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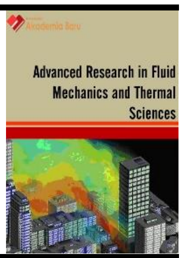

Flow Behaviour of Nata de Coco Suspension in Circular and Spiral Pipe

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ABSTRACT

Recently, energy efficiency research in several fields is an important topic to be developed. In fluid flow, several methods are constantly be innovated to increase pressure drops. In the piping system, some researchers add several types of additives to the base fluid to get a reduction in resistance. The purpose of this study is to determine the effect of the Nata de Coco fiber solution that was flowed through the pentagon test pipeline. In this test, the discharge variation carried out to obtain a low to high Reynolds number, namely 20,000. The percentage of drag reduction calculated using experimental data obtained, where the pressure drop measured at the test pipe with a distance of 1500 mm. From the research results, it is known that the addition of Nata de Coco fiber suspension into the water can reduce resistance in both round and spiral pipes. The maximum drag reduction of working fluid with a concentration of 100 ppm for spiral pipes is around 34.68% and for circular pipe, it is around 22.1% at the same Reynolds number, which is around 19,000. Nata de Coco fiber solutions tend to spread and flow straight in the middle of the experimental pipe and buffer region layer and continue to expand towards the wall; these reduce wall friction and achieve maximum drag reduction. Furthermore, Nata de Coco fiber suspension is good for mechanical degradation effects. Based on this research, it can be concluded that Nata de Coco can be considered as a solution to reduce the friction of flow.

1. Introduction

Transportation system issues in the pipeline continue to be addressed due to energy efficiency. The pipeline is an effective method for transporting liquids, especially for distributing liquids to distant places. Various types of fluids are channeled through pipes for various needs such as cosmetics, food, sludge, and various industrial needs because they are considered the most effective way. However, the most important problem is high energy consumption. Therefore, new development methods are needed to reduce pressure loss. As is known, the method for obtaining

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obstacle reduction is divided into two categories: passive control and active control. In passive control of fluid flow, the most effective method of drag reduction is the addition of drag-reducing additives which are high molecular weight polymers. Applications of polymer drag reduction or surfactant additives are limited to piping systems because the disposal of these solutions is toxic to the environment.

Both methods, namely the active method and the passive method are used to reduce obstacles in the fluid. The passive method is to vary the geometry of the pipe, such as using a layered pipe, injecting micro bubbles to reduce skin friction as in marine applications [1,2], and utilizing grooves in spiral pipes [3,4]. Whereas, the active method is to add a small amount of additive to the liquid, which can reduce the friction factor in turbulent flow [5,6]. Tom [7] was the first to report this method by adding a small amount of a polymethyl methacrylate solution to monochlorobenze to reduce the friction resistance of turbulent walls.

Polymers are not the only type of drag-reducing agent because in the development of active controls, some additives are found to be sufficiently good enough. Surfactants and fibers are also known as barrier absorbers. Some researchers using Surfactant [8-10] as a drag reduction agent be effective for increasing drag reduction in turbulent flow however, this is not environmentally friendly. Likewise, the use of polymers [11-15] is the most widely used in the industry because it is cheap and shows good results as a surfactant. However, mechanical degradation occurs significantly. Nanoparticles [16] have also been shown to show good results on reducing barriers, but require higher concentrations and require quite complex treatments to prevent sedimentation. Like other types of inhibitory agents, fiber also shows a significant inhibitory reduction effect [17-21]. Coconut fiber [22] as a natural fiber has been investigated as an additive and shows good results in reducing barrier.

On the other hand, fibers [23] such as asbestos or nylon are resistant to mechanical degradation but have a disadvantage with regard to environmental load, while pulp, which is a plant-based fiber, requires high concentrations to achieve drag reduction effects. Research on the use of fiber to reduce the loss of pressure drop was made by Ogata, Nukawa and Kubo [24]. They reported that the use of fibers of the material of nata de coco can reduce the pressure drop in turbulent flow. Effect of the addition of nata de coco fiber is a very good impact. Drag reduction that obtained was 11%.

