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A pore-scale study of viscoelastic surfactant flow through porous media

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The interest in viscoelastic surfactant solutions (VES) as enhanced oil recovery fluids has been increasing in recent years, due to their practical advantages over polymeric solutions. However, during their flow inside the porous medium, complex geometries (such as throats that connect pores) might cause high shear-extensional components, affecting the flow behavior, and therefore the performance of these systems. For that reason, it is important to understand the rheology of these systems and the relationship with different parameters/conditions such as geometries, temperature, flow rates, and concentrations. The aim of this work is to employ an interactive experimental/numerical paradigm where: 1) experimental data are obtained and used in the process of developing the computational model; 2) systematic simulations are designed and carried out to map the rheological response; 3) the simulation data will be used to improve and/or fill the gap in the empirical correlations used in experiments, as well to guide the design of the next round of experimental matrix; and 4) the improved experimental data are analyzed to select a final set of critical conditions, for which the computational model is improved.

We present a comprehensive and systematic experimental-modeling study on pore-scale rheology of three different viscoelastic solutions in a converging-diverging micro-channel. We evaluated the effects of salt/surfactant concentrations, elevated temperatures (up to 65 ℃), and flow rates (100-1000 μL/min). We used an extensional Viscometer-Rheometer On a Chip (e-VROC) for these measurements. This system comprises a hyperbolic contraction channel and micro-electro-mechanical systems technology for accurate pressure measurements along the channel. We consider non-ionic, zwitterionic/anionic, and cationic surfactant solutions composed of commercial Aromox APA-TW plus calcium chloride (APA-TW + CaCl2) N-tetradecyl-N,N-dimethyl-3-ammonio-1-propanesulfonate plus sodium dodecyl sulfate and sodium chloride (TPDS + SDS + NaCl), and cetyltrimethylammonium bromide plus sodium salicylate (CTAB + NaSal). A complete analysis of concentrations, temperatures and flow rate effects on extensional rheology is described, providing an extensive results and remarkable highlights of the effects of different parameters on extensional flow behavior of VES.

Computational Fluids Dynamics (CFD) methods will be used for modeling and simulations of the viscoelastic solutions. In the current step, we use the Navier-Stokes equations for an incompressible and isothermal single-phase flow in the two-dimensional micro-channel geometry. In the next steps, additional complexities, physical and geometrical, will be included in the computational model, one at a time, to simulate and study larger patterns such as multiple contraction-expansion geometries in serial configurations, interconnected flow paths and cross-flow, under different flow velocities. Consequently, the numerical results will allow us to design specific experiments using micro-PIV technique that shall expand our understanding on flow behavior of viscoelastic fluids in large patterns of pores and throats extracted from real images of porous rocks. The PIV measurements will also provide flow field data that can be used for comparison with the computational results. In the final step, we intend to perform advanced two-phase experiments on micro-PIV devices and geometries extracted from real porous medium to monitor oil displacement at the microscopic scale.

References

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