ME – PhD Thesis Defense

Spatio-temporal dynamics in droplet combustion under diverse flow conditions

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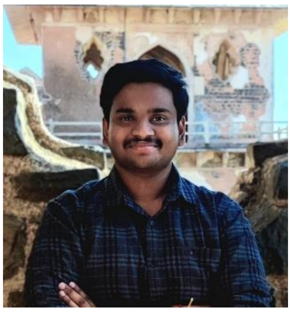
ABSTRACT

Spray combustion of liquid fuels is one of the most ubiquitous modes of combustion used in a wide range of applications ranging from IC engines for transportation to Gas turbines in propulsion systems, owing to the high energy density, ease of handling of liquid fuels. It consists of a fuel jet that atomizes into small droplets, which vaporize and undergo combustion inside the combustors. The droplet-level phenomena such as vaporization, secondary atomization, droplet flame dynamics, and their interaction with the local flow all play a significant role in the overall performance of such spray systems. Although droplet combustion studies cannot be directly extended to practical results for reacting spray systems, isolated single droplet combustion provides us insights into certain phenomena (extinction, stabilization, pollutant formation etc.) under well-controlled conditions, which allows us to make predictions for more complex situations. Thus, the present study investigates the isolated droplet flame behavior under a wide range of flow conditions.

The first part of the study investigates the interaction of droplet flame with continuous low-speed flows. This has been experimentally investigated in a drop tower by studying the flame dynamics in a freely falling burning fuel droplet. Two different types of flame dynamics i.e., near-field wake flame and far-field wake flame have been shown to occur in a freely falling burning droplet depending on the ignition mechanism. Experimental investigation has been carried out to comprehensively study and understand the flame transitions, different stabilization mechanisms occurring in a freely falling droplet. The underlying mechanisms influencing the flame dynamics such as topological evolution, shedding, extinction, blowout, etc. have been understood. Separate set of drop tower experiments were conducted to investigate the near-wake flame dynamics over a wider range of Reynolds number ($0 < Re < 150$) using a co-flow arrangement. These experiments furthered the understanding of the flame transition between different stabilization mechanisms and showed a correlation between flame topology and imposed flow velocity.

The second part of the study investigates the other end of the spectrum, i.e., interaction of the droplet flame with high-speed transient compressible flows. A series of experiments have been carried out using an in-house shock generation apparatus which works on the principle of exploding wire technique. The interaction of the blast wave generated by the shock generator with a burning droplet is experimentally investigated using high-speed imaging techniques. A wide range of shock Mach numbers ($1.03 < M_s < 1.8$) have been achieved by modifying the extent of shock focusing and charging voltage during the shock generation. The experiments showed two stage simultaneous interaction of the flame and droplet with the incident blast wave and induced flow respectively. The flame and droplet response corresponding to the flow imposed has been investigated in detail and different timescales of interactions were uncovered. The experiments were also carried out using nanofuels to further the understanding of the underlying mechanisms.

ABOUT THE SPEAKER



Vadlamudi Gautham is a PhD student under the supervision of Prof. Saptarshi Basu in the Department of Mechanical Engineering at IISc Bangalore. His research focuses on the flame and droplet dynamics involved during droplet combustion under diverse flow conditions. He earned his B. Tech. in Mechanical Engineering from the Birla Institute of Technology and Science (BITS) Hyderabad in 2017. His research interests include Fluid Mechanics, Combustion and Heat transfer. To pursue his research and academic interests, he joined IISc as a Ph.D. student in 2018.