ME – PhD Thesis Colloquium

Electrohydrodynamics of Viscoelastic Drop

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ABSTRACT

The behavior of liquid drop in electric fields is critical for diverse natural and industrial applications, including inkjet printing and electrohydrodynamic atomization. This complex phenomenon is governed by the balance of normal stresses at the deformable interface, dictating drop deformation, stability, and eventual breakup. While Newtonian drop deformation is well-studied, research on viscoelastic drop remains limited.

This study investigates the deformation and breakup dynamics of viscoelastic drop subjected to an electric field, employing both analytical and numerical methodologies. Analytically, an asymptotic solution is derived for an Oldroyd B drop suspended within an Oldroyd B ambient fluid, under the limiting conditions of small deformation (characterized by a small electric capillary number, Ca_E) and weak viscoelasticity (quantified by a small Deborah number, De). At a viscosity ratio of unity, the $O(Ca_E De)$ contribution to deformation is always negative, indicating that prolate deformation diminishes with increasing De, whereas the magnitude of oblate deformation increases with De. The viscoelasticity of the drop has a more pronounced influence on the deformation than that of the surrounding ambient fluid. This analytical framework delineates six distinct regions, PR_A^+, PR_B^+, PR_A^-, PR_B^-, OB^+ and OB^-, within the (σ_r, ϵ_r) phase plot. Each region is uniquely characterized by its deformation type (prolate, PR, or oblate, OB), the direction of flow circulation (equator-to-pole, subscript A, or pole-to-equator, subscript B), and the sign of the deformation coefficient at $O(Ca_E^2)$ (superscript $+$ or $-$), indicating accelerated or decelerated deformation with increasing Ca_E. Oblate deformation is always accompanied by pole-to-equator flow.

Numerically, the behavior of Linear Phan-Thien-Tanner (LPTT) and Oldroyd B fluid drop in an electric field is explored. Investigation of LPTT drop reveals that deviation from Newtonian behavior is negligible within the PR_A^-, PR_B^-, and OB^+ regions, where drop deformation exhibits a decelerated rate of increase with Ca_E. Consequently, the numerical analysis focuses on the regions where the magnitude of drop deformation shows an accelerated increase with Ca_E (PR_A^+, PR_B^+, and OB^-). For the PR_A^+ region, drop deformation shows a monotonic decrease with De for both LPTT and Oldroyd B drop. Conversely, in the PR_B^+ and OB^- regions, the deformation varies monotonically with De for Oldroyd B drop, while it varies non-monotonically for LPTT drop. Finally, the study extends to investigate Oldroyd B drop behavior in an alternating electric field across PR_A^+, PR_B^+, and OB^- regions for varying applied electric field frequencies. The drop deformation oscillates at twice the imposed electric field frequency. In the OB^- region, at high Ca_E and high De, the drop exhibits dimpled shapes at high and intermediate frequencies of electric field, while it breaks up at low frequencies.

ABOUT THE SPEAKER

Sarika is a PhD student in the Department of Mechanical Engineering at the Indian Institute of Science. She earned her B.Tech. in Mechanical Engineering from the National Institute of Technology (NIT), Trichy. After graduation, she joined Bajaj Auto as a Graduate Engineer Trainee for a year. Then she pursued her M.Tech. in Aerospace Engineering at the Indian Institute of Space Science and Technology (IIST), Thiruvananthapuram. Sarika's research primarily focuses on the electrohydrodynamics of viscoelastic drops, encompassing both analytical and numerical solutions. Her research interests also include linear stability analysis of fluid flows. Outside of her academic pursuits, she enjoys swimming, trekking, and reading.