Experimental Study of the Optical Properties of Soot and Smoke

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The accurate measurement of flame-generated particulates is a problem of current interest to researchers in the fire and combustion community. Within the flame, the soot concentration measurement is central to the study of soot growth [Santoro *et al.*, 1987; Harris and Weiner, 1983] and for radiant transport analysis [Choi *et al.*, 1994a]. In the post-flame region of large fires, particulate measurements are important in developing computational modeling of smoke plume movement [Evans et al, 1993; McGrattan, et al, 1993], in the detection of fires [Mulholland *et al.*, 1989], in assessing the reduction in visibility arising from a fire within a building [Mulholland, 1988; Peacock et al. 1993] and for estimating the health and environmental impacts [Benner *et al.*, 1990].

In the fire and combustion community, particulate concentrations are typically measured using light extinction techniques. However, it has been found that the accuracy of the measurements is sensitive to the choice of dimensionless extinction constant, K_e and the assumptions made regarding the light scattering behavior of particulates. The dimensionless extinction constant is calculated using reported values of refractive index along with the assumption of negligible scattering/absorption ratio. However, the reported refractive index can vary by a factor of two [Choi et al., 1994b] and the scattering to absorption ratio can be as high as 30% [Patterson et al., 1991]. These uncertainties can result in a factor of two variation in the calculated particulate concentrations. Thus, accurate measurement of the dimensionless extinction constant is necessary to improve the usefulness of the light extinction technique for determining concentrations of smoke-generated particulates.

Accurate determination of K_e is also important for improving current understanding of radiative and burning characteristics of large fires. Thermal radiation from the fire to the fuel surface is controlled by emissions from soot and product gases. Therefore, analysis of the burning characteristics of practical fires requires detailed information regarding the species and temperature distribution above the fuel surface.

The temperature measurements using ITWP technique is also very sensitive to the choice of dimensionless extinction constant and therefore suffers from the same degree of uncertainty as in the particulate concentration measurements. Compounding this is that all radiation heat transfer models use reported refractive index in determining the radiative characteristics of soot.

Thus, in order to improve the accuracy of the light extinction and ITWP techniques for use in combustion and fire applications, the dimensionless extinction constant must be determined accurately without relying on the available optical properties of soot. The focus of this study is on the development and the use of a new and innovative technique to measure K_e called Gravimetric-Sampling/Light-Extinction technique. This technique consists of isokinetically sampling the soot at a known flow rate, measuring the mass of soot collected and determining the density of soot using helium pycnometry. The optical extinction measurements will be calibrated with the gravimetric soot volume fraction to calculate K_e. In this manner the magnitude and the spectral variation of K_e can be determined without relying on the refractive index of soot or making drastic assumptions regarding its scattering characteristics. Preliminary experiments demonstrated that K_e can be measured with an uncertainty less than 15% using the GSLE technique.

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