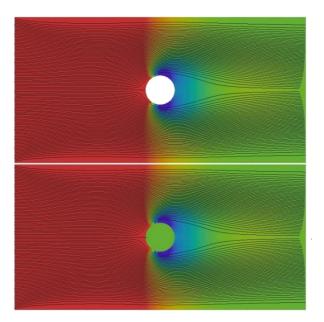


Geometric Immersed Boundaries (GIB) – A New Framework For Applying Boundary Conditions in OpenFOAM®



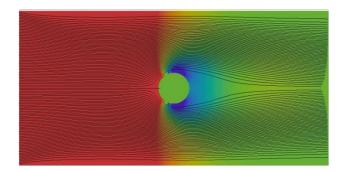
October 19 - 21, Stuttgart, Germany

Georgios Karpouzas, ENGYS Ltd. – NTUA Eugene de Villiers, ENGYS Ltd.



info@engys.com | Tel: +44 (0)20 32393041 | Fax: +49 (0)20 3357 3123 | www.engys.com

- Motivation
- Methodology
- Validation
- Applications
- Moving GIB
- Closing Comments

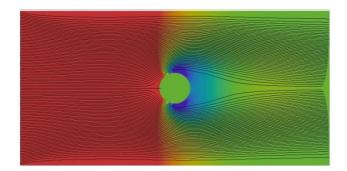


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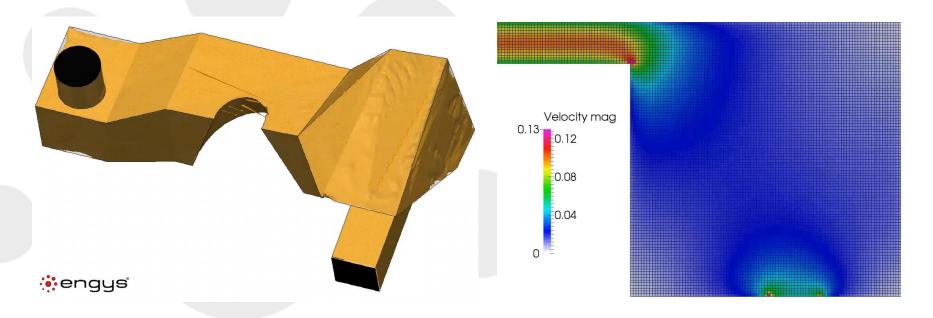
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Motivation

- Topology optimization
- Level-set coupled with the continuous adjoint method



*G. Karpouzas, E.M. Papoutsis-Kiachagias, T. Schumacher, E. de Villiers, K.C. Giannakoglou, C. Othmer. **"Adjoint Optimization for Vehicle External Aerodynamics",** JSAE - to be published soon *C. Othmer. **"Adjoint methods for car aerodynamics",** Journal of Mathematics in Industry 2014 4:6

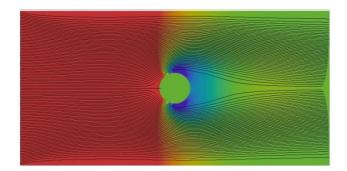


Motivation

- Currently simple immersed boundaries (IB) are applied on the fluid-solid interface
- Resistance/porosity is added to the solid cells of the matrix which blocks the velocity
- Lacks of accuracy especially in the turbulent cases
- In-situ IB primal results do not exactly match boundary fitted equivalent
- Results in approximate objective/optimal
- Solution: Implement immersed boundaries with the same accuracy as a real boundary



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Methodology | Goals

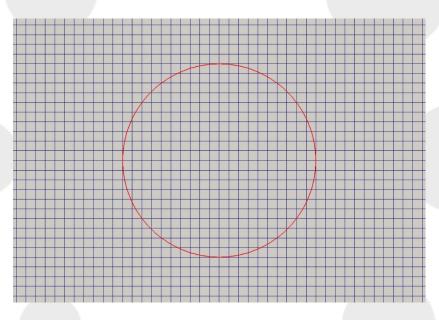
- Same accuracy as body fitted meshes
- Automation: Work with every solver and operation
- Same interface as the other boundaries
- Apply the existing boundary conditions (fixedValue, zeroGradient...) on the immersed boundaries

