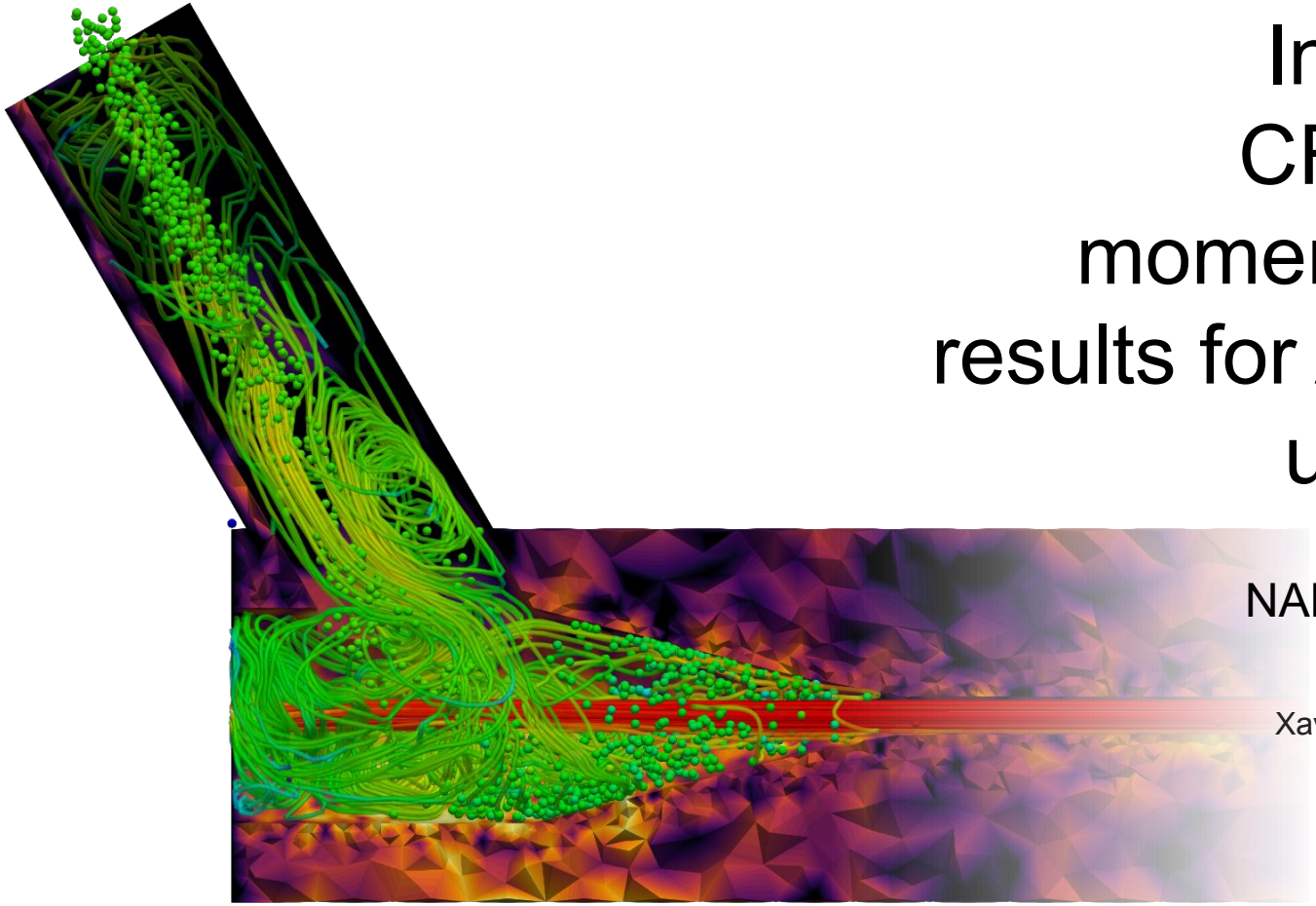

Investigation of CFD-DEM-FEM momentum coupling results for AWJC Nozzle using preCICE

NAFEMS Multiphysics 2023

by **Prasad ADHAV**,
Xavier BESSERON, Bernhard PETERS

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

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Contents

- Brief Introduction
- Coupling in brief
- AWJC Nozzle Case Setup & Results
- Conclusions, WIP & Future work

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Introduction to eXtended Discrete Element Methods (XDEM)

- Dynamics
  - Particle Motion
  - Forces, and torques
- Conversion
  - Heat & Mass Transfer
  - Chemical Reactions
- AD-Hoc Coupling
  - CFD: OpenFOAM/Foam-Extend
  - FEM: Diffpack
- License/Usage:
  - Binaries/Source Code available on request (bernhard.peters@uni.lu)

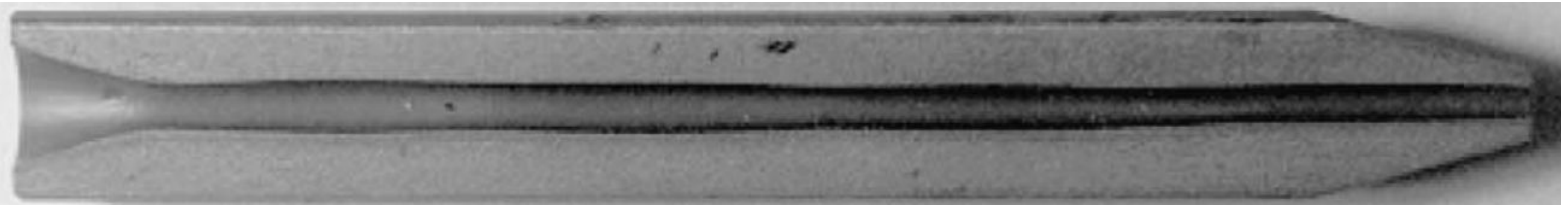
Why is Abrasive Water Jet Cutting (AWJC) important & revelant?

- Applications: **Aerospace, Automobile,** etc.
- No thermal residual stresses after cutting
- Does not affect the material microstructure
- Cuts as small as 0.076 mm (human hair)
- Cuts various materials (which traditional methods can’t cut)
- Less scrap produced
- User not exposed to toxic gases as none produced

Abrasive Water Jet Cutting (AWJC) in action

Research Aim

- Development of multiphysics simulation environment
- Evaluation of erosion in AWJC Nozzle by CFD-DEM-FEM coupling
- Experiments record temporal data, displacements & vibrations[1]



[2] Sectioned Nozzle with erosion

[1] Copertaro, Edoardo, Francesco Perotti, and Massimiliano Annoni. "Operational vibration of a waterjet focuser as means for monitoring its wear progression." The International Journal of Advanced Manufacturing Technology 116 (2021): 1937-1949.
[2] Nanduri, Madhusarathi, David G. Taggart, and Thomas J. Kim. "The effects of system and geometric parameters on abrasive water jet nozzle wear." International Journal of Machine Tools and Manufacture 42.5 (2002): 615-623.

