UNIVERSITY OF FERRARA
- EX LABORE FRUCTUS -

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CFD ANALYSIS OF NON-NEWTONIAN FLUID PROCESSING PUMP

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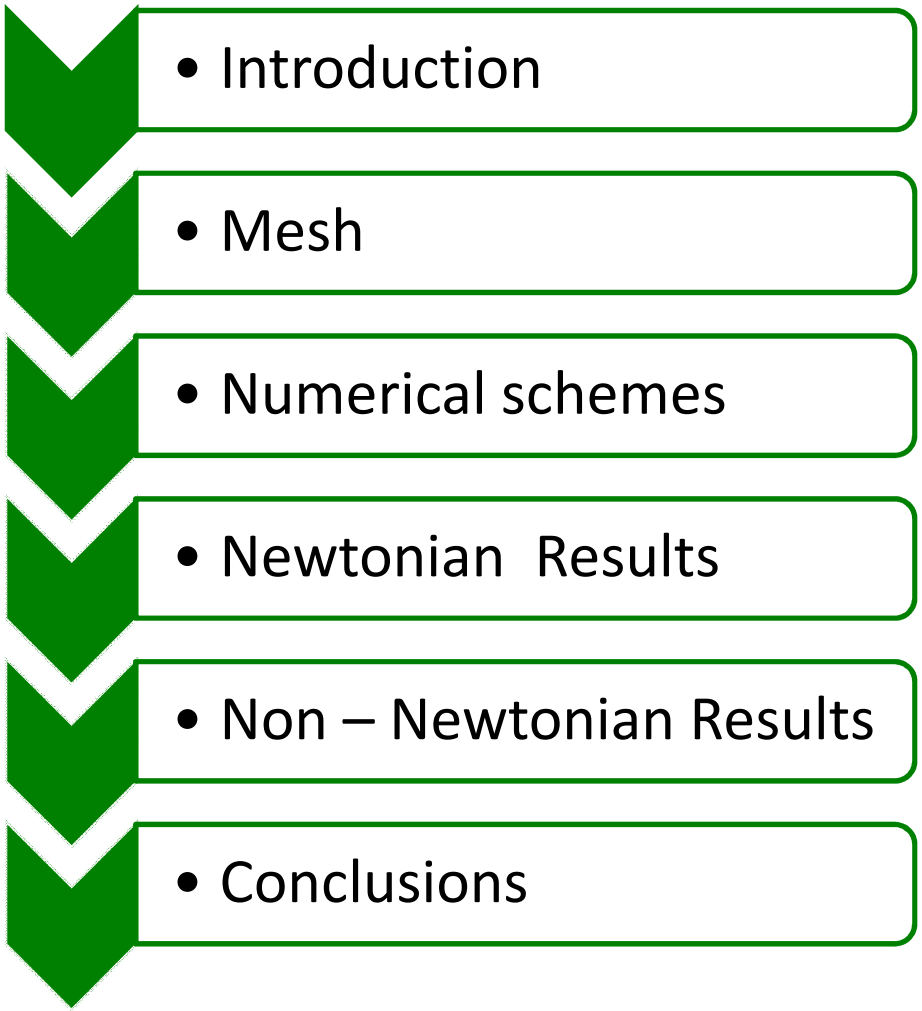
Fluid-A


• Introduction
• Mesh
• Numerical schemes
• Newtonian Results
• Non – Newtonian Results
• Conclusions

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Definition of non-Newtonian fluid

