Transient flow simulations of Gasoline Direct injection (GDi) nozzles: nozzle flow and sprays

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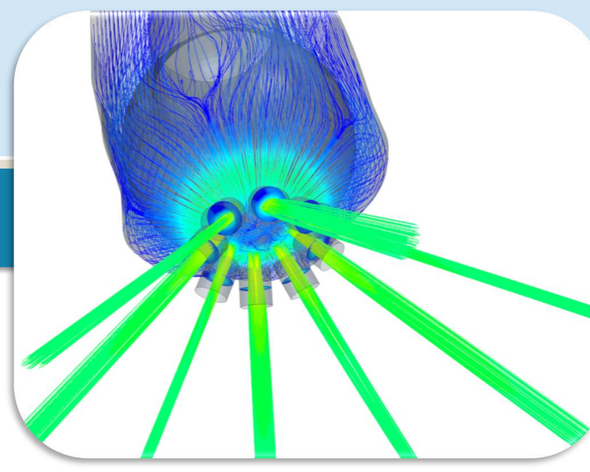
Ph.D Programme in Transport Propulsion Systems

CMT-Motores Térmicos



1.- Objectives

- Internal nozzle flow characterization. Analysis of the flow structure and the phenomena during the injection process.
- External flow analysis. Eulerian-Lagrangian approach focus on mixing and atomization.

2.- CFD Methodology

Internal Flow Analysis

- CFD software used:

CONVERGE CFD SOFTWARE CD-adapco

Homogeneous Relaxation Model (HRM). Phase change (cavitation and flash boiling).

- Rate of change of local vapor quality.

$$\frac{Dx}{Dt} = \frac{\bar{x} - x}{\Theta}$$

- Time scale:

