Evaluation of erosion inside AWJC Nozzle by 6-way coupling of DEM+CFD+FEM using preCICE

preCICE 2nd Workshop

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Contents

- Problem statement & Goals
- 6-way DEM+CFD+FEM coupling
- Results
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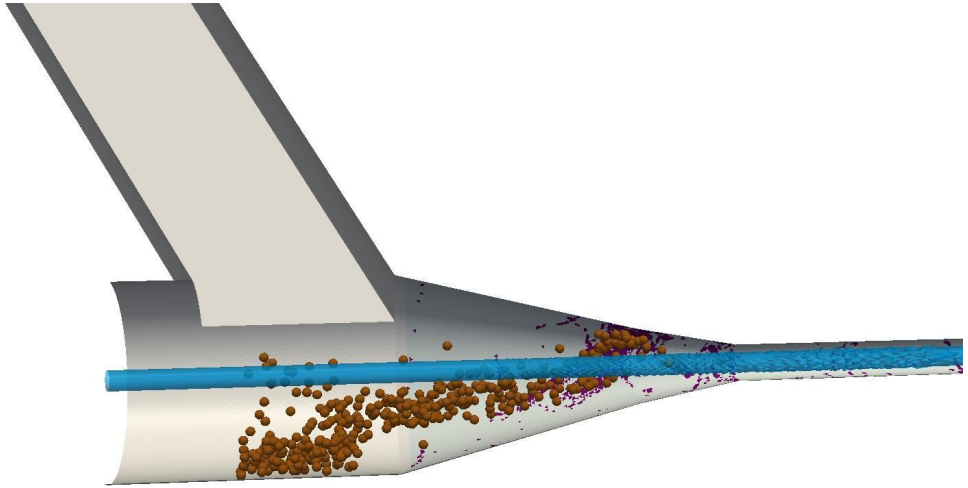
Problem Statement

- Abrasive WaterJet Cutting Nozzle
- AWJC Nozzle the first target of abrasive particles
- Erosion difficult to capture through experimentation

Challenges and Goals

- DEM+CFD coupling used to identify erosion zones
- Particle impact velocity and angle of attack ignored
- Evaluation of erosion in AWJC Nozzle by DEM+CFD+FEM coupling



[1] Gas, liquid and abrasive particles flow in a AWJC Nozzle

[1] Pozzetti, Gabriele, and Bernhard Peters. "Evaluating Erosion Patterns in an abrasive water jet cutting nozzle using XDEM." Advances in Powder Metallurgy & Particulate Materials (2017): 191-205.

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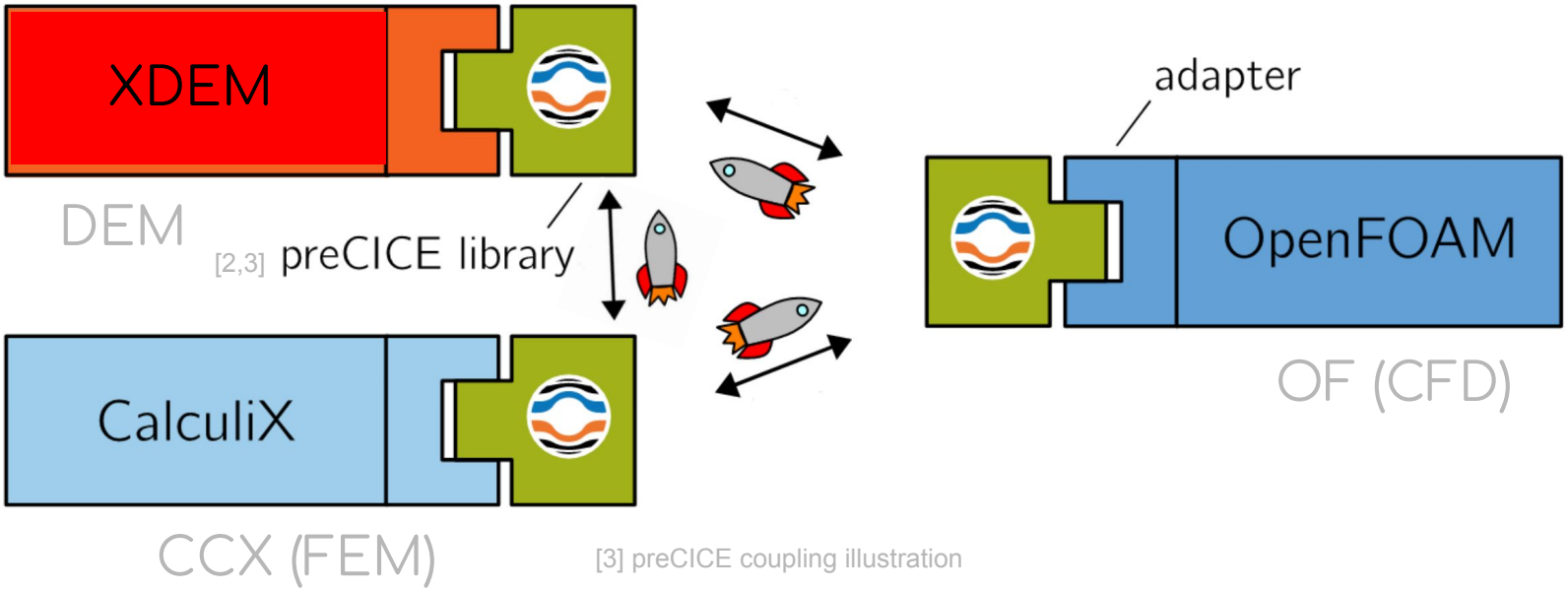
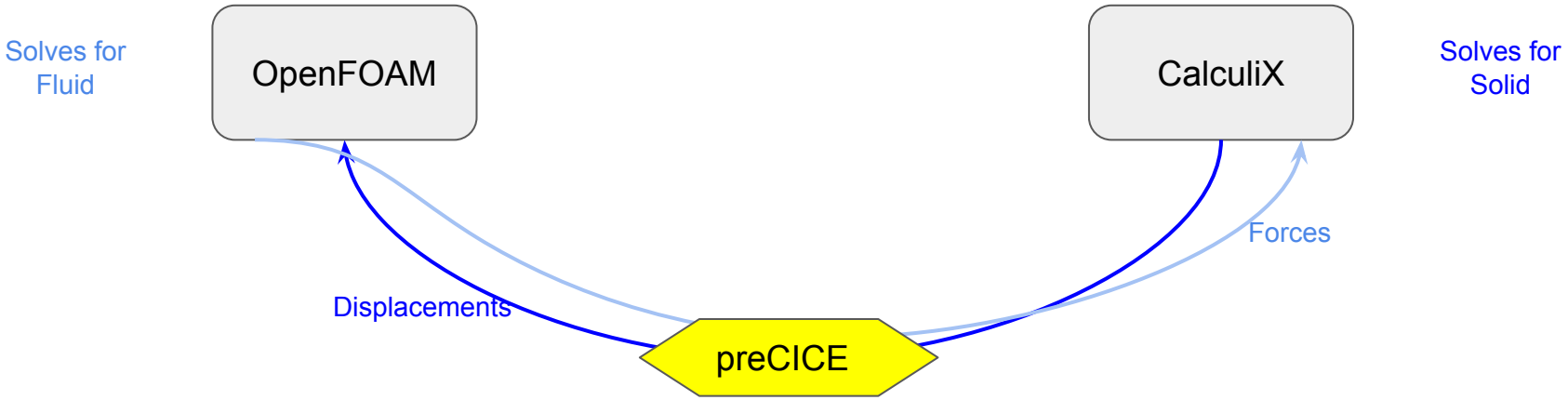
6-way DEM+CFD+FEM coupling



