Contribution ID: **114** Type: **Poster**

Quasi-continuous generation and rheological characterisation of CO2-gas hydrate ice crystal slurries

Tuesday 9 January 2018 12:35 (1h 30m)

CO2 gas hydrates are non-stoichiometric crystalline structures consisting of CO2 molecules entrapped in a 3D lattice of polyhedrals formed from water molecules. These structures, stable under moderate pressures and low temperatures, play a crucial role in in many environmental and energy sectors. Understanding and controlling the flow of hydrate slurries can bring rapid solutions for some applications in these areas.
In this study, a robust methodology for clathrate slurry generation and flow/rheology control is discussed. An in-house built high-pressure loop with an embedded surface scraped heat exchanger enhancing hydrate crystal formation kinetics and high-pressure rheology were used to study CO2 gas hydrate slurry flow properties during hydrate nucleation, growth and decomposition processes. The slurries were formed from high water cut sugar solutions. The aim of the study was to investigate the clathrate slurry flow behaviour and apply high-pressure pipeline (in-line) and rotational (off-line) rheometry at specific positions in the CO2 hydrate phase diagram, relevant for technological applications.
CO2 gas hydrate slurries were formed in situ (i) in a high-pressure loop reactor (4.5 L, pipe diameter ½") with a built-in Coriolis flowmeter recording density and viscosity or (ii) in a high- pressure rheometric cell (25 ml) of a rotational rheometer (MRC 200) equipped with a four-blade vane mixer geometry. The vane mixer elucidated the formation of hydrates in situ allowing for a well-mixed system throughout the whole measurement. From the flow rate-pressure drop trends in the loop-reactor pipeline apparent flow functions were derived and compared to such received from the rotational rheometer measurements. A robust flow model coupling the strain rate - shear stress responses of the non-Newtonian slurries was derived. This simple approach to compare clathrate slurry flow in a quasi-continuous loop reactor to related, well-defined laboratory scale precision measurements, exhibits new insights into flow assurance relevant characterisation of hydrate suspensions.

Significance statement

The introduced methodologies offer new possibilities for gas hydrate slurry flow characterisation from analytical and process application perspectives.

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Session Classification: Poster & Lunch