Wall-Slip Control in Micro-Flows of Microgels and Emulsions by Surface Roughness Using Doppler-OCT

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Abstract

The occurrence of slip on the rheometer geometries lead to inaccurate measurement and determination of rheological data in Yield Stress Fluids (YSFs). The correlation between the slip velocity and the surface roughness[1] is known to the practitioners to prevent slip to a practically reachable limit. The current manuscript explores the velocity profiles of microchannel flows of YSFs in terms of slip control using commercially available surface roughness elements. High-resolution Doppler-Optical Coherence Tomography (D-OCT) has been used as the velocimetry technique, alongside 3D-OCT for surface topographical characterization on a 1×3.25mm² cross-section duct. The ~2.5μm depth resolution of the D-OCT sheds light on the slip velocity alterations in response to the surface structure. Two emulsions (0.7oil-2%surfactant and 0.8oil-20% surfactant, drops size 1.4 to 1.5 μm) and two microgels (8.5%gel-5%BIS and 3%gel-0.5%BIS, particles size ~700 nm) are used as Elastoviscoplastic (EVP) fluids with different particle sizes, obtained from D/SLS, and yield stress ranges, obtained from Herschel-Bulkley fits to the rheometry data in absence and presence of the micro-scale surface roughness. The experiments are performed in a range of Bi and Re numbers to address the dependency of the outcome to the fluid yield stress, as well as that of the flow conditions. As surface roughness the easily accessible sandpaper in two grain sizes of 15.3 and 46.2μm are used, in comparison to the smooth, polished PMMA. Advantaging from the otherwise arduous task of velocimetry in opaque and strongly translucent fluids with optical flow measurement techniques, D-OCT uses the opaqueness as local contrast to back-scatter the coherent light and obtain tomographic data. 2D full cross-section flow fields of the experiments with fluid/flow combinations are presented using spanwise scans, while pointwise 1D scans are utilized to capture precise velocity profiles in all surface/fluid/flow juxtapositions (Fig. 1). The data are validated using Newtonian reference measurements and Plane Poiseuille flow solutions, as well as analytical solutions for confined flows of EVPs with heterogeneous wall-slip using Herschel-Bulkley constitutive equations. The results obtained from microchannel flows of the mentioned EVPs in terms of slip suppression/prevention comply greatly with the rheological data and the particle size and structure of the material.

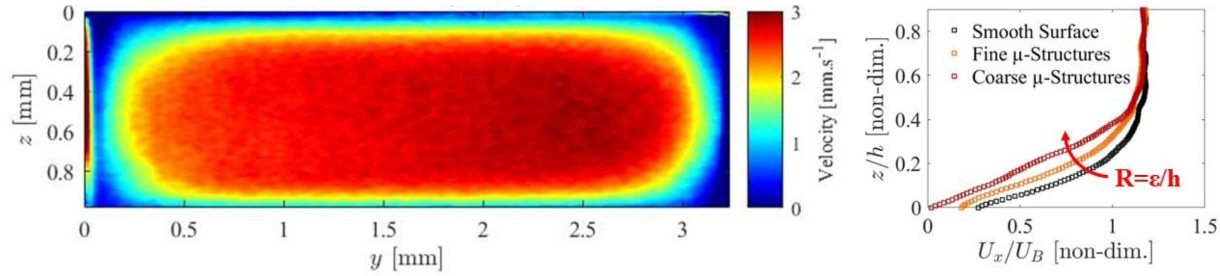

Figure 1. Emulsion sample 0.7oil low surfactant concentration, volumetric flow rate 0.4 ml/min, left) cross-sectional velocity field, right) velocity profile over duct half-height on with relative surface roughness R=0, 0.031, and 0.092.

[1] M. Cloitre and R. T. Bonnecaze, *Rheol Acta* **56**, 283 (2017).