Partitioned FSI-coupling with Open-source technology.

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Simulation solutions based on Open-source solver technology

Engineering:

CFD services with OpenFOAM® and CalculiX

Software

Standard/ Customised:

GUIs (CastNet), Extensions

User Support Training:

OpenFOAM®/our Extensions

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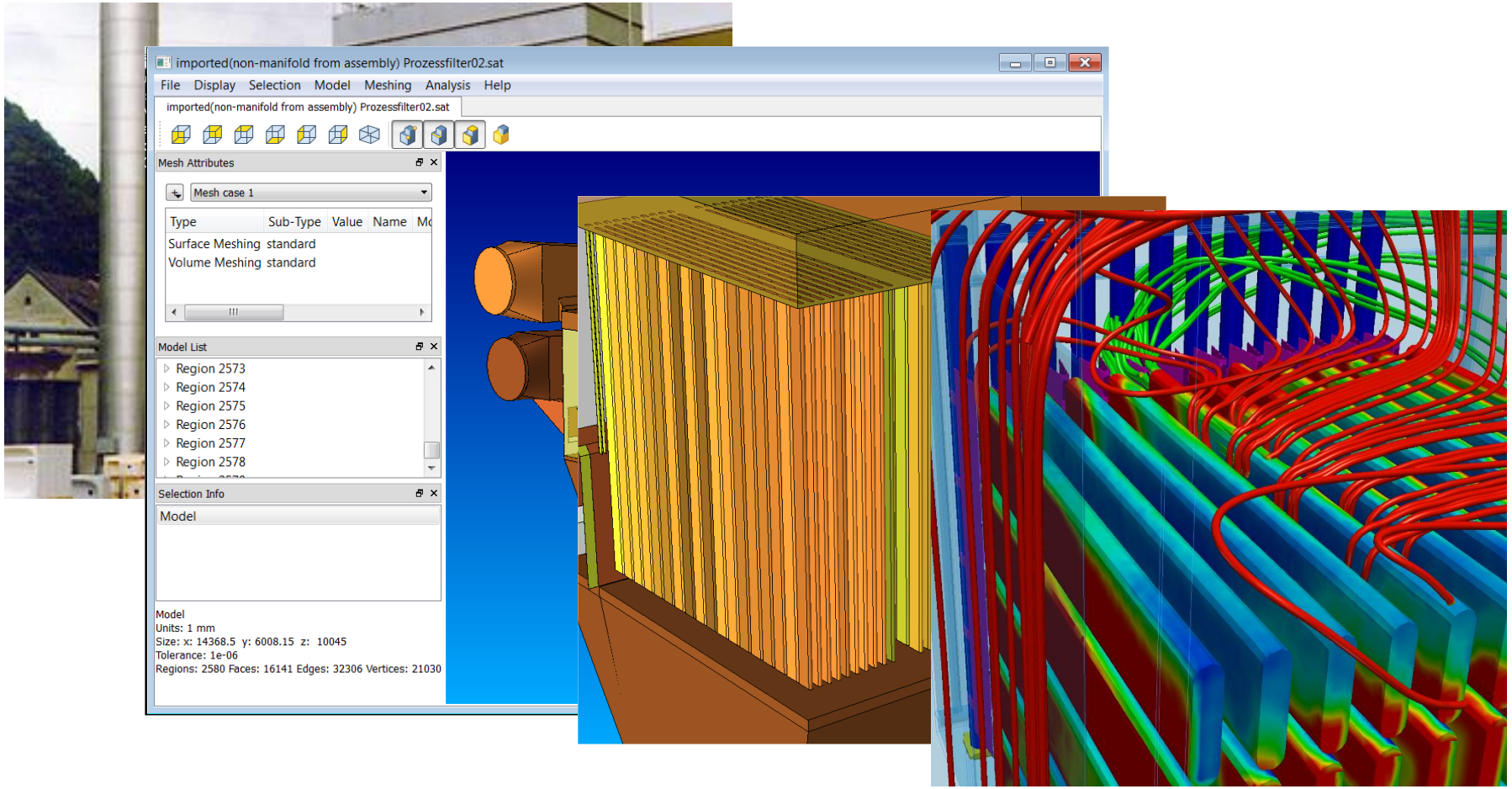
- Types of FSI-coupling
- FSI-coupling using Open-source technology
- Example/Validation
- Conclusion

Filter application



Types of FSI-coupling

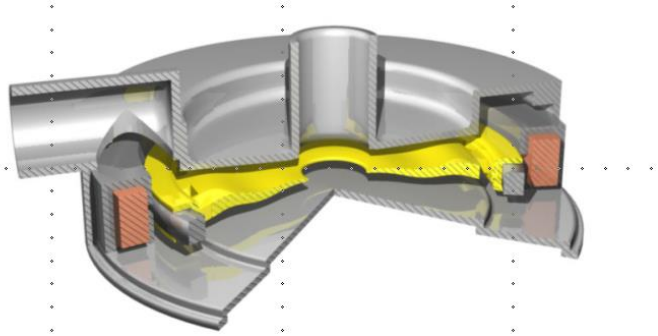
Partitioned Coupling:

Individual solution of fluid and structural part.

