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Accurate Modeling of Relaxation Time and Liquid Holdup for Multiphase Flow in Production Wells

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Abstract

A homogenous model applicable for reservoir fluids flowing along a pipe with constant cross-sectional area is presented. This model is simplified for flowing fluids across a circular pipe at steady state. The differential conservation laws of mass, momentum, and energy are applied. By estimating the multiphase fluid properties, the differential laws of conservation are solved to compute the change in the pressure, temperature, and flowing velocity. The velocity is computed by knowing the fluid density. Because the flow might not be in equilibrium, the density of the multiphase fluid system is not calculated from any equation of state. Two approaches are presented to determine the density at non-equilibrium conditions. One is the differential conservation law of gas mass that can be solved by estimating the relaxation in time of gas separation, and the other is predicting the liquid holdup by estimating the slip ratio which is the ratio of the phase velocities. The later was used for the application. The presented homogeneous model combined with the proposed and novel liquid holdup model is applied to the study cases. The results of the application are employed to predict and characterize the nature of the relaxation time for hydrocarbon fluids.

Introduction

In general, hydrocarbon fluids present in reservoirs contain a large number of various substances. Each of these substances has different physical properties and behavior affecting in specific ways the properties of the fluid phases. Moreover, the interfaces or surface borders between the fluid phases have physical properties and behavior on their own. Consequently, large amounts of measurements have to be performed in order to determine the fluid properties by means of a detailed model. For that reason, theoretical models of fluid dynamics for reservoir fluids in producing wells have been proposed in various types and successes.

Typically, the reservoir fluid consists of three distinct phases. These are the gas, oil, and water phases. Thus, the flow of the reservoir fluid in wells can be modeled as the flow of a multiphase-fluid system of several phases. By considering the well fluid as a single multiphase-fluid system containing gas, oil, and water phases, the flow in the production pipe can be described by the fundamental equations governing the flow of fluids in conduits.

In the present modeling approach, it is assumed that the three fluid phases (gas, oil, and water) are homogeneous and uniformly distributed over a cross-sectional area. As the multi-phase fluid flows upward along the pipe from the bottom-hole to the wellhead, a spontaneous mass transfer is considered to occur across the gas and liquid (oil and water) interface. The mass transfer may be bidirectional. However, only the separation of the gas from the liquid phases (oil and water) is considered in this study. Because the pressure continuously decreases during the upward motion of the fluid, no gas-phase dissolution into the liquid phases may occur during flow. Within a particular cross-sectional area, the multiphase fluid has a distribution of the mass fraction for the various phases depending on the local state of properties. While moving upward, the multiphase fluid of various phases may undergo a change in mass fraction distribution along the well.

Usually, depending on the prevailing conditions of the fluids inside a pipe, the interface mass transfer between the liquid and gas phases occurs without necessarily reaching equilibrium. Presently, a well-proven and satisfactory model is not available for such cases involving the flashing of hydrocarbons from the liquid phases. A generalized model for flashing hydrocarbons has been developed in a limited number of previous studies, such as by Civan (2006), and Michel and Civan (2008). This flashing model considers a relaxation in time for gas separation from the liquid phases by a gradual mass transfer between the gas and liquid phases. A unidirectional cumulative mass transfer from the liquid phases to the gas phase is assumed in the present study. The mass transfer from the liquid phases to the gas phase begins when the multiphase-fluid system pressure drops to below the bubble-point pressure. As the multiphase-fluid flows along the pipe length, the pressure