HOKKAIDO UNIVERSITY

Title	Study of Nitrogen-Brine Two-Phase Flow Behavior under High-Pressure Condition [an abstract of dissertation and a summary of dissertation review]
Author(s)	柴田, 尚人
Degree Grantor	北海道大学
Degree Name	博士(工学)
Dissertation Number	甲第15361号
Issue Date	2023-03-23
Doc URL	https://hdl.handle.net/2115/89672
Rights(URL)	https://creativecommons.org/licenses/by/4.0/
Type	doctoral thesis
File Information	Shibata_Naoto_abstract.pdf, 論文内容の要旨

学 位 論 文 題 名

Study of Nitrogen-Brine Two-Phase Flow Behavior under High-Pressure Condition
(高圧条件における窒素-塩水系の気液二相流挙動に関する研究)

Gas-liquid two-phase flow, in which the mixture of gas and liquid flows, presents complex flow and heat transfer behavior due to the interactions at the gas-liquid interface. Its flow appears in many industrial systems including nuclear power plants. Furthermore, technological developments have led to the emergence of new industrial systems that handle unconventional gas-liquid two-phase flows, such as gas production from offshore methane hydrates and fusion reactors that utilize superconductivity. While these systems have the advantage of utilizing the knowledge of gas-liquid two-phase flow developed to date, they also pose new challenges arising from the novel system, and gas production from offshore methane hydrates is one of them.

Methane hydrates are the clathrate where methane dominates as a guest molecule. In recent years, these are drawing attention as an alternative to the existing natural energy source such as natural gas and oil. The Japan＇s Methane Hydrate R&D Program has developed a gas production method from marine gas hydrate, which is expected to deposit significantly in the offshore areas surrounding Japan. To date, the offshore methane hydrate production test has been conducted twice, with the successful gas production from marine gas hydrate using the depressurization method. This method produces gas by dissociating the hydrate through depressurizing the bottom-hole with extracting the liquid present inside the wellbore. With this procedure, the gas production rate highly depends on the bottom-hole pressure, thus, its control is crucial for the stable gas production. Also, assurance of production stability in the long term is necessary for the commercial use. In order to meet this demand, proper specification and design of downhole and control equipment such as gas-liquid separators, water pumps, etc., are essential to stabilize the bottom-hole pressure. To design these devices, determination of the process conditions is necessary considering the flow behavior in the wellbore. In general, there are several mechanistic models for estimating the process condition of wellbore used in the oil & gas industry. Hasan and Kabir model is one of them which can analyze the wellbore with the flow regime and pressure drop of the upward gas-liquid two-phase flow. The pressure drop of internal flow is comprised of gravitational, frictional and acceleration component and the fundamental knowledges are adequate for the oil & gas use, but are few for new application such as the methane hydrates. Thus, the present study has conducted the foundation of nitrogen-brine two-phase flow behavior under low and high-pressure to estimate the process condition using the conventional model. This study includes (1) void fraction and frictional pressure drop model as the foundation study of gas-liquid two phase

flow and (2) objective flow regime identification method using machine learning technique.

The experiment is performed with the test facility comprised of the 28 m long test section whose inner diameter of 52.7 mm at low and 2.8 MPaG. In order to obtain the sequential image of the flow regime, high-speed cameras were used. The void fraction and pressure drop were measured with gamma-ray densitometers and differential pressure.

As the foundation study of gas-liquid two phase flow in chapter 2, the models for the void fraction and frictional pressure drop were derived with non-dimensionalized drift-flux model and two-phase friction multiplier of separate flow model utilizing the of experimental results. The gas velocity of bubbly flow showed good correlation with the existing model under tap water, but was lower for all regions under brine. With the inhibition of coalescence by brine, the gas velocity is lower because of the uniformity of bubble distribution and lower bubble rise velocity due to the reduction in bubble diameter. The frictional pressure drop estimated from the experiment were in good correlation with tap water and the two-phase flow friction multiplier increases with elevated height, while decreases with increased system pressure.

As the study of objective flow regime identification in chapter 3 and 4, the identification method utilizing machine learning technique trained or input with experimental data was established and used to quantify the flow regime. The results in the transition region have quantitatively shown that the transition region exists for the bubbly to slug flow and were in good agreement with Mishima-Ishii's flow regime transition criteria.

With these findings, nitrogen-brine two-phase flow behavior under low and high-pressure has partially found and established the baseline for stimulating the process conditions that reflects the flow behavior in the wellbore. Hence, the present study will contribute to not only the stable gas production through the proper specification and design of downhole and control equipment, but also to the progress of multiphase flow engineering and to the design of many industrial systems including nuclear power plants.