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Formulation of Okra-natural Mucilage as Drag Reducing Agent in Different Size of Galvanized Iron Pipes in Turbulent Water Flowing System

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Abstract: The problem of pumping power losses in pipelines carrying liquids and flowing in turbulent mode is one of the major challenges in the power saving field. Pumping power saving by the addition of minute quantities of additives to the main flow was applied in the present study. Natural drag reducing agent was prepared and extracted from okra fruit and it was tested in a closed loop of turbulence water flowing system. Flow tests were conducted using water as the carrying liquid. The experimental work starts by pumping water from reservoir tank that had mixed with mucilage was pumped with six different flow rates in two different pipe diameters (0.015, 0.025 m ID). The types of pipe used are galvanized iron pipe. The testing length of this flow system is 1.5 m. The aim of this study is to formulate and to test the efficiency of okra-natural mucilage as drag reducer agent on transport of water in pipes; different concentrations of mucilage (100, 300, 500, 700 and 1000 ppm) were used. Six different flow rates were used in the purpose to investigate the flow rates effect. The efficiency of mucilage was tested using clear water. The results shows that, percentage drag reduction (Dr%) increases by increasing the concentration of okra-natural mucilage. Maximum Dr% of 71% was obtained using 1000 ppm of okra-natural mucilage in water flow system.

Key words: Drag reduction, okra-natural mucilage, closed loop, galvanized iron pipe, power saving

INTRODUCTION

Fluids such as water are routinely transported through pipelines which may extend over long distances. It is well known that drag between the fluids and pipe wall causes substantial pressure drops along such pipelines as the fluids flow there through. To compensate for these pressure losses, pump stations are spaced along the pipelines to boost the pressure of the flowing fluids back to or near their original values in order to keep fluid flowing at the desired flow rates and to insure that they will ultimately reach their destination.

Due to the high costs associated with installing, maintaining and operating each booster station, economics dictate that the size and number of such station for any particular pipeline is limited even though the actual throughput or flow rate may wind up being substantially less than the pipeline could otherwise carry.

Since, the size and number of booster station are normally fixed at the time the pipeline is constructed, other techniques have been proposed to increase the maximum flow rate of the fluids which can be carried through a pipeline at a constant pressure drop in the line.

One such known technique proposed for this purpose involves reducing the drag of the fluids within the pipeline. The term drag reduction, as recognised in the art, is the increase in the volumetric flow rate of a fluid at a constant pressure drop due to the addition of a material known as a drag reducer or drag reducing agent to the flowing fluids.

Drag reduction agent can be classified in three categories which are high and low molecular weight polymers, cationic-anionic-zwitterionic surfactants and fibers (Myska *et al*., 2001). Many researchers have proven the efficiency of these additives in their investigations.

Virk *et al*. (1967) studied experimentally drag reduction on turbulent pipe of dilute polymer solutions and reported that the onset of drag reduction occurs at a well defined wall shear stresses related to the random coiling effective diameter of the polymer. Laminar to the turbulent transition is not, in general delayed. The extent of drag reduction induced by a homologous series of polymers in a given pipe is a universal function of concentration, flow rate and molecular weight. The maximum drag reduction possible is limited by an asymptote that is independent of polymer and pipe diameter.

According to the study performed by Warholic *et al*. (1999), he injected polymer solutions had concentrations that varied from 50 to 2000 wppm and flow rates, from

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0.7 to 30 L min^{-1}, after the experiments a range of drag reduction of 10-69% was obtained.

Surfactants with its major classifications are proven to be drag reducer in turbulent flow in pipes because of their drag reduction ability at concentrations as low as part per million was carried by the micelles present in the solution. These micelles play an important role in the mechanism of turbulence damping and in the significant friction decrease while media transported through piping system.

There was a special interest in the use of high molecular weight surfactants to reduce pressure drops and friction effects and there are a large number of experimental and numerical studies that document the effects of surfactant additives on such flows (Pinho and Whitelaw, 1990; Tiederman, 1990).