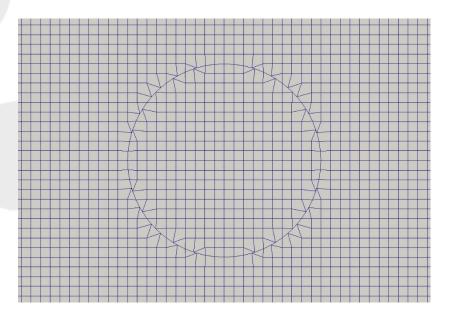




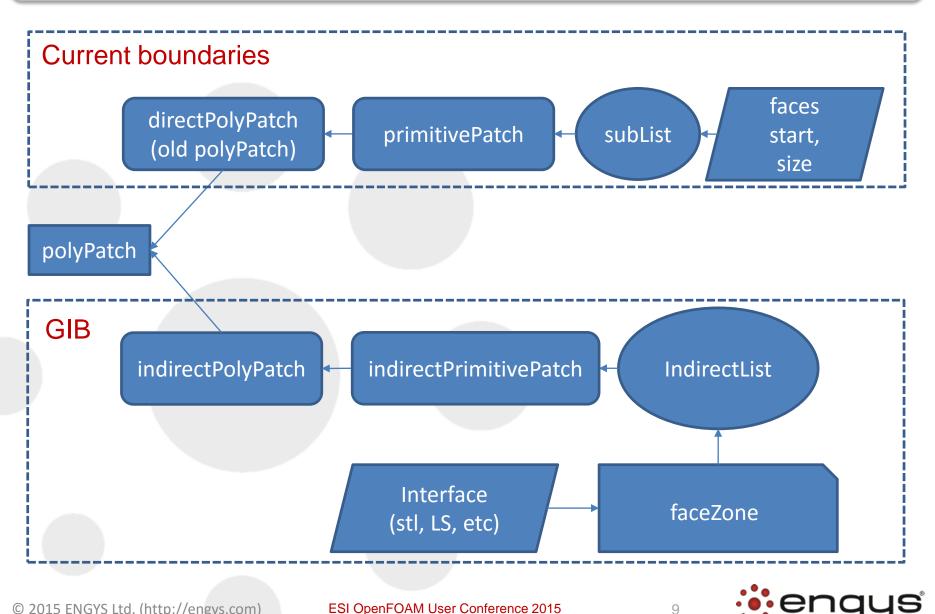
Methodology | Concept

- Perform snapping on the interface (LS, .stl, etc.)
- After snapping some of the faces are located on the interface.
- All the quantities needed from the finite volume are updated
- Problem: There is not a code structure in OpenFOAM[®] to apply boundary conditions in internal faces.









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- Two new boundaries (one from each side) are constructed based on the faceZone and the flipMap.
 - faceZone represents the addressing of the face list that constructs the GIB
 - The flipMap boolean list is used to define the two sides of the GIB
- Based on faceZone and the flipMap, the geometric characteristics of the boundary (Cf, Sf etc) are calculated from the internal faces.



- Existing boundary conditions can be used on the GIB.
- The GIB boundary faces give the appropriate contributions to the matrix.
- The GIB can behave like:
 - a pass-through (like not existing)
 - normal boundary (fixedValue, zeroGradient etc)
 - boundary with communication (CHT tempetarure boundary condition)

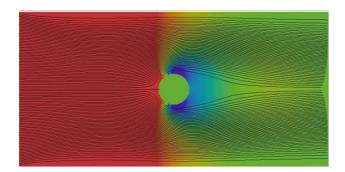


Boundary file sample	U Boundary Conditions sample	p Boundary Conditions sample										
<pre>7 (Inlet { type patch; physicalType inlet; nFaces 100; startFace 39700; } ib1 { type indirectWall; neighbourPatch ib2; faceZone ib; indirectPolyPatchType master; startFace 80300; } ib2 { type indirectWall; neighbourPatch ib1; faceZone ib; indirectPolyPatchType slave; startFace 80300; })</pre>	<pre> boundaryField { Inlet { surfaceNormalFixedValue; redValue uniform -1; } ib1 { type fixedValue; value uniform (0 0 0); } ib2 { type fixedValue; value uniform (0 0 0); } }</pre>	<pre> boundaryField { Inlet { type zeroGradient; } ib1 { type zeroGradient; } ib2 { type zeroGradient; } }</pre>										