2. Methodology

2.1 Experimental Setup

Figure 1 is a set up of the rheology measurement of nata de coco fiber suspension. The detailed experimental set-up consisted of the main tank, diaphragm pump, voltage regulator, spiral pipe P / At 10.8, circular pipe with an inner diameter of 3 mm, ball valve, pressure transducer, DAQ, computer, and measuring cup. Horizontal pipes with circular cross sections and spiral sections with five helical lobes are used to determine the flow in the pipe (Rheology). The flow rate varies by adjusting the valve opening. Two manometers are mounted on a test pipe which is connected to a pressure transducer to determine the value of the pressure drop. Flow discharge is accommodated by a measuring cup which is accommodated within a certain time period to get the flow capacity. The relationship of shear stress to shear strain will be obtained to create a flow curve.

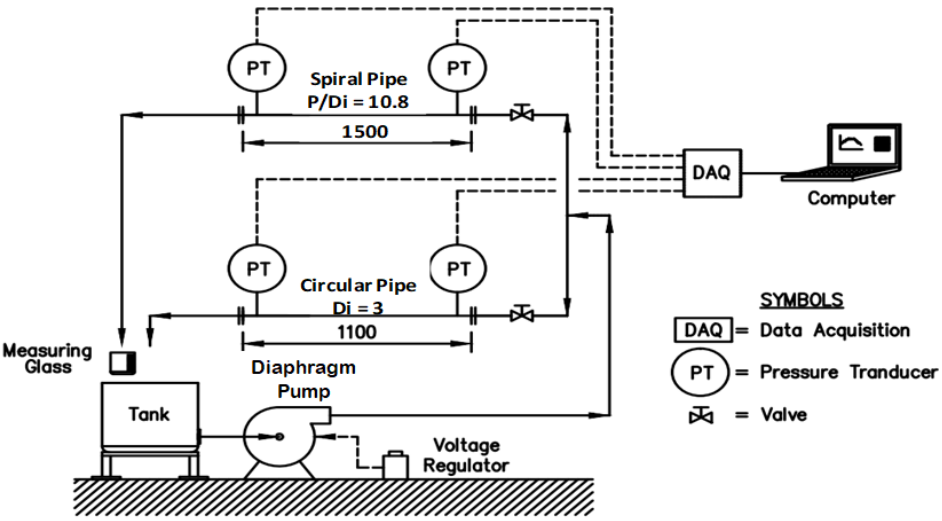

Fig. 1. Experimental setup

Table 1 is the spiral pipe data used in this study where P is pitch, Do is the outer diameter, Di is the inner diameter, Δd is the difference between Do and Di, and P / Di is the ratio of pitch to the inner diameter (see Figure 2).

Table1
Dimension of experimental pipes

Pipe	Di (mm)	Do (mm)	Δd	P (pitch)	P/Di
Circular Pipe	3	4	1	-	-
Spiral Pipe	15	25	10	162	10.8

