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Dedication lecture

PROGRESS IN THE INVESTIGATION OF THE INTERACTION BETWEEN TURBULENCE AND RADIATION

Pedro J. Coelho

IDMEC, Instituto Superior Técnico, Universidade de Lisboa
Av. Rovisco Pais, 1049-001 Lisboa, Portugal

Fluctuations of temperature and concentration of species due to turbulence have an impact on the time averaged radiative emission, radiative absorption and radiation intensity that leads to values of the time-averaged radiative heat fluxes and radiative heat sources that are different from those that would be found if such fluctuations did not exist. Moreover, the solution of the radiative transfer equation based on time-averaged values of the temperature and species concentrations does not account for turbulent fluctuations on the radiative emission and absorption, and may significantly underestimate the time-averaged radiative heat fluxes and radiative heat sources. The interaction between turbulence and radiation (TRI) has been recognized for many years, but only in the last two decades serious efforts have been made to incorporate this effect in the models used in the numerical simulation of turbulent reactive flows.

We begin this lecture by clarifying what we are talking about when we refer to TRI, and following a brief reference to the case of non-reactive flows, we will concentrate mainly in the progress made to computationally account for the influence of turbulence on radiation in turbulent reactive flows. Different methods may be used to model TRI, depending on how turbulence is dealt with (Reynolds-averaged Navier-Stokes – RANS, large-eddy simulation – LES or direct numerical simulation – DNS), on the combustion model employed (eddy dissipation, presumed pdf or transport pdf models) and on how thermal radiation and radiative properties of the medium are simulated (P1, discrete ordinates/finite volume method or Monte Carlo method for radiative transfer, and global, band or line-by-line models for the radiative properties). These methods will be summarized, addressing their advantages and limitations.

A priori estimation of the influence of TRI on the temperature self-correlation, absorption coefficient self-correlation and absorption coefficient-blackbody radiation intensity correlation are addressed, and the importance of these correlations is shown for several cases reported in the literature. The influence of TRI is particularly important in the emission term and all the three correlations mentioned above need to be considered, while the optically thin fluctuation approximation is often adequate to model the radiative absorption. Examples of application that highlight the importance of TRI will be presented for non-luminous and luminous gaseous flames. Application to practical problems will also be shown, including pool fires, combustion chambers and recent liquid spray and coal flame simulations. In general, TRI contributes to increase the radiative heat loss and decrease the mean flame temperatures. This latter effect is particularly relevant when highly dependent temperature phenomena need to be simulated, such as the NO emission, since the rate of formation of thermal NO is very sensitive to the temperature. We will conclude with some remarks concerning the main consequences of TRI and some open questions will be outlined.