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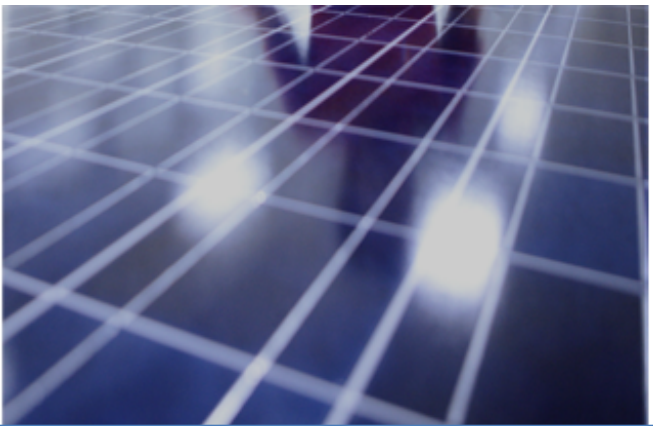
Open-source applications for naval design on HPC platforms

Roberto Pieri - SCS

18 June 2015



Presentation

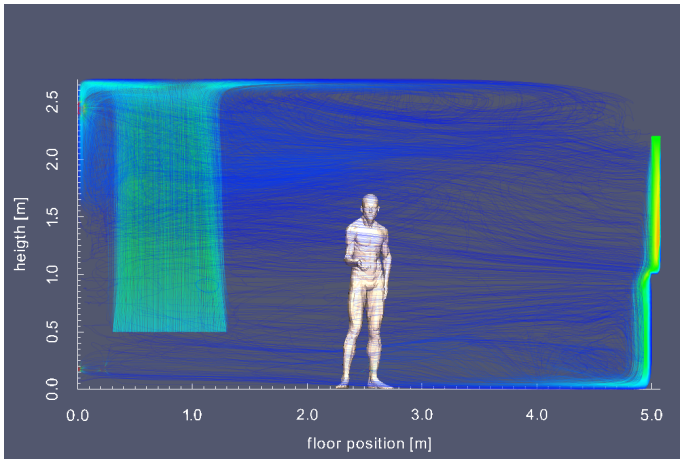
SuprerComputingSolutions

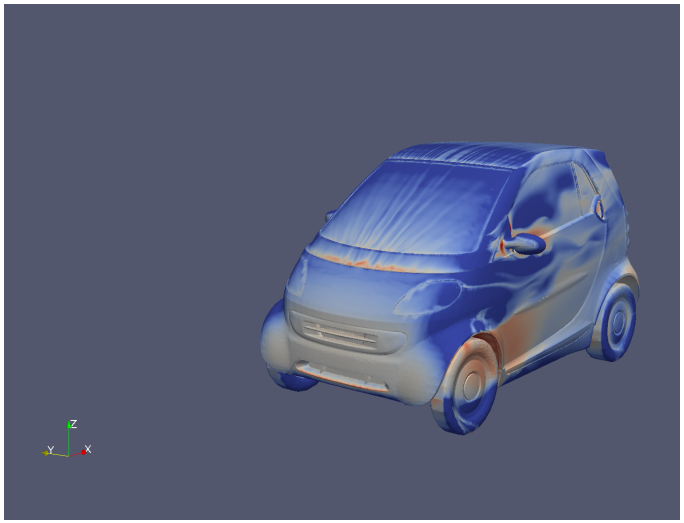
- Is a CINECA company
- Provides services for industrial partners
- Provides CAE solutions and workflows on HPC platforms

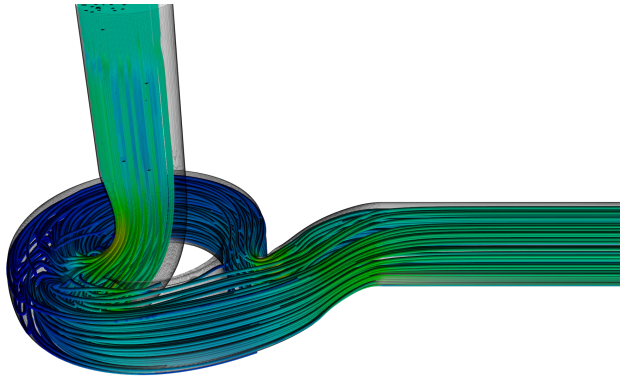
Roberto Pieri

- Aeronautical Engineer from Politecnico di Milano
- Master thesis in adjoint-based shape optimization in CFD
- CFD Engineer in SCS since February 2014

