Size distribution, mass-mobility, and effective density of soot particles generated from large-scale turbulent diffusion flames

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Abstract

Size distribution, mass-mobility, and effective density of soot particles generated from a large-scale turbulent diffusion flame was characterized under various fuel composition and exit velocity conditions. The turbulent diffusion flame was set up at Carleton University Lab-scale Flare (CULF) facility which allowed controlled experiments on turbulent flames up to approximately three meters tall at fuel gas flow rates up to ~250 SLPM (standard litres per minute at 0°C and 101.325 kPa). Three different burner sizes with a diameter of 38.1, 50.8, and 76.2 mm were used in this study. The fuel exit velocities at the burner tip were 0.5, 0.9, and 1.5 m/s and the fuel flow rates were adjusted accordingly for each burner size, which resulted in a range of flow rates from 60.5 to 246.2 SLPM. Three different fuel mixture compositions (light, medium, heavy) were tested which resembled Alberta flare gas composition. The fuel gas mixture had 6 components (i.e., C1 to C4 alkanes, carbon dioxide, and nitrogen) and the mole fraction of methane in the light, medium, and heavy composition was 0.925, 0.866, and 0.769, respectively.

Combustion products were diluted by the ambient air on the order of ~20:1 to ~120:1 as they were drawn in the collecting fume hood and insulated duct using a variable speed fan. Size distribution of soot particles was measured using a scanning mobility particle sizer (SMPS), sampling from the downstream of the duct and after the sample was further diluted by a factor of ~10:1 using an ejector diluter. Mass-mobility relation of soot particles were studied by a tandem arrangement of a differential mobility analyzer (DMA), a centrifugal particle mass analyzer (CPMA), and a condensation particle counter (CPC). Such arrangement was also used to determine the effective density of soot particles. The volatility of particles was studied by adding a catalytic stripper denuder between the DMA and the CPMA. Results showed that particle size distribution changed noticeably with the fuel mixture composition. Fuel mixtures with heavier hydrocarbons produced larger particles in size and higher number of particles per unit mass of fuel. Mass-mobility results showed that the effective density of particles for all test conditions did not change significantly. The average mass-mobility exponent, D_m, of particles was approximately 2.55 for all test conditions, which is in very good agreement with the reported value (D_m=2.49) for the mass-mobility exponent of particles from different combustion sources in the literature.