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EXPERIMENTAL STUDY ON THE REDUCTION OF PRESSURE DROP OF FLOWING WATER IN HORIZONTAL PIPES USING PADDY HUSK FIBERS

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ABSTRACT

Abundant of waste from rice production in Malaysia have become the trigger for this investigation. Paddy husk are the waste from the rice production. Utilization of this waste in transportation of fluid can reduce the pressure drop in pipelines. Several studies have shown that addition of minute quantities of fiber additives can reduce the drag in pipe and maintain the pressure drop along the pipelines. Experimental works have been conducted in the laboratory in order to test paddy husk fibers in a closed loop of turbulence water flowing system. Flow tests were conducted using water as the transport liquid. The experimental work starts by pumping water from reservoir tank that had mixed with paddy husk fibers was pumped with six different flow rates in same pipe diameters a (0.025m ID). The types of pipe used are galvanized iron pipe. The testing length of this flow system is 1.0m. The pressure drop and drag reduction were measured in the flow varying concentrations of fiber (paddy husk). After adding the fibers to the water, the results have shown that the percentage drag reduction (Dr%) of 32% at the first flow rate setting and become depleted in term of the reading after travel at larger flow rate setting, but still there was drag reduction involve during transportation of the water.The results have shown that the fibers (paddy husk) have an effect on the pressure drop. In addition to this, we point out that the paddy husk fiber is available as drag reducing agent.

Keywords: Waste, paddy husk fiber, closed loop, galvanized iron pipe, reduce drag.

INTRODUCTION

The addition of minute amounts of additives such as surfactants, polymers or rigid particles can result in important drag reduction effects in many types of flows. Most of the existing literature dealing with drag reduction by additives has focused on wall-bounded flows such as pipe flows, due to their importance in many technological processes. For this class of flows, 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). 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 authors. 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 authors 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.

Later, the usage of the suspended solid (insoluble in liquid media) as Drag Reducer opened the wide door for more research to examine the availability of the solubility condition in the drag reduction phenomena (Hideo *et al*., 2000; Toorman, 2002; Mawla and Naderi, 2006).

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The aim of this study is to formulate and to test the efficiency of paddy husk fiber as drag reducer agent on transport of water in pipes; different sizes of fiber (500 μm and 800μm) were used. Six different concentrations were used in the purpose to investigate the concentration effect. The efficiency of fiber was tested using clear water.

MATERIALS AND METHOD

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 (C), 0.025 (B) and 0.038 (A) 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 three sections with different pipe diameters at testing section. The testing sections were 1.0m long, 0.025m ID 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 ms^{-1} can be detected.

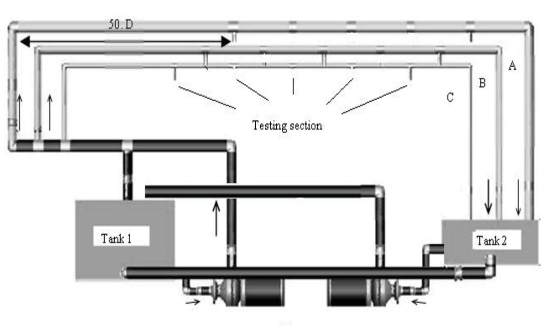

Fig. 1. Schematic of the flow system.

Materials Investigated

Paddy Husk Fibers

Paddy husk is obtained from Bernas Sdn. Bhd. at Jitra, Kedah. The paddy husk was dried by the oven overnight at temperature of 100°C. Once dry, the fibers is graded into fibers by using grinder then sample was sieve using a screen into two sizes which are 500 and 800μm. Physical properties of the paddy husk were determined by using pycnometer. The results are as shown in table 1.

Table 1. Physical properties of paddy husk fibers.

Paddy husk size (μm)	Fibers Density (gcm^{-3})
500	2.0811
800	1.2538

Transported Liquid

The transported liquid used in the present investigation was water. The physical properties of water are shown in table 2.

Table 2. Physical properties of water.

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

Experimental Procedure

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

- Paddy husk fibers concentration (100, 300 and 500ppm)
- Paddy husk sizes (500μm and 800μm)
- Pipe diameter (0.025m)
- Solution flow rates (2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 m^3/hr)

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 fibers concentrations and sizes to test its effect on the drag reduction operation.

