CFD analysis of non-evaporating sprays using the DQMOM method

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Abstract

In this paper FLUENT will be used to simulate the experimental data obtained from Nijdam et al [1]-[3]. The modelling of the experimental data is done using an Eulerian multifluid model. The Direct Quadrature Method Of Moments (DQMOM) developed by Marchisio and Fox [4] will be implemented to simulate the evolution of the droplet size distribution (DSD) due too breakup and coalescence. This work is a continuation of the work presented by Madsen et al. [5] at the 20th ILASS conference in Europe 2005.

Introduction

This work is a computational continuation of the work presented by Madsen et al. [5] at the 20[th] ILASS confernce in Europe 2005. The primary focus of this work will be to model the experimental data from Nijdam et al. [1]-[3] using the spray model developed by Madsen et al. [5]

Experimental and computational fluid dynamic studies have been done in the past in this field by Nijdam et al. [1]-[3]. The primary focus of Nijdam et al. [1] was to investigate the influence the effect of turbulence, evaporation and coalescence on the droplet size distribution (DSD) within the jet. The work proved that two distinct zones appear in a typical jet. In the near-field, a potential core exits where the high-velocity airflow provided by the nozzle persists and the droplet slip velocity and airflow is low, and, hence very little turbulent dispersion or evaporation of droplets occur. At the egdes of the spray within the near-field, a band of slower-moving air with high turbulence develops, and thickness downstream of the nozzle as air is entrained from the co-flow. Once that air from the slower moving co-flow penetrates the center axis, and the potential core does the droplets disperse more rapidly. Here the smaller droplets disperse more rapidly then larger due to a smaller inertia, and so they are able to follow the turbulent fluctuations of the droplet flow.

In the work of Nijdam et al. [2] both Lagrangian and Eulerian modellling approaches were used for comparison of the turbulent dispersion and the coalescence of droplets within the spray. The work of Nijdam et al. [2] concluded that both Lagrangian and Eulerian approaches are able to simulate droplet turbulent dispersion and coalescence for a wide range of droplets and gas flows, and for sprays from nozzles that produce different droplet-size distributions. It was found that the time required for simulating coalescence within a steady axisymmetric spray is of similar order of magnitude for both of these approaches.

The later work of Nijdam et al. [3] used the spray for studying turbulence dispersion of non-evaporating droplet both experimentally and theoretically. For this purpose a set of experimental data with a well-defined inlet boundary with low turbulence intensity at the nozzle exit was produced, so that droplet dispersion was not affected by the transport of nozzle-generated fluctuating motion into the jet, and was influenced solely by turbulence in the gas phase produced in the shear layer of the jet.

In the past most polydisperse spray models have been based on either discretizing the liquid flow field into groups of equally sized droplets, as in the discrete droplet model (DDM) in which parcels of droplets are tracked in a Lagrangian framework, or by solving separate Eulerian conservation equations for a number of size ranges. An attractive alternative is the moment methods that involve transportation of moments of the droplet size distribution (DSD). The advantage of the moment methods is that the number of moments required is very small (about 4-6). The main issue is the so-called closure problem, related to the difficulties in writing the transport equations of the moments in terms of lower-order moments .

In the computational studies of the experimental data Nijdam et al. used either a Eulerian or a Lagrangian model working with between nine and thirteen classes [1]-[3].

A recently developed method called the Direct Quadrature Method Of Moments (DQMOM) developed by Marchisio and Fox [4] works by solving the moments rather then solving the particle size distribution itself like a class method does.

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The work of Madsen et al [5] used the DQMOM model for modelling sprays. The model of Madsen et al. [5] was validated against experimental data from Wu et al. [6]. This work was presentated at the 20th ILASS conference in Europe 2005. This DQMOM spray model was limited to modelling on non-evaporating sprays.

This paper will try to model the experimental data from Nijdam et al. [1]-[3] using the Direct Quadrature Method Of Moments (DQMOM) developed by Marchisio and Fox [4]. The work will be an extension of the work presentated at the 20th ILASS conference by Madsen et al. [5]. The model will build upon the DQMOM model and kernels for non-evaporating sprays developed by Madsen et al. [5] and in the thesis of Madsen [7]. Instead of using nine to thirteen secondary phases like Nijdam et al. did, this work will reduce the number of secondary phase to three using the DQMOM method. The purpose of using the DQMOM model and reducing the number of secondary phases is to reduce the simulation time and CPU power, but still be able to predict the lower moments.

The modelling will be done using the commercial CFD software FLUENT.

References

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