Two-Phase Flows

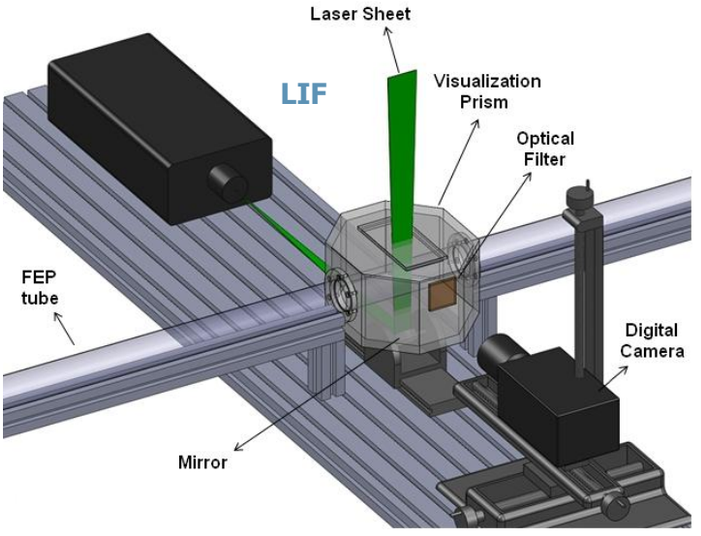
Flows with two or more phases are commonly found in various industrial processes. In the case of oil production, for example, multiphase flow patterns occur both in the wells and in the lines that connect them to the platform. Thus, it is common for the mixture to be transported through long distances before the phases are separated. This emphasizes the importance of studying the properties of such flows.

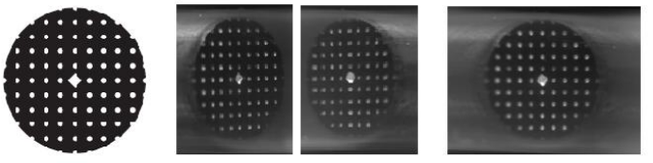
Taylor bubble visualization using pulsed shadow technique (PST)

Different geometrical arrangements of the interfaces between fluids can occur depending on operational conditions (flow rate, pressure, temperature), transport line configuration (dimensions, inclination) and fluid properties (density, viscosity, surface tension). The combination of these characteristics determines the flow pattern, which can be annular, wavy, stratified, or in slugs.

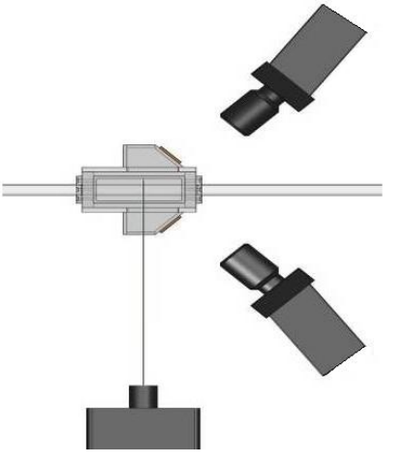
The Fluids Engineering Laboratory has been developing non-intrusive optical techniques for visualization and field measurements in two-phase flows, in order to study the different patterns and phenomena observed in practical applications. Laser-induced fluorescence (LIF), particle image velocimetry (PIV) and pulsed shadow (PST) techniques, as well as digital image processing and index of refraction matching methods have been combined to yield innovative results in this research field (see more about the optical techniques employed). Some of the topics experimentally approached at LEF are briefly presented here.