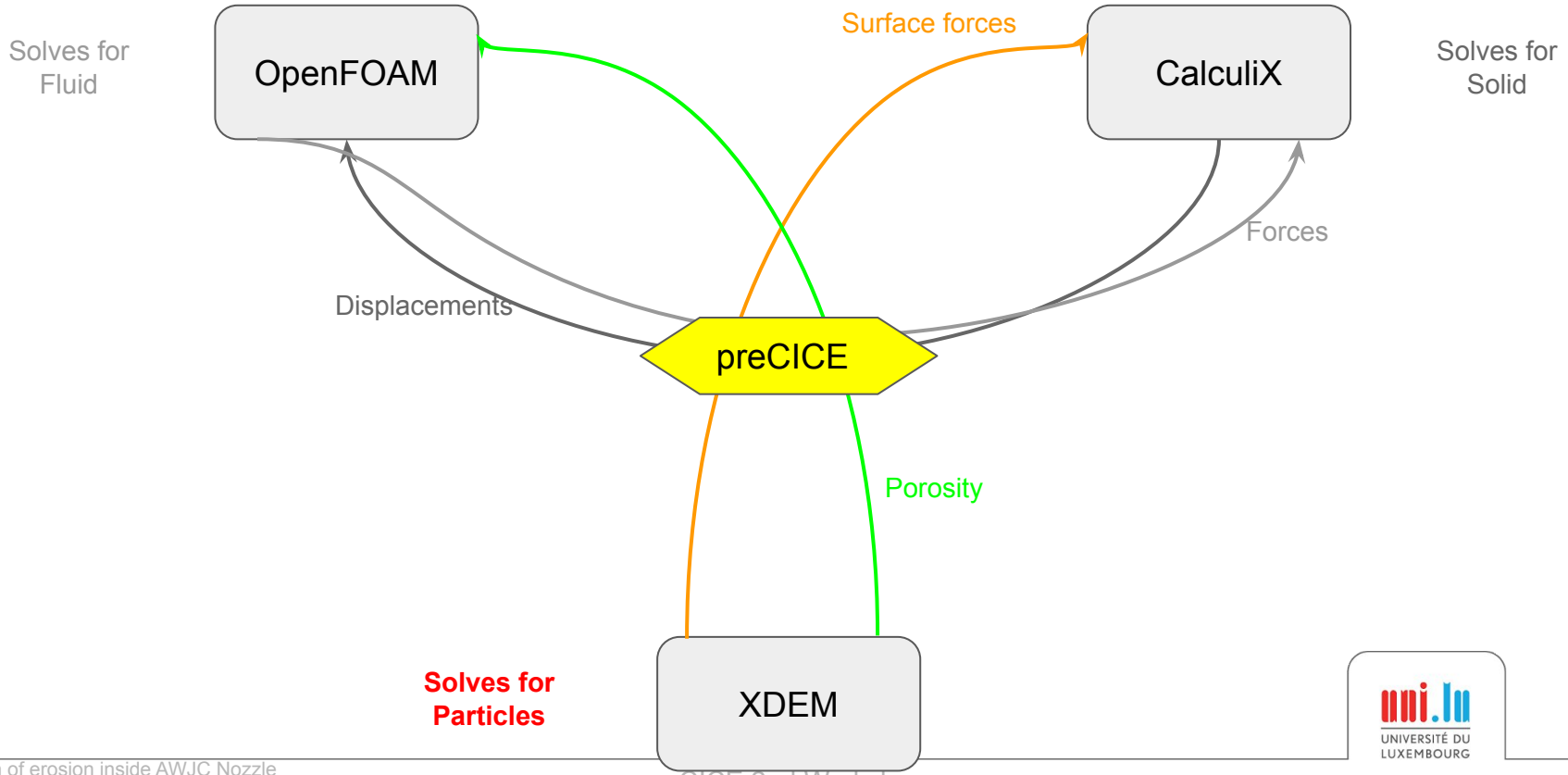
[3] preCICE coupling illustration

[2] Hans-Joachim Bungartz, Bernhard Gatzhammer, Florian Lindner, Miriam Mehl, Klaudius Scheufele, Alexander Shukaev, Benjamin Uekermann, "preCICE -- A Fully Parallel Library for Multi-Physics Surface Coupling" , 2016 in Computers and Fluids, Volume 141, p. 250—258. Elsevier.
[3] https://www.precice.org

