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VELOCITY PROFILE MEASUREMENTS FOR NEWTONIAN FLUID IN A PDMS MICROCHANNEL USING MICRO-PIV

P. N. Marques[1], J. M. Maia[2], L. Hilliou[1] and J. A. Covas[1]
[1]IPC – Instituto de Polímeros e Compósitos, University of Minho, 4800-058 Guimarães, Portugal
[2]CLiPS - Center for Layered Polymeric Systems, Case Western Reserve University, 2100 Adelbert Rd. Cleveland, USA

KEYWORDS

Microfluidic device, Microchannel flow, Velocity profile, PDMS microchannel.

ABSTRACT

The dynamics in micro-scale systems needs to be extensively investigated because the small scales change the equilibrium of forces and effects in comparison with large scales. The goal of this work is to develop a microfluidic laboratory and to investigate in detail the flow of viscoelastic fluids in microchannels of different complexity. The flow of Newtonian fluid was investigated experimentally for a rectangular microchannel in order to validate our equipment,. We report preliminary results from using micro Particle Image Velocimetry visualization technique and compare measured velocity profiles with those computed from an analytical solution.

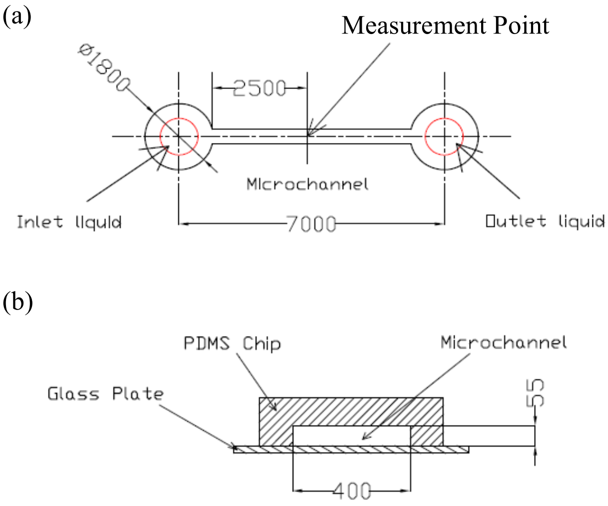
INTRODUCTION

The importance of the geometric scale in micro hydrodynamics has been of particular interest over the past decade. The validity of the continuum assumption at micrometer-lengthscales and the influence of surface properties on the effective boundary conditions at the solid–liquid interface have been frequently questioned (Rodd, Scott et al. 2005). The measurements for micro- and nano-liter flow rates have more important applications in biological, medical and chemical analyses chips (Lab-on-a-chip) as well as microelectronicmechanics system (MEMS) (Wang and Wang 2009). A microchannel with rectangular cross section was prepared, which is made of Polidimethylsiloxane (PDMS), and velocity profiles were measured using Micro-Particle Image Velocimetry visualization technique, through the microchannel.