constant thermodinamics properties

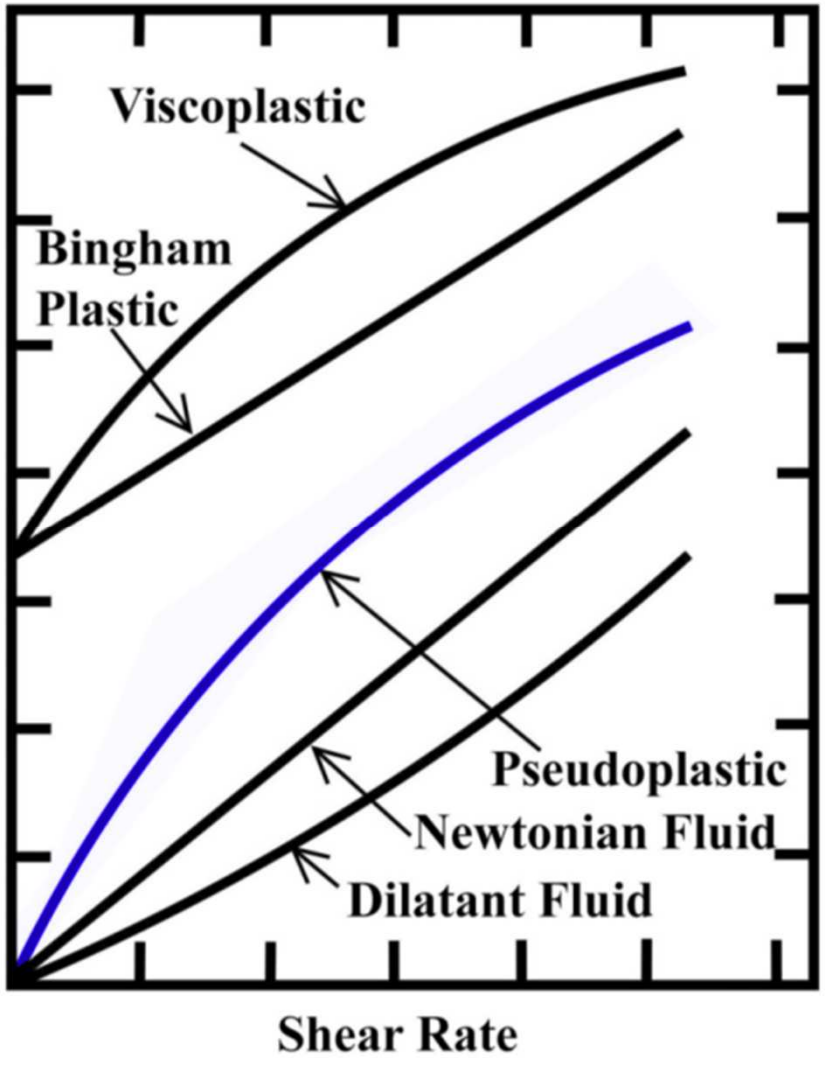
$$\sigma_{ij} = \mu\,\dot{\gamma}$$

σ_{ij} = shear stress
μ = dynamic viscosity
$\dot{\gamma}$ = shear strain rate

Newtonian fluid
μ = constant

non-Newtonian fluid
$\mu \neq$ constant

Pseudo plastic/shear-thinning fluid



Apparent viscosity

$$\mu_a = \sigma/\dot{\gamma}$$

Example of pseudoplastic fluid model: Ostwald De Waele

$$\sigma = k\,\dot{\gamma}^n$$

$$\mu_a = k\,\dot{\gamma}^{n-1}$$

Definition of non-Newtonian fluid

oil and gas/mineral industry

bentonites, extraction mud, slurries

food industry

tomato paste, fruit juices, suspensions

pharmaceutical industry

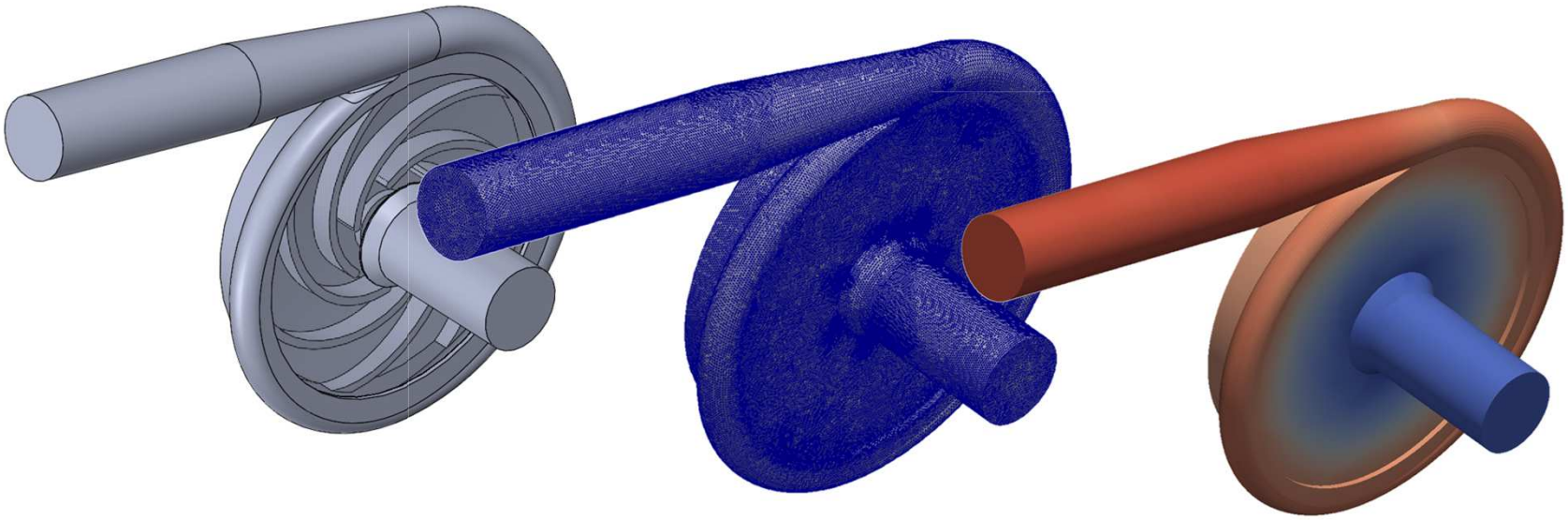
tooth paste, cremes

medical applications

blood

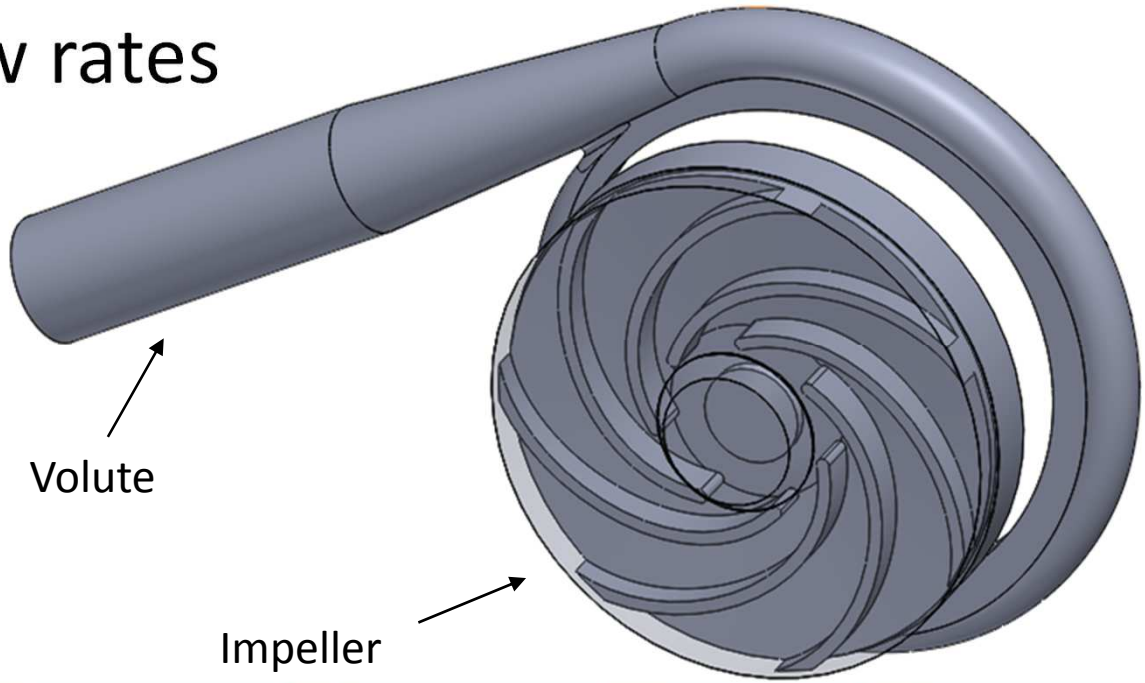
Objectives

- Test OpenFOAM in an industrial turbomachinery application
- Test a toolchain that makes pump simulations setup as fast as possible



Semi – Open Impeller Centrifugal Pump

- No shroud – ideal for dirty fluids
- Lower efficiency
- Designed for high pressure variation and medium flow rates



Fluid processed

- Water
  - Newtonian Fluid
  - Experimental results available
- Virtual non-Newtonian fluid
  - Non-Newtonian fluid
  - Power law for apparent viscosity

$k = 100.71\ Pa \cdot s^n$
$n = 0.320$

$$\mu_a = k\,\dot{\gamma}^{n-1}$$

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software used

OpenFOAM v3.0+

- snappyHexMesh
- simpleFoam

Salome-Platform 7.6

- geometry module
- mesh module

snappyHexMesh

PRO

- snappyHexMesh generates high quality mesh
- It's fast (if run in parallel)

CONS

- Sometimes the setup process requires case specific settings

Salome-Platform

PRO

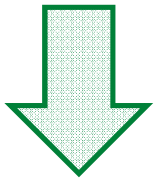
- Fast Surface grouping/naming
- Acceptable quality tetra mesh (NETGEN)
- Reliable mesh conversion to OpenFOAM

CONS

- Only serial run
- Internal prismatic layer generation is not compliant with OpenFOAM quality requirements

