region could significantly reduce drag exerted by the fluid. The seminal paper of contains a systematic experimental investigation of the effect in turbulent pipe flow of dilute polymer solutions, followed by a dimensional analysis and concluded polymer drag reduction could cause the changing in molecular structures of liquids hat tend to produce Reynolds stress [8], [9].

A polymer is a large molecule (macromolecule) composed of repeating structural units typically connected by covalent chemical bonds. Polymers can be either natural or synthetic polymers. It can synthesis from varies of chemicals as well.

However, polymers can be degraded and lost their effectiveness in turbulent flow in a very short time period. The long chain of polymers will be breaking into smaller chain due to the mechanical force which caused by shear stress. It can also occur due to chemical reaction between polysaccharide with the solvents [10]

2.3.1.1 Okra mucilage as natural polymer

Its scientific name is Abelmoschus esculentus and also Hibiscus esculentus. Okra known by many other names, is a flowering plant in the mallow family (along with such species as cotton, cocoa, and hibiscus). Okra is considered to be Indian origin but grown as garden crop or home-yard plant in many parts of the world, mostly in tropical and sub-tropical parts of India.

Woodruff was perhaps the first to report the high protein and fatcontent of okra. Later studies, besides confirming these observation, have shown that its protein is rich in lysine and methionine and its fat contains 66% unsaturated fatty acids. Okra contains high percentage of mucilage and it is very viscous, sticky and gummy. Okra mucilage is a polysaccharide that composes from D-galaktose, I-rhambose and I-galacturonic acid that form slippery, aqueous colloidal suspension [11].

2.3.1.2 Halba mucilage as natural polymer

Halba or also known as Fenugreek (Trigonella foenum-graecum) is used as an ingredient in traditional medicine. This plant has been widely cultivated in Central and Southeastern Europe, Western Asia, India and Northern Africa. Its dried ripe seed is well known for its pungent aromatic properties and is often used to add flavor to foods in Malaysian homes. The plant is an erect, strongly aromatic, annual herb reaching 60 cm high. The leaves are trifoliate with a large petiole and leaflets 2-2.5 cm long

The composition of fenugreek seeds was extensively studied and their composition reveals a few specific features which are high content of proteins around 30% of the seed weight, lipids: 5.5-7.5%, the fatty acids are dominantly linoleic acid

(~40%) and linolenic acid. This contributes to a high yield of mucilage from the halba [12].

2.3.1.3 Cocoa husk mucilage as natural polymer

Cocoa husk is considered a valuable source of dietary fibre and is gaining considerable interest in economically advanced countries. They are a good source of mineral elements, lipid, polyphenolic compounds, organic and fatty acids for human nutrition. The knowledge of the quality of the protein fraction in the husk is imperative in developing nutritional formulations in new products (Makkar, Becker, Abel & Pawelzik, 1997). The by-products of cocoa husk have a high dietary fibre content as non-starch polysaccharides (NSP) (43.8 g/100 g), Klason lignin (13.7 g/100 g), considerable mineral elements (10.7 g/100 g), residual level cocoa butter (3 g/100 g) and proteins [13], [14].

Knowledge of the protein composition of cocoa husk may be interesting because of its potential application as a new product. These polysaccharides in the cocoa husk give high percentage of the mucilage content in cocoa husk.

2.3.2 Suspended solid DRA

Drag reducing fibers are well known as safest and cheapest DRA compare to surfactants and polymers. The drag reduction in a present of fibers occurs when the concentration of the fiber was enough for fibers interaction to occur. Most of the researches have a good agreement that the key to understand the mechanism behind the drag reduction of fibers additive is the interaction of fibers in core region of turbulent and the orientation distribution of fibers [15].

It is found that in a present of fibers, the relative turbulence intensity is smaller than without fibers. This phenomena interpreted that the fibers capable of suppressing the turbulent flow

2.3.3 Surfactants DRA

Surfactants are surface active agents which are the main constituent in soaps and detergents. Apart from the classical soaps, which are the alkaline salts of higher fat acids, new surfactants have been synthesized over the years, which also consist of a polar (hydrophilic) head and non-polar (hydrophobic) tail. Depending on the electrical charge of the head group, the surfactants can be classified as anionic, cationic, nonionic and zwitterionic. It is found that the effect of surfactant on the pressure drop varies, depending on the flow regime [16].

2.4 Drag Reduction Mechanism

The ideas of mechanism have been form in models and stimulations. These topics have discussed since 1948 when Toms create a technologies to reduce drag in the pipelines.

2.4.1 Turbulent Intensities of Stream Wise

Turbulent intensities in stream wise component are one of reason for the drag reduction.

2.4.2 Transverse Intensity Component

Radial fluctuation will strongly damp the buffer region in present of DRA. Therefore, intensities of turbulent is reduce which will caused drag reduction in the pipelines

2.4.3 Streak Spacing

Streak spacing is the measurement of coherent eddies size in viscous and buffer layer. Drag reduction increase when the non dimensional streak spacing increases as well.