• Study of two-phase flow dynamics in different regimes



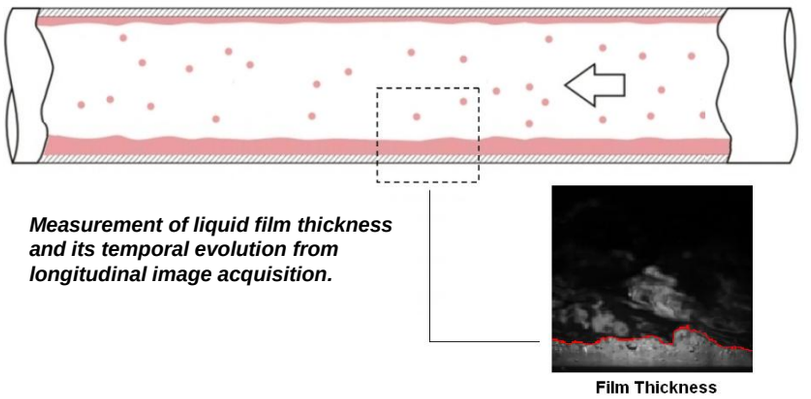


Annular Flow



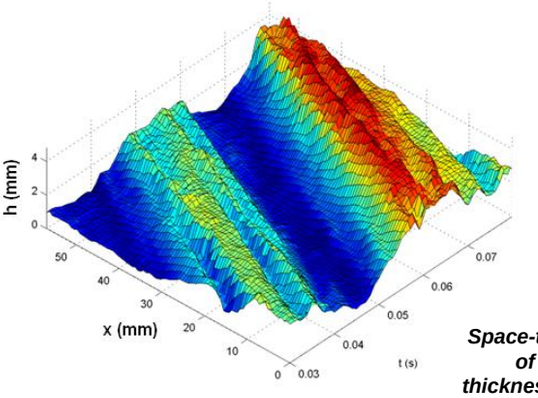
The experimental test section enables visualizations and quantitative measurements of annular flow dynamics, both from longitudinal (above) and transversal (right) perspectives. The transversal measurements, that is, of the cross section of the tube as if seen frontally, are made possible with the use of the stereoscopic viewing technique. Two cameras are used with an angle with respect to the flow axis, mounted in the Scheimpflug condition, and a careful calibration procedure is carried out with a special target before acquisition of flow images.

Two-Phase Flows

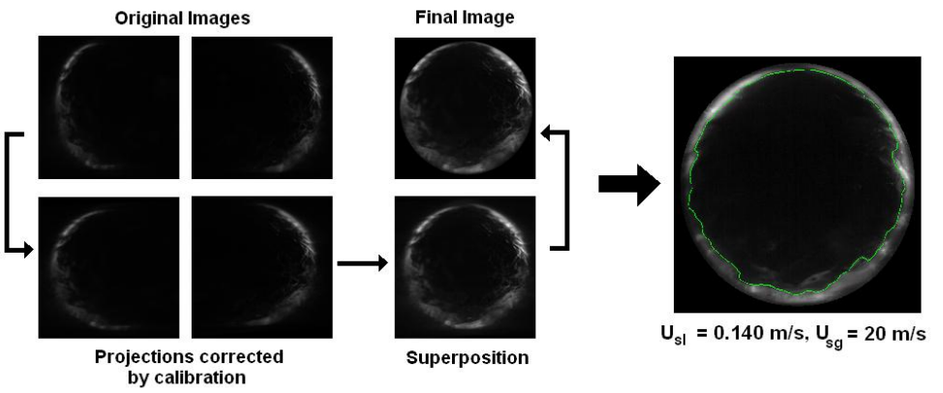


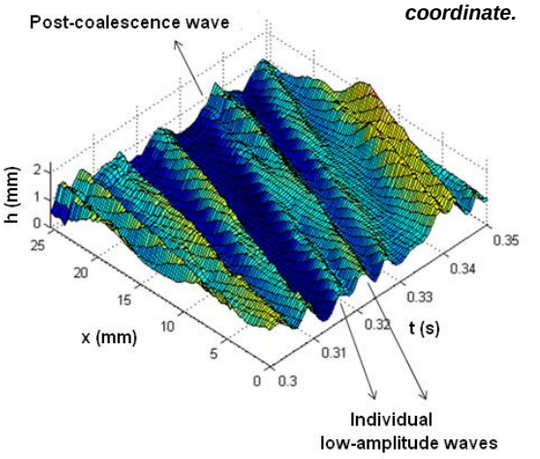
Film Thickness

Measurement of liquid film thickness and its temporal evolution from longitudinal image acquisition.



