ME – PhD Thesis Defense

Aerobreakup of a polymeric droplet

Navin Kumar Chandra, Department of Mechanical Engineering, IISc Bengaluru

November 20, 2024 at 10:30AM

Venue: Conference Room, ME@IISc

ABSTRACT

Aerobreakup of a liquid droplet refers to the process of breaking the droplet into smaller fragments by subjecting it to a sufficiently high-speed stream of gas (generally air). This process lies at the core of various natural and industrial processes like fuel atomization in IC engines, breakup of falling raindrops, spray atomization of paints and pharmaceutical chemicals, breakup of sneezed ejecta, etc. The present study investigates the aerobreakup of a polymeric droplet. A polymeric liquid exhibits viscoelastic nature due to the presence of long-chain polymer molecules, and the aerobreakup of such viscoelastic droplets can be drastically different from that of a purely viscous (Newtonian) droplet. Studying the aerobreakup of a polymeric droplet draws special attention because of two reasons. First, many liquids of practical importance are inherently viscoelastic, and second, polymers can be added as a rheological modifier to gain control over the aerobreakup process. While extensive research has been conducted on the aerobreakup of Newtonian droplets, studies on viscoelastic droplets are scarce, and the mechanism through which liquid elasticity influences the process remains elusive. The present study delves into both the mechanism and the impact of liquid elasticity on the aerobreakup of a polymeric droplet. The study is structured into three major parts. The first part provides an experimental study on the shock-induced aerobreakup of a polymeric droplet. Here, we explore the role of liquid elasticity on the aerobreakup process for a wide range of Weber number ($\sim 10^2 – 10^4$) and elasticity number ($\sim 10^{-4} – 10^2$) by subjecting polymeric droplets (aqueous solutions of polyethylene oxide) of different concentrations to an induced airflow behind a moving shock wave. In the first part of our study, the viscosity of the polymeric solutions differed from that of the Newtonian solvent (DI water), and some of these polymeric solutions displayed shear-thinning behavior. Therefore, isolating the effect of elasticity from the viscosity and shear-thinning behavior remains an unresolved issue. This forms the basis for the second part of the research work. Here, we employ Boger fluids , which do not show a strain rate-dependent viscosity in shear flows (like Newtonian liquids) but exhibit viscoelastic properties. By comparing the shockinduced aerobreakup of a Boger fluid droplet with that of a Newtonian droplet with similar shear viscosity, we eliminate any effect that may come from the shear-thinning behavior. The third part of this work provides an experimental study on the aerodynamic bag breakup of a polymeric droplet at a fixed Weber number of ≈15, while the elasticity number is varied in the range of $\approx 10^{-4} – 10^{-2}$. Here we attempt to address the most fundamental aspect of studying aerobreakup, i.e., to predict the fragmentation. We provide a framework to approach this complex problem, identify the stages where the role of liquid elasticity can be neglected and where it must be considered, and finally, establish a criterion that governs the occurrence or the absence of fragmentation in a specified time period.

ABOUT THE SPEAKER

Navin Kumar Chandra is a Prime Minister's Research Fellow in the Department of Mechanical Engineering at IISc Bangalore. His research, supervised by Prof. Aloke Kumar, encompasses the broad area of rheology and non-Newtonian fluid flows. He earned his B. Tech. in Mechanical Engineering from the National Institute of Technology (NIT) Raipur in 2014. Following graduation, he held positions as an Executive at HSCC India Limited (2014-2017) and as an Operations and Maintenance Engineer at Indian Oil Corporation Limited (2017-2018). To pursue his research and academic interests, he joined IISc as a Ph.D. student in 2018.