CFD solutions in SCS







- Internal fluid-dynamics
- External aerodynamics
- Thermo-fluid-dynamics
- Multiphase flows

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Naval design

OpenFOAM overview

Test case

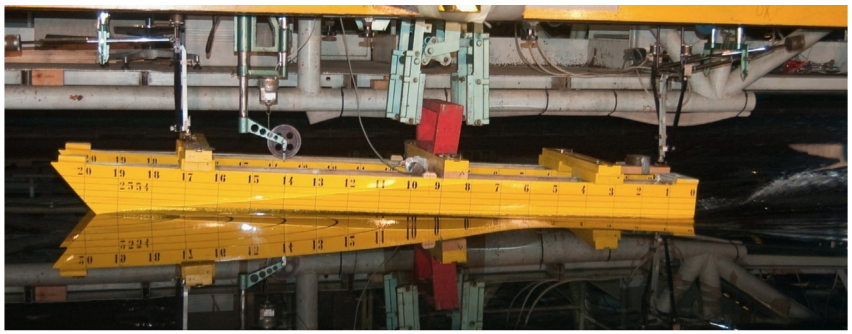
Results

Scalability

Conclusions

Naval design

- Use of stabilized techniques or workflows based on know-how or expertise.
- Currently, thanks to the increase of the computing power, CFD is the most powerful tool.
- Designers look for the cutting-edge solutions with high ratio between costs and benefits.
- Virtualization of design tools.



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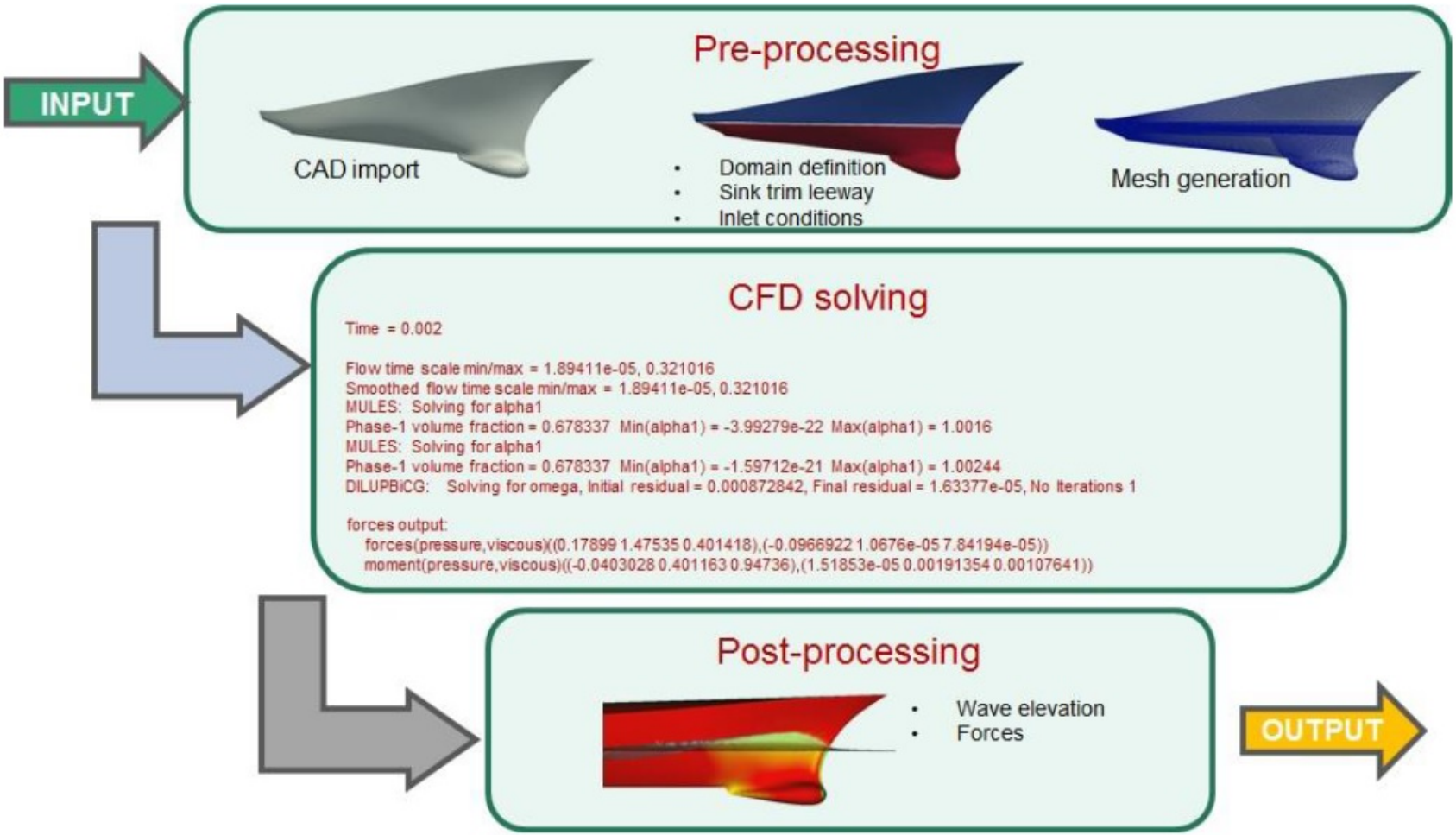
Workflow