- Changes in ~ 100 files
- OpenFoam library:
 - polyMesh/patch to insert the GIB classes
 - GeometricField to automate the operators
 - GAMG agglomerator
- finiteVolume library:
 - fv(s)PatchField, fvPatch
 - fvm, fvc operators
- Parallelization
- Mapping functions for moving GIB
- Wall distance for turbulence



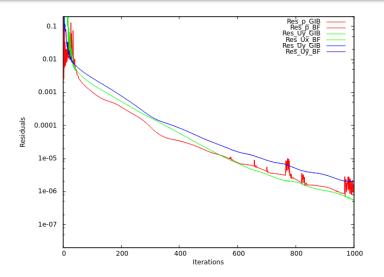
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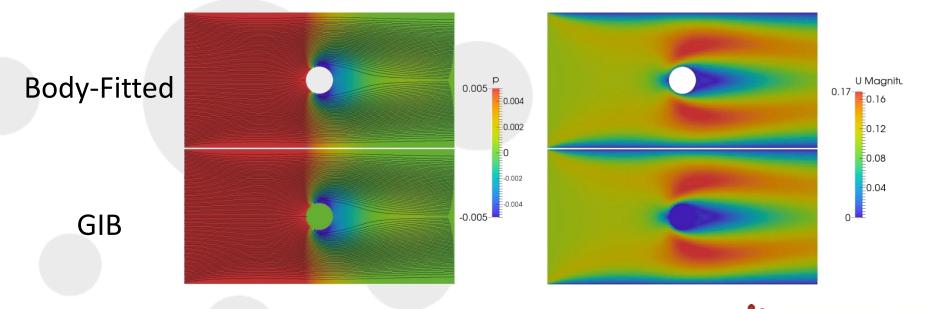




Validation | cylinder

- Bodyfitted vs GIB cylinder results
- Identical residuals-results (machine accuracy)

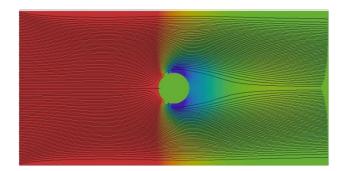




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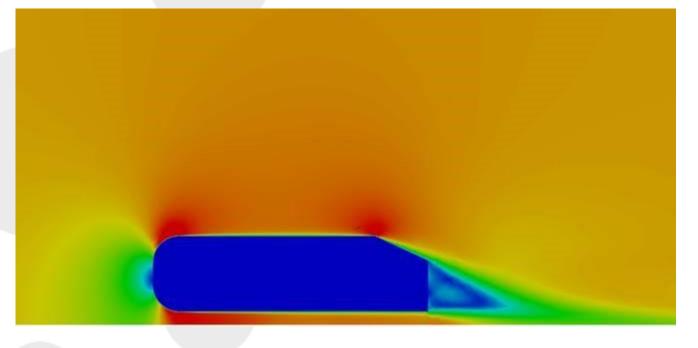


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Applications | Ahmed

- Fully parallel
- Works with turbulence
- No top level change is required in the standard solvers





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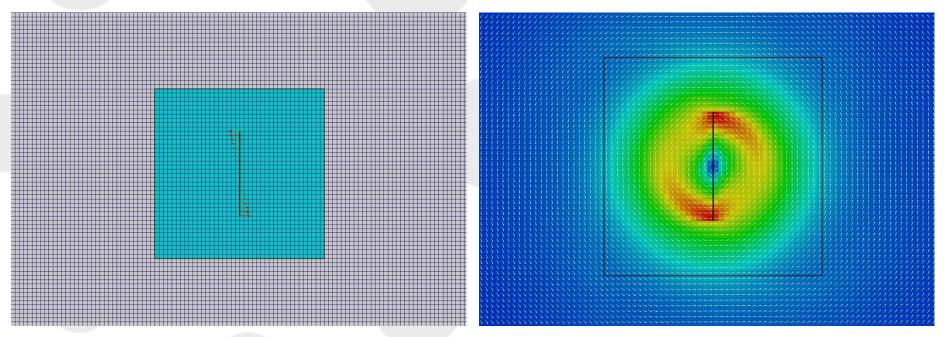
Applications | MRF | concept

