AWJC Nozzle simulation by 6-way coupling of DEM+CFD+FEM using preCICE coupling library

ECCOMAS Coupled Problems 2021

Prasad ADHAV, Xavier BESSERON, Alban ROUSSET, Bernhard PETERS

University of Luxembourg
Luxembourg XDEM Research Centre
http://luxdem.uni.lu/

UNIVERSITÉ DU LUXEMBOURG

Contents

UNIVERSITÉ DU LUXEMBOURG

Contents

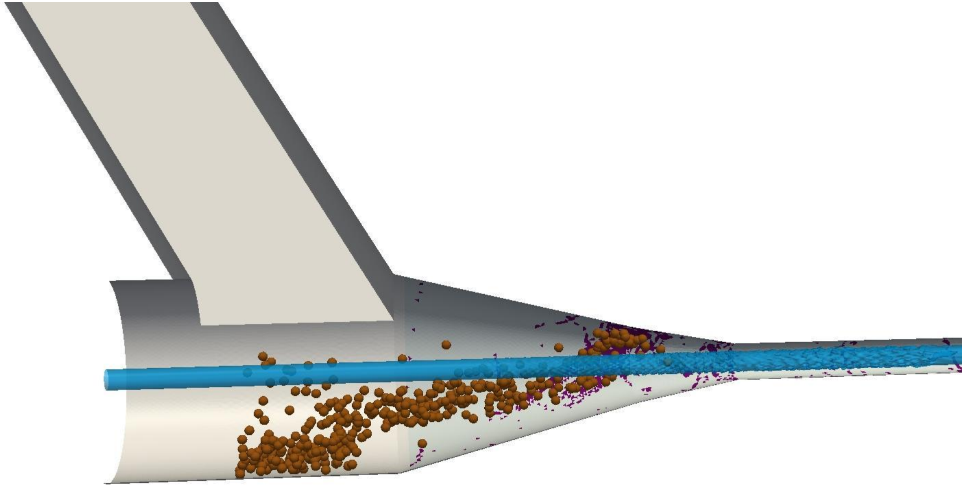
UNIVERSITÉ DU LUXEMBOURG

Problem Statement

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

Previous Work

- DEM+CFD coupling used to identify erosion zones[1]
- Particle impact velocity and angle of attack ignored



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

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

Challenges and Goals

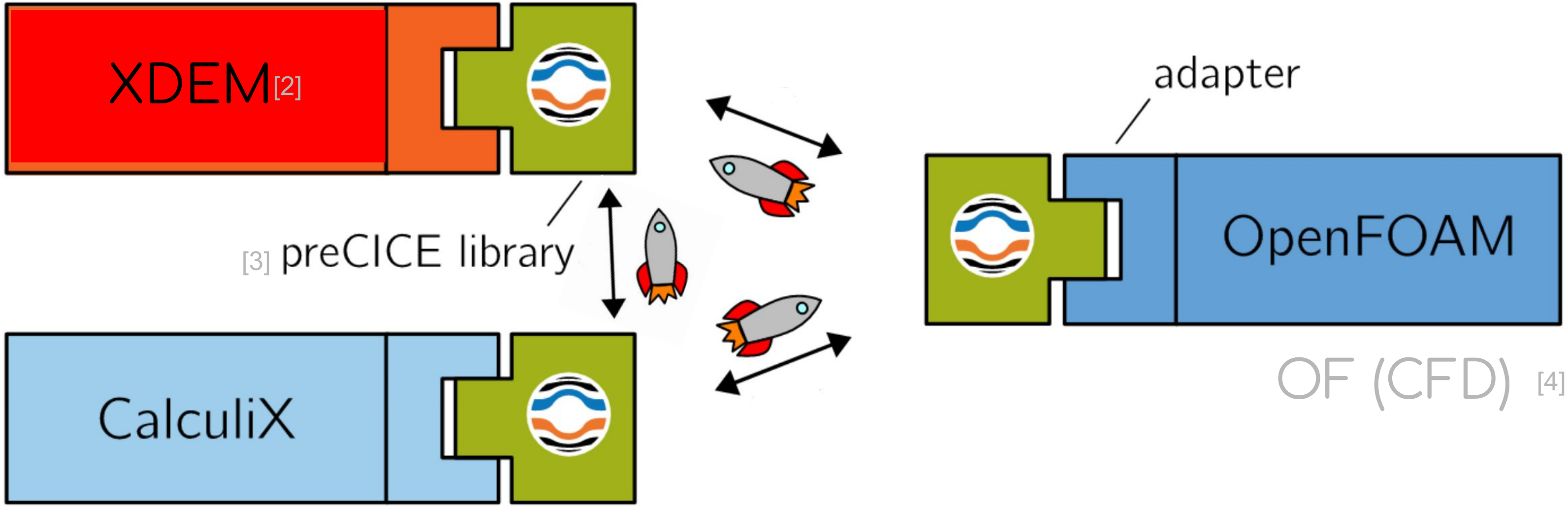
- Evaluation of erosion in AWJC Nozzle by DEM+CFD+FEM coupling
- Using out of the box resources

Contents

UNIVERSITÉ DU LUXEMBOURG

Methodology

Discrete Element Method

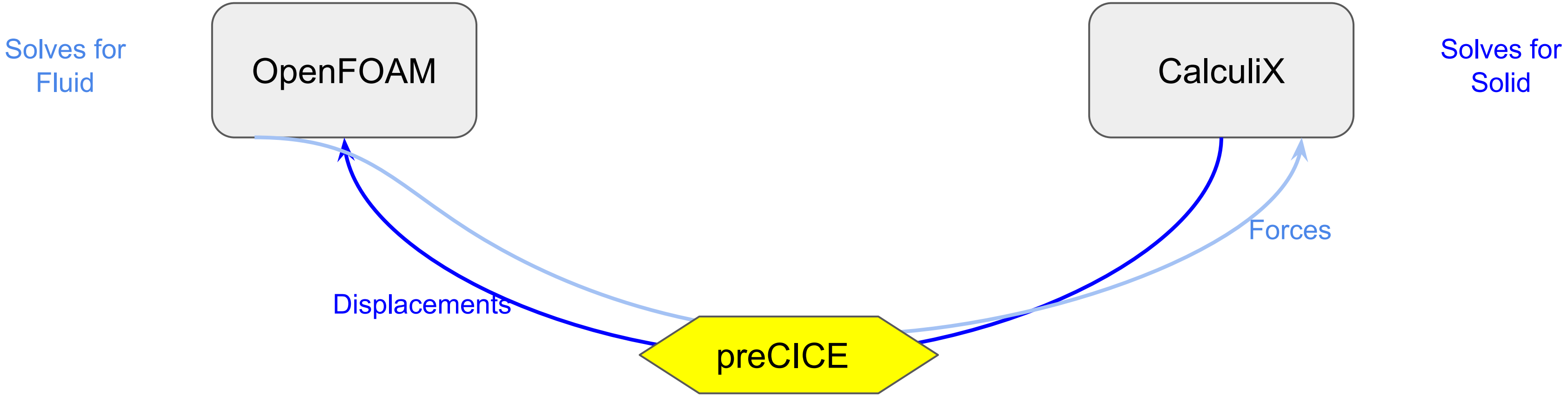


OF (CFD) [4]

