

Determination of Distributions of Velocity and Concentration of Solids in a Horizontal Slurry Pipeline with a Digital Video Camera System

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ABSTRACT

This paper reports measurements of particle velocities and concentrations in circular and rectangular conduits by means of a high-grade digital video camera and a stroboscopic lamp. The distributions of the velocity and the concentration are determined by image processing for the motion of solid particles. The results are discussed in terms of the criterion for the identification of particles on the images and the dependence of the velocity distribution on the concentration distribution.

KEYWORDS: Settling slurry, hydraulic transport, concentration distribution, velocity distribution, image processing, horizontal pipe, sand slurry

1. INTRODUCTION

For the more effective design of transporting settling slurry through pipes, a precise determination of the distributions of the concentration and velocity in the whole flow section is essential. Pressure drops and critical deposit velocities in pipes are important parameters and are dependent on such distributions (Roco and Shook, 1985; Sato et al., 1991). Some measuring systems for determining local particle velocities and/or concentrations have been conducted by Newitt et al. (1962), Ayukawa (1972), Brown et al. (1983), and Nasr-El-Din et al. (1986). Furthermore, models of theoretical prediction have been proposed in predicting the concentration distributions (Roco and Shook, 1984, 1987; Gillies and Shook, 1994; Sato et al., 1997). In most of the reports, however, one could not compare experimental data of the concentration distribution with those of velocity distribution in the corresponding flow conditions in pipes. The absence of a broad base of experimental data of a pair of distributions of the velocity and the concentration from previous studies prompted the experimental work in this paper.

Experiments were performed in 1-in transparent pipe connected to a rectangular channel 2.48 cm x 2.48 cm and 2 m in length with sand slurries. A high-grade digital video camera was positioned at the return pipe of a closed loop where conditions were sufficiently stable for the testing period. A stroboscopic lamp was also used for the velocity profile measurement. On this experimental system a new procedure of image processing was proposed for: the criterion of identification of superimposed solid particles, modification of the optical distortion near the bottom of pipes, and the correlation between three-dimensional and two-dimensional concentrations.

It appears that the present measuring system will provide useful information concerning the flow structure, flow patterns and the determination of the critical deposit velocity, since the system makes the continuous and direct observation of the slurry flow in pipes possible.

2. EXPERIMENTAL TECHNIQUES

2.1 Experimental equipment and procedure

A schematic diagram of the experimental equipment is shown in Fig. 1. It consists of a pumping system, an optical observation system for distributions of local velocity and concentration, and a measuring system to obtain a set of operational conditions such as the slurry flow rate, the pressure drop, and water temperature.

The slurry was circulated by a solid pump in horizontal closed flow loops containing circular and rectangular test sections in the conduits made of glass with an internal size of diameter 2.62 cm and 2.48 cm x 2.48 cm, respectively, and 2m in length. The observing section in the conduits was surrounded by a box of square cross-section, filled with water in order to decrease parallax effects near the upper and lower ends of the conduits, according to a conventional measurement