# Elastic instabilities in pillared micro channels in effect to polymer flooding

De, Shauvik; van der Schaaf, John; Kuipers, Hans; Peters, Frank; Padding, Johan

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synergic effects of elastic forces and deformability-induced forces. In the shear-thinning liquid, most of the particles migrate towards the walls. In contrast, cells suspended in the shear-thinning liquid at 8 cm from the inlet are found between the walls and the centerline, due to the competition between the elastic force (directed towards the wall in shear-thinning liquids) and deformability induced force (directed towards the centerline). The Jurkat cells (softer) are found to migrate closer to the centerline than NIH 3T3 cells (more rigid).

Wednesday 16:50 Schackenborg MN13

## Flow of wormlike micellar solutions around confined microfluidic cylinders

Amy Q. Shen[1], Simon J. Haward[2], and Ya Zhao[3]

*[1]Okinawa Institute of Science and Technology, Onna-son, Okinawa 904-0495, Japan; [2]Okinawa Institute of Science and Technology, Onna-son, Okinawa 904-0495, Japan; [3]University of Washington, Seattle, WA 98195, United States*

Wormlike micellar (WLM) solutions are frequently used as fracture and proppant-carrying fluids in enhanced oil and gas recovery applications in porous rock beds where complex microscopic geometries result in mixed flow kinematics with strong shear and extensional components. To gain understanding of WLM fluids flowing through porous media, we examine the flow around a single micro-scale cylinder aligned on the flow axis1. We study flow behavior of an aqueous WLM solution consisting of cationic surfactant cetyltrimethylammonium bromide (CTAB) and a stable hydrotrope 3-hydroxy naphthalene-2-carboxylate (SHNC) in microfluidic devices with three different cylinder blockage ratios, ß. The WLM solution is strongly viscoelastic and exhibit shear banding behaviour. Flow of WLM solutions around confined cylinders results in the onset of a sequence of low Re flow instabilities, which depend on both Wi (as high as 105) and ß. Interestingly the flow instabilities first emerged upstream of the cylinder, which are associated with high stresses in fluid that accelerates into the narrow gap between the cylinder and the channel wall, while upstream vortex growth is reminiscent of that seen in microfluidic contraction geometries. Instabilities downstream of the cylinder are associated with stresses generated at the trailing stagnation point and the resulting flow modification in the wake, coupled with the onset of time-dependent flow upstream and the asymmetric division of flow around the cylinder. The strong shear thinning and shear banding nature of the WLM solution also contributes to the observed instabilities.

[1] Ya Zhao, Amy Q. Shen, Simon J. Haward, Soft Matter, 2016, 12, 8666-8681.

Wednesday 17:10 Schackenborg MN14

## Elastic Instabilities in Pillared Micro channels in Effect to Polymer Flooding

Shauvik De[1], John van der Schaaf[1], Hans Kuipers[1], Frank Peters[1], and Johan T. Padding[2]

*[1]Chemical Engineering and Chemistry, Eindhoven University of Technology, EINDHOVEN, The Netherlands; [2]TU Delft, Delft, The Netherlands*

Polymer liquids are used in the oil industry to improve the volumetric sweep efficiency and displacement efficiency of the oil from a reservoir. Surprisingly, it is not only the viscosity but also the elastic properties of the displacing fluid that determine the displacement efficiency. To understand the effects of viscoelasticity on enhanced oil recovery, both single and multiphase experiments are performed in pillared microchannels of different pitches. Different shear thinning viscoelastic fluids are used to obtain insights into flow structures in these pillared micro channels. Particle image velocimetry (PIV) technique is applied to characterise the complex flow structures at very low Reynolds number ($< 0.01$). The pressure drop across the channel for a range of Deborah numbers is measured using a pressure sensor. We observe an onset of flow asymmetry for the viscoelastic fluid after a critical Deborah number depending on the channel configuration. This flow asymmetry increases with an increase in Deborah number and shows characteristics of elastic turbulence. This can be characterised by an increase in velocity and pressure fluctuations which has a temporal and spatial dependency. The sudden increase in the velocity fluctuations is also visible from the micro-PIV experiments. Though the fluid is shear thinning in nature, we observe an increase in the apparent viscosity after the critical De number is reached, which represents a thickening behaviour. So strong shear and extensional effects of the viscoelastic fluid are responsible for the asymmetric flow structures. Next we performed multiphase flow experiments, by saturating the microchannel with oil, and then displacing it by different non-Newtonian fluids. Surprisingly we found the enhanced recovery corresponds to the critical De number where the onset of instability initiates for the single phase experiments. The elastic instabilities and the relation to enhanced displacement provides fundamental insights in the mechanism of polymer flooding.

Wednesday 17:30 Schackenborg MN15

## Velocity profiles and shear-induced structuring in wormlike micellar solutions flowing in a microcapillary

Carla Caiazza[1], Valentina Preziosi[1], Giovanna Tomaiuolo[1], Denis O'Sullivan[2], Vincenzo Guida[2], and Stefano Guido[1]

*[1]DICMaPI, Università degli Studi di Napoli Federico II, Napoli, Italy; [2]Brussels Innovation Center, Procter & Gamble, Brussels, Belgium*

In the last decades, both in basic and applied research a growing attention has been devoted to wormlike micellar solutions, thanks to their widespread utilization in cleaning and personal care products. In spite of all these efforts, the unique rheological and flow properties, characterized by the occurrence of flow instabilities [1] at high shear rates (such as shear banding [2]) have not been fully elucidated.

In this scenario, microfluidics is a powerful tool to get a deeper insight into the flow behaviour of a wormlike micellar solution, as it provides the opportunity to both enhance confinement effects [3] (and, thus, surface forces driven instabilities) and directly visualize the system under flowing conditions. In fact, the small dimensions of a microfluidic device allow one to couple confined flow and optical microscopy, and to perform flow visualization and structural imaging at the micro-scale.

Here, by feeding a widely used wormlike surfactant solution in a microcapillary geometry we measure the velocity profiles by particle tracking techniques. The results are related to a complex flow structuring and to the rheological properties of the system investigated.