- Current limitation:
 - The cellZone must be circular.
 - <u>Reason</u>: The relative and absolute fluxes should be the same at the interface of stationary and rotating part
- We apply GIB on the interface:
 - The pressure boundary is a pass-through
 - The velocity and the derived fields (phi, ...) takes the value of the GIB wherever needed from the FV
 - The relative flux is added only in one side of the GIB



Applications | MRF | simpleMixer

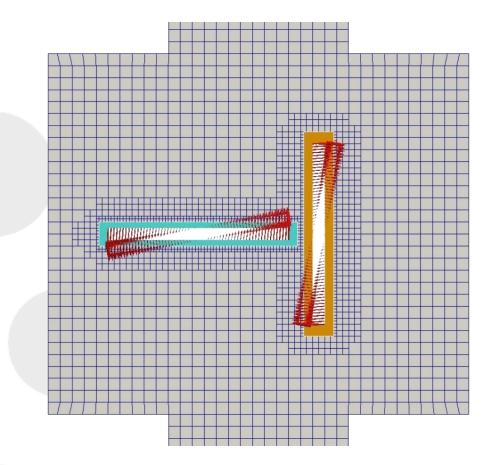
- Simple blockMesh geometry with a blade and a cellZone.
- GIB are applied at the perimeter of the cellZone





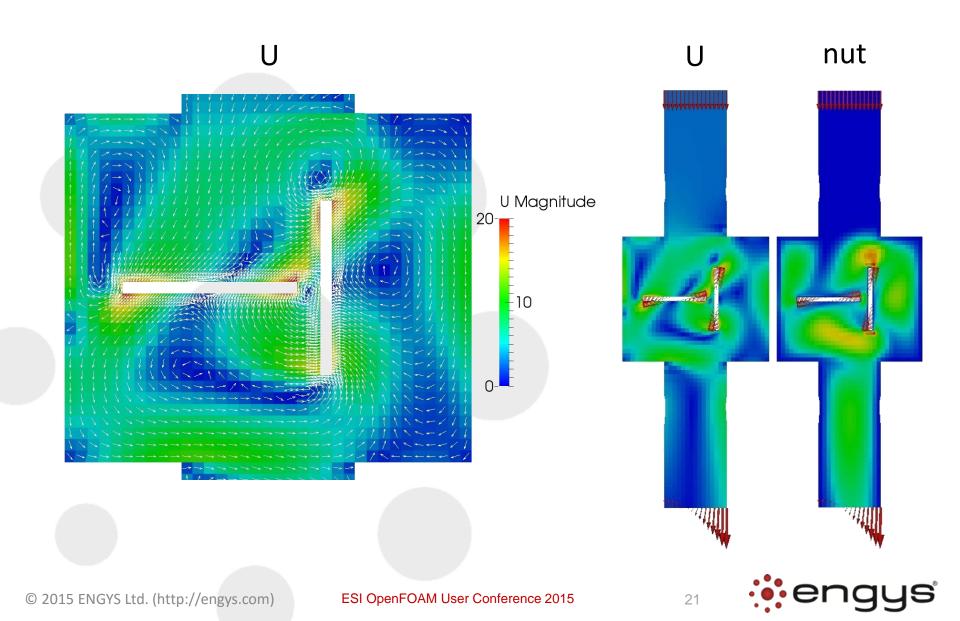
Applications | MRF | gearPump

- Pressure-pressure boundaries at the top and bottom
- Cyan and orange areas are two cellZones
- Two GIB are applied on the two interfaces (outside the two MRFzones).
- GIB boundary conditions are coupled (communication is required)
- The standard MRF method in OpenFOAM[®] not able to simulate the flow





