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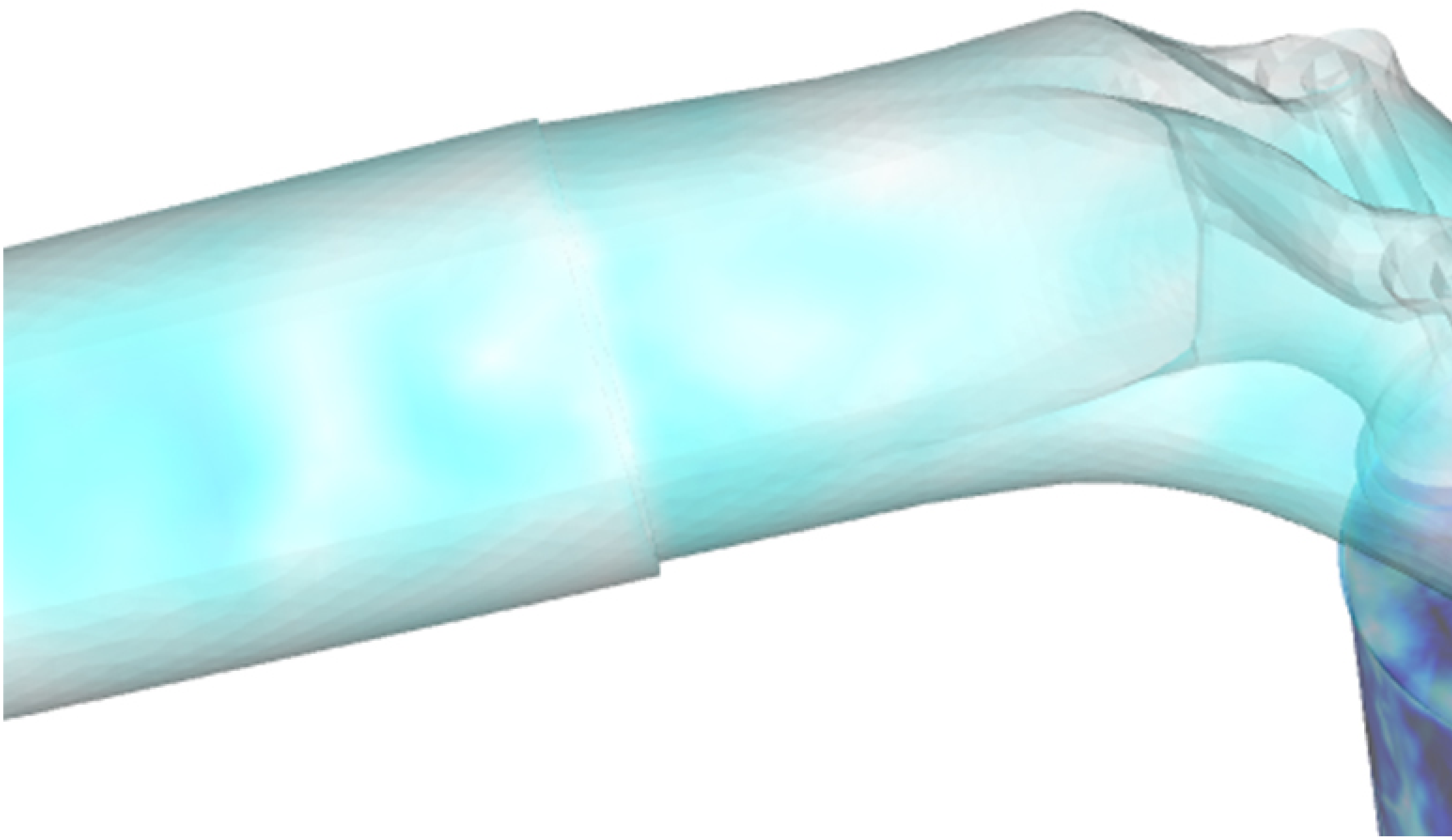

Written on 06 January 2020 5 minutes of reading
News

- Fundamental Research

- [Engineering sciences]
- [Fluid mechanics]
- [Combustion and engine technologies]
- [Systems modeling and simulation]

Future constraints on pollutant emissions pushed car manufacturers towards Direct-Injection Spark-Ignition (DI-SI) technologies to improve engine performances and reduce both fuel consumption and emissions. New challenges are then introduced in terms of combustion optimization, due to a more complex phenomenology and a larger number of degrees of freedom, while system models require developments to approach such new engine architectures with the sufficient level of detail.

A combustion model that works toward a more comprehensive approach

In order to achieve the latter objective, a PhD work performed at IFPEN[1] hosted the development and validation of a Zero-Dimensional (0D) model of DI-SI combustion for system simulation. The proposed model focuses on physics of atomization and drop evaporation, fuel/air mixing, flame propagation in heterogeneous charge and mutual interaction between these phenomena, Figure 1.

