Multi-color extinction/emission measurements for estimation of soot maturity in non-premixed laminar flames

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Abstract

Nanometric soot particles generated by incomplete oxidation of fuels have a negative impact on the climate change and human health. Although the soot production improves the radiative heat transfer in combustion systems, their mechanisms of formation/oxidation are not well understood due to the complex morphology and composition of soot particles inside the flame. In addition, measurements in flames are challenging due to high gradients of concentration and temperature, so non-intrusive techniques with high spatial and temporal resolution must be applied. After fuel pyrolysis, soot production beginning with the birth of incipient nascent soot particles; which are then transform into young soot by surface chemical reaction and surface condensation of polycyclic aromatic hydrocarbons (PAHs). This is followed by further growth of soot particles through surface reactions and clusters aggregation. Finally, soot oxidation occurs in regions with the presence of oxidizing compounds and high temperature. The maturity level of soot particles describes how much soot has evolved to a fully mature graphite-like particle (Michelsen et al., 2020). Also, the chemical and physical properties of soot can change during soot maturity evolution. Changes in soot composition affect its ability to absorb light, modifying the spectral dependence of the soot absorption function E(m) (Yon et al., 2021). This is an important property required to estimate the soot absorption/emission radiation in techniques such as two color pyrometry, line-of-sight attenuation (LOSA), and laser-induced incandescence (LII) (Escudero et al., 2016). In this work, a non-intrusive experimental technique is proposed to characterized the maturity of soot particles within a laminar co-flow flame of ethylene and air. Emission and extinction measurements were carried out at four wavelengths (500,532,660 and 810 nm), in order to evaluate the spatial distribution of the absorption function at each spectral band. A maturity index is defined to evaluate soot maturity based on the spectral variation of E(m). In addition, the soot volume fraction and soot temperature distribution were determined in the flame. Mature soot particles are found on the top of the flame in the centerline region and also in the flame wing region.

Keywords: Soot maturity, pyrometry, light extinction, scattering.

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