Space-time maps of liquid film thickness h(x,t) in the bottom wall of the tube. x is the longitudinal coordinate.





Measurement of liquid film thickness and its temporal evolution from transversal (stereoscopic) image acquisition.

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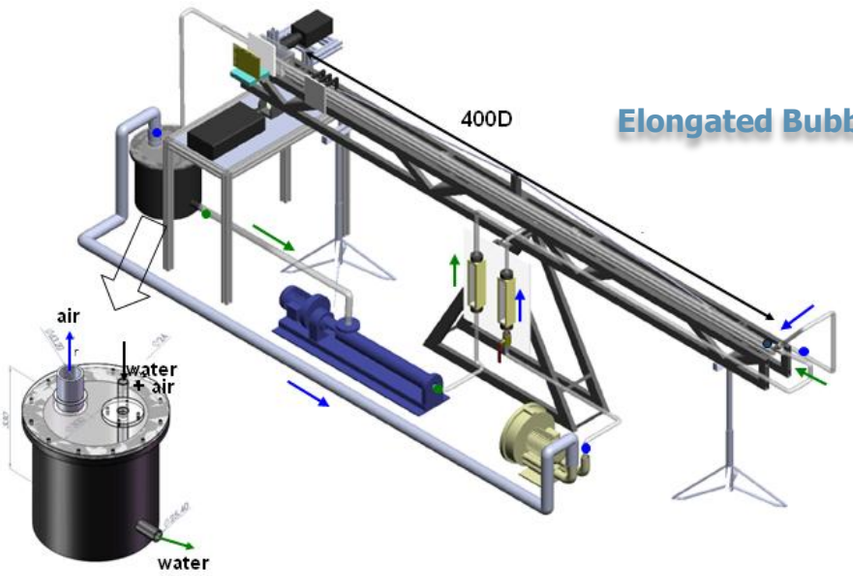
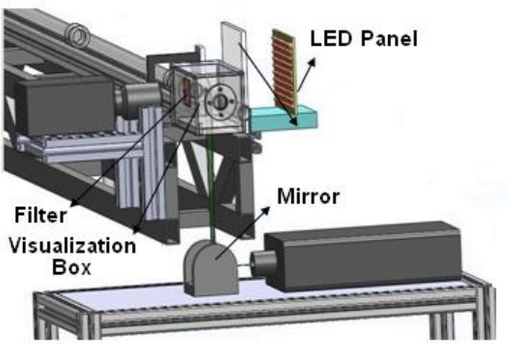
Two-Phase Flows

