Real-Time Slug Velocity in Micro-Channels

Fabiana Cairone[1], Salvina Gagliano[1], Giovanni Galvagna[2], Maide Bucolo[1*]

[1]DIEEI, University of Catania, Catania, Italy
[2]Faculty of Engineering University of Catania, Catania, Italy
*corresponding author: maide.bucolo@unict.it

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. A challenge in this context is the development of velocity detection systems non-invasive and suitable for on-chip integration. In this works the attention has been focused on two-phase flows obtained by the interaction of immiscible fluids {air and water} in micro-channels, called slug flows. Two approaches previously used by the authors based on the optical signal's analysis were implemented and compared. The first is based on the spectral signal analysis and the second is based on the dual-slit methodology. Additionally, the latter was integrated in a LabVIEW platform to monitor the slugs velocity in real-time.
Keywords: Velocity; slug flow; dual slit

1 Introduction

In the experiments considered, a continuous slugs flow 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 neMESYS syringe pumps were connected to the two channel inlets and constant equal flow rates of {0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7} ml/min were imposed. The process was monitored in a position after three bends from the Y-junction, see the insert in Fig.1. The optical setup consists in the simultaneous acquisition of the light intensity variations by a couple of photodiodes placed at a distance of 10 mm (sample rate of 2 kHz). A detailed description of the experimental set-up and the signals pre-processing is given in [1]. Initially the two methodologies, the spectral signal analysis used in [1] and the dual-slit methodology used in [2], were tested off-line. In Fig.1 for the experiment with an input flow-rate 0.1 ml/min the trends of the signals acquired by the two photodiodes {ph1, ph2} are shown. In Fig.2 (first column) for the same experimental condition it is shown the cross-correlation between {ph1, ph2}and the spectrum of ph2. The delay between the two signals, as evident in Fig.1, was detected by the cross-correlation equal to 104 samples, that has been associated to a slug velocity of 0.19 m/s. The mean frequency of the slugs passage was computed by the peak detection in the spectrum equal to 0.44. Both analyses were extended for the other six experiments and the value detected are plotted in Fig.2 (see the graphs in the second column). In the y-axis is the input flow-rate and in the x-axis the values obtained for the two parameters taken into account: the slug velocity and the mean frequency of the slugs passage.

Then the dual-slit methodology (approach based on the cross-correlation analysis) was implemented in LabVIEW to have a real-time monitoring of the slug-flow velocity. Both the neMESYS pump control and the velocity detection algorithm were integrated in the developed LabView project as shown in the GUI in Fig.3. In the left part of the GUI it is possible to set all the parameters of interest to run the experiment: photo-diode distance, sampling frequency, input flow-rate of the pumps. Another important parameter to be defined is the length of time windows to be used in for the analysis, in our case the signals are analyzed cyclically each 20s.The pump control was obtained thanks to the neMESYS SDK software. In the right part of the canvas it is possible to visualize the photo-diode signals (on the top) and the velocity obtained versus the cycle.

In future works this platform will be used to investigate the slug flow in different experimental conditions. A wide study to correlate the slug velocity detected by cross-correlation and the spectral analysis will be carried out.

