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Characterization of Oil Water Flows in Inclined Pipes

S. Atmaca*, SPE, C. Sarica, SPE, H.-Q. Zhang, SPE, and A.S. Al-Sarkhi, The University of Tulsa
* Currently with Schlumberger Oilfield Services

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Abstract

The flow of oil-water for different inclination angles (0^o, $\pm1^o$, $\pm2^o$ and -5^o) was studied through the analysis of high-quality experimental data on flow pattern, pressure gradients, water holdup and phase distribution (Atmaca (2007). A total of 324 tests were conducted in a 0.0508-m. ID 21.1 m. long, inclinable test section using tap water and mineral oil (with a density of 0.85 gr/cm^3 and viscosity of 15 cp) with superficial velocities ranging from 0.025 m/s to 1.75 m/s.

Oil-water flow in the petroleum industry is a common occurrence during production and transportation of gas-oil-water in pipes. Facilities design is strongly dependent on the flow behavior. The specific applications include design and troubleshooting of flow lines and wells, separator design, interpretation of production logs, etc.

Non-intrusive high-speed camera technique was used to determine the flow patterns at various conditions. Experimental flow pattern maps were compared against Trallero (1995) and Zhang and Sarica (2006) models. Trallero model predicted the most flow pattern boundaries well except stratified flow pattern. For most of the cases, the pressure gradients were over predicted by the Zhang and Sarica model. Quick closing valves are used for holdup measurements giving phase slippage information. For the low superficial velocities, slippage behavior was observed very clearly for upward and downward flow. For the high superficial velocities, slippage effects were diminished. Representative phase distributions, and interface boundaries were observed for different flow conditions by examining conductivity probe data.

This paper provides significant insight in phase distribution and slippage behavior. The results presented in this study are applicable not only to oil-water flow but also to three-phase gas-oil-water flow models.

Introduction

Two-phase liquid-liquid pipe flow is defined as the simultaneous flow of two immiscible liquids in pipes. Oil-water flow in pipes is a common occurrence in the petroleum industry during transportation and production. Moreover, two-phase liquid-liquid flow is common in the process and petrochemical industries. Although the accurate prediction of oil-water flow is essential, oil-water flow in pipes has not been explored as much as gas-liquid flow.

Results from gas-liquid systems cannot be readily used in liquid-liquid ones due to significant differences, such as the large difference in viscosities and similar densities, and more complex interfacial chemistry compared to gas-liquid systems. Currently, the more complex gas-oil-water flow is receiving significant attention due to the interest to better understand gas-oil-water flow since some of the flow configurations of gas-oil-water flow are quite similar to those of oil-water flow.

During the simultaneous flow of oil and water, number flow patterns can appear which range from fully separated to fully dispersed ones (Lovick and Angeli (2004)). Stratified flow has received more attention during the past years due to its low phase velocities and well defined interface. Moreover, most studies for the dispersed flow pattern are in stirred vessels, and can not be applied to pipe flow systems directly, due to different system configurations and energy requirements. In stirred vessels, the energy and the turbulence introduced by impellers are the main reasons for the breakage of the droplets. On the other hand, for pipe flow systems, turbulent and shear forces are effective and responsible for breakage of droplets. There is also limited information on an intermediate flow pattern, which lies between stratified flow and fully dispersed flow.

Experimental Facility and Flow Loop

The facility (as shown in Fig. 1) consists of a closed flow loop with the following components: pumps, heat exchangers, metering sections, filters, test section, separator and storage tanks. The test section is attached to an inclinable boom.

Oil and water storage tanks are equipped with valves at the outlet of each tank to control the flow rates. Two progressive cavity pumps feed the system. After the progressive cavity pumps, there are manual bypass valves to obtain low flow rates, and pressure relief valves for excessive pressure control. Following the valves, there are two copper-tube type heat exchangers