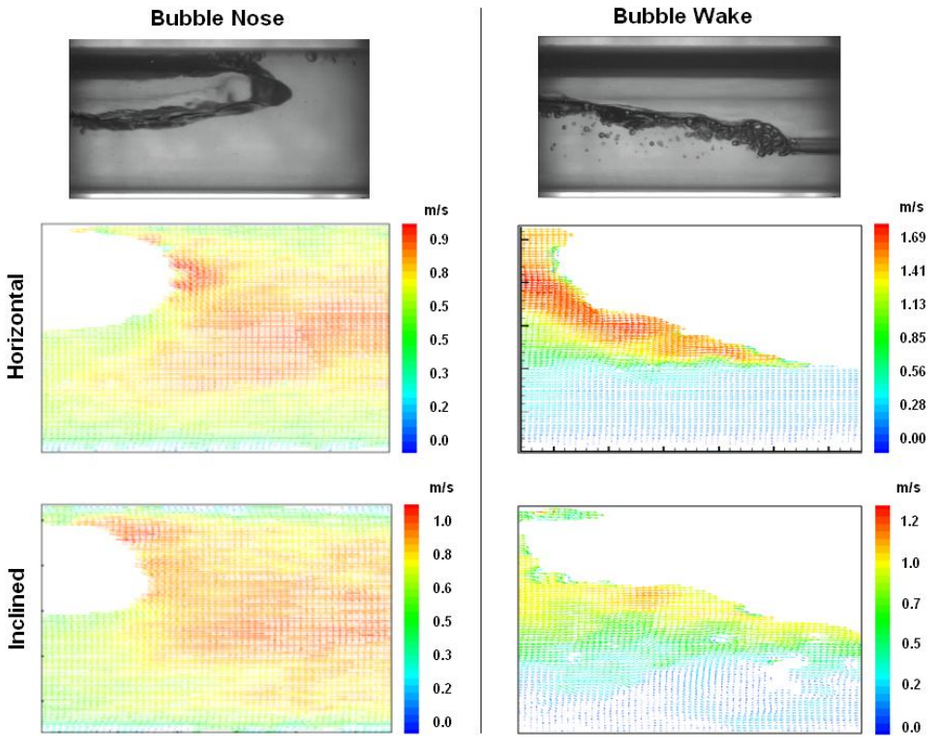


Elongated Bubble

PST + LIF + PIV

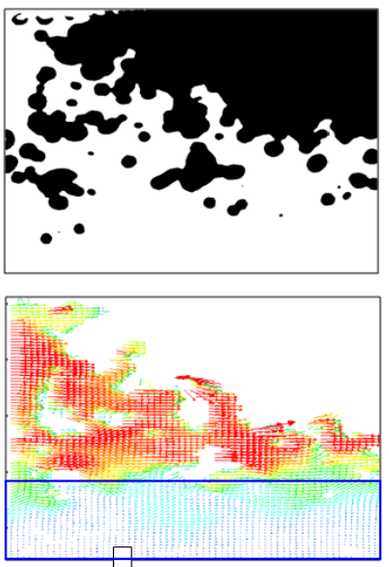


In this test section, which can be inclined in different angles, pulsed shadow (with LED backlighting), fluorescence, and particle image velocimetry techniques are combined. In this way, acquired images have good interface contrast and velocity fields in the liquid portion can be calculated.

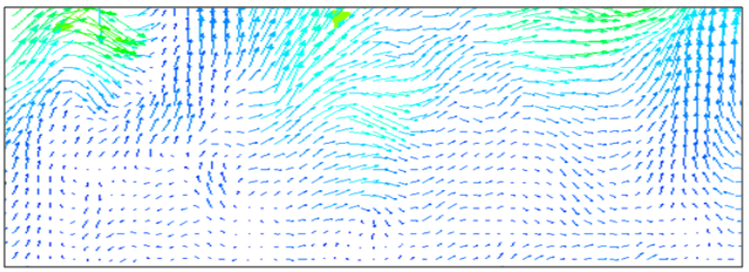


Left: visualization and velocity fields at bubble nose and wake, for horizontal and inclined tube and liquid/gas superficial velocities U_{sl} = 3 m/s e U_{sg} = 5 m/s.

Below: Image processing and zoomed image of the vector field in the inferior portion of the wake flow.