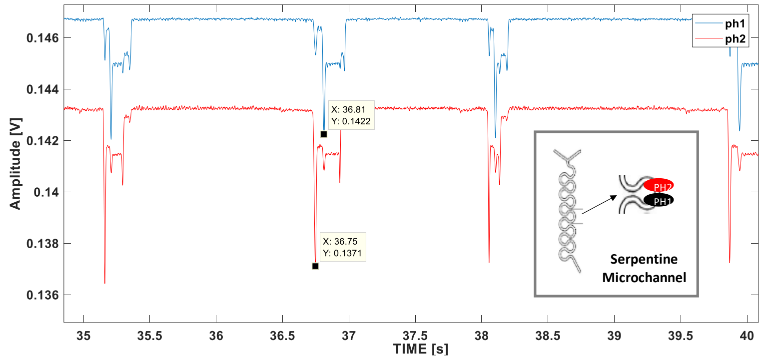

Fig. 1 Example of a figure caption

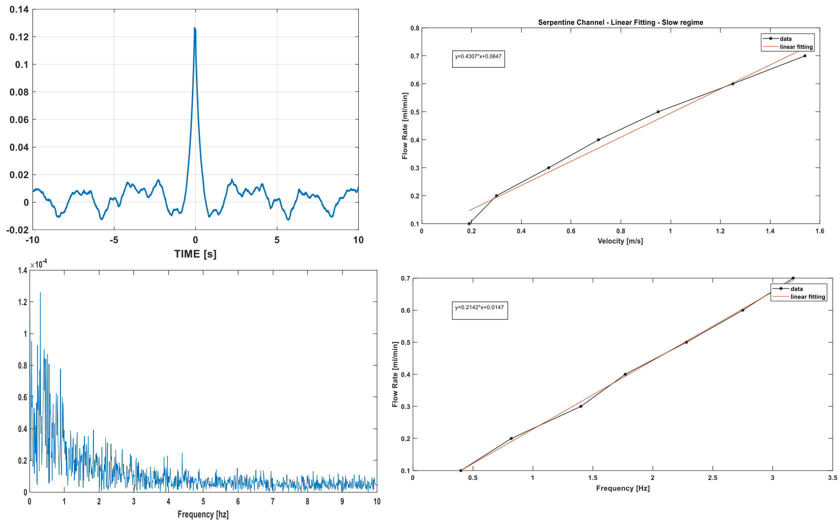

Fig. 2 (Right column) For the experiment with an input flow-rate 0.1 ml/min the cross-correlation between {ph1, ph2} and the spectrum of ph2. (Left column) Results collected for all the 7 experiments. The input flow-rate is in the y-axis and in the x-axis the values obtained for the two computed parameters the slug velocity and the mean frequency of the slugs passage.

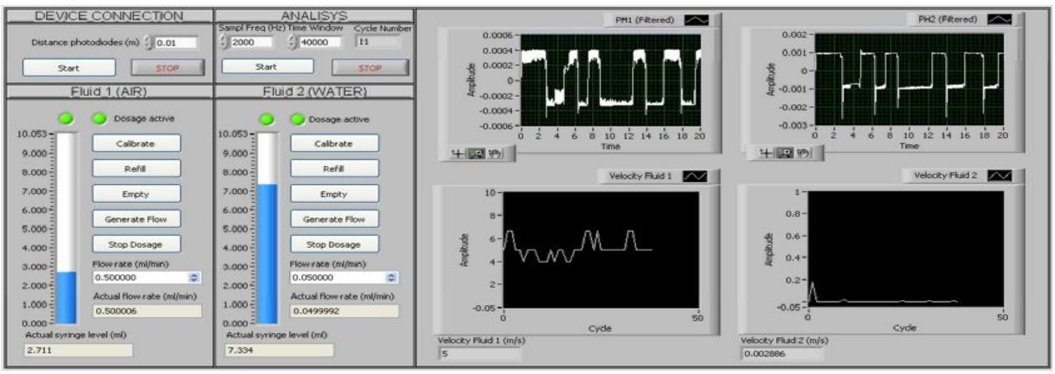

Fig. 3 GUI of the LabVIEW real-time monitoring system developed.

References

[1] Fabiana Cairone, Salvina Gagliano, Maide Bucolo "Experimental study on the slug flow in a serpentine microchannel" Experimental Thermal and Fluid Science 76 (2016) 34–44.

[2] Francesca Sapuppo, Maide Bucolo, Marcos Intaglietta, Paul C. Johnson, Luigi Fortuna, and Paolo Arena Improved Instrument for Real-Time Measurement of Blood Flow Velocity in Microvessels IEEE Transactions on instrumentation and measurement, 56, 6 (2007) 2663-2671.