Dependence of Gas Hydrate Formation Kinetics on System Size and Kinetic Inhibitor Concentration from Stirred Lag Time Experiments

Chenglong Li[1, S], Peter Metaxas[1], Michael L. Johns[1], Zachary Aman[1] and Eric May[1, C]

[1]*University of Western Australia, Crawley, WA - Western Australia, Australia*
eric.may@uwa.edu.au

A rigorous characterization of hydrate formation kinetics is critical to achieving a comprehensive understanding of natural gas hydrate blockages in pipelines. Unlike traditional experimental apparatus such as rocking cells and autoclaves, the high pressure, stirred automated lag time apparatus (HPS-ALTA) enables high resolution mapping of formation probability within short, practical time frames thanks to its small mass and rapid thermoelectric temperature control. However, a major remaining challenge is to accurately apply such benchtop data to quantifying formation risk in industrial flowlines. Indeed, the relevant system size(s) for scaling has not yet been identified for gas hydrate nucleation.

Here we present the newly developed Pipe-ALTA, which enables hydrate formation probability mapping in a pipe geometry with dimensions that are more than an order of magnitude larger than the HPS-ALTA. The Pipe-ALTA has been designed to investigate both size scaling (via variable liquid loading and a larger size than the standard HPS-ALTA) and the effects of varying turbulence levels on hydrate nucleation (via variation of the mixing intensity and location). The ability to control turbulence also makes the Pipe-ALTA an excellent tool to investigate the shutdown and start-up of subsea flowlines.

We demonstrate that the nucleation rates in the Pipe-ALTA are significantly higher than those seen in the smaller HPS-ALTA cells. Although the experimentally accessible subcooling values are different in each system, we show that the nucleation rate data from the differently sized apparatus can be reconciled by scaling the nucleation rates by either the gas water interfacial area or three-phase line. However, simple system size scaling does not apply to systems with kinetic hydrate inhibitors (KHI). We introduce a new framework for system size scaling in the presence of KHI, outlining a technique that enables predictions of induction time based on system size and KHI dosage at specific subcooling. This represents an important step in predicting hydrate formation probability for field scale systems using rich benchtop data sets.