Solution – hybrid approach

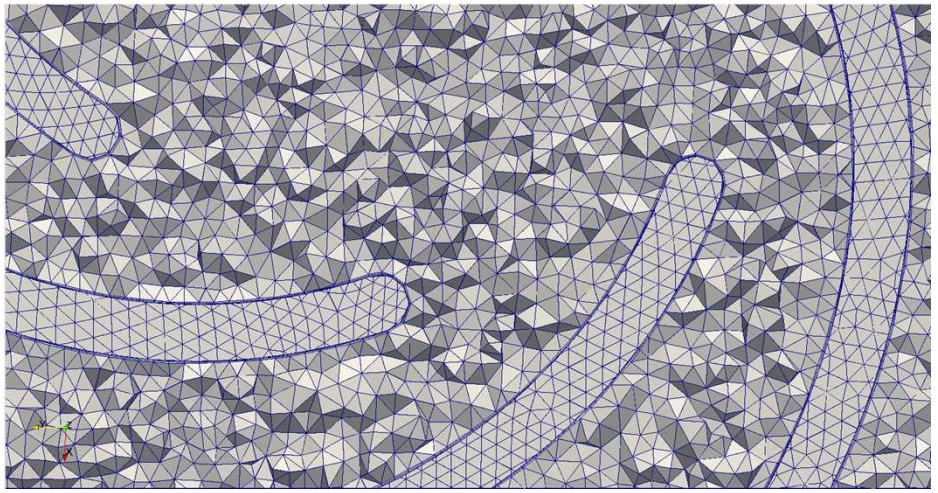
- Salome-Platform:
  - tet mesh generation
  - patch and zone naming
- OpenFOAM: snappyHexMesh
  - prismatic layer addition
  - The overall grid quality benefits from the snappyHexMesh smoothing/quality control