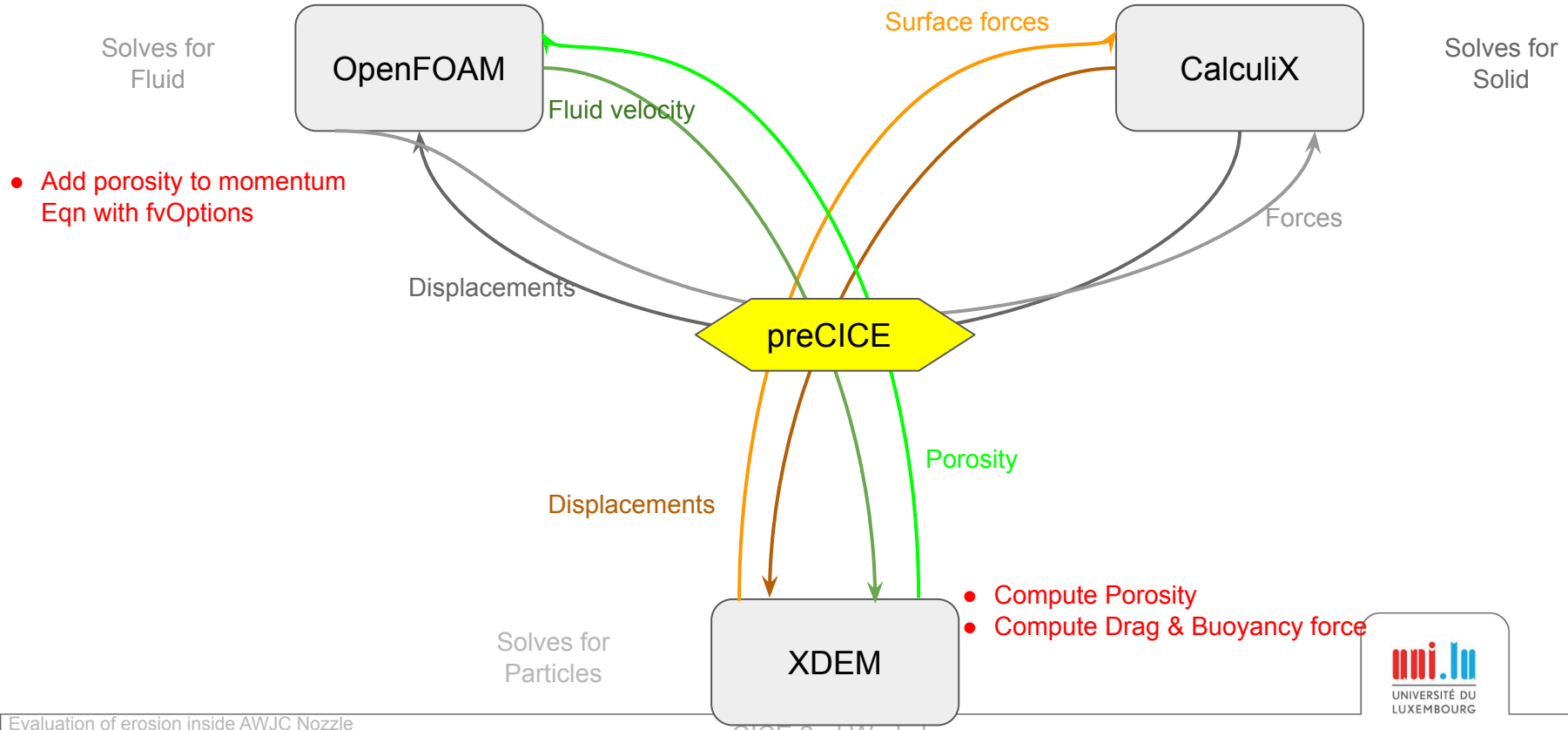
6-way DEM+CFD+FEM coupling



6-way DEM+CFD+FEM coupling



6-way DEM+CFD+FEM coupling

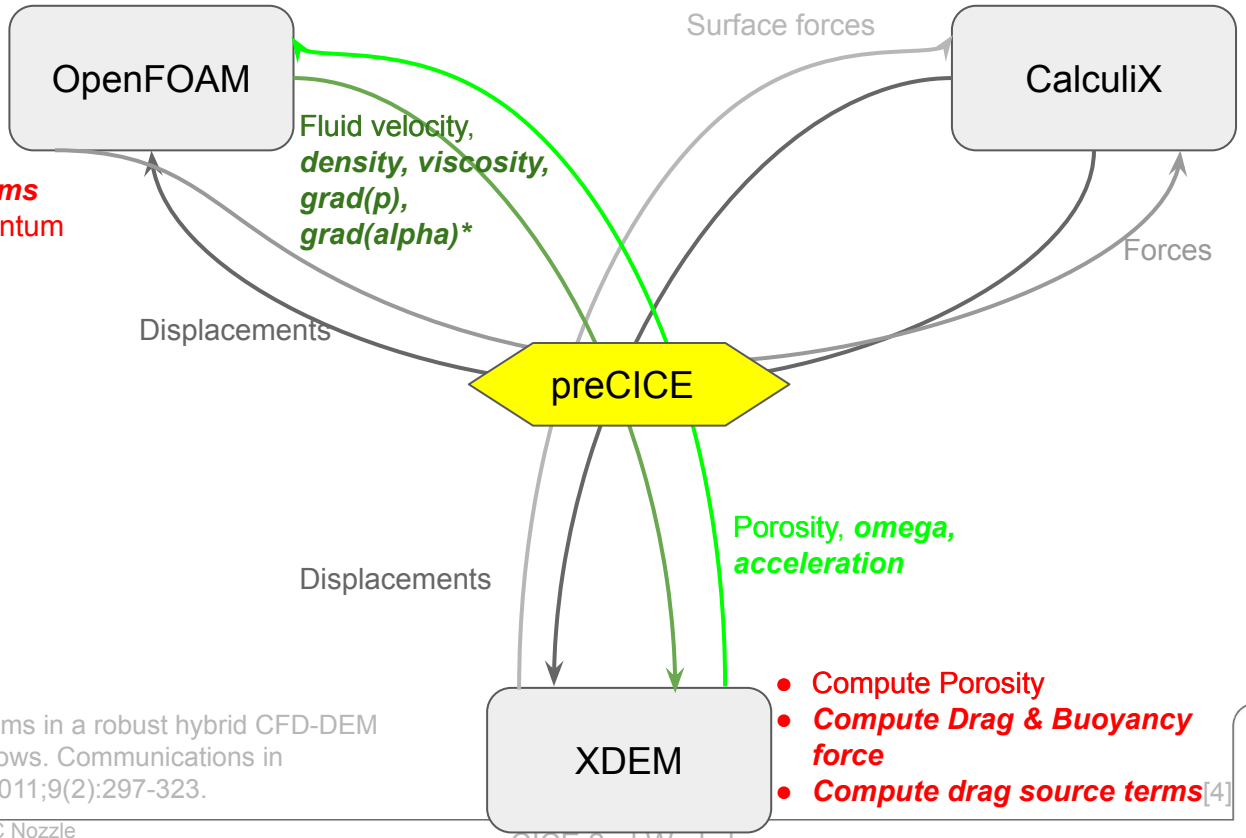


- Add porosity to momentum Eqn with fvOptions

- Compute Porosity
- Compute Drag & Buoyancy force

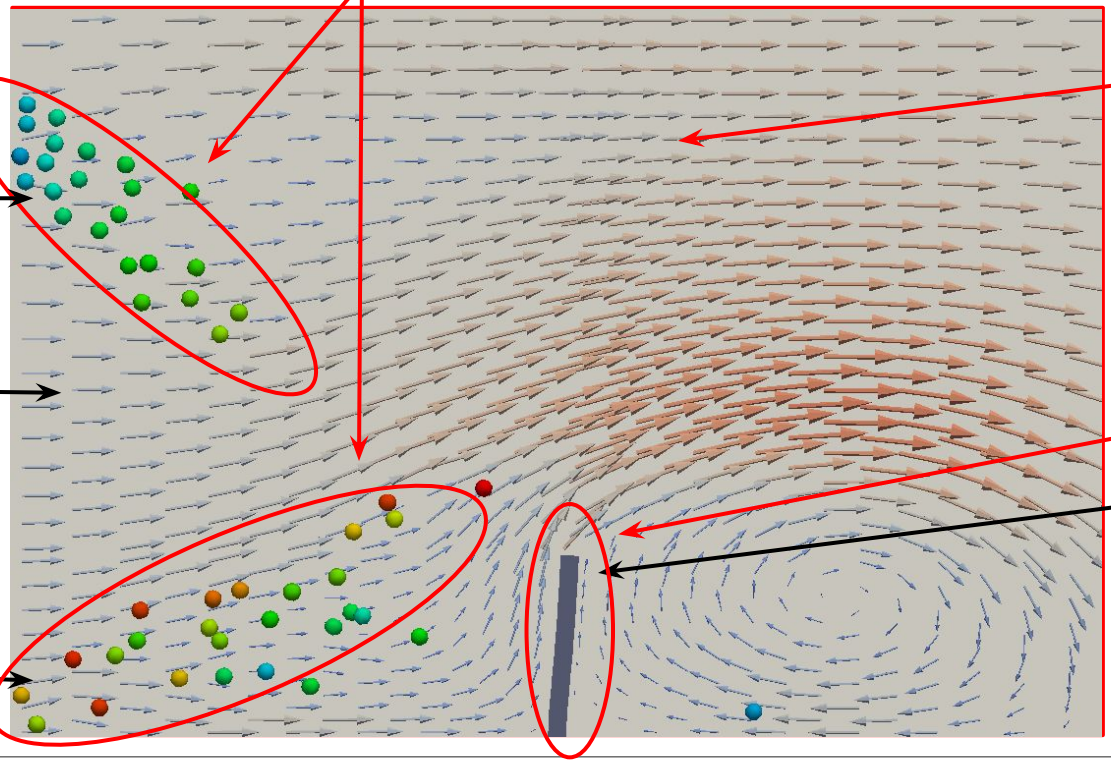
6-way DEM+CFD+FEM coupling

- ***Add drag source terms*** and porosity to momentum Eqn with fvOptions



[4] Xiao H, Sun J. Algorithms in a robust hybrid CFD-DEM solver for particle-laden flows. Communications in Computational Physics. 2011;9(2):297-323.

Test-case setup

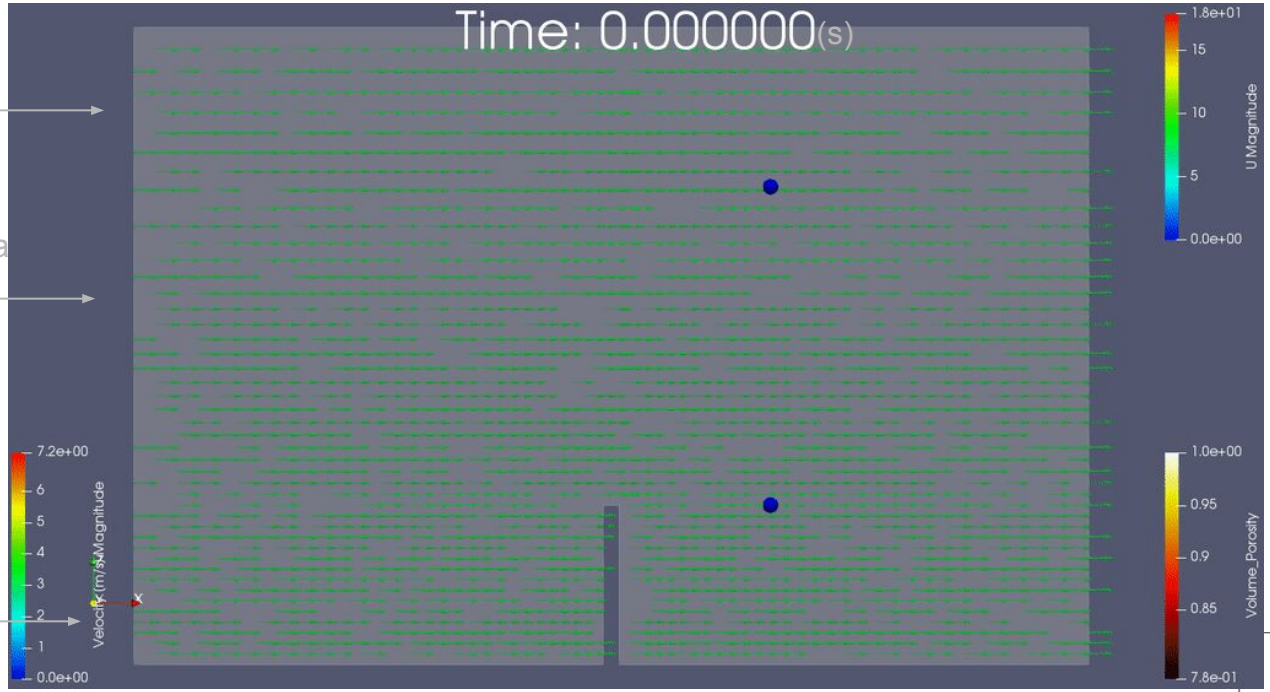


6way coupling OF + CCX +XDEM results: pimpleFoam

heavy particles
1 m/s (50p/s)

