

Shape Effect of Solids on Pressure Drop in a 2-Phase Vertically Upward Transport: Silica Sands and Spherical Beads

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ABSTRACT

Experimental investigation is conducted to study the flow characteristics of a 2-phase vertically upward hydraulic transport of 2 types of small solid particles of nearly identical specific gravity and size in a clear, smooth-surfaced, PVC pipe of 1-in (2.54 cm) diameter: Irregular-shaped silica sands and equivalent spherical glass beads. The emphasis of the investigation is placed on the shape effect of particles on the pressure gradients and flowrates. Pressure drops and mass as well as volumetric flow rates were measured by 2 types of flowmeters: electromagnetic (EM) flowmeter and mass flowmeter. The particle sizes used are 30-40 mesh and 8-10 mesh. The results over a turbulent flow range of $10^4 < Re < 10^5$ show the pressure gradients or friction factors are smaller for the spherical glass beads than the irregular-shaped sands. The larger the size of particles is, the larger the shape effect on the pressure gradient becomes, and the more distinct the effect of the particle shape becomes at lower particle concentrations. The larger the size and concentration of the particles are, the larger the pressure gradients become. The larger the particle concentration is, the less the effect of particle shape on pressure gradients becomes. The shape effect is greater for the minimum particle transport velocities than for the settling velocities.

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Unit conversion: 1 m = 3.281 ft.

KEY WORDS: Vertical hydraulic transport, 2-phase flows, silica sands, spherical glass beads, concentrations, size, pressure gradient, friction factor, electromagnetic flowmeter, mass flowmeter.

INTRODUCTION

The present experiment series is to investigate various effects for vertical 2-phase mixture transport and flow characteristics of the particle-water mixture. Its ultimate purpose is to model a vertically upward hydraulic transport system to produce solid particles or solids in alluvial form, including heavy mineral particles from the deep-ocean

floor. The present results come from one of the first series of experiments with a 1-in-diameter test loop.

Among the many experiments of the vertical particle-water mixture flows that were previously conducted for the vertical hydraulic transport of solid particles, Newitt et al. (1961) presented comprehensive measurements and analysis of the particle-water flows; namely, the flow rates, hydraulic gradients and concentrations. But no direct instrument measurements were made at the time, and the measurements were made with the slurry sample collection from the flow. Matching their 0.71-mm silica sands, Sand C in 25 mesh in the U.S. standards, equivalent silica sands of 30-40 mesh in the U.S. standards are used as a reference in validating the present experiment setup and flow data measurements. Their presentation includes the hydraulic gradients and flow rates, but not directly the pressure gradients.

The friction factors from the present experiment with tap water are validated by the Blasius equation. The present results of the hydraulic gradient, with 30-40 mesh ($d = 0.6-0.425$ mm in average diameter) silica sands, generally agree with those of Newitt et al. (1961). As to the effects of the solid concentration, their measurements with the 1-in-diameter brass pipe show that the hydraulic gradients of their 0.71-mm-diameter silica sands were independent of the sand concentration for the cases equivalent to the present 30-40 mesh ones. Contrary to theirs, the present results obtained with the flowmeters show that the hydraulic gradient increases with the increase in the sand concentrations, and this is discussed further below.

Often minerals (e.g., manganese nodules and coal) for the laboratory-scale experiment of the 2-phase transport were simulated with substitute materials of identical specific gravity (for example, see Kitahara et al., 1985). Their pipe size is 15.72 cm and solids tested are an order-of-magnitude larger than the present particles. They tested with simulated nodules, sands and rubber balls: 6.4-42 mm in size and 1.17-2.71 in specific gravity (S.G.). Hydraulic gradients including the static head were presented. Trend of shape effect can be observed from their data. Because of the larger pipe diameter, they were able to use γ -ray radioactive densitometer. Systematic analysis of shape effects on the pressure gradients for alluvial minerals rarely appear in the literature.