$$\Theta = \Theta_0 \alpha^{-0.54} \psi^{1.76}$$

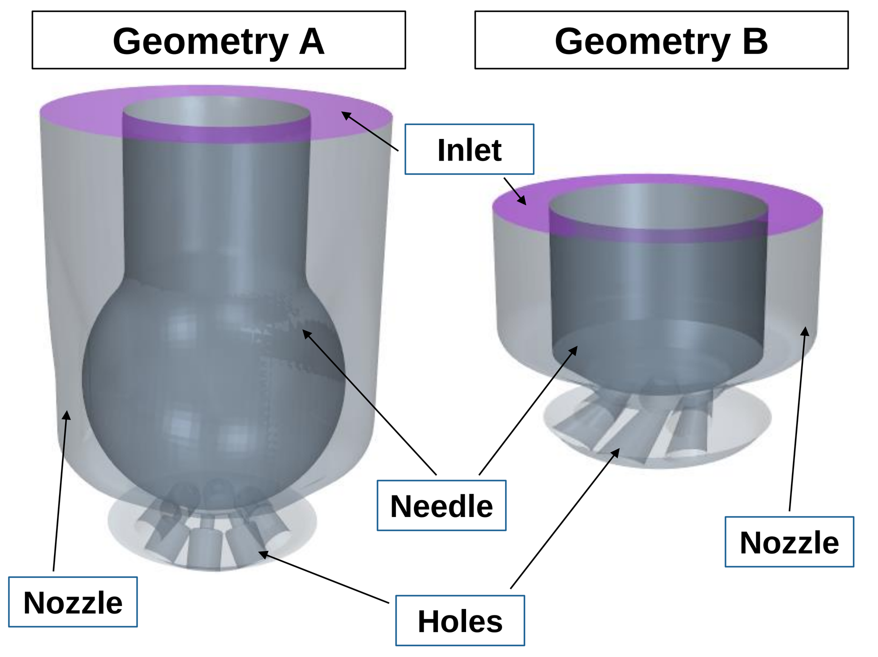
Θ : 3.84 e-07 s

α : fuel void fraction

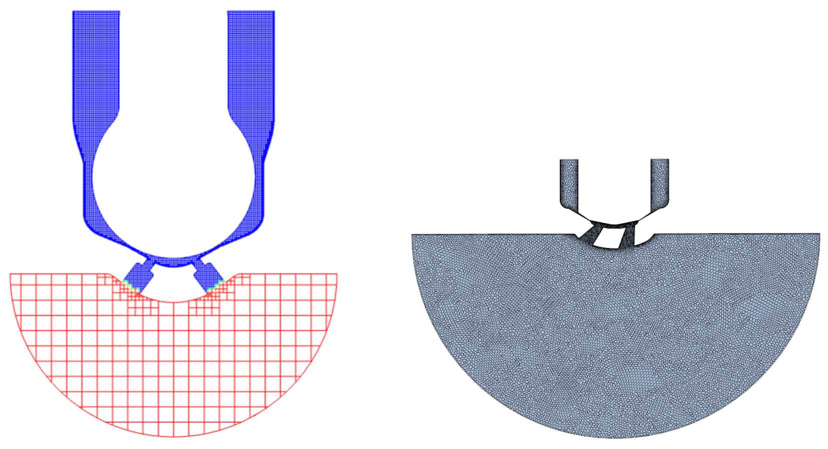
Ψ : dimensionless pressure

X-Ray geometry

Geometry A Geometry B



Example of employed mesh



1.1 millions + AMR | 1.6 millions of cells

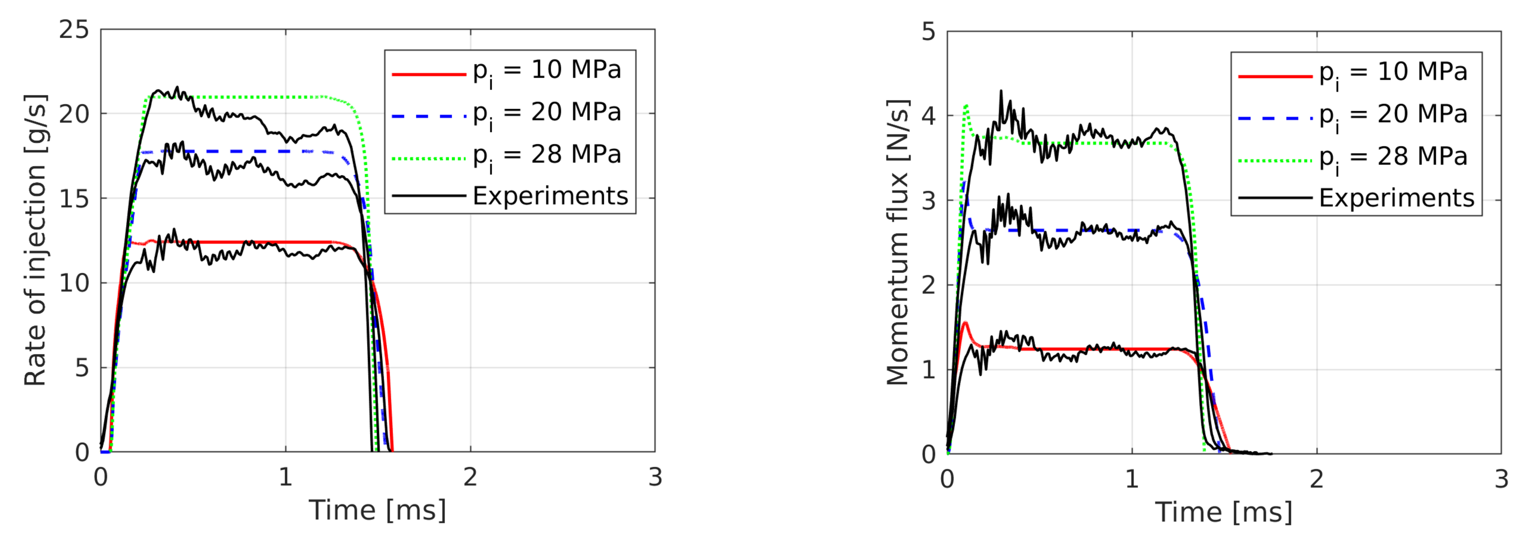
External Flow Analysis

Discrete Droplet Model (DDM)

