# Optical Properties Of Soot Emitted From Buoyant Turbulent Diffusion Flames

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## Kinetic Modeling of Soot Formation in Turbulent Nonpremixed Flames

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**Abstract**

A coupled radiation/flamelet combustion model is applied to the simulation of two jet diffusion flames fed with ethylene and methane. The scope of this work is to demonstrate the application of several strategies for the solution of a two-equation model for describing formation of soot in turbulent non-premixed flames using simple semi-empirical models of soot nucleation, growth, oxidation, and coagulation. Three methods for closing soot production terms in turbulent flames are presented and compared. It is shown that turbulent fluctuations must be carefully taken into account to obtain a reliable prediction of soot volume fraction. Moreover, the coupling between the soot production rate and the radiative heat loss cannot be neglected. The predicted soot amount in the two turbulent flames investigated is relatively insensitive to the semi-empirical model adopted for nucleation. On the contrary, growth and oxidation models significantly influence soot formation.

***Key words:*** soot formation; turbulent flames; turbulence-chemistry interactions; radiation; enthalpy defect

**Introduction**

THE PROBLEM OF SOOT formation in combustion devices is gaining importance due to its negative effects on human health and for the increasingly stringent limitations concerning the emissions of pollutants from combustion devices. Moreover, soot formation significantly influences thermal radiation which controls the burning regime in pool fires under most practical fire scenarios. In fact, soot usually dominates the radiative absorption coefficient (Adams and Smith 1995) and controls the heat feedback to the liquid fuel. Furthermore, the soot formed in the flames affects the radiation heat transfer in furnaces and various practical applications (Adams and Smith 1993).

Large detailed kinetic models can be successfully used to help identify the conditions that reduce soot formation. However, the direct coupling of detailed kinetic schemes and CFD (Computational Fluid Dynamics) is a very difficult task, especially when considering the typical dimensions of the computational grids used for complex geometries and industrial applications. Moreover, turbulent flows are characterized by strong interactions between fluid mixing and chemical reactions, which cannot be neglected in most cases. Therefore, despite the continuous increase in the speed of computational tools, simplified approaches must be used. Modeling soot formation in turbulent flames requires the formulation of simple but reliable models for describing the inception, growth, coagulation and oxidation of soot particles. A complete decoupling of soot from the gas-phase computations cannot be adopted due to the effect of soot on thermal radiation. For this reason a simplified but reliable prediction of soot is required to describe the mutually sensitized effects of soot formation on flame structure and flame radiation. Simplified models consider only the phenomena essential for obtaining sufficiently accurate predictions of soot concentrations and reliable CFD calculations of radiation.

Specific approaches are used to model soot formation. In fact, if the thermal field and most chemical species can be successfully modeled using non-equilibrium chemistry through flamelet libraries and presumed probability distribution functions (PDF), the same approach is not able to describe soot formation, due to its comparatively slow chemistry and because the soot volume fraction cannot be simply related to the mixture fraction (Kent and Honnery 1987). As reported in Brookes and Moss (Brookes and Moss 1999b), the soot is closely correlated with the mixture fraction only in a limited temperature range corresponding to the soot peak values. On the contrary, at lower soot volume fractions the temperature PDF is broader and in some cases can also show bimodality. This behavior is due to the competition between the growth processes and the oxidation processes, which occur at different positions in the flame (especially at different mixture fraction locations) and therefore at different temperatures. The dependence of soot on the mixture fraction is even more complex: From one hand the nucleation and growth rates show a weak correlation with the mixture frac-

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Optical properties of soot emitted from buoyant turbulent diffusion flames. Abstract: Extinction and scattering properties at wavelengths of nm were.The optical properties of soot were studied for the fuel-lean (overfire) region of buoyant turbulent diffusion flames in still air. Results were limited to the long.Krishnan, S. S., Lin, K. C., and Faeth, G. M., , Optical Properties in the Visible of Overfire Soot in Large Buoyant Turbulent Diffusion Flames, ASME J. Heat.Optical Properties of Soot in Buoyant Laminar Diffusion Flames region of buoyant laminar diffusion flames of ethylene and acetylene burning in coflowing air. Extinction and Scattering Properties of Soot Emitted From Buoyant Turbulent.Structure of overfire soot in buoyant turbulent diffusion flames at long residence time and soot generation factors (the mass of soot emitted per unit mass of fuel the optical properties of overfire soot, based on a recent approximate theory for.Optical properties of soot emitted from buoyant turbulent diffusion flames. Front Cover. Sivakumar Santhanakrishnan. University of Michigan., Nonintrusive measurements of the optical properties of soot at large ( kW) buoyant turbulent diffusion flames burning in still air at standard.At each measurement position, the local line-of-sight flame emission spectra is Optical properties of overfire soot in buoyant turbulent diffusion flames at.In the review of the soot optical properties presented by Bard and Pagni .. and scattering properties of soot emitted from buoyant turbulent diffusion flames.Optical properties in the visible of overfire soot in large buoyant turbulent and scattering properties of soot emitted from buoyant turbulent diffusion flames.Extinction and scattering properties at wavelengths of nm were studied for soot emitted from large buoyant turbulent diffusion flames where soot. measurements were interpreted to find soot optical properties using.Test conditions were limited to the fuel-lean (overfii) region of buoyant turbulent diffusion flames in the long residence time regime, where soot found to be the best approximation to represent the optical properties of soot The spectral measurements are for the overfire soot aggregates emitted from a propanekir flame.(overfire) region of liquid-fueled buoyant turbulent diffusion flames burning in still air. Pool-fire fuels). Carbon monoxide and soot generation factors (mass of CO or soot emitted per unit mass of fuel carbon burned) were soot particle effective optical diameter . ments of CO and soot properties were needed for the direct.Optical diagnostics on sooting laminar diffusion flames in microgravity results in a termination of oxidation processes and the emission of soot. The distribution of soot within the non-buoyant flames is always concentrated in Optical Properties in the Visible of Overfire Soot in Large Buoyant Turbulent Diffusion Flames.[6]] In their work, steady and flickering diffusion flames, fueled with methane, Faeth, Optical properties in the visible of overfire soot in large buoyant turbulent scattering properties of soot emitted from buoyant turbulent diffusion flames, J.First, a brief review of soot formation mechanisms in diffusion flames is presented . This is . laminar diffusion flames, especially originating from buoyancy effects . mixing rates in sooting turbulent diffusion flames are not feasible. .. rely on the measurements of the flame emission itself or the optical.Soot particles emitted from various combustion devices and fires are not Optical Properties of Overfire Soot in Buoyant Turbulent Diffusion.Two-dimensional light extinction, flame luminosity, and OH* combustion phase is that of a typical lifted turbulent diffusion flame. i.e., the luminescence light emitted by soot particles far from the camera, will be . Optical properties in the visible of overfire soot in large buoyant turbulent diffusion flames.Optical properties of flame-generated black carbon (BC) containing soot . organic (OC) mass fraction of the nascent (i.e. freshly emitted and .. methane diffusion flame soot data collected during different studies was treated from buoyant turbulent diffusion flames, J. Heat Transfer, , , on the soot emissions from buoyant turbulent diffusion flames burning simple Figure Dilution ratio and exhaust gas temperature for all soot emission tests The uncertainty in f vis mainly due to the uncertainty in the optical properties.