Pressure Field Around Bubble Break-Up In a T-Junction microchannel From Experimental Velocity Field

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In the traditional microfluidics approach, reagents or products are distributed over the single phase flowing in the microchannel. A different approach is the bubble-based or droplet-based microfluidics, where chemical reaction are confined in small bubbles or droplets, allowing for strong reduction of reaction volume and time in biochemical processes [1]. In particular, the study of the gas-liquid two-phase flow, it is of fundamental importance in biological applications to calibrate the amount of gas, or size and speed of microbubbles in microdevice, used in the manufacture porous materials, or in the dissolved gas in biological control flows. Bubbles are generated by mixing a secondary gaseous stream with the main liquid flow, e.g. by using a T-junction configuration. Controlling size and frequency of the bubbles is essential to achieve well-defined and reproducible regimes [2]. The pressure field, which is crucial for bubble break-up, remains an elusive quantity, usually estimated from theoretical considerations or numerical simulations [3,4,5]. Here, the bubble break-up process is investigated using micro Particle Image Velocimetry (µPIV) together with high-speed imaging. The purpose is to evaluate the pressure field around the bubble during the break-up instant by post processing the experimentally measured velocity fields.

The experimental set-up (Fig.1) consists of an inverted microscope (Zeiss Observer Z1) combined with µPIV, based on a Nd:YAG double-pulse laser (Litron NanoPIV) at 532 nm. A dual frame camera (SX-4) captures pairs of images to be post processed using the LaVision Davis software. The continuous phase is seeded with polystyrene fluorescent particles of different diameters (D = 1.47-5.47 µm). Some tests on the influence of the particles on the capillary number have been performed, to recognize the correct bubble generation regime (Fig.2 and Fig3). Several commercial and laboratory-manufactured chips are tested and compared. The microfluidic network is supplied by a syringe pump (PHD Ultra-Harvard) for the liquid phase and a pressure pump (Dolomite Mitos P-Pump) for the gas phase. The set-up has been validated by comparing the threshold capillary number with reference results for stable bubble flow rate [3].

Two dimensional velocity fields around the developing bubble were acquired on different focal planes. For each acquisition the bubble interface was reconstructed by image analysis to enable phase locked averaging of the velocity fields (Fig.4). From this information, the symmetry plane is identified and the two principal curvatures of the bubble are estimated, to try to evaluate the pressure at the bubble interface. Interesting preliminary results have been obtained in small regions close to the interface and we are presently working to extend the analysis to the whole region around the bubble.

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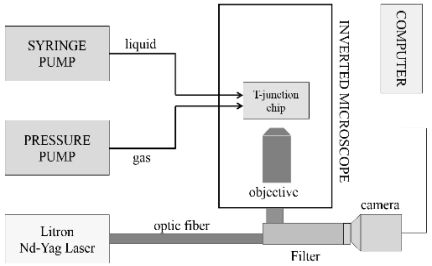

Figure 1. Scheme of experimental set-up.

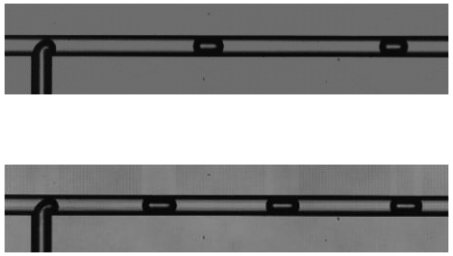

Figure 2. Example of squeezing regime to validate the set-up at different regimes (5x objective; 20000fps).

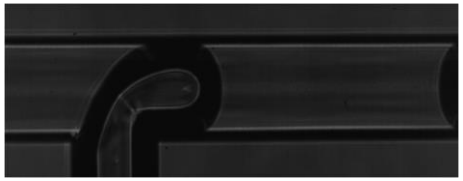

Figure 3.Snapshot of bubble break-up (channel width 110 µm; 20x objective; 40000 fps).

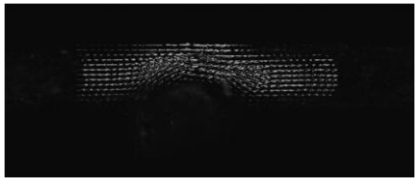

Figure 4. Example of average velocity field around bubble during break-up.