Large Eddy Simulation of a polydisperse, evaporating spray jet with a presumed function method of moments

P. Dems*[1], J.N.E. Carneiro[2], W. Polifke[1]
[1]Lehrstuhl für Thermodynamik, TU München, Germany
[2]Instituto SINTEF do Brasil, Rio de Janeiro, Brazil
dems@td.mw.tum.de, joao.carneiro@sintefbrasil.org.br and polifke@td.mw.tum.de

Abstract

A polydisperse Eulerian-Eulerian two-phase model has been used to simulate evaporation of acetone droplets dispersed in an air jet. The presumed function method of moments model considers the polydispersity of the spray in terms of droplet diameter by transporting low order moments of the particle size distribution function. This approach takes into account the dependency on the droplet diameter of particle motion, evaporation rates and phase interaction forces, e.g. drag. Transport equations for the moments are obtained by integration of the Eulerian Multi-Fluid equations over the diameter spectrum. The phase interaction forces, acting as source terms in the gas phase equations and the moment transport equations, can be formulated in terms of the moments. Unknown moments, e.g. higher order moments which are not transported but needed for closure, are calculated assuming a functional form of the number density function. Herein a Gamma distribution is used whose reconstruction is possible by three consecutive moments. In order to capture the development and change of the particle size distribution in time and space by convection, i.e. the effect of different inertia of each droplet size class on the particle motion, the moments are transported with their respective moment transport velocities. However, only one equation for the third moment transport velocity is solved for, which is the particle phase momentum equation. Other moment transport velocities are obtained using an interpolation between the third moment transport velocity and the gas phase velocity. The interpolation is based on the particle relaxation times. The development of the model including validity of moment sets and formulations for Reynolds-Averaged Navier-Stokes and Large Eddy Simulations as well as the application to several configurations of cold particle-laden and bubbly flows have been shown in previous publications.

The objective of the present study is the formulation of model equations for non-isothermal flows to be used with Large Eddy Simulation and to validate the model against detailed experimental data. Derivation of the evaporation source terms and the coupling of the compressible gas phase with the particle phase are shown. Since the particle loading is very small in the experimental configuration, it has been neglected in the formulation of the compressible gas phase equations. The evaporation rate is determined using a modified film model due to the Stefan flow and the correction of the Sherwood and Nusselt numbers by the Frossling correlation. To obtain source terms for the moment transport equations, the formulation is integrated over the diameter spectrum. In the filtered LES equations these source terms were determined by using the averaged flow properties. Explicit sub-grid scale effects of drag force and evaporation rates have not been considered. The gas phase sub-grid stresses are closed using a compressible single phase Smagorinsky model. The two-phase moments model is then applied to simulate the evaporation of acetone droplets which are ejected by an air jet into a slow co-flow of air with room temperature. This configuration, investigated experimentally, e.g., by [Stårner et al.(2005) 'Effects of turbulence and carrier fluid on simple, turbulent spray jet flames', *Combustion and Flame* 143:420-432], was designed for well-defined boundary conditions and detailed measurement data for evaporating and combusting sprays are available. Therefore it is very applicable to validate the numerical results. Gas phase and droplet velocities as well as the moments of the particle size distribution function and mean diameters obtained from the numerical simulation are compared to the experimental findings.

---

*Corresponding author: dems@td.mw.tum.de