Recirculation at bubble wake



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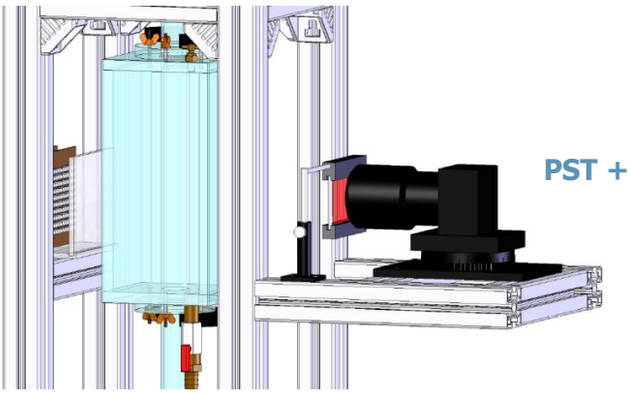
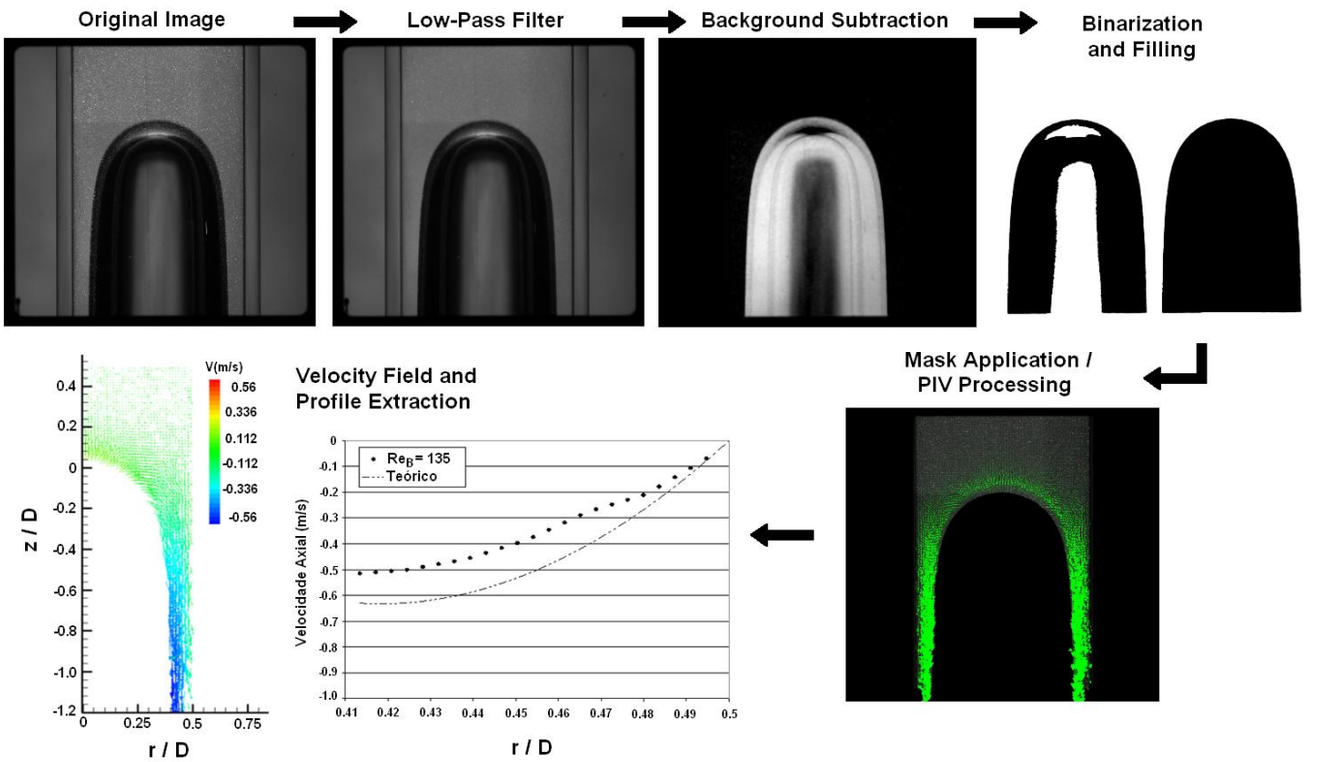


