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A Narrow-Band k-Distribution Model with Single Mixture Gas Assumption for Radiative Flows

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Abstract

In the present study, the narrow-band *k*-distribution (NBK) model parameters for mixtures of H_2O, CO_2, and CO are proposed by utilizing the line-by-line (LBL) calculations with a single mixture gas assumption. For the application of the NBK model to radiative flows, a radiative transfer equation (RTE) solver based on a finite-volume method on unstructured meshes was developed. The NBK model and the RTE solver were verified by solving two benchmark problems including the spectral radiance distribution emitted from one-dimensional slabs and the radiative heat transfer in a truncated conical enclosure. It was shown that the results are accurate and physically reliable by comparing with available data. To examine the applicability of the methods to realistic multi-dimensional problems in non-isothermal and non-homogeneous conditions, radiation in an axisymmetric combustion chamber was analyzed, and then the infrared signature emitted from an aircraft exhaust plume was predicted. For modeling the plume flow involving radiative cooling, a flow-radiation coupled procedure was devised in a loosely coupled manner by adopting a Navier-Stokes flow solver based on unstructured meshes. It was shown that the predicted radiative cooling for the combustion chamber is physically more accurate than other predictions, and is as accurate as that by the LBL calculations. It was found that the infrared signature of aircraft exhaust plume can also be obtained accurately, equivalent to the LBL calculations, by using the present narrow-band approach with a much improved numerical efficiency.

Keywords: Radiation modeling; Line-by-line method; Narrow-band k-distribution model; Single mixture gas assumption; Radiative transfer equation; Finite-volume method

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