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What is *OpenFOAM* ?

OpenFOAM

The Open Source CFD Toolbox

- **Open** **F**ield **O**peration **A**nd **M**anipulation.
- Free and open-source toolbox of C++ libraries, licensed under the GNU General Public Licence.
- Produced by *OpenCFD Ltd*.
- The development started in the late 80s at Imperial College of London.
- Mostly used for computational fluid dynamics.

Discretisation of equations in *OpenFOAM*

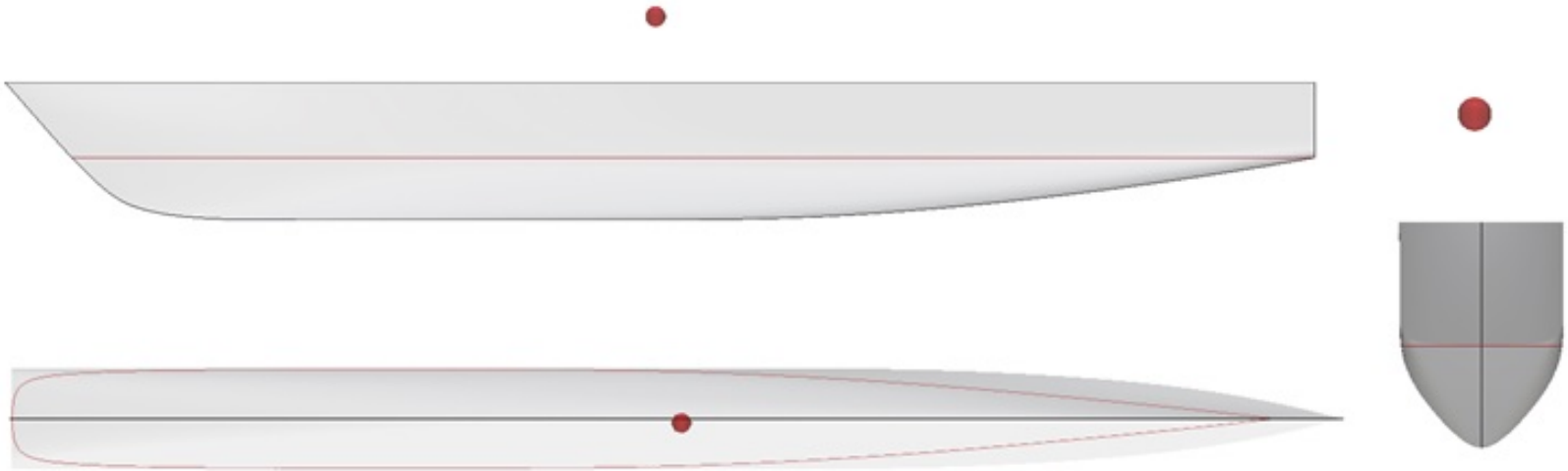
$$\frac{\partial \mathbf{U}}{\partial t} + \nabla \cdot (\phi \mathbf{U}) - \nabla \cdot (\nu \nabla \mathbf{U}) = -\nabla p$$

```
UEqn
(
    fvm::ddt(U)
  + fvm::div(phi, U)
  - fvm::laplacian(nu,U)
);

solve(UEqn() == -fvc::grad(p));
```

