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A critical review of the measurement techniques for the analysis of gas microflows through microchannels

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ABSTRACT

In Microfluidics, a large deviation in the published experimental data on the dynamic and thermal behavior of microflows has been observed with respect to the classical theory but, from a chronological analysis of these experimental results, it can be realized how the deviations in the behavior of fluid flows through microchannels from that through large-sized channels are decreasing. Today, it seems to be clear that some of the inconsistencies in the data were originated from the experimental methods used for the investigation of convective microflows. This fact highlights the need for the development of specific measurement techniques for Microfluidics. In this work, we explore and categorize different approaches found in literature for measuring microflow characteristics, especially for gas flows, and the geometry of the microchannels pointing out the advantages and disadvantages inherent to each experimental technique. Starting from the operative definition of friction factor, the main parameters that must be checked in an experimental work in order to characterize the flow are reviewed. A discussion based on uncertainty analysis will be presented in order to individuate the main operative parameters that one must be able to measure accurately to determine pressure drop in the microchannels with a low level of uncertainty. In the paper each measurement technique is critically analysed to evidence the important issues which may have been overlooked in previous researches. The main goal of this study is to give a summary of experimental procedure and a useful guideline for experimental research in Microfluidics.

1. Introduction

During the last 10 years a rapid development of new microflow devices (MFD) in several scientific fields has taken place. Nowadays, the manufacture of MFDs, like micropumps, microvalves, microcold plates, microheat exchangers, and other microcomponents and sensors used in chemical analysis, in biomedical diagnostics or in flow measurements, is a consolidated reality. The design of new MFDs requires a deep knowledge of the fluid-dynamic and heat transfer phenomena within microchannels in which a liquid or gas flows.

For this reason, many experimental studies have been conducted in order to analyze the behavior of convection through microchannels, of which a review is given in [1–3]. In particular, the main goal of these studies was to determine the friction factors and the convective heat transfer coefficients through microchannels in which a pressure-driven flow was imposed.

These experimental results have been used in order to verify if the laws governing transport phenomena within channels of macroscopic dimensions still hold at the microscale, and, if not, which new effects must be taken into account at the microscale.

A large scatter in published experimental data and inconsistencies have been observed with respect to the classical theory but, from a chronological analysis of these results, it is possible to extrapolate how the deviations between the behavior of fluids through microchannels and through large-sized channels are decreasing. The last experimental works in Microfluidics seem to highlight that some of the observed discrepancies in the data were originated from the experimental methods used for the investigation of convective microflows.

In fact, in the last years a dramatic improvement of the techniques of microfabrication has enabled a more accurate control over the geometry of microchannels and innovative and more accurate measurement techniques for microflows have been proposed with a general improvement of the reliability/accuracy of the experimental data reported in the literature: these latest data seem to be in agreement with the classical theory.

This highlights the need for the development of specific measurement techniques for the Microfluidics field or a refinement and adaption of the ones used at larger scales.

In this work, we explore and categorize different approaches found in literature for measuring microflow characteristics – especially for gas flows – and the geometry of the microchannels

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