Applications | MRF | gearPump



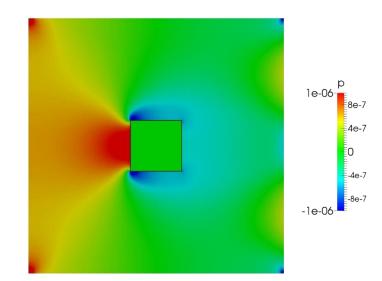
Applications | CHT | Current technique

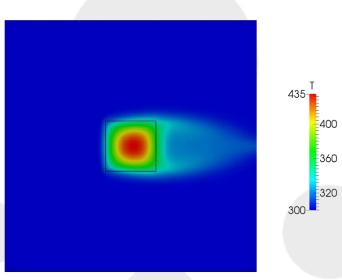
- Multi-region
- Everything is segregated. Basic equations:
 - For fluid:
 - Pressure
 - Velocity
 - Energy (enthalpy or temperature)
 - For solid:
 - Energy (enthalpy or temperature)
- Result: slow solution

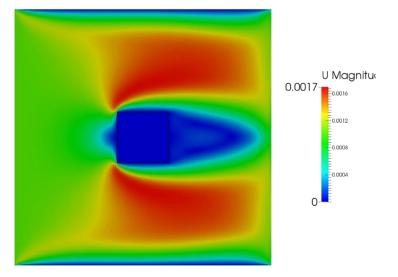


Applications | CHT | GIB

- One region CHT
- The solid and fluid are communicating using GIB (black line)
- Boundary conditions for T or h are coupled because communication is required.
- Heat source is applied on the solid
- 1 matrix -> faster convergence





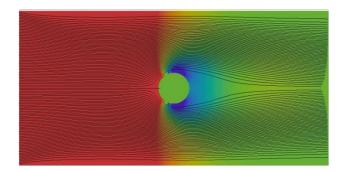




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- Motivation
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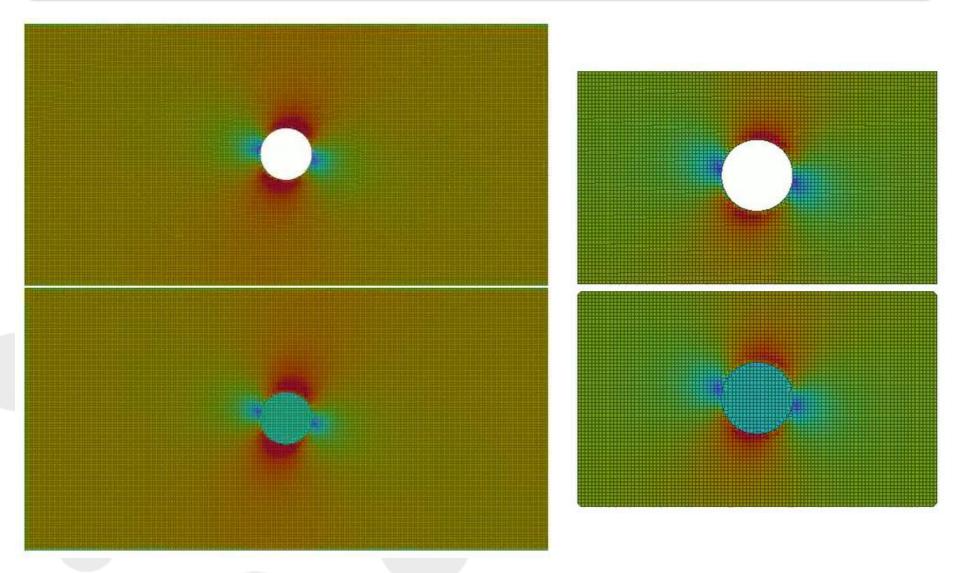
Moving GIB | Basic steps

- New location of the interface
- Perform snapping from the base mesh to the new interface
- faceZone update
- polyPatches class update
- GIB patch Fields update with mapping
- Special treatment for the freshly solid/fluid cells is needed