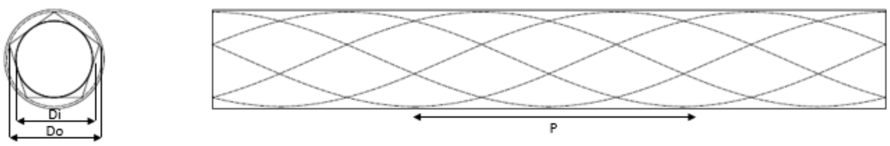

Fig. 2. Schematic diagram of spiral pipe

Nata de coco material was obtained by the market which is traded for food needs. Nata de coco was pressed to separate the liquid contained and dried in the refrigerator to avoid damage to the nata de coco fiber. This process is carried out referring to previous study that have been conducted by Ogata *et al.,* [21]. Nata de coco was prepared in 20 ppm, 60 ppm, and 100 ppm of concentrations into the working fluid and mixed using an agitator for 90 minutes with a rotation of 1500 rpm. The temperature was maintained constant at 27 ° C during the testing process. The nata de coco fiber solution is mixed in the main tank and then circulated to the experimental pipe using a diaphragm pump. Spiral and circular pipes are tested alternately through valve settings. The experiments were carried out in a closed-loop system, where the output flow from the experimental pipe returned to the main tank. To find out that the setup experiment was made already meets the standards, the test is carried out using pure water. The data obtained were calculated and compared with the Hagen-Poiseuille equation for laminar flow and Blasius for turbulent flow.

2.2 Rheological Model

Experimental data plotted in the moody chart. The laminar region refers to Hagen-Poiseuille line and the turbulent region refers to the Blasius line. Drag reduction is defined by decreasing the coefficient of friction on the flow. The friction factor caused by shear stress that occurs between each layer of the velocity. The shear stress, τ is proportional to the velocity gradient, γ (shear rate), can be described by Newtonian model

$$\tau = \mu \frac{du}{dy} \tag{1}$$

where μ is constant for the particular fluid that is viscosity. The Newtonian viscosity depends on the temperature and the pressure and is independent of the shear rate. The viscosity is defined as the ratio of shear stress to shear rate. Several rheological models or rheological equations of state have been proposed in order to describe the nonlinear flow curves ofnon-Newtonian fluids. Non-Newtonian fluids Bingham, pseudo plastics, and dilatants are those for which the flow curve is not linear. The viscosity of anon-Newtonian fluid is not constant at a given temperature and pressure but depends on other factors such as the rate of shear in the fluids. Thus, the relationship shear stress and shear rate may be described by measuring the pressure drop gradient and the volumetric flow rate in circular pipe flow is given by

$$\frac{D\Delta P}{4L} = \mu \frac{8u}{D} \tag{2}$$

where D is the inner pipe diameter, ΔP is pressure drop, L is the length of pipe (test section), and u is the avarage velocity. Coefficient of friction, f, can be obtained by Darcy Equation

$$\Delta P = \frac{fLU^2}{2D\rho} \tag{3}$$

where f is the coefficient of friction, Δh is the head gradient over the considered pipe length, and g is the gravity acceleration. The solution concentration, Cw was determined based on the mass ratio of nata de coco fiber to pure water to made test fluid, which is defined by

$$C_w[\%] = \frac{M_n}{M_n + M_w} \times 100\% \tag{4}$$

Mn and Mw denote the masses of nata de coco and pure water, respectively. Drag reduction can be obtained by using Eq. (5) as stated below

$$DR = \frac{f_{water} - f_{fiber}}{f_{water}} \times 100\% \tag{5}$$

3. Results

Flow characteristic of the nata de coco fibber solution can be determined by comparing the results of based fluid in a circular pipe. Variations of nata de coco solution were divided into three concentrations including 20, 60, and 100 ppm. Test results are displayed on the relationship between shear stress and shear rate.

The relationship between shear stress and shear rate of a nata de coco fiber solution treated with different DRA concentrations are illustrated in Figure 3. This figure shows that the non-linear relationship at each DRA concentration. The figure shows the value of the power law index below 1 which indicates the working fluid is non-Newtonian. Especially for 20 ppm of concentration the working fluid have the Newtonian behavior. The reason of Newtonian for 20 ppm of concentration is the power law index n, equal to 1. Following, b the graph will shown the power law index and consistency coefficient K; $y = K x^n$.

