Determination of Flow Properties of Mud Slurry

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Abstract-Although many types of viscometer are available, most of them are quite unsuitable for collecting scientific or engineering data. Due to various features of their construction make it impossible to determine both shear stress and shear rate at the same known point in the equipment. The flow curve therefore can not be constructed from data obtained with such devices. Most of these unsatisfactory instruments give complex reading functions of several type of fluid properties. The aim of this study will examine the viscous properties and to make curve of mud slurry by horizontal pipe as viscometer. These viscometer determine relationships between shear stress and shear rate. The diameter of pipe was 12,7 mm. The length of pipe was 1000 mm. Calculated the shear stress and the shear rate by measuring the pressure loss gradient and the gradient of velocity, respectively. Weight fraction of mud slurry were 20 %, 30 % and 45 %. The results indicated the apparent viscosity of mud slurry is not proportional to the shear stress and shear rate but the relationship could be approximated by power law's mode with the index n = 0.93 – 1.0

Keywords: shear stress, shear rate, flow curve, mud slurry, horizontal pipe, viscometer, apparent viscosity.

I. INTRODUCTION

The hydraulic transport of solids in pipes is economically attractive in comparison to transport by truck, railway or ship. The goods transported over long distances are mainly coal and iron ore and the carrier fluid is water. Since the longest pipelines for the hydraulic transport are about 400 km in length, by using drag reducing additives considerable energy saving should be possible in the hydraulic transport of solids. Mud slurry is essentially a mixture of solids and liquids. Its physical characteristics are dependent on many factors such as size of particles, concentration of solids in the liquids phase, size of the conduit, temperature and viscosity of the carrier [1]. The flow slurry in a pipeline is much different from the flow of a single-phase liquid. Theoretically, a single-phase liquid of flow absolute (or dynamic) viscosity can be allowed to flow at slow speeds from a laminar flow to turbulent flow. If the slurry's speed of flow is not sufficiently high, the particles will not be maintained in suspension. On the other hand, in the case of highly viscous mixture will be too viscous and will resist flow. The flow regimes were classified into six categories: homogeneous flow, heterogonous flow, fully moving bed, part stationary bed and stationary bed, and the empirical formulations to estimate the pressure drop in two phase flow was obtained. [6]

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II. BASIC THEORY

The Pressure drop flow throught a section of pipe a constant diameter between two location 1 and 2 can be write: [1]

$$F_{12} = \frac{\pi}{4} D^2 (P_1 - P_2)$$

This force is balanced by the friction Force, Fr

$$F_r = \tau_w \pi D L$$

Where L is the distance between point 1 and 2

$$\frac{\pi}{4} D^2 (P_1 - P_2) - \tau_w \pi D L = 0$$

or

$$\tau_w = \frac{D(P_1 - P_2)}{4L} = \frac{D \Delta P}{4L} \quad \textbf{(1)}$$

where R is pipe inner radius, D is pipe inner diameter, and τ_w wall shear stress.

For a Newtonian fluid the shear stress is proportional to the velocity gradient (shear rate), can be write: [2,3,4]

$$\tau_w = \mu \frac{\partial u}{\partial y} \qquad (2)$$

Where $\vartheta u/\vartheta y$ is Shear rate (velocity gradient). The constant of proportionality (μ) is called the Newtonian viscosity. The Newtonian viscosity depends only on temperature and pressure and is independent of the rate of shear. The diagram relating shear stress and rate of shear the so – called flow curve, see fig.1

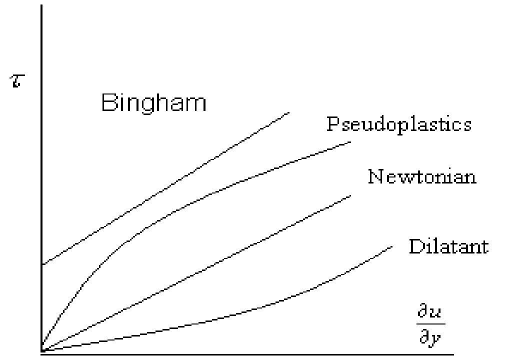

Fig 1. Flow curves
Newtonian and non-Newtonian Fluids [1],[7]

