Eulerian Multi-Fluid models for the description of polydisperse coalescing sprays : evaluation of various numerical strategies

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Mots-clés : Eulerian Multi-Fluid Model, Coalescence Kernel, Analytical solution, Experimental result

The accurate simulation of polydisperse sprays undergoing coalescence in unsteady gaseous flows is a crucial issue for solid rocket motor optimization. Indeed, the engine internal flow depends strongly on the droplet size distribution of the alumina produced by solid propellant combustion and this distribution spreads up with coalescence [1]. Eulerian Multi-Fluid methods have proven to be efficient and numerically affordable by providing a continuous description of the droplet size variable which allows to account for coalescence while conditionning local droplet velocities and temperatures to this size parameter in order to spare ressources [2, 3, 4]. One of the key issues in terms of numerical strategy and numerical analysis is to choose among the various level of description offered by the first and second order methods, which will have an impact in terms of polydisperse dynamics (and potentially evaporation in the case of fuel droplets but not for alumina particles) and the resulting approximation of the coalescence kernels. Two points are important : 1- first the behavior of the method when a fine discretization is reached for the various orders of description, 2- second, the behavior of the method when only a few sections, that is, size intervals are provided, which is crucial for practical applications. A 1-D bimodal configuration has been specifically designed to validate coalescence kernel models as well as numerical methods. It features a homogeneous fog of small droplets in which big droplets fall, coalesce and grow. In this configuration, an ONERA team has yielded experimental results and an analytical estimation of droplet growth based on a Lagrangian formulation [5]. In this paper, we first derive an analytical solution by linearizing the coalescence terms and considering the discrete sizes in which the big droplet distribution lives. Depending on the collision-coalescence kernel, this approach allows to compute any moment for the big droplet size distribution. The mathematical form of the resulting system is commented. Second we provide a comparison between this linearized solution and Eulerian Multi-Fluid simulations using various reconstructions of the big droplet size distribution. This work highlights that the Eulerian Multi-Fluid method with second order size reconstruction has a remarkably low level of diffusion in size phase space compared to classical first order methods. This method therefore allows to use coarse size discretizations, yielding fewer conservation systems to be solved which has immediate interest for industrial 3D unsteady codes.

Références

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