OTC 19434

Multidimensional Simulations of Multiphase Flow for Improved Design and Management of Production and Processing Operation

Harald Laux, Ernst Meese, Sjur Mo, Tor Erling Unander and Stein Tore Johansen, SINTEF, Norway
Kris M. Bansal and Thomas J. Danielson, ConocoPhillips, USA
Alexandre Goldszal, and Jon Ingar Monsen, TOTAL, Norway

This paper was prepared for presentation at the 2008 Offshore Technology Conference held in Houston, Texas, U.S.A., 5–8 May 2008.

Abstract

Over the past five years, ConocoPhillips, TOTAL, and SINTEF have developed a novel transient multiphase flow simulator, called LedaFlow, with both one- and multi-dimensional capabilities. The aim of the development is to meet industry needs for improved simulation of fluids management and related flow assurance issues in oil/gas production and processing operations. LedaFlow is composed of a suite of models, including a complete one-dimensional transient model with compositional tracking, a complex network solver, and algorithms to couple models of different dimensions. The transient multi-dimensional model offers detailed flow distributions that are impossible to obtain with one-dimensional models. It was demonstrated recently that flow regime transitions, observed pressure gradients and liquid holdup can be accurately reproduced (Laux et al., 2007).

In the present paper, we analyze 2-phase flows in vertical risers and demonstrate the capabilities of multi-dimensional modeling. The prediction of vertical flows are very good except for low flow rates. We demonstrate that complex flow regimes (such as churn flow) are predicted with the LedaFlow quasi three dimensional (Q3D) model, without resorting to assumptions about flow regimes and structures. Q3D simulations show that small deviations from perfectly vertical flow may have a large effect on liquid hold-up and pressure drop. The Q3D model is furthermore applied to simulate an operational situation where fluids are displaced to prevent hydrate formation during shut-down.

Introduction

Using the LedaFlow quasi three-dimensional (Q3D) model it is possible to predict complex flow regimes such as gravity-induced and hydrodynamic slugging, as well as transitional flow (between wavy stratified and slug flow) in pipelines (Laux et al. 2008). Prediction results for wavy stratified flow is presented in Laux et al. (2007). In this paper, we address churn flow in vertical and deviated risers as well as fluid displacement to prevent hydrate formation during a shut-down situation. For multiphase flow in risers and wells, flow regimes are often very complex and can not be treated satisfactorily with 1D models.

One-dimensional (1D) models have been developed over the last 50 years to predict multiphase flows in pipelines. These models have been successful in assisting the industrial development but still have significant shortcomings due to simplifications and the use of empirical correlations. At the same time, new three-dimensional (3D) modeling techniques are developing fast, made possible by the continuous growth in available computational power. 3D Computational Fluid Dynamics (CFD) models can give information that both qualitatively and even quantitatively surpasses information obtained from 1D models.

A major problem, with most current 3D approaches, is that they are based on direct simulation of interface evolution. Due to the span in time and length scales in industrial problems, a multi-scale approach has to be developed. Such an approach needs to handle large-scale interfaces representing waves, coexisting with transport of bubbles and droplets, including deposition and entrainment. In addition, the Q3D approach should be able to represent large-scale spatial and temporal features of the real flows without using any assumptions about flow organization (flow regime). To meet these challenges, the development