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Two-phase Vertically Upward Transport of Silica Sands in Dilute Polymer Solution: Drag Reduction and Effects of Sand Size and Concentration

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An experiment of a 2-phase vertically upward hydraulic transport of silica sands in the dilute polymer solution Xanvis L in a pipe is conducted to investigate the effects of a polymer additive, silica-sand particle size and concentration on pressure gradient Δp/L or drag. The sand particles are in 3 sizes: 8~10, 30~40 and 80~100 mesh (2.36~2.00, 0.6~0.425, 0.180~0.150 mm). The concentration ranges are from 2.2% to 9.3%, and the flow loop is made of a clear PVC pipe 2.54 cm in diameter. Pressure drops and average flow rates were measured in the Reynolds number range of $10^4 < Re < 10^5$. Flows in a dilute polymer solution significantly reduce the Δp/L or drag of water-sand mixture flows in the higher Reynolds-number range, where drag or Δp/L reduction is as much as 60%. In the lower Re range, however, the Δp/L for the mixture flows either with or without the polymer additives becomes larger than the flows of water without the sand mixture. Higher drag reduction or lower Δp/L occurs at the higher Re range, while drag gradually increases with the lower Re over flows of water alone (without the mixture and additives.) The trend of the drag increase over water alone with a polymer additive over the flows without starts at the higher Re values with the increase of the concentration. The conventional perception is that the smaller the particles, the smaller the drag or Δp/L. Instead, the measured Δp/L values for the 80~100-mesh finer sand particles are larger than those of the larger 30~40 mesh sands. Similar results were also previously reported for the flows without polymer additives.

KEY WORDS: Vertical hydraulic transport, pipe, 2-phase flows, silica sands, size, concentrations, Xanvis-L polymer, non-Newtonian effect, drag, pressure gradient, coil tubing, oil drilling.

Unit conversion: 1 m = 3.281 ft

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INTRODUCTION

The present experiment investigates the effects of sand particle size and concentration on pressure gradient or drag in 2-phase flows of silica sands in water for vertical upward hydraulic transport. Chung et al. (1998 and 1999) previously reported on the shape effects of sand particles on the pressure gradient. This experiment's ultimate purpose is to model vertically upward hydraulic transport with the effects of solid particles on the flows of solid particles or minerals in alluvial form from the deep-ocean floor (see Chung, 1996), and coiled tubing in oil drilling. The present result is one of a series of experiments of solid particle-water mixtures in a 1-in-diameter ((2.54-cm-diameter) flow loop.

The conventional perception of fine particle flows in water, but without defining the size range of the fine solid particles, has been that there may be non-Newtonian-type drag reduction for the pipe flows of fine particles. This led to the present investigation, which conducted experiments of the mixture flows of 3 sand particle sizes, including fine sands of 80~100 mesh in water as well as a dilute polymer solution (Chung and Graebel, 1972). This fine sand size is also in the range of the sand particle size in the coil tubing of the petroleum industry. The present result has not indicated the validity of this conventional perception.

Using the previous experiment setup and procedure for the 2-phase vertical hydraulic transport of silica sand particles (e.g., Chung et al., 1998, 1999, 2001), the investigation of drag reduction, particle size and concentration effects in the flows of a dilute polymer solution on pressure gradients is reported. Before presenting the results, however, instrument and data analysis are summarized as follows.

EXPERIMENT SETUP, SOLID PARTICLES AND POLYMER CONCENTRATION

The test particles used are silica sand particles in 3 sizes (8~10, 30~40