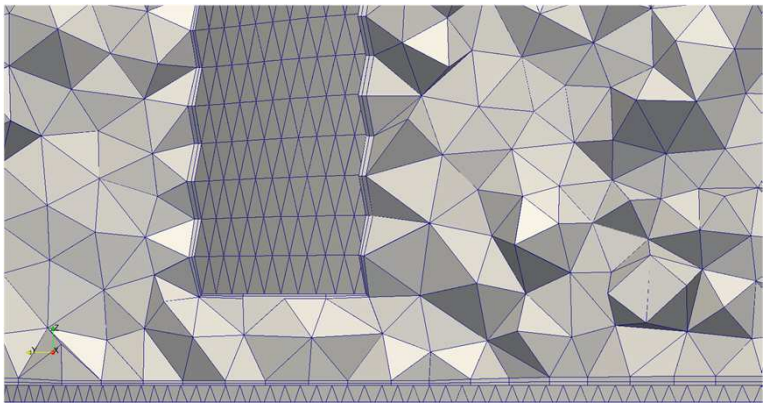


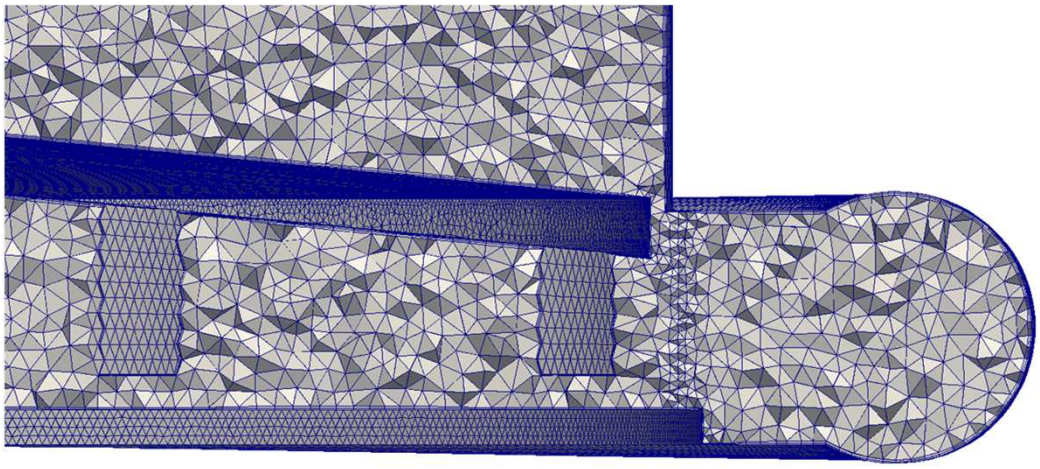
- OpenFOAM's checkMesh satisfied

Sample Mesh

- $5 \cdot 10^6$ elements
- y+ = 5÷ 30
- maxNonOrtho ≅ 68







Rotor Stator Interaction - AMI

PRO

- The AMI interface can connect domains with non-conforming surface mesh

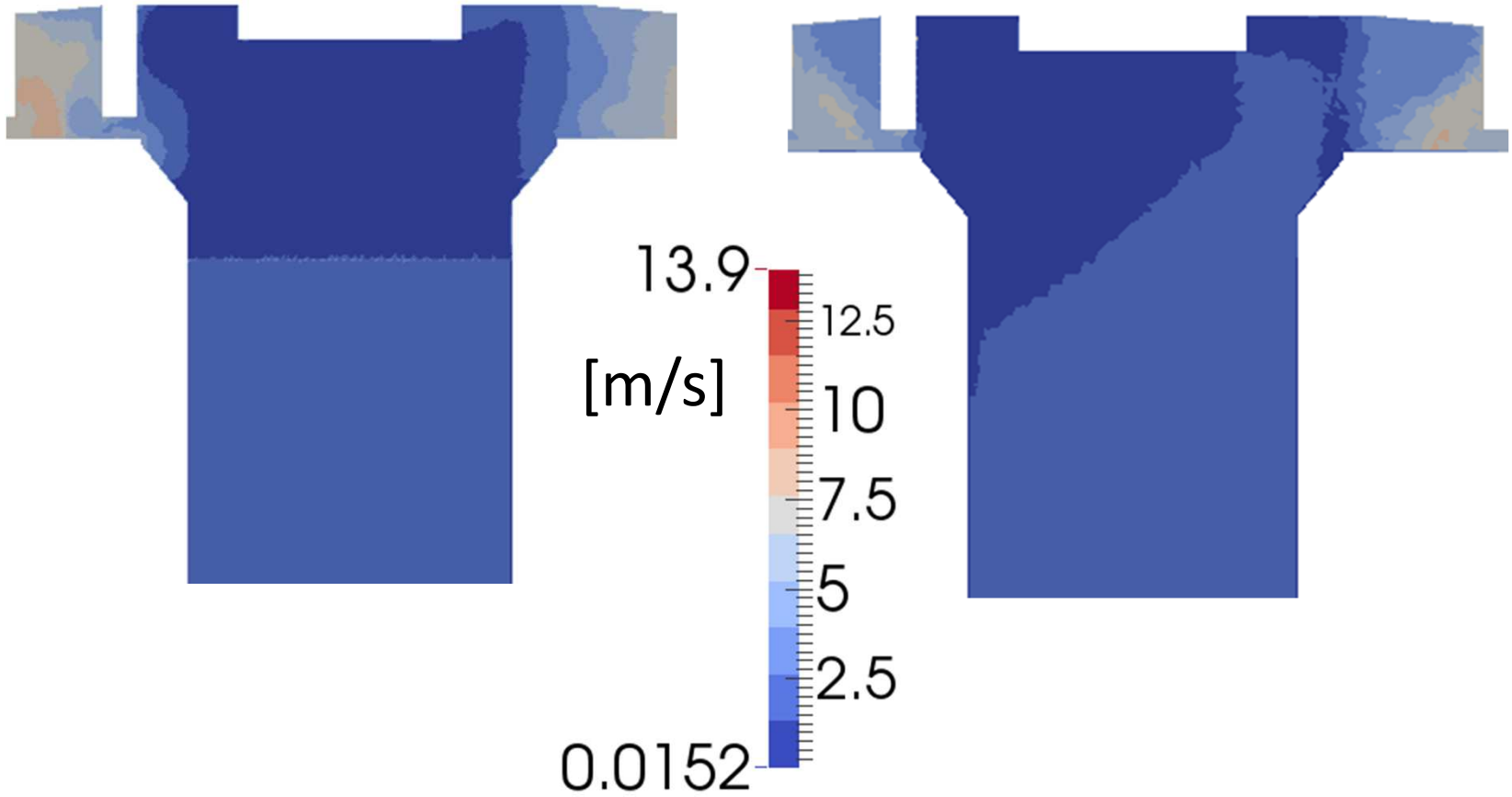
PROBLEMS

- Local flow modification
- Increase instability
- Continuity error

Rotor Stator Interaction - AMI

AMI

Conformal Mesh



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Numerical schemes

- The simulations have been carried out both with a first and second order discretisation scheme
  - First order: upwind
  - Sercond order: linearUpwind

Schemes and solvers

- Tet mesh: leastSquares grad limiter
- Laplacian and snGradient: corrected and limited
- Solvers
  - GAMG for pressure
  - SmoothSolver for other quantities

