

Laser-induced incandescence and shifted vibrational CARS in laminar premixed flames at atmospheric and elevated pressures

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An experimental investigation of various laminar premixed flames at atmospheric and elevated pressures (1-5 bar) has been conducted. Quantitative soot volume fraction measurements were obtained using laser-induced incandescence coupled with a quasi-simultaneous absorption measurement for calibration; the data were corrected for signal trapping using an "onion peeling" algorithm. Temperature measurements were obtained using shifted vibrational coherent anti-Stokes Raman scattering. Results are presented for stable homogeneous flames using air as oxidizer and ethylene, propylene, and toluene as fuels. The data identify trends and features useful for the validation of numerical models of soot formation.

Introduction

A study of laminar premixed flames under different operating conditions was performed. The study improves upon existing applied laser diagnostic techniques and enables a validation of kinetic soot models.

Experiments

Stable flames, chosen for the validation of kinetic soot models, were studied under the following conditions: six ethylene/air flames at 1, 3 and 5 bar, five propylene/air flames at the same pressures and three toluene/air flames at 1, 1.5 and 3 bar.

Laser-induced incandescence excited at 1064 nm, calibrated with an extinction measurement on the same optical pathway and at a wavelength of 532 nm, was used for the determination of soot volume fractions. Applying a refractive index of 1.60-0.59i [1] and a correction for signal trapping between the experimental plane and the detector [2], determination of the soot concentration profiles along the flame axis was possible. Since the extinction measurement was performed with a laser sheet and for each flame in situ, in principle, a calibration is possible at any height in the flame. Practically, a position between young forming soot and aged soot, thus close to the start of the soot plateau, was chosen as representative of the whole flame with one single calibration position. Clear trends of the calibration constant value with operating conditions could not be observed. Flame temperature measurements on the burner axis were performed with shifted vibrational coherent anti-Stokes Raman scattering (SV-CARS) [3].

Because the flames proved to be sufficiently stable and reproducible, each diagnostics could be applied consecutively with only a few minutes' gap in between for exchanging the respective optics. At the chosen rich equivalence ratios and flow rates the maximum temperature remained below 1730 K. Determined soot plateau concentrations

varied between 0.6 ppm for the atmospheric ethylene flames and 11 ppm for the richest 5 bar ethylene flame. Clear trends could be observed with respect to the thickness of the flame front (temperature rise) in changing from the relatively simple fuel ethylene to toluene and from low to high pressure. The first variation increases the width of the flame front while the second influences it in the opposite direction. Soot concentrations typically increase with equivalence ratio (moderately), pressure (strongly) and complexity of fuel. Sample data from the study are presented in Figure 1.

In addition to the benefit for kinetic model validation, the gained accurate temperatures can be used to improve the typical uncertainty of estimated ambient temperatures for deduction of the particle size from LII decay curves in future experiments in the now defined flames.

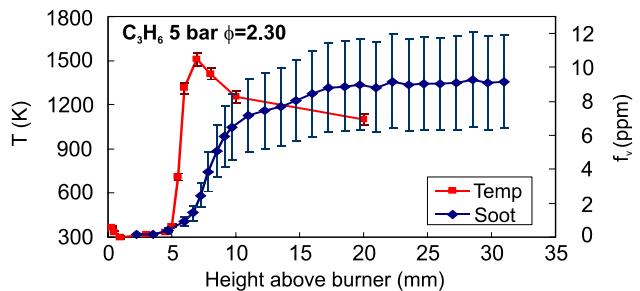


Fig. 1. Correlated soot concentration and temperature profiles along the burner axis for one studied flame.

References

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Proceedings of the International Bunsen Discussion Meeting 2005: Laser-induced Incandescence, Quantitative interpretation, modelling, application