Non Newtonian fluids (Bingham, Pseudoplastics, and dilatants) are those for which the flow curve is not linier. The "viscosity" of a non Newtonian fluids is not constant at a given temperature and pressure but depends on other factors such as the rate of shear in the fluids. Non-Newtonian fluids may be described by theological equation of the form: [5,7]

$$\tau_w = \mu_a \left(\frac{\partial u}{\partial y}\right)^n = \mu_a (\gamma)^n \qquad (3)$$

where μ_a is apparent viscosity, 'n ' is power law Index, and γ shear rate

Power Law Index (n), can be write from equation:[10]

$$n = \frac{Log \dfrac{\tau_1}{\tau_2}}{Log \dfrac{\gamma_1}{\gamma_2}} \qquad (4)$$

The relationship between volume percent solids, solids specific gravity of the suspending medium, and the weight percent concentration of solids is given as follows: [7,8]

$$Cw = \frac{Cv\rho_s}{Cv\rho_s\,(100 - Cv)} = \frac{Cv\,\rho_s}{\rho_m} \qquad (5)$$

where Cw is weight percent solids, Cv is Volume percent solids, ρs density of solids, and density of mixture.

III. EXPERIMENTAL SETUP

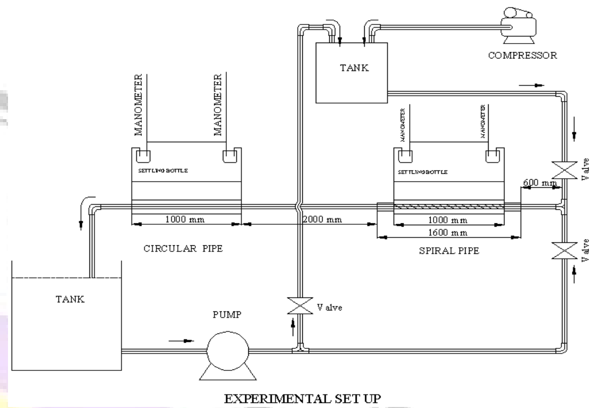

Fig.2. Experimental Set Up

The experimental set up was shown in fig.2. The mud slurry were circulated by pump and collected in tank where they were mixed to uniform concentration. The pressure drop was measured at 1000 mm length between each pressure tap by manometer through a settling botole. The inner diameter of test pipe was 12,7 mm. The shear stress and the shear rate can be obtained by measuring the pressure loss gradient and the gradient of velocity, respectively. Weight fraction (Cw) of mud slurry was 20 %, 30 % and 45 %. The temperature was keep at 27 ^oC.

III. RESULTS AND DISCUSSION

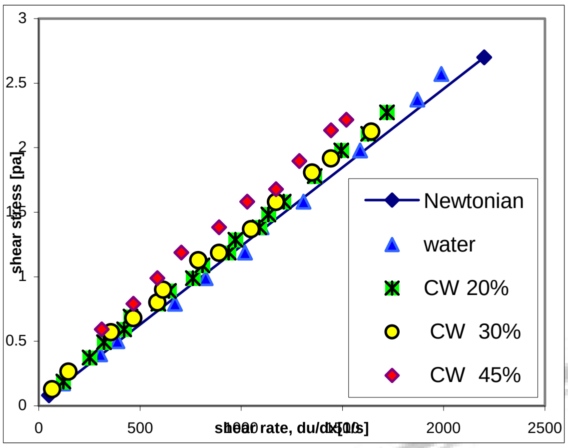

Fig.3. Flow curve of mud slurry

Fig.3 shows the flow curve of the mud slurry solution measured using a horizontal pipe. The temperature of mud slurry was maintained at T = 27 ± 0.5 ^{o}C throughout the experiments because the mud slurry rheology is temperature dependent. The effect of mud slurry degradation on the result was examined by means of pipe friction loss measurement at the start and end of the experiment. The plot data for Cw = 45 % is not linier, indicating that the material is a power law fluid over this range of shear stress.