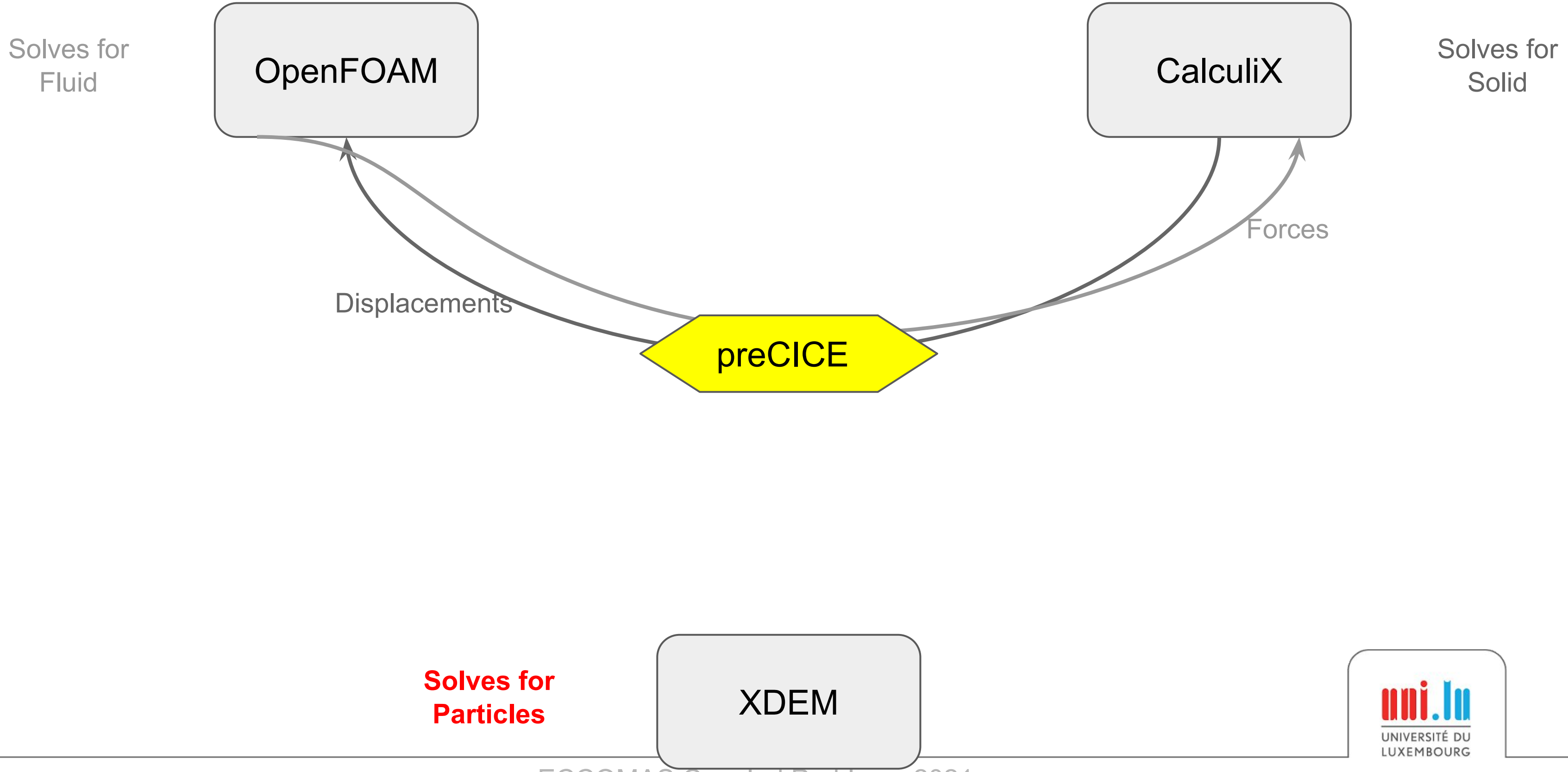
CCX (FEM) [5]

[2] Peters, Bernhard, et al. "XDEM multi-physics and multi-scale simulation technology: Review of DEM–CFD coupling, methodology and engineering applications." Particuology 44 (2019): 176-193
[3] Bungartz, Hans-Joachim, et al. "preCICE–a fully parallel library for multi-physics surface coupling." Computers & Fluids 141 (2016): 250-258.

