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A combined 1D3D–CFD approach for reducing mesh dependency in Diesel spray calculations

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ABSTRACT

A 1D3D–CFD coupled spray model is proposed in this work for the simulation of Diesel sprays under non-evaporative conditions and constant injection velocity in time. The basic idea of the model is to reduce the poor estimations of the gas velocity and droplets/gas relative velocity obtained with the standard 3D–CFD Eulerian–Lagrangian spray model, when coarse meshes are used. The coupling has been achieved in the calculation of the momentum source interaction term. General considerations, descriptions and implementation of the model in a commercial CFD code are outlined. Diesel spray simulations performed using the proposed approach have been compared with those obtained with the standard 3D–CFD, 1D models and experimental data. Encouraging results were found in terms of spray evolution when changing meshes and ambient conditions.

1. Introduction

The 3D–CFD Eulerian–Lagrangian approach proposed by Dukowicz, O'Rourke and Bracco [1,2] was originally developed for simulating highly dispersed sprays. Nevertheless, it is commonly used for the simulation of Diesel sprays. The model solves the interaction of two phases: the continuous phase (in-cylinder gas) and the disperse one (liquid droplets). The conservation equations of mass, momentum and energy are formulated for each dispersed element in the Lagrangian form and in Eulerian form for the gas phase. The gas equations are suitably modified with source interaction terms and the void fraction in order to consider the presence of the droplets.

The void fraction is calculated in each cell and it is the ratio between the total liquid volume in a cell and the volume of such a cell. In order to keep the model hypothesis of dispersed sprays, this value is very small compared to unity in many CFD codes [3,4], restricting the use of meshes with very small cell size. However, performing spray simulations with coarse meshes leads to poor estimations of the numerical spray evolution [5,6].

As nowadays fuel injection pressures are very high, nozzle hole diameters are very small and air density inside the combustion chamber is also high, the complete atomization regime is reached very near the nozzle exit. Therefore, the assumptions of mixing controlled hypotheses for Diesel sprays are valid, and they can be analysed from a point of view of gas jet theory [7]. The one-dimensional (1D) Eulerian model based on this analogy simplifies the calculation of complicated two-phase flows by defining an equivalent one-phase flow instead with a mesh-independent formulation.

In this work the equations and strategies for obtaining a coupled 1D3D–CFD spray model are presented, which aims to improve the calculation predictions and reduce mesh dependency of the 3D–CFD standard model. The coupling is achieved in the momentum source interaction term calculation, where the CFD axial gas velocity is replaced by the gas jet velocity.

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