4th Micro and Nano Flows Conference
UCL, London, UK, 7-10 September 2014

Continuous and Simultaneous Measurement of Micro Multiphase Flow Using confocal Micro-Particle Image Velocimetry (Micro-PIV)

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Keywords: Confocal Micro-PIV, Micro Droplet, CIP Method

This paper presents a "Multicolor Confocal Micro Particle Image Velocimetry (Micro-PIV)" technique to visualize and measure dynamic behavior of each phase of micro multiphase flow separately and simultaneously. The technique is applied to two types of micro two -phase flow. The first case is to investigate a mechanism of microdroplet formation at a micro T-shaped junction. The measurement data are compared to the numerical simulation using CIP method. The second case is to investigate the tank-tread motion of red blood cell induced by the surrounding plasma flow.

1 Introduction

Microfluidic devices can perform various kinds of complicated fluidic and chemical operations such as mixing on small chips that can range in a size from a few millimeters to a few centimeters (Auroux, et al, 2002). The devices usually handle more than two different materials, i.e., a "multiphase flow", for example, solid-liquid multiphase flow for a blood analysis (Shevkoplyas, et al 2005) or liquid-liquid multiphase flow for micro droplets used in a drug delivery system. In order to clarify the phenomenon of micro multiphase flow inside these devices, it is necessary to measure the flow field or movement of each phase simultaneously.

In order to visualize and measure multiphase flow in a micro channels, the authors have been developing a multicolour confocal micro-PIV system (Kinoshita, et al, 2006, Oishi, et al, 2011,2012). Since confocal micro-PIV can provide clear PIV images with a very this measurement depth, the three-dimensional velocity field can be obtained by calculating an out of plane velocity from the continuity equation. The paper presents the measurement technique of confocal micro-PIV as well as its applications.

2 Multicolor confocal micro-PIV system

The multicolour confocal micro-PIV system is developed based on a conventional confocal micro-PIV system (Oishi, et al, 2011,2012). To measure two different phases simultaneously and separately, the system has an extra set of laser and camera in addition to one set in the conventional system as well as a multi-wavelength separation unit. Two different types of illumination laser beams are combined using a dichroic mirror in a laser combiner. The lasers illuminate the target, and scattered lights from the target return through a confocal scanner. Multi-wavelength emitted lights are then separated at the separation unit and are recorded by two high-speed cameras. The range of the velocity is determined by the rotational speed of the confocal scanner. Since the tank-tread motion of red blood cells is induced by the velocity of their surrounding plasma larger flow than that of the confocal scanner, a translational stage has been added to the present multicolor confocal micro-PIV system.

3 Results

The drop formation in a T-shaped junction has been measured by the present multi-confocal micro-PIV system. Three components of the velocity are obtained for both internal flow of the droplet and its surrounding flow. Droplet formation is varied depending on a capillary number, which is represented by the ration between the shear force and surface tension. When the capillary number becomes small, the droplet is in the stage of squeezing such that its shape becomes a relatively large barrel. On the other hand, when the capillary number becomes larger than 0.1, it is in the stage of dripping such that its shape becomes small and round. The details of flow features of both phases are examined by comparing to the numerical simulation using the CIP method under the same flow condition.

The translational micro-PIV is applied to measure a motion of a red blood cell in a micro channel. The tank-treading motion of RBCs and the corresponding movement of the surrounding flow structure are measured simultaneously and quantitatively. The relationship between the tank-treading frequency and the shear rate of the surrounding flow is on the same order as in Fischer's report (1978).

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