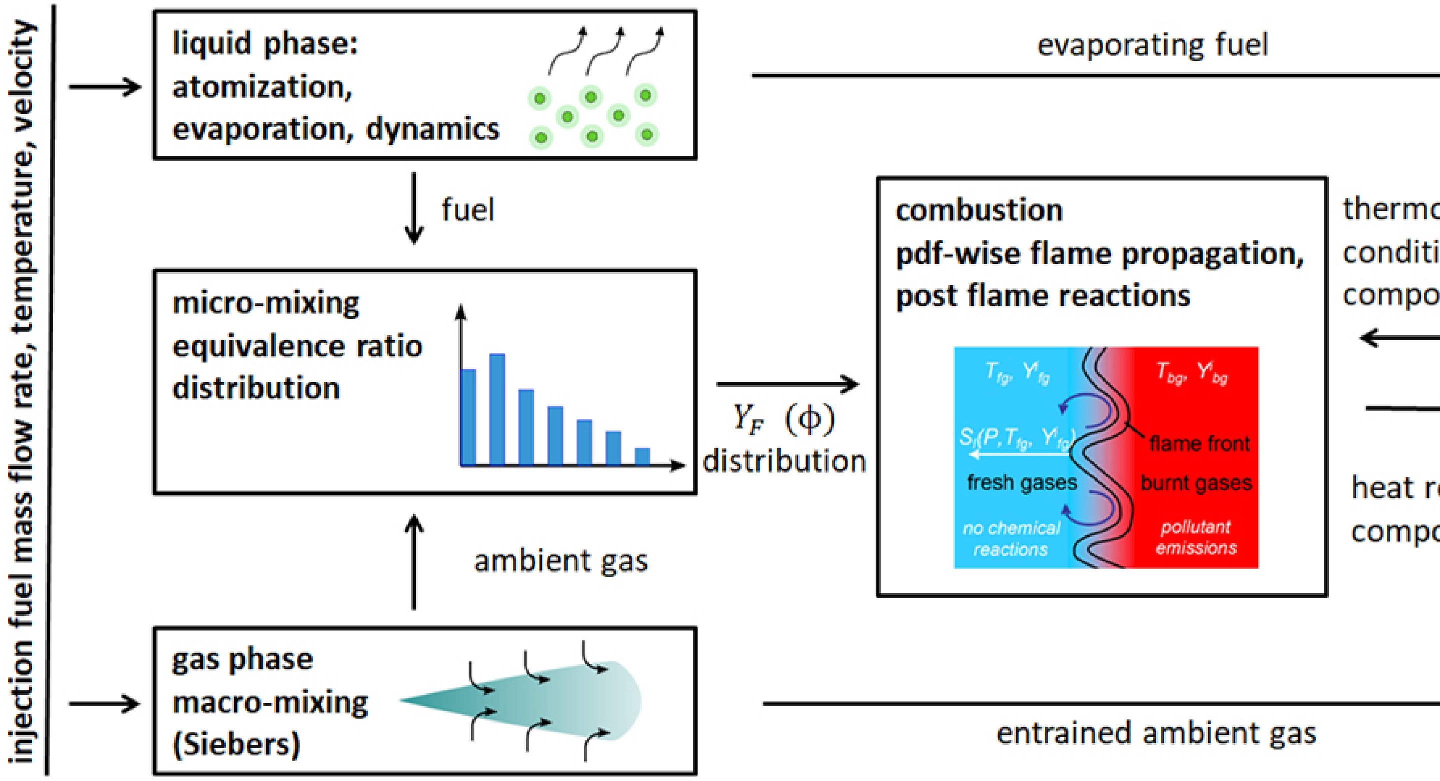

Figure 1: Synoptic diagram of the modelling approach

In particular, it is characterized by the following aspects:

- The liquid phase is discretized in parcels grouping drops of the same size. An empirical atomization model based on injection velocity, fuel characteristics and thermodynamic conditions provides initial diameters. A Lagrangian model including drag-inertia dynamics, heat-up and forced convection describes drop parcel penetration and evaporation.
- Fuel / air mixing is described using a discrete Probability Density Function (PDF) approach, based on constant-mixture-fraction classes interacting with each other and with the drop parcels[2].
- Flame propagation takes into account mixture heterogeneity effects on flame speed and pollutant production is modeled.

A validation method based on experimental results and simulation tests

The approach was validated against experimental results, when available, and 3D CFD* RANS** simulations[3], Figure 2 and Figure 3.