In the case of the mixing layer, it was observed that surfactant or surfactant additives are also responsible for the delay in the formation of the typical structures of roll-up and pairing. Linear stability analysis and full numerical simulations of viscoelastic free shear flows at very large reynolds and weissenberg numbers allowed to better understand the mechanisms responsible for the attenuation of the instability and shed new light on the interactions between the flow and the viscoelastic additives (Azaiez and Homsy, 1994; Rallison and Hinch, 1995; Kumar and Homsy, 1999).

On the other hand, the use of fibre additives as drag-reducing agents remains limited. There are, however, few experimental studies that show the great potential of these additives and drag reduction effects of up to 60% in pipe flows have been reported by Arranaga (1970) and other researchers. Depending on the flow geometry, the particle size and the importance of viscous effects versus inertial effects, the addition of fibres to a flow can have either a stabilizing (Vaseleski and Metzner, 1974) or a destabilizing effect (Pilipenko *et al*., 1981). In general, where particle additives tend to stabilize the flow, it has been observed that the stabilizing effect increases with the particle aspect-ratio and concentration (Vaseleski and Metzner, 1974).

There are much less studies devoted to the effects of fibre additives on the mechanisms of instability and transition to turbulence in free shear flows. The flow visualizations reported by Filipsson *et al*. (1977) represent one of the few available experiments on this subject. In this study, the presented results for a jet flow of viscoelastic (Polyox WSR-301), fibre suspension (chrysotile fibres) and Newtonian (water) fluids at high Reynolds numbers. The addition of a small amount of either surfactant or fibres led to similar trends towards an enhancement of the large-scale turbulent structures and a modulation of the turbulence by the suppression of small-scale structures. In spite of the well-documented experimental and theoretical evidence for drag reduction by surfactant and solid particle additives, the physical mechanisms responsible for these phenomena are still not well understood and are subject to debate.

Herod's study (Safri and Bouhadef, 2008) explored the possibility of using drag reducing polymers to reduce the power consumption required by pump slurries as well as the possibility of increasing the solid content without causing pipeline blocking. They used 100 wppm concentration of the polyacrylamide (Separan AP-273). Flow rate pressure drop tests were carried out using fresh water. Up to 70% drag reduction was achieved.

In this recent research, okra mucilage will be used as Drag Reducing Agent (DRA). Okra mucilage is one of natural polymer. Okra is a plant came from mellow family. Its scientific name is hibiscus esculentus or abelmoschus esculentus. Okra is available in many countries, inexpensive, renewable source stable in its chemical and physical properties, hydrophilic, a modifiable polymer and biodegradable (Chauhan *et al*., 2001).

Okra mucilage is polysaccharides that compose from D-galaktose, I-rhamnose, I-galacturonic acid (Mishra *et al*., 2008) and form slippery, aqueous colloidal suspension. It has very high molecular weight up to 200,000 and more.

MATERIALS AND METHODS

During the year 2009, this study was conducted in Open Laboratory which located at Faculty of Chemical and Natural Resources Engineering, University Malaysia Pahang.

Liquid circulation system: Figure 1 shows a schematic diagram of a build up liquid circulation system used in the present investigation. Generally, this system consists of reservoir tank, pipes, valves, pumps, flow meter and pressure gauge. The reservoir tank was supported with two exit pipes connected to centrifugal pumps. The first exit pipe with was connected to the main centrifugal pump which delivers the fluid to the testing sections. The other exit is connected to the other centrifugal pump for deliver excess solvent to reservoir tank.

