Slip Velocities in Mixture Vertical Pipe Flow

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ABSTRACT

The paper presents results of an experimental investigation of conveyed particles and carrier liquid velocities during flow of heterogeneous mixture in a vertical pipe. Measurements were carried out in hydraulic laboratory of Wroclaw University of Environmental and Life Sciences in transparent pipe of inner diameter $D = 150$ mm. Velocities of individual particles of different diameters were measured by radiometric method during vertical mixture flow. Goal of investigation was determining of slip velocities for the artificial nodules of mean diameter $d \approx 30$ mm during the heterogeneous mixture flow in vertical pipe for mixture velocity range from 1.5 m/s to 3.5 m/s, mean volume concentration of solids was about 5%.

KEY WORDS: Slip velocities, vertical flow, mixtures, radioisotope, pipeline

INTRODUCTION

Hydraulic pipe transport is one of the basic systems of transporting nodules from the ocean bed to the surface. The physical mechanism of the flow of the mixture of nodules and water in a vertical pipe has been studied by various laboratories. The key parameters of this mechanism are the velocities of the two phases of the mixture, as these phases move towards the ocean surface at different speeds. Therefore, in order to correctly determine the efficiency of a system of transporting nodules to the ocean surface, it is necessary to know the velocities of individual phases. The difference between these velocities is referred to as the interfacial slip and is a subject of research of few laboratories. This includes the studies by Lichter et al (2004), Xia et al. (2004), Yoon et al, (1999, 2009), and the previous studies by the authors of this paper (Sobota et al., 2000, 2001, 2007).

SCOPE AND METHODOLOGY

The studies of interfacial slip were performed for a mixture of water and artificial nodules at a volumetric concentration $c_v=0.05$. The volumetric density of the particles representing the nodules was $\rho_p=2000$ kg/m³. Slip values for the particles with a diameter $d$ of 30 mm were determined for various average flow rates of the mixture in a vertical pipe with a diameter $D=150$ mm. Table 1 presents the characteristics of 30 mm grade particles. The particles are shown in Figure 1. Radioisotopes were used to study the interfacial slip in a vertical pipe.

Table 1 Characteristics of the examined artificial nodules

<table>
<thead>
<tr>
<th>Particle size grade</th>
<th>Dimensions</th>
<th>Weight</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 mm</td>
<td>31.2x47.7x27.0</td>
<td>47.9 (47.9*10^-3)</td>
<td>K1</td>
</tr>
<tr>
<td>34.3x46.5x30.7</td>
<td>47.6 (47.6 *10^-3)</td>
<td>K4</td>
<td></td>
</tr>
</tbody>
</table>

![Fig.1. The image of the particles before the experiment (right-hand side: the particle with a bore for the isotope)](image)