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Multiphase Flow Modelling Based on Experimental Testing: A Comprehensive Overview of Research Facilities Worldwide and the Need for Future Developments

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Abstract

Multiphase flow models for the oil and gas industry are required to investigate and understand the co-current or counter-current flow of different fluid phases under a wide range of pressure and temperature conditions and in several different flow configurations.

To compliment this theoretical effort, experimental measurements are required to verify multiphase flow models under controlled conditions and assess their range of applicability. This is why there exists a large number of multiphase flow loops around the world.

However, there are numerous varieties of multiphase flow occurrences due to differences in pressure and temperature, fluid types, flow regimes, pipe geometry, inclination and diameter, and whether the flow is steady-state or transient.

Consider the example of hydrocarbon producing fields in the North Sea. Typical parameters for an oil well in the northern basins are as follows: production rate of 800-1600 cubic meters per day, tubing diameter of 0.102-0.130 meters, reservoir depth of 3000-3500 meters, oil density of 825-930 kilograms per cubic meters, gas-oil-ratio of 100 standard cubic meters per standard cubic meters and water cut up to 90%. For a gas well in the southern gas basin, the typical parameters become: initial production rate of 0.7 to over 2.8 million standard cubic meters per day, tubing diameter of 0.114-0.140 meters, reservoir depth of 2500-3500 meters and initial liquid-gas-ratio of less than 1 to over 30 standard cubic meters per million standard cubic meters. The operational pressure at the wellhead may reach up to 10 MPa and reservoir pressures can be as high as 30 MPa. Furthermore, not only do well performance values vary considerably across the world and, they also vary with time for the same field.

Building a flow loop that reproduces real hydrocarbon wells, including the reservoir inertia and the complex heat transfer process taking place between the wellbore and the reservoir, is not feasible. Thus, downscaling of typical field parameters is necessary for the study of multiphase flows at laboratory conditions.

This paper presents a critical review of multiphase flow loops around the world, highlighting the pros and cons of each facility with regard to reproducing and monitoring different multiphase flow situations.

The authors suggest a way forward for new developments in this area.

Introduction

Multiphase flows consist of the simultaneous passage through a system of a stream composed of two or more phases. They are very common natural phenomena: the flow of blood in our body, the rising gas bubbles in a glass of beer and the steam condensation on windows are all examples of naturally occurring multiphase flows.

However, the large scale multiphase flows, such as those that occur in the petroleum industry, are difficult to visualize. For example, in a typical oil and gas development, multiphase flow is encountered in the wells, in the flow lines and risers transporting the fluids from the wells to the platform and in the multiphase flow lines that carry the produced fluids to the treatment facilities at shore.

Multiphase flow systems can be very complex, due to the simultaneous presence of different phases and, usually of different compounds in the same stream. Thus, the development of adequate models presents a formidable challenge. The combination of empirical observations and numerical modelling has proved to enhance the understanding of multiphase flow.

Models to represent flows in pipes were traditionally based on empirical correlations for hold-up and pressure gradient, but it is more usual nowadays to use codes based on the multi-fluid model, in which averaged and separate continuity and momentum equations are written for the individual phases. For these models, closure relationships are required for interface and pipe wall friction.

To compliment the theoretical effort, experimental measurements under controlled conditions are required to verify multiphase flow models and assess their range of applicability. This is why there exists a large number of multiphase flow loops around the world, each of them with specific capabilities and limitations.

This paper attempts to review the major world-wide facilities that allow a wide range of two- and three-phase flow