# Computation of Weakly Compressible Flows Induced by Boundary Movements
# Parallel Finite Volumes Method on 3D Unstructured Moving Meshes

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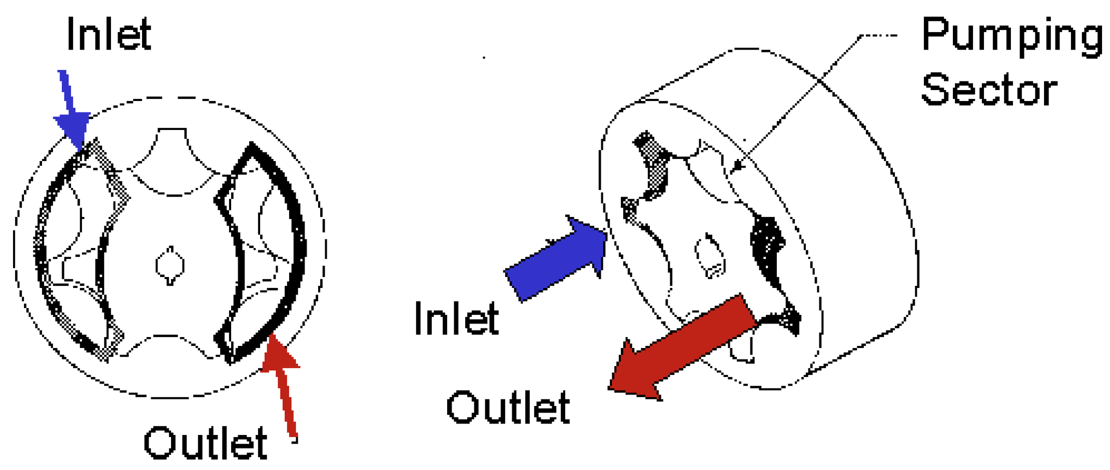
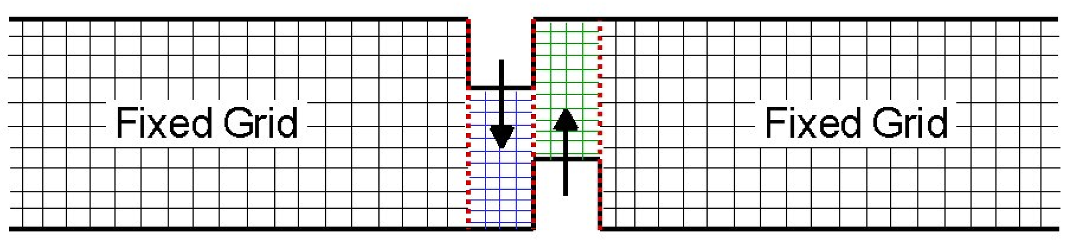
## Simulation of flow through G-Rotor Pumps

- Weakly compressible Air/Oil mixture
- Detection of cavition
- Pump efficiency analysis




