管路を用いたモンモリロナイト懸濁液の流動特性の解析

Flowing Characteristics of Montmorillonite Suspension in Pipe

Hu Tianchen [1]・Roknujjaman Md [2]・Yohei Asada [2]・Yasuhisa Adachi [2]

[1] Graduate School of Science and Technology, University of Tsukuba

[2] Faculty of Life and Environmental Sciences, University of Tsukuba

Abstract

In order to study the hydrodynamic characteristics of clay suspension from laminar flow to turbulent flow, we have constructed a simple set-up of circular type pipeline experiment equipped with two pressure sensors and a flow meter. Flowing characteristics are monitored by the pressure drop as a function of flow rate. To examine the excluded volume effect of the floc formation, we tested four different types of fluid in the experiments: (a) water; (b) 1.0M NaCl solution; (c) water + 0.1% volume fraction Montmorillonite; (d) 1.0 M NaCl solution + 0.1% volume fraction Montmorillonite. By the pre-experiment using spiral capillary viscometer, (a) –(c) can be confirmed to be approximate as Newtonian fluid while (d) as non-Newtonian. To determine the viscosity of fluid (d) for the calculation of Reynolds number (**Re**), we assumed sample (d) follows Bingham model and applied the method purposed by Ohgaki and Matsuo. As the result, flocculated suspensions are confirmed to have significantly higher friction in the laminar flow region but mostly similar or slightly smaller friction in the turbulent flow region than those of other three samples.

Key words: Flowing characteristic, Pipe flow, Montmorillonite, Flocculated Montmorillonite

1. Introduction

In natural environment, nutrients and chemical pollutant that cannot dissolve in water are apt to adsorb on the colloidal particles which are ubiquitously present in soil and water. Clays are major components of environmental colloid. Understanding the behavior of such colloid is very important to predict the transportation and fate of chemical substances [1].

However, there are few studies on the flowing characteristics of clay suspensions in turbulent flow yet. In the present study, we focus on the flowing characteristics of water containing clay particles which is apt to flocculate in pipe flow system. The montmorillonite is used as the typical clay material. Especially, we focus on the friction factor changes with Reynolds number.

2. Materials and Method

In this study, we used four types of fluid in the experiment. They are (a) pure water, (b) 1.0M NaCl, (c) 0.1% volume fraction of montmorillonite and (d) 0.1% montmorillonite with 1.0M NaCl.

Figure 1 shows the schematic diagram of experiment setup of the pipe flow system. Here P is the Pressure logger. The length of the measure is 1.0m. The inner diameter is 9.0mm. The material of the main pipe is transparent acrylic resin. The evaluation of flowing characteristics is carried out on the basis of the Darcy-Weishbach equation:

$$\Delta p = f \cdot \frac{L}{D}\frac{\rho v^2}{2} \qquad (1)$$

Here, Δp is the pressure difference between the two measuring points; f is the friction number; L is the length between the measuring points; D is the inner diameter of the pipe; ρ is the density of the fluid and v is the flow velocity in the pipe. In order to obtain the **Re**, viscosity of the fluid is necessary.

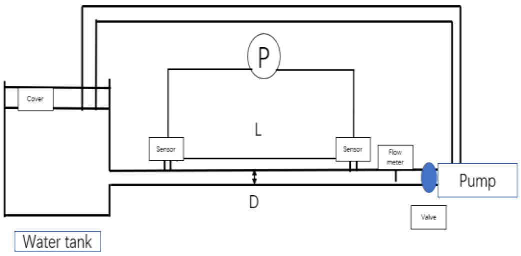

Figure 1. Schematic diagram of experimental setup up.

As pre-experiment, we measured temporal change of the difference of the liquid level, $h(t)$, of the spiral capillary viscometer depicted in **Figure 2** of four samples. From the result indicated in **Figure 3**, sample (a) –(c) were confirmed to be Newtonian flow, their viscosity can be calculated as the relative viscosity compared to the water from the slop of $ln\frac{h(t)}{h(0)}$ vs. t [2].

