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Improved Predictions of Hydrate Plug Formation in Oil-Dominated Flowlines

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Abstract

This work demonstrates the application of transient multiphase flow simulations with hydrate formation kinetics and thermodynamics to predict plugging in multiphase oil production lines. The aim of this paper is to report the continued development of the hydrate plug formation tool CSMHyK-OLGA since our previous report at OTC 2008. We show how the refined model (CSMHyK v. 2.0) can be used to predict the formation of hydrate plugs in two industrial scale flow loops by combining well known engineering correlations with state-of-the-art measurements. Experimental measurements have allowed two fitted parameters to be eliminated. We demonstrate the difference in simulator performance compared to the original model for forecasting hydrate formation rates in wellbores and flow lines. Further developments have allowed hydrate formation in systems with varying concentrations of thermodynamic inhibitor to be simulated by moving the hydrate equilibrium P - T curve as the concentration of inhibitor changes.

Introduction

In many cases, the cost of thermodynamically inhibiting hydrate formation in tiebacks, especially during transient operations can be prohibitive and it is often not possible for the flow assurance engineer to avoid the hydrate stability zone in all foreseeable operating scenarios (Kinnari et al. 2008). The ability to accurately quantify the risk of operating within the hydrate formation region is the key to a successful risk-management strategy for hydrate formation. Since 2003, the Center for Hydrate Research at the Colorado School of Mines has been developing a model for hydrate plug formation in collaboration with the SPT Group. The hydrate formation model – CSMHyK – is available as a plug-in module for the transient multiphase flow simulator – OLGA.

The rate of hydrate formation in early generations of the model (Boxall et al. 2008) was calculated based on the temperature driving force for hydrate formation. An adjustable rate constant was regressed to industrial flow loop data to account for the mass and heat transfer resistances in the flow loop; the value of the fitted rate constant was 500 times lower than the intrinsic kinetic rate constant (Turner et al. 2005) suggesting substantial heat and mass transfer resistances were present in the flow loop. This approach was successfully able to predict the rate of hydrate formation in a second flowloop for four different crude oils. However, the mass and heat transfer resistances will be system dependent so the reliability of the scale-up of the model to industrial flowlines is questionable. In order to address this problem, a study was initiated into the mass and heat transfer resistances to hydrate formation in oil dominated systems. This paper summarizes the findings of this study and presents a revised hydrate formation model that has been validated on both the laboratory and industrial scales.

Theory

The conceptual picture for hydrate formation in water-in-oil (W/O) emulsions is shown in Figure 1. There are two critical interrelated steps in the formation of a plug: hydrate (shell) growth and hydrate agglomeration. Hydrate growth is the focus of this paper.