Fluid flowing through a channel
10 m/s

light particles
1 m/s (50p/s)



Incompressible

Transient

laminar flow

dt OF = 1e-04

dt CCX = 1e-03

dt XDEM = 1e-05

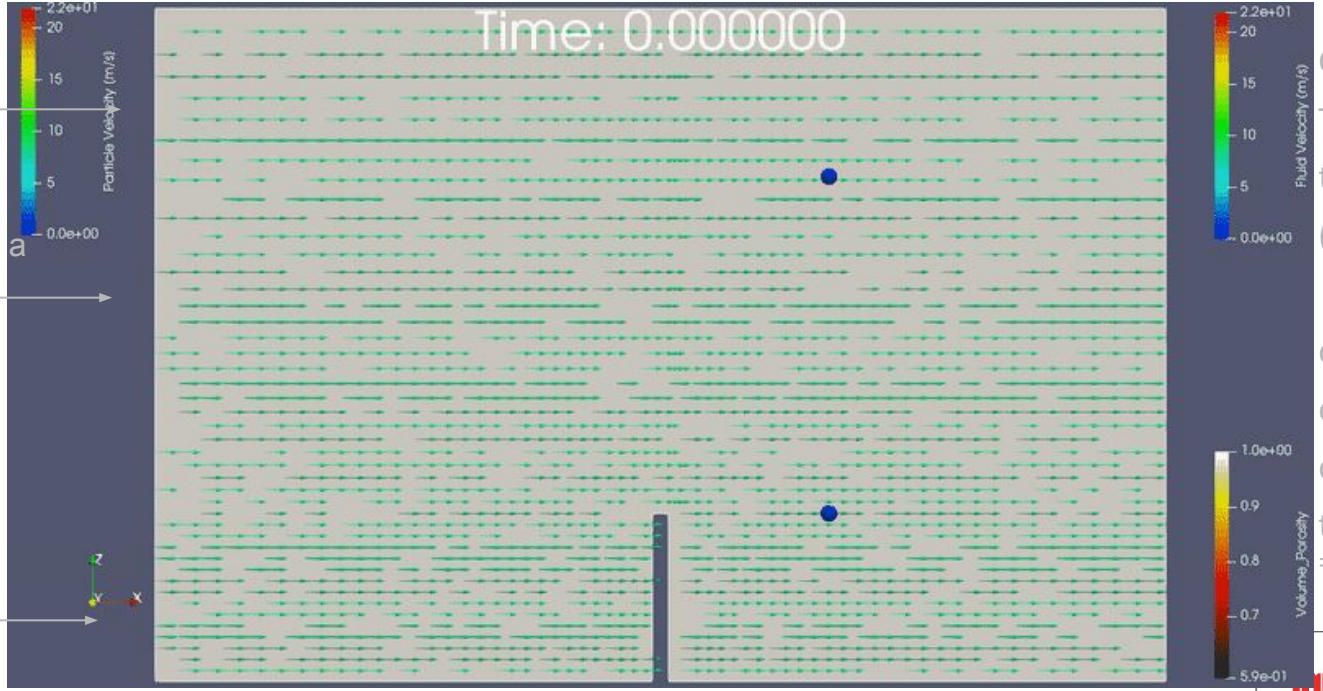
time-window-size = 1e-03

6way coupling OF + CCX +XDEM results: rhoPimpleFoam

heavy particles
1 m/s (50p/s)

Fluid flowing through a channel
10 m/s

light particles
1 m/s (50p/s)



Compressible

Transient

turbulent flow

(LES)

dt OF = 1e-04

dt CCX = 1e-04

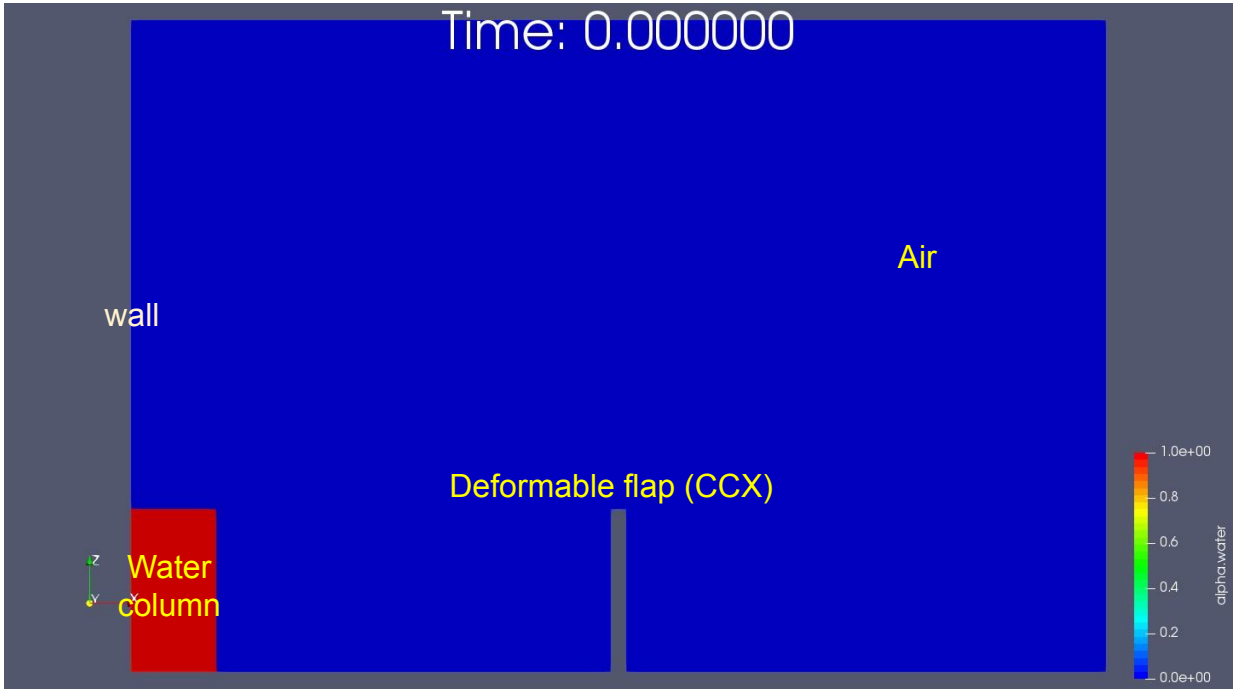
dt XDEM = 1e-05

time-window-size = 1e-04

OF adapter modification for multiphase flow

- Modifications based on moaxm's branch
- Solver used interFoam
- preCICE flap FSI tutorial modified for interFoam (OpenFOAM+CalculiX)
- Case with porosity region