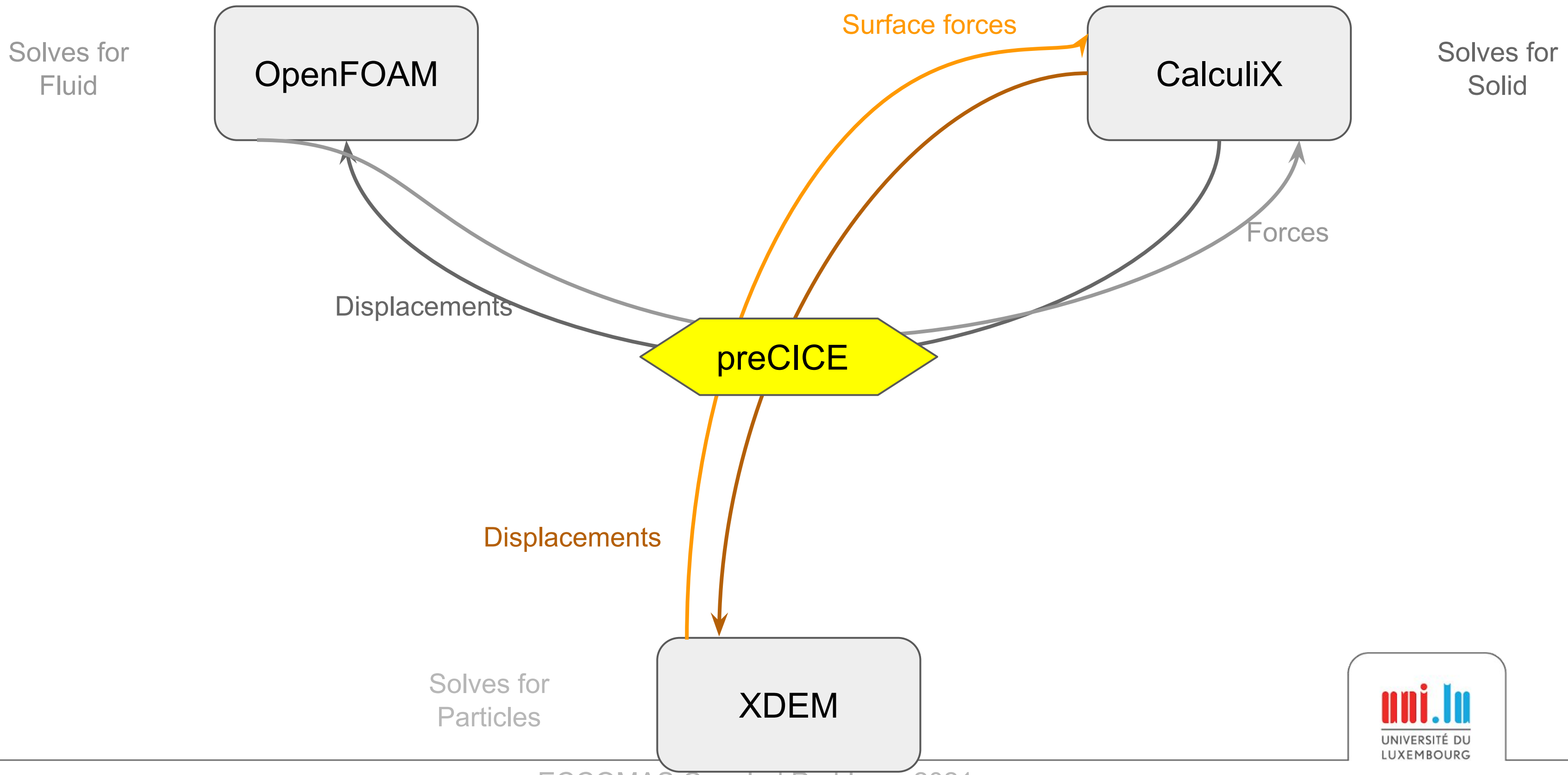
6-way DEM+CFD+FEM coupling



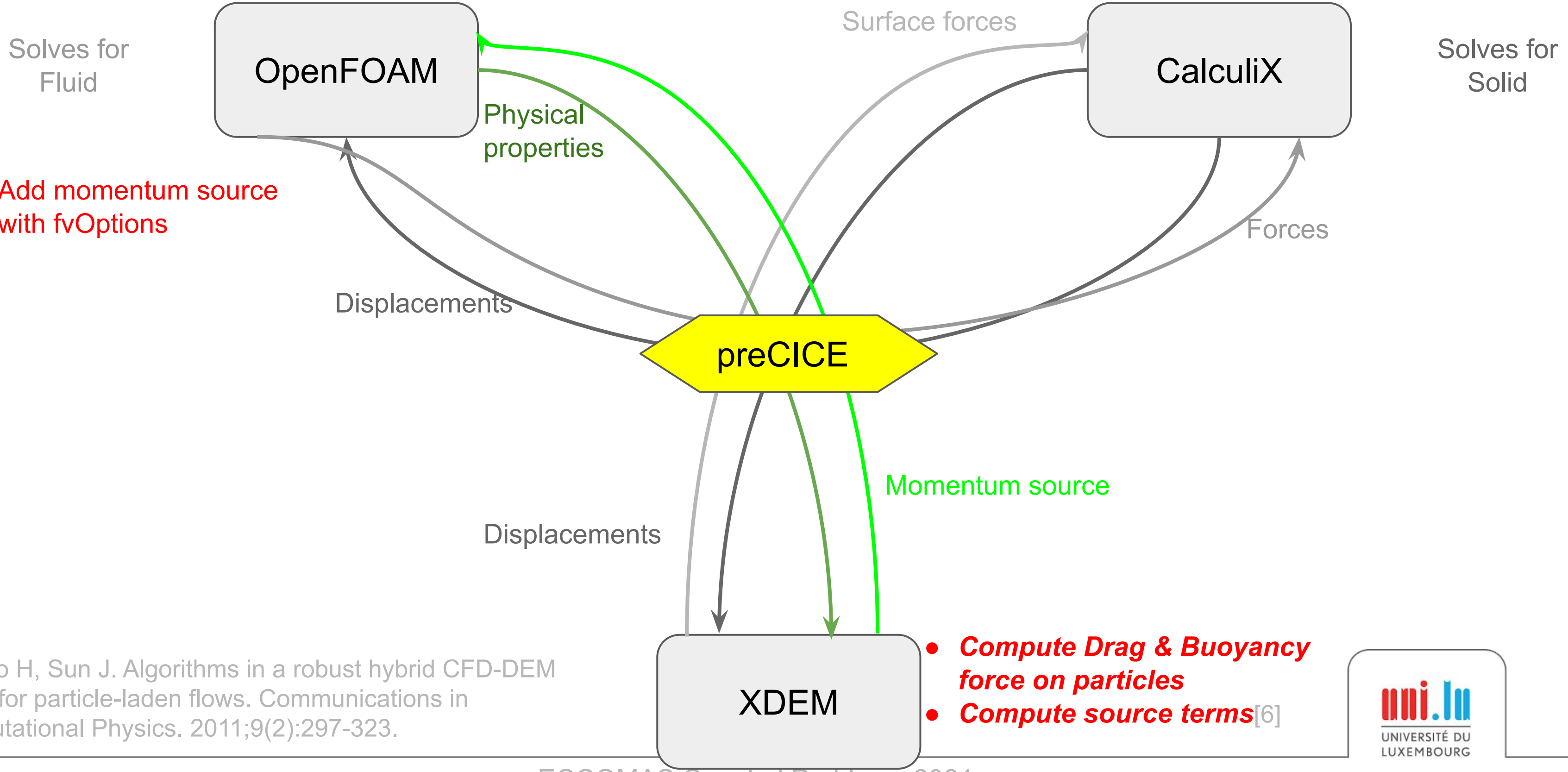
6-way DEM+CFD+FEM coupling



6-way DEM+CFD+FEM coupling



6-way DEM+CFD+FEM coupling

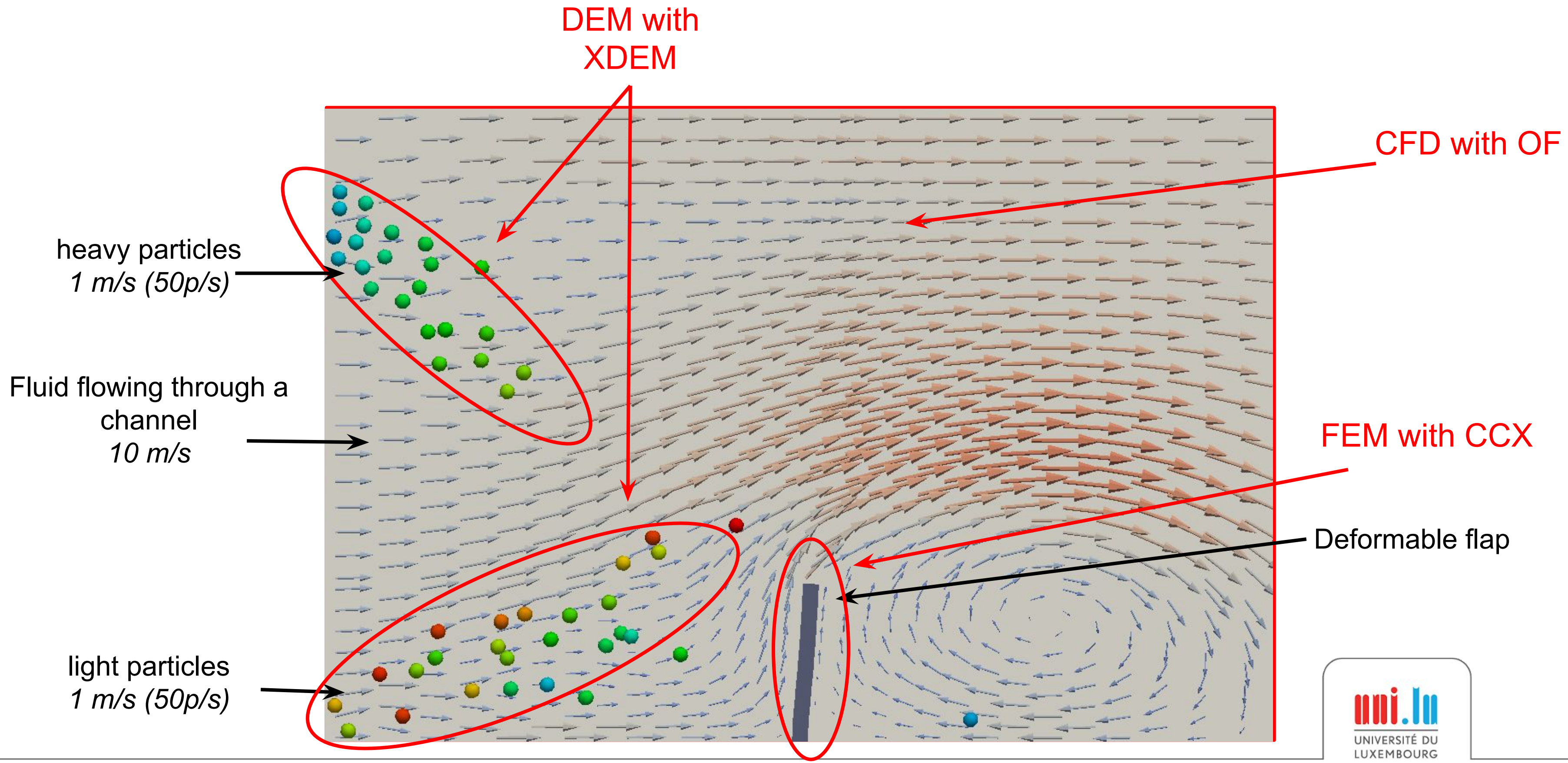


- Add momentum source with fvOptions

- ***Compute Drag & Buoyancy force on particles***
- ***Compute source terms***[6]