Monolithic Coupling:

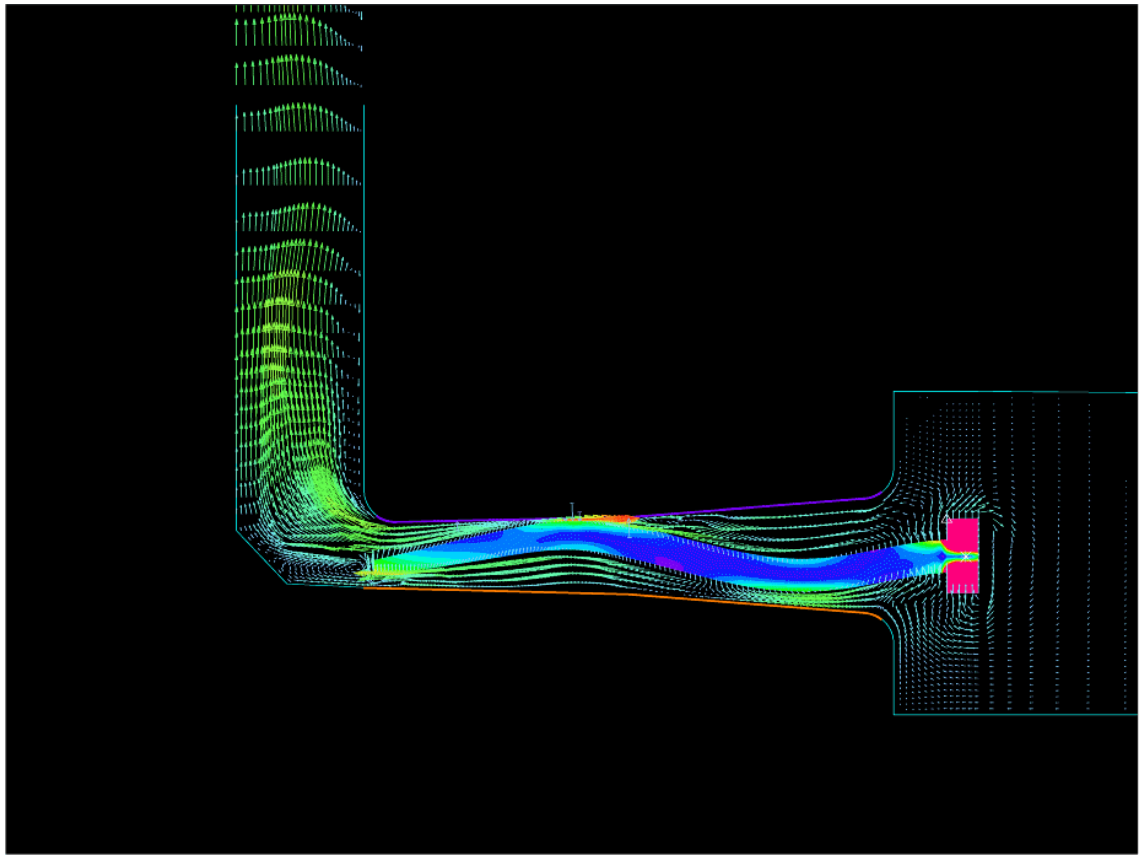
Combined solution of fluid and structural part with common matrix.

Monolithic Coupling



- Incompressible fluid/ soft structure
- Hyperelastic material
- Highly dynamic f~100-200Hz
- Wall contact

Error: Pressure/Flow ~ 10 %



Partitioned Coupling

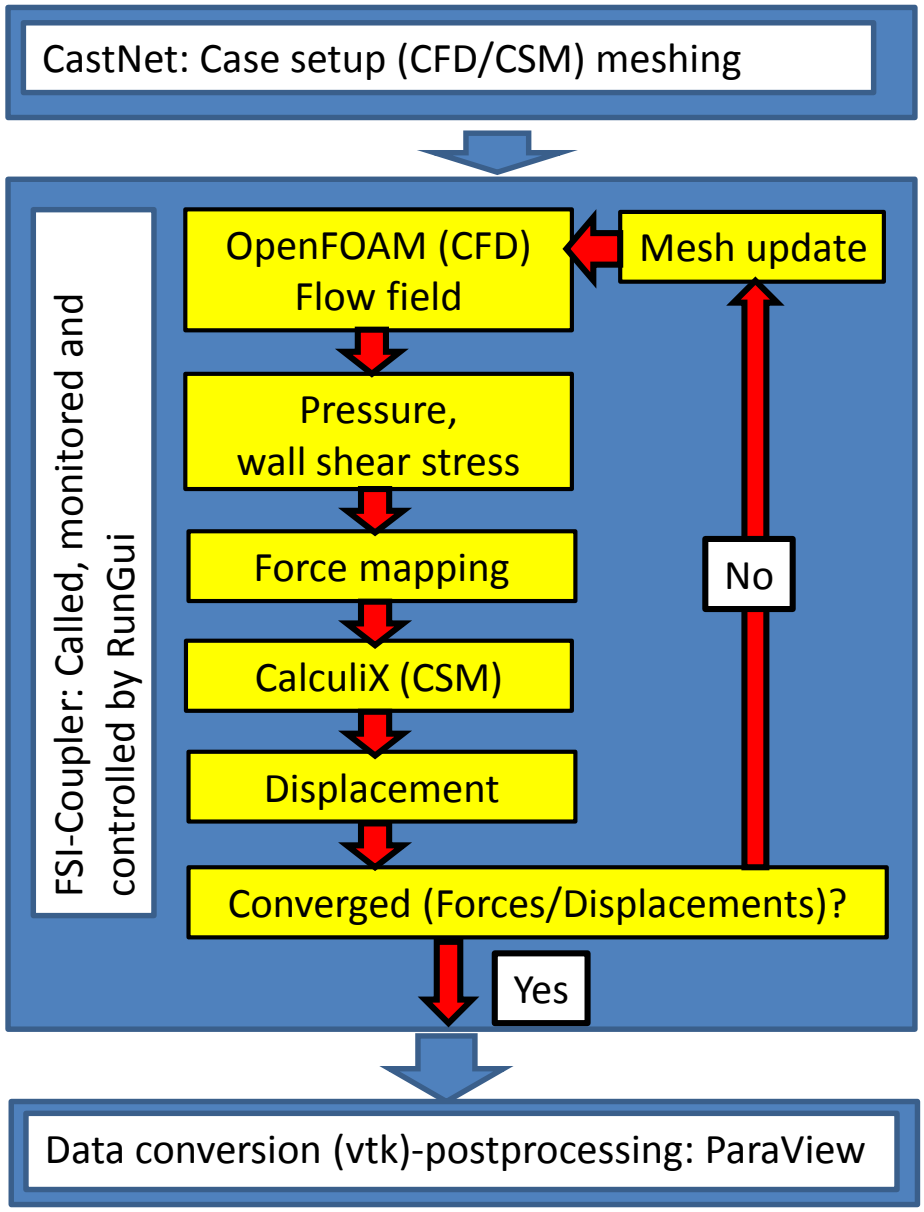
- OpenFOAM as CFD solver.
- CalculiX/Abaqus as structural solver