Three galvanized iron pipes of various inside diameters 0.015, 0.025 and 0.038 m ID were used in constructing the flow system. A complete closed loop piping system was build. Piping starts from the reservoir tank through the pump, reaching a connection that splits the pipe into two sections. The first section returns to the reservoir tank, build up as bypass and the other splits into

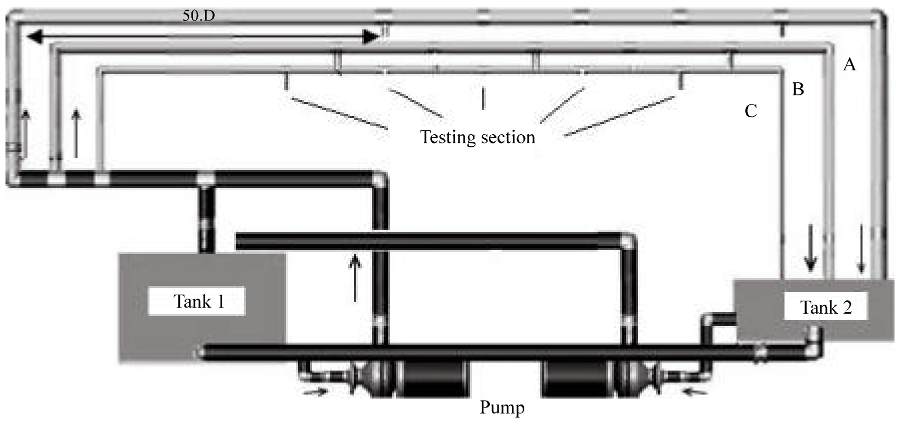

Fig. 1: Schematic of the flow system

three sections with different pipe diameters at testing section. The testing sections were 1.5 m long and it was located about 50 times of pipe diameter to ensure the turbulent flows are fully developed before the testing point. Two sets of baumer differential pressure gauge were used to detect the pressure drop in pipelines with maximum differential pressure reading up to 0.10 and 0.20 bars for both. In order to measure the flow rate of fluid in pipelines, ultraflux portable flow meter minisonic P has been used. This ultrasonic flow meter measurement was sensitive with small changes in flow rate as low as 0.001 m sec^{-1} can be detected.

Materials investigated

Okra-natural mucilage: Okra is the common name of abelmoschus esculentus (synonym hibiscus esculentus). Okra belongs to the malvaceae family. The flowers of the plant are hibiscus-like and after flowering edible capsules are formed. The fruit of okra is a pentagonal, narrow, cylindrical capsule, from 2-12 inches and contains a mucilaginous substance. Its mucilage is commonly used as a thickener in cooking. There is a long tradition of using okra in cooking as well as for medical uses. A pectin-like polysaccharide isolated from the mucilage from fruit pods of okra possesses viscoelastic properties, when dissolved in a physiological buffer, suitable to use as viscoelastic substances.

Preparation of okra mucilage: The immature okra fruit were purchased from a local market; a variety of okra noted for its sliminess was chosen. One hundred grams of okra were chopped into small pieces. Then, okra will be soaked with 1 L of distilled water for 1 h and were exposed to heat and stirring for another hour to motivate and speed up the extraction operation. The soaked okra will produce mucilage that change clear water into very thick viscous green in colour mucilage. Then, okra mucilage will be filtrated by muslin cloth to prevent any big colloidal and suspended solid to get through. To prevent any degradation of the okra mucilage due to bacteria of oxidation, Triton-X was used as anti oxidant. The percentage of Triton-X added to the extracted mucilage was between 1.5 to 3.0 wt.%.

Table 1: Physical properties of water

Water properties @ 25°C	Values
Viscosity ($\mu_{water @ 25°C}$)	0.8973×10^{-3} Pa.s
Density ($\rho_{water @ 25°C}$)	997.08 kg m^{-3}

Transported liquid: The transported liquid used in the present investigation was water. The physical properties of water are shown in Table 1.

Experimental procedure: All the experiments were carried in a constructed liquid circulation system, testing different variables, which are:

- Okra-Natural Mucilage concentration (100, 300, 500, 700 and 1000 ppm)
- Pipe diameter (0.015 and 0.025 m)
- Solution flowrate (0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 m^3 h^{-1})

The experimental procedure starts by testing every additive concentration and pipe diameter, the operation begins when the pump starts delivering the solution through the testing section. The solution flow rate is fixed at the certain value by controlling it from the bypass section. Pressure readings are taken to this flow rate. By changing the solution flow rate to another fixed point, pressure readings are taken again until finishing the six desired values of flow rates. This procedure is repeated for each pipe diameter and polymer concentration to test its effect on the drag reduction operation.