[6] 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

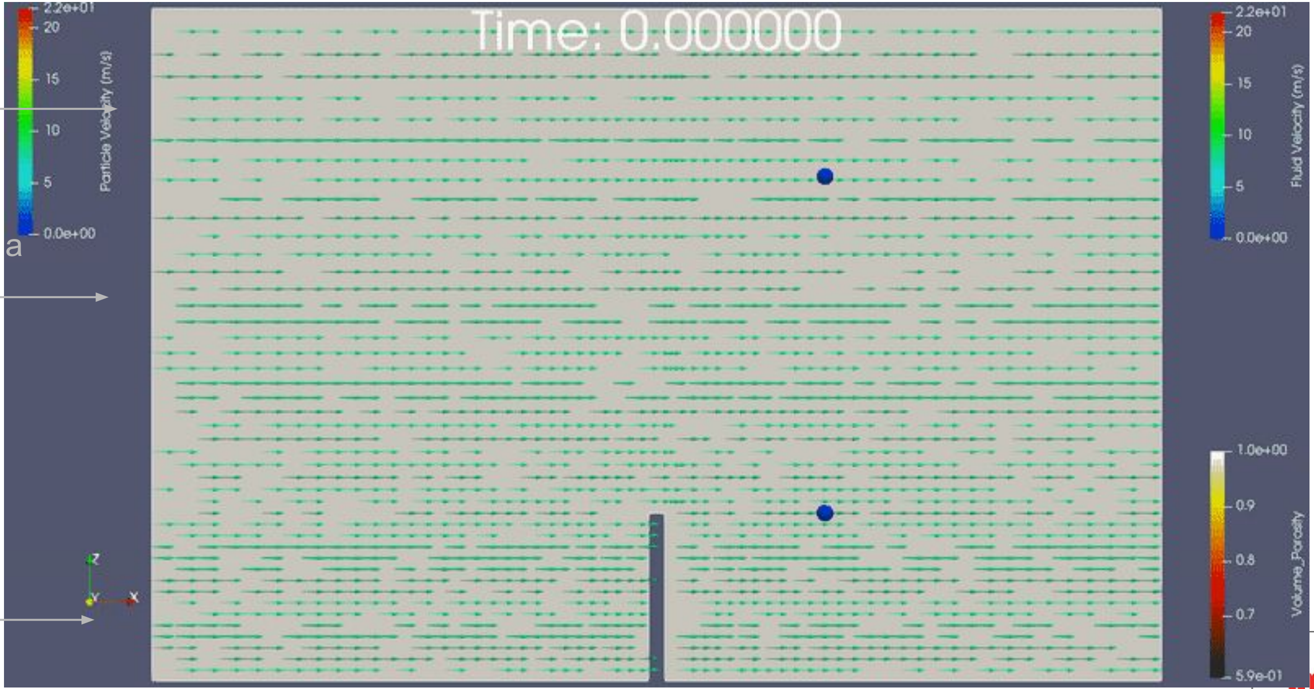


6way coupling OF + CCX +XDEM results: rhoPimpleFoam

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

preCICE coupling
dt = 1e-04

UNIVERSITÉ DU LUXEMBOURG

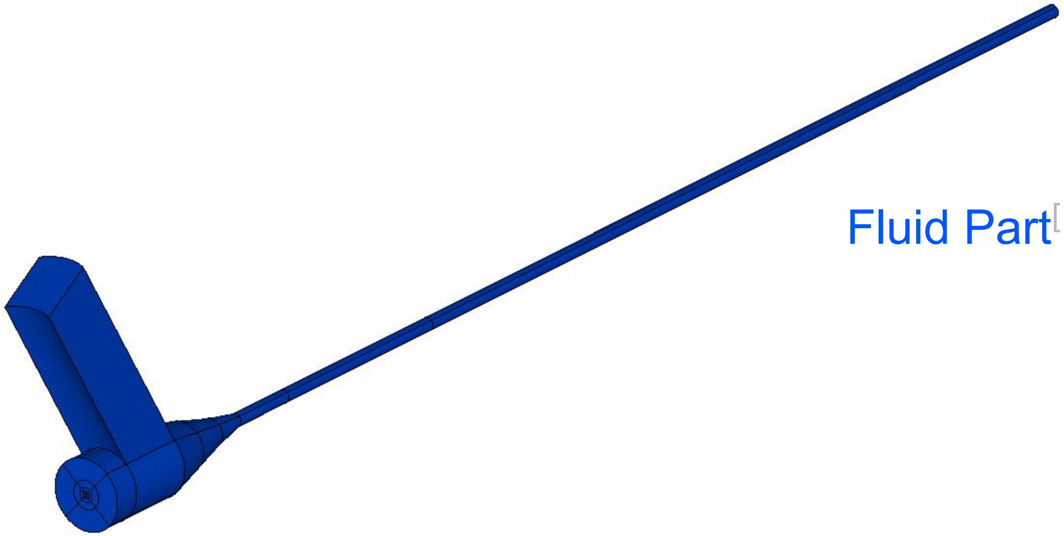
Contents

- Problem statement & Goals
- Methodology
- Results
- Conclusions
- Next Steps

UNIVERSITÉ DU LUXEMBOURG

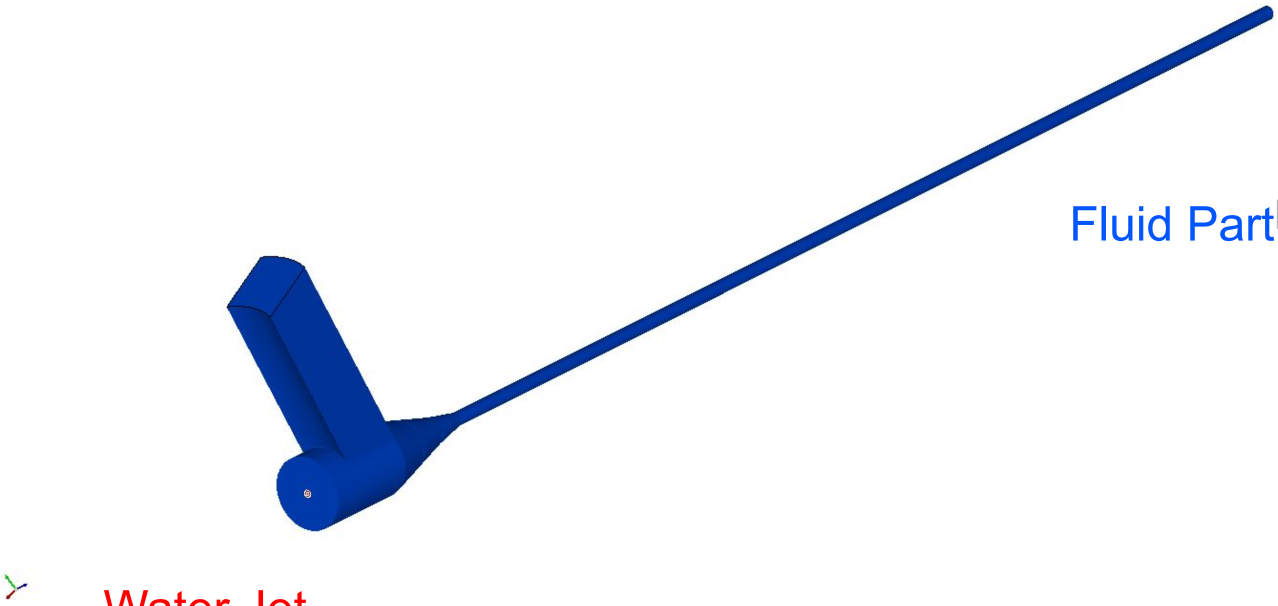
Nozzle case setup

Nozzle coupled simulation set-up



Fluid Part[1]

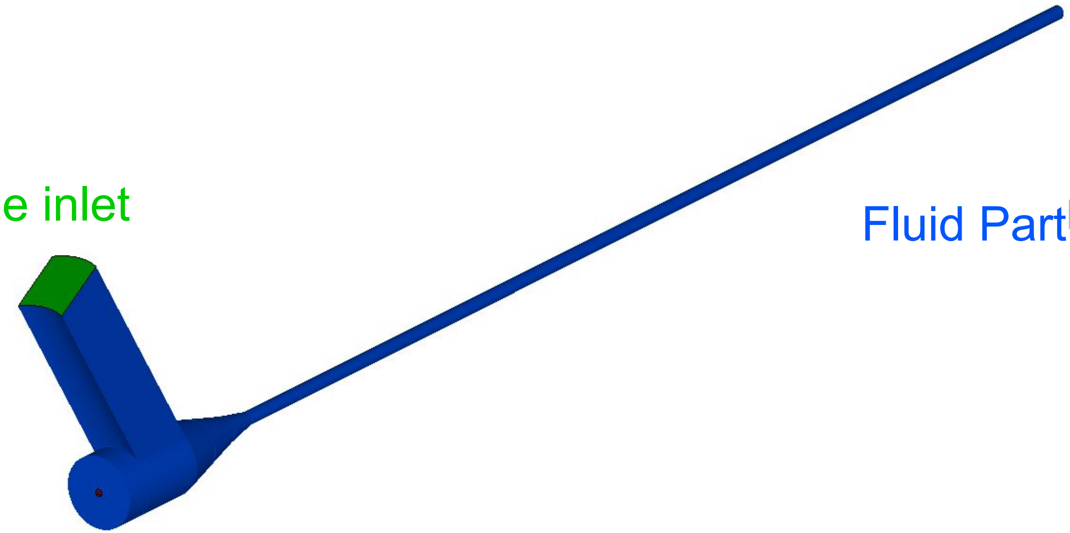
Nozzle coupled simulation set-up



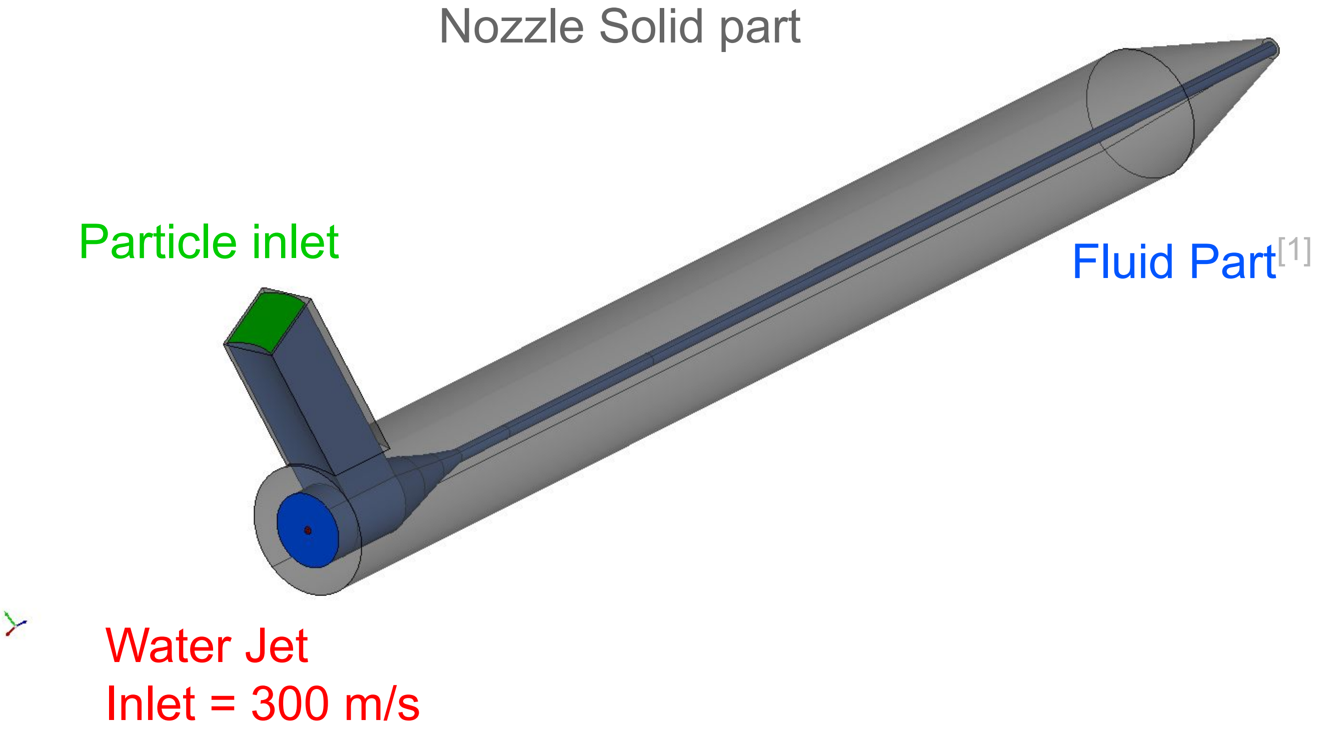
Fluid Part[1]