Advantage OpenFOAM:

- Flexible solver structure
- Mapping tools (sample)
- Point based mesh-motion

Objectives:

- Static applications
- Use of OpenFOAM functionalities
- Extension/Development for transient applications

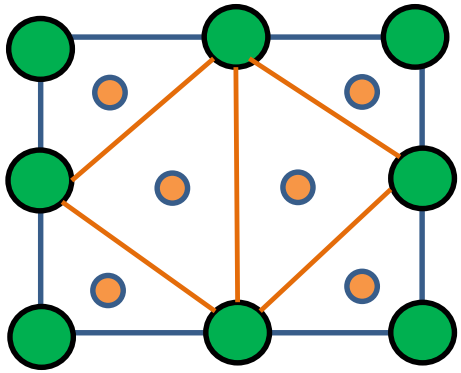


Pressure/ Wall shear stress

- Determine pressure and wall shear stress on FSI-Interface

P, Wss	P, Wss
P, Wss	P, Wss

- Use of **sample** utility for pressure values and **wallShearStress** utility for shear stress values



- Triangulation of surface mesh

- Use of triangulated element mid points as **sampling point**.

Pressure/ Wall shear stress

- Integration to get forces.
- Distribution of forces on nodes.
- Computation of displacements with Abaqus/CalculiX.

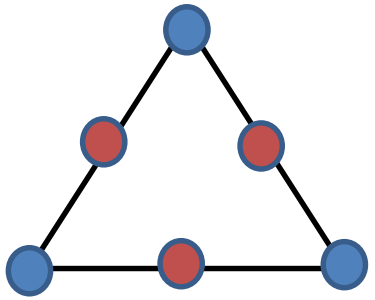
Force Distribution

- Linear Element
  - Triangular element

    $F_{node} = \frac{1}{3} F_{Total}$

  - Quad element

    $F_{node} = \frac{1}{4} F_{Total}$



- Quadratic Element
  - Triangular element

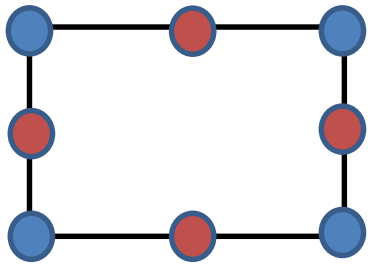
    $F_{corner\_Node} = 0$

    $F_{mid\_Node} = \frac{1}{3} F_{Total}$

  - Quad element

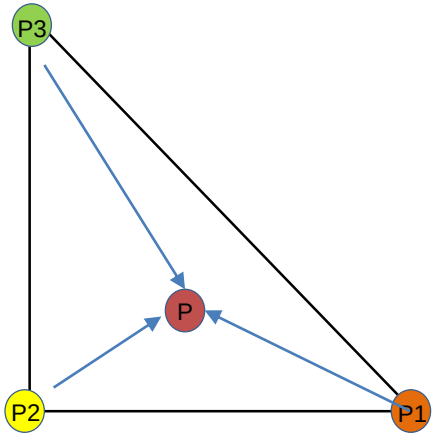
    $F_{corner\_Node} = -\frac{1}{12} F_{Total}$

    $F_{mid\_Node} = \frac{1}{3} F_{Total}$



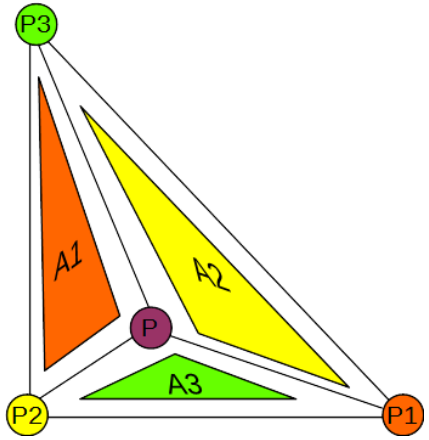
Displacement

- CFD mesh is usually finer compared to structural mesh



- Interpolation method

- Barycentric Interpolation:
  - Weighted based on surface area
  - Special treatment of the corner points.