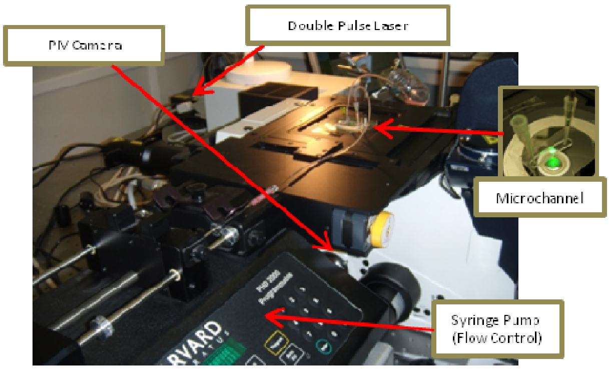
EXPERIMENTAL TECHNIQUES

Device design and fabrication

The microfluidic device, Figure 1, was manufactured in polydimethylsiloxane (PDMS), which is a hard silicon rubber, and was fabricated by the standard soft lithographic methods (McDonald, Duffy et al. 2000)
 and SU-8 photo-resist molds. The microchannel considered in the present experiments has a rectangular microchannel cross-section with 400 μm in width and 55 μm in depth and are composed of two inlets/outlets located at the extremity, indicating the fluidic path. Deionized water seeded with Nile Red fluorescent modified microspheres (diameter 1 micron), was used as the working fluid at room temperature for different flow rate ranges. The seeding load was approximately 0.2% (per volume). The flow was driven by a syringe pump (PHD 2000, Harvard Apparatus).. The optical set-up (see Fig. 2) consists of an inverted epi-fluorescence microscope (Leica Microsystems, DMI 5000M), equipped with a FlowSense 2M CCD camera with an active 1600x1200 pixel array and a 7,4 μm pixel-to-pixel spacing. The computation of velocities was performed with standard Adaptative Correlation schemes using the commercial software package FlowManager from Dantec. The interrogation area size was 32x32 pixels with 50% overlap. This corresponds to 24 μm x 24 μm in the object plane, and a vector spacing of 12 μm.



Figures 1: Schematic geometries of the microchannel: (a) top view and (b) cross section

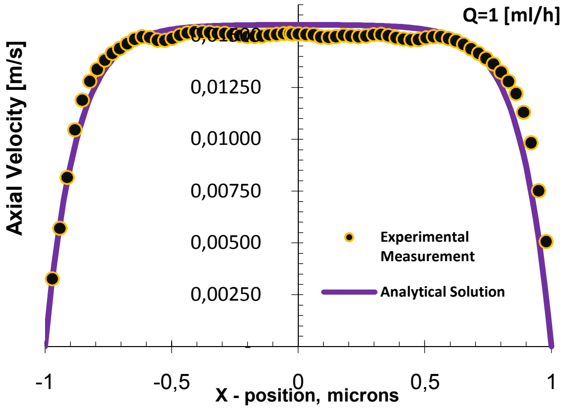


Figures 2: Picture of the micro PIV experimental set up.

Micro-PIV image pairs were acquired by a FlowSense double frame camera in conjunction with a double-pulsed 532 nm Nd:YAG laser. Images of 1 µm epi-fluorescent particles were obtained through a 10x (NA=0.25) objective lens for the present work, resulting a measurement depth of 37,90 µm; this is equivalent to 68% of the channel depth. But we may use higher magnifications (40x or 63x), disposables in our equipment, to get thinner measurement depth values, meaning more reliable and accurate experimental results. (Meinhart, Wereley et al. 2000). Comparisons between the experimental velocity profiles and the analytical solution with the corresponding analytical solution for a Newtonian fluid given by (White 1991), Equation (3), were made.

$$V_z(x,y)=\frac{12Q}{ab\pi^3}\frac{\sum_{i=1,3,\ldots}^{\infty}\frac{(-1)^{(i-1)/2}}{i^3}\cos\left(i\pi x/2a\right)\left(1-\frac{\cosh\left(i\pi y/2a\right)}{\cosh\left(i\pi b/2a\right)}\right)}{\left(1-\frac{192a}{\pi^5 b}\sum_{i=1,3,\ldots}^{\infty}\frac{\tanh\left(i\pi b/2a\right)}{i^5}\right)}, \quad (3)$$

where V_z is the streamwise velocity, *a* the channel half-width (w/2), and *b* the channel half-depth (h/2). For the upstream channel width dimensions *a*=w/2=200 µm and *b*=h/2=22.5 µm.



Figures 3: Velocity profile along the x-axis direction measured experimentally (symbols) at constant flow rate Q=1ml/h, compared with the analytical solution (solid line equation 3).

In figure 3, we present the variation of the streamwise velocity $V_z(x)$ at the center plane (y=0). Close agreement is found between the experimental measurements (symbols) and the analytical solutions.

CONCLUSIONS

We carried out the experimental measurement of the velocity profile in a rectangular microchannel. The working fluid used was de-ionized water, and the microchannel was manufactured of PDMS and it was mounted on the glass plate. The experimental velocity profile against the analytical solution informs us of the uniformity of the test section.

ACKNOWLEDGEMENTS

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AUTHOR BIOGRAPHIES

Pedro N. Marques was born in Braga, Portugal and went to the University of Minho, where he studied Polymer Engineering and obtained his degree in 2005. Currently, he is a PhD student at the Department of Polymer Engineering, University of Minho with ion project SFRH/ BD/ 25312/ 2005. His e-mail address is: p.marques@dep.uminho.pt.