Water Jet
Inlet = 300 m/s

Nozzle coupled simulation set-up



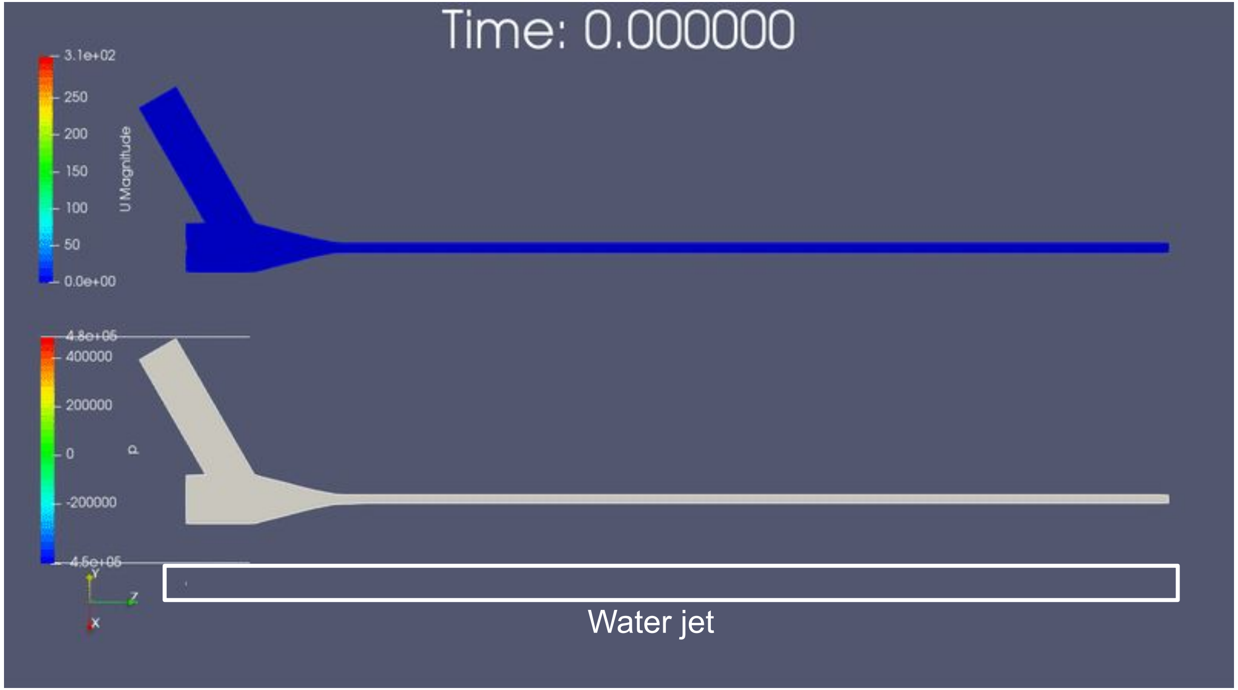
Nozzle coupled simulation set-up



UNIVERSITÉ DU LUXEMBOURG

Nozzle
CFD results

Nozzle CFD results



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

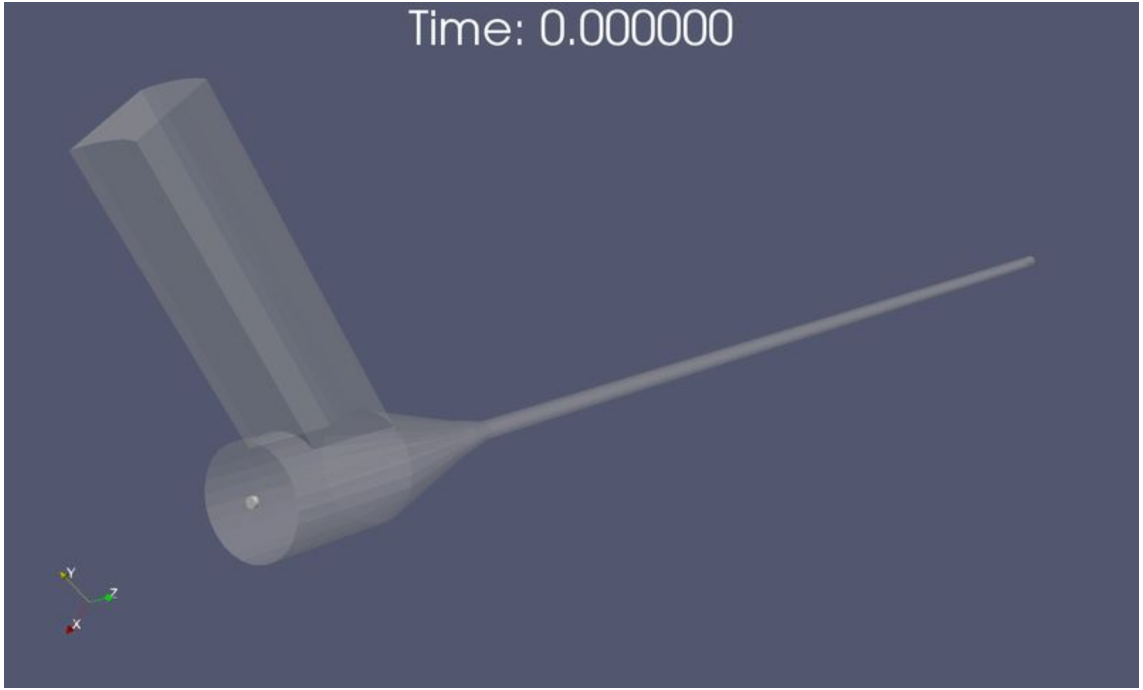
dt OF = 1e-08

dt CCX = 1e-07

preCICE coupling dt = 1e-07

UNIVERSITÉ DU LUXEMBOURG

Nozzle CFD results (waterjet)



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

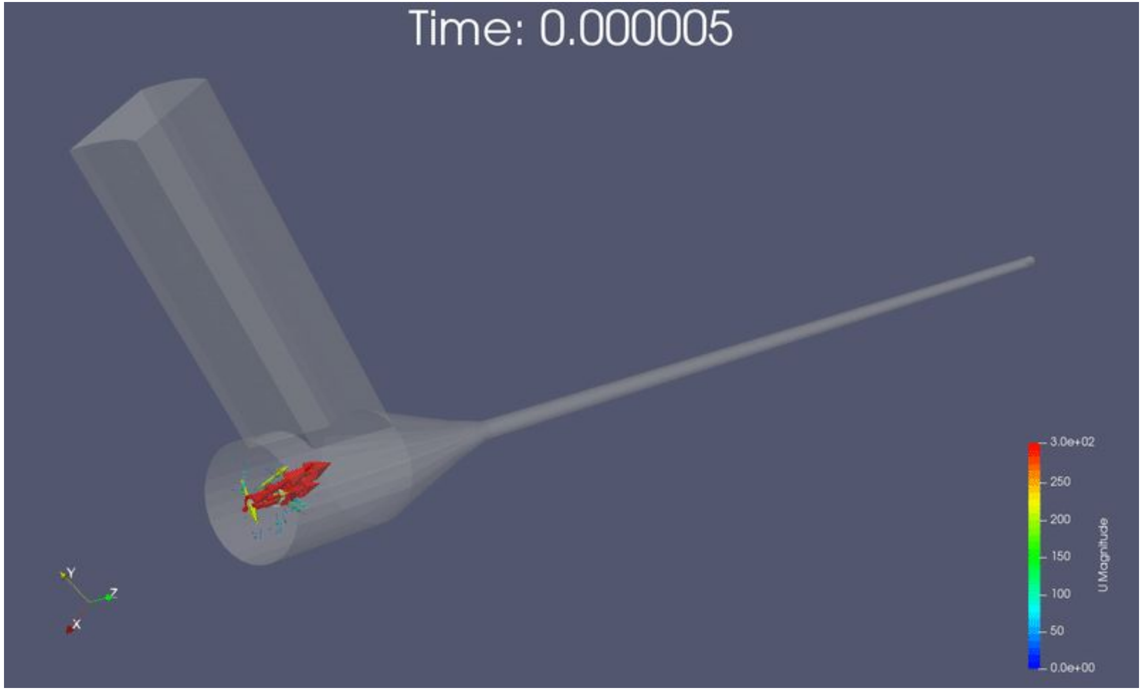
dt OF = 1e-08

dt CCX = 1e-07

preCICE coupling dt = 1e-07

UNIVERSITÉ DU LUXEMBOURG

Nozzle CFD results (waterjet)