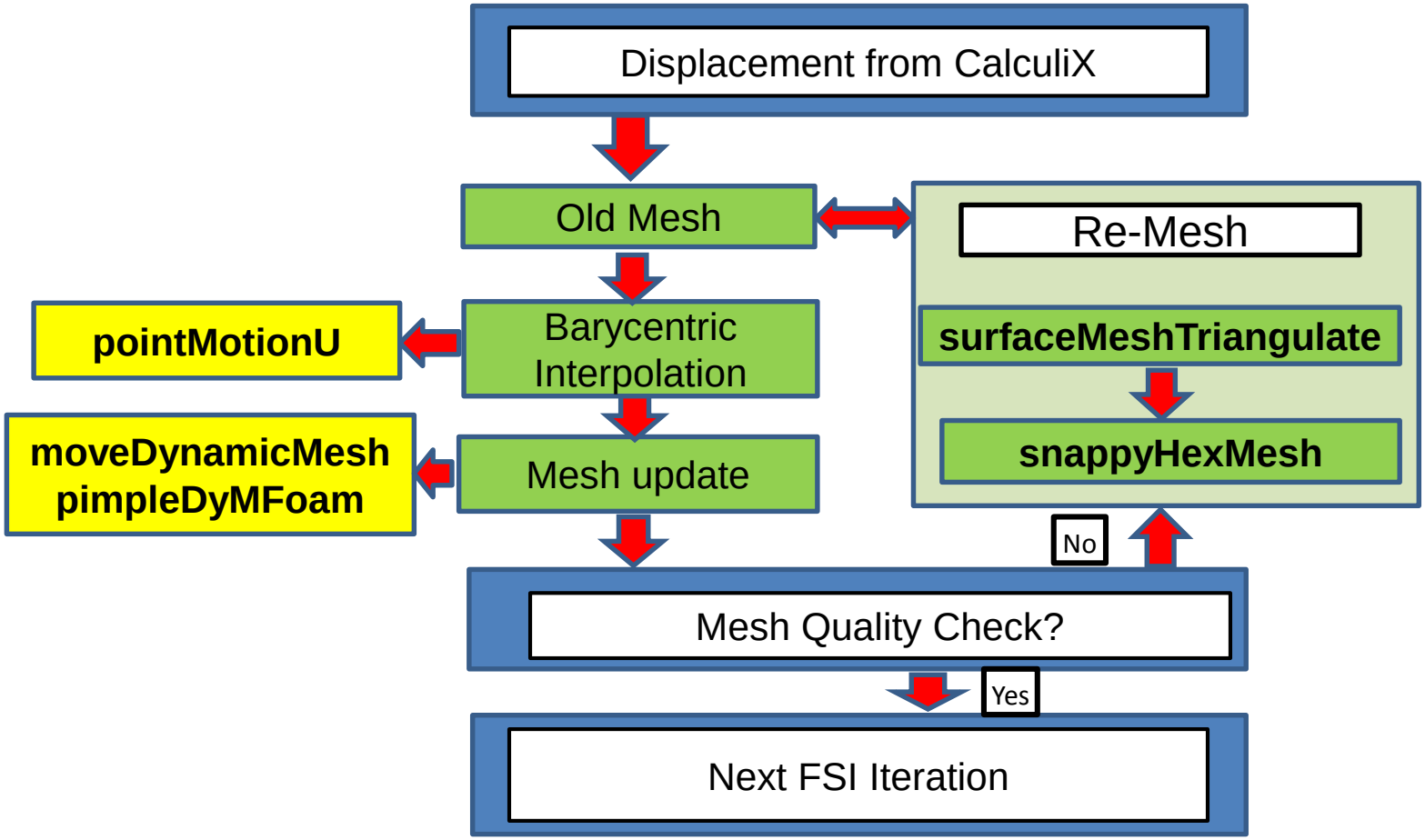


Coupling

- **Relaxation possibilities:**
  - Forces
  - Displacements

- **Different re-mesh options**
  - Full
  - Partial

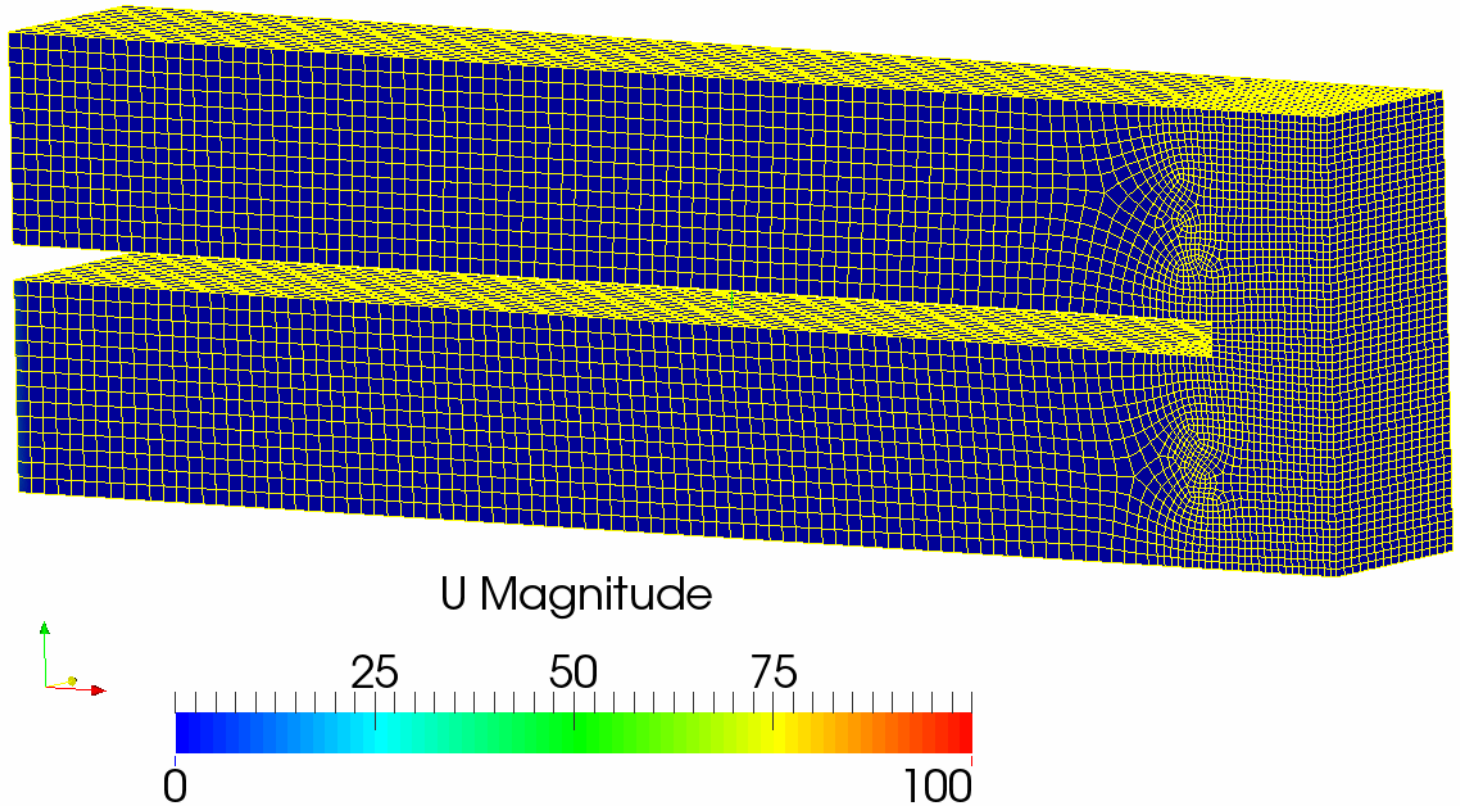
Mesh update & Re - mesh



Advantage:

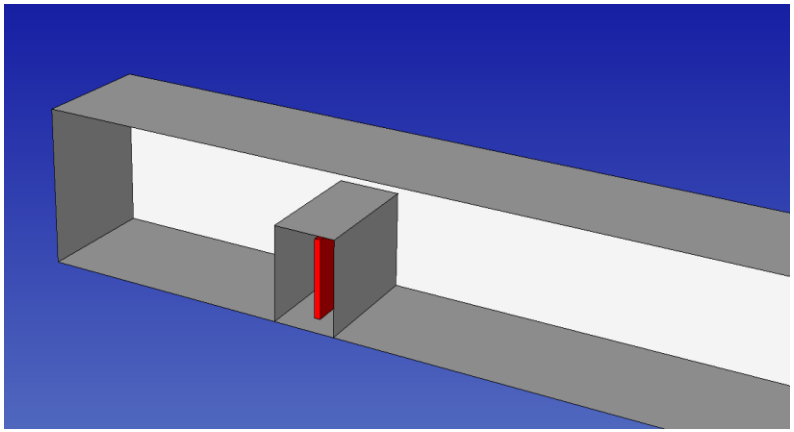