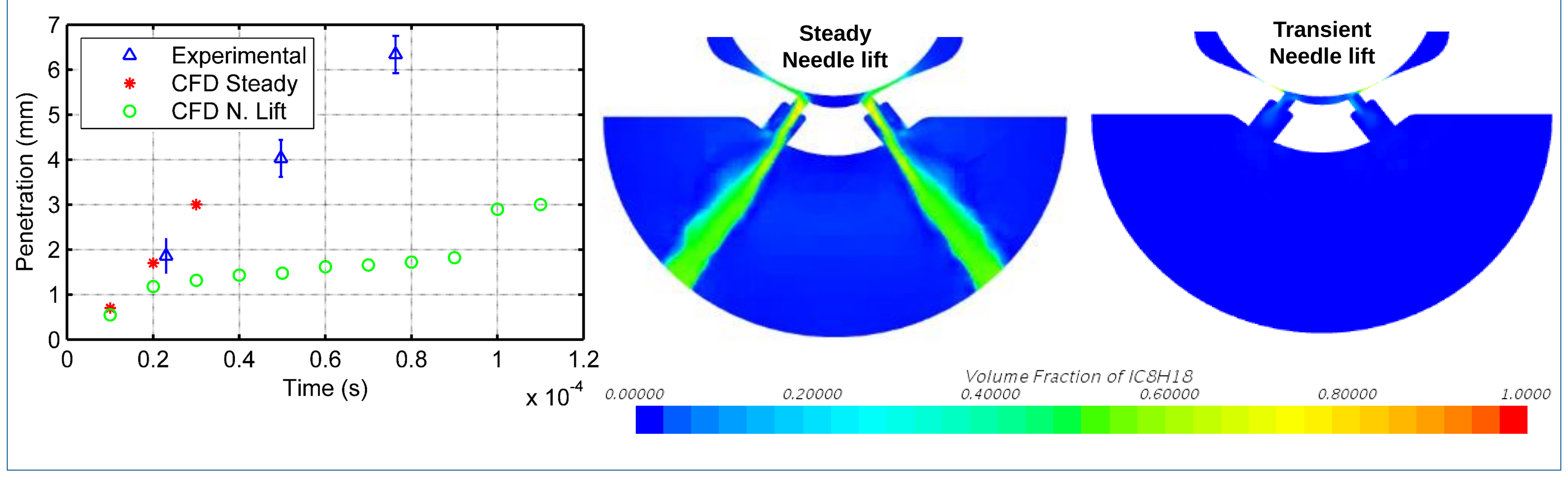
- Primary Atomization: ***Huh Model***
- Secondary Atomization: ***KH-RT***

