Methane–Water Bubbly Flows through Perforated-Annulus Passage at High Pressures

Tsutomu Shimizu, Yoshitaka Yamamoto, Norio Tenma
Research Institute of Energy Frontier (RIEF), Methane Hydrate Project Unit (MHPU)
National Institute of Advanced Industrial Science and Technology (AIST)
Tsukuba, Ibaraki, Japan

ABSTRACT

Gas-liquid separators are the key devices in production wells with high gas content. In this study, bubbles passing through a perforated annulus are investigated under methane-in-water flows at 4.5 MPa. The size and formation kinetics of bubbles are analyzed using a high speed camera. Influence of the background flow field on bubble behavior is discussed based on numerical analysis. It is evident that higher pressure and/or flow velocity can lead to the regime shift from bubbling to jetting flow. The results give fundamental information to be considered for design and operation of two-phase flow control in methane hydrate field.

KEY WORDS: Breakup; bubble size distribution; flow assurance; flow loop; fragmentation; jetting; two phase flow

NOMENCLATURE

Greek symbols

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>void fraction [-]</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>von Kármán constant [-]</td>
</tr>
<tr>
<td>$\nu_L$</td>
<td>kinematic viscosity of liquid [m²/s]</td>
</tr>
<tr>
<td>$\nu_T$</td>
<td>turbulent viscosity [m²/s]</td>
</tr>
<tr>
<td>$\rho$</td>
<td>liquid density [kg/m³]</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>surface tension [mN/m]</td>
</tr>
<tr>
<td>$\omega$</td>
<td>impellor speed [s⁻¹]</td>
</tr>
</tbody>
</table>

Abbreviations

| BSD | bubble size distribution |
| ESP | electric submersible pump |
| P-A | perforated-annulus |

INTRODUCTION

Multiphase flow control in pipelines is of great importance in oil and gas industries. It is well known that hydrate formation can plug the pipelines when water and light hydrocarbons coexist in the produced fluid under high pressure, low temperature conditions (Sloan and Koh, 2008). Also, presence of heavy oil can form wax under low temperature, resulting in flow plugging. In practice, these flow assurance problems may be circumvented either by mechanical procedure so called “pigging” (Tran et al., 2015) or by chemical application of hydrate/wax inhibitors into the pipelines (Turner et al., 2015).

Gas treatment in production wells and pipelines can also bring some challenges for the flow assurance problems when significant fraction of gas is mixed in the liquid bulk flows. For example, formation of methane hydrate in the mixture of methane gas in 100% water cut systems can cause flow plugging of the pipelines (Joshi et al., 2013). Aside from plugging by hydrate formation, pump flows in submersible turbo pumps can be plugged by gas suction. It has been demonstrated that only a few percent of void fraction can severely penalize the pump performance of a centrifugal turbo pump even at elevated pressures up to about 4 MPa (Shimizu et al., 2015a).