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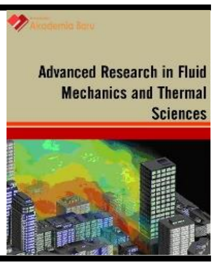

Spiral Pipe Geometry for Particle Mud Slurry in Semau Island, Indonesia

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ABSTRACT

Oil and gas exploration in Semau, one of some islands in East Nusa Tenggara of Indonesia has caused by eruption of gas and mud. This incident is considered a disaster because it harms the people around who lost their property and fields. The mud slurry characteristics by passive control method of highly concentrated mud eruption containing solid particles have been investigated. Actually, when the particles that flowed not sufficiently high, it caused by low velocity of mud slurry. This natural phenomenon can illustrate the reality of how the behaviour of the phenomenon of sludge flow deposition occurs. Spiral pipe with twist grooves are constant on the axis pipe and slurry that also rotates when it is flowed. By the behaviour of the swirl flow, particles are allowed to flow at low speeds. The purpose of this study is to examine the characteristic flow of mud slurry that is flowed in the three lobe spiral pipe. The shear rate and shear stress are obtained by measuring the pressure drop and the volumetric flow rate in circular pipe. By the experiment, the power law exponent in this study ranged from 0.72 to 1 for liquid and solid particles of 20%, 30%, and 45% by weight of concentration. The particle diameter of the test in this study is 1-5 µm and density is 2.7 x 10^3(kg/m3). The degree of homogeneous distributed suspension of liquid and solid particles for horizontal axis of the pipe were compared with circular pipe and spiral pipe in laminar and turbulent flow. Through this research, P/Di = 7 spiral pipes proved to reduce friction resistance higher than circular pipe. The higher drag reduction happened for 25.58 % with the generalize Reynolds number 5 x 10^3. The value obtained shows that the spiral pipe impacts the drag reduction to the mud slurry.

Keywords:
Drag reduction, Spiral pipe, mud slurry, power law exponent, pressure drop

1. Introduction

In wider flow applications, piping systems are used to channel mudflows from a variety of conditions such as drain mud from a catastrophic outburst. The result of eruptions that occurred in Semau Island in East Nusa Tenggara, one of some islands in East Nusa Tenggara of Indonesia resulted in agricultural land and residence of the victims.

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Drag reduction can occur when the higher liquid ratio in the solution mix but performance in moving the particle mass needs to be considered by increasing the ratio of the particle solid ratio itself[1]. At higher concentration the properties of the working fluid change and affect the flow characteristics. In the pseudoplastic flow, it is evident that the higher the concentration of solid particles, the higher the apparent viscosity and the density.

This research is also interesting because it can be applied to problems related to handling and as a concept to transport mud from the mudflow disaster that occurred in East Nusa Tenggara, Indonesia. Yanuar *et al.,* conducted a study with mudflow results in Sidoarjo-Indonesia found that slurry with Cw = 30% concentration had the higher drag reduction effect [2]. The heterogeneous flow in the horizontal pipe is occurs when the solid-liquid mixture precipitates. Most of the solid particles are concentrated at the bottom of the pipe, while most of the liquid flows through the top of the pipe along with a relatively small proportion of solid particles. The solid and liquid phases still provide different flow patterns, each having its own behavior but interacting with each other [3-6]. The interaction of solid and fluid particles is greatly influenced by the geometry of the pipe. Yanuar *et al.,* conducted a study using a spiral pipe with varying P / Di and circular that the force swirl formed resulted in the highest slurred mass in the spiral pipe with P / Di = 7 [7]. In this research, the best pitch per diameter ratio (P/Di) = 7 of spiral pipe is conducted inorder to clarify the reduction of drag. In the other hand, using the spiral pipe, the sedimentation phenomena is eliminated compare to the circular pipe. The characteristics of velocity distribution pattern in the spiral pipe is different with circular pipe. The velocity distribution in the circular pipe has provided by some researchers [8-9]. The velocity distribution of spiral pipe is used to clarify that the sedimentation of mud slurry is not occured.

Deposition of solid particle has been developed since 1960; but there are still things that have not been thoroughly studied and need to conduct further research [10-12]. The precipitating occurs is influenced by particle size, pipe diameter, pipe geometry and the concentration of the particle mixture [13-15].

