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The Multi-Sized Slurry Flows in Horizontal Pipes : Innovated Models and Verification*

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In designing pipeline systems for commercial slurries, it is essential to accurately determine the hydraulic gradient at transport velocities. It is crucial to note that the slurries are conveyed as a mixture of multi-sized solids and water. Although many researchers have proposed correlations for the prediction of hydraulic gradient, most have been developed for slurries with uniform sized particles of solids.

By considering two different transport conditions of a mixed-sized slurry, innovated models were proposed and then verified with experimental data. The data was also analysed with the Wasp method and the conventional method by Condolios-Chapus.

Measurements of hydraulic gradient, solids concentration, and flow velocity in a 1-inch pipeline were made in this study. Predictions with the innovated models could be correlated with the data including experimental results from large scale pipelines, in spite of discrepancies at unstable flow regimes.

Key Words : design model, hydraulic gradient, multi-sized slurry, horizontal pipeline

1. Introduction

Although multi-sized particles slurries are transported in practical pipelines, most reported correlations were proposed for single-size slurries. If the average diameter of solids is used to estimate the drag coefficient of multi-sized particles slurries, the hydraulic gradients with these correlations lead to considerable scatter of data [1]. Kazanskij [2], Moro [3], and STSJ (Slurry Transport Society of Japan) [4] summarised some empirical equations of hydraulic gradient of slurry flow with experimental data. The Wasp method [5] recommended by Liu [6] has been used by designers of pipeline systems for predicting hydraulic gradient of compound slurries of homogeneous and heterogeneous flows. However, the method is limited for application to a wide range of transport conditions. Kaushal et al. [7] also discussed the limitations and attempted to modify the method. They concluded that the Wasp method provided reasonable accurate results at limited low concentrations.

The purpose of this paper is to discuss the limitations of application of other researchers' correlations and to develop innovated models, based on the single-size slurry model of Seitshiro et al. [8] The analytical models depend on particle size distribution: (1) coarse-coarse model; for a slurry consisting of two different coarse solids flowing in water, and (2) coarse-fine model; for coarse solids being transported in a modified vehicle containing fine particles in high concentration. The fine solids are defined as particles with sizes smaller than the critical diameter [9] in this study. For both models, it is assumed that the coarse solids in the slurry do not hinder each other's movements.

Experiments were performed in a 1-inch transparent pipe with sand-bakelite mixed slurries. The data of Shook et al. [10], Boothroyde et al. [11], and that of this study were used to verify the application of the models. The analytical results suggest that the innovated models can be effective for designing slurry pipelines.

2. Experimental

For verifying the applicability of the models, a wide range of data from three different systems is used: a 1-inch pipeline system of the authors, closed and open loop systems of Shook et al. [10], and prototype systems of Boothroyde et al. [11]

2.1 Experimental techniques

The experiments were conducted in a closed-loop, horizontal transparent perspex pipe of diameter 2.62 cm and length 25.7 m, presented schematically in Figure 1. For clarifying the solids behaviours, two different kinds of solids, sand and coloured bakelite (Polyoxybenzyl methylene glycol anhydride), were used for the mixed-sized slurry flow experiments : particle sizes ranging