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

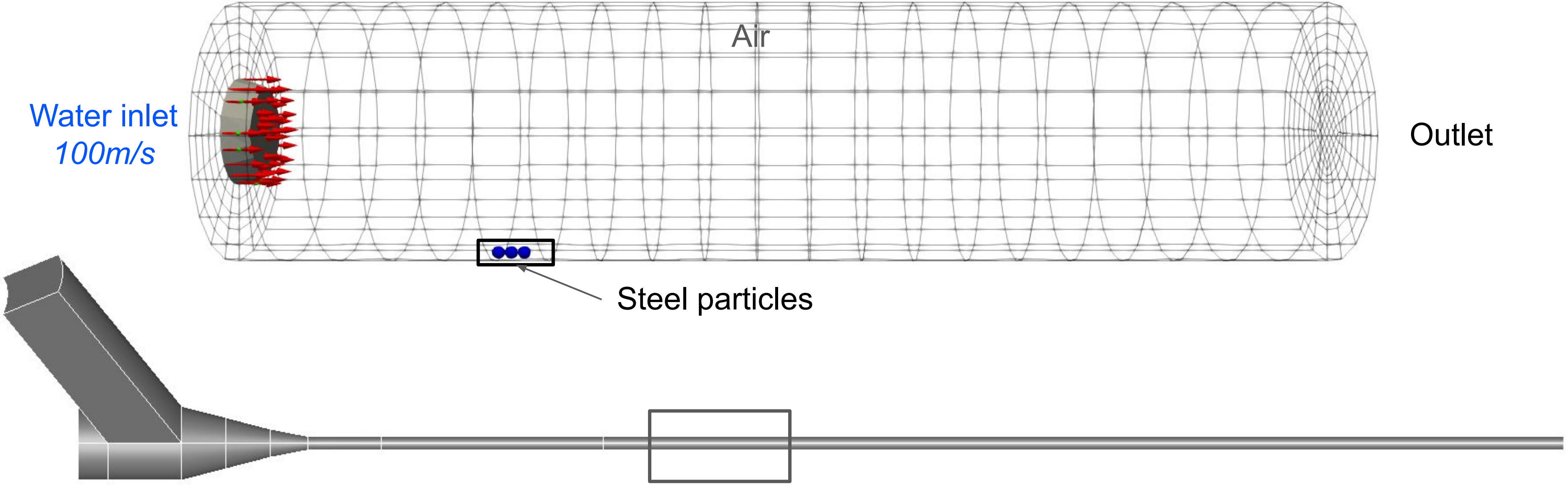
dt OF = 1e-08

dt CCX = 1e-07

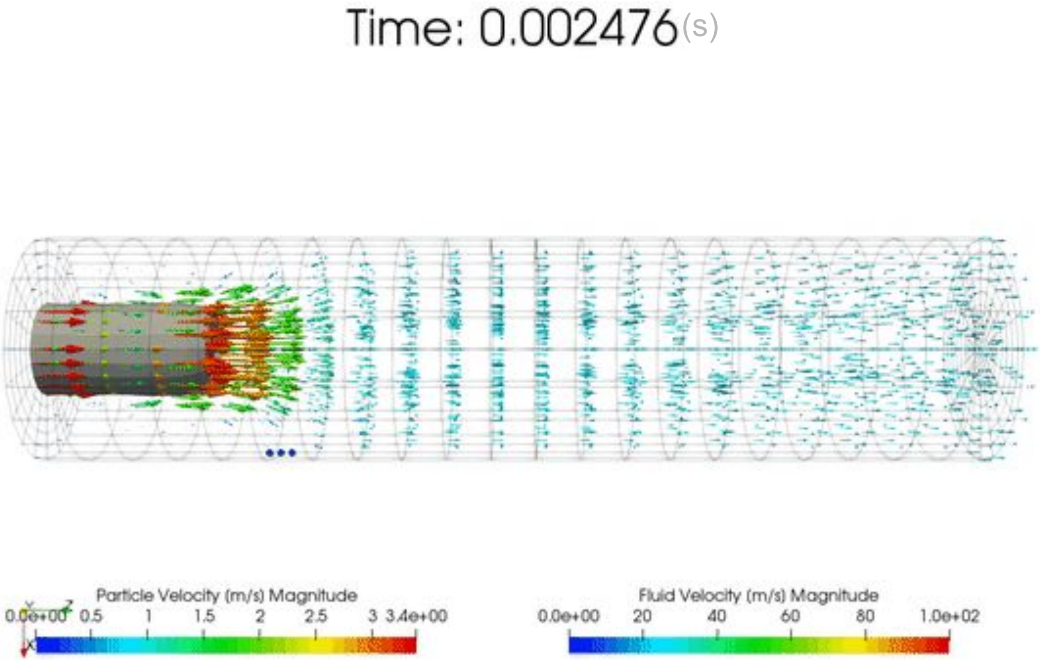
preCICE coupling dt = 1e-07

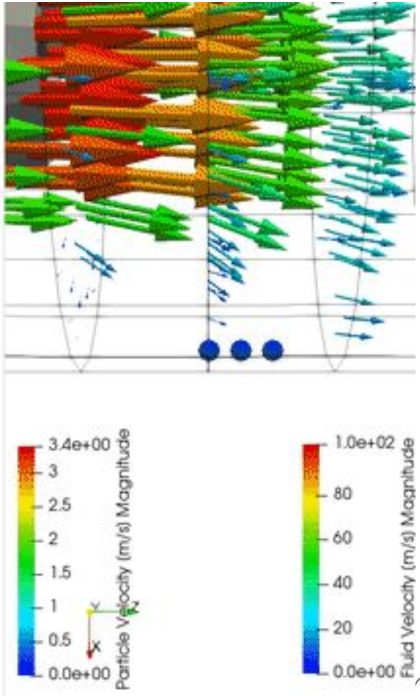
Nozzle 2way CFD+XDEM results

2way CFD+XDEM Nozzle test case



2way CFD+XDEM Nozzle test results





Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

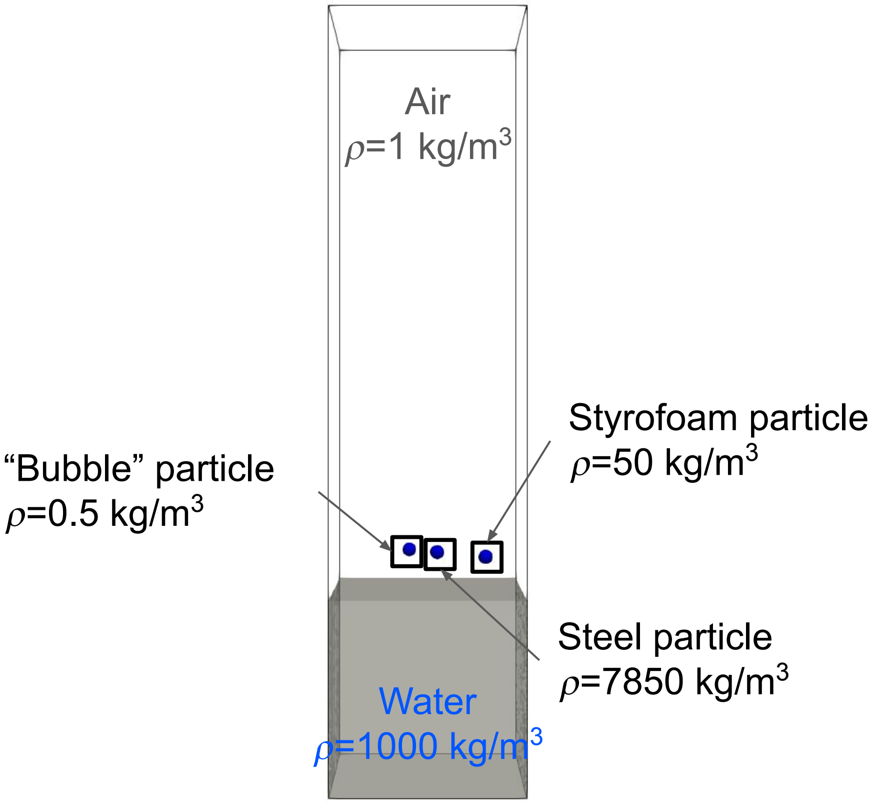
dt OF = 1e-04

