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OpenFOAM Research Migration Project
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Modelling and Simulation of Fuel Injection during Motoring of Internal Combustion Engine

Bikash Kumar Jaiswal[1], Manjil Sitoula[2], Dhiraj Garg[3], and Pushkar Seth[4]

[1]Department of Mechanical and Aerospace Engineering, Institute of Engineering, Pulchowk Campus, Tribhuwan University
[2]Research Assistant at FOSSEE, IIT BOMBAY
[3]Assistant Professor, Department of Chemical Engineering, Shiv Nadar Institution of Eminence, NH-91, Tehsil Dadri Gautam Budhha Nagar, U.P., India-201314
[4]Engineering Technical Leader at Wabtec Corporation

Synopsis

This research migration project focuses on the numerical study of non-reacting fuel spray dynamics in an internal combustion engine is presented using the open source CFD solver OpenFOAM. The investigation is conducted in three stages to meet the physical realism and to ensure the proper validation of the numerical setup.

Initially, a simple IC engine cycle simulation without fuel injection and combustion was conducted for for 6 complete cycle to validate if the setup and boundary conditions are working properly. Then fuel injection is simulated separately in a constant volume configuration to validate spray breakup, evaporation, and penetration characteristics against experimental reference setting ECN Spray A as benchmark. Subsequently, a full engine cycle comprising air intake, compression, expansion and exhaust is modeled followed by fuel injection after the compression stroke for detailed analysis of spray evolution under realistic in-cylinder conditions.

The liquid phase is described using a Lagrangian particle tracking method, while the gas phase is treated as a compressible multi-component mixture. Spray physics are modeled using established sub-models, including cone nozzle injection , Reitz-KHRT breakup, Ranz-Marshall heat transfer, and boiling evaporation. Results from the constant-volume simulations shows good agreement with experimental data during the early spray penetration phase, with a modest initial overprediction of liquid length is observed due to slower evaporation. After the transient stage, the simulated liquid length stabilizes close to the measured quasi-steady value of 11.828 mm. Vapor penetration follows the expected momentum driven trend. The simulation captures rapid early breakup, leading to a decrease in droplet diameter from over 7 μm to around 2 μm in 0.4 ms and then stabilizes at approximately 0.5 μm. Temperature drop caused by fuel evaporation is also captured confirming proper energy exchange between phases. The work demonstrates the capability of OpenFOAM to predict evaporating spray behavior and highlights the importance of careful model calibration for accurate results.

The project aims to migrate the study by Lyle M. Picket et. al. In their work, fuel injection was simulated using the operating conditions specified by the ECN Spray A benchmark case and the numerical results were validated against the experimental measurements provided by the Engine Combustion Network (ECN). The present project follows a similar approach with the objective of implementing the methodology in OpenFOAM and applying the analysis toward realistic internal combustion engine conditions.

Migrated Paper Details

Title: Comparison of Diesel Spray Combustion in Different High-Temperature, High-Pressure Facilities Authors: Lyle M. Pickett, Caroline L. Genzale, John Manin, Lei Malbec, Luis Hermant, and others Journal/Publication: SAE International Journal of Engines (Society of Automotive Engineers, SAE)

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