Pressure drop influenced by several factors such as the length of the channel flowed by the fluid, the diameter and also the surface roughness. The reduction in pressure in the liquid is as small as possible when flowing continues to be endeavored so that the energy actually used to flow the fluid. Pressure at the inlet pipe will be higher than the pressure at the outlet pipe as a common phenomenon. The pressure drop value is an important parameter in fluid flow because it is related to the energy needed in the fluid distribution process

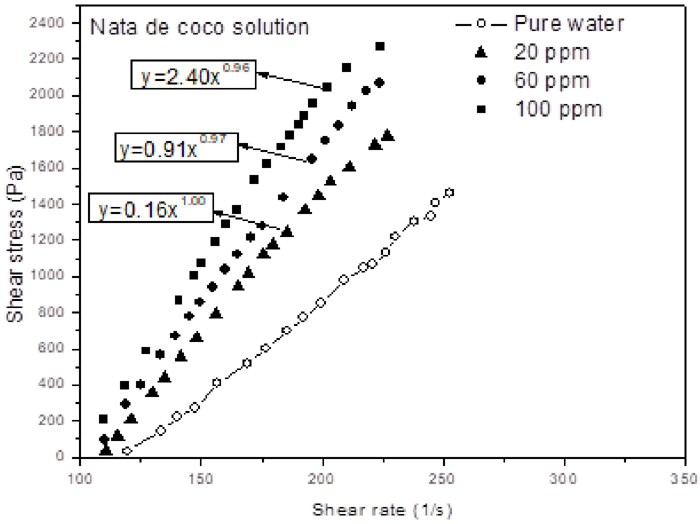

Fig. 3. The relationship of shear stress and shear rate of pure water and nata de coco fiber solution in circular pipe

The relationship of flow rate and pressure drop in nata de coco fiber solutions with concentrations of 20, 60, and 100 ppm and water in circular and spiral pipes can be seen in Figure 4. This shows that at low flow rate ranging from about 0.4 lpm to 1 lpm, the pressure drop of the nata de coco fiber solution in a circular pipe is still relatively the same as water. However, at a flow rate above 1 lpm, the pressure drop in the nata de coco fiber solution is higher than the water in both round and spiral pipes. Based on Figure 4, the pressure drop in the spiral pipe is higher than the circular pipe. In addition, the increase of nata de coco concentration in base fluid also affects the pressure drop value where, the higher the concentration value, the higher the pressure drop value occurs. The value of the increase in pressure drop due to the addition of nata de coco fiber percentage occurs in round or spiral pipes. The higher the concentration of nata de coco fiber solution, the higher the pressure drop when compared to water. This can occur because nata de coco fiber solution has a higher viscosity than water, especially at higher concentration around 100 ppm. Thus, the shear stress that occurs is also higher than water at the same velocity.

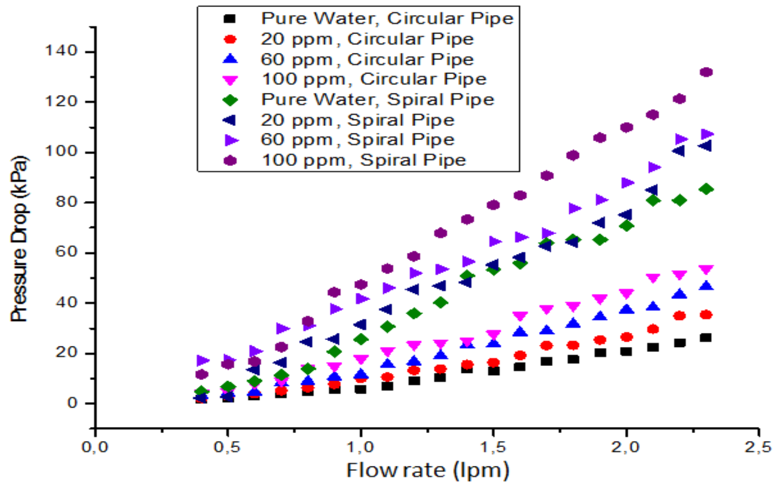

Fig. 4. Pressure drop of nata de coco fiber solution compared to water on circular and spiral pipe

