Summary of the Deliverable 3.2: "TUM-LES validation"

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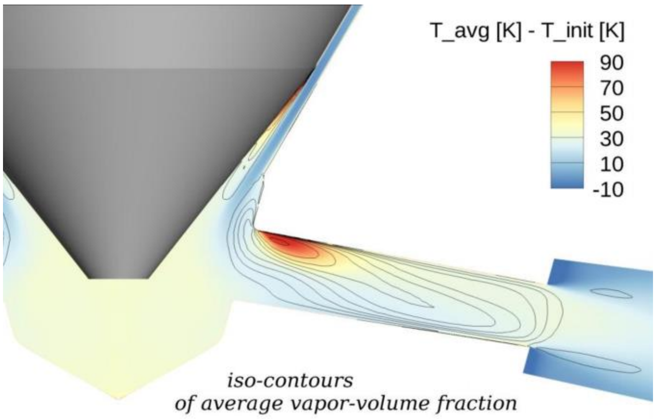
According to the work package description, **Task 3.2** for ESR 7 consists of **validation and application of a simplified and numerically efficient implicit LES model for cavitation to fuel injectors**.

The work described in this report was performed in strong collaboration with Delphi Technologies. They provided a barotropic Equation of State for a diesel-like test-fluid (ISO4113) which was utilized to obtain tabulated thermodynamic data. Furthermore, Delphi Technologies defined the test-cases and provided necessary geometrical data.

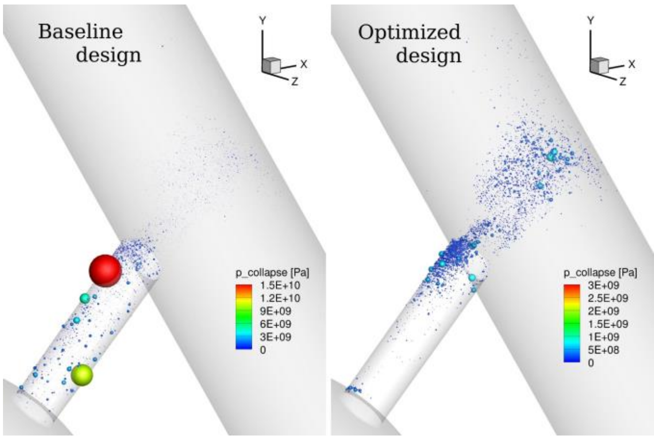
Implicit LES methodology for cavitating flows using thermodynamic equilibrium assumption was described in details in [1]. Two-phase regions are modeled by a parameter-free thermodynamic equilibrium mixture model. Compressibility of the working fluid is taken into account for both pure phases and for the mixture region in order to capture the formation and propagation of pressure waves to predict potentially erosive flow events. For the description of thermodynamic states two methods are used: pre-computed barotropic tables and newly introduced by the ESR pre-computed full-thermodynamic adaptive tables, using the REFPROP library [2] to obtain the thermodynamic properties of dodecane as substitute fluid.

The ESR investigated effects of thermodynamic modelling for simulation of (one eigth of) a typical Diesel injector using barotropic and full-thermodynamic pre-computed tables with 800 bar inlet and 50 bar outlet pressures and effects of design optimisation for Diesel injector control orifice using barotropic tables with 1380 bar inlet and 340 bar oulet pressures.

Simulation results show, that for the Diesel injector nozzle dynamics for full-thermodynamic case are faster: frequencies of the inflow and outflow mass flow rates are higher. Vapor volume in the whole domain is lower for the full-thermodynamic case. Both cases do not predict erosive events close to the material surface – which is in agreement with experimental findings. However, the barotropic simulation shows higher pressure impacts on the walls. Finally, viscous heating is assessed in the case of the full-thermodynamic computation. Due to viscous forces in the fluid it is heating up near the walls. At the exit of the spray hole, where heated vapor is mixed with liquid, the average temperature increase is about 30K.



Simulation results for the control orifice show, that a slight, almost not visible, change in orifice conicity can significantly alter the flow dynamics. For the baseline design vapor volume is about twice as high as for the optimised design and has strong periodic oscillations, causing oscillations in the inflow mass flow rate with the same frequency. For the baseline design the flow experiences periodic shedding with bubbly-shock waves as a driving detachment mechanism with a similar behavior as in [3]. The optimized design leads to a significant reduction of the number of collapse events and their intensity, cousing much lower pressure "footprints" on the walls.



References:

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3. Daniel Bush, Celia Soteriou, Mark Winterbourn & Christian Daveau, “Dynamic cavitation inside a high performance diesel injector – an experimental and CFD investigation”, Journal of Physics: Conference Series 656, 012080 (2015).