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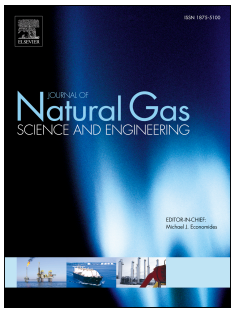

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An Experimental Investigation on Flow Pattern Map and Drift-Flux Model for Co-Current Upward Liquid-Gas Two-Phase Flow in Narrow Annuli

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Abstract

This study explored flow patterns and void fraction prediction models for co-current upward liquid-gas two-phase flow in narrow annular spaces. Experiments on two-phase flow in both narrow and wide annular conduits were performed in a 4-inch (0.102 m) outside-diameter test section, with 3.5-inch (0.089 m) and 2-inch (0.051 m) inner pipes as representations of different annular geometries. Flow patterns and liquid holdup were recorded while flowing air and water upward through the test sections. The experimental results showed that the two-phase flow pattern maps in narrow annulus and wide annulus are with different major regime transition lines. A new drift-flux model for water-air two-phase flow in narrow annuli was developed using experimental data collected in this study. The new model was compared against previous models that were developed for wide annuli, and the results showed a better match in void fraction predictions for two-phase flow in narrow annuli with experimental data. The understanding of two-phase flow in narrow annuli is vital for real-time prediction of void fraction and annular pressure loss in wells with gas influx during casing/liner/slimhole drilling operations. An enhanced prediction can ensure delivery of safer wells with lower non-productive time and associated trouble encountered during well control operations.

Keywords: Narrow Annuli, Two Phase Flow, Drift-flux Model, Flow Pattern, Casing while Drilling, Well Control

1. Introduction

Two-phase gas-liquid flowing through narrow annuli occur in various engineering applications, which include the flow during natural gas influx and well control practices while performing Casing while Drilling (CwD) and slimhole drilling operations. The behavior of liquid-gas two-phase flow in a narrow annulus is governed by the fluid rheology, annular and geometry, and flow rates. The geometry of flow conduit has a major effect on the liquid velocity distribution at a cross section and therefore affects the flow regime/pattern transition and the two phase flow behavior in general. It is not possible to understand the two-phase flow phenomena without a clear understanding of flow patterns, void fractions and pressure drops in narrow annuli.

Figure 1 shows the annuli geometries in CwD and slimhole drilling compared to conventional drilling. Casing while Drilling (CwD) technology has shown strong potential for drilling in depleted sections to mitigate lost circulation problems and reduce non-productive time (NPT) in drilling operations, especially in narrow pore-fraction pressure sedimentary basins and offshore applications. Researchers suggested many benefits of CwD, which include improvement of well economics, borehole stability, wellbore integrity, increased personal safety, and reduction of fluid losses (Rosenberg et al. 2010, Karimi et al. 2011, Salehi et al. 2013). Other authors reported that CwD showed a 10% reduction in cost and 30% saving in time (Lopez and Bonilla, 2010).In slimhole drilling, the hole diameter is generally less than 6 inches (0.152 m) and it requires its own drilling hardware and also using small- bits. Instead of the conventional kelly bushing, the system uses a hydraulic rotating torque head mounted on the mast. A key development area in slimhole drilling is the drilling mud. Slim holes generally have an annular space of about 0.5 inch (0.013 m) compared with 1.5–9 inches (0.038–0.229 m) in conventional wells. Because of the narrow annulus, high annular velocities are generated at low pump rates, which necessitates the need for viscosity building additives (Randolph et al. 1991).

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