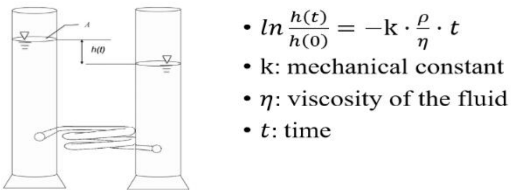

Figure 2. Spiral capillary viscometer. The two cylinders are connected with a spiral capillary.

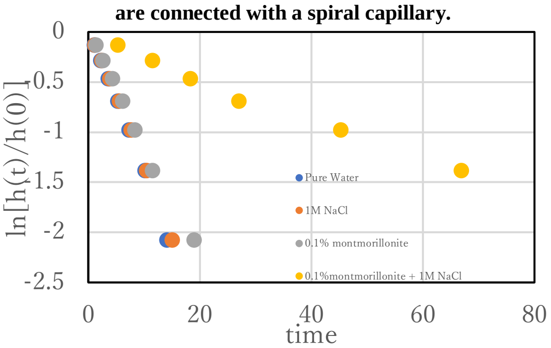

Figure 3. Pre-experiment in spiral capillary viscometer

The sample (d) was a non-Newtonian fluid, we assume sample (d) follows Bingham model and applied the method purposed by Ohgaki and Matsuo [3]. That is, in pipe flow system, form the force balance, the shear stress at wall (τ_w) can be expressed as:

$$\tau_w = \frac{\Delta P}{4}\cdot\frac{D}{L} \qquad (2)$$

For Bingham model in laminar region, we have:

$$\frac{8v}{D} = \frac{\tau_w}{\eta} - \frac{4}{3}\cdot\frac{\tau_y}{\eta} \qquad (3)$$

Here η is the plastic viscosity of the fluid and τ_y is the yield stress of the fluid. Therefore, with the pressure difference and the flow rate we got from the experiment, the plastic viscosity and yield stress can be obtained as shown in **Figure 4**.

3. Results and Discussion

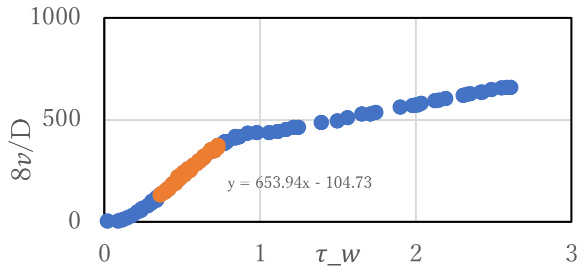

Figure 4. $\frac{8v}{D}$ **vs.** τ_w **of sample (d) in Bingham model.**

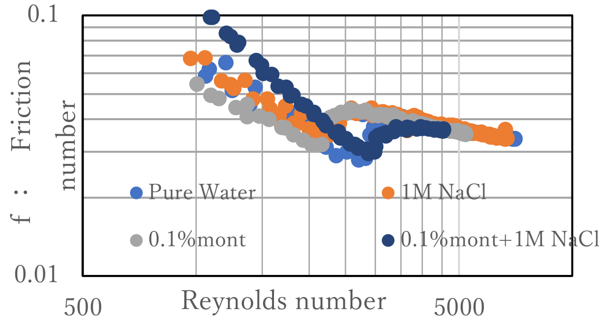

Figure 5. Moody diagram of four samples

4. Conclusion

As indicated in **Figure 5**, for montmorillonite, flocculated suspensions are confirmed to have significantly higher friction in the laminar flow region but mostly similar or slightly smaller friction in the turbulent flow region as those of other three samples.

References

[1] Y. Adachi, Y. T. Kawashima, M. E. B Ghazali (2020), KONA Powder and Particle Journal, 2020 Vol. 37 P145-165

[2] Kobayashi S. and Adachi. Y, JSIDRE 2005, Vol. 2005 Issue, 238 P79-84

[3] Ohgaki S. Matsuo T. Proceedings of the Japan Society of Civil Engineers, 02/1973, Vol. 1973, Issue 210, P 21-32