MICRO-FLOWS INVESTIGATIONS IN PRODUCTION PROCESS OF EMULSIONS CONTAINING NANOPARTICLES

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INTRODUCTION

The design of new procedures for fabrication of nano-structured materials is one of the "hot topics" in the current materials science, due to the great potential for their applications in various modern technologies. Preparation of micro and nano-size structures is a fundamental task of research in this area. Most of the processes involve fluid mechanics, however due to extreme dimensions modifying physical description of the phenomena, modelling of the flow is mainly based on empirical data. The experimental and theoretical work is focussed on production of emulsion droplets in turbulent flow using a narrow-gap homogenizer. The need to get detailed and accurate measurements in micro-scale of the device enforces application of new experimental techniques, unusual in classical fluid mechanics. One of them is micro-PIV, full field microscopic velocity measurements using tracers with only several nano-meters dimension.

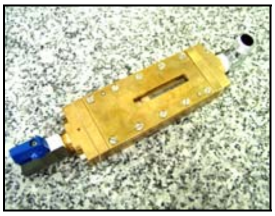
EXPERIMENTAL APPARATUS AND PROCEDURE

The microflow measurements are based on epifluorescence illumination and high speed imaging, allowing collecting detailed data on turbulent shear stresses in the flow, necessary for modelling the emulsification process. The experimental setup consists of the experimental emulsifier cell, epifluorescence microscope, high speed camera (up to 40720 fps), high resolution PIV camera (1280x1024 pixels), double pulse Nd:YAG laser (30 mJ per pulse) and pressure system for flow acceleration (Figure 1a). A simple model of shear flow induced emulsifier consists of a small channel formed between two glass plates and separated by a triangular obstacle (Figure 1b, c).

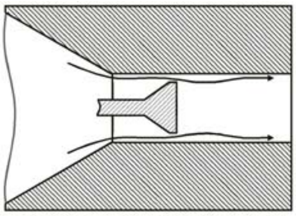
Dispersion of silicon oil in water was pumped under pressure through a small slit between the obstacle and side walls of the channel. Observations of the flow have been performed through a transparent top and bottom walls. Dimensions of the channel are *7.5mm x 15mm x 0.5mm* and the gap between end of the triangular head of the obstacle and the side walls is *0.5mm.* A typical flow rate of the mixture in this study was $60 \cdot 10^{-6}$ m^3/s.

Due to very small dimensions of the channel and microscopic scale of the flowing media standard observation techniques used in the fluid mechanics fail. Hence, for evaluation of droplets size and their velocity a micro-resolution particle image velocimetry (micro-PIV) system has been developed. It permits measurements of instantaneous flow fields in micron–scale fluidic devices for particle dimensions smaller then light wavelength (500nm). It is made possible by using for particles observation laser induced fluorescence, instead of direct particle scattering. Particle Image Velocimetry (PIV) based on correlation of pairs of images is used to evaluate instantaneous velocity field in the channel. These full field data allow for evaluation of local velocity gradients, hence for estimation of conditions for the droplet break-up.

a



b



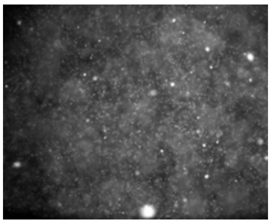
c

Figure 1. Experimental setup for micro-PIV (a) and experimental emulsifier cell: photo (b) and cross-section (c).

SELECTED RESULTS

The flow vector fields are analysed using a double-frame cross correlation PIV algorithm or Optical Flow PIV algorithm [2]. In this technique, the spatial resolution and the accuracy of the velocity measurements is limited by the diffraction limit of the recording optics, noise in the particle image field and the interaction of the fluid with the finite-sized seed particles [1]. Figure 2a shows an example of the images of investigated micro flow observed under microscope and figure 2b shows velocity field obtained by processing experimental data. Width of images is about 4 mm.

a)



b)

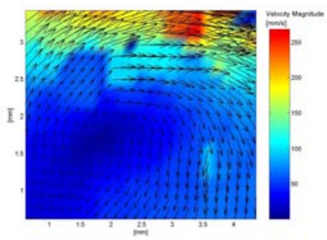


Figure 2. Image of the micro flow (a) and velocity field obtained by processing the experimental data.

References

[1] M. Raffel, C. Willert, J. Kompenhans, Particle Image Velocimetry, A Practical Guide, Springer 1998

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[3] H.A. Stone, Dynamics of drop deformation and brakeup in viscous fluids, Annu. Rev. Fluid Mech. 26, 65-120, 1994.