

MECHANICAL ENGINEERING COLLOQUIUM



JYOTI R. SETH
DEPARTMENT OF
CHEMICAL
ENGINEERING, IIT
BOMBAY

NEGATIVE ELECTORHEOLOGY IN NETWORKED SUSPENSIONS: ELECTRIC FIELD-DRIVEN DISRUPTION OF WAX PARTICLE NETWORKS

ABSTRACT

Flow assurance in hydrocarbon pipelines presents a formidable challenge in the energy sector. At low temperatures, dissolved waxes in crude oil precipitate and form percolating particle networks that dramatically elevate viscosity, induce gel-like rheological behaviour, and can cause complete pipeline blockages, with significant economic consequences. Conventional remediation strategies, including thermal and chemical treatments, are either energy-intensive or environmentally burdensome, motivating the search for physics-based alternatives.

This talk introduces Negative ElectroRheology (NER), a counterintuitive phenomenon whereby an applied DC electric field reduces the viscosity and elastic moduli of a structured suspension. Our work demonstrates that non-polar wax particle networks suspended in a relatively more polar and electrically conductive oil medium are susceptible to field-driven network disruption. We present systematic experiments quantifying rheological breakdown as a function of electric field intensity, temperature, and the dielectric contrast between the solid and liquid phases.

The mechanism is rooted in the Taylor–Melcher leaky dielectric framework. When a field is applied, the mismatch in permittivity and conductivity between the two phases generates compressive Maxwell stresses at particle–particle contacts that exceed their yield strength, rupturing interparticle bonds and irreversibly breaking down the network. Leveraging this physical picture, our group has developed a semi-empirical model that quantitatively predicts the onset and extent of field-induced network breakdown. To systematically isolate the role of dielectric properties, we validate these concepts using two-component model suspensions with independently tunable dielectric constants. Overall, this work brings together electrohydrodynamics, suspension mechanics and flow engineering.

ABOUT THE SPEAKER

Prof. Jyoti R. Seth is a Professor in the Department of Chemical Engineering at the Indian Institute of Technology Bombay. She received her B.Chem.Engg. from Institute of Chemical Technology (ICT), Mumbai and her M.S. and Ph.D. in Chemical Engineering from The University of Texas at Austin. Before joining IIT Bombay, she worked in industry. She was a Research Scientist at Unilever R&D in Bangalore and a consultant at Alternative Petroleum Technologies. Her research is in soft matter rheology and complex fluids. She is especially interested in how microscale interactions between particles shape the large-scale flow of dense suspensions, gels and soft glassy materials. Her group combines experiments, particle-scale simulations and continuum modelling. Current projects include electric-field control of rheology, the yielding and flow of networked and jammed suspensions, and applications in energy and process industries, such as flow assurance for waxy crude oils. She serves as an Associate Editor for the journal *Physics of Fluids*. She also works to turn research into innovative products and technologies. She founded Seriate Innovations Pvt. Ltd., a deep-tech startup based in Mumbai, India, specialising in continuous manufacturing equipment and processes for multiphase and complex fluids.

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