Experimental calculation

Velocity and reynolds number calculations: The average velocity (V) and reynolds number (Re) were calculated using the solution volumetric flow rate readings (Q), density (ρ), viscosity (μ) and pipe diameter (D), for each run as follows:

$$\mathrm{Re} = \frac{\rho . V . D}{\mu} \tag{1}$$

Percentage drag reduction calculations: Pressure drop readings through testing sections before and after drag reducer addition, were needed to calculate the percentage drag reduction %Dr as follows (Virk, 1975):

$$\%\mathrm{Dr} = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \tag{2}$$

RESULTS AND DISCUSSION

Figure 2 and 3 show, the behaviour of the %Dr versus reynolds number (Re) in different additive concentrations through the two pipe diameters investigated. Its can be noticed that the %Dr increases by increasing the Re in certain ranges (0 to 11788) reaching maximum value up to 71% power saving with 1000 ppm addition concentration in the 0.015 m ID pipe and 57% pumping power saving with 1000 ppm addition concentration in the 0.025 m ID. The result complies with Warholic *et al.* (1999), when the drag reduction recorded around 10-69%. Further increase in the Re resulted in a decrease in the %Dr compared with the maximum value. This behaviour is due to the differences of the degree of turbulence that provides a suitable media for the drag reducing agent to act efficiently in media. Increasing the degree of turbulence relates to the increase in the number of eddies that absorb the energy from the main flow to complete its shape. Generally, the diluted molecules of the okra-natural polymer added will be part of these eddies resulting new media of flow. The presence of these additives as part of the flow structure will make the formation of an eddy harder because of the viscoelastic properties of the mucilage molecule which will lead to the cracking of eddies. These environments agree with the finding by Azaiez and Homsy (1994) that stress on the interaction within the flow and the viscoelastic additives. Increasing the Re will result in a more turbulent media which will lead to overcoming the effect of the mucilage molecules in suppressing the turbulence in this concentration. That will lead to the decrease in the value of the %Dr by increasing the Re beyond the optimum value where the maximum %Dr occurs.

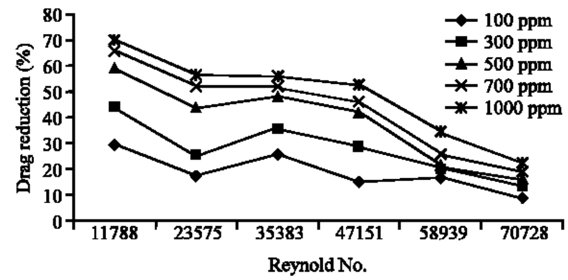

Fig. 2: Effect of Reynolds number on percentage drag reduction for okra-natural mucilage with different concentrations dissolved in water flowing through 0.015 m ID pipe

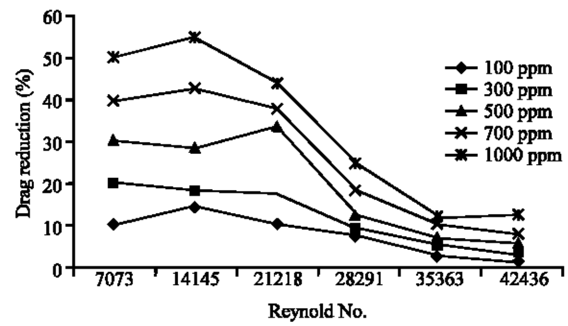

Fig. 3: Effect of reynolds number on percentage drag reduction for okra-natural mucilage with different concentrations dissolved in water flowing through 0.025 m ID pipe

