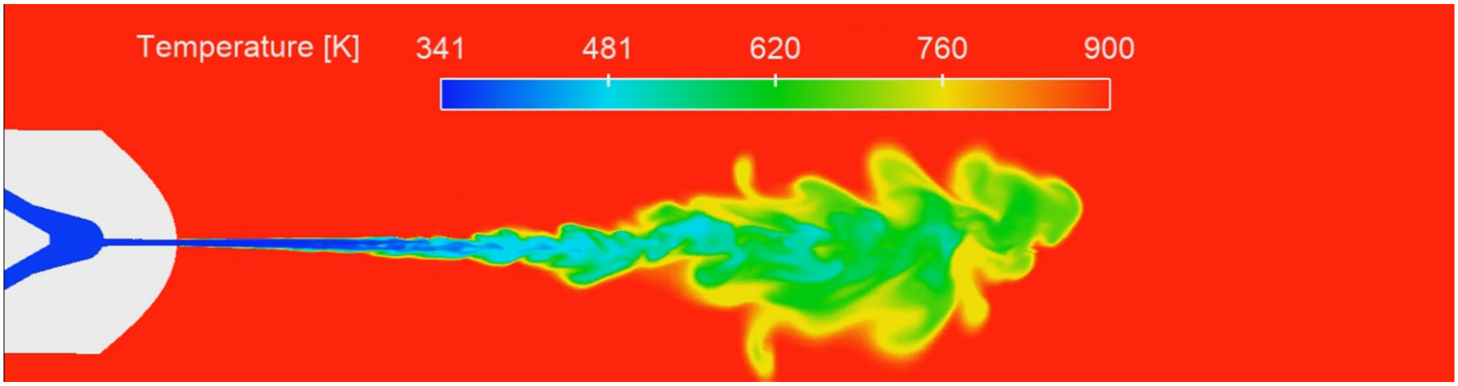

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5 minutes of reading

News

Fundamental Research

Physical Sciences | Thermodynamics/Molecular modeling | Engineering sciences | Fluid mechanics | Combustion and engine technologies

Research conducted at IFPEN has led to the development of an original approach to overcome persistent challenges in the field of injection processes, based on a combination of CFD and real-fluid thermodynamics.

Recent regulations governing vehicle emissions **require further progress to be made concerning IC engine efficiency**. **A significant source of improvement** can be found **in the fuel injection process** taking place **in the combustion chamber**, where numerous complex phenomena are still not fully understood.

While numerous CFD (Computational Fluid Dynamics) **software solutions incorporate sophisticated injection process modeling**, taking into account phase transition to simulate the cavitation phenomenon, for example, **few CFD codes are capable of accurately simulating transcritical injection conditions**[a] - i.e., from a temperature condition for which the fuel is in a subcritical liquid state, to a supercritical gas mixture in the combustion chamber. Thus **most existing models can only simulate single-phase flows**, potentially **in supercritical conditions, or two-phase flows in subcritical conditions**.

This lack of complete model, capable of the dynamic treatment of transcritical injection conditions, **was addressed by IFPEN** within the framework of post-doctoral research[1] and a thesis[2] funded by the European Union as part of the ITN IPPAD project[2,3]. In order to overcome the persistent challenges associated with transcritical flows, **an original approach was developed**, **consisting in combining a compressible two-phase flow model**, based on a Eulerian-Eulerian approach[b], **with a real-fluid thermodynamic model, incorporating liquid-vapor equilibrium**.

The proposed method involves **combining a phase equilibrium solver with a four-equation model, to handle liquid and gas balances in mechanical and thermal equilibrium**.

This model was validated:

- firstly, using a series of test scenarios based on a one-dimensional (1D) configuration, in particular via the simulation of evaporation and condensation phenomena, in subcritical, transcritical and supercritical conditions,
- and, secondly, by comparing three-dimensional (3D) results obtained with data in the literature.

This new model has proved to be extremely accurate for the 3D simulation of cavitation phenomena in real-size injector nozzles. The importance of taking into account the gases dissolved in liquid to describe bubble nucleation[2] has thus been demonstrated. Moreover, the consistency with experimental data proves that **the proposed solver is capable of managing the complex behavior of the phase transition, in subcritical, transcritical and supercritical conditions**, making **this new model unique**. Finally, **the capacity of the solver to handle transcritical injection at high pressures and temperatures was validated** by the successful modeling of the **Spray A injector**, **used as a reference by members of the Engine Combustion Network** (**ECN**) (see video)[3].

3D transcritical injection simulation for the Spray A injector

Operating conditions:
- Fuel injected = n-dodecane / Injection pressure 150 MPa / Injection temperature 365 K
- Combustion chamber gas = nitrogen / Pressure 6 MPa / Temperature 900 K

a) Every fluid has a critical point defined by its critical temperature and critical pressure (Tc, Pc). For a pure substance, it is said to be in a supercritical state when its pressure P>Pc or its temperature T>Tc. In the opposite case, the fluid is in a subcritical state. Transcritical conditions are said to exist when a fluid in a subcritical state is injected into a fluid in a supercritical state. Transcritical injection is common in direct injection compression ignition engines.

b) For two-phase flows (liquid and gas, for example), several methods can be used, including the Eulerian method and the Lagrangian method. The Eulerian-Eulerian approach refers to a problem that is solved using a Eulerian method for both the liquid and gas.

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Publications

[1] P. Yi, S. Yang, C. Habchi, and R. Lugo, ***A multicomponent real-fluid fully compressible four-equation model for two-phase flow with phase change***, Physics of Fluids 31, 026102 (2019) >> https://doi.org/10.1063/1.5065781

[2] S. Yang, PhD thesis at Paris-Saclay University (2019)

[3] S. Yang, P. Yi, C. Habchi, Int. Journal of Multiphase flow (2019) >> https://doi.org/10.1016/j.ijmultiphaseflow.2019.103145

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