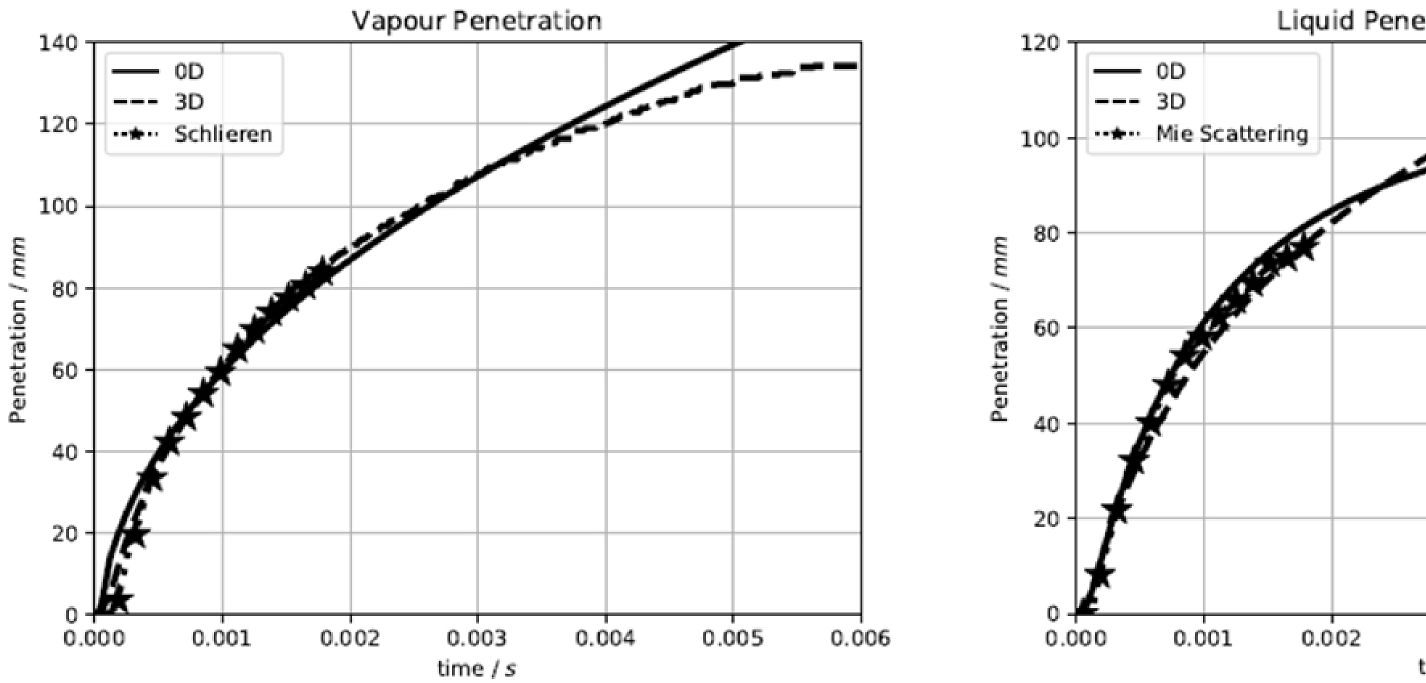

Figure 2: Comparison of the gaseous (left) and liquid (right) penetrations 0D model results to experiments (Schlieren for gaseous penetration and Mie Scattering for liquid penetration) and 3D CFD results, in a constant volume vessel (operating conditions are P=1.54bar and T=388K; fuel is isooctane).

