Development of LIF techniques applied to gas-liquid annular flows

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HIGHLIGHTS

- Downwards annular flow was investigated using PLIF, BBLIF, shadowgraphy and twin-wire techniques.
- Typical (i.e., gradient and fluorescent intensity based) processing routines were employed.
- Several limitations of LIF techniques have been identified during the image processing phase.
- Adaptive algorithms were developed in order to locate the gas-liquid interface with a higher fidelity.

ABSTRACT

An interfacial flow of gas and liquid where the liquid occupies the area around the circumference of a pipe and the gas is located in the pipe core is defined as annular flow. This two-phase flow regime presents a challenge due to its complexity and multi-scale character, and thus is not fully understood even after decades of research.

The topology of the gas-liquid interface can be measured by a number of different techniques, e.g. ring electrodes, flush mounted electrodes, laser focused displacement, conductance probes array or parallel wire electrodes. Relatively recently, non-intrusive laser based measurement techniques, such as Laser-Induced Fluorescence (LIF), are gradually being introduced into the efforts to measure and characterise multiphase flows. These techniques provide spatiotemporally resolved qualitative and quantitative information of the gas-liquid interface in a 2-D plane. Two main types of LIF techniques are commonly used for the characterisation of downwards annular flows (DAFs), namely Planar Laser Induced Fluorescence (PLIF) and Brightness Based Laser Induced Fluorescence (BBLIF). Nevertheless, the LIF techniques, as currently used, have some limitations, e.g. reconstruction of gas-liquid interface in flows with high gas entrainment or an overestimation of the film thickness due to total reflection from the gas-liquid interface.

The experimental work presented in this paper is aimed at the development of LIF measurement as well as processing routines in order to decrease the uncertainty of the gas-liquid topology measurements. Laser Induced Fluorescence (Planar at 90° and 60°, and Brightness Based) techniques together with shadowgraphy imaging and twin-wire probes have been employed to measure the topology of the gas-liquid interface in downwards co-current annular flows. The flow conditions investigated were in the range of \( \text{Re} \approx 150 – 1,500 \) and \( \text{Re} \approx 0 – 80,000 \); covering four distinct sub-regimes, i.e. dual-wave, thick ripple, disturbance wave and regular wave. Several limitations of LIF techniques have been identified during the image processing phase. These include fluorescent signal distortion caused by the presence of entrained gas bubbles, and by the reflections from the gas-liquid interface. These lead to the over-prediction of the measured location of the gas-liquid interface. New algorithms were developed to minimise the effect of the aforementioned optical distortions. These allowed for the discrepancy between the PLIF and BBLIF measurements to be within ~5%. The future work will focus on the development of a processing routine to use information gathered from both LIF techniques that had been implemented simultaneously in order to further minimise the uncertainties.