ME – PhD Thesis defence

Insights into evaporation,atomization and precipitate formation of polymer droplets.

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ABSTRACT

Evaporation of polymer droplets is an active area of interest due to its applications in systems such as ink jet printing, thin films, spray combustors to name a few. Thus, understanding complex dynamics of evaporating polymer droplets in different experimental configurations is crucial to cater to the wider industrial applications. This study investigates evaporation and subsequent dynamics of two classes of polymeric droplets-low viscoelastic (PAM) and high viscoelastic (PEO) in two different experimental configurations: Laser induced evaporation of droplet under acoustic levitation, Natural evaporation of droplet on hydrophobic surfaces.In the first part, we investigate the interaction of a aqueous low viscoelastic polymer droplet (PAM) with a tunable continuous laser in an acoustically levitated environment. Depending on the laser irradiation intensity and polymer concentration, we observe four temporal phases: droplet evaporation, vapor bubble growth followed by membrane inflation, bubble/membrane rupture through hole nucleation, and droplet breakup. During the initial droplet evaporation phase, concentration build-up at the droplet surface beyond a critical limit leads to the formation of a skin layer. It is revealed that at a given location inside the droplet, hot spots occur, and the maximum temperature at the hot spots scales linearly with irradiation. The low-intensity laser interaction leads to symmetric membrane inflation. On the contrary, high intensity causes early bubble nucleation followed by asymmetric membrane inflation. Furthermore, the growth and rupture of the membrane is followed by a catastrophic breakup of the droplet. Two dominant atomization modes are reported at significantly high irradiation intensities: stable sheet collapse and unstable sheet breakup.In the second part, we investigate the interaction of a aqueous high viscoelastic polymer droplet (PEO) with a tunable continuous laser in an acoustically levitated environment. Depending on the laser irradiation intensity and polymer concentration, we observe four temporal phases: droplet evaporation, bubble/membrane growth, shape oscillations and precipitate formation. The scaling analysis reveals that bubble growth follows Plesset-Zwick criteria independent of the viscoelastic properties of the polymer solution. Further, we establish that the onset of bubble growth has an inverse nonlinear dependence on the laser irradiation intensity. At high concentrations and laser irradiation intensities, we report the expansion and collapse of polymer membrane without rupture, indicating the formation of a high-strength skin layer. The droplet oscillations are primarily driven by the presence of multiple bubbles and, to some extent, by the rotational motion of the droplet. Finally, depending on the nature of bubble growth, different types of precipitate form contrary to the different modes of atomization observed in low viscoelastic modulus polymer droplets.In the third part, we experimentally report the concentration and molecular weight dependence of the deposit patterns of low viscoelastic evaporating polyacrylamide (PAM) droplets on hydrophobic surfaces. We find that with an increase in non-dimensional concentrations c/c^* ranging from 0.16 (dilute) to 66.66 (semi-dilute entangled) there is a gradual transition from ring to uniform precipitates**.** However, with a decrease in the molecular weight of the polymer by one order, the coffee ring formation was not suppressed for the reported range of concentration. We attribute these results to the role played by the critical overlap concentration (c^*) and diffusion coefficient of polymer along with the evaporation modes.Lastly, the authors report the experiments on the precipitate formation of evaporating high viscoelastic (PEO) droplets on hydrophobic surfaces. We observe the final precipitates to be deformed with the formation of central dip over the concentrations ranging from semi-dilute un entangled to semi-dilute entangled.

Overall, this study provides valuable insights into the complex phenomenon of evaporation of polymer droplets in different configurations and its importance in various industrial and natural processes. The findings can help optimize these processes and improve our understanding of them.

Area of research topic: Fluid Mechanics

Field of investigation: Evaporation of polymeric droplets.

ABOUT THE SPEAKER

Gannena K S Raghuram is a Ph.D. student in Mechanical Engineering at IISc Bangalore. His research is supervised by Professor Aloke Kumar, Professor Saptarshi Basu and focuses on the evaporation of a polymer droplet in diverse interaction settings. He is interested in understanding the mechanisms of droplet atomization through bubble nucleation, precipitate formation in evaporating polymer droplets. Before joining IISc in 2017, he completed his M.Tech from Amrita university in 2017. He received his B.Tech in Mechanical Engineering from Guru Ghasidas Vishwavidyalaya (A central university) in 2015.