Graduate Student Research Seminar

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On Burning Rate and Flame Extinction for Toluene Droplets in Low Gravity

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3:00 pm (EST) – 132 Fluor Daniel Building

Abstract

Toluene ($C_6H_5CH_3$, boiling point of 384 K) is a monocyclic aromatic compound found in transportation fuels, which plays an important role in soot formation during combustion. To understand its combustion and sooting dynamics, an attractive experimental platform is the spherically symmetric droplet flame. In this work, droplet combustion experiments carried out on the International Space Station are reported to study near spherically symmetric burning of unsupported or free-floating toluene droplets at atmospheric pressure over a wide range of initial droplet diameters (D_0 ~ 1 to 7 mm). Spherically symmetric burning conditions and one-dimensional gas transport provide a useful environment to reveal the burning characteristics of this complex fuel, including the influence of D_0 on radiative transport, fuel burning rate, and flame extinction.

Results showed that droplets burned to completion without experiencing radiative extinction for $D_0 < 2.5$ mm, while a two-stage burning process was noted for larger droplets: steady combustion with a visible flame, then radiative extinction, after which the droplets continued to evaporate because of thermal transport from the locally hot ambience. After radiative extinction, wide-band and narrow-band radiometer measurements indicated no cool flame or low-temperature combustion regimes. Results also showed that the extinction diameter increased with D_0, which is consistent with trends previously reported for other hydrocarbon fuels. The instantaneous droplet burning rate (K) was initially steady as combustion developed and then decreased with time, accompanied by a significant reduction in flame radiance when the flame radiatively extinguished. A scaling analysis by an energy balance at the droplet interface revealed that the estimated flame temperature dropped sharply from approximately 1400 K to 560 K shortly after radiative extinction, then gradually decreased toward ambient levels. Finally, an averaged K (K_{avg}) was obtained for each D_0 prior to radiative extinction and correlated by a power-law relation $K_{avg} \sim D_0^{-n}$.

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