Detailed numerical investigation of turbulent atomization of liquid jets

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Abstract

The objective of this work is to improve the understanding of primary atomization of turbulent liquid jets through detailed numerical simulations. For this problem to become numerically tractable, several key ingredients are combined. Since the Reynolds number associated with atomization is generally high, numerical schemes have to be tailored for the simulation of turbulence. For this purpose, an arbitrarily high order conservative finite difference scheme for variable density, low Mach number flows is used. Combining this scheme with the Ghost Fluid Method (GFM), the discontinuous material properties encountered in multiphase flows can be robustly handled. Also the surface tension force, which is singular in nature, is considered in a more accurate way. In order to correctly represent the phase-interface geometry, spectral refinement of a level set function is introduced. Thanks to a sub-cell polynomial reconstruction of the level set function, this approach provides great accuracy even for poorly resolved interface structures, while the use of a narrow-band formulation and semi-Lagrangian transport leads to a limited cost. This method is found appropriate for simulating primary atomization because of the excellent resolution it provides. A temporally evolving turbulent planar jet is simulated for several values of the Reynolds and Weber numbers, and statistics are extracted. Direct visualization of the flow structures allows to lay out a clear picture of the atomization process. Early interface deformation is caused by turbulent eddies that carry enough kinetic energy to overcome surface tension forces. Then, liquid protrusions are stretched out into ligaments that rupture following Rayleigh's theory or due to aerodynamic forces. This numerical study provides a wealth of much-needed detailed information on the turbulent atomization process, which is invaluable to large eddy simulation modeling.

Key words: Turbulence, atomization, direct numerical simulation, level set method, Diesel injection.

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