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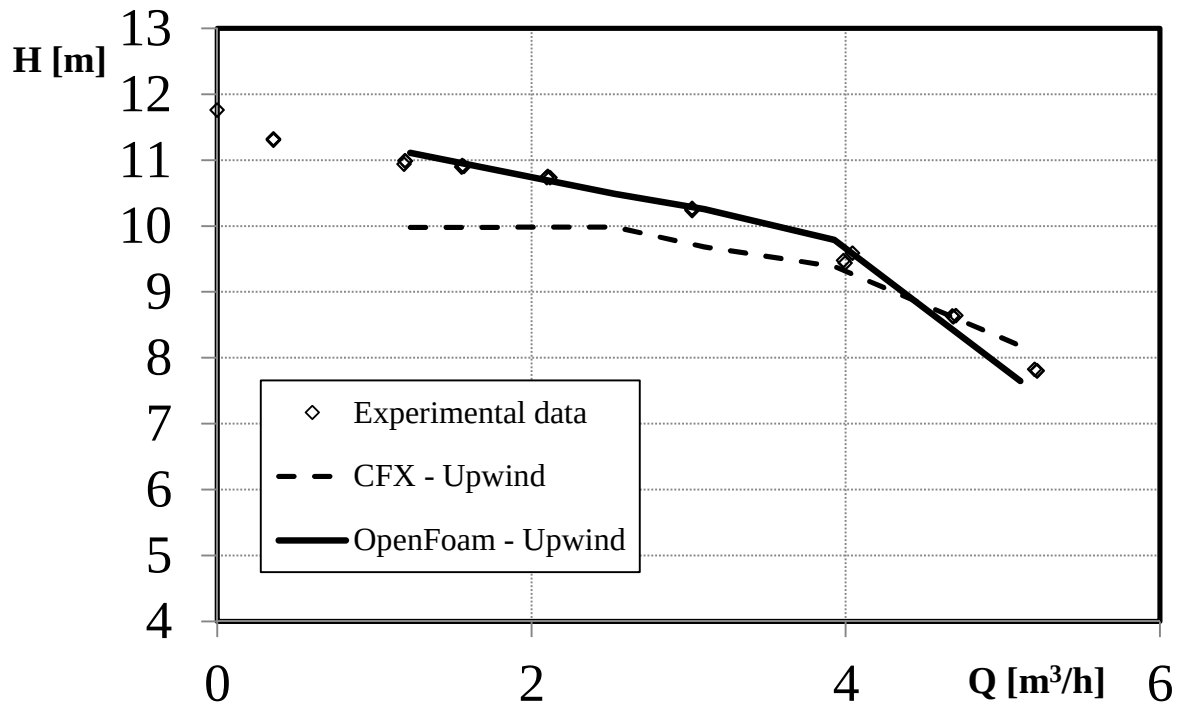
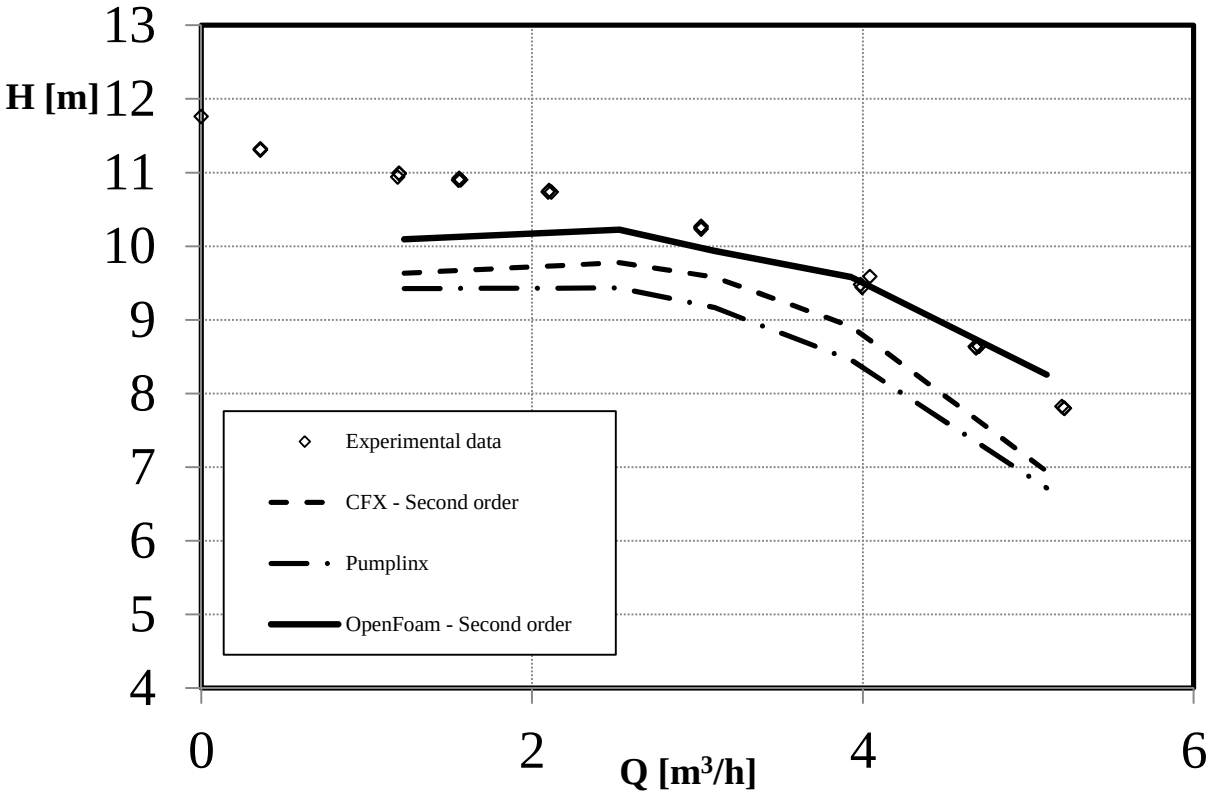
Newtonian Results
First Order