2. Methodology

2.1 Experimental Setup

The test equipment is shown in Figure 1 consist of a spiral pipe with P/Di =7, circular pipe with an inner diameter

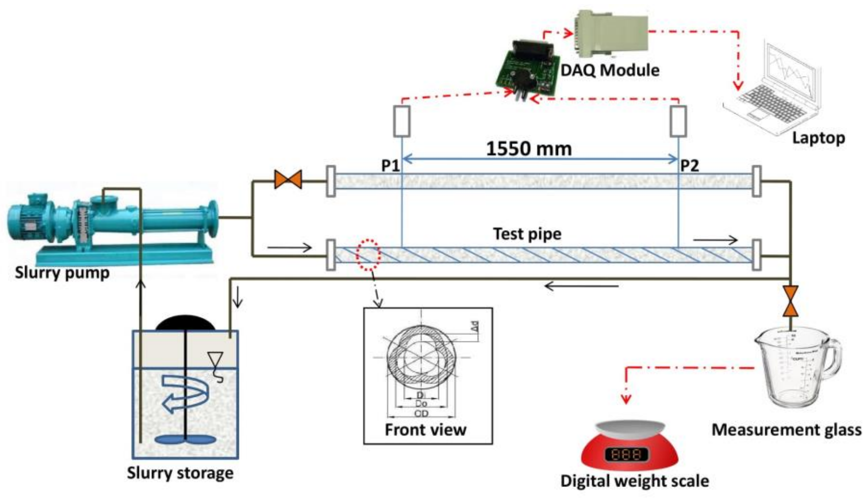

Fig. 1. Experimental setup

Working fluid is circulated through the main test tube with the main test tube sized as well as the length of 1000 mm. The working fluid used is a mixture of water and solid particles obtained from mud bursts on Semau Island, East Nusa Tenggara Indonesia. The material obtained from the location of the mud flow, dried then overhauled and drawn for each required concession.

The working fluid consist of the mixture of pure water and solid particles with variations of concentrations Cw = 20%, 30%, and 40%. Variations of flow rate by setting the valve opening at each step of data taking per unit time. The data of pressure drop measurements were obtained by using different pressure sensor and DAQ Module and then the data obtained is recorded in the computer. The variation of the obtained is accommodated on the measuring cup and then weighed. The test apparatus is validated by using pure water to ensure the accuracy and readiness of the piping system. Initial test by using pure water is done to know the coefficient of friction by variety Reynolds number value.

2.2 Test Analysis

The test was performed under isothermal condition with room temperature 27 ^{0}C. Rheological model is done to determine parameters of power law index (n) and consistency coefficient (K). This parameter is done by plotting log-log scale between shear rate and shear stress. The intersection value of the logarithmic graph can indicate the value of n and K [16].

$$\tau_W = K\left[\left(-\frac{du}{dr}\right)\right]^n \tag{1}$$

where,τ_W is shear stress and $\frac{du}{dr}$is the velocity gradient. The friction factor value is obtained through the pressure drop measurement value (ΔP) as follows:

$$f = \frac{Dh}{LP}\frac{\Delta P}{\left(1/2\right)\rho u^2} \tag{2}$$

where D_h is the hydraulic diameter of the pipe, $\bar{u}$ the average velocity of the flowed fluid, L_p is the length of the main test pipe. The friction factor values will be compared with the generalized Reynolds number used for non-Newtonian flow.

$$\mathrm{Re}' = \frac{\rho u^{2-n} D^n}{K 8^{n-1}} \tag{3}$$

where R_e' is generalize Reynolds number. To know the value of drag reduction then used the following equation:

$$DR = \left[\frac{f_c - f_{sp}}{f_c}\right] x100 \%_0 \tag{4}$$

where DR is drag reduction, f_c is the friction factor in the circular pipe and f_{sp} is the friction factor coefficient of the spiral pipe.

3. Results

3.1 Pressure Drop and the Apparent Viscosity

In the Figure 2 can be seen that the increase in pressure drop is proportional to the increase of flow rate, presentation of solid particles and also the influence of spiral pipe geometry. Through the graph it can be seen that the pressure drop gradually increases from the 20% CW presentation to the highest at a concentration of 40%. The influence of pipeline geometry gives an impact on the pressure drop that is the highest pressure drop value for each concentration on the spiral pipe compared to the circular pipe. For the obtained flow rate, the lowest flow rate values average is 6 lpm and the highest are 15 lpm. The combination of resistance to high flow rates and particle interactions plays an important role in influencing increased pressure drop.

