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CNES CENTRE NATIONAL D'ÉTUDES SPATIALES

LIQUID INJECTION MODELLING IN LOx/GCH4 ROCKET ENGINES WITH A DIFFUSE INTERFACE METHOD

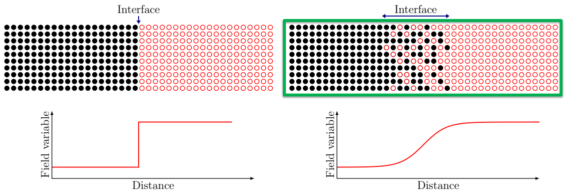
Liquid rocket engine simulation

Motivation
Need for liquid simulation in the context of rocket engine configurations

Objective
Implementation of a predictive methodology for sub/trans/super-critical liquid rocket engines

Diffuse interface approach

interface is considered as a continuous transition zone



Multi-fluid method

A unique transport equations system for both single-phase and two-phase flows

3-equations system

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0$$

$$\frac{\partial \rho \vec{u}}{\partial t} + \nabla \cdot (\rho \vec{u} \otimes \vec{u} + P\underline{I} - \underline{\tau}) = \vec{F}_{ST}$$

$$\frac{\partial \rho e_t}{\partial t} + \vec{\nabla} \cdot ((e_t + P)\vec{u} - \underline{\tau} \cdot \vec{u}) = \vec{u} \cdot \vec{F}_{ST}$$

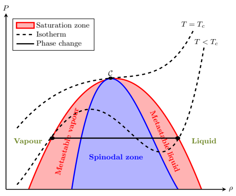
One-phase
Equation of state resolution

Two-phase
Metastable + spinodal
Multi-species equilibrium resolution
Equation of state resolution

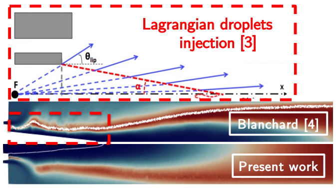
Simplified multi-species equilibrium [1]

- Equality of **chemical composition** between phases : $Y_{k,l} = Y_{k,v} = Y_k$
- ρ_l^{SAT} and ρ_v^{SAT} obtained from a tabulated saturation curve

➢Simplified approach reduces complexity and CPU cost



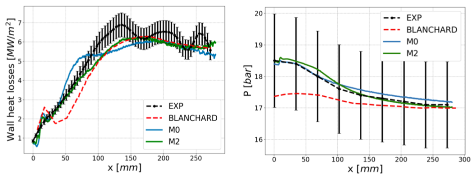
Results for a LRE configuration [2]



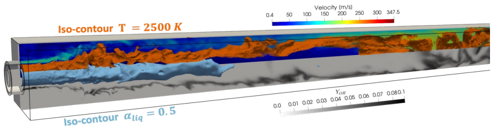
A same shape and length of a liquid core can give different results depending on how it is modelled

→ Imposition of a lagrangian injection along a given liquid core length

→ Computation of the liquid injection



- Good agreement with experimental data
- Accuracy improved in the liquid core region compared to a lagrangian injection methodology



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Next steps

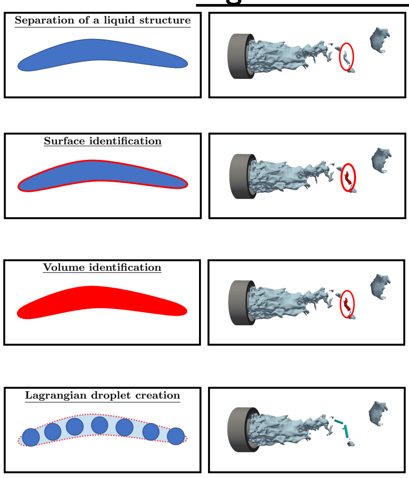
- Improve and refine the mesh
- Use a complex chemistry (ARC)

Eulerian to Lagrangian transition model

Motivation
Atomization process is mesh dependent and requires very fine meshes

Objective
Reduce mesh dependency of the droplet distribution and liquid core length

Algorithm description [5]

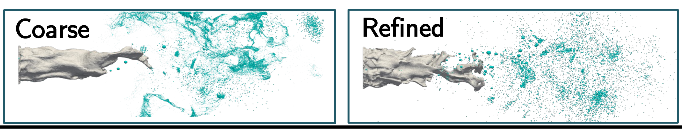


- Detachment of a liquid structure from the liquid core due to shear stress and surface tension

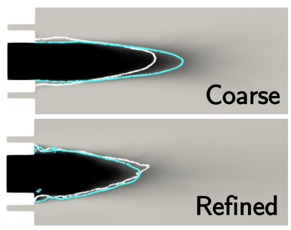
- Structure surface identification with the liquid volume fraction iso-contour $\alpha_{liq} = 0.5$
- Recovering interfacial properties: T, P, Y_k

- Recover the liquid structure nodes
- Determine if the structure has to be atomized (structure geometry)
- Determine $\Delta\rho = \rho_l - \rho_g^{SAT}$ with the interfacial properties

- Apply $T^{SAT}, P^{SAT}, \Delta\rho$ for all eulerian structure nodes
- Determine the lagrangian droplet number, radius and temperature to ensure mass and energy conservation



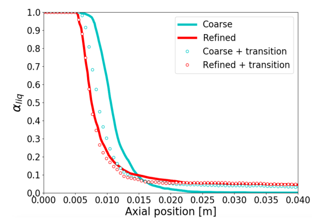
Results



Without transition model
With transition model

- Liquid core length is reduced with the transition model for the coarse mesh
- Liquid core length is no affected by the transition model for the refined mesh

→ **Transition model seems to make the liquid core length less dependent of the mesh refinement**



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Next steps

- Validation of the model against experimental data
- Evaluate the impact of the model on a reactive LRE configuration

Publication : "INJECTION MODELLING IN LOx/GCH4 ROCKET ENGINES WITH A DIFFUSE INTERFACE METHOD", T. GIOUD *et al*, SpacePropulsion 2022

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[1] M. Pelletier et al, Computers and Fluids, 2020
[2] C. B. von Sethe et al, EUCASS, 2019
[3] L. Potier et al, Entropy, 2022
[4] S. Blanchard, PhD thesis, 2021
[5] T.Laroche, PhD thesis, 2021 (2D, mono-species)