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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　　博士（工学）　　氏名　YOON Dongik

学 位 論 文 題 名

Study on Behaviors of Gas–Liquid Two–Phase Flow in Slope Conditions
(傾斜環境における気液二相流の挙動に関する研究)

In a long history of study on the gas–liquid two–phase flow for several decades, a lot of numerical models for the two–phase flow have been proposed with the understanding of physics in the two–phase flow, and they enrich the knowledge of the two–phase flow. However, no universal models are covering all inclined conditions (horizontal to vertical) because the characteristics of the two–phase flow are completely varied with the conditions. Most studies have mainly focused on the two–phase flow in the horizontal and vertical conditions. Several studies have been completed in inclined conditions, but most of them have dealt with only sliding bubbles in quiescent fluids. In other words, the two–phase flow in the inclined conditions with the liquid base flow has not been fully understood, although it exists in many industries such as ocean engineering, oil transportation, and nuclear reactor. One of the reasons why it has not been studied is due to the high level of difficulty to measure the two–phase flow. Meanwhile, an ultrasound measurement is a powerful tool to measure the two–phase flow. Because it does not depend on light sources, a flare of the lens and an unfocused problem for measuring bubbles and tracer particles occurring in the use of optical measurements can be negligible. Furthermore, an echo intensity relies on the acoustic impedance of a medium, the fluid phase can be identified based on the intensity. Nevertheless, the ultrasound measurement has not been vigorously utilized in the flow measurement because of fatal problems. For example, only a single velocity vector can be obtained from the ultrasound measurement. In other words, the ultrasound measurement can play an important key in elucidating the gas–liquid two–phase flow in the inclined conditions with the liquid base flow by overcoming the problems. This thesis aims to develop the advanced ultrasound measurement technique and understand the fundamental physics of the two–phase flow proposing useful numerical models based on the technique.

Chapter 1 summarizes the literature reviews and objectives of this study. Chapter 2 proposes a novel technique for the instantaneous velocity vector profiling method using conventional ultrasonic transducers. A problem when using the conventional transducers for the velocity vector profiling is introduced, and the principle of a new equation and a configuration of the transducers is explained to overcome the problem. The developed system shows high accuracy to measure the velocity vector within 5 percent error. In demonstrations, the good performance of the developed method is verified in the measurement of two unsteady flows.

Chapter 3 suggests a new method of ultrasound measurement to identify the large bubbles rising with high velocity in an inclinable pipe. Several problems when using the ultrasound measurement for the slug flow with the high superficial velocity of gas–phase are introduced with corresponding solutions. The maximum 10 percent error of the proposed method is verified by the optical measurement in

validation. In extensive applications using the method, the velocity of large bubble and slug-passing frequency are measured in an airlift pump.
Chapter 4 describes the motions of bubbles sliding beneath the towed model ship. The boundary layers, which are varied by the inclination, are visualized to estimate the base flow. The behaviors of sliding bubbles beneath the towed model ship are observed by optical measurement, and the measurement results confirm that the behaviors are governed by buoyancy at low towed speeds while the inertia of liquid flow is dominant to the bubbles. Finally, correlation models of the drag coefficient and velocity of bubbles sliding inside the boundary layers on the tilt plate are proposed using the measured variables.
Chapter 5 studies the behaviors of the bubble sliding inside turbulent boundary layers in an inclinable channel investigated by an optoacoustic measurement. The qualitative visualization confirms a periodic deformation of the sliding bubbles, and the optoacoustic measurement quantifies the deformation. The lift coefficient of the bubble is estimated using a force balance equation among the lift, buoyancy, and surface tension to further analyze the interface force inducing the deformation. The numerical model of the lift coefficient is proposed using Weber and Bond numbers.
Chapter 6 investigates the characteristics of the wall-sliding bubbles in the inclinable turbulent channel flow are clarified using optoacoustic measurement with a wide range of inclination. The variation of bubble shape and velocity are measured by optoacoustic measurement. A constitutive equation of ellipticity is established based on the measurement results that the ellipticity is linearly reduced with the increase of inclination. The drag coefficient is estimated to further analyze the variation of bubble shape and velocity, and the numerical model for the drag coefficient is suggested.
Chapter 7 summarize the notable finding and future works.