**Hydrodynamics and heat transfer in two-phase gas-liquid flows**

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The structure of gas-liquid flows is not determined only by channel Reynolds number but depends significantly on channel orientation and flow direction. The variety of flow regimes makes it necessary detailed experimental studies of the hydrodinamical flow structure and heat transfer.

Local characteristics of downward bubbly flow in a 42.3 mm i.d. vertical pipe were investigated. An electrochemical technique was used to measure flow parameters. A gas-liquid mixer was used permitting the change in size of gas bubbles for the same gas and liquid flow rates. Special attention was paid to measurements close to the pipe wall. Wall shear stress in downward bubbly flow is higher than in a single-phase flow with the same liquid velocity. The value of the wall shear stress ratio depends strongly on the mean bubble size increasing with larger bubbles. A good correlation with the prediction of Clark and Flemmer was observed. Liquid velocity measurements demonstrated the validity of the single-phase ‘‘law-of-the-wall’’ for two-phase velocity profiles. Turbulence suppression phenomena were observed for downward bubbly flow both for wall shear stress and liquid velocity fluctuations.

Experimental study of downward bubbly flow in a 20 mm i.d. vertical pipe was carried out. Experiments were performed at superficial liquid velocities of 0.2 to 1 m/s. Both mean and fluctuating liquid velocity and wall shear stress were obtained. A strong deformation of liquid velocity distribution takes place even at very low gas flow rate ratios. A significant decrease of liquid velocity fluctuations close to the wall compared to those in single-phase flow was observed.

A study of the local structure of the turbulent gas-liquid bubble flow in a tube with an inner diameter of 20 mm was conducted. A special feature of this research is the relatively small (up to 5% of the volume) quantities of gas added to the flow. It was shown that adding even small quantities of gas into the flow leads to a change in the liquid velocity profile in comparison with the one-phase flow and rearrangement of the turbulent structure of the flow. It is shown that it is on the turbulent structure of the flow that the gas addition exerts the maximum influence. Increasing of the gas bubble size leads to a complex increase of the turbulent pulsations of the flow. As the liquid flow rate decreases, the influence of the gas addition on the liquid velocity profile increases.

An experimental study of laminar downward bubbly flow in a 20 mm i.d. vertical pipe was performed. Water-glycerine solution with the viscosity five times higher than that of water was used as the test liquid. Experiments were made for subcritical pipe Reynolds numbers, Re= 500, 1000 and 1500. The experiments demonstrated the strong effect of gas phase on the flow structure resulting in the increase of wall shear stress and flattening of the velocity profile in the central part of the pipe. Effect of the gas phase on the flow parameters was observed even at very low gas flow rate ratios. A significant deviation from the single-phase flow occurs even at gas flow rate ratios of 0.005 to 0.01. The main feature of downward flow is the concentration of the bubbles in the central part of the flow and the flattening of the liquid velocity profile in the central part of the pipe. The development of wall-induced turbulence was indicated. This behaviour correlates with the previous measurements in the turbulent flow regime (Kashinsky, Lobanov, & Randin, 2008).

Experimental investigation of a bubbly gas-liquid flow in an inclined flat channel was performed. The measurements were carried out in the range of superficial liquid velocities of 0.3-1.1 m/s and with different values of the volumetric gas flow rate ratio. Values of average shear stress and heat transfer coefficient for different orientation of the channel were found. It is shown that in a bubbly gas-liquid flow the shear stress and heat transfer depend substantially on the channel inclination angle. The wall shear stress and the heat transfer in a two-phase bubbly flow in a rectangular channel with variable orientation were experimentally investigated. It has been shown that in a gas-liquid flow the channel inclination angle relative to horizon has substantial effect on shear stress and heat transfer. The greatest values of shear stress and heat transfer correspond to intermediate channel inclination angles. Qualitative similarity of the behavior of shear stress and heat transfer with changing channel inclination angle was noted. It has been shown that the influence of the gas phase on the shear stress and heat transfer decreases with an increase of superficial liquid velocity. A good correlation with the prediction (Gorelikova, Kashinskii, Pakhomov, Randin, Terekhov, & Chinak, 2017) was observed.

The experiments performed provide a complete set of detailed experimental data on the structure of bubbly flows in different channels and flow regimes. These data are usefull for the development and testing of analytical and numerical models for gas-liquid flow predictions.

# References

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