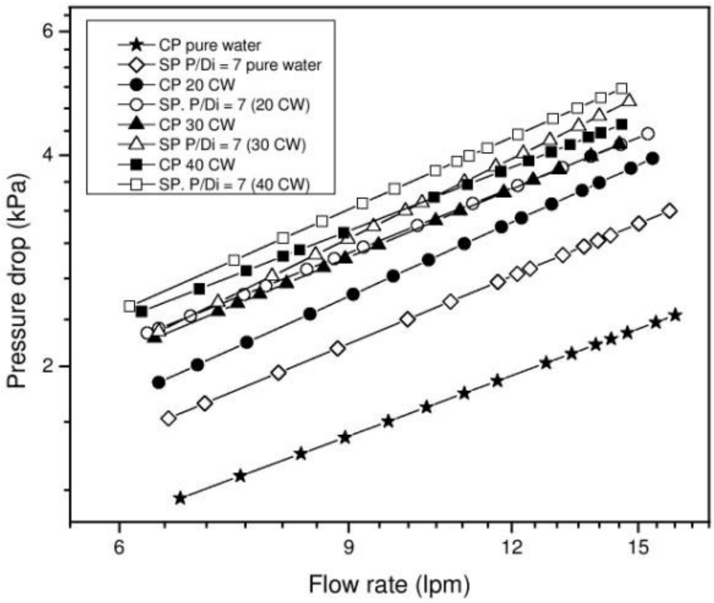

Fig. 2. Comparison of flow rate against pressure drop

Figure 3 can be seen comparison of apparent viscosity and shear rate. In the figure it can be seen that the apparent viscosity μ, is linearly proportional to the shear rate for each contents of slurry. Apparent viscosity is increase with an increase in content of concentration Cw. Apparent viscosity decreases dramatically to be the constant line.

This condition is similar to previous studies to determine the characteristics of the pseudoplastic working fluid flowing in natural pipes [17]. Under these conditions the working fluid characteristics behave like a gel called shear bending.

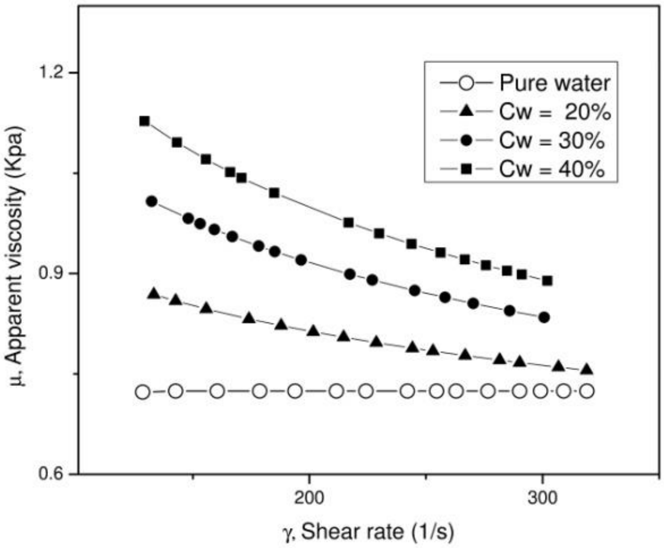

Fig. 3. Comparison of shear rate against apparent viscosity

3.2 Drag Reduction

In Figure 4 and 5 can be seen that the friction factor of the mud that occurs in the circular pipe is higher than that of pure water. In the turbulent flow, friction factor tends to decrease but does not reach the pure linear water value to the Blasius equation. In the spiral pipe, the friction factor value in laminar flow occurs much higher than the Hagen-Poiseuille equation.

In the passive control, this phenomenon occurs due to the geometry of the spiral pipe. At low Re, the shear rate value of the low working fluid impacts on a relatively high apparent viscosity value. Swirl flow resulting from the geometry of the spiral pipe resulted in apparent viscosity gradually decreasing to affect the effect of a lower friction factor from pure water at about Re' 8 x 10^3 to 5 x 10^4. This effect resulted in the highest DR on spiral pipe reaching 25.58% on Re' 5 x10^4.

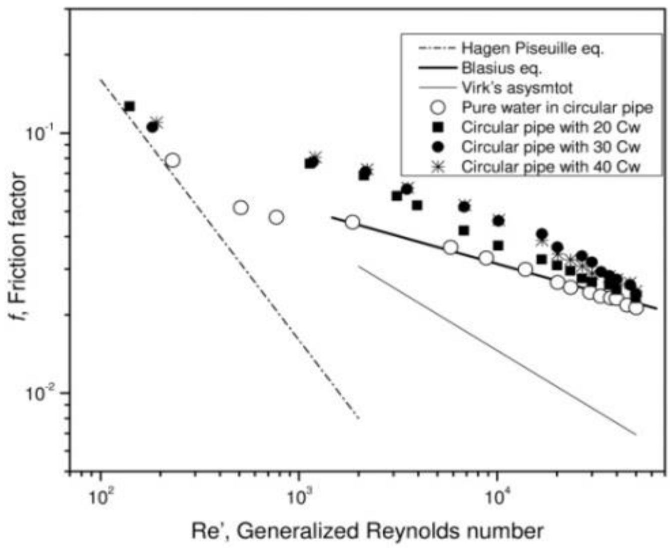

Fig. 4. Comparison of generalized Reynolds number with friction factor for circular pipe

