Complex Fluids in Superhydrophobic Channels

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In polymer processing, understanding the behavior of viscoplastic fluids, which exhibit both solid and liquid characteristics under different stress conditions, is crucial for optimizing manufacturing techniques. When these fluids flow through superhydrophobic channels, which are characterized by their ability to repel liquids, the interaction between the fluid and the channel surfaces can significantly affect the processing efficiency and product quality. Superhydrophobic surfaces can be engineered with various groove orientations and dimensions to control the flow behavior of viscoplastic fluids, thus enhancing processing capabilities. In this context, we investigate the transport of viscoplastic fluids through channels with grooved superhydrophobic walls using a comprehensive modeling approach and numerical simulations. Our goal is to understand the interactions between the fluid and the superhydrophobic surface and identify factors that influence flow behavior. Groove orientation, defined by angle theta, can be longitudinal, transverse, or oblique with respect to the main flow stream. We assume that the interface between the viscoplastic fluid and trapped air in the Cassie state is flat and we model it using the Navier slip law and Bingham model for viscoplastic rheology. A range of channel thicknesses, characterized by the ratio of groove period to half channel height, and flow parameters including Bingham number, slip number, groove periodicity length, slip area fraction, and groove orientation angle are considered. Perturbation theory is used to derive semi-analytical and closed-form solutions for velocity fields in thick channels, while numerical simulations are employed for both thick and thin channels using the Papanastasiou regularization method. These solutions are developed for all groove orientations, with the oblique case being unique due to the nonlinear effects of viscoplastic rheology, a feature absent in corresponding Newtonian flows. We obtain closed-form relations for the flow mobility tensor and effective slip length, highlighting the strong nonlinear effect of viscoplastic rheology. Linear stability analysis of the homogeneous slip condition for a particular flow configuration reveals stabilizing/destabilizing effects

Biography

Dr. Seyed Mohammad Taghavi holds the Canada Research Chair in Modeling Complex Flows and is currently a Professor at Université Laval. In 2011, he received his Ph.D. from the Chemical Engineering Department at the University of British Columbia (UBC). He has around three years of postdoctoral experiences in analyzing complex flows at UBC, University of Michigan, and McGill University, where he held the Banting and Tomlinson Postdoctoral Fellowships. His research interests revolve around complex flows, fluid mechanics, interfacial flows, hydrodynamic stability, and non-Newtonian fluid mechanics. He has received numerous awards/grants from the Natural Sciences and Engineering Research Council of Canada, Canada Foundation for Innovation, etc. He has co-authored 100+ publications on various fluid flow problems in prestigious peer-reviewed journals.