- First and second order have been compared to the experimental results
- Max. difference @ first order – 5%



Newtonian Results
Second Order

- Max Difference @ Second order – 10%



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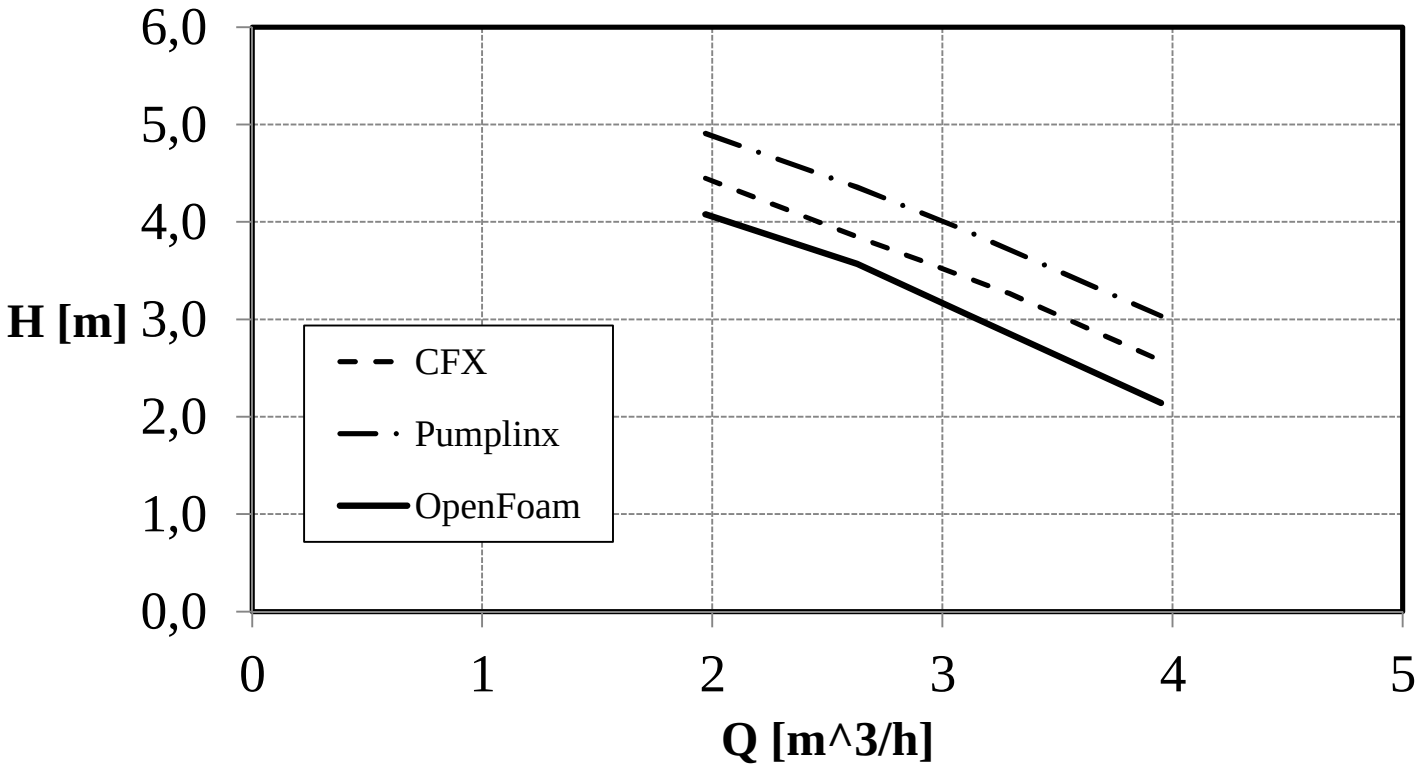
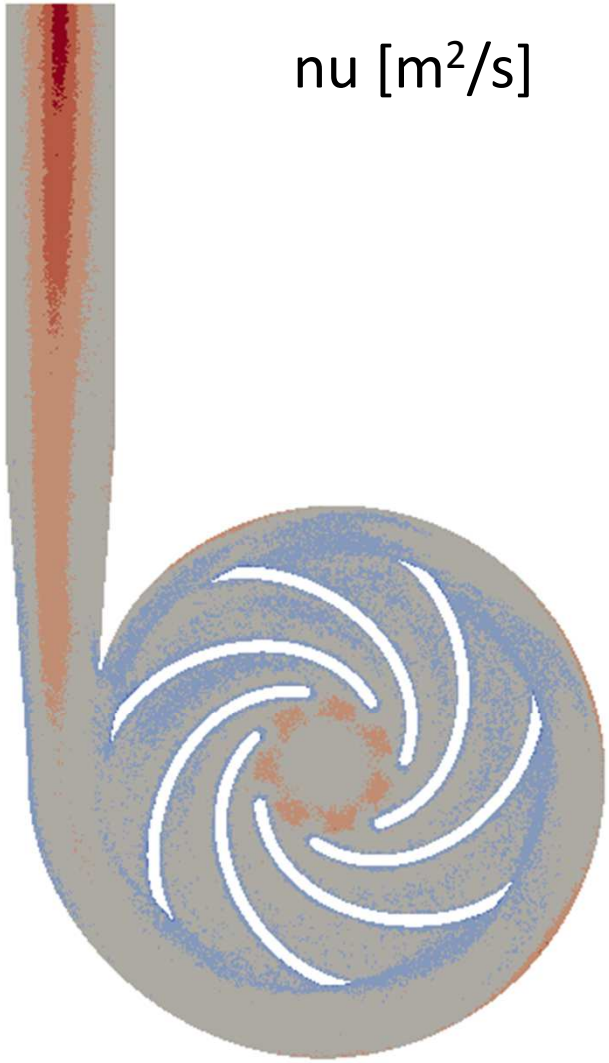
Non - Newtonian Results Second Order

