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A Perspective on Rheological Studies of Gas Hydrate Slurry Properties

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Research**Green Industrial Processes—Perspective****A Perspective on Rheological Studies of Gas Hydrate Slurry Properties**Ahmad A.A. Majid ^{a,b}, David T. Wu ^{a,c}, Carolyn A. Koh ^{a,*}^a Center for Hydrate Research, Chemical and Biological Engineering, Colorado School of Mines, Golden, CO 80401, USA^b Faculty of Chemical and Natural Resources Engineering, Universiti Malaysia Pahang, Pekan 26600, Malaysia^c Department of Chemistry, Colorado School of Mines, Golden, CO 80401, USA

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ABSTRACT

Gas hydrates are solid inclusion compounds that are composed of a three-dimensional hydrogen-bonded network of water cages that can trap small gas molecules, such as methane and carbon dioxide. Understanding the rheological properties of gas hydrate crystals in solution can be critical in a number of energy applications, including the transportation of natural gas in subsea and onshore operations, as well as technological applications for gas separation, desalination, or sequestration. A number of experimental and modeling studies have been done on hydrate slurry rheology; however, the link between theory and experiment is not well-defined. This article provides a review on the current state of the art of hydrate slurry viscosity measurements from high- and low-pressure rheometer studies and high-pressure flowloops over a range of different sub-cooling ($\Delta T_{\text{sub}} = T_{\text{equil}} - T_{\text{exp}}$) and fluid conditions, including for water and oil continuous systems. The theoretical models that have been developed to describe the gas hydrate slurry relative viscosity are also reviewed. Perspectives linkage between the experiments and theory is also discussed.

1. Introduction

Clathrate hydrates, also known as gas hydrates, are crystalline structures in which small gas molecules are trapped inside hydrogen-bonded water-molecule cages [1]. These gas molecules must be small enough to be trapped inside the water cages. As such, typical gas hydrate formers include methane, ethane, propane, and carbon dioxide. Gas hydrate formation typically requires high pressures and low temperatures (e.g., 10 MPa, 277 K for methane). Due to such formation conditions, gas hydrates can form in and plug subsea oil/gas flowlines, and thus pose a serious safety and

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