Taylor Bubble

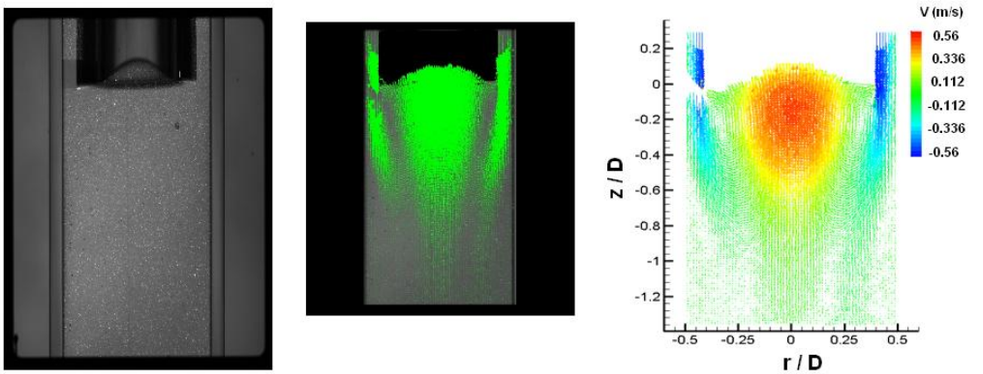
PST + LIF + PIV

These experiments aim to study the dynamic behavior of the flow generated around a rising air bubble in initially stagnated fluid (water). In this case, a combination of pulsed shadow, fluorescence and particle image velocimetry techniques is also used.



Above: image acquisition, processing and post-processing steps for analysis of the nose of a Taylor bubble. Only one of the images from a PIV pair is presented for illustration.

Right: images from the wake of a bubble: particle image, velocity field, and post-processed field coloured by velocity magnitude.



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Two-Phase Flows

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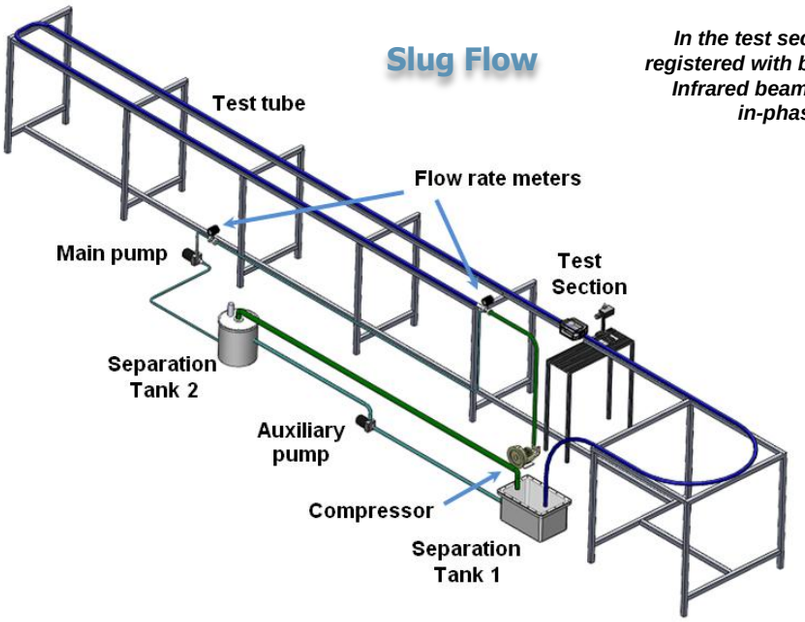
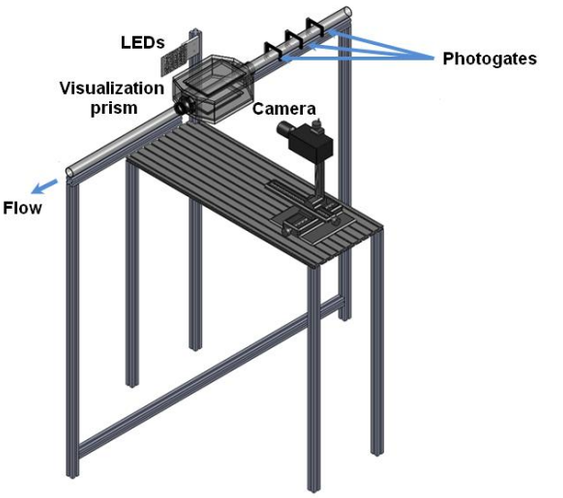
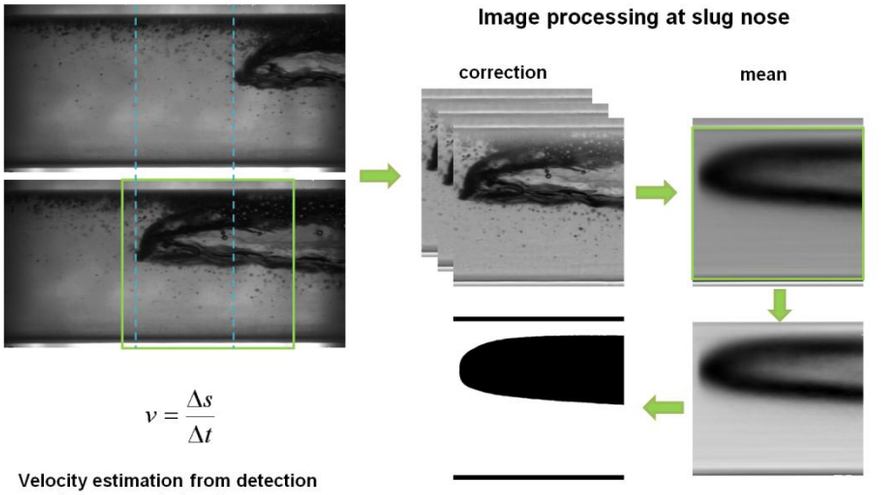
Slug Flow



