Laser-induced incandescence measurements in a laminar co-annular non-premixed methane/air flame at a pressure of 0.5 - 4.0 MPa

K. A. Thomson*, D. R. Snelling, G. J. Smallwood, F. Liu
Institute for Chemical Processes and Environmental Technology
National Research Council of Canada, Ottawa, Canada

Auto-compensating laser-induced incandescence (AC-LII) was applied to a high pressure non-premixed flame to measure soot volume fraction (SVF) and effective primary particle diameter (dp_{eff}). Measured SVF and dp_{eff} showed annular structures and good radial symmetry. LII determined SVF were lower than previous LOSA SVF measurements (60% lower at p = 0.5 MPa up to 30% lower at p = 4.0 MPa). The LII SVF curve shapes were similar to the LOSA SVF curves, though the former had lower measurement spatial resolution at the higher pressures (*i.e.* P = 2.0 and 4.0 MPa). Effective primary particle diameter increased with pressure and radius (e.g. 20 nm at r = 0 mm, p = 0.5 MPa to 100 nm at p = 4.0 MPa).

Introduction

The objective of the present work is to apply the AC-LII method [1] to the SVF and size measurement of soot in a non-premixed high pressure flame. Measurements were compared to previous line-of-sight attenuation SVF measurements (LOSA) for the same burner [2].

Experiments

A laminar co-annular non-premixed flame was operated with methane and air mass flow rates of 0.55 mg/s and 0.4 g/s, respectively, in an optically-accessible pressure vessel for pressures of 0.5, 1.0, 2.0, and 4.0 MPa. The experimental apparatus is described in [2]. Soot particles were heated by a pulsed Nd:YAG laser frequency doubled to a wavelength of 532 nm and formed into a vertical sheet. The laser intensity normal to the sheet was approximately Gaussian (σ = 36 μm). The LII emission was collected perpendicular to the laser sheet and imaged onto an optical fiber (100 μm core diameter). The fiber output was first split and filtered with interference filters having central wavelengths of 445 and 798 nm and widths of 60 nm and then imaged onto two fast photomultipliers. LII emission was sampled at 1 ns intervals. The detection system was calibrated for absolute emission intensity with a calibrated integrating sphere light source located coincident with the flame centerline. Measurement scans were made at a height of z = 6.0 mm above the burner tip along an axis through the flame centerline (*i.e.* $x = 0$) with measurement spacing of Δy = 50 μm. The peak laser fluence, before entering the flame, was 0.59 $\mathrm{mJ/mm^2}$. The fluence dropped by as much as 20% due to attenuation in the flame. Additional data points were collected at the end of each scan with a fluence of 0.67 $\mathrm{mJ/mm^2}$ to compensate for flame attenuation. The theory used in the evaluation of the LII emission is described in [1].

Results

SVF measurements for p = 1.0 MPa are included in Fig. 1 with LOSA SVF measurements at z = 5.5 and 6.0 mm. The data symmetry despite position variant fluence demonstrates that AC-LII works well in an unknown attenuating environment. Based on curve shapes (location of peak SVF and ratio of peak to centerline SVF), the LII data appears to fall between the two LOSA curves. The LII measurements are 30-40% lower in magnitude.

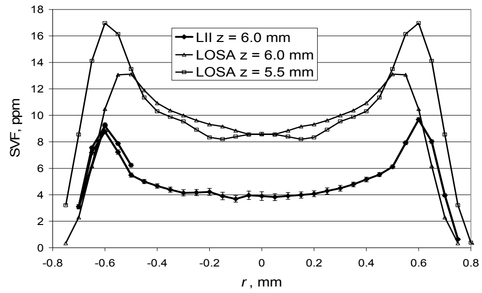

Fig. 1: LII and LOSA SVF, p = 1.0 MPa.

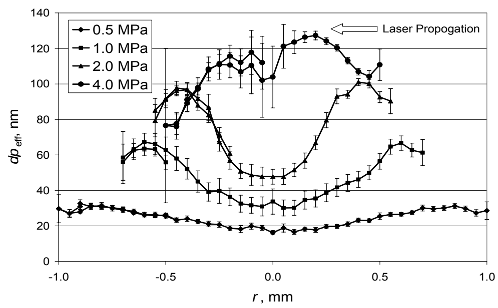

Fig. 2: Effective primary particle diameter.

Fig. 2 shows the measured dp_{eff}. Symmetry is excellent except at p = 4.0 MPa. There is a pronounced increase of dp_{eff} with increasing P and r. Overall these preliminary measurements made in a challenging high-pressure and high-property gradient environment are encouraging for future high pressure LII research.

References

1 Snelling, D. R., G. J. Smallwood, F. Liu, Ö. L. Gülder, W. D. Bachalo (2005), Applied Optics, *accepted*.
2 K. A. Thomson, Ö. L. Gülder, E. J. Weckman, R. A. Fraser, G. J. Smallwood, D. R. Snelling (2005), C&F, v. 140, i. 3, pp 222-232.

* Corresponding author: kevin.thomson@nrc-cnrc.gc.ca
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