3.- Internal Nozzle Flow Results

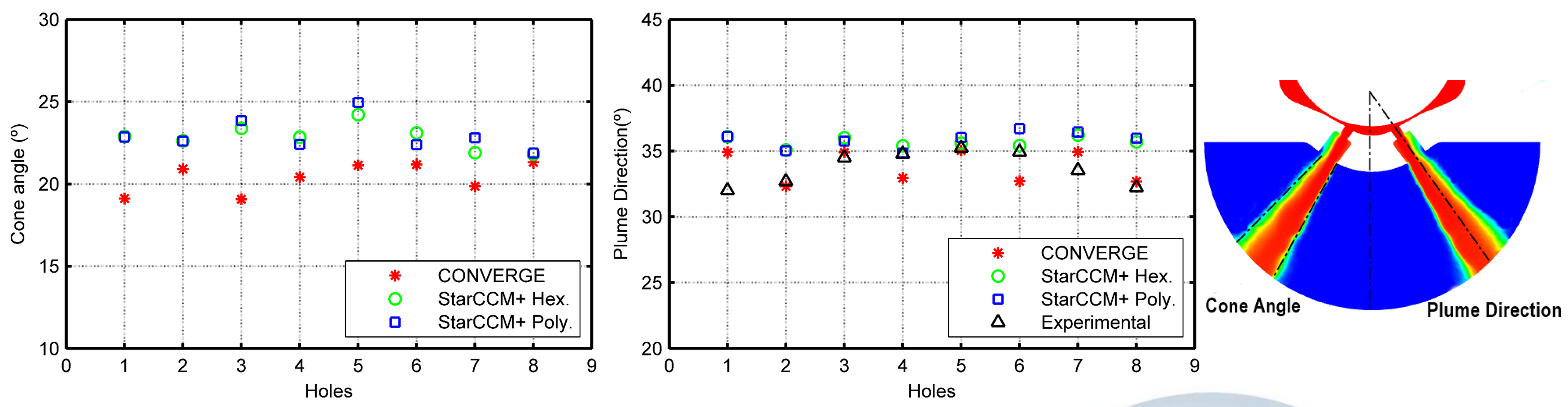
Transient Needle Lift Simulation

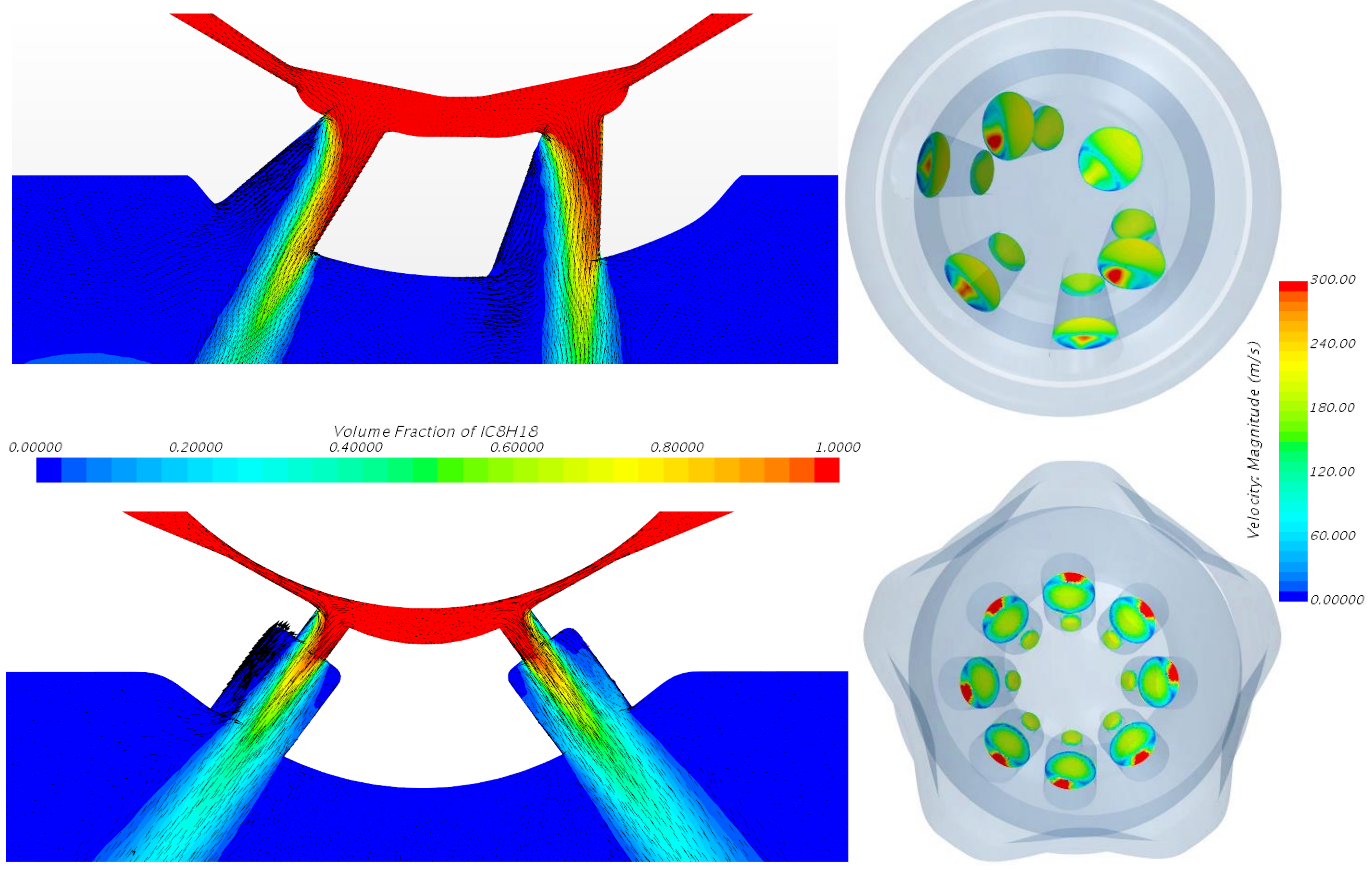


Penetration Calculation



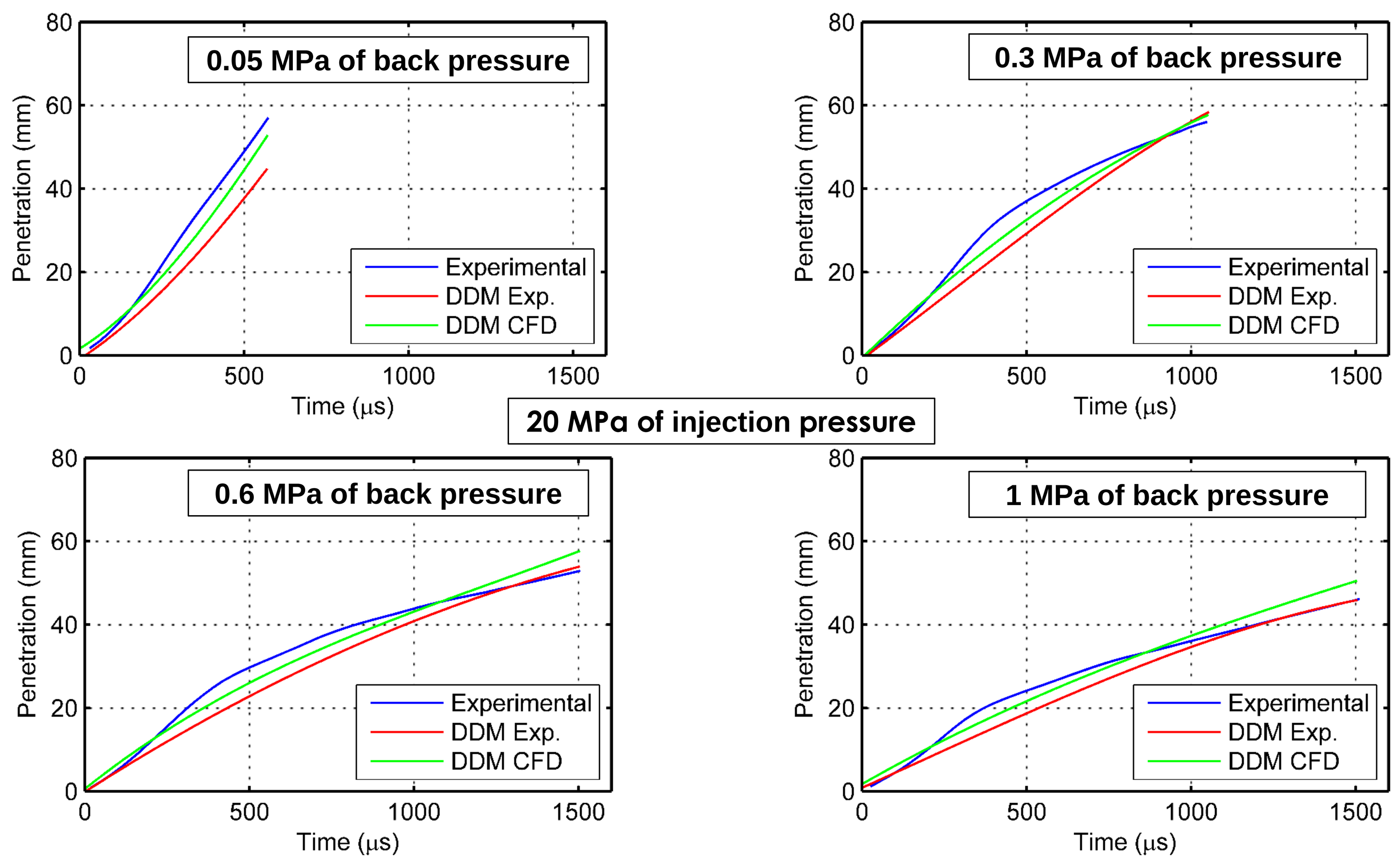
Spray Cone Angle & Plume Direction





4.- External Flow Results

Eulerian-Lagrangian Approach

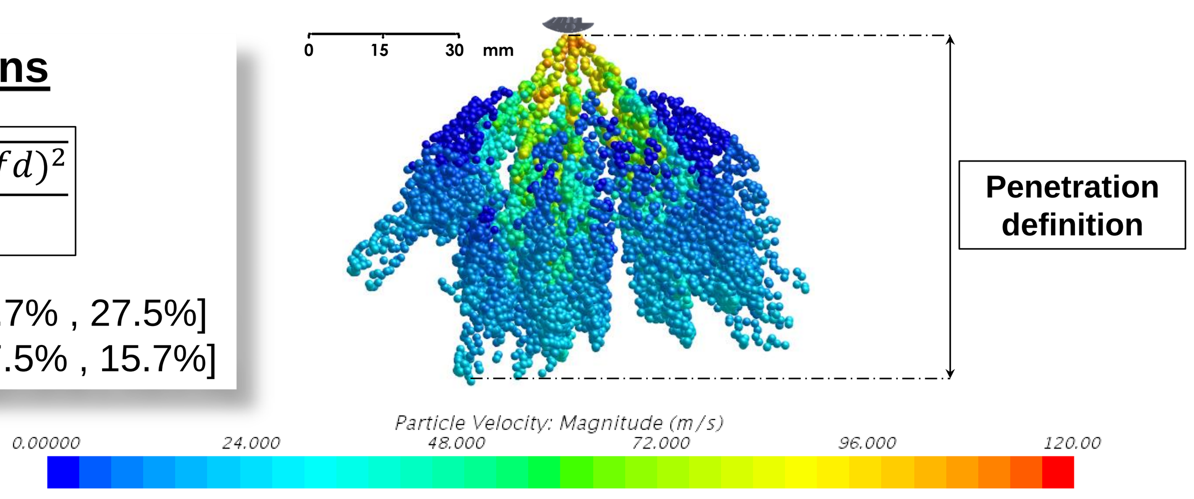


Error calculations

$$\varepsilon = \sum_{t=0}^{t_{end}} \frac{\sqrt{(Sexp - Scfd)^2}}{Sexp}$$

DDM experimental inputs: [9.7% , 27.5%]

DDM computational inputs: [7.5% , 15.7%]



5.- Conclusions & Future Work