OF + CCX multiphase case set-up



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

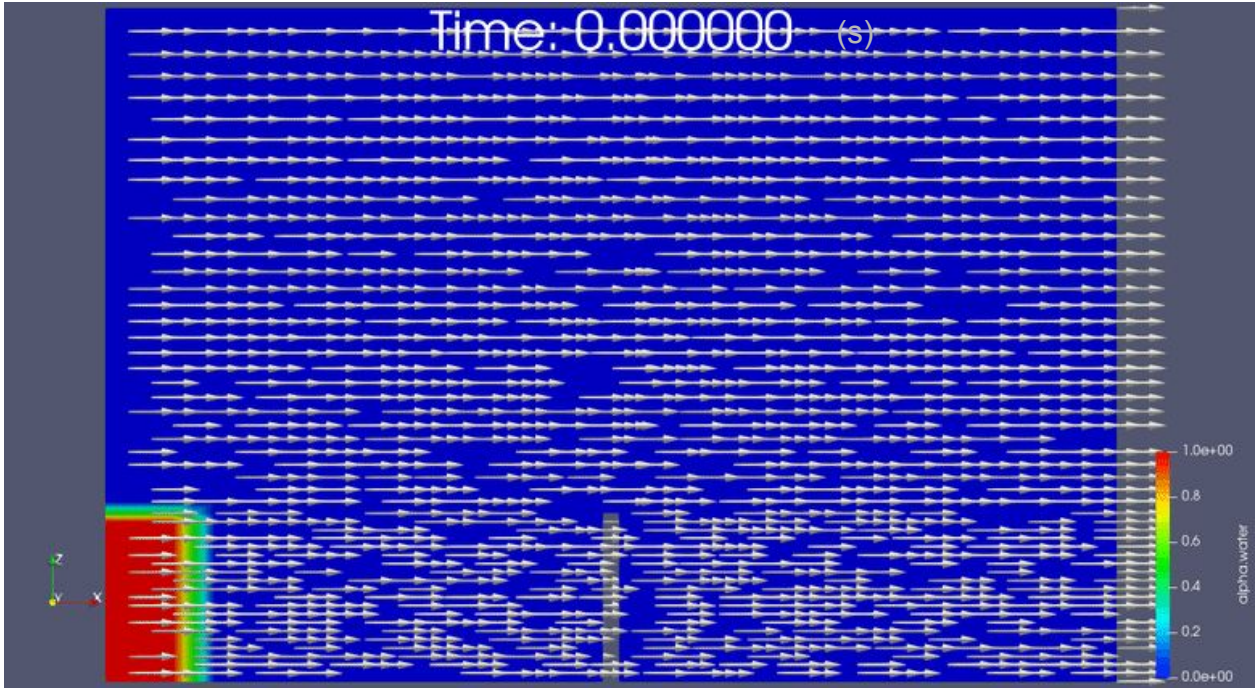
(LES)

dt OF = 1e-04

dt CCX = 1e-04

time-window-size = 1e-04

OF + CCX multiphase case results



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

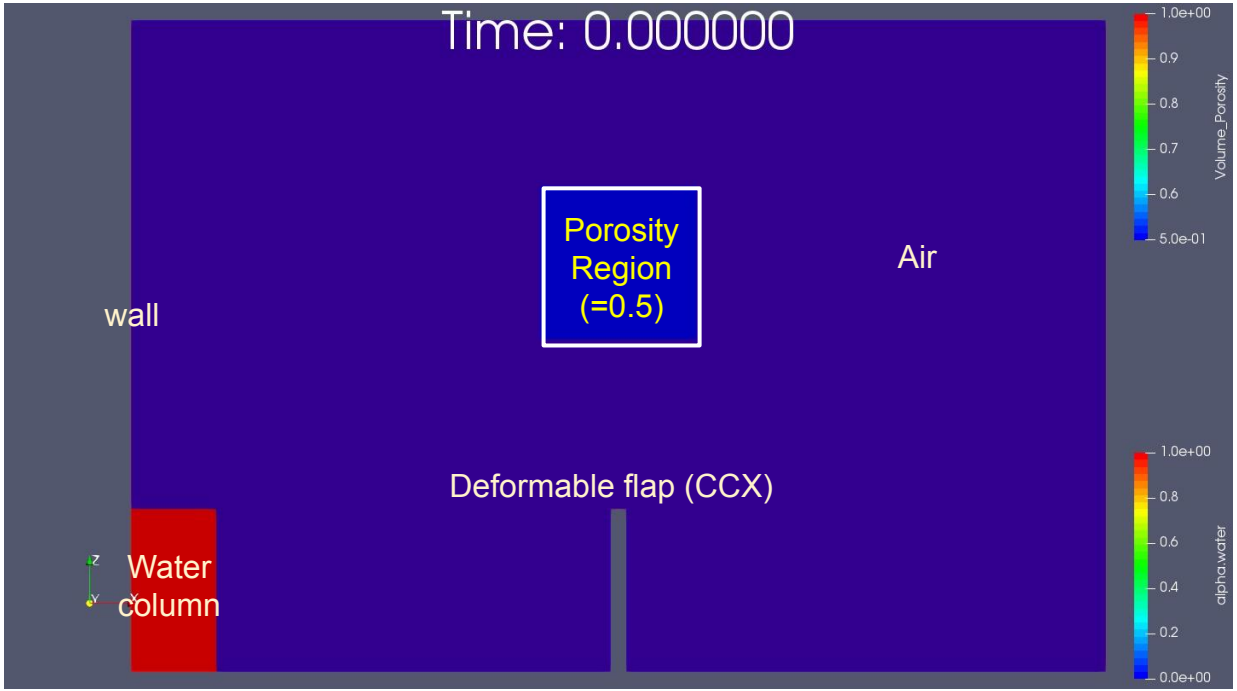
(LES)

dt OF = 1e-04

dt CCX = 1e-04

time-window-size = 1e-04

OF + CCX multiphase case set-up with porosity



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

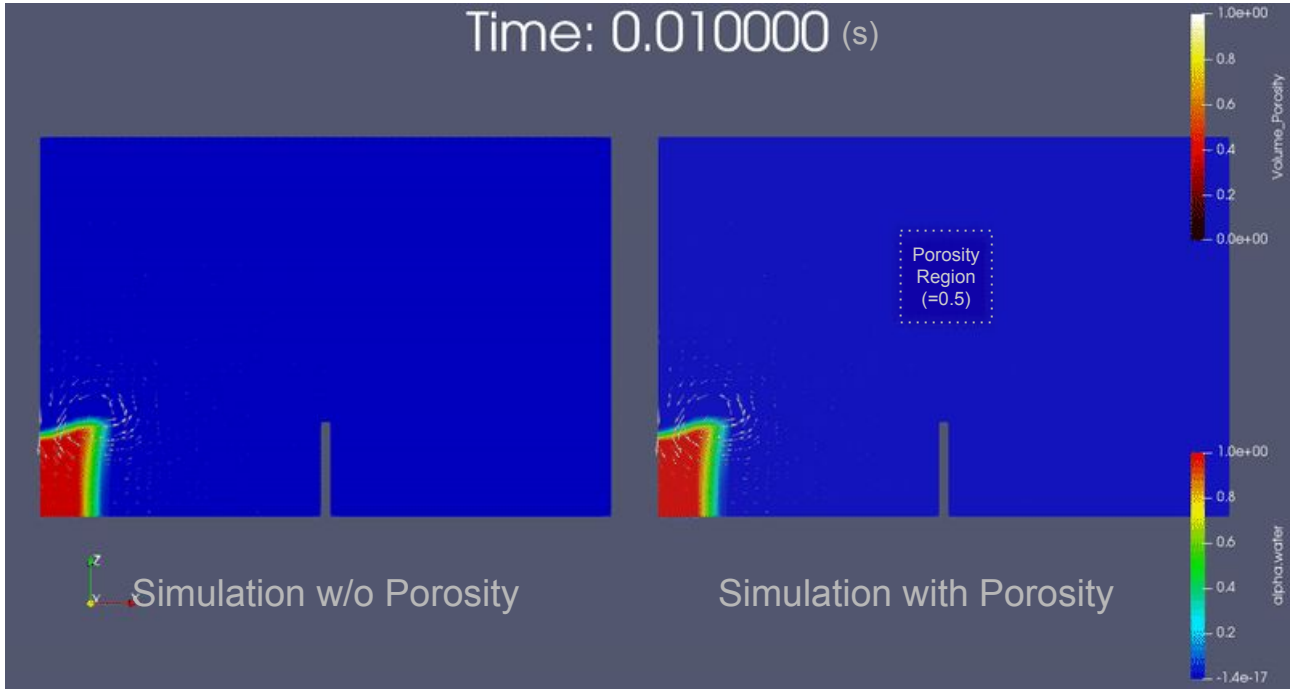
(LES)

