DPIV Analysis for Slug Flow Detection in Micro-channels

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Abstract Standard 3D optical velocity measurements in micro-channels is based on Particle Image Velocimetry (PIV), bulky and costly equipment are necessary to run this analysis. Recently, the computer-based image processing approach called Digital Particle Image Velocimetry (DPIV) has brought the possibility of obtaining a satisfactory evaluation of micro-particles displacements by the analysis of fast CCD data acquired during experiments, with no-need of any laser set-up. In our previous studies the DPIV algorithm was used for the analysis of RBCs velocity in micro-channels, in this work this method was extended to analysis of the slugs flow (obtained by two immiscible fluids) in a microchannel. The slugs flow was monitored simultaneously by a CCD and a photodiode. The results show the possibility to have a detailed information on the flow by the DPIV analysis of the CCD data and envisage a further simplification in the experimental set-up thanks to an approach based on a photodiode acquisition.
Keywords: Image Processing; slug flow

1 Introduction

In this paper the experiments consider a continuous slugs flow that was generated by pumping de-ionized water and air at the Y-junction of a serpentine micro-channel with a side of 320 µm, a square section and positioned horizontally. Two syringe pumps were connected to the two channel inlets and constant equal flow rates of {0.3, 0.4, 0.5}ml/min were imposed. The process was monitored in a position after three bends from the Y-junction. The optical setup consists in the simultaneous acquisition of the light intensity variations by means of a photodiode-based system (sample rate of 1 kHz) and a standard CCD (frame rate of 15 fps). The experimental set-up is described in detail in [1] In Fig.1 four frames of the acquired video showing the air slug passage inside the micro-channel are reported respectively {water, air-slug front, air and air-slug rear}. The movies acquired were analyzed by the DPIV procedure in frequency domain [2]. The Region of Interest (ROI) selected per frame has the size {810x350} px (see in Fig.1). It was investigated using three steps Discrete Fourier Transform by setting the integration areas respectively {64, 32, 16} px and the step size of 16px. Two platforms were used JPIV [3] and PIVlab[4]. In Fig.1 (second row) the vector field distribution obtained at those instant times by JPIV are shown. The color codes the velocity magnitude that is greater at the fluid interface during the air slug passage {front and rear}.

Then by a batch algorithm based on PIVLab, the values of the velocities on the horizontal and vertical directions $\{V_x(x,y,t), V_y(x,y,t)\}$, where (x,y) are the coordinate of a point in the selected ROI, were computed. The time-varying velocities maps obtained $\{V_x(x,y,t), V_y(x,y,t)\}$ were post-processed to have average velocity magnitude in time$\{V_m^2(t)=V_x^2(t)+V_y^2(t)$ where $V_x(t)=<V_x(x,y,t)>$, $V_y(t)=<V_y(x,y,t)>$ in $(x,y) \in ROI\}$.

In particular, in Fig. 2 it is shown the trend obtained for the $V_m(t)$ in the experiment {0.5}ml/min where the slug passage is clearly detected by the peaks for the air front and rear and a low level at the slug center, confirming a trend equivalent similar at those acquired by photodiode down-sampled.

The results obtained opens the way to a new approach for the slug-flows analysis in micro-channels, confirming the possibility to use less expensive equipment suitable for a future miniaturization to be embedded in a System-on-Chip portable device.
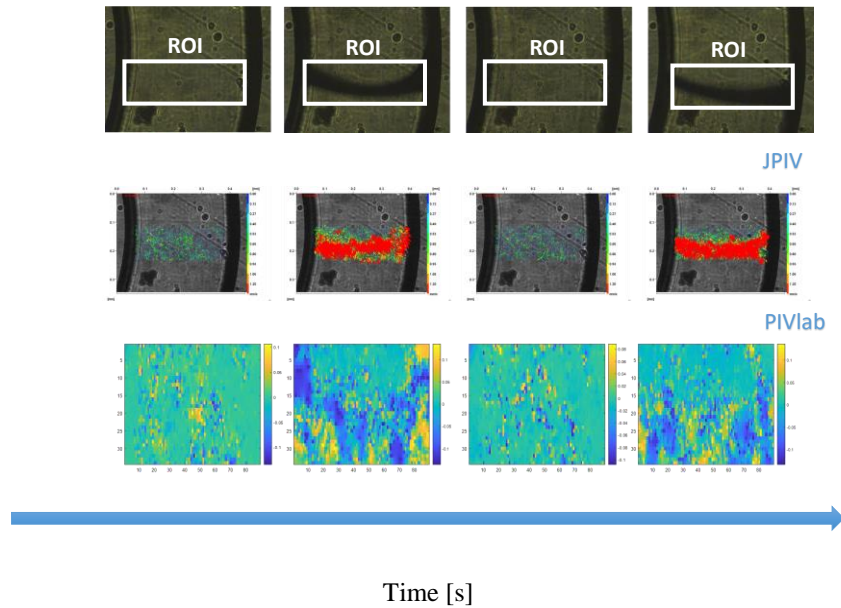
Time [s]

Fig. 1: For the experiment {input flow rate 0.5 mml/min} a sequence of four frames related to the slug passage in the micro-channel {water, air-slug front, air and air-slug rear} at four time instant {t1,t2,t3,t4} is reported. In the first row it is evidenced the Region of Interest (ROI) analyzed by DPIV. In the second row the four frames are overlaid by the vector field obtained with JPIV. The third row shows the velocity maps on the horizontal direction Vx(x,y,t) obtained by PIVlab for t ∈ {t1,t2,t3,t4}.
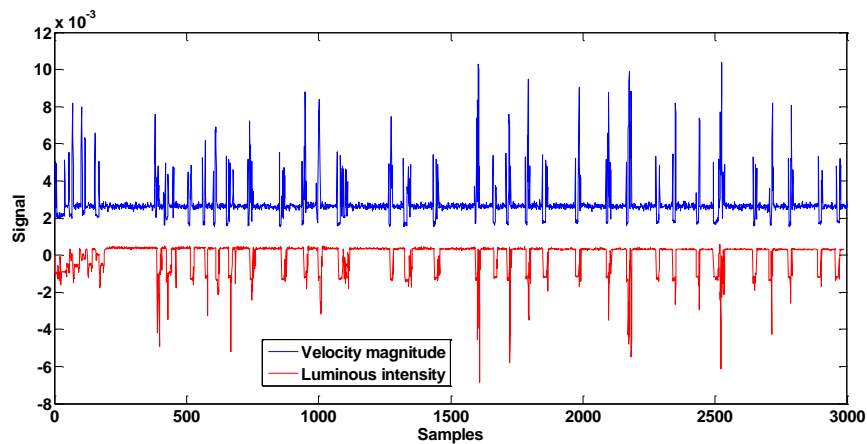

Fig. 2: For the experiment {input flow rate 0.5 mml/min} Comparison between the trend of the velocity magnitude and signal acquired by photodiode.

References

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