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Estimation of Optical Uncertainties in a Particle Laden Flow

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Extended Abstract

Particle laden flow in a turbulent regime develops stochastic structures. If the flow is in a radiative environment, these clustering effects make numerical prediction of absorption and transmission difficult. Furthermore, consistent comparisons of these predictions to experimental measurements is made more challenging due to the large number of input parameters with associated uncertainties [1].

In this work, a discrepancy between Monte Carlo radiative transfer simulations and experimental measurements on a particle-laden duct are examined [2]. In the experiment, a series of microparticles are entrained in a turblent flow of air in a square duct. A glass test section is irradiated using a near-infrared light source. For the numerical predictions, the microparticles are taken to be pure nickel spheres of diameters ranging from seven to fifteen microns. The scattering properties of these particles are calculated using Mie theory [3]. However, these assumptions lead to an overprediction of the average radiative absorption of the flow in comparison to measured values. It is not believed that the particle size distribution or particle locations are misrepresented in these simulations. One potential option to close the gap between simulation and experiment is to consider higher fidelity approaches to modeling the optical properties, in particular, the absorption efficiency.

A series of chemical and optical parameters are considered that would change the optical properties from that of a pure nickel sphere. For all these changes, the resultant particles cannot be treated by Mie theory, but are instead treated with unique solution techniques. For example, an oxide layer is considered to have formed on the outside of the particles. It is shown that only particles with an oxide layers thickness of 50 microns or greater have sufficient absorption efficiency to match the experiments. The particles in the experiment are known to also be non-spherical. The spheres exhibit both surface roughness and an ellipsoidal shape. The spherically asymmetric particles may also couple to shear forces in the flow to induce non-random orientations that have the potential to affect the optical properties.

These calculations provide estimates on the sensitivity of the particle optical properties to the various chemical and mechanical properties of the experimental particles. However, since each mechanism is considered using a different solution method, one cannot combine mechanisms to determine the optical properties of a general particle. Nonetheless, one can determine which particle properties must be examined in a refined characterization of the experimental particles.

References

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