Simultaneous HS-PIV and shadowgraph measurements of gas-liquid flows in a horizontal pipe

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Keywords Gas-liquid pipe flow, HS-PIV, pulse shadowgraph, Stratified Flow, Wavy flow, Plug Flow, Slug flow

1. Motivation

The development of computational codes for the simulation of two-phase flows relies heavily on the physical understanding of the complex multiphase flow phenomena. Spatial and temporal high resolution information about two-phase flow is needed for a successful detailed 3D modeling of this problem. In this work, simultaneous High Speed Particle Image Velocimetry (HS-PIV) and pulsed shadowgraph (PS) with one camera are used to characterize the velocity and turbulence fields in different two-phase flow patterns.

2. Measurement technique

The measurement technique is based on the particle image velocimetry (PIV). The main problem in two-phase flows is an accurate detection of the phases. If a separation of the phases is not realized, the standard PIV image evaluation would generate incorrect velocity vectors in the air phase and near the interface. The simultaneous use of a shadow technique, a uniform background illumination of the flow, enables a clear separation of the phases in the PIV images. The PIV technique uses fluorescent tracer particles as markers in the flow, which are illuminated with a double cavity Nd:YLF laser. As it can be seen in figure 1, an optical filter placed in front of the camera blocks scattering-light and intense reflections close to the interface regions and the pipe walls. In addition, the flow is illuminated from the back with a monochrome panel of light emitting diodes (LEDs). Due to this background illumination the zones close to the interface of the gaseous phase produce a shadow. The digital camera records the information of the fluorescent particles of the PIV measurement and the back light shadow of the air phase.

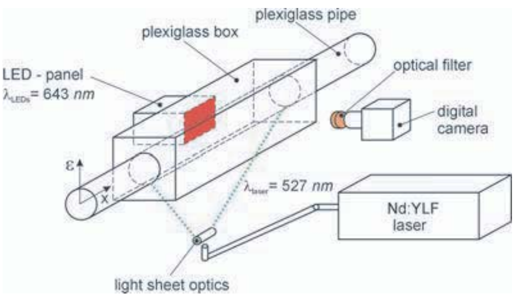

Fig. 1. Set up of the simultaneous HS/PIV and PS technique

There are three ranges of grey levels on the recorded image. The highest range of grey levels corresponds to the light emitted from the tracers, the medium grey level to the light coming of the LEDs and the lowest grey level to the shadow of the zones near the interface of the gaseous phase. The images are processed with a self developed software, where the air phase is covered with a black mask. The resulting image is used for the PIV evaluation.

3. Experiments

In order to study the suitability of the measurement technique 15 different operating points of the experimental facility were investigated. These include the flow regimes of stratified, wavy, slug and plug flow in a horizontal pipe. The two-phase test rig is operated at pressures and temperatures close to atmospheric conditions. The transparent test section is a plexiglass pipe with a length of 11 m and inner diameter of 0.054 m. The PIV/PS measurements were conducted 89D downstream of the two-phase mixer. A plexiglass box filled with water surrounds the test section to minimize the optical distortion.

4. Results

With the simultaneous PIV/PS technique the detection and separation of the liquid and gas phases can be accurately done. The PIV/PS image is covered with a black mask of the gaseous phase, allowing proper determination of the velocity vectors.

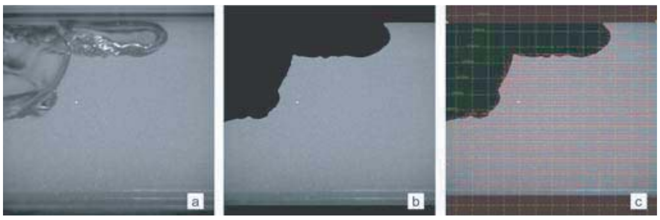

Fig. 2. Determination of the velocity vectors: a) Original PIV/PS image. b) PIV/PS image covered with the mask of the gaseous phase. c) Velocity vectors in the liquid phase

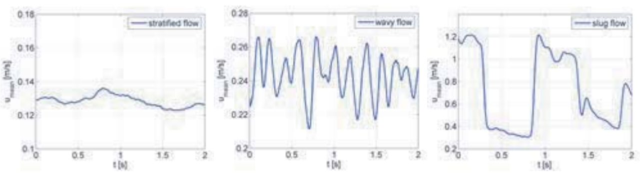

Fig. 3. Mean superficial velocity. From right to left stratified, wavy and slug flow

5. Conclusion

Simultaneous PIV/PS is well suitable for the investigation of stratified, wavy and elongated bubble flow. The results show that this measurement technique is able to measure the velocities of the liquid phase and the interface with high resolution. The measurements may also serve to investigate the turbulence structure in different flow-patterns. For the investigation of bubbly, slug and plug flow this measurement technique is only conditionally applicable. If the gaseous phase is highly mixed with the liquid phase, only a part of the tracer particles can be seen and an accurate determination of the velocity vectors is not possible.