Absorption correction of two-color LII-signals

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In this work we present a numerical iterative procedure for the evaluation of the effect of signal absorption in two-color laser-induced incandescence (2C-LII) measurements. The correction process is applied to experimental results, previously published by our group, in an axisymmetric diffusion flame. We have studied the influence of signal trapping on peak soot temperature and on soot volume fraction determination. The influence was found to be minimal for the investigated flame. Some numerical tests were also performed in order to investigate the effects of soot concentration, flame size and soot refractive index on the magnitude of the corrections due to signal absorption.

Introduction

Two-color LII technique is proposed for absolute soot volume fraction measurements without the need for a calibration procedure performed in an environment of known soot concentration. Absorption corrections, as obtained trough an iterative numerical procedure, are applied in order to evaluate their influence on peak temperature and, therefore, on soot volume fraction measurements. This work shows that 2C-LII technique present an intrinsic stability in the determination of soot volume fraction, even in the case of soot load and refractive index variations.

Numerical Procedure and Results

The procedure for absorption correction is essentially based on an iterative process[1]. It has been applied to raw LII data taken on a laminar ethylene diffusion flame and reported in a previous publication[2.] The correction for absorption of LII signals at two wavelengths takes into account the soot amount in the region between the detection optics and the origin of the LII signals. The iterative procedure is quite simple. The original measured signals at two wavelengths are elaborated through an Abel inversion procedure in order to obtain radial LII emission profiles. From the ratio of the two signals the radial profiles of peak soot temperature and volume fraction are calculated. This last is utilized in the calculation of the absorption corrected signals. The entire procedure is repeated until the difference in soot volume fraction is minimized. Because the absorption at the two wavelengths is different, the result of the procedure is to increase the "true" corrected temperature (about 50-70 K) with the consequent decrease of volume fraction even though signals are higher because of absorption corrections. The application of the 2C-LII technique, with the competitive effects of the correction for the two signals allows to obtain soot volume fraction values that weakly depend on absorption corrections.

In order to gain a better view of different aspects of signal trapping, some numerical simulations have been also performed. These tests were carried out by changing the soot amount, trough variation of the LII-signal intensities and flame size, by multiplying them by factors 2, 5 and 10. The trend is the same as previously observed. Only for the unreal largest correction (factor 10) the peak temperature profile is heavily distorted and, as a consequence, also the soot volume fraction profile is much different from the original one.

Another interesting test was performed to analyze the role of soot refractive index. Soot temperature depends on the ratio of the values of E(m) calculated at the two measuring wavelengths. The choice of the refractive index is still a debated issue and comparison of soot volume fraction results must take this into account. In general we use the data of Chang and Charalampopoulos[3], involving a slight decrease of E(m) with wavelength. In this test we used the data of Krishnan et alii[4] which present an opposite slope. The results of the calculations show that the peak temperatures reach values around 4500-4600 K. This influences the soot concentration values that are half of what was previously measured and in disagreement with extinction measurements using the same set of refractive index. Nevertheless the absorption correction is negligible even in this case.

Conclusions

The 2C-LII technique has been shown to be rather insensitive to absorption corrections. Considering that it can also give absolute soot concentration measurements the 2C-LII technique results to be a very powerful tool for soot diagnostics.

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