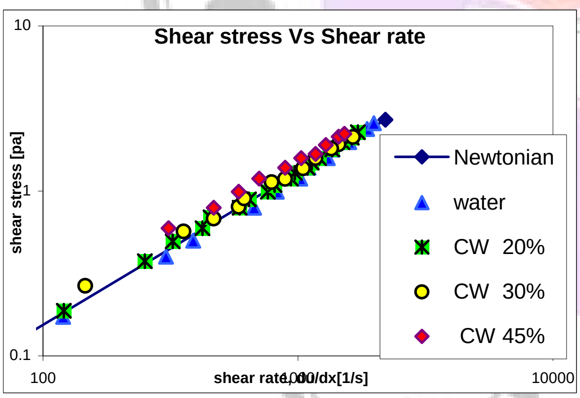

Fig.4. Flow curve of mud slurry (log-log)

In Figure 4. Using standard tangent-drawing procedures, tangents are drawn to the curve at various 8V/D, to obtain corresponding value of n from the tangent slop K from the tangent intercept at 8V/D equal to unity. The flow curve shear Stress τ is plotted against shear rate, du/dx for mud slurry.

The plot is linier, indicating that the material of mud slurry is a power law fluids over this range of shear stress. Since the value from all there weight fraction of solution on the same single curve, the value of power law index for mud slurry were n = 0.93 – 1.0.

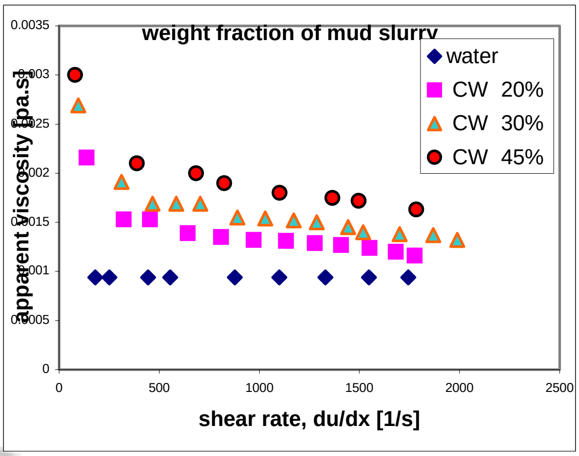

Fig.5. Apparent Viscosity of mud slurry

Measurement of the viscosity of mud slurry was carried out bt horizontal pipe viscometer, and the data of 20 %, 30 %, and 45 % weight fraction of mud slurry, Cw solution are presented apparent viscosity versus shear rate in fig.5. It can be seen that the viscosity increased with decreasing shear rate although tended to a constant value in the high shear rate region. The viscosity differed with the type of viscometer and the hysteresis of the viscosity occurred. Because the viscosity of mud slurry was complicatedly depend on many parameters, the generalized Reynolds numbers was calculated using the apparent viscosity of mud slurry.

IV. CONCLUSIONS

Curve flow characteristics of mud slurry were measured by horizontal pipe viscometer and calculated the shear stress and shear rate at the wall by the measurement of flow rate and the pressure loss. The results are summarized follows:

The mud slurry behaves as the Newtonian fluids for Cw 20 %, 30 % and the shear thinning fluid (pseudoplastics fluid) for Cw = 45 %. The power law model describes approximately the behavior of mud slurry and the range of the power law fluids index is n = 0.93 ~ 1.0.

List of Symbols

Cw = weight percent solids (%)
Cv = Volume percent solids (%)
D = Pipe inner diameter (m)
K = Power Law coefficient
L = length (m)
n = Power Law index (-)
U = Mean velocity (m/s)
τ_w = wall shear stress (Pa)
ρ = density [kg/m^3]
γ = du/dx = shear rate (1/s)
γ = 8 U/D
μ_a = Apparent viscosity (Pa.s)

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