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Flow pattern changes influenced by variation of viscosities of a heterogeneous gas–liquid mixture flow in a vertical channel

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ABSTRACT

In the steady-state flow of a heterogeneous mixture such as an air–liquid mixture, the velocity and void fraction are space- and time-dependent parameters. These parameters are the most fundamental in the analysis and description of a multiphase flow. The determination of flow patterns in an objective way is extremely critical, since this is directly related to sudden changes in spatial and temporal changes of the random like characteristic of concentration. Flow patterns can be described by concentration signals in time, amplitude, and frequency domains. Despite the vital importance and countless attempts to solve or incorporate the flow pattern phenomena into multiphase models, it has still been a very challenging topic in the scientific community since the 1940's and has not yet reached a satisfactory solution.

This paper reports the experimental results of the impact of fluid viscosity on flow patterns for two-phase flow. Two-phase flow was created in laboratory equipment using air and liquid as phase medium. The liquid properties were changed by using variable concentrations of glycerol in water mixture which generated a wide-range of dynamic viscosities ranging from 1 to 1060 MPa s. The in situ spatial concentration vs. liquid viscosity and airflow velocity of two-phase flow in a vertical ID = 50.8 mm pipe were measured using two concomitant computer-aided measurement systems. After acquiring data, the in situ special concentration signals were analyzed in time (spatial concentration and RMS of spatial concentration vs. time), amplitude (PDF and CPDF), and frequency (PSD and CPSD) domains that documented broad flow pattern changes caused by the fluid viscosity and air velocity changes.

1. Introduction

The heterogeneous mixture in this study consists of two phases; gas and liquid. The viscosity and density of liquid mixture component is changed by varying the amount of concentration of glycerol in the water solutions to gradually reach a mixture of glycerol only with air. In relation to single-phase flow, two-phase flow is significantly more complicated due to the presence of many parameters such as velocity of the mixture components, spatial concentration and temporal distributions. In two-phase flow of heterogeneous mixtures, the presence of space- and time-dependent parameters such as velocity and spatial concentration are manifested as a flow patterns which additionally introduce a higher degree of difficulty to determine and analyze the in situ flow conditions. Despite its vital importance and countless attempts to solve or incorporate the flow pattern phenomena into models for a Newtonian fluid two-phase flow, it continues to be a challenging topic in the scientific community and has not yet reached any close satisfactory solution in two issues: one, to incorporate it into a model and secondly, to find and objective method to measure it. When an additional independent variable is added such as viscosity the flow becomes more complicated and challenging [1–3].

Frequent applications of two-phase flow in space transportation systems, nuclear reactors, micro-heat exchanger, oil and gas piping, fuel cell bipolar plates, aerospace, transport, bioengineering, medicine, and power engineering technologies create urgent necessity to better measure and control parameters such as velocities, concentration, pressure losses, and flow patterns.

This paper reports the results of experimental investigations on two-phase flow parameters for various two-phase flow patterns in gas–liquid heterogeneous mixture flows in a 50.8 mm diameter vertical pipe with viscosity variations starting from air–water mixture and gradually increasing liquid viscosity until pure glycerol. Liquid viscosity variation is accomplished by changing the concentration of water and glycerol in the mixture. The concentration of glycerol in the mixture is changed from water with the viscosity of 1 MPa s to different viscosities by changing the concentration of glycerol in water generating a homogenous liquid mixture of 10, 20, 80, and 430 MPa s, finally pure glycerol with viscosity 1060 MPa s. In the measurement of the in situ concentration vs. time, the developed two concomitant measurement systems with capacitive and resistive sensors are used to measure and validate

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