



Full Length Article

Microscale evaluation of natural anti-agglomeration behavior of oils via gas hydrate interparticle cohesive force measurements

Nur Aminatulmimi Ismail^{a,b}, Jose G. Delgado-Linares^a, Carolyn A. Koh^{a,*}

^a Center for Hydrate Research, Department of Chemical & Biological Engineering, Colorado School of Mines, 1600 Illinois St, Golden, CO 80401, USA

^b Faculty of Chemical and Process Engineering Technology, Universiti Malaysia Pahang, Gambang, Kuantan, Pahang 26300, Malaysia



ARTICLE INFO

Keywords:

Gas hydrates
Cohesive force
Non-plugging oil
Anti-agglomerants
Salinity

ABSTRACT

Gas hydrate formation in flowlines presents one of the major threats to flow assurance. Exploitation of a non-plugging oil, which contains hydrate anti-agglomerant (AA) properties is an attractive hydrate management strategy. Hence, it is important to evaluate an oil for its potential as a non-plugging oil, considering its significant economic savings, since the properties to prevent hydrate plugging already exist in the oil without additional cost. In this work, a High-Pressure Micromechanical Force (HP-MMF) apparatus was used to quantify the cohesive forces between hydrate particles to provide insight into the natural anti-agglomeration tendencies of oils. Investigation was conducted using seven oils (A – G). Based on the significant reductions ranging from 81 to 99.8% to the cohesive force observed for oils A – E, these oils were categorized as potential non-plugging oils. The cohesive force reductions are attributed to the presence of natural surfactants in these oils that take the role as AAs. Increase in water content in the presence of non-plugging oils led to higher cohesive force, which weakened the non-plugging oil's performance in preventing hydrate agglomeration, but can be overcome by salt. Oils F and G showed no significant reductions to the hydrate cohesive force, therefore are classified as plugging oils. These results show that the microscale evaluation in the HP-MMF can be applied to identify natural anti-agglomeration behavior of different oils, providing important insights to optimize hydrate flow assurance strategy in the field.

1. Introduction

Gas hydrates are non-stoichiometric crystalline solids composed of small guest molecules, such as methane, ethane, or carbon dioxide, entrapped in a host lattice connected by hydrogen-bonded water molecules [1]. Gas hydrates (or hydrates) in nature are known to form three different crystal structures, which are structure I (sI), structure II (sII), and structure H (sH). The type of structure formed depends primarily on the size of the guest molecule. Small guests, such as methane, ethane, and carbon dioxide form sI hydrate, whereas large molecules, such as propane and isobutane form sII hydrate. Even larger guest molecules, such as isopentane, will form sH with the presence of a help gas, such as methane, occupying the small cavities [2]. Fig. 1 illustrates the typical structures of sII hydrates with small pentagonal dodecahedral (5^{12}) and large hexakaidecahedral ($5^{12}6^4$) cages, which is the same structure typically found in the oil and gas flowlines, and the focus of this work.

In conventional oil and gas flowlines and offshore production facilities, formation of hydrates is undesirable. Hydrate formation at high

pressure and low temperature, the condition that is similar to the flowlines, is one the largest threats to flow assurance, compared to other fluid flow assurance issues [4–6]. With offshore oil platforms moving to deeper water operations, the harsher conditions increase the risk for hydrate formation. Hydrate growth, followed by aggregation will reduce the flow area of the pipe, and ultimately result in blockage of the flowline. This could lead to decreasing production levels, damage to equipment, safety hazards, and even emergency shutdown.

In the flowlines that transport oil and light hydrocarbon gases, hydrate blockages can form by following several steps as the conceptual picture shown in Fig. 2 from Turner [7]. In this conceptual picture, water droplets are entrained within the oil phase under flow, creating water-in-oil emulsions. When the gas hydrate thermodynamic condition is met (i.e., high pressure and low temperature), nucleation will take place. Hydrate nucleation is the first instance of hydrate formation, where the hydrate shell grows along the water–oil interface. These particles can interact with each other to form larger particles or hydrate agglomerates that could plug the system. This conceptual picture

* Corresponding author at: Department of Chemical & Biological Engineering, Colorado School of Mines, 1600 Illinois St, Golden, CO 80401, USA.

E-mail address: ckoh@mines.edu (C.A. Koh).