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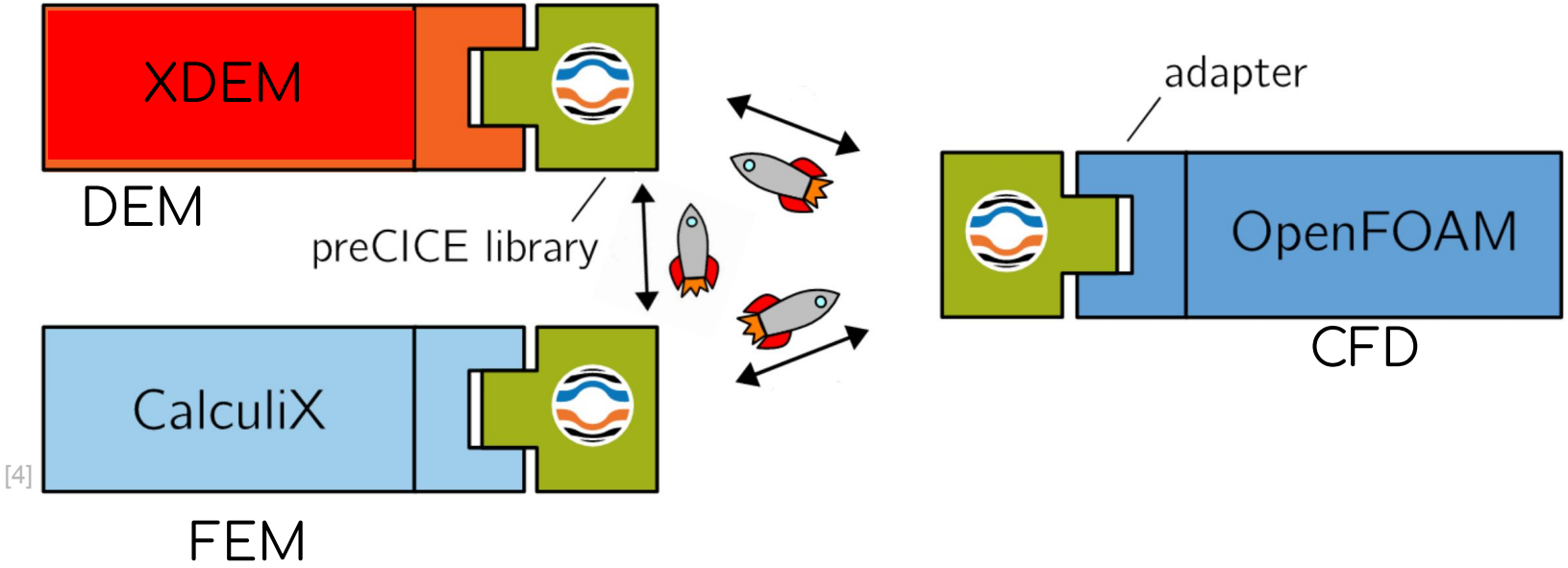
How is the Fluid - Structure - Particle coupling done?



[4]

[3] Chourdakis, Gerasimos, et al. "preCICE v2: A sustainable and user-friendly coupling library." arXiv preprint arXiv:2109.14470 (2021).
[4] https://www.precice.org

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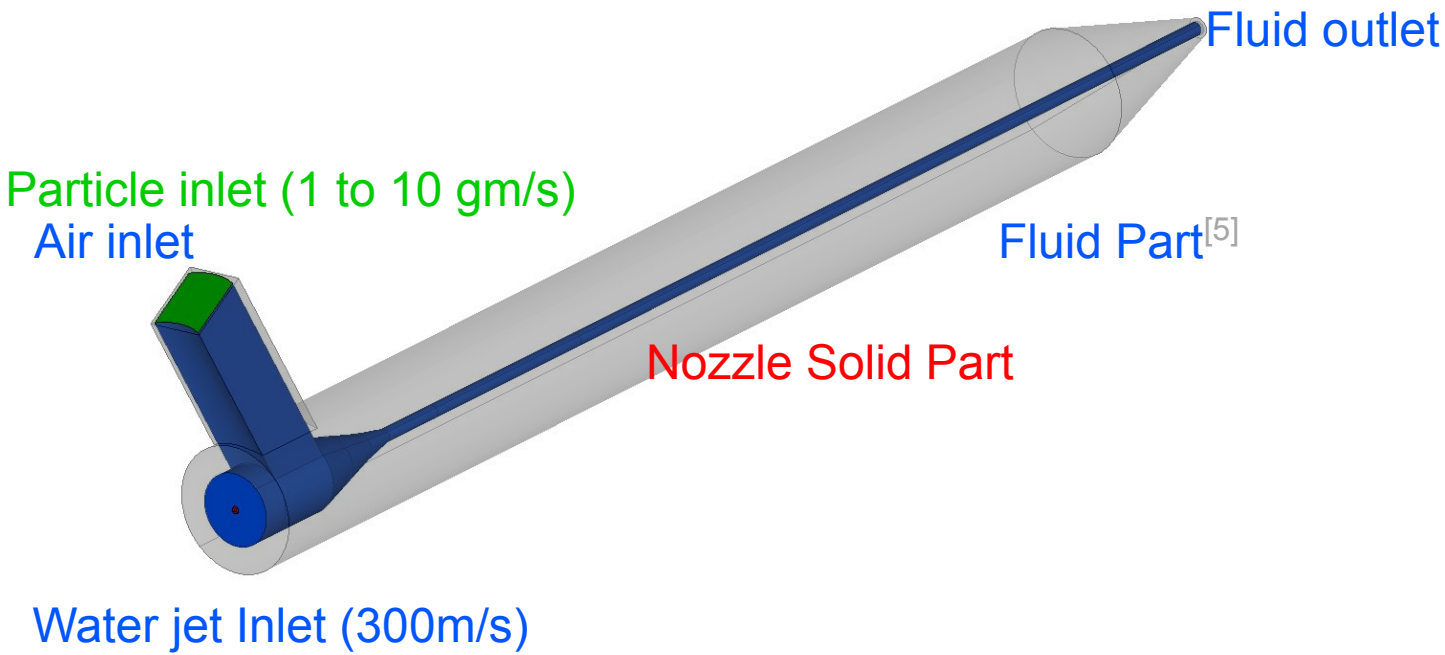
Nozzle set-up