dt XDEM = 1e-04

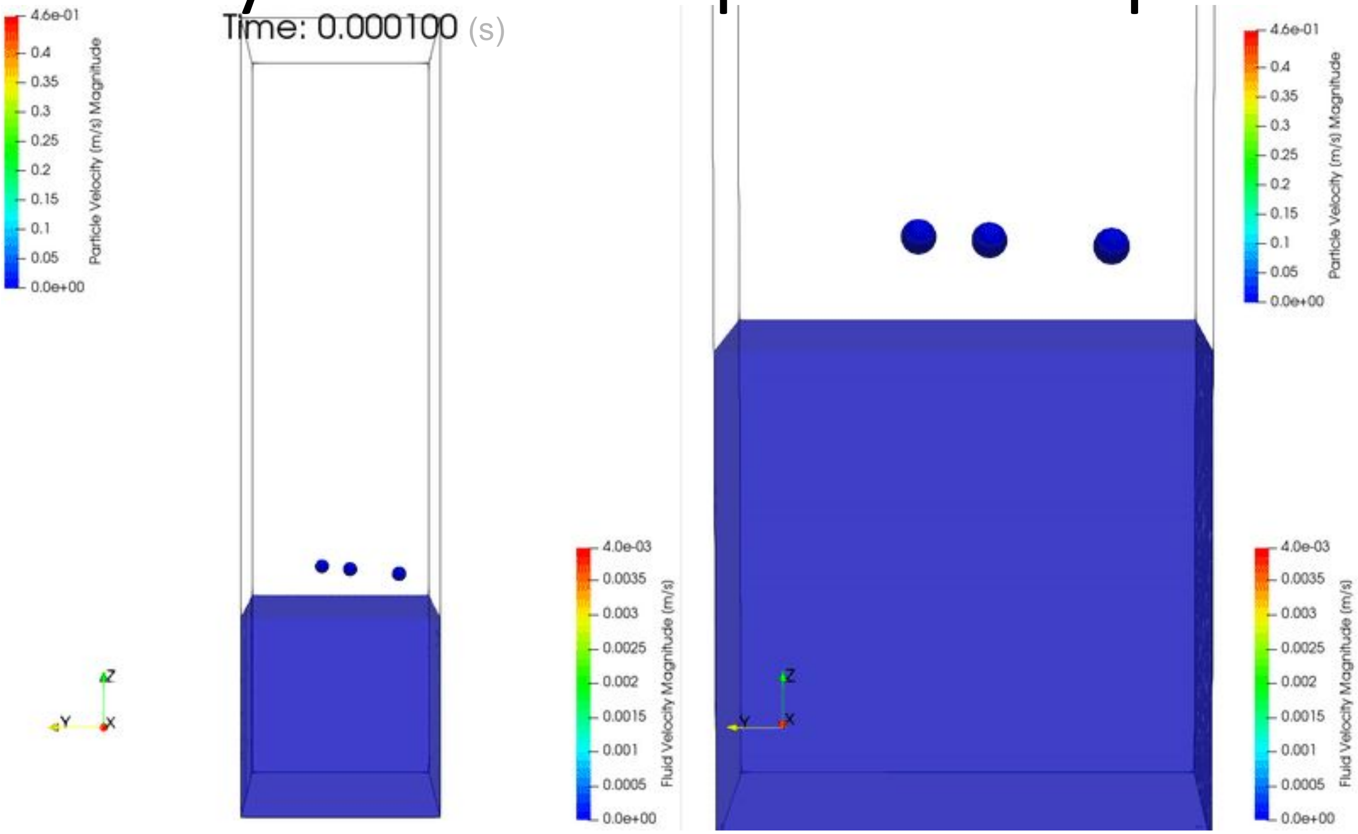
preCICE coupling dt = 1e-04

UNIVERSITÉ DU LUXEMBOURG

2way CFD+XDEM particle drop test results

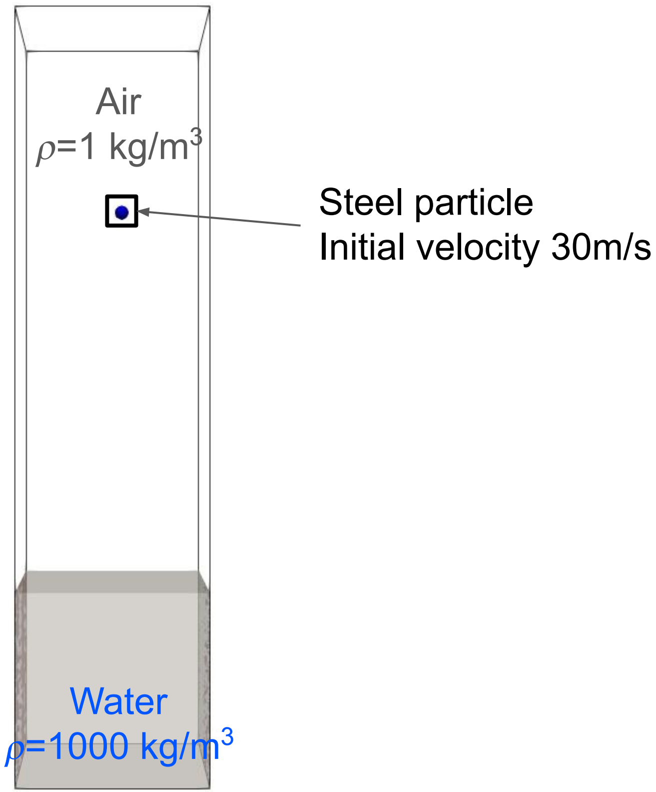


2way CFD+XDEM particle drop test results

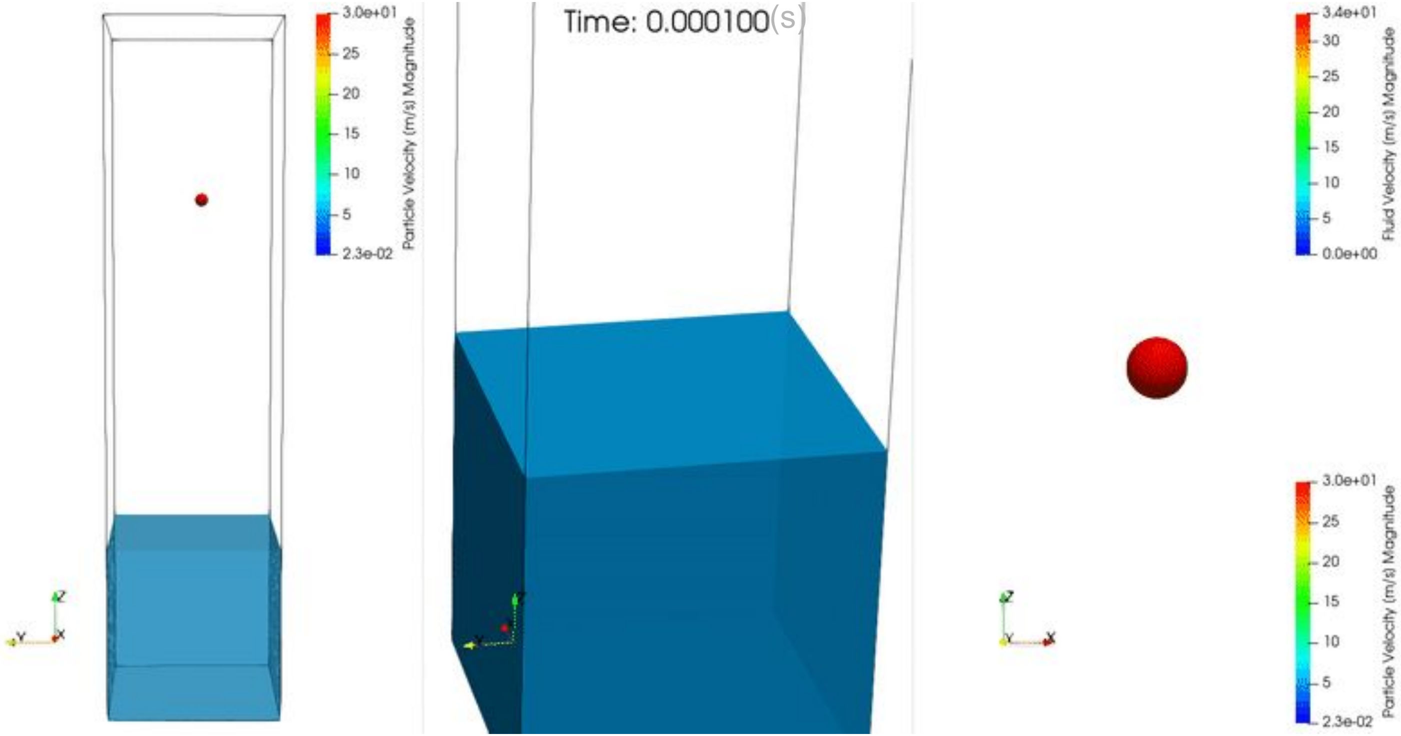


- Incompressible
- Transient
- multiphase: 2 immiscible phases
- isothermal
- turbulent flow (LES)
- dt OF = 1e-04
- dt XDEM = 1e-04
- preCICE coupling dt = 1e-04

