A LES-VOF solver for High-Fidelity CFD Modelling of String-Cavitation in Fuel Injectors

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The development of a novel three-phase Volume-of-Fluid (VOF) solver for the simulation of internal-nozzle flows and primary jet breakup in high-pressure fuel injection is discussed. The cavitating fluid, the vapor and the non-condensable gas in the three-phase flow are included in a single-fluid approximation as a mixture of phases, in which the phase-fraction distribution includes a sharp yet resolved transition between the phases. Extensions to support phase change with three phases (liquid fuel, fuel vapor and non-condensable gases) has been implemented. High-fidelity LES simulations on leadership class machines have been compared against experimental measurements on transparent glass nozzle geometries. It is shown that the proposed approach is able to capture the effect of the evolution of vorticity, generation of swirling structures and in-nozzle phenomena such as the hydraulic flip and string cavitation. The link between vorticity dynamics and cavitation is analyzed, in order to establish a correlation between the production of fuel vapor from shear and string cavitation. The developed code is included in a C++ Object-Oriented Library developed by the authors at PoliMi/DAER, that is linked to the most recent releases of the software OpenFOAM.

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