HYDRODYNAMICS OF SLUG FLOW

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The two-phase flow pattern, usually called "slug flow" is encountered when gas and liquid flow simultaneously in a pipe, over certain ranges of flow rates. It is characterised by long 'Taylor' bubbles, also called gas slugs, rising and nearly filling a pipe cross-section. In a slugging column, with flowing gas and liquid, the flow field is extremely complex. In order to understand the hydrodynamics of such a complicated flow, the first step is to study the entire field around a single Taylor bubble rising through a vertical pipe.

A facility consisting in a vertical column of Plexiglas has been built at VKI. A pump allows the study of slug flow both for stagnant and flowing liquid in the pipe. The velocity of the bubble was calculated from the signals of two photocells that receive light from two laser diodes placed opposite them in the column. A technique of PIV using fluorescent particles has been developed and applied to study the flow pattern around a single Taylor bubble. The spurious optical effects that occur at the bubble interface when cross-illuminated by a laser (mirages of PIV particles appear inside the bubble) have been extensively studied and the conclusion was to use shadowgraphy as a complementary technique to determine the bubble interface. However, for undeveloped or transient slug flow the bubbles are neither axisymmetric nor steady and it is necessary to record the shadow of the bubble at the precise instant and position of the PIV image. A recent technique of simultaneous PIV and pulsed shadow technique (PST), which allows simultaneous measurements of the flow field and bubble shape with one single CCD camera, has been developed and successfully applied to slug flow

A complete set of measurements of the flow field around one single Taylor bubble and its shape have been performed, for different solutions of water/glycerol. The measurements achieved a spatial resolution of 0.0022 tube diameters. The results in the wake of the gas slug are in agreement with experimental data in the literature. The velocity profile measured in the annular liquid film is in agreement with the falling film theory, for laminar film. The optical perturbations, found in the single PIV measurements, are solved around the nose (Fig.1a), in the annular liquid film as well as in the rear of the bubble for cases in which the bottom is flat. However, for Taylor bubbles with concave oblate bottoms, the bubble shadow eliminates any information concerning the concave bottom. The approximate bubble bottom shape in the concave part is, thus, designed from the PIV image (Fig.1b). Figure. 1c shows the result of this approximate treatment, where, for the first time, the wake boundary position (line marked) is determined by mass-balance and the portion of the wake flow inside the concave bottom of the Taylor bubble is described. Optical distortions, creating erroneous velocity vectors, are identified in this region, caused by the light crossing successive interfaces.

The results of this work are essential to validate existing models and to understand slug flow hydrodynamics.



Figure 1: Flow field, around the nose of a Taylor bubble (a), at the wake of a Taylor bubble (c) (reference frame moving with the bubble); (b) PIV image rear of a Taylor bubble