2way CFD+XDEM particle drop test results



2way CFD+XDEM particle drop test results



Incompressible

Transient

multiphase: 2 immiscible phases

isothermal

turbulent flow

(LES)

dt OF = 1e-04

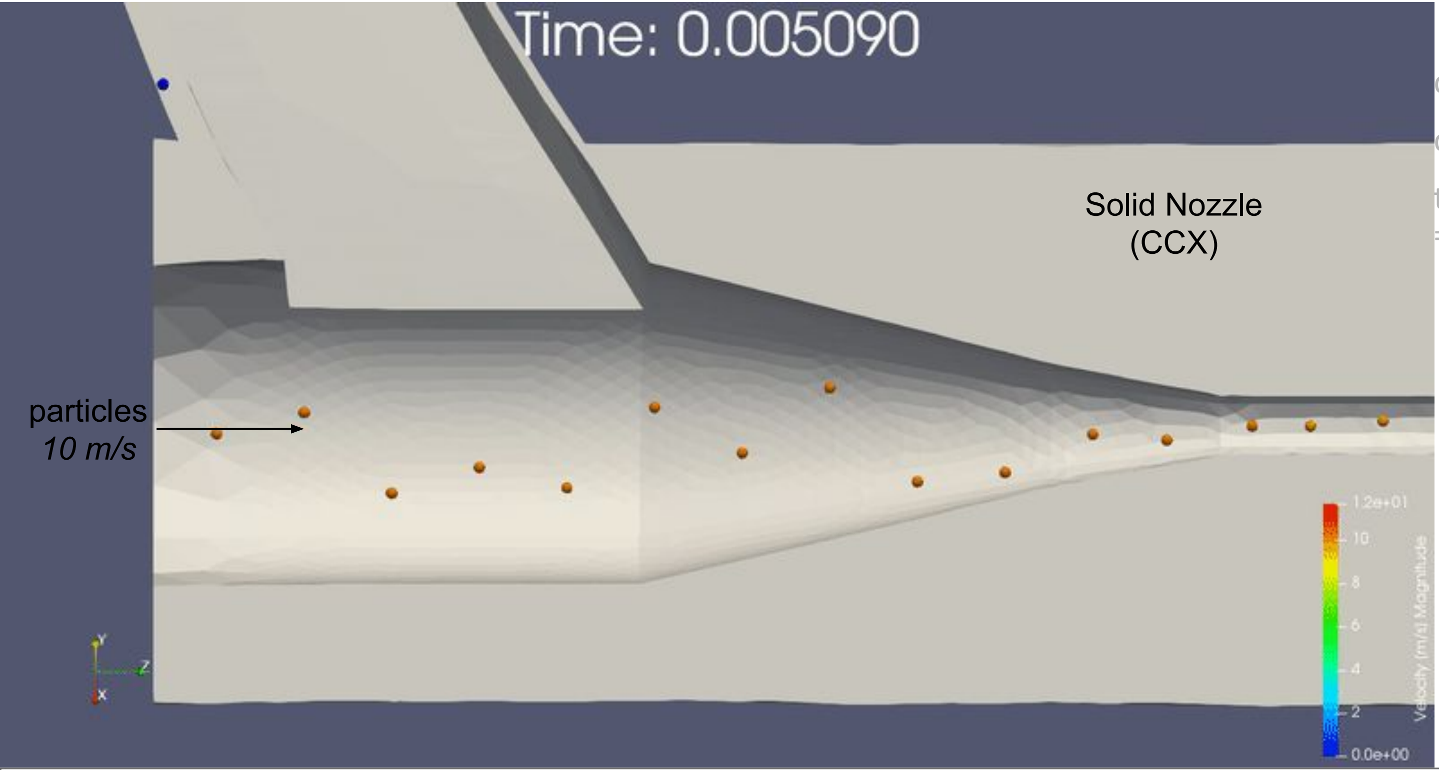
dt XDEM = 1e-04

preCICE coupling dt = 1e-04

UNIVERSITÉ DU LUXEMBOURG

Nozzle 2way XDEM+FEM results

Nozzle XDEM + CCX results

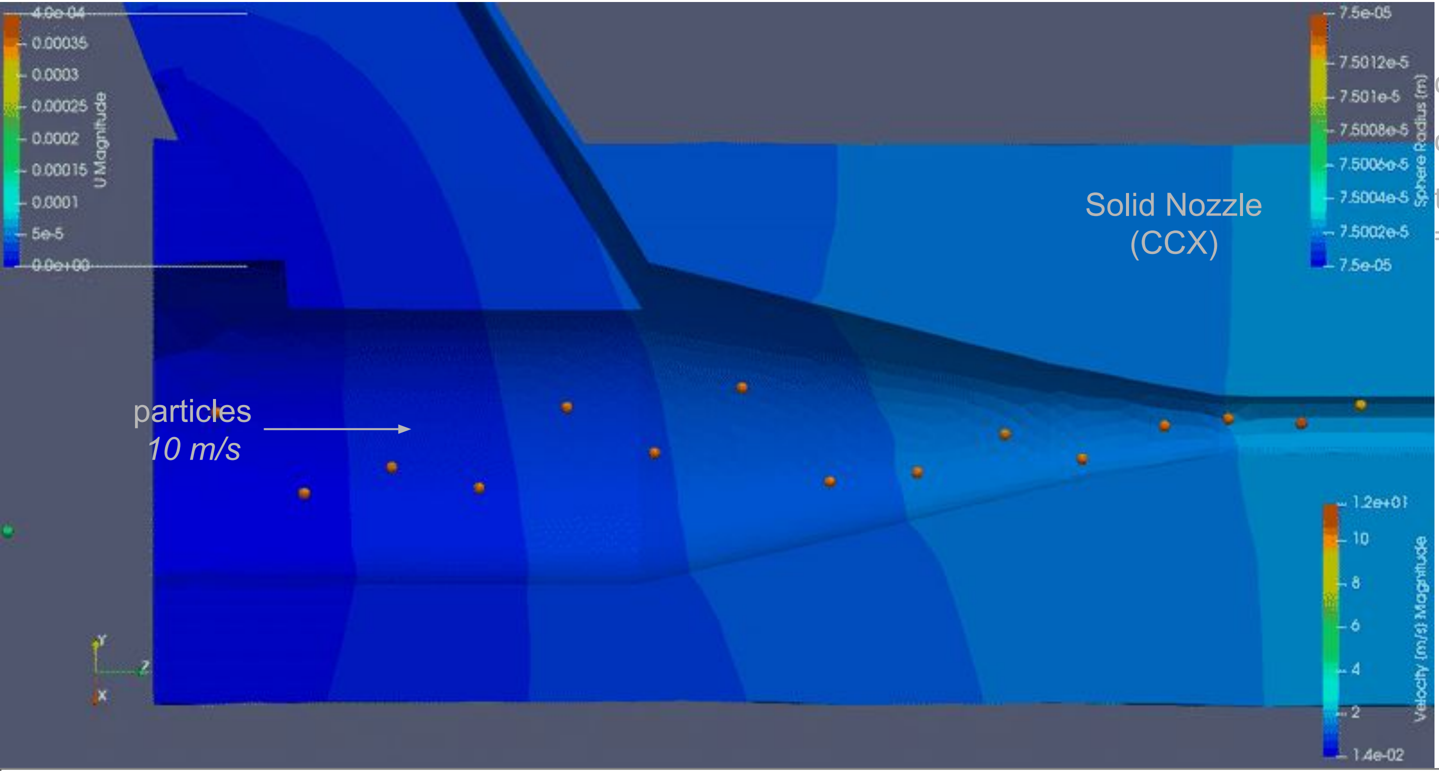


dt CCX = 1e-06

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

UNIVERSITÉ DU LUXEMBOURG

Contents

UNIVERSITÉ DU LUXEMBOURG

Conclusions

- General 6-way coupling achieved
- Strong CFD to DEM coupling
- Weak DEM to CFD coupling
- Particle interaction with Air-Water interface incomplete
- DEM+FEM coupling working as expected

UNIVERSITÉ DU LUXEMBOURG

Contents

- Problem statement & Goals
- Methodology
- Results
- Conclusions
- Next Steps

Next Steps

- Particle effects in Transport and pressure equations
- Particle volume in CFD
- Validation of CFD+XDEM coupling
- Erosion predictions and calculations inside Nozzle
- Vibrational analysis of Nozzle through FEM

Thank you for your attention!

Luxembourg XDEM Research Centre

http://luxdem.uni.lu/

University of Luxembourg

References

[1] Pozzetti, Gabriele, and Peters, Bernhard. "LES-VOF simulations of a pure water jet developing inside an AWJC nozzle: preliminary observations and guidelines." Proceedings of 2017 WJTA-IMCA (2017).

[2] Peters, Bernhard, et al. "XDEM multi-physics and multi-scale simulation technology: Review of DEM–CFD coupling, methodology and engineering applications." Particuology 44 (2019): 176-193.

[3] Bungartz, Hans-Joachim, et al. "preCICE–a fully parallel library for multi-physics surface coupling." Computers & Fluids 141 (2016): 250-258.

[4] https://openfoam.org/ (Online; accessed 01 April 2020)

[5] Dhondt, G. and Wittig, K., Calculix: a free software three-dimensional structural finite element program. MTU Aero Engines GmbH, Munich. (1998)

[6] Xiao, Heng, and Jin Sun. "Algorithms in a robust hybrid CFD-DEM solver for particle-laden flows." Communications in Computational Physics 9.2 (2011): 297-323.

Luxembourg XDEM Research Centre

http://luxdem.uni.lu/

University of Luxembourg