2.4.4 The bursting Period

Bursting period indicate the relationship of secondary instabilities occurs within a period. The bursting frequency decrease when drag reduction increased.

2.4.5 Homogenous Drag Reduction

Homogenous drag reduction is achieved by adding the polymer into solvent and mix homogenously. The shear rate decrease indicates interaction between polymers and eddies increased.

2.4.6 Polymer Treads Influence

High concentration polymer will be injected at centered wall continuously to develop coherent treads polymer and mix heterogeneously downstream up to 100 and above downstream pipelines. Polymer treads limit formation of eddies thus reduce drag.

2.4.7 Visco elastic properties

Visco elastic properties of low concentration polymer can damp threshold motions and keeps remaining turbulent stretch [17].

2.4.8 Align Polymer

Shear stress will deform spherical polymer and form ellipsoid that align in the flow direction. This can hinder vortex formation and interact with turbulent structure.

2.4.9 Elastic Theory

Based on theory of polymer elastic behavior proposed, it explained the onset drag reduction and maximum drag reduction asymptote [18].

2.4.10 Viscous Sub layer Extended into Buffer Region

Isolated polymer will extend elongation flow in turbulent hence increase elatic sub layer. The viscous or elastic sub layer will extendbuffer region thus decrease intensity of small eddies formation and eventually lead to the drag reduction.

2.5 Commercial Application of DRA

Intensive research on DR using several techniques in the past several decades has been paid off with several successes. For example, reduced drag can provide increased range or increased speed in nearly any transportation system or can result in fuel saving. Water-soluble polymers, surfactants micro bubbles have been tested on ship hull with success. While could achieve 10 – 15 % DR for ship, greater DR can be reached with a system developed by Mitsui Engineering & Shipbuilding Co. In this system, the bottom of the ship is coated with a highly water-repellent paint and air is supplied by a compressor (refer Figure 2.1).

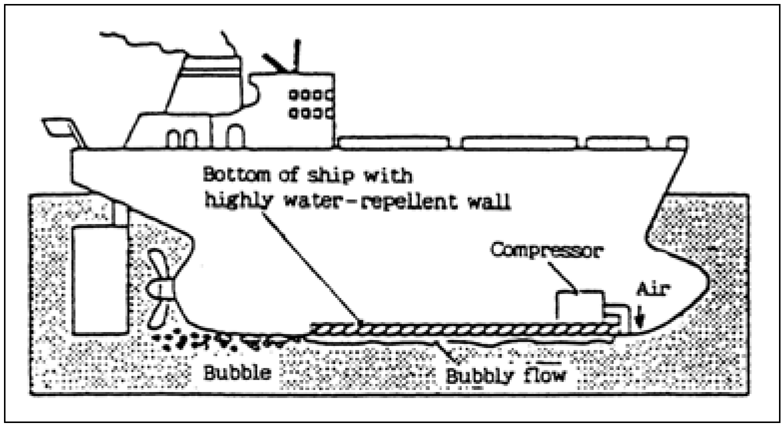

Figure 2.1: Model of drag reduction systems for a ship

These DR methods have been applied to submarines and torpedoes. However, due to the secret nature of the work there are few results in the open literature. A general description of the work on submarines can found in popular scientific magazine. Turbulent flows over the surface of a submarine affect its acoustic signature, its endurance and impair the ability of the operators to resolve the incoming signals against the self-noise of the submarine. The US Navy has performed a full-scale testing using polymer ejection. The results showed that polymer ejection can reduce the self-noise of a submarine and decrease the drag of the hull and the radiated noise generated by the propulsor. Speed increases of 10 to 15 % and reduction in self-noise exceeding 10 dB at certain frequencies are possible. Polymer ejection can be deployed locally to improve sensor performance and reduce signal processing requirements. Although the application of DR technologies to submarines have been actively conducted for the last four decades in the US and former Soviet Union, similar research activities have not been performed in Australia. The DR technologies are so complex that even though the research has lasted for several decades many problems remain to DSTO-GD-0290 17 be solved. As an indication of the interest, an international symposium which was organized on 22 –23 July 1998 at the Naval Undersea Warfare Center (Newport, Rhode Island, USA) has attracted more than 70 papers . Several well known research groups in Australian universities are active in hydrodynamics, fluid mechanics and rheology. A group at Monash University has been involved in DR technologies investigating the effect of polymers on DR in kerosene. However, the effect of DR on the performance of the sonar systems and how to control the growth of biofouling that increases the friction of the ship hull has not been investigated in Australia. Technology base information on DR technologies with application to submarines is extremely important in acoustic signature management for submarines. A systematic approach is important in designing a long term investigation within DSTO, as the research on DR technologies is extremely complex in theory and challenging in practical applications, and is multidisciplinary involving hydrodynamics, materials science, physics and chemistry [19], [20] and [21].