Experimental Calculation

(a) 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:

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

(b) 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)

$$\%Dr = \frac{\Delta P_b - \Delta P_a}{\Delta P_b} \quad \textbf{(2)}$$

RESULTS AND DISCUSSIONS

Effect of Fluid Velocity (Re)

Figures 2 and 3 shows the behaviour of the transported water velocity on the percentage drag reduction (Dr%). The velocity (V) was represented by the Reynolds number (Re). Figures 2 and 3 shows the effect of (Re) on Dr% for water transported with paddy husk fibers (500 and 800 μm) with different addition concentrations.

From figure 2, it can be noticed that the Dr% reaching maximum value 32% power saving with 500ppm addition concentration of 500μm in Re number ranges (35363 to 70726) in the 0.025m ID pipe. Further increase of Re resulted decreasing in the Dr% compared with maximum value.

Meanwhile, in figure 3, it was shown that the Dr% reaching maximum value of 25% power saving with 100ppm addition concentration of 800μm fibers size before decreasing slowly after Re are above 40000.

These phenomenons may be caused by the particle momentum generated from paddy husk fibers drive the eddy to flow straight along the pipe because the momentum of the particle is larger from the energy to form turbulence eddies.

Effect of Solid Particles Concentration

The results of analysis of paddy husks drag reduction performances as a function of fibers concentration and Re which is from 100 to 500ppm in the range of 35363 to 70726 are shown in figure 4. Note that the profile pattern of each concentration is similar but varies in its value. As shown in figure 4, the maximum drag reduction values of 32 % in 500ppm of concentration occur when the Re at

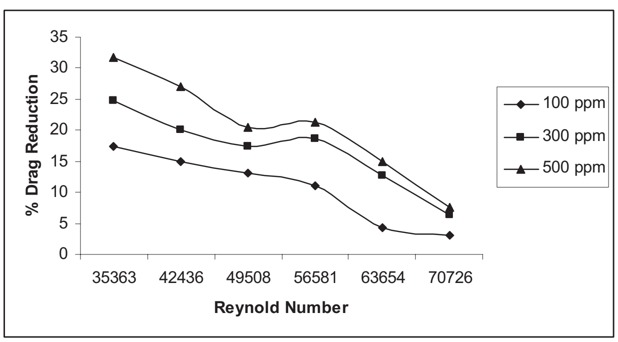

Fig. 2. Effect of Re on Dr% for transported water with Paddy husk fibers (500μm) with different addition concentrations.

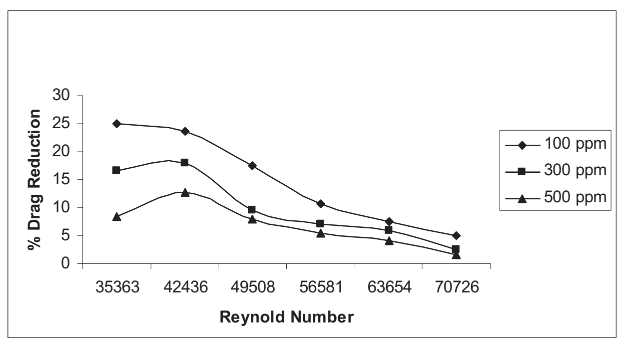

Fig. 3. Effect of Re on Dr% for transported water with Paddy husk fibers (800μm) with different addition concentrations.

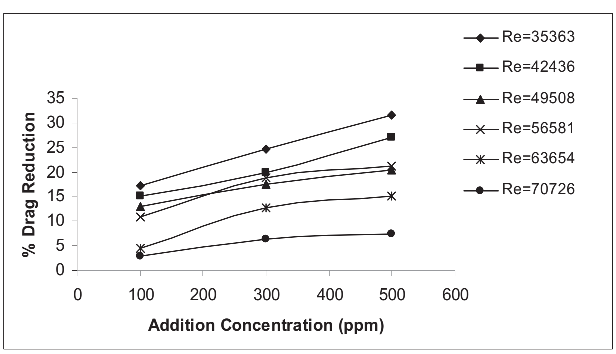

Fig. 4. Effect of fibers concentration on Dr% for transported water with Paddy husk fibers (500μm) with different flowrates (Re).