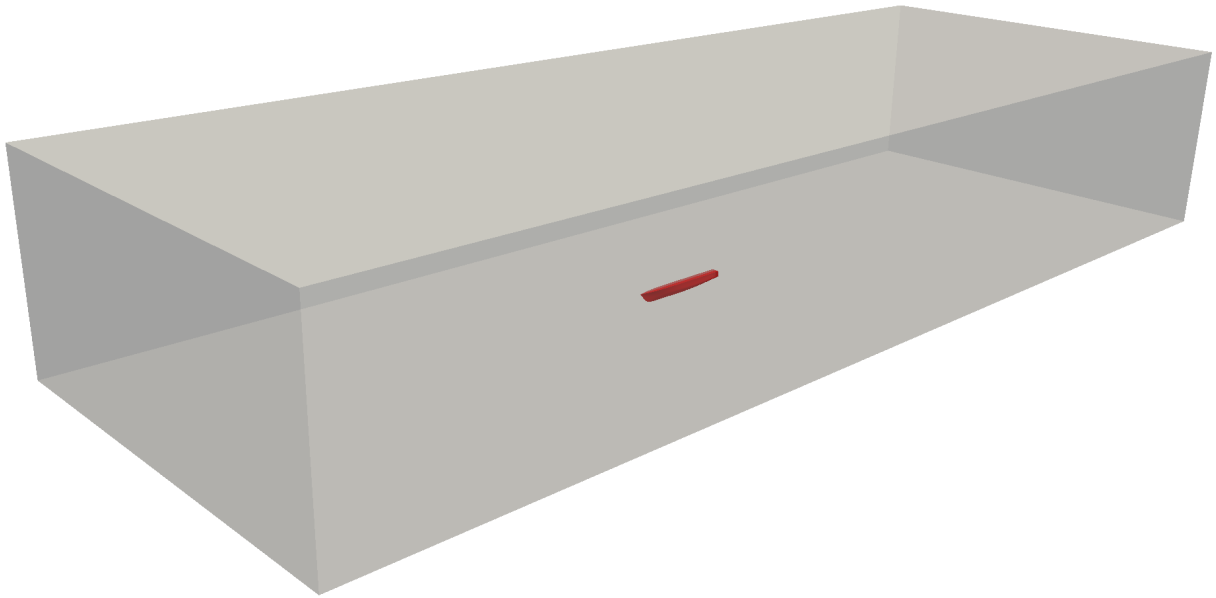
Geometry

- Delft 372 monohull
  - Length $= 3.0\,\mathrm{m}$
  - Mass $= 43.5\,\mathrm{kg}$
  - CoG $= (1.41 \quad 0.0 \quad 0.34)\ \mathrm{m}$



Numerical details

- URANS multiphase simulation using VoF method
- 2Dof (pitch and sink) dynamic simulation
- $k - \omega$SST turbulence model
- 2.45 mln cells domain dimension
- Froude range from 0.4 to 0.8