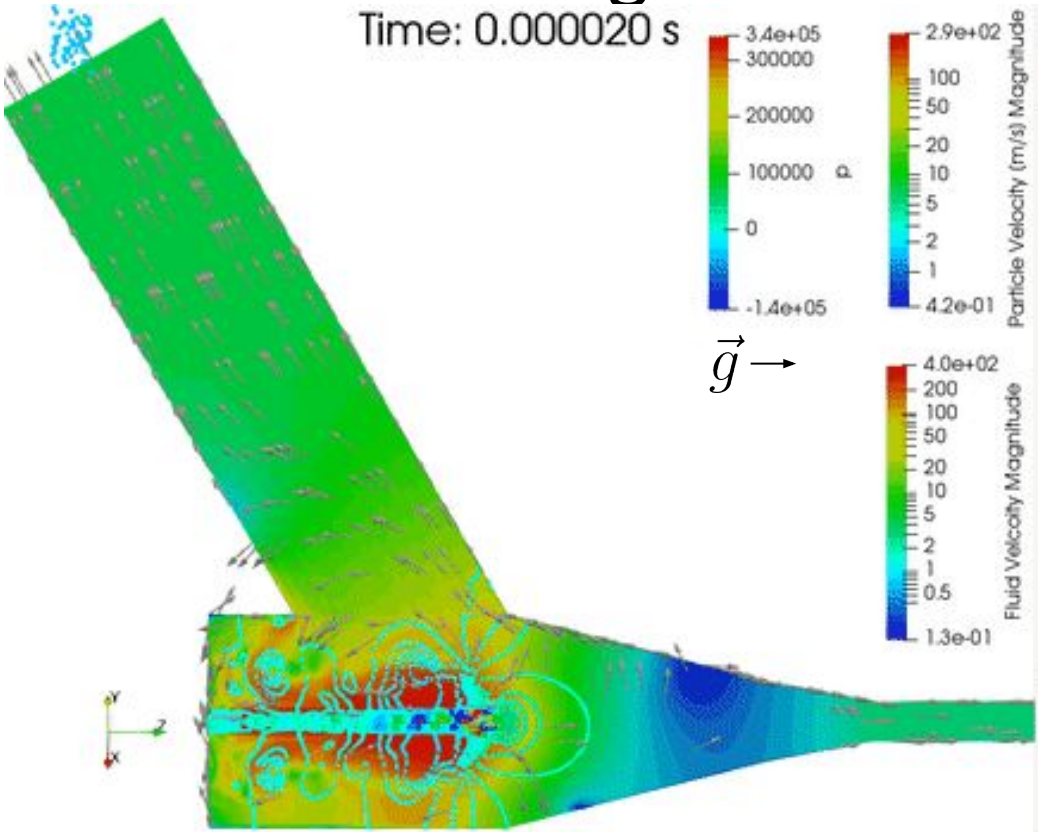


[5] Pozzetti, Gabriele, and Bernhard Peters. "Evaluating Erosion Patterns in an abrasive water jet cutting nozzle using XDEM." Advances in Powder Metallurgy & Particulate Materials (2017): 191-205.

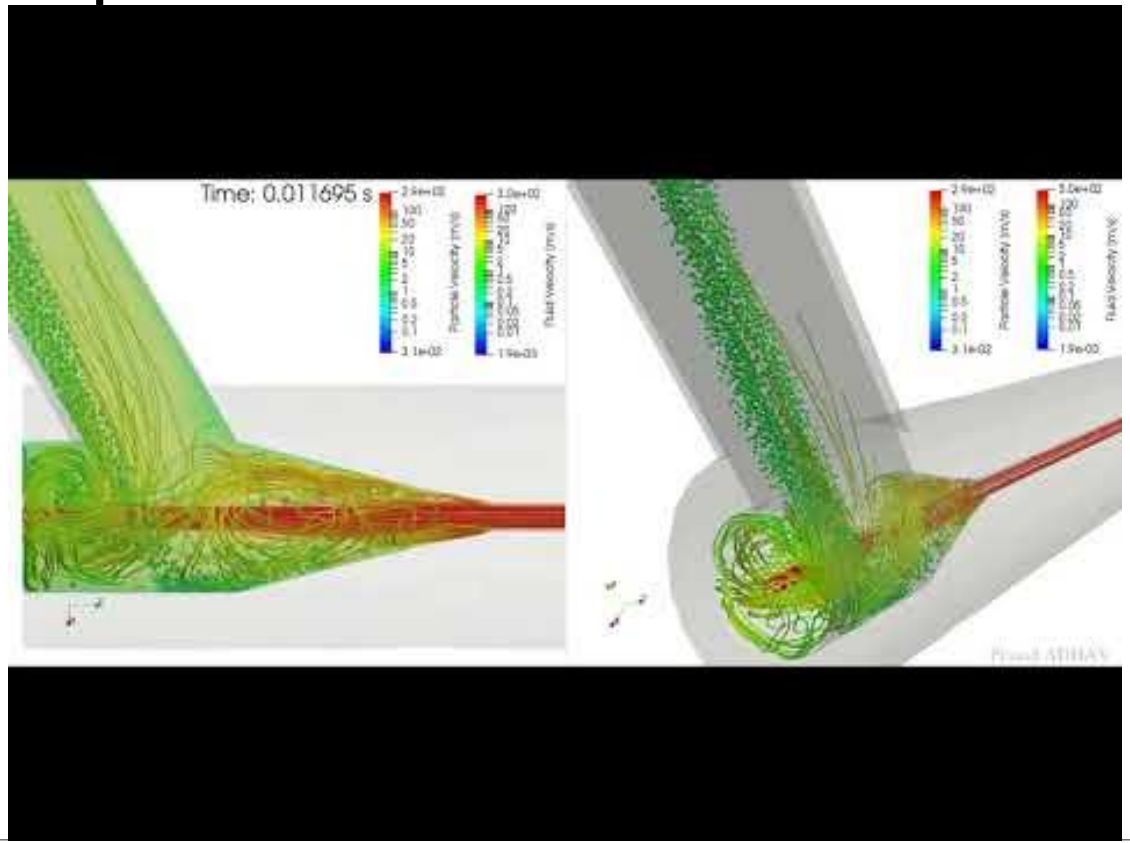
CFD

Results showing influences of fluid flow on particles movement

Negative fluid pressures in the focusing tube pull particles in the mixing chamber