dt OF = 1e-04

dt CCX = 1e-04

time-window-size = 1e-04

OF + CCX multiphase case results with porosity



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

dt OF = 1e-04

dt CCX = 1e-04

time-window-size = 1e-04

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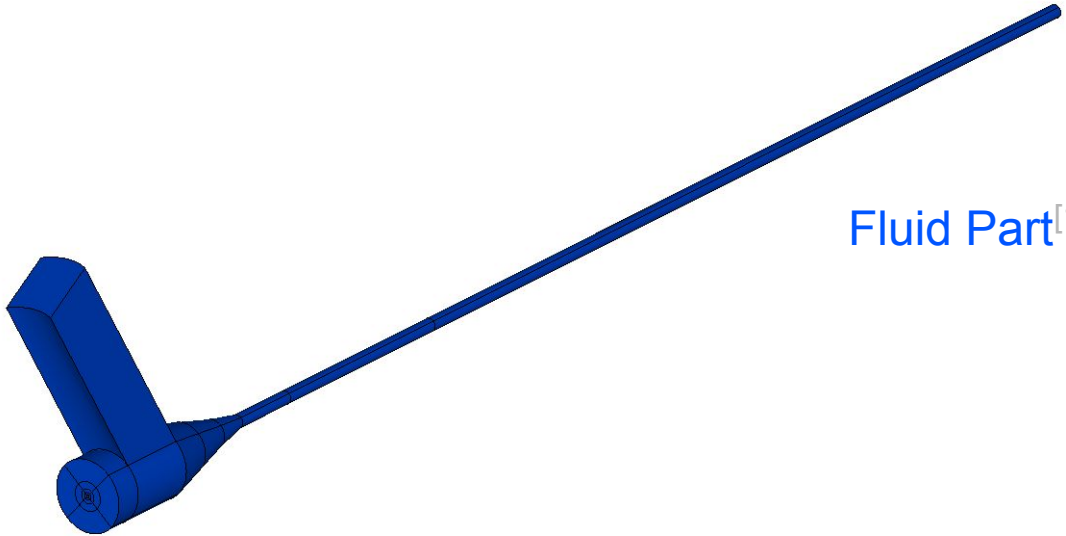
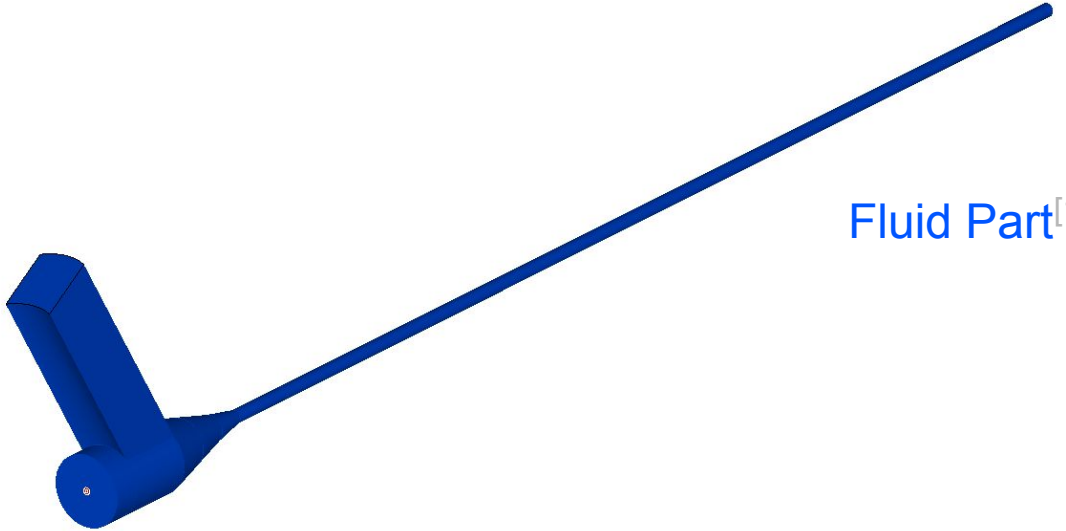
Nozzle coupled simulation set-up



Fluid Part[1]

Nozzle coupled simulation set-up

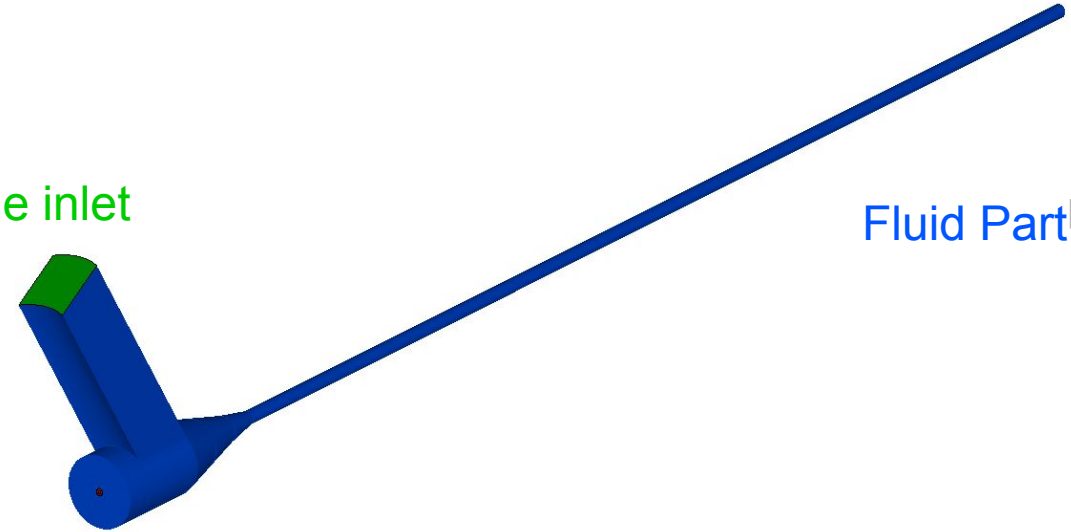


Fluid Part[1]

Water Jet
Inlet = 300 m/s

Nozzle coupled simulation set-up

Particle inlet

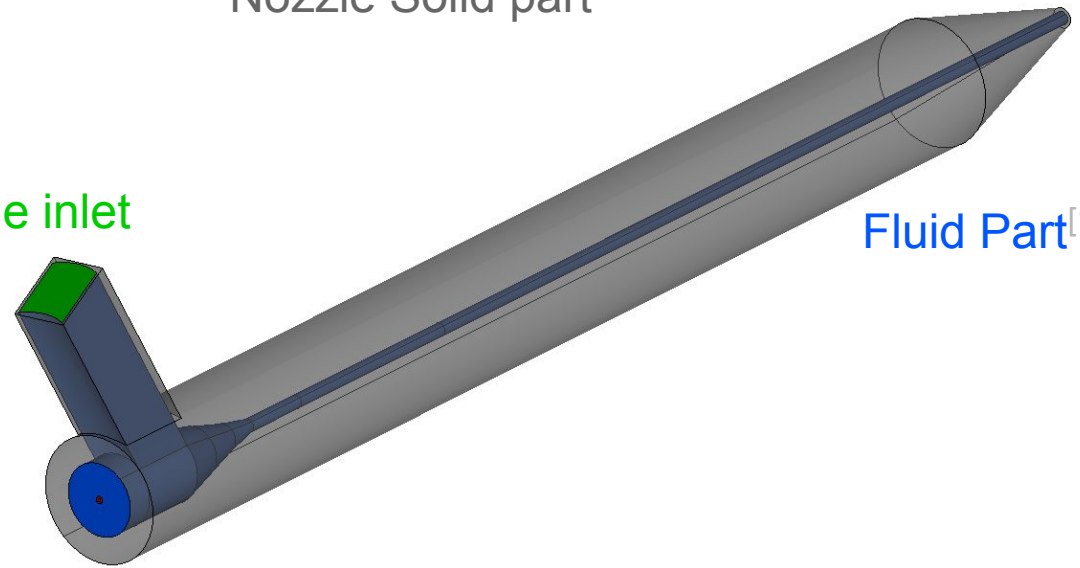


Fluid Part[1]

Water Jet
Inlet = 300 m/s

Nozzle coupled simulation set-up

Nozzle Solid part



Particle inlet

Fluid Part[1]