large displacement can be realized

Re-mesh flow area



Partial Re-mesh/ Partial FSI Area

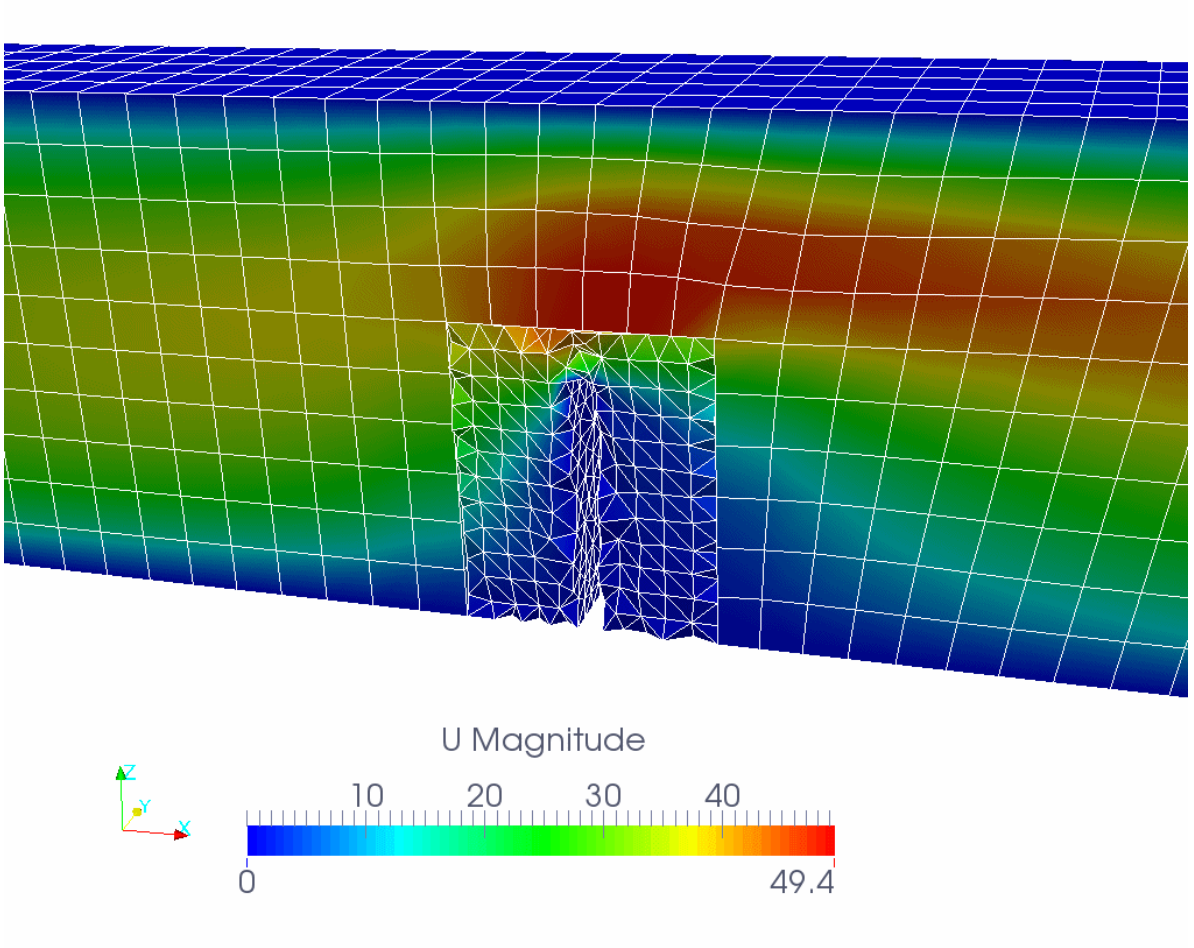
- Division of FSI-area in small region.
- Use of **Arbitrary Mesh Interface(AMI).**
- Re-mesh for only selected region, reduces time required.
- **mergeMesh** for complete fluid area.