## Sliding Multi-Block Meshes Interface

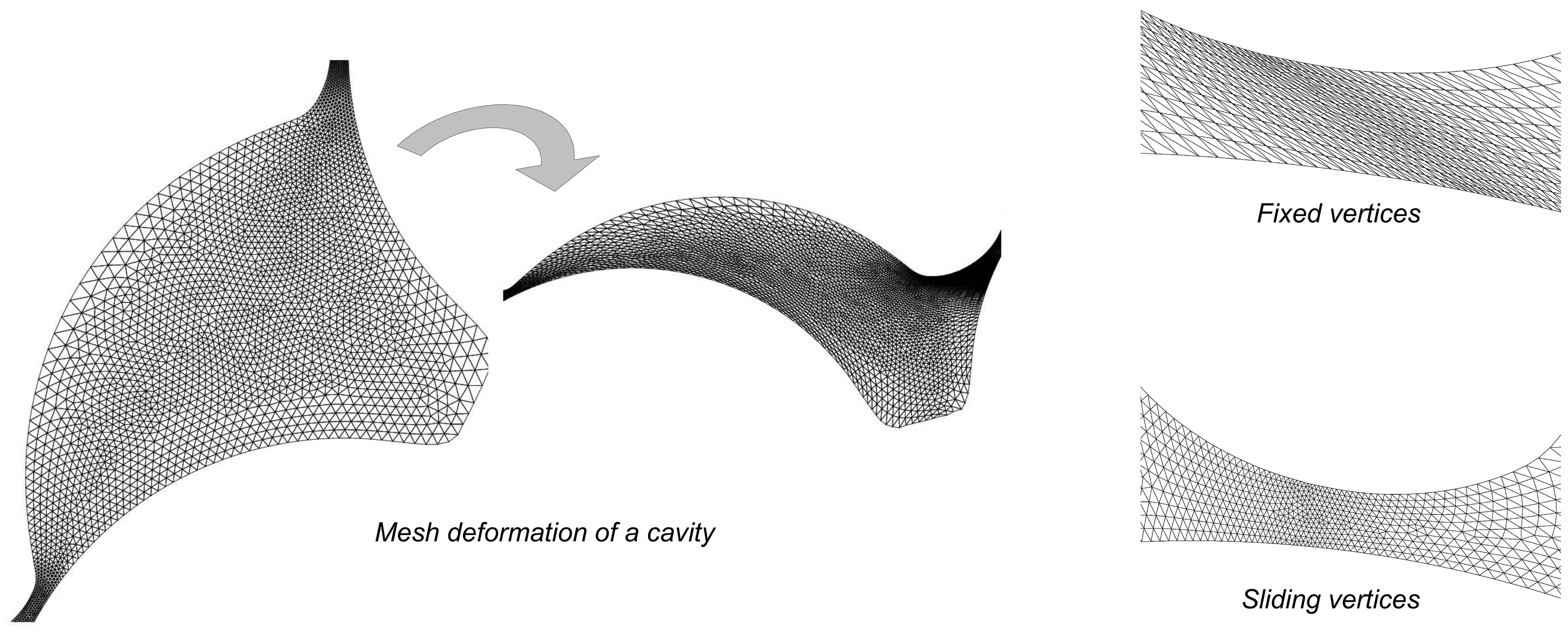
- Interface treatment between fixed and moving grids
- Use of multi-block sliding meshes
- Construction of a common interface grid using non conforming grid with hanging vertices




*2D illustration of 3 interfaces of sliding grids*

## Mesh Deformation Technique

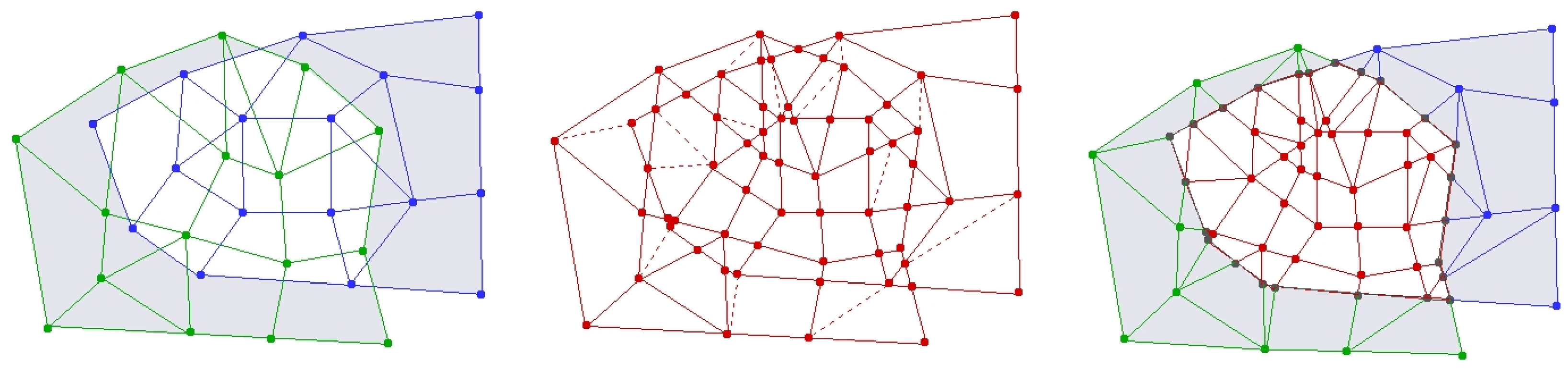
- Computation of vertices displacement as the solution of elasticity equations
- Sliding vertices on boundaries
- Analytical or numerical description of boundaries