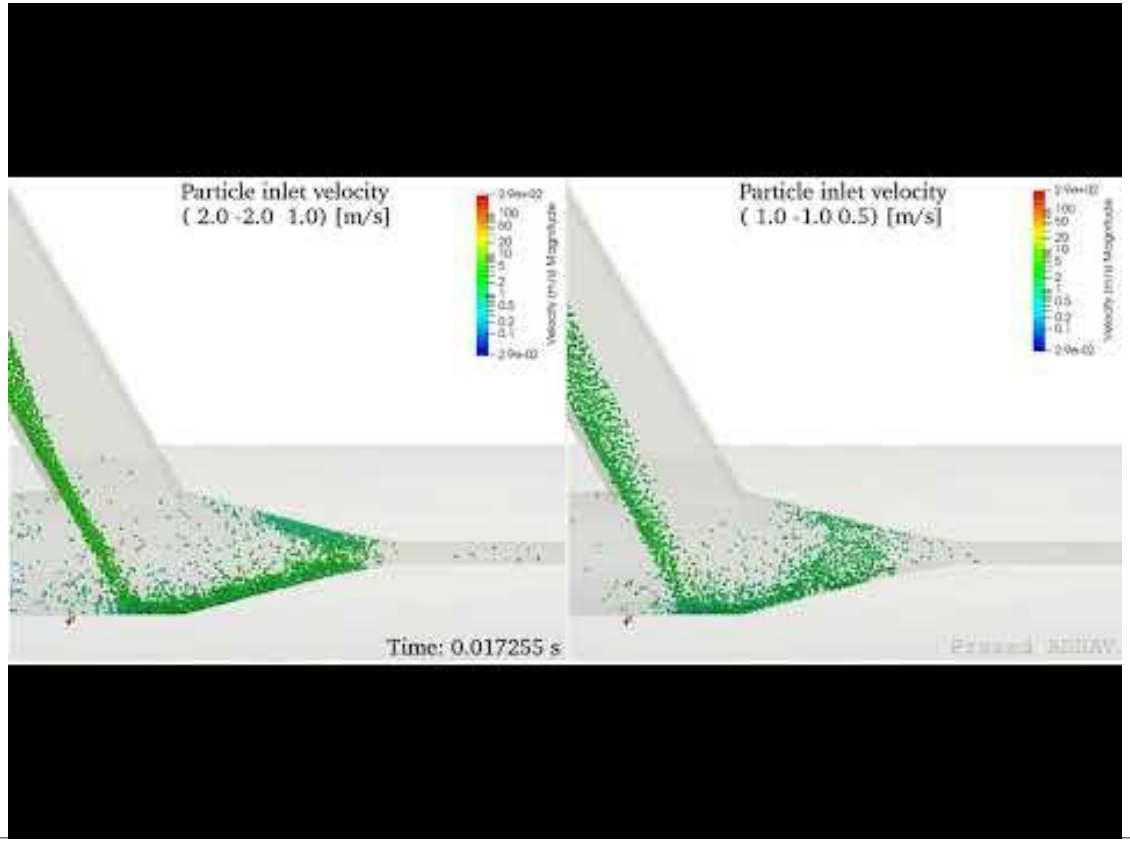
Streamlines to illustrating interaction between particles & turbulent flow



DEM

Effect of particle initial conditions

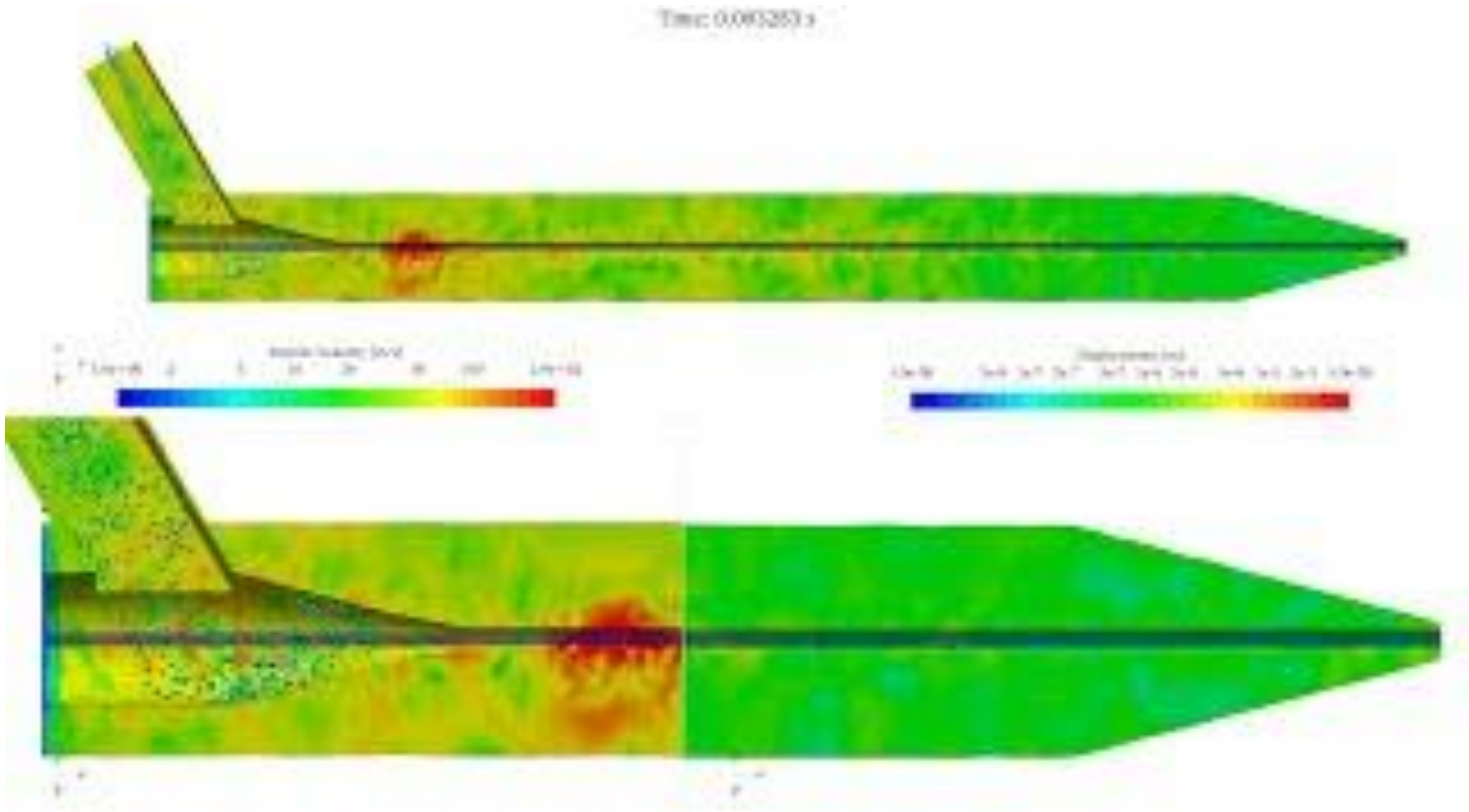
Comparison of different particle inlet velocities & it's effects on flow



FEM

Particle impacts on the Nozzle

Nozzle displacements due particle impacts



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Particle laden flow characteristics in Nozzle same as the literature[5]

- Simulate different operating conditions
- Monitor nozzle tip displacements
- Restart simulation for longer simulated time[6]
- WIP: Performance analysis for Nozzle case
- WIP: Vibrational response of nozzle
- Future work: Compare results with experimental observations

Luxembourg XDEM Research Centre

http://luxdem.uni.lu/

[6] Paweł Łojek, Resuming FSI simulations with OpenFOAM/CalculiX: https://pawel-lojek.medium.com/resuming-fsi-simulations-with-openfoam-calculix-896088861ae#:~:text=For%20Calculix%2C%20you%20have%20to,results%20or%20resume%20the%20simulations.