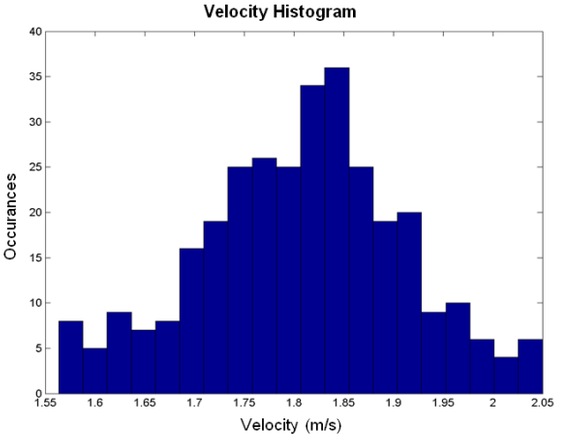
In the test section designed for two-phase slug flow measurements, images are registered with backlighting provided by a LED panel (Pulsed Shadow Technique). Infrared beams (photogates) are used to generate trigger signals which activate in-phase image acquisition, at the desired moments when slugs pass by.



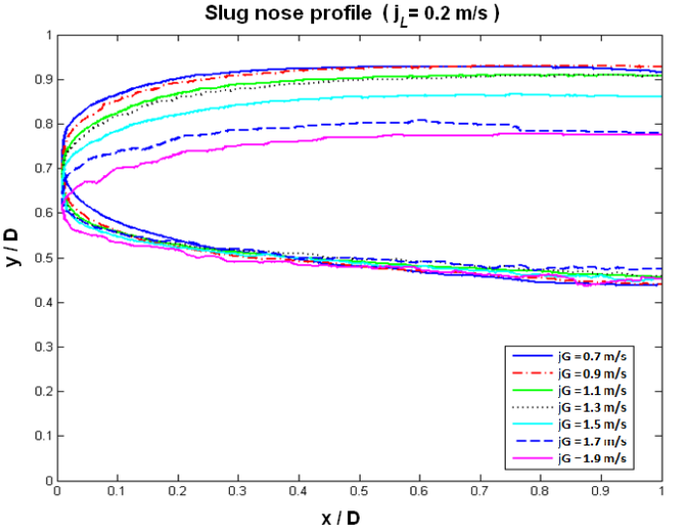


$$v = \frac{\Delta s}{\Delta t}$$

Velocity estimation from detection of slug nose in two images



Above: various processing steps enable the analysis of geometric characteristics of slugs, as well as the evaluation of the average propagation velocity for different values of superficial velocity.



