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Characterization of fluid flow in a microchannel with a flow disturbing step

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Microfluidics has been identified as one of the most promising fields in modern process engineering. Additionally, microfluidics is one of the key components used in order to realize *lab-on-a-chip* systems. The main advantages of microsystems are the high surface-to-volume ratios leading to more compact equipment, the increased efficiency and operability especially in heat transfer applications and the enhancement of fluid mixing.

In the micro-scale, mixing can be induced by active or passive methods. In passive micromixers there is no need for external energy and mixing performance is enhanced by complex designs of the microchannel geometry that modify the flow path and increase contact time between fluids. A typical modification of the channel wall is an orthogonal barrier, effectively creating a step in the fluid flow path that promotes mixing. Although flow over a step has been extensively studied in the macroscale, to the authors' best knowledge limited research have been done in the microscale.

The scope of this work is to characterize the flow around a flow disturbing step aiming to investigate the effect of key design characteristics on the length of the recirculation zones (*reattachment length*). This parameter has been identified as the most important in applications of microchannels like fluid mixing and heat transfer enhancement. In the macroscale it has been found that the reattachment length depends primarily on the geometrical characteristics of the channel and the fluid Reynolds number[1].

We identify the ***recirculation zones*** using two techniques, i.e.:

- The *electrodiffusion technique*, that uses gold microelectrodes flush-mounted on the wall, is usually implemented to measure local values of wall shear stress (*WSS*)[2]. On the active surface of the electrode a fast electrochemical reaction takes place and the current is measured under diffusion-limited conditions. *Lévêque's* formula is then applied to determine the mean *WSS*.
- The μ-Particle Image Velocimetry (μ-*PIV*), a common non-intrusive technique for measuring 2D velocity fields in μ-channels with high spatial resolution. In this case the *WSS* is estimated using methods based on curve fitting on the measured velocity data.

Experiments were conducted in a microchannel (***Fig. 1a***) made by micro-milling a *PMMA* plate. Gold electrodes, realized by a novel technique based on sacrificed substrate, are implemented on the channel wall. An *UV* lithography technique was used in order to build μ-structures on the μ-channel later filled with gold using galvanic deposition[3].

To assess the effect of different geometrical characteristics of the step on the extent of the recirculation zones, the expensive and time consuming experiments were replaced by CFD simulations. The *CFD* code employed was validated using experimental data obtained by both the aforementioned techniques. Three dimensionless groups (***Fig. 1b***) are introduced and used as design variables for the *CFD* simulations, namely:

- The step aspect ratio (*l/d*) defined as the length of the step (*l*) divided by its height (*d*).
- The step height to channel height ratio (*d/H*) that expresses the blockage ratio of the step in the channel.
- The *Reynolds* number using as characteristic length the step height (*d*).

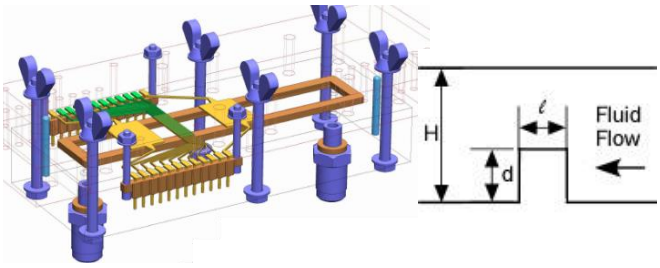

Figure 1: *a) 3D reconstruction of the microchannel with electrodiffusion microsensors, b) geometrical parameters of the μ-channel.*

During the post-processing, using a custom software routine, it is possible to calculate the reattachment lengths of the recirculation zones shown in ***Fig. 2***.

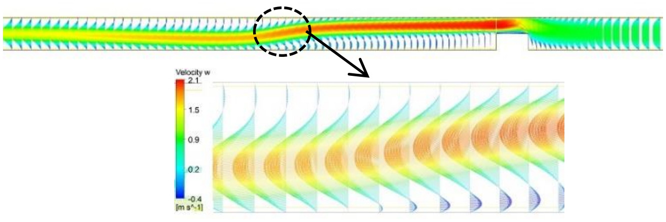

Figure 2: *Typical velocity field over a step with two recirculation zones.*

Preliminary results show that the extent of the reattachment length is significantly affected by the set of design variables used. The study, which is still in progress, is expected to give useful insights concerning the design of μ-channels with flow disturbing steps.

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