Water Jet
Inlet = 300 m/s

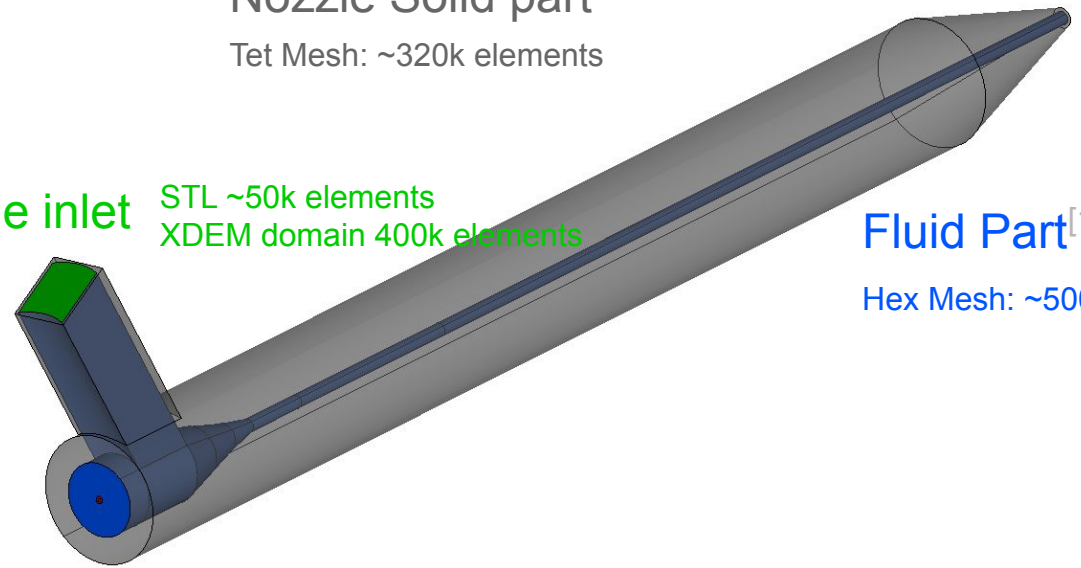
Nozzle coupled simulation set-up

Nozzle Solid part

Tet Mesh: ~320k elements

Particle inlet

STL ~50k elements
XDEM domain 400k elements



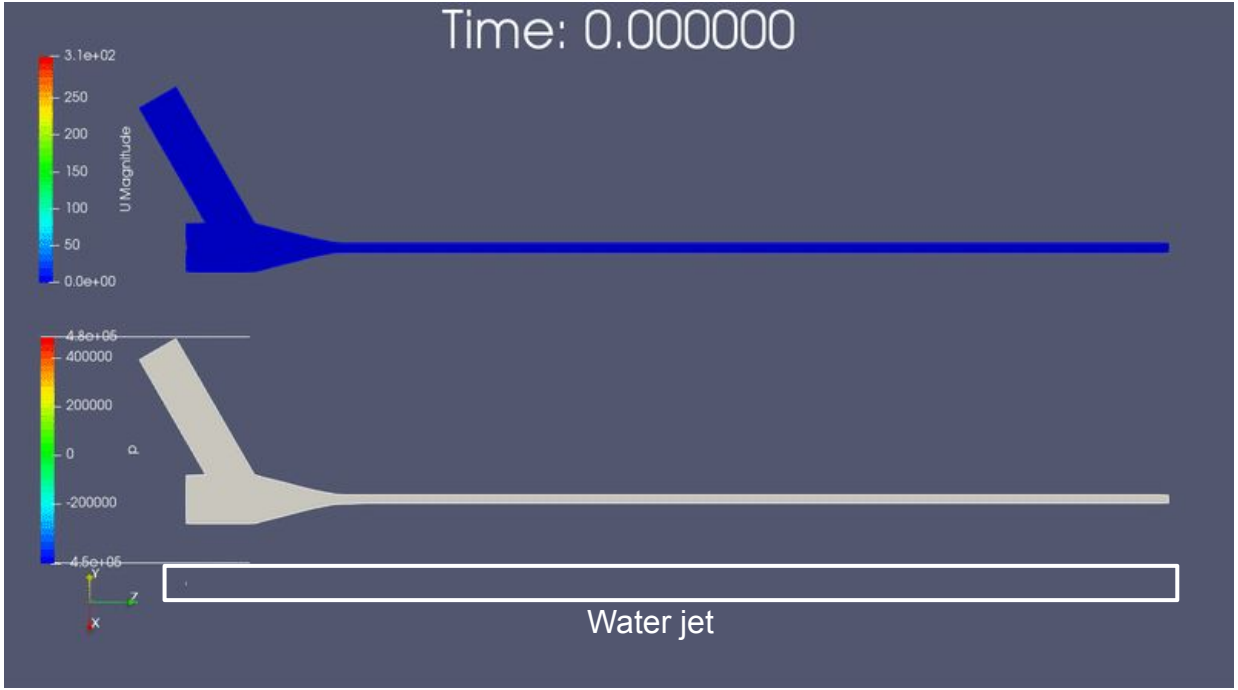
Fluid Part[1]

Hex Mesh: ~500k elements

Water Jet
Inlet = 300 m/s

Nozzle 2way CFD+FEM results

Nozzle CFD results



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

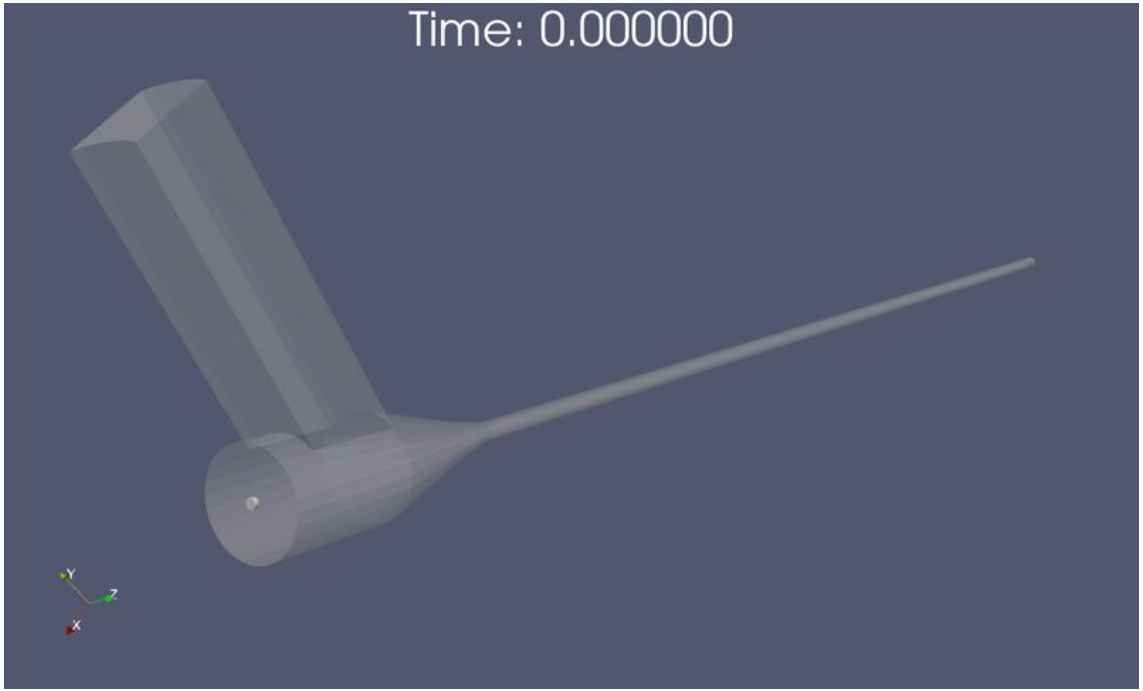
(LES)

dt OF = 1e-08

dt CCX = 1e-07

time-window-size = 1e-07

Nozzle CFD results (waterjet)



