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Liquid layer characteristics in stratified gas-liquid downflow: a study of transition to wavy flow

JS Lioumbas, AA Mouza, SV Paras*, AJ Karabelas

Laboratory of Chemical Process and Plant Design
Department of Chemical Engineering
Aristotle University of Thessaloniki
Univ. Box 455, GR 54124 Thessaloniki, GREECE

ABSTRACT

Realistic modelling and simulation of long distance two-phase pipe flow necessitate, among other things, an adequate understanding of the liquid layer characteristics in stratified gas-liquid downflow. The purpose of this work is to study the transition from the smooth to the wavy stratified flow regime for various pipe inclination angles and liquid physical properties. Accurate characterization of both the gas-liquid interface structure and the flow field inside the liquid layer will improve our physical understanding of the mechanisms involved in the evolution of waves in stratified gas-liquid flow.

In order to study the influence of liquid properties on the mechanisms promoting wave formation and on the liquid field structure under the gas-liquid interface several liquids are used (i.e. water, aqueous glycerine and Tween® solutions) covering a sufficiently broad range of viscosity (1.0-2.5 mPa.s) and of surface tension (40-70 mN/m). The experiments are conducted in a 24mm i.d. pipe for various gas and liquid flow rates (Q_L=0.2-5 Lt/min and Q_G=0-10 Lt/s) and for various inclination angles (1 to 9 deg) with respect to the horizontal position.

Observations of the flow characteristics, based on fast-video recordings, are employed to identify the main patterns of wave evolution. Liquid layer thickness time records are acquired using a parallel-wire conductance technique from which mean layer thickness, RMS and power spectra of the fluctuations, as well as wave celerities are calculated. Measurements of the axial velocity component in the thin liquid layer (i.e. ~ 6mm) using Laser Doppler Anemometry (*LDA*) reveal the interplay of the liquid flow structure with the gas-liquid interface. These data in conjunction with the liquid layer characteristics (i.e. local mean and RMS of velocity, power spectra and signal autocorrelation) suggest that the onset of the interfacial waves is strongly affected by the transition from laminar to turbulent flow.

More specifically, local axial liquid velocity measurements conducted in the *absence* of gas, suggest that, regardless of pipe diameter and inclination angle, the transition from laminar to turbulent flow occurs in a narrow range of Re_L~2100 to 2300, which corresponds to the large amplitude wave appearance on the interface. For the case of *co-current* gas-liquid flow, the liquid flow field structure indicates that the transition to turbulence occurs at liquid flow rates close to those observed for free flowing layer case. However, the addition of small quantities of surfactant (Tween®) in the water causes the first large amplitude wave to appear at lower Re_L. Finally, results of numerical calculations using a *CFD* code (*CFX®*) are compared with the experimentally obtained flow field structure inside the free flowing liquid layer, in both the laminar and turbulent regime and are found to be in fairly good agreement.

e-mails:

*paras@cheng.auth.gr**
karabelas@cheng.auth.gr
mouza@cheng.auth.gr
lioumbas@cheng.auth.gr

**author for correspondence*