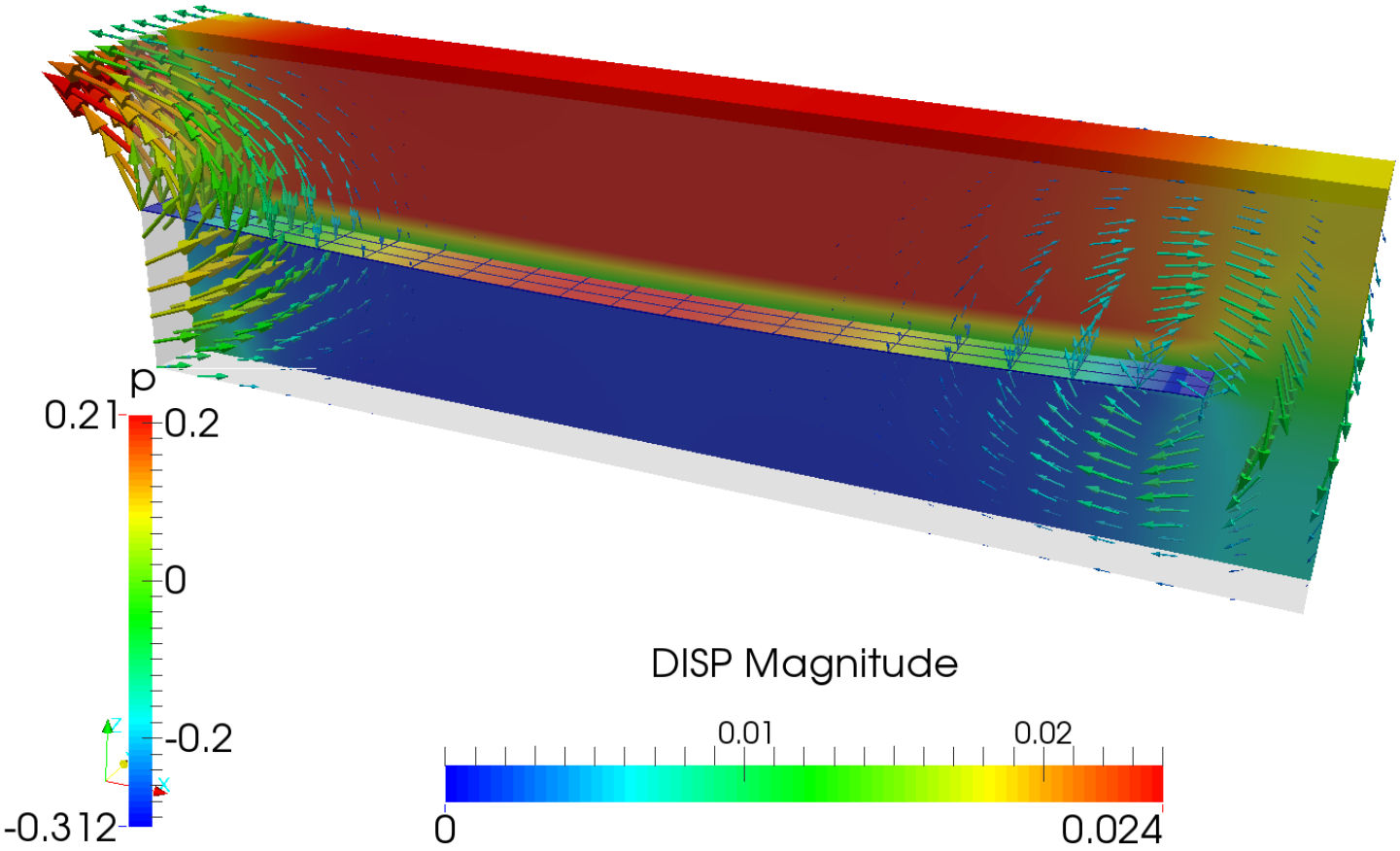
Advantage:

Complex geometry need not to be fully re-meshed.