*Mesh deformation of a cavity*

*Fixed vertices*

*Sliding vertices*



*3D non conforming meshes interface with fluid/fluid or fluid/boundary interfaces*

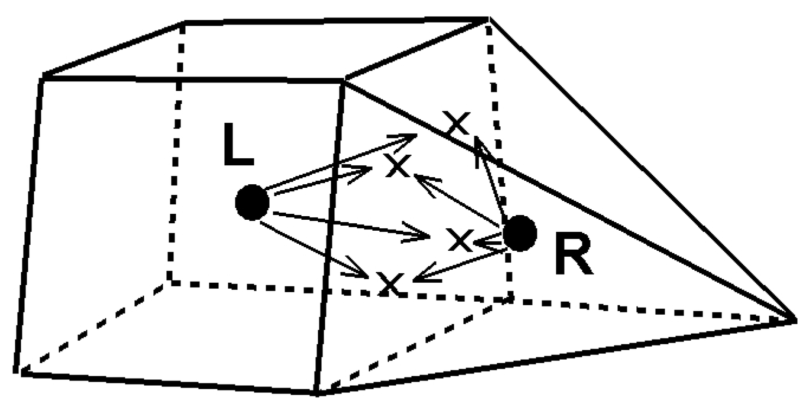
*Construction of a single interface grid (cutting)*

*Cutting up cells for having triangles or quadrangles Detection of fluid/fluid or fluid/boundary interfaces*

*Construction of 2D interface of 3D multi-block unstructured meshes*

## ALE Finite Volumes Discretization on 3D Unstructured Meshes (cell-centered approach)

- Implicit Crank-Nicolson temporal integration (second order of accuracy)
- Face by face conservative spatial integration
- Left and Right quadratic reconstruction of primitive variables
- Use ALE version of Van Leer, Roe or AUSM(+up) numerical flux functions taking grid velocity into account
- Exact preservation of a uniform and time independent flow on moving grids (DGCL condition)
- Modification of Coirier diamond path for viscous fluxes to obtain first order accuracy and preserve positivity property
- Parallel computing based on domain decomposition (Metis, MPI, PETSc)



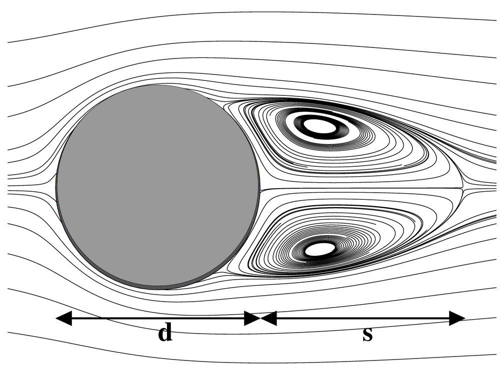

$$\frac{V^{l+1}\mathbf{s}(\mathbf{w}^{l+1})-V^{l}\mathbf{s}(\mathbf{w}^{l})}{V^{l+1}\,\Delta t^{l+1}} = \frac{1}{2}\,\frac{1}{V^{l+1}}\,\mathbf{Rhs}^{l+1} + \frac{1}{2}\,\frac{1}{V^{l+1}}\,\mathbf{Rhs}^{l}$$

$$\mathbf{Rhs} = \sum_i \int\int_{\triangle_i/\square_i} \left[\tilde{\mathbf{f}}^a_n\left(\tilde{\mathbf{w}}_L,\tilde{\mathbf{w}}_R,\tilde{v}^g_n\right) + \mathbf{f}^d_n\left(\tilde{\mathbf{w}},\tilde{\nabla\mathbf{w}}\right)\right]\, dS_i$$