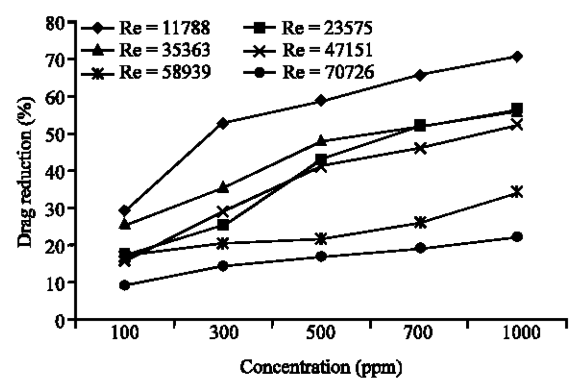

Fig. 4: Effect of concentration on percentage drag reduction for okra-natural mucilage dissolved in water flowing through 0.015 m ID pipe

Figure 4 and 5 show the effect of additive concentration on the %Dr versus the Re number. Generally, it can be noticed that the %Dr increases by increasing the additive concentration in the same Re

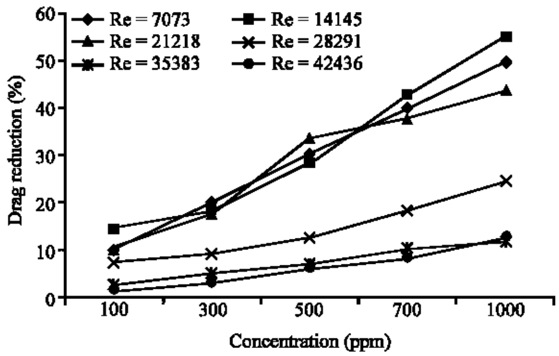

Fig. 5: Effect of concentration on percentage drag reduction for okra-natural mucilage dissolved in water flowing through 0.025 m ID pipe

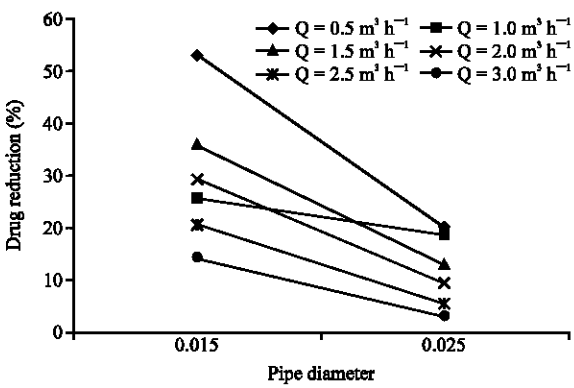

Fig. 6: Effect of pipe diameter on percentage drag reduction at different volumetric flow rates, with 300 ppm concentration of okra-natural mucilage dissolved in water

number. This behaviour is due to the fact that increasing the additive concentration means increasing the number of mucilage molecules involved in the drag reduction operation which will lead to the increase of the turbulence spectrum that is under the additive suppressing effect.

The results of this study showed that within certain polymer type and concentration, % DR increases by decreasing the pipe diameter, which means that the polymer will have a better media to work in smaller pipe (Fig. 6). Decreasing the pipe diameter means increasing the velocity inside the pipe and by that, the turbulence will increase.

Although, the flow inside pipelines is turbulent but the degree of turbulence is different. For smaller pipe, the energy absorbed by eddies in turbulence mode from the main flow will be higher than the energy that absorbed for larger pipes. By this phenomena, when the degree of turbulence become higher, the number of collisions between eddied will increase and produce smaller eddies. These collisions provide extra number of eddies to absorb energy from the flow to complete their shape.

Overcoming smaller eddies is easier by natural polymers than larger once, this is because of the amount of energy absorbed by smaller eddies is lower. This indication was supported by large number of the experimental results of the present study. In general, % Dr values for pipes of 0.015 and 0.025 m ID are close to each other.

CONCLUSIONS

In the present investigation, it was proven that the Okra-Natural Mucilage can be used as drag reducing agent in an aqueous media and mechanism of drag reduction for polymers in turbulence flow can be adopted to explain this phenomenon. It was proven that the percentage Drag Reduction (DR %) increases with increasing of the addition concentration and reduced by the increasing the pipe diameter and the flow rate inside the pipe. All that due to the changes in the turbulence media that the drag reducer works with have resulting the laminar flow at the pipe surface so that the flow inside pipeline was transported successfully..

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