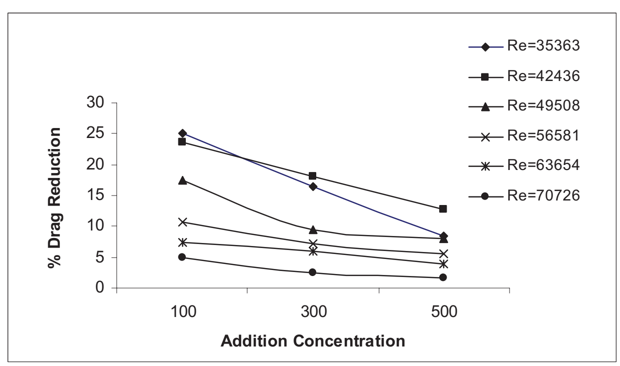

Fig. 5. Effect of fibers concentration on Dr% for transported water with Paddy husk fibers (800μm) with different flowrates (Re).

35363. In general based on the experiments conducted, all concentration showed a drastic reduction of drag reduction at 35363 to 70726 of Re which the drag reduction values ranged between 3 and 27%. These results showed that the optimum performance of the fibers additive investigated is limited to the degree of turbulence, that by increasing the flow the degree off turbulence will increase also which will provide more suitable environment for the drag reducer to perform. Further increase in the flow will cause the reduction in the additive efficiency due to the decrease of the additive concentration to degree of turbulence ration. In another words, the reduction of drag as obtained in this experiment shows that the paddy husk capable to act as drag reducing agent at 500μm size of fibers.

Figure 5 shows the performance of drag reduction as a function of fibers concentration and Re which is from 100 to 500ppm in the range of 35363 to 70726. The profile pattern of each concentration is similar but different in values. As shown, the highest drag reduction occurs at 100 ppm concentration of 800μm fibers size with 25%. Further increase of fibers concentration shows decrease in drag reduction but still reduction of flow still occur. The lowest drag reduction was obtained in 500ppm of paddy husk fibers that is 2%. These phenomena probably can be defined as the result of the diameter effect towards the flexibility of the fibers to acts as drag reducer. By increasing the diameter of the fibers lead to the decrease of flexibility. In order fibers to act as drag reducer agent, basic criteria such as flexibility and surface roughness should be fulfilled (Singh, 1990). Singh proven that drag reduction of fibers with small diameter is higher than drag reduction cause by the fibers with larger diameter because fibers with small diameter can improved the flexibility of fibers in flow system. These results are consistent with the findings in a few literatures, in which the drag reduction increase as addition concentration is increases.

Effect of Particle Size

There were two sizes of paddy husk fibers that were used to investigate drag reduction in this present research (500 and 800μm). Figure 6 shows a selected sample of fibers size effect data. These results clearly shows that the DR% of the paddy husk with the size 500 μm is larger than the paddy husk with the size of 800μm.

This may be due to the small momentum needed in order to transport smaller particles that make these particles easily been drag by the turbulent flow in pipe. Small diameter of fiber material increases the flexibility. Flexibility is the important for fibers to act as drag reducer. From this condition, there was a decreasing effect in the spectrum of turbulence causing the drag reduction higher at this smaller particles size.

Normally, during fibers are travelled in pipe, the fibers was torn into pieces due to an eddy during turbulence flow. In this case, smaller size of fibers has become great impact to make larger eddies to break up to smaller eddies which as the result, an increment of the Dr%.

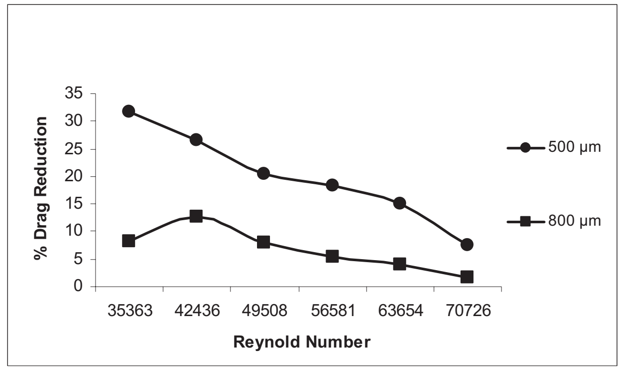

Fig. 6. Effect of changing the particle diameter (500 to 800μm) on the Dr% for transported water with paddy husk fibers with different Re at 500ppm.

CONCLUSIONS

Paddy husk fibers were found to behave as good drag reducing agent at 500μm of sizes and 500ppm of concentrations. Drag reduction for fibers materials was found to increase by smaller fibers size used as drag reducer.

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