In Figure 5, we can see the Hagen-Poiseuille equation for laminar flow, Blasius equation for turbulent flow and Virk's equation for maximum DR. In the laminar regime, the friction coefficient data is slightly higher than the Hagen-Poiseuille equation. It can be said that, in laminar flow there is no reduction for the friction. However, in the turbulent regime, nata de coco suspension data is lower than the Blasius equation. This shows that in turbulent flow, the reduction of obstacles occurs. In the other hand, pure water data in turbulent flow coincides with the Blasius equation in a round pipe. The maximum drag reduction ratio in circular pipe is around 22.1% at 1.9 x 10^4 Re with a concentration of 100 ppm. There are two factors which suspected to affect the drag reduction ratio, namely the Reynolds number and the concentration of nata de coco solution. The higher of Reynolds number, generated the lower coefficient of friction. The low coefficient of friction results in lower wasted energy usage, so savings occur. The higher concentration of the nata de coco fiber solution generated the greater the drag reduction ratio.

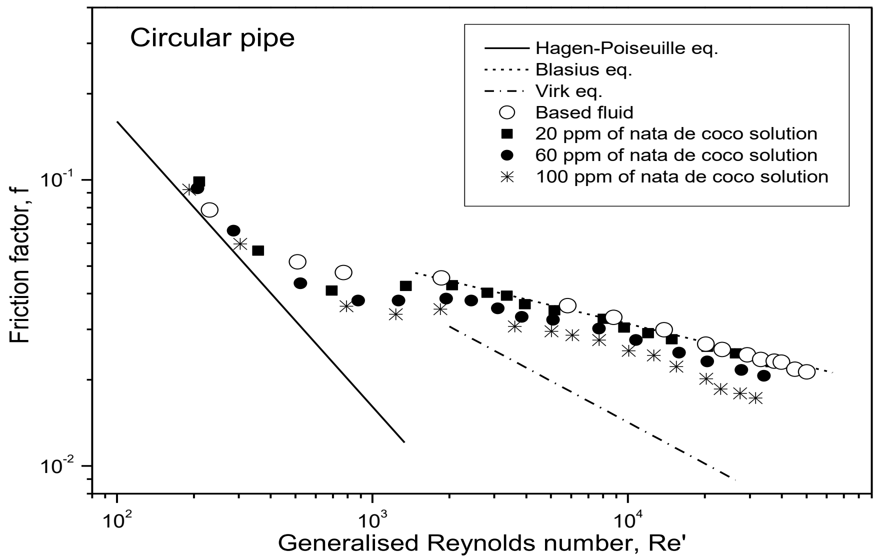

Fig. 5. Friction coefficient of nata de coco fiber solutions in circular pipe

The relationship between Reynolds numbers compared to the friction factor in the Spiral Pipe P/Di 10.8 is illustrated in Figure 6. The fluid working is the same, namely the solution of nata de coco fiber and water. Hagen-Poiseuille equation lines for laminar flow, Blasius equations for turbulent flow and Virk equation for maximum DR. Test data in this study include laminar flow and turbulent flow.

