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Investigation of liquid phase characteristics in an inclined open microchannel

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Under the moto ‘doing more with less’ process intensification is one of the most interesting fields of research the last decade. Many microsystems have been developed in order to build smaller, more compact and less expensive production equipment and plants.

An important parameter in the designing of gas-liquid reactors is the available interfacial area between gas and liquid phases. Falling film microreactors (FFMR) are devices which can offer extended specific surfaces (up to 20.000 m^2/m^3) while it is important that in FFMR the flow patterns remain unchanged over a wide range of liquid and gas flow rates ***[1]***. Mass and heat transfer can be especially enhanced due to the very large specific surfaces and interfaces achieved, allowing for reactions which cannot be realized with conventional reactors ***[2]***. In addition to the heat and mass transfer capabilities, improved safety is another advantage of FFMR. This relies on the very small reactant hold-up and the shift of explosion limits due to the small channel dimensions. Although there are many works concerning the efficiency of specific reactions in FFMR, little research have been done about the operating parameters of a FFMR ***[2],[3]***.

The aim of this work is to measure the geometrical characteristics (i.e. thickness and surface shape) and the velocity of the liquid film. The effect of the microchannel width as well as the liquid flow rate and the physical properties of the liquid phase (i.e. density, viscosity) on the shape and the dimensions of the liquid film are investigated.

Experiments were conducted in three different microchannels with widths *1200, 600* and *300*μm, constructed by micromachining techniques on a polymeric plate (***figure 1***). Pure water is used as reference fluid. Aqueous solutions of glycerol and aqueous solutions of butanol are also employed in order to explore the effect of viscosity and surface tension respectively.

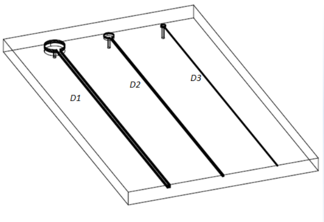

Figure 1*: Geometry of the experimental module (D_1=1200μm, D_2=600μm, D_3=300μm).*

To define the shape of the liquid film a micro Particle Image Velocimetry system is used. Although a micro-PIV is a common non-intrusive technique for measuring two-dimensional velocity fields in microchannels, in this study due to the very short depth of field it is found to be suitable for estimating meniscus shape. By varying the depth in which microscope is focused, measurements are taken on many planes. Using the data of each measurement the film shape can be reconstructed. In order to validate this method a comparison between the experimental data and an expression for predicting meniscus shape in a capillary tube is made (***figure 2***). It was found that there is good agreement between them.

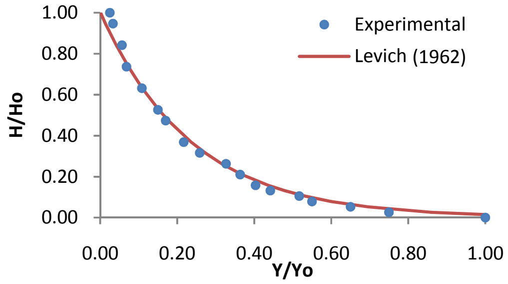

Figure 2*: Meniscus shape. Comparison between experimental data and theretical expression* ***[4].***

The mean velocity of the liquid phase can be estimated using velocity data on each plane. As it is known the forces which define flow in microscale are quite different comparing with those in microscale. Gravity effect is minimized while the importance of surface tension becomes significant. Taking this into account it is important to check the validity of well-known equations of macroscale, in microscale. Experimental data for liquid film thickness and mean velocity are compared with values predicted by Nusselt and Kapitza’s expressions. It was found that as the microchannel characteristic dimension becomes smaller these equations become more inaccurate (***table 1***). Taking this into account it is obvious that there is the need for more accurate expressions valid in the microscale.

Table 1*: Comparison between experimental film thickness and theoretical predictions for various Re numbers and channel widths.*

Re	***D (μm)***	***Experimental (μm)***	***Nusselt (μm)***	***Kapitza (μm)***
13.5	1200	212	214	171
19.8	1200	272	242	194
13.5	600	458	213	171
20.7	600	532	246	197
0.9	300	172	85	69

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