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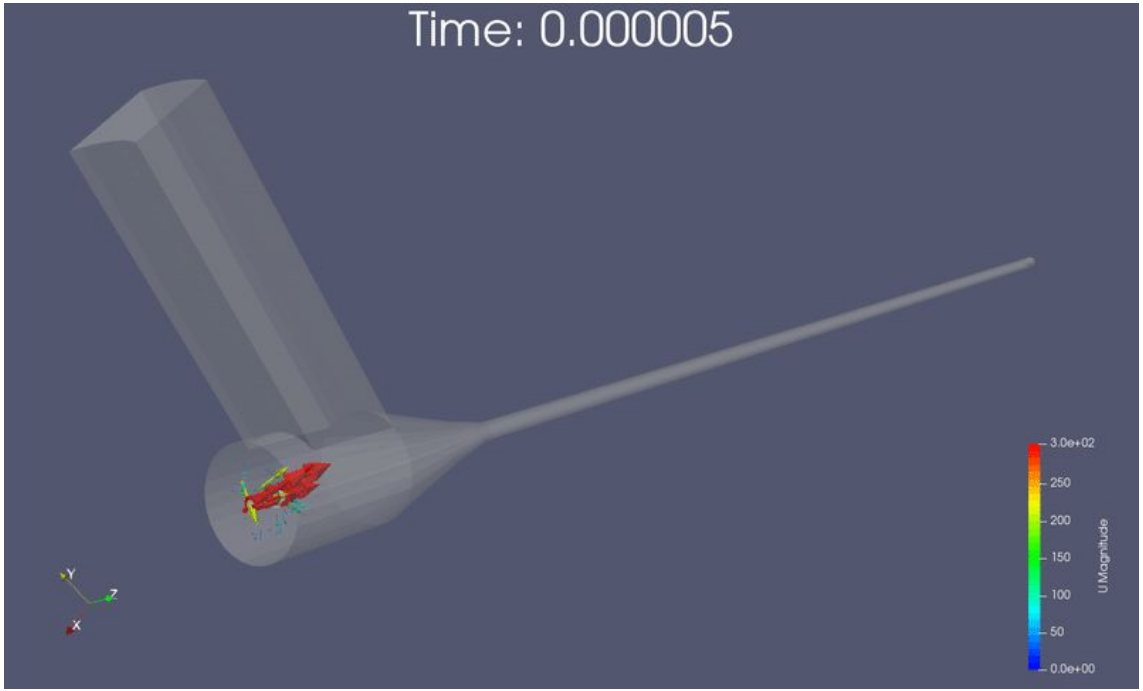
Nozzle CFD results (waterjet)



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Transient

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turbulent flow

(LES)

dt OF = 1e-08

dt CCX = 1e-07

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Nozzle 2way XDEM+FEM results

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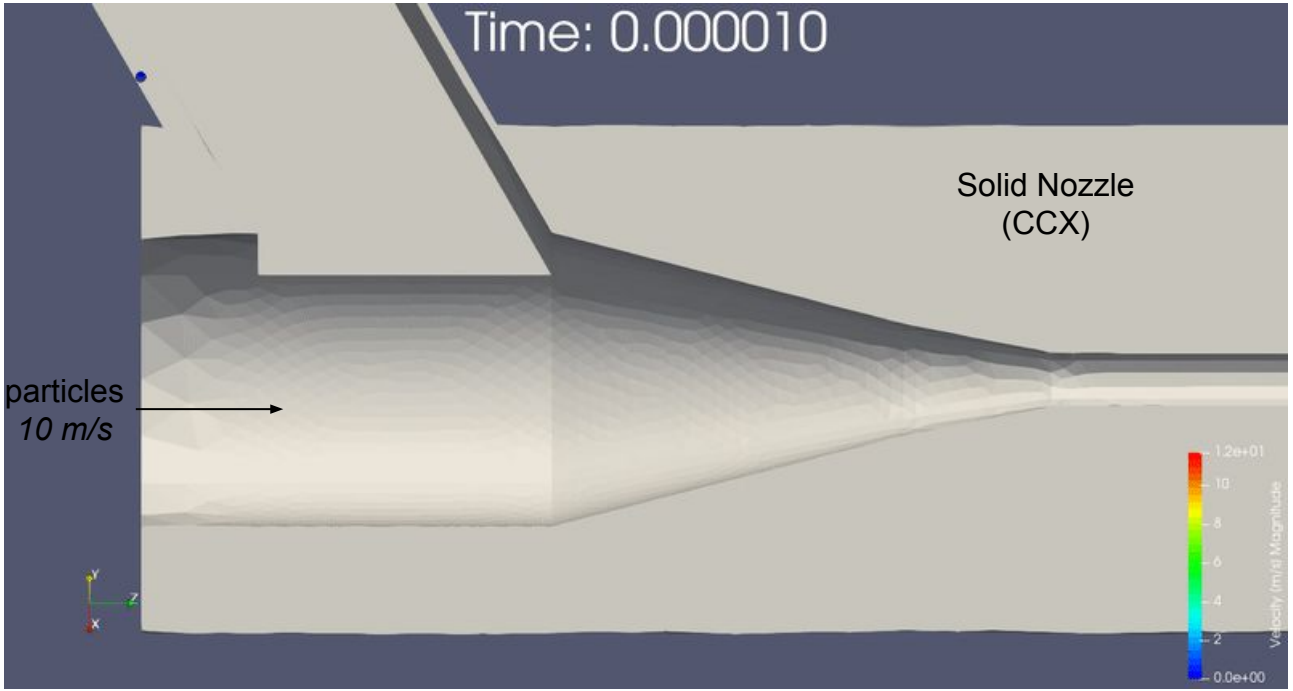
Nozzle 2way XDEM + CCX results

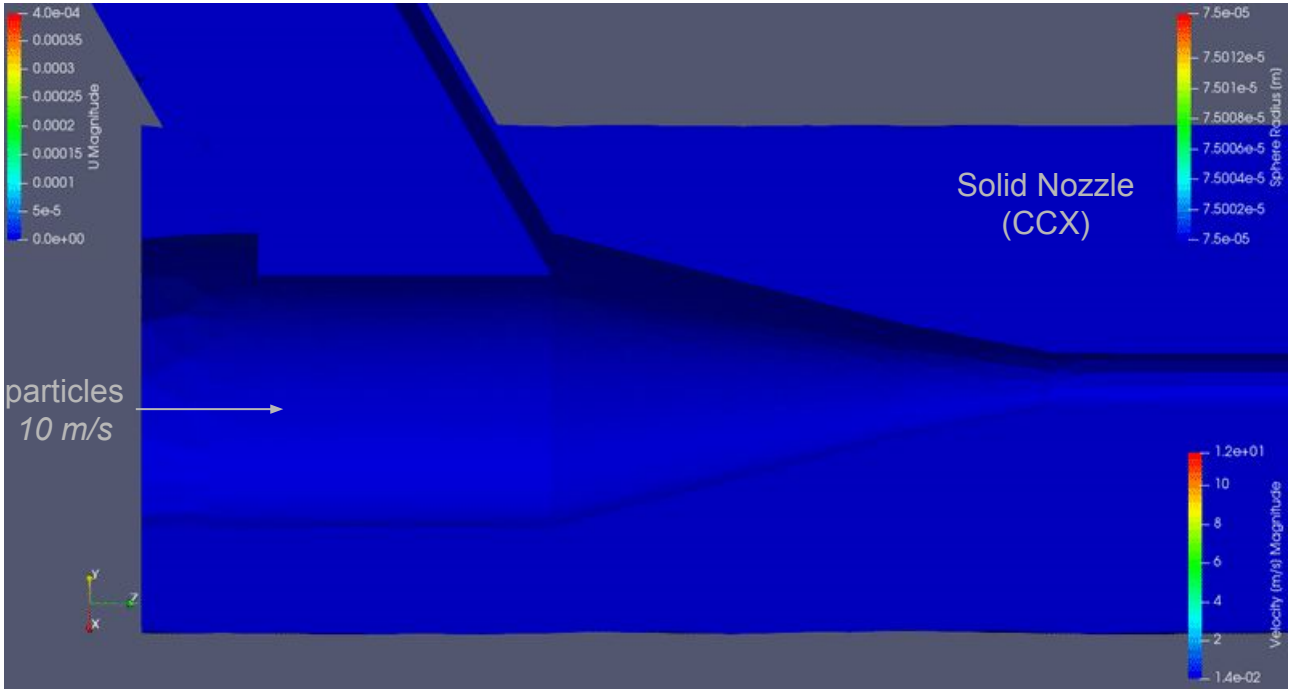


dt CCX = 1e-06

dt XDEM = 1e-06

time-window-size = 1e-06

Nozzle XDEM + CCX results



dt CCX = 1e-06

dt XDEM = 1e-06

time-window-size = 1e-06

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Work in Progress

- Injecting new source terms in fvOptions
- DEM+CFD (interFoam) coupling
- Summation action on Forces
- Conversion of results from CCX format to ParaView format
  (https://github.com/calculix/ccx2paraview)

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Future Work

- Post-processing of results
- Erosion predictions and calculations inside Nozzle
- Do vibrational analysis of Nozzle through FEM
- Generalized XDEM adapter
- DEM+FEM+CFD coupling, with ANSYS used for CFD

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Thank you for your attention!

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