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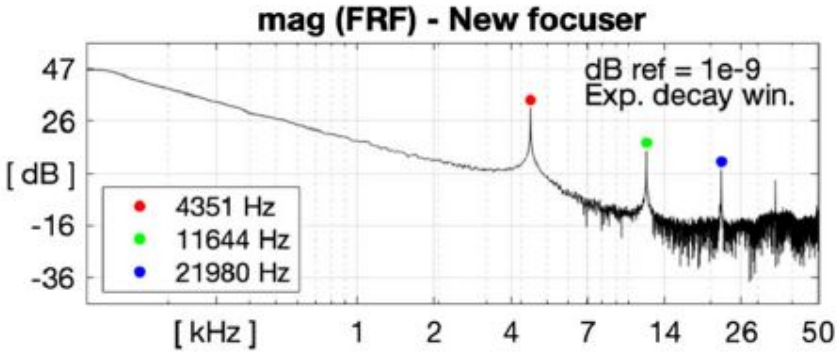
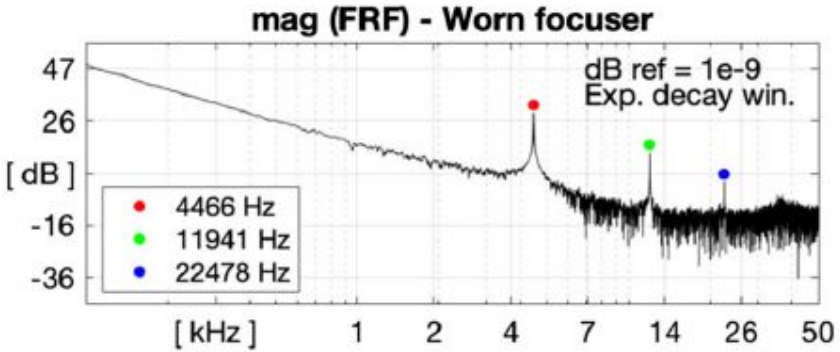
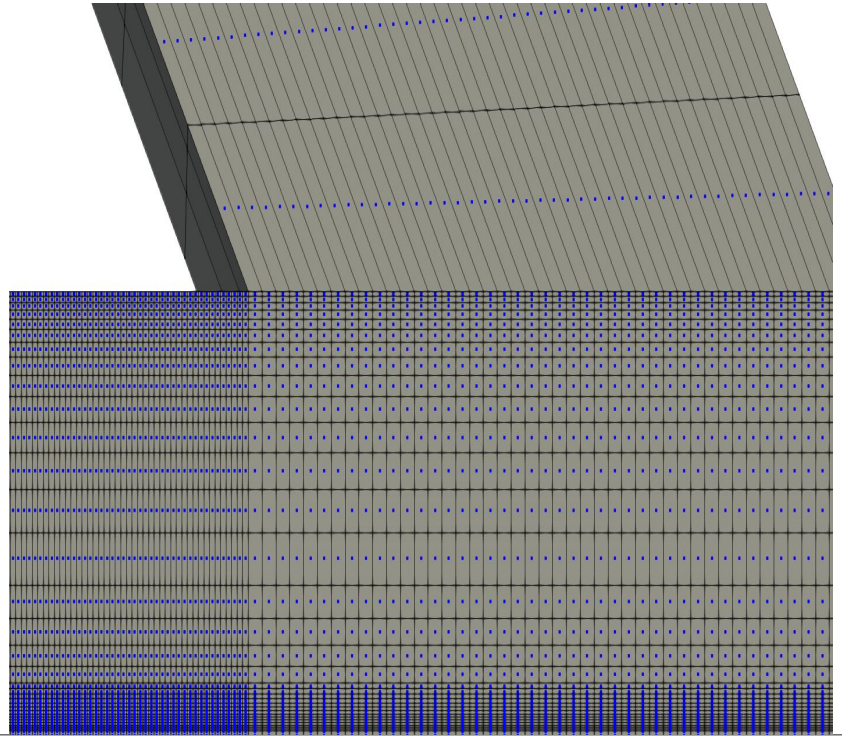
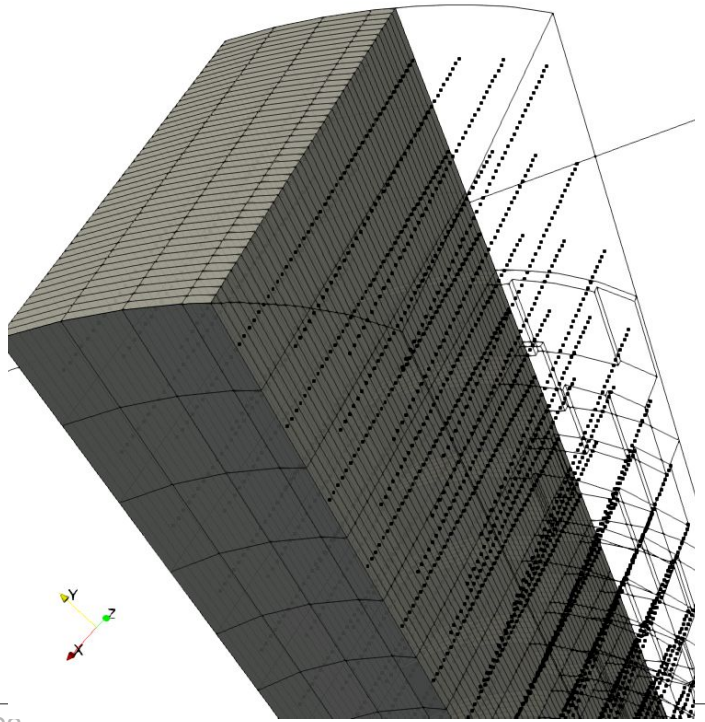
Change in frequenc response before & after wear[1]



