RADIATION STATISTICS IN HOMOGENEOUS ISOTROPIC TURBULENCE

C.B. da Silva[1], I. Malico[2] and P.J. Coelho[1*]

[1] Mechanical Engineering Department, IDMEC/LAETA,
Instituto Superior Técnico, Technical University of Lisbon,
Av. Rovisco Pais, 1049-001 Lisboa, Portugal

[2] Physics Department, University of Évora,
Rua Romão Ramalho, 59, 7000-671 Évora, Portugal

ABSTRACT

An analysis of the interaction between turbulence and radiation in statistically stationary (forced) homogeneous and isotropic turbulence has been carried out. A direct numerical simulation (DNS) code was used to generate instantaneous turbulent scalar fields, and the radiative transfer equation (RTE) was solved to provide statistical data of the radiation intensity and absorption coefficient, as well as correlations related to radiative emission and absorption. In addition, the time-averaged RTE was solved and the mean radiation intensity, mean absorption coefficient, and mean radiative emission were computed and compared with those derived from the statistical data. An analysis of the number of samples required to achieve statistically meaningful results is presented, and the influence of the optical thickness of the medium, mean and variance of the temperature and variance of the mean molar fraction of the absorbing species are studied. The moments of the radiation intensity, Planck-mean and incident-mean absorption coefficients, and emission and absorption correlations relevant to the turbulence – radiation interaction (TRI) are calculated. It was found while turbulence yields an increase of the mean blackbody radiation intensity, it causes a decrease of the time-averaged Planck-mean absorption coefficient. The absorption coefficient self-correlation is small in comparison with the temperature self-correlation, and the role of TRI in radiative emission is more important than in radiative absorption. The correlation between fluctuations of the absorption coefficient and fluctuations of the radiation intensity is small, which supports the optically thin fluctuation approximation (OTFA), and justifies the good predictions often achieved using the time-averaged RTE.