Taking into account polydispersity for the modeling of liquid fuel injection in internal combustion engines

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The general context of the PhD is the simulation of fuel injection in an internal combustion engine, in order to improve its thermal and ecological efficiency. This work more generally concerns any industrial device involving a multiphase flow made of liquid fuel injected in a chamber filled with gaz: automotive or aircraft engines, or turbo machines. In and of itself, it is possible to simulate this flow without any modeling. However the small structures created during injection (droplets of diameter until 10 μm or less) lead to a prohibitive computational cost for any industrial application. Therefore modeling is necessary. In this context, two areas are formally distinguished: the dense liquid core close to the injector called separate-phase flow, and the spray made of a polydisperse droplet population (i.e. droplets with different sizes) generated after the atomization processes downstream of the injector.

This PhD work investigates Eulerian models for the description of polydisperse evaporating sprays, for industrial computations. They represent a potential alternative to Lagrangian models, widely used at present, yet suffering from major drawbacks. Thus, the Multi-Fluid model ([1] and references herein) has been assessed. Although it is very promising, two difficulties are highlighted: its cost for a precise description of polydispersity, and its inability to describe particle trajectory crossing (PTC).

Solutions to these two limitations are considered. Both rely on high order moment methods. First, the Eulerian Multi Size Moment (EMSM) proposes a much more efficient resolution of polydisperse evaporating sprays than the Multi-Fluid model does. Mathematical tools are used to close the model and combined with original finite volume kinetic-based schemes in order to preserve the moment-set integrity, for evaporation and advection. An answer to the second limitation is provided with the Eulerian Multi Velocity Moment (EMVM) based on high order velocity moments. A bimodal velocity distribution can be locally reconstructed for the moments using the quadrature method of moments (QMOM) [2], in one or multi-dimensions. Here also, finite volume kinetic-based schemes are studied in order to preserve the moment set integrity. Moreover, a mathematical study of the one-dimensional dynamic system highlights its peculiarity and constitutes a necessary basis for the design of high order numerical schemes. In order to assess them, both the models and their numerical tools are implemented in the MUSES3D code, an academic DNS solver that provides a framework devoted to spray method evaluation [1]. Achievements of the EMSM and the EMVM models can be found in [4] and in references herein. The extension of the EMSM model to an industrial context is then considered, with its implementation in the IFP-C3D code, a 3D unstructured reactive flow solver with spray. In order to perform computations within a moving domain (due to the piston movement) the Arbitrary Lagrangian Eulerian (ALE) [3] formalism is used. A numerical study has been achieved, in order to extent to this formalism the properties of accuracy and stability of the EMSM model, which already induces strong stability condition in an Eulerian approach. The robustness of the EMSM model in the IFP-C3D code has been successfully demonstrated on a case involving a moving piston, and also on a comparison with the MUSES3D code [4]. Moreover, very encouraging results demonstrate the feasibility of the EMSM model for spray injection.

Références

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