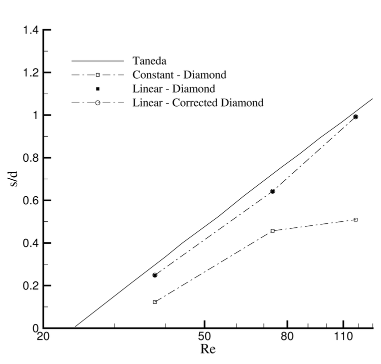
$$\tilde{\mathbf{f}}^a_n\left(\tilde{\mathbf{w}}_L,\tilde{\mathbf{w}}_R,\tilde{v}^g_n\right) \approx \mathbf{f}^a_n\left(\mathbf{w}\right) - \mathbf{s}\,v^g_n$$

$$\tilde{w}_{L/R} = w_{L/R} + \left(\mathbf{x}-\mathbf{x}_{L/R}\right)^T \nabla(w)\rfloor_{L/R} + \frac{1}{2}\,\left(\mathbf{x}-\mathbf{x}_{L/R}\right)^T \mathbf{H}(w)\rfloor_{L/R}\,\left(\mathbf{x}-\mathbf{x}_{L/R}\right)$$

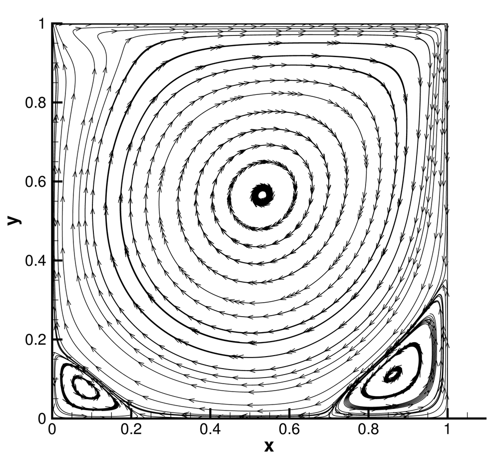
$$\tilde{v}^{g\,l}_n = v^g_n\left(\frac{t^l+t^{l+1}}{2} - \frac{\sqrt{3}}{3}\,\frac{\Delta t^{l+1}}{2}\right) \qquad \tilde{v}^{g\,l+1}_n = v^g_n\left(\frac{t^l+t^{l+1}}{2} + \frac{\sqrt{3}}{3}\,\frac{\Delta t^{l+1}}{2}\right)$$



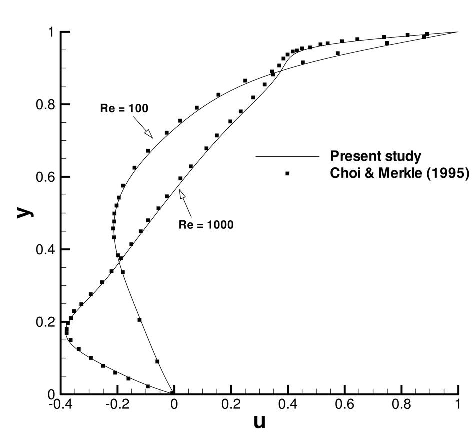
*Steady flow past a sphere Re = 118*



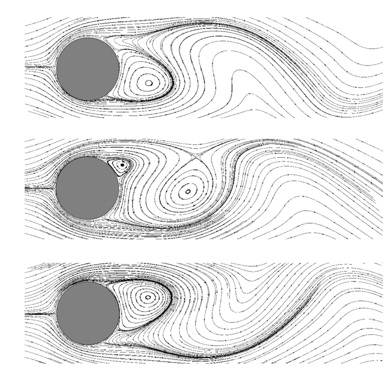
*Steady flow past a sphere*
*Scheme accuracy analysis*