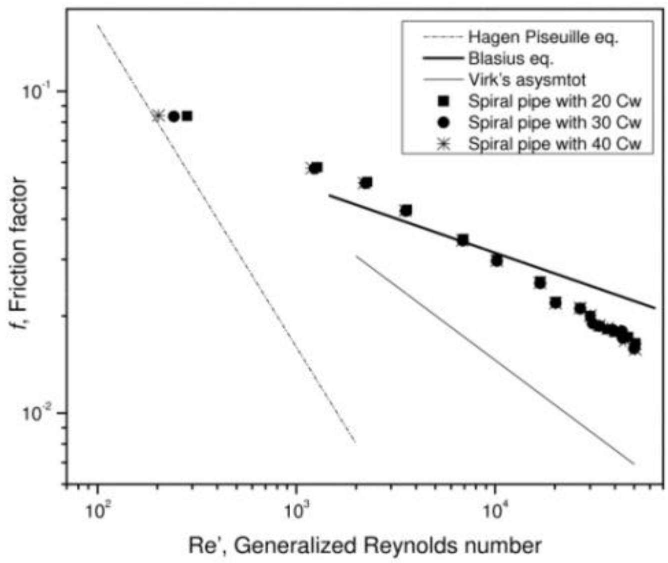

Fig. 5. Comparison of generalized Reynolds number with friction factor for spiral pipe

3.3 Density Changed of Working Fluid

Figure 6 illustrate the relationship between the flow rate and density of the spiral pipe in the event of drag reduction. The density of each known concentration before flow was 2333 kg/m^3, 2461.26 kg/m^3, and 2470.14 kg/m^3 for Cw = 20%, 30% and 40% respectively. The phenomenon that occurs in the slurry when flowed is a density change as shown in Figure 6 below.

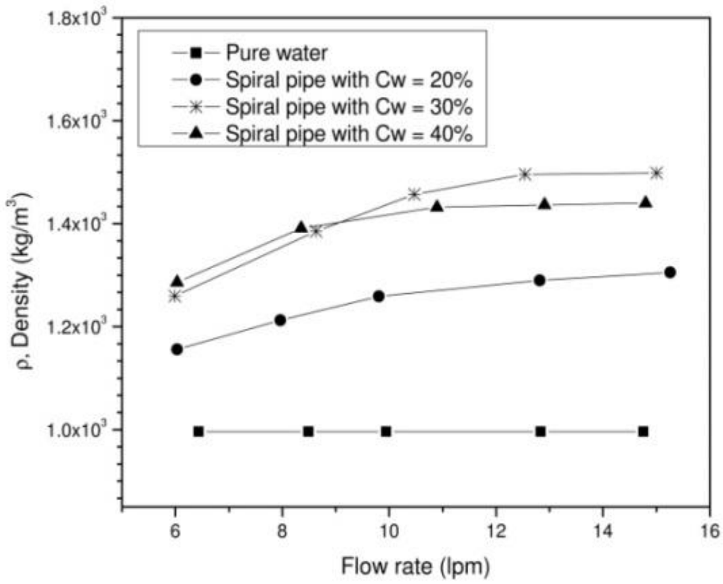

Fig. 6. Comparison of flow rate versus density of slurry in the spiral pipe

The data collection to know the value of density change is done at the same time range for each working fluid concentration. In pure water flow no temporary density changes occur in the 2 phase fluid change occurs where the fluid density is increasing proportional to the increase of discharge.

Density changes that occur in the slurry at the beginning of the measurement, the density increases drastically and tends to be constant at the discharge debit which reaches approximately 15 lpm. At the beginning of the flow, the lowest sludge density value is at concentration Cw = 20% next 30% and 40%. At a discharge of about 7 lpm the working fluid density with Cw = 30% increases beyond the working fluid density value of Cw = 40%.

4. Conclusion

The flow characteristic of mud slurry suspension in the circular pipe is categorized as shear thinning fluid. It can be seen from the viscosity that is depend on the shear rate. On the other hand, the drag reduction is occurred using the spiral pipe in all concentration. However, the highest drag reduction (DR) is obtained for Cw = 30% with 25.58% of DR at Re' about $5x10^4$. The value of DR obtained is directly proportional to the amount of mass per unit volume of the suspension collected.

Acknowledgements
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