- The **plume direction** is well captured by the in-house post-processing code. The spray direction differs from the geometrical axis of the hole. The lack of experimental measurements does not allow to validate the **spray cone angle** results.
- Eulerian approximations adequately predict the **liquid penetration** in the first millimeters of the injector exit. The simulation with a fixed needle lift has a faster response than the transient simulations.
- There is an overestimation of about 5% in the **internal nozzle flow** calculations. This overrating compensates the deficiencies in the **Eulerian-Lagrangian approach** and reduces the errors. More experimental and numerical investigation is needed to understand the spray behavior.

Finished publications

[1] Payri, R. et al. (2019). Nozzle Flow Simulation of GDi for Measuring Near-Field Spray Angle and Plume Direction. *SAE Technical Paper 2019-01-0280*, 1–11.
[2] Shahangian, N. et al. (2019). One-way Coupling Methodology of Nozzle Flow and Spray for a Multi-Hole GDi Injector. SAE Technical Paper 19ICENA-0244. (Accepted article)
[3] Payri, R. et al. GDi Nozzle Flow Transient Simulations. (*Under internal revision to be submitted to Energy Conversion and Management*)
[4] Mohapatra, C. et al. Collaborative Investigation of the Internal Flow and Near-nozzle Flow of a 8-Hole Gasoline Injector (ECN Spray G). (Submitted to International Journal of Engine Research)