An Extended Moment Method for Crossing Polydisperse Sprays

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Abstract

A moment method for the modelling of polydisperse sprays is developed that captures the polydisperse nature of sprays as well as the bi- (or multi-) modal character of the droplet velocity distribution, for example, when droplets cross each other in a turbulent spray flow. This Eulerian method is a combination of the quadrature-based moment method of Desjardins et al. [1] and the sectional method of Dufour and Villedieu [2]. For the highly unsteady spray behaviour in combustion chambers of car or aeroplane engines, the methodologies of CFD are not matured. In the lean combustion technology in new airplane engines, for example, combustion instabilities are more likely to occur and hence unsteady LES calculations are necessary to predict the behaviour of the reactive, two-phase flow system. The two main approaches used to describe the gas-liquid behaviour in combustion systems are the Euler-Lagrange and the Euler-Euler method. For the spray part, the Lagrangian procedure is widely used, also for unsteady flows but it is limited by the immense computer power which is necessary to obtain results that are not disturbed by statistical noise. In addition, the parallelisation of the Lagrange code leads, for inhomogeneous spray distributions in the computational domain, to an unbalanced workload distribution on the processors. For the Eulerian procedure, on the other hand, the same number of equations has to be solved irrespective of the amount of droplets in the computational domain. The bad news about Eulerian methods is the difficulty to capture droplet size effects like breakage, coalescence, etc. Moreover, the phenomenon of particle trajectory crossing, which is present in turbulent spray flows, was only considered recently by Desjardins et al. [1] for monodisperse sprays.

The combined moment method is tested in three one-dimensional configurations which are organised in such a way that crossing of two spray distributions is always included. In the first test case the polydisperse spray hits a wall, where the droplets break, lose mass and rebound with a certain velocity. In a second test case, two spray distributions are moving towards each other entering the domain with different velocities from $x = 0$ and $x = 1$. During this crossing motion they are evaporating. In the last test case the crossing distributions are affected by a Stokes drag force which results from the velocity difference between the moving droplets and the non-moving gas. For all three test cases parameter studies have been performed for the physical parameters and for the discretisation in real and size space (shown in the full paper). In the above test cases, the comparison of the moment method with accurate Lagrangian calculations reveals a convincing agreement even for crude discretisation in size space. This method opens a new way of describing unsteady spray phenomena with Eulerian methods, because it resolves the principle difficulties of classical Eulerian methods, namely the description of polydisperse and crossing sprays.

Key words: polydisperse spray, particle trajectory crossing, sectional method, quadrature method of moments

References:

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