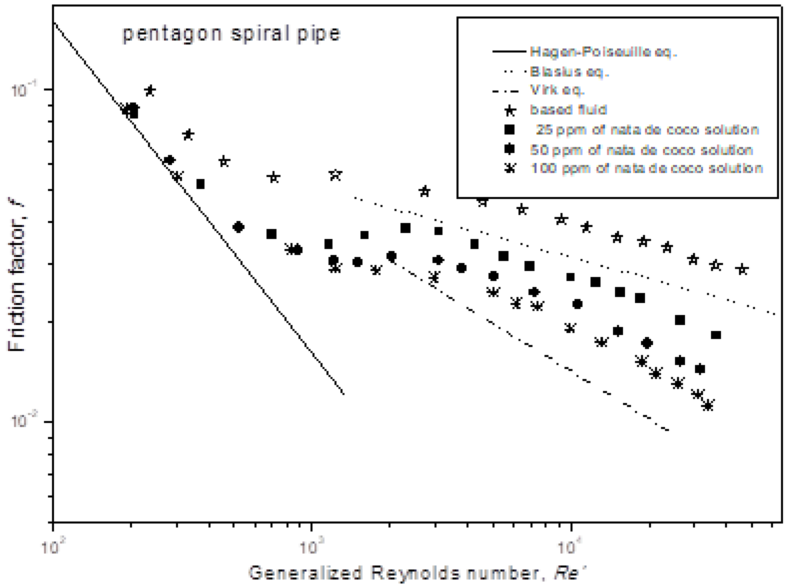

Fig. 6. Friction coefficient of nata de coco fiber solutions in spiral pipe

In the laminar regime, the friction coefficient data is slightly higher than the Hagen-Poiseuille equation. It can be said that, in the laminar flow there is no drag reduction. However, in the turbulent regime, the data of nata de coco suspension is lower than the Blasius equation. This is indicated that in the turbulent flow, the drag reduction occurs. In the other hand, nata decoco data of pure water in the turbulent flow is higher than the Blasius equation. The higher of Reynolds number is generated the lower the friction coefficient for fluid working with nata de coco mix. The low friction coefficient results in lower energy use, which can save energy. The maximum drag reduction ratio in the spiral pipe is about 34.68 % at around 1.9 x 10^4 Re with 100 ppm concentration. This is occurred due to the presence of fluid flow in the spiral pipe experiencing the swirl flow. The swirl flow causes the flow not only moves horizontally towards through the pipe axis, but also flows along the pipe groove at certain d stances. Then, the right distance allows the drag reduction occurred in the flow.

Figure 7 shows the drag reduction of fluid working for all the concentration through the spiral pipe. Research focused on working fluids with *Re'* which experiencing the highest DR at each concentration. Based on the graph the stability of drag reduction is seemed very well. DR which occurs in the working fluid begins to degrade in time range for about 8 hours. It can be concluded that the reliability of nata de coco fiber solution in pipe depends on the time.

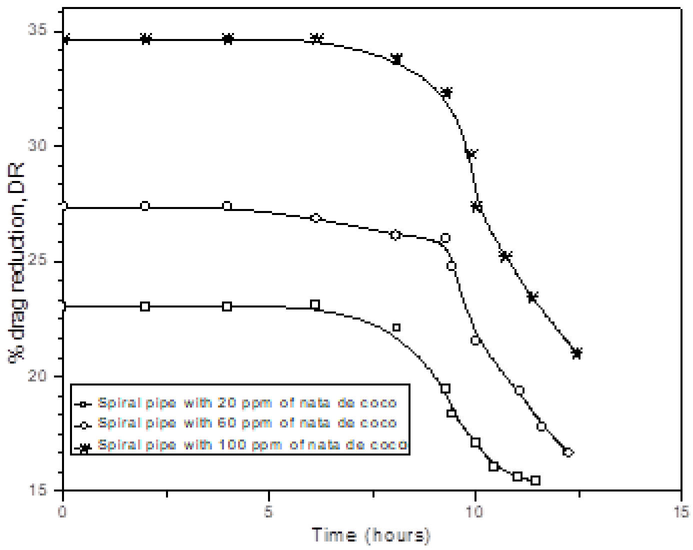

Fig. 7. Drag Reduction Stability of nata de coco solution

4. Conclusions

The results of this reseach shown that the nata de coco fiber solution in the circular pipe has an effect on the drag reduction about 22.1% at Reynolds number around 19,000. Whereas the drag reduction in the spiral pipe P/Di 10.8 is about 34.68%. % at Reynolds number 19,000. The drag reduction is affected by the concentration of fiber solution and the Reynolds number. The higher the concentration of nata de coco fiber suspension, the greater the drag reduction ratio that occurs. However, the best concentration for this research is 100 ppm. In this study, the degradation of drag reduction due to the effect of mechanical equipment is described. DR which occurs in the working fluid begins to degrade in time range for about 8 hours.

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