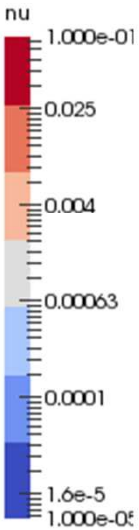
- Comparison between numerical results



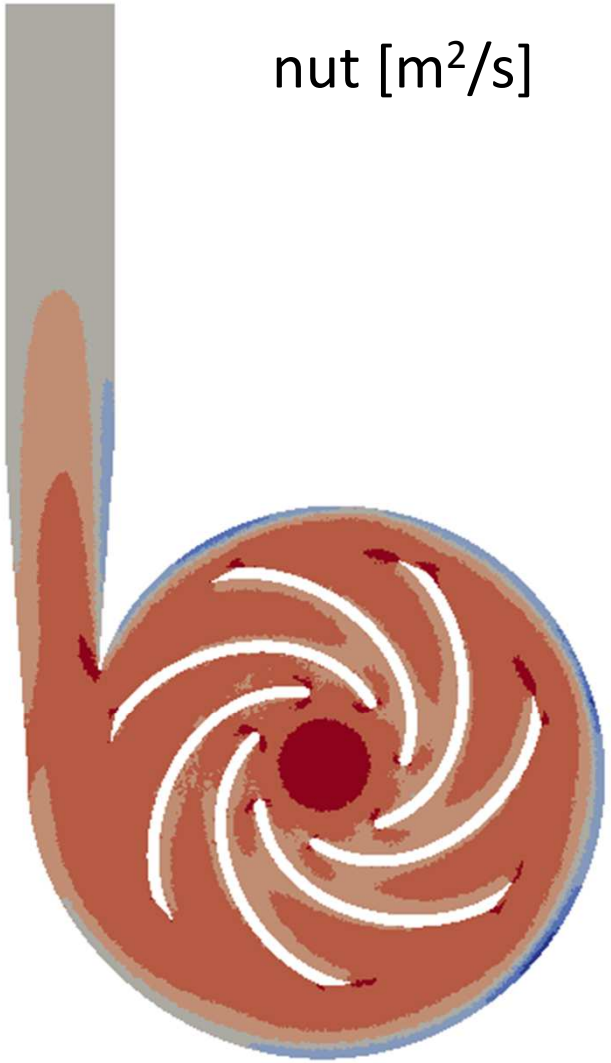
Non - Newtonian Results

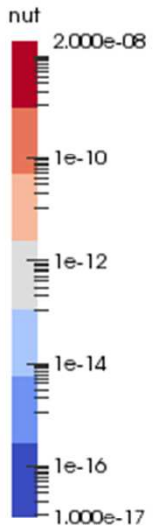
nu [m^2/s]





nut [m^2/s]





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Conclusions - OpenFOAM solver

- Good match between OpenFOAM results both for Water and tomato paste non-Newtonian fluid

- AMI introduces significant errors in the simulation, the conformal mesh is suggested

Conclusion – Simulation toolchain

- An hybrid pre-processing approach has been tested for tetrahedral with prism mesh
  - Salome-Platform: netgen
  - OpenFOAM: snappyHexMesh
- The toolchain proposed takes ~ 12h from a 3D geometric model of the pump

Future development

- A test rig for non-Newtonian fluids is under development, to provide more accurate validation of the results
- Test of the GGI interface of foam-extend

Thank you for your attention