The PIV technique is also employed for measuring complete velocity fields in the liquid phase. Hydrodinamic instabilitty and slug control and suppression studies are also conducted at LEF.

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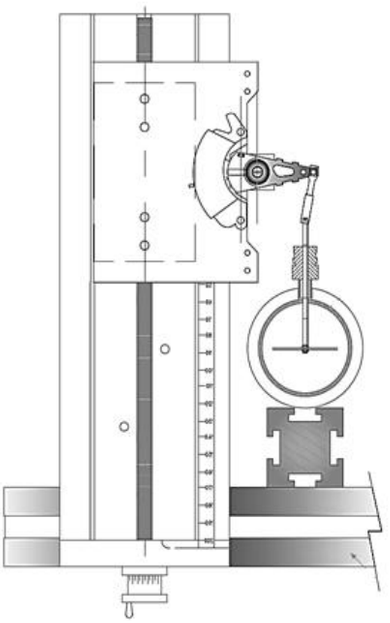
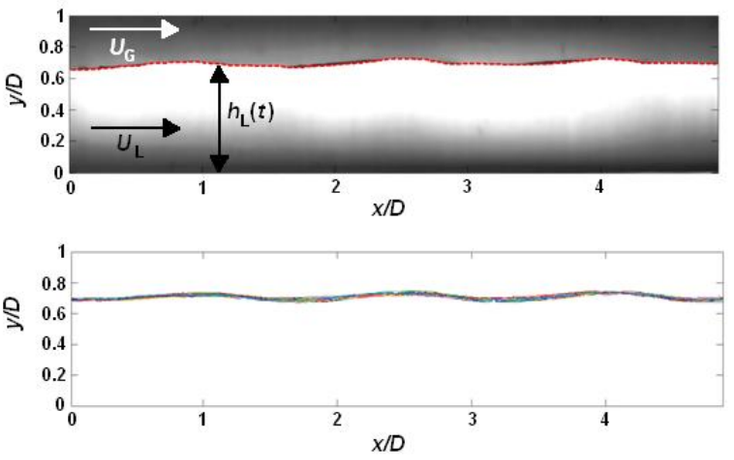
• Study of hydrodinamic instabilities associated with two-phase flow patterns

For the study of hydrodinamic instabilities in the slug-formation process in horizontal ducts, stratified flow is disturbed in a periodic and controlled manner. The evolution of these perturbations along the tube is measured by means of triggered image acquisition and later image processing. The liquid height measurements, made at the same cycle phase as the disturbance generator, demonstrate the reproducibility of the flow. This shows that it is possible to study the transition from stratified to slug regime in a sistematic way, in order to obtain relevant data for validation of numerical simulations and predictive models, and also for testing control mechanisms.





• For multiphase flow studies, the laboratory is equipped with:

✓Experimental flow arrangements with plexiglass or FEP (Fluorinated_ethylene_propylene) tubes up to 20 meters long, with 3/4", 1" and 2" diameters;

✓Several volumetric pumps providing flow rates up to 10m³/h;

✓Compressors and blowers with flow rate and pressure up to 22 m³/min and 4100 m.m.c.a;

✓High speed cameras IDT X3 Pro with 3kHz rate;

✓4 megapixels TSI cameras with rates up to 15Hz;

✓ Synchronizers and pulse generators;

✓Data acquisition systems;

✓NdYAG lasers with 120mJ/pulse;

✓High frequency laser, with 10mJ/pulse @ 1kHz;

✓Laser Doppler with 2 channels;

✓TSI Hot wire;

✓Diverse pressure, flow rate and temperature measurement equipment.

Partnerships

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