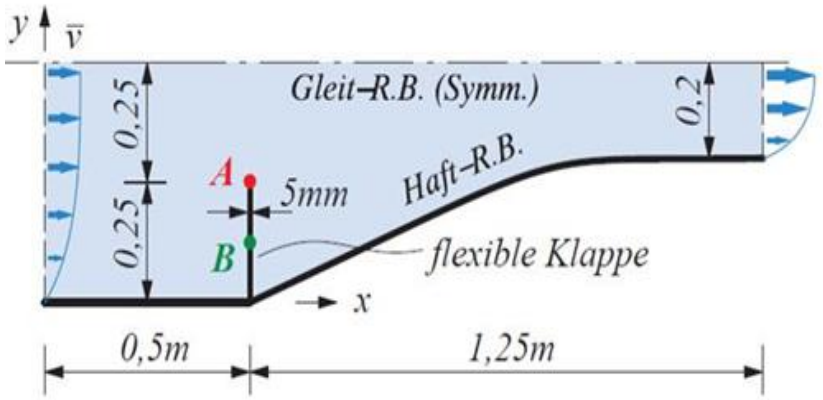
Partial Re-mesh



Permeable shell element

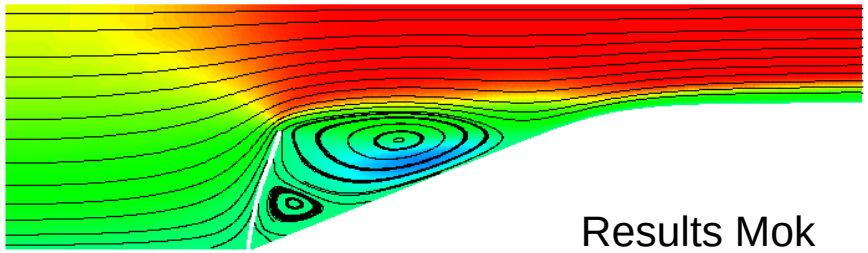


Validation

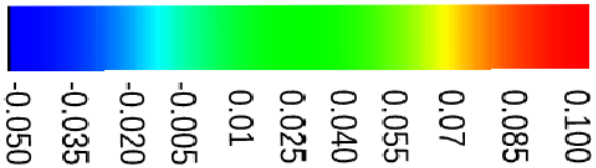


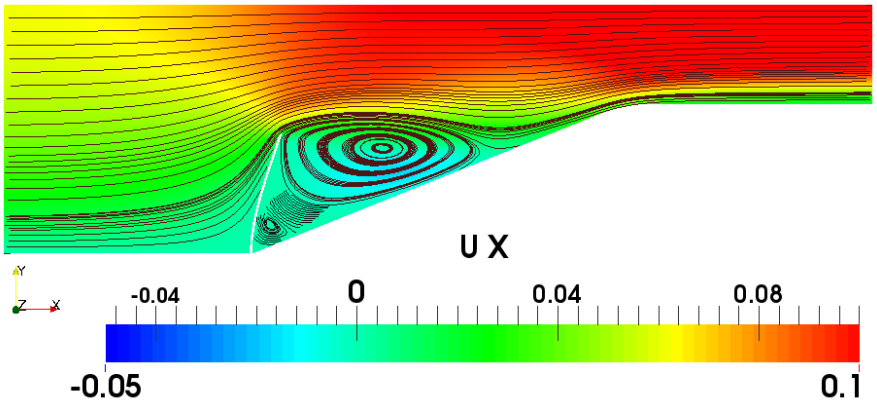
	Results-Mok	OpenFOAM-CalculiX
Displacement A	0.061m	0.06047m
Displacement B	0.0225m	0.021557m

Daniel Pinyen Mok: „Partitionierte Lösungsansätze in der Strukturdynamik und der Fluid-Struktur-Interaktion“, PHD-Thesis, 2001.



Results Mok

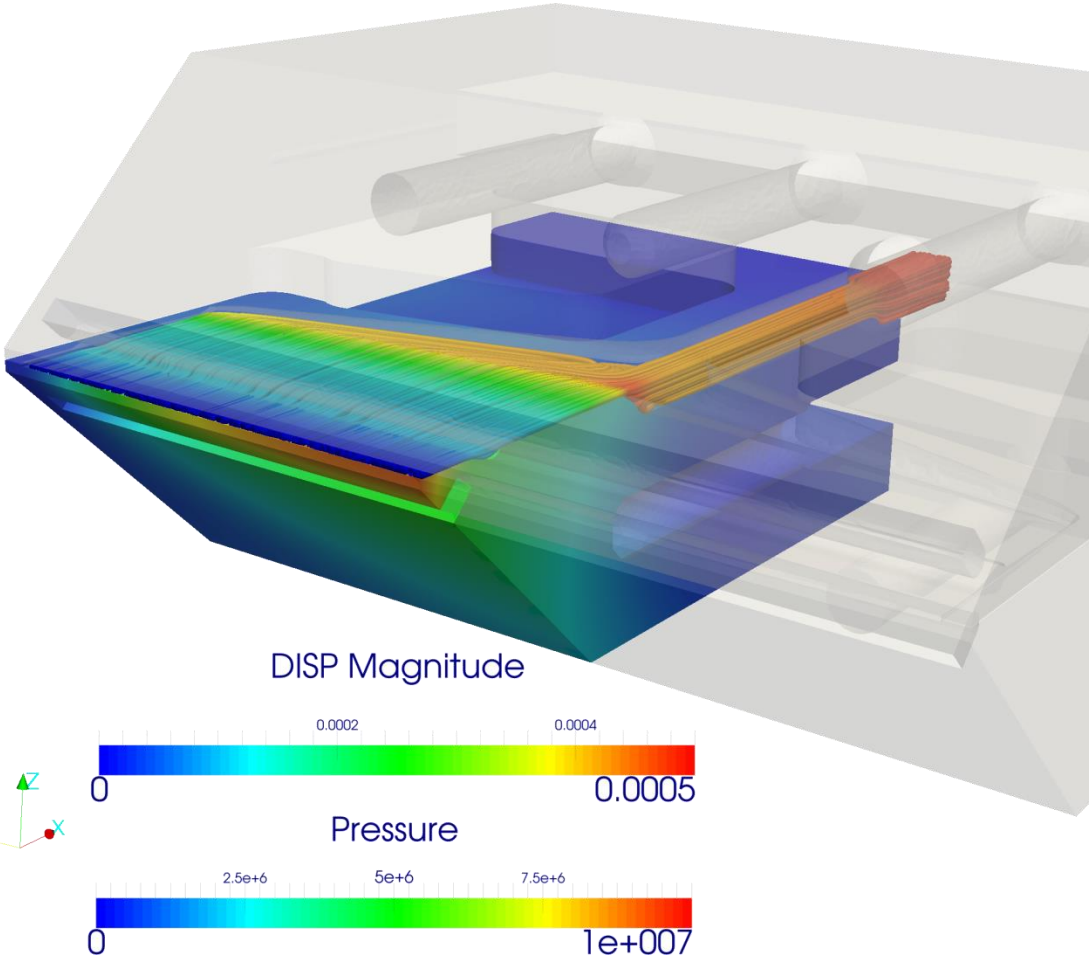




OpenFOAM CalculiX Coupling

Validated with other commercial FSI-tools.

