EFFECTS OF PARTICLES OPTICAL PROPERTIES ON UV RADIANCE FIELD IN AXISYMMETRIC SCATTERING HOT MEDIA

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Understanding radiative properties from ultraviolet to infrared of rocket motors plumes is required in a variety of engineering problems such as base heating or rocket detectability through plume optical emission. The middle ultraviolet band may be of interest for rocket plume detection, because the sky background seen from low Earth atmosphere can be considered completely dark. This darkness, which is due to solar radiation absorption by stratospheric and tropospheric ozone, allows one to detect a rocket plume with a good contrast, especially in the so-called "solar-blind" band located approximately between 240 and 290 nm. Solar-blind emission of rocket plumes results from gases and particles inside the plume. Due to high content of H_2 and CO at the nozzle exit plane, afterburning may occurs during mixing with ambient air, giving rise to chemiluminescence emission such as CO-blue flame emission or UV bands from OH*. The CO-blue flame emission results from the recombination between carbon monoxide and atomic oxygen and produces a UV-visible continuum. Particles such as soot or metallic oxide may also be present, depending on the propellant type.

In order to study UV radiative transfer in alumina loaded rocket plumes, we have recently extended a 3D radiative transfer model initially developed for atmospheric problems. The radiative transfer equation is integrated along discrete ordinates defined by a Gauss-Legendre quadrature, and the in-scattering integral is evaluated by using spherical harmonics base. The extended model computes chemiluminescence emission, based on available reaction rates[1]. This volumetric power gives rise to a new term in the source function. Particles emission and scattering are also taken into account. Alumina optical properties are calculated with Mie theory, assuming spherical and homogeneous particles. As particles temperature is size dependent, the corresponding thermal emission in the radiative transfer equation is calculated with an equivalent temperature. Various tests cases published in literature have been computed by this new model.

The role of alumina particles and chemiluminescence reactions is studied in simple axisymmetric media of finite length. In each case, the thermochemical properties are assumed to be independent of the axial coordinate. The media properties are constructed from realistic profiles extracted from flowfield calculations in the afterburning region of a rocket plume. Alumina particles with sizes ranging from 0.1 to 100 μm may be found in plumes, depending on motor and propellant characteristics. The alumina refraction index depends on a number of parameters like particles phase (solid : α, γ, liquid), temperature, the presence of additional metallic oxide like iron oxide, and the environmental gases. In consequence, alumina optical properties, which are input of the 3D radiative transfer model, may span a large domain. The new 3D radiative transfer model has been used to study the effect of these optical properties variability on the radiance field characteristics. Examples will be presented, which compare the role of particles and gases on the total plume emission, and which demonstrate the effect of particles optical properties on the angular dependence of the total media intensity. Distinction is made between lines of sight perpendicular and parallel to the media axis. Scattering effects are stronger in the second case, especially if the volume close to the axis is shaded by a mask which would represent the motor's body. For constant alumina mass density, effect of particles scattering is more important for small particles. In this case, the influence of optical refraction index on the radiance field is also stronger. These examples also enable to classify the experimental measurements performed on rocket plume, based on their sensitivity on particles optical properties. Finally, simpler approach like two-flux model has been used to deduce radiance profile, and the limit of this model will be shown.

REFERENCE

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