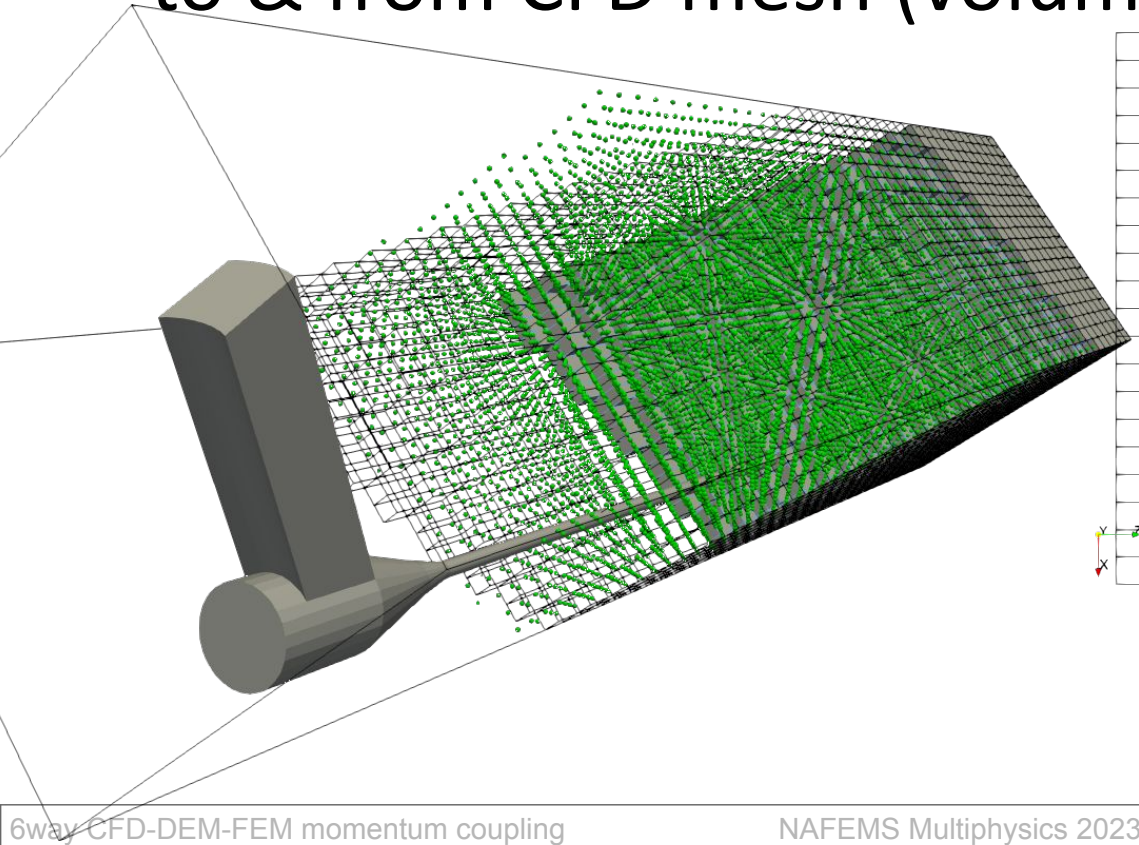


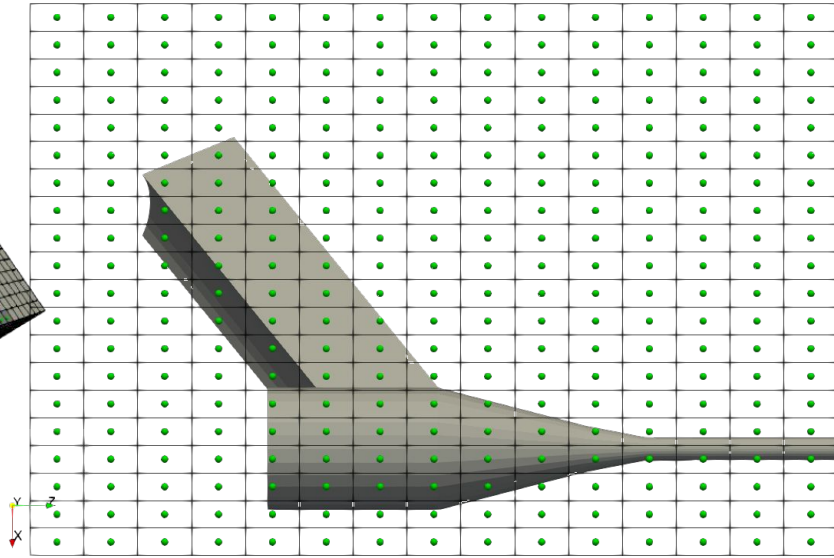
Data from XDEM mapped to CFD cell centers





XDEM cell centers used mapping data to & from CFD mesh (volume coupling)





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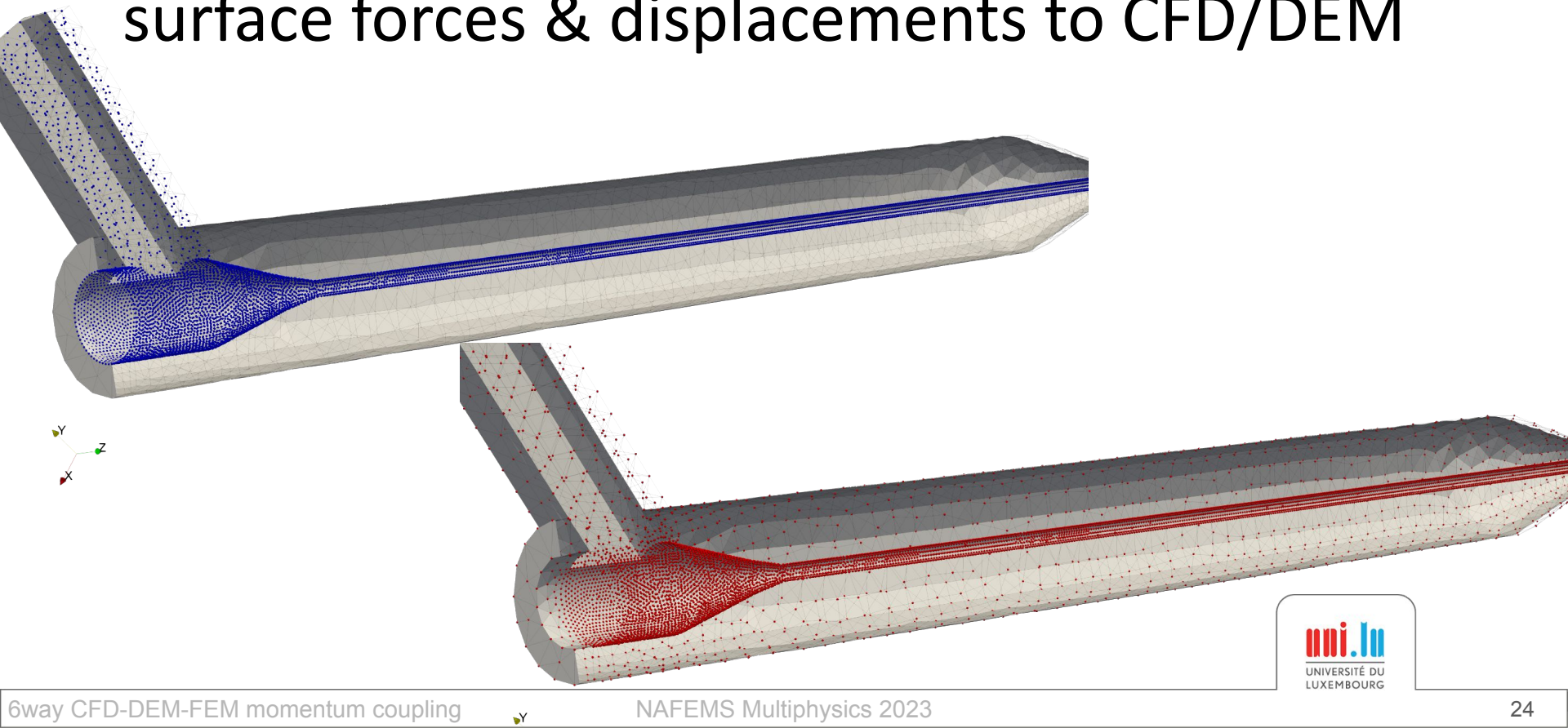
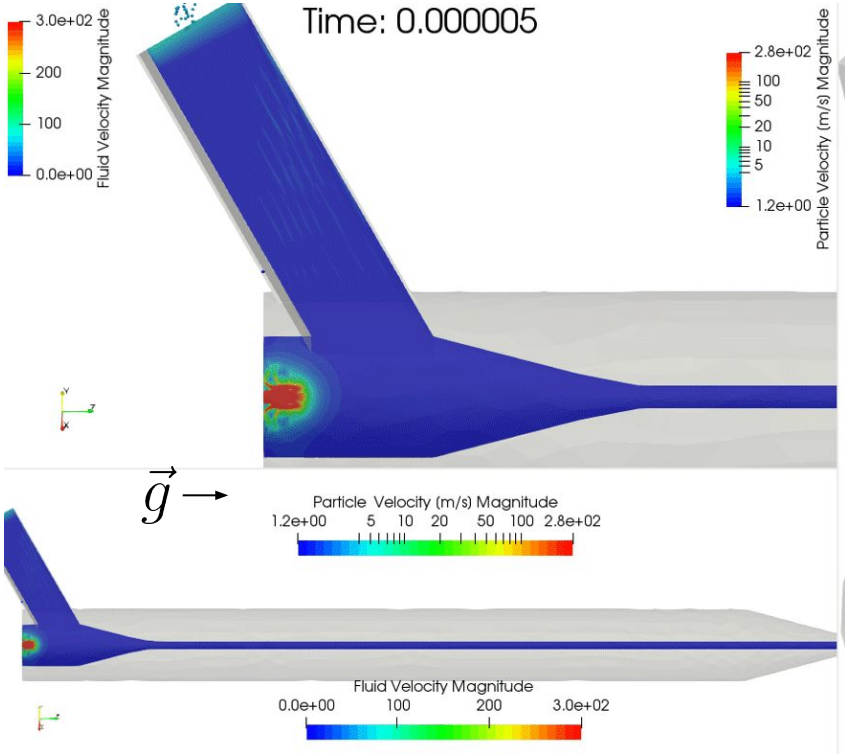
Surface nodes on FEM model used to couple surface forces & displacements to CFD/DEM

