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ETHYLENE LAMINAR DIFFUSION FLAMES AT SUB-ATMOSPHERIC PRESSURES TO SIMULATE MICROGRAVITY

Abstract

The subject of combustion in non-buoyant or microgravity environments has become a prominent branch of combustion science and research. While understanding combustion will help to decrease particulate emissions and pollution from combustion technology used in earth-based applications, the future of space exploration depends on the safety of space technology, which includes a complete understanding of combustion processes in non-buoyant environments. This combustion research is essential for improving spacecraft safety for space missions and is also indispensable for gaining an in-depth understanding of combustion processes on earth. Without buoyant effects, novel flame behaviors are revealed.

A less common method to simulate non-buoyant conditions is through sub-atmospheric pressures. At low pressures (pressures ranging from atmospheric down to a vacuum), the effects of buoyancy can be minimized during combustion. As a result, the characteristic residence times for combustion are longer than under buoyant conditions.

In this work ethylene/air diffusion flames were studied at super and sub-atmospheric pressures to simulate a non-buoyant environment at flow rates of 0.482 mg/s and 1.16 mg/s. Flame properties including flame dimensions and soot formation were studied. Overall, luminous flame height decreased with decreasing pressure to the point of visible luminosity disappearance, resulting in blue flames at a near vacuum. Flame width increased with decreasing pressure until the flame was almost spherical. Soot formation was also found to decrease with decreasing pressure and existed at very negligible concentrations in a near vacuum. Sub-atmospheric peak soot volume fractions ranged from 0.076 ppm to 0.93 ppm at 0.482 mg/s, whereas at 1.16 mg/s, peak soot volume fractions ranged from 0.24 ppm to 5.8 ppm. Even at sub-atmospheric pressures, higher fuel flow rates produced flames with higher soot concentrations. Soot production was restricted to an annular region with this annular region shifting closer to the flame centerline with increasing height from the burner. At locations about halfway between the burner rim and the flame tip, soot volume fraction decreased with increasing radial distance from the flame centerline. These results are consistent for both high and low pressure flames. The annular soot formation region was also located further from the flame centerline for the higher flow rate flames because of the difference in luminous flame shape. At 0.482 mg/s, the percentage of carbon converted into soot was between 0.01% and 0.12% in the sub-atmospheric pressure range, whereas at 1.16 mg/s, this percentage was between 0.5% and 11% at sub-atmospheric pressures.