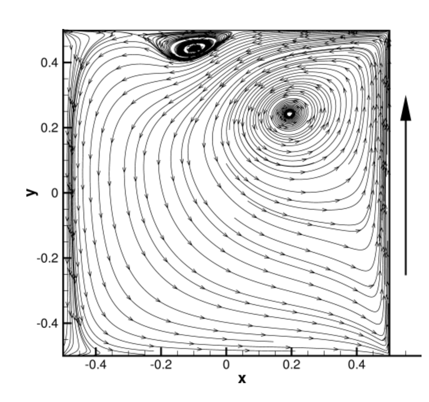
*2D steady lid-driven cavity flow Re =1000*




*2D lid driven flow x-velocity*



*Unsteady flow past a cylinder Re=100*



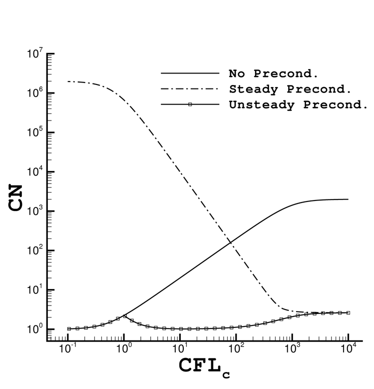
*3D lid-driven cavity flow Re = 1000*

## Local Preconditioning Techniques

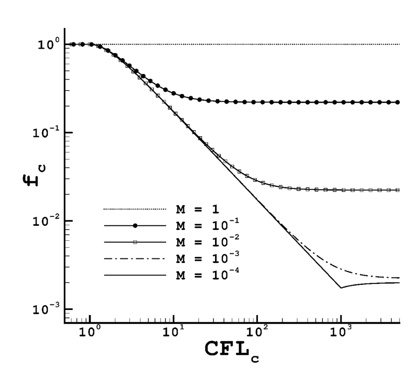
- Fully implicit dual time stepping
- Matrix free Newton-GMRes algorithm
- Introduction of an artificial speed of sound to improve the condition number for all Mach, Reynolds and Strouhal numbers
- New scaling of numerical flux dissipation for accuracy

$$M_* = \frac{c_*}{c} = \min\left[1,\max\left(\sqrt{M^2+CFL_c^{-2}},M_\epsilon\right)\right]$$

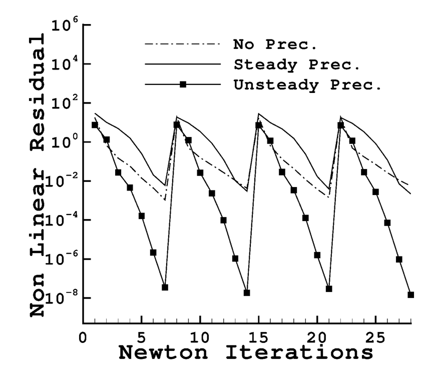
$$\left[\frac{\mathbf{P}^n}{\Delta\tau^n} + \frac{\mathbf{S}^n}{\Delta t^{l+1}} - \frac{1}{2}\,\mathbf{J}^n\right]\,\left(\mathbf{w}^{n+1}-\mathbf{w}^n\right) = -\frac{V^{l+1}\,\mathbf{s}\left(\mathbf{w}^n\right) - V^l\,\mathbf{s}\left(\mathbf{w}^l\right)}{V^{l+1}\,\Delta t^{l+1}} + \frac{1}{2}\,\frac{1}{V^{l+1}}\,\left[\mathbf{Rhs}\left(\mathbf{w}^n\right) + \mathbf{Rhs}\left(\mathbf{w}^l\right)\right]$$



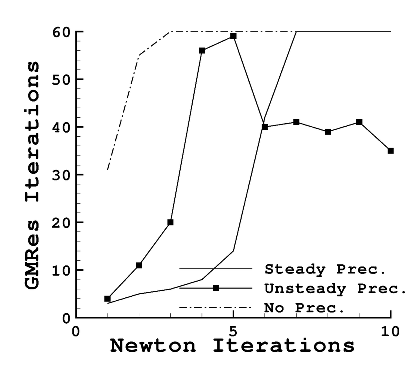

*Condition number*




*Ausm+up dissipation scaling function*




*Newton convergence*




*GMRes convergence*

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