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Moving GIB | movingCylinderBenchmark

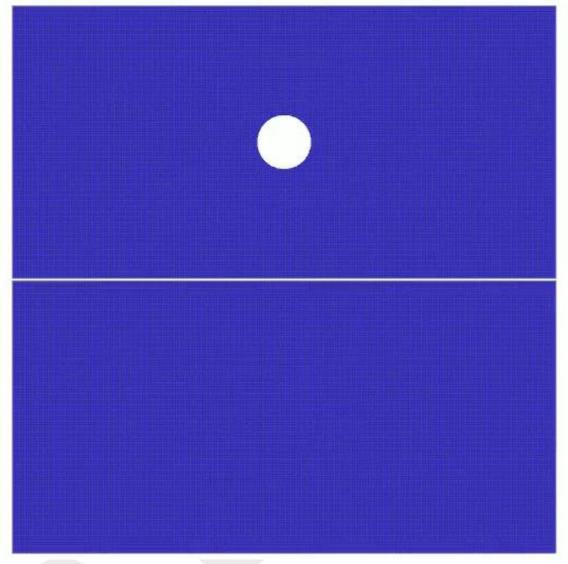


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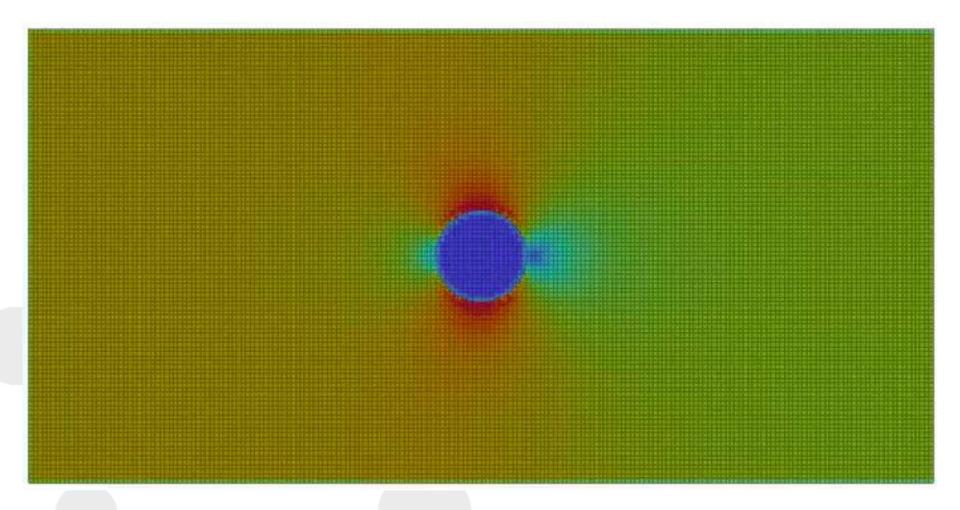
Moving GIB | crashingCylinder



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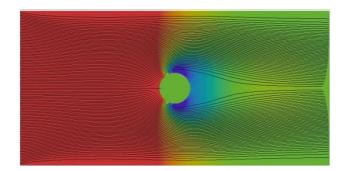
Moving GIB | growShrink Cylinder



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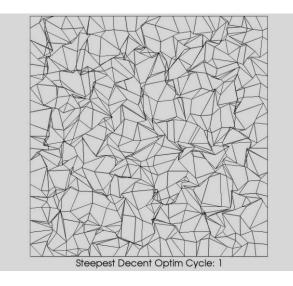
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Closing comments | Next steps

- Closing comments:
 - New framework for applying boundary condition in internal group of faces is implemented
 - General implementation. Top level change is not required.
- Next steps:
 - Coupling with the adjointFoam engine
 - Mesh optimization for improving the mesh quality near the interface
 - Mesh adaptation





Looking forward

- It can be applied in every application with a static/moving interface.
- Applications such as:
 - CHT
 - MRF
 - FSI
 - multiphase
 - Gear pumps
 - 6 DoF
- Adjoint version of them
- Challenges: Add layers to the GIB with overset grids



The end

Thanks for your time! Any questions?

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