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200
100
0.0e+00
Particle Velocity (m/s) Magnitude
2.8e+02
100
50
20
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5
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Particle Velocity (m/s) Magnitude
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Fluid Velocity Magnitude
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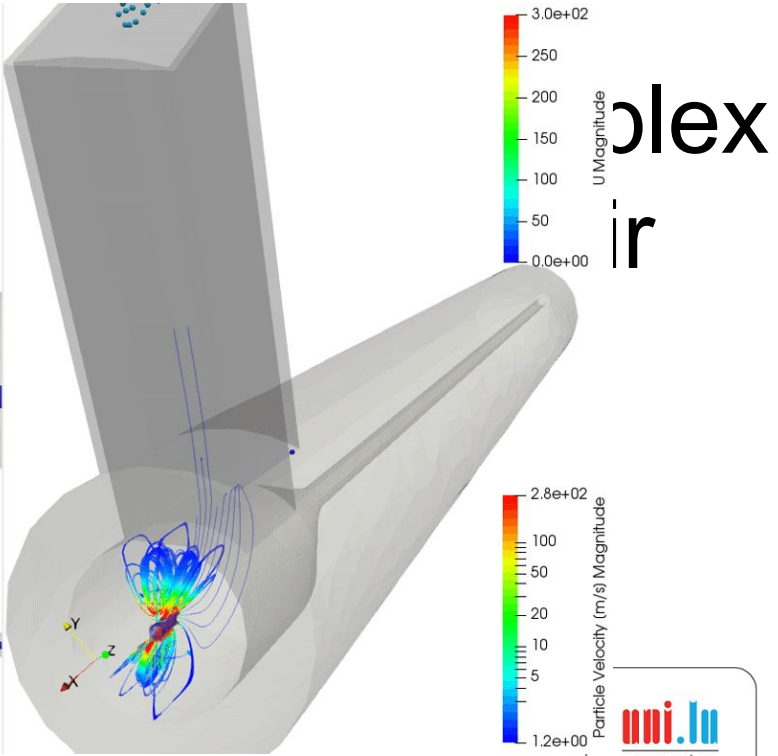
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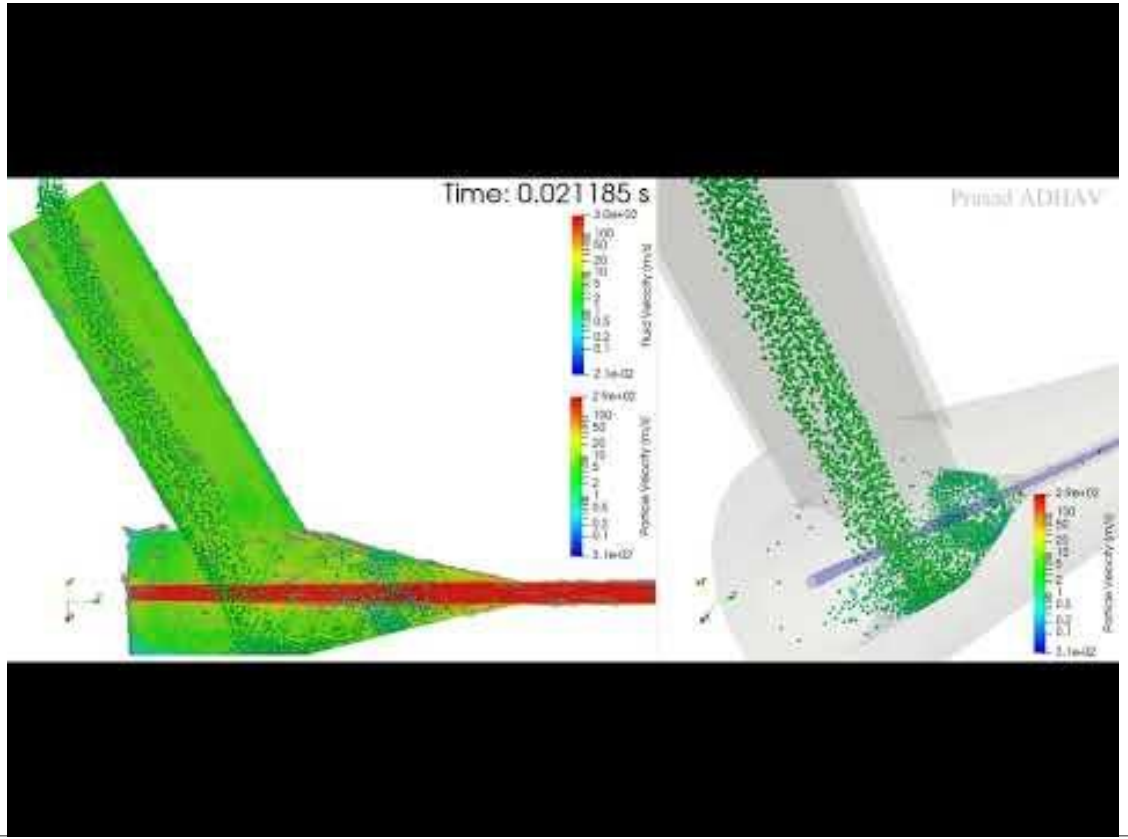
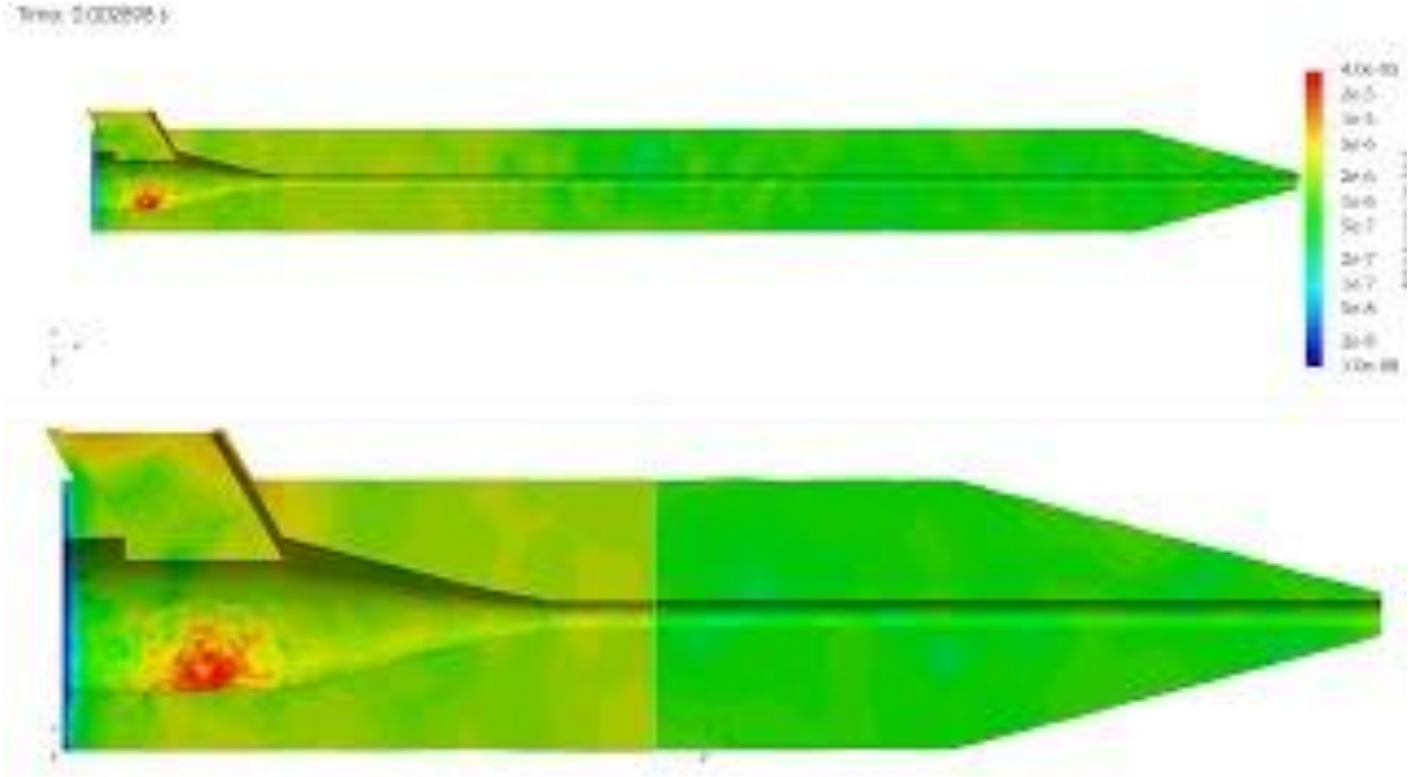
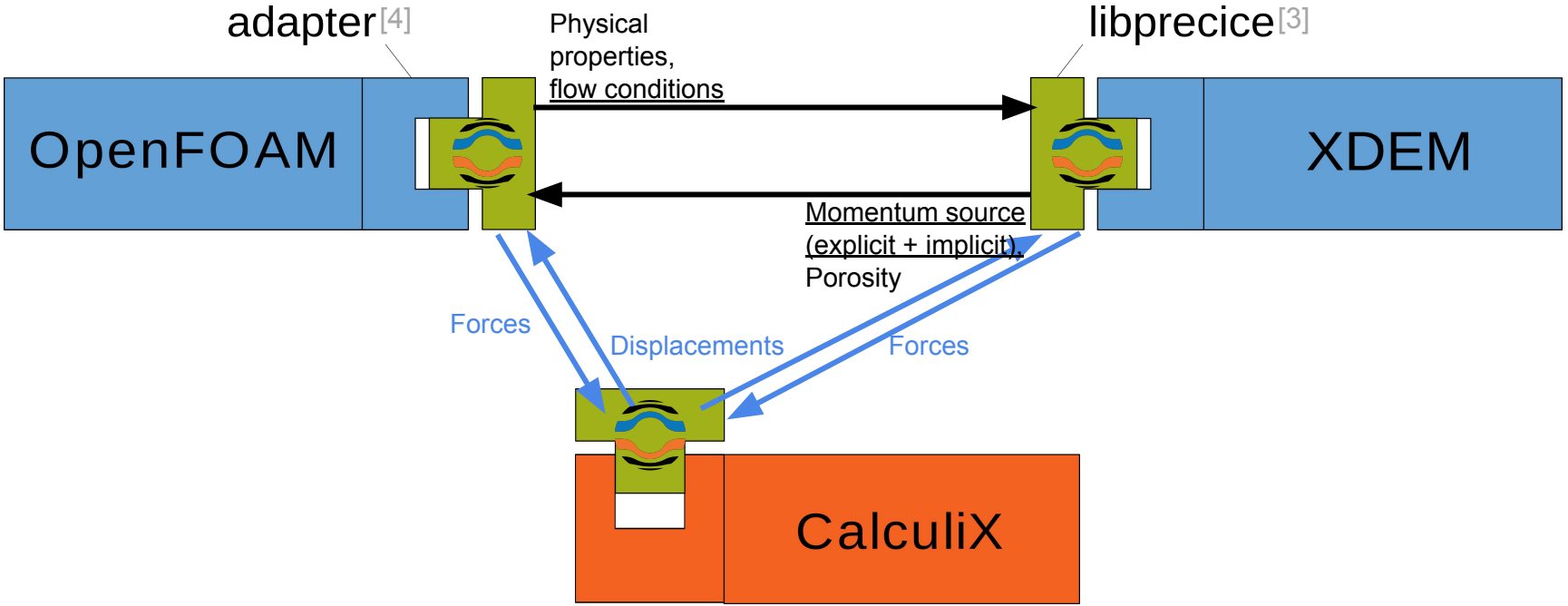
Particle flow and interaction with waterjet



Nozzle displacements due particle impacts



6-way CFD-DEM-FEM
Momentum coupling summary



[2] 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.

[3] Chourdakis, Gerasimos, et al. "preCICE v2: A sustainable and user-friendly coupling library." arXiv preprint arXiv:2109.14470 (2021).

[4] Chourdakis, Gerasimos, David Schneider, and Benjamin Uekermann. "OpenFOAM-preCICE: Coupling OpenFOAM with External Solvers for Multi-Physics Simulations." OpenFOAM® Journal 3 (2023): 1-25.

[-] preCICE 2021, Momentum coupling: https://youtu.be/7fpRsB55Oss