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Effects of High Oil Viscosity on Drift Velocity for Upward Inclined Pipes

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Abstract

The translational velocity, velocity of slug units, is one of the key closure relationships in two-phase flow mechanistic modeling. It is described as the summation of the maximum mixture velocity in the slug body and the drift velocity. The existing equation for the drift velocity is developed by using potential flow theory. Surface tension and viscosity are neglected. However, the drift velocity is expected to be affected with high oil viscosity. In this study, the effects of high oil viscosity on drift velocity for horizontal and upward inclined pipes are experimentally observed. The experiments are performed on a flow loop with a test section 50.8 mm ID for inclination angles of 0º to 90º. Water and viscous oil are used as test fluids. Liquid viscosities vary from 0.001 to 1.237 Pa·s. A new drift velocity model is proposed for high oil viscosity for horizontal and upward inclined pipes. The experimental results are used to evaluate the performances of proposed model for drift velocity. The calculated drift velocities are compared very well with the experimental results. The proposed model could be easily implemented into translational velocity equation. It improves the existing two-phase flow models in the development and maintenance of heavy oil fields

Introduction

High viscosity oils are produced from many oil fields around the world. Oil production systems are currently flowing oils with viscosities as high as 10 Pa·s. Current multiphase flow models are largely based on experimental data with low viscosity liquids. Commonly used laboratory liquids have viscosities less than 0.020 Pa·s. Multiphase flows are expected to exhibit significantly different behavior for higher viscosity oils.

Gokcal et al. (2006) observed slug flow to be the dominant flow pattern for the high viscosity oil and gas flows. The knowledge of the slug flow characteristics is crucial to design pipelines and process equipments. In order to improve the accuracy of slug characteristics for high viscosity oils, new models for slug flow are needed such as translational velocity.

Translational velocity is composed of a superposition of the bubble velocity in stagnant liquid, i.e. the drift velocity, v_d, and the maximum velocity in the slug body. The research efforts have been focused on the drift velocity in horizontal and upward inclined pipes.

Nicklin et al. (1962) proposed an equation for translational velocity as,

$$v_t = C_s v_s + v_d \quad (1)$$

The parameter C_s is approximately the ratio of the maximum to the mean velocity of a fully developed velocity profile. C_s equals approximately 1.2 for turbulent flow and 2.0 for laminar flow.

Dumitrescu (1943) and Davies and Taylor (1950) performed a potential flow analysis to find the drift velocity for vertical flow. Both derived the same dimensionless group ($v_d / \sqrt{gD}$) has a constant value. Davies and Taylor estimated the constant value as 0.328. Dumitrescu made more accurate calculations and theoretically determined this value as 0.351 which agreed well with the air/water experimental data of Nicklin et al.

$$v_d = 0.351\sqrt{gD} \quad (2)$$

Zukoski (1966) experimentally investigated the effects of liquid viscosity, surface tension, pipe inclination on the motion of single elongated bubbles in stagnant liquid for different pipe diameters. He also found that the effect of viscosity is negligible on the drift velocity for Re ($= v_d \rho D/\mu$) >200. Wallis (1969) and Dukler and Hubbard (1975) claimed that there is no drift velocity for horizontal flow since gravity can not act in the horizontal direction. However, Nicholson et al. (1981), Weber (1981), and Bendiksen (1984) showed that drift velocity exists for the horizontal case and the value of drift velocity can