Technical Application

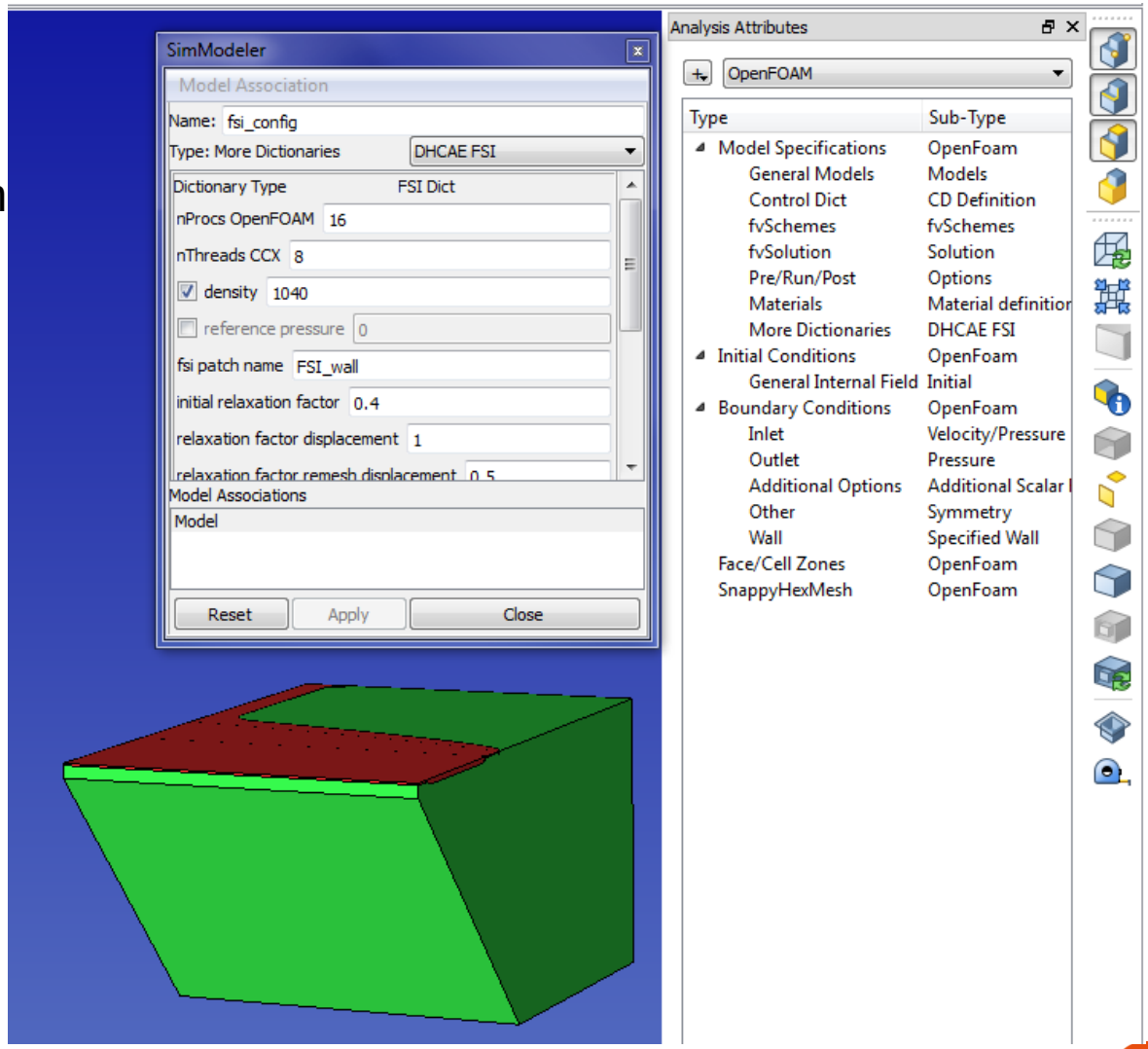


Extrusion-Tool
Fluid domain:
Approx. 4 Mio fluid cells
Structural domain:
Approx. 25 000 quad elements

Currently used in an EU funded Cloud-Computing project for FSI-simulations of polymer extrusion dies.

CastNet FSI-Setup

- FSI-setup for both OpenFOAM and CalculiX in a single case definition.
- Automated workflow based on input in FSI property file.
- Export of intermediate data for **stl** file generation.



Conclusion

Current status:

- Partitioned FSI-coupling for static applications
  - for shells and solids
  - With Re-meshing (Full/Partial)

- Validation with literature examples and commercial software

- With CalculiX: Completely Open-source
- With Abaqus: Complex non-linear effects

- GUI-Integration with CastNet/RunGui

Fundings

Parts of the project received public fundings:

- Zentrales Innovationsprogramm Mittelstand (ZIM):

  „Methods for simulating particle retention at porous structures and its effects on flow resistance“.

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Thank You