Turbulence radiation coupling in boundary layers of heavy-duty diesel engines

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The lack of accurate submodels for in-cylinder radiation and heat transfer has been identified as a key shortcoming in developing truly predictive, physics-based computational fluid dynamics (CFD) models that can be used to develop combustion systems for advanced high-efficiency, low-emissions engines. Recent measurements of wall layers in engines show discrepancies of up to 100% with respect to standard CFD boundary-layer models. And recent analysis of in-cylinder radiation based on the most recent spectral property databases and high-fidelity radiative transfer equation (RTE) solvers has shown that at operating pressures and exhaust-gas recirculation levels typical of modern heavy-duty compression-ignition engines, radiative emission can be as high as 40% of the wall heat losses, that molecular gas radiation (mainly CO2 and H2O) can be more important than soot radiation, and that a significant fraction of the emitted radiation can be reabsorbed before reaching the walls. That is, radiation not only contributes to heat losses, but also changes the in-cylinder temperature distribution, which in turn affects combustion and emissions. The goal of this research is to develop models that explicitly account for the potentially strong coupling between radiative and turbulent boundary layer heat transfer. For example, for optically thick conditions, a simple diffusion model might be formulated in terms of an absorption-coefficient-dependent turbulent Prandtl number.