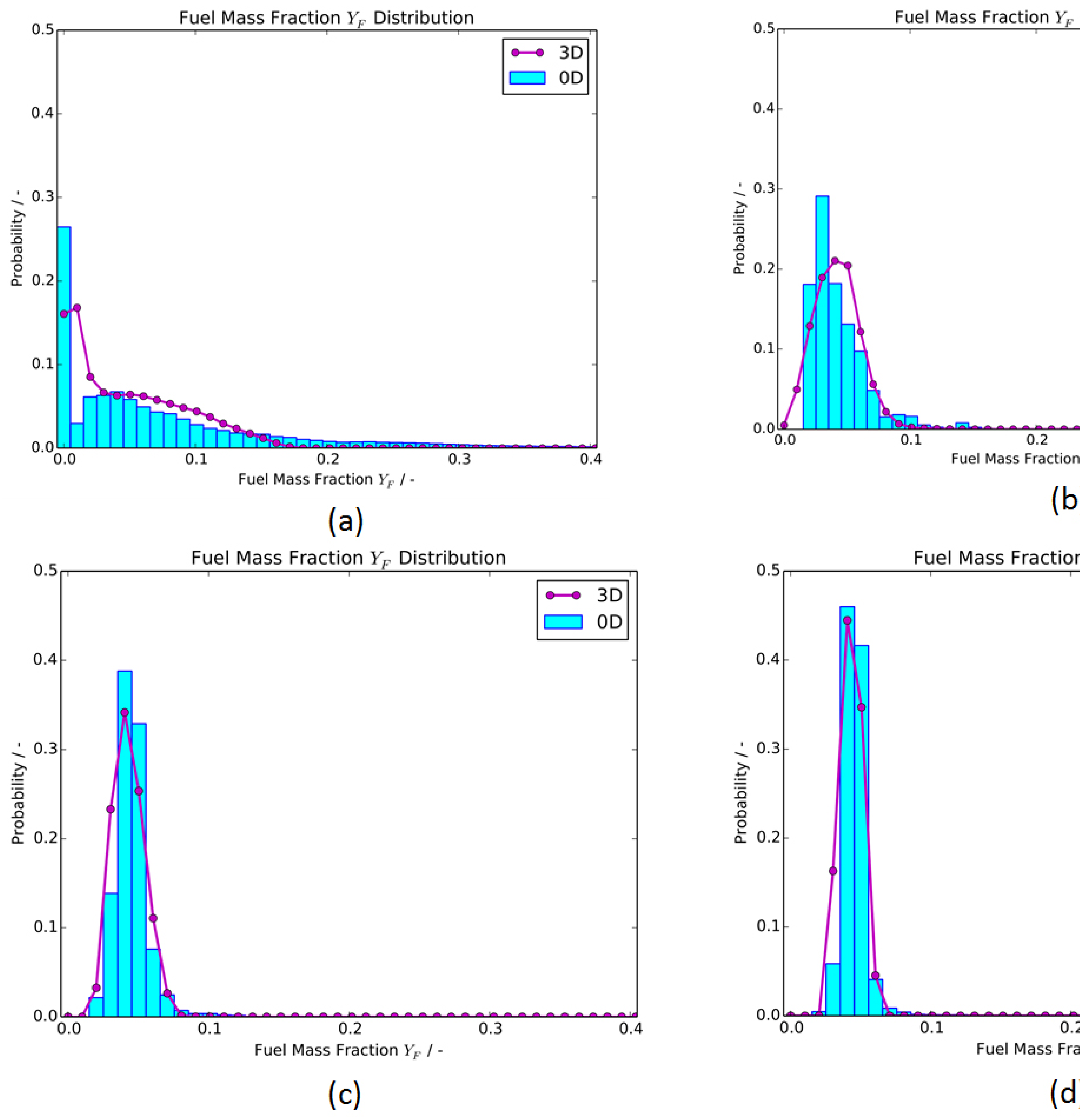

Figure 3: Comparison of fuel mixture fraction distribution 0D-model results to 3D CFD results, in a DI-SI engine at different crank angles instants: a, 270 CAD*** BTDC**** ; b, 180 CAD BTDC; c, 90 CAD BTDC; d, 0 CAD BTDC. Operating conditions of the engine are 6bar of IMEP and 1200rpm of rotational speed; injection starts at 278.6 CAD BTDC.

* CFD = *Computational Fluid Dynamics*
** RANS = *Reynolds-Averaged Navier–Stokes*
*** 270 CAD = Crank Angle Degree
**** BTDC = Before Top Dead Center

The implemented model already opens up multiple perspectives

The model was implemented in the Simcenter Amesim platform for multi-physical modelling of the Siemens Digital Industries Software and integrated in the CFM Spark Ignition combustion chamber submodel of the IFP-Engine library.

This PhD work opens various perspectives for future works:

- The discrete PDF, only applied so far to the fresh mixture, could be employed to describe the mixing-controlled post-oxidation reactions in the exhaust gas, thus improving the gaseous pollutant emissions prediction capability of the model;
- The parcel-based liquid phase model could be used to predict the mass of liquid fuel colliding with the cylinder walls, information that can be used to develop a liquid film model;
- Predicting mass and drops size of liquid fuel present in the cylinder during combustion is also highly relevant in the context of soot formation modelling.

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Publications

[1] F. Pellegrino, ***System Simulation of Combustion in Direct-Injection Spark-Ignition Engines***, CentraleSupelec PhD thesis, 2019.

[2] F. Pellegrino, A. Dulbecco, D. Veynante, ***Development of a Quasi-Dimensional Spray Evaporation and Mixture Formation Model for Direct-Injection Spark-Ignition Engines***, SAE Technical paper, 2015
>> DOI: 10.4271/2015-24-2471

[3] F. Pellegrino, A. Dulbecco, D. Veynante, ***Development and validation of a quasi-dimensional spray model for DI-SI engines, Thiesel conference on Thermo-and-Fluid Dynamic Processes in Direct Injection Engines***, poster session, 2018.

System Simulation of Combustion in Direct-Injection Spark-Ignition Engines
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