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Isothermal induction time measurements for hydrate formation: study on temperature program

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ABSTRACT

For investigating the effect of any additive on the hydrate formation kinetics, it should be determined the specifications and parameters of the blank test (with no additive). Isothermal induction time measurement facilitates the study of nucleation mechanisms and the effects of KHIs on the kinetics of hydrate nucleation and growth. The effect of different cooling rate of temperature program is investigated. It is observed that for low cooling rate hydrate forms during gas compression simultaneously. It is an undesirable factor in measurement of induction time. The optimum cooling rate is determined based on gas composition and sub-cooling. In this work, the cooling rate of 5 ˚C/h is determined for the sour gas of South Pars Oil & Gas field and sub-cooling of 7.5 ˚C, applied for isothermal induction time measurements.

Keywords: hydrate formation, induction time, cooling rate, sour gas, sub-cooling.

1. INTRODUCTION

Gas hydrates, consisting of hydrate former molecules plus water molecules in their crystalline structure, are stable typically at high pressure and relatively low temperature conditions. Common guest molecules are light hydrocarbons (C1 to C4) and gases such as N_2, CO_2, and H_2S [1,2].

In multi-phase offshore pipeline, hydrate formation risk is so high due to the availability of thermodynamic conditions. Kinetic hydrate inhibitors (KHIs) are lately developed for gas hydrate control not leading to pipeline blockage. There are three major stages of phase transitions associated with hydrate plug formation, that is, nucleation, growth and agglomeration. Based on the difference between operational temperature and hydrate equilibrium temperature, called sub-cooling, they only delay hydrate formation (kinetics) and their efficiency are then time-dependent. It is believed that the higher the sub-cooling, the shorter the protection time and subsequently the higher the required dosage of KHI. Practically, KHIs extend the hydrate induction time (the time hydrate nuclei do not growth macroscopically) to exceed the residence time of the pipeline. KHIs performance should be evaluated and verified before any field application in laboratories [1,2].

When performing laboratory KHI performance investigations, three main foundations may consider: experimental apparatus, monitoring techniques and experimental procedures. Experimental procedures are mainly categorized into induction time measurements and formation temperature measurements. It is believed that the induction time data measured at isothermal conditions are usually more accurate and easier to analyze [1].

At different laboratories, hydrate performances are relatively reported in comparison with a blank test. The blank tests performed exactly at the same conditions only without any KHIs [1,3]. Therefore, the operational procedure followed in blank test may play a critical role in reasonable KHI performance evaluation.

In this work, the effect of cooling rate on the isothermal induction time measurement was investigated.

2. EXPERIMENTAL

2.1 Material

The gas mixture and gas condensate (liquid hydrocarbon), sampled from South Pars Gas & Oil field, were used. The gas composition, determined by gas chromatography, was given in Table 1. Deionized water was used in all experiments.

2.2 Apparatus

A 750-ml stainless steel pressure vessel equipped with a magnetic drive stirrer was used. A programmable cooling bath was used for regulating the vessel temperature. A digital pressure transducer measured the pressure and a PT100 measured the temperature of the fluids in the vessel, logging throughout the test by an in house data logger.