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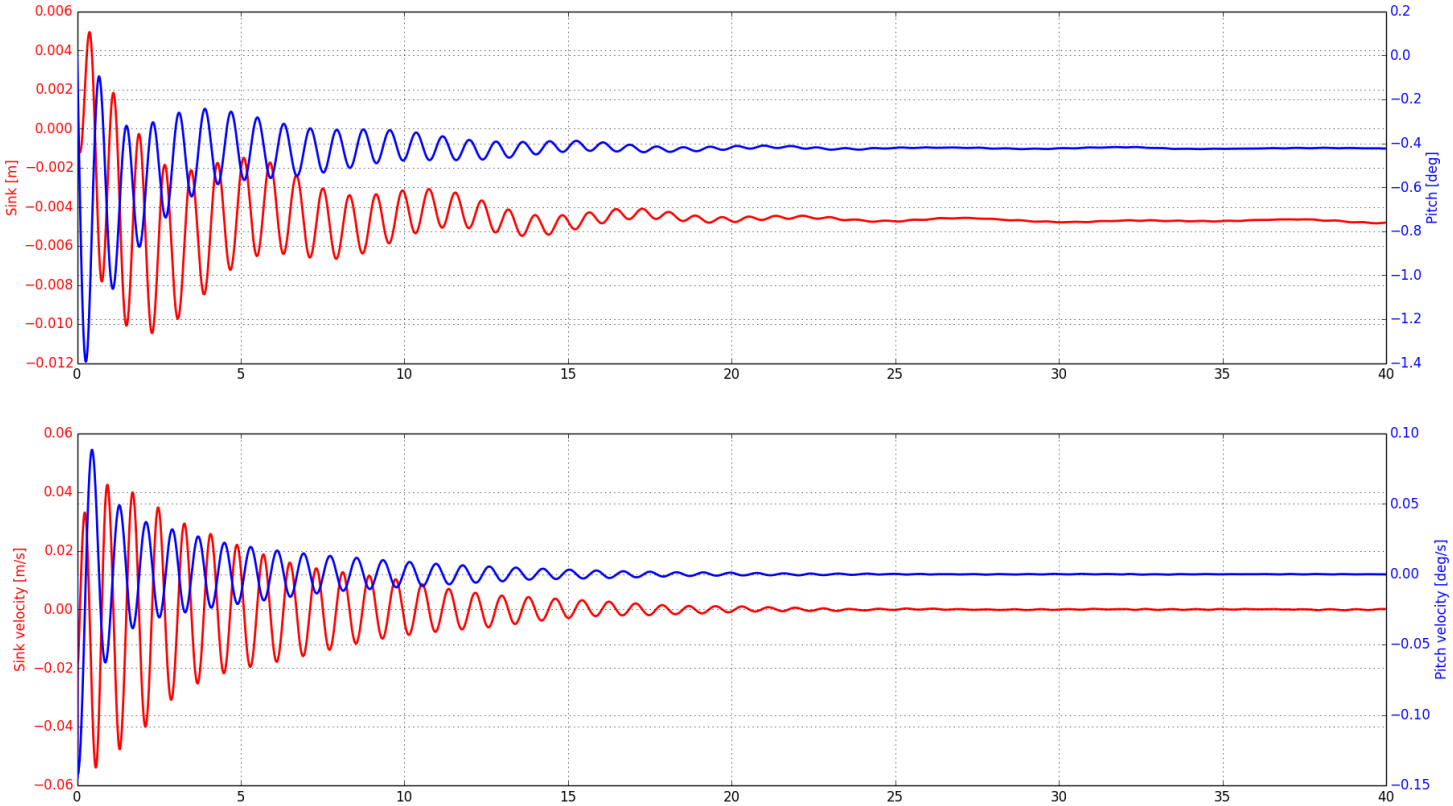
VoF method in *OpenFOAM*

Two-phase algorithm in *OpenFOAM* is *interFoam*, based on VoF method:

- Specie transport equation used to determine the phase fraction α in each cell.
- Physical properties are calculated as weighted averages based on this fraction.
- Interface between the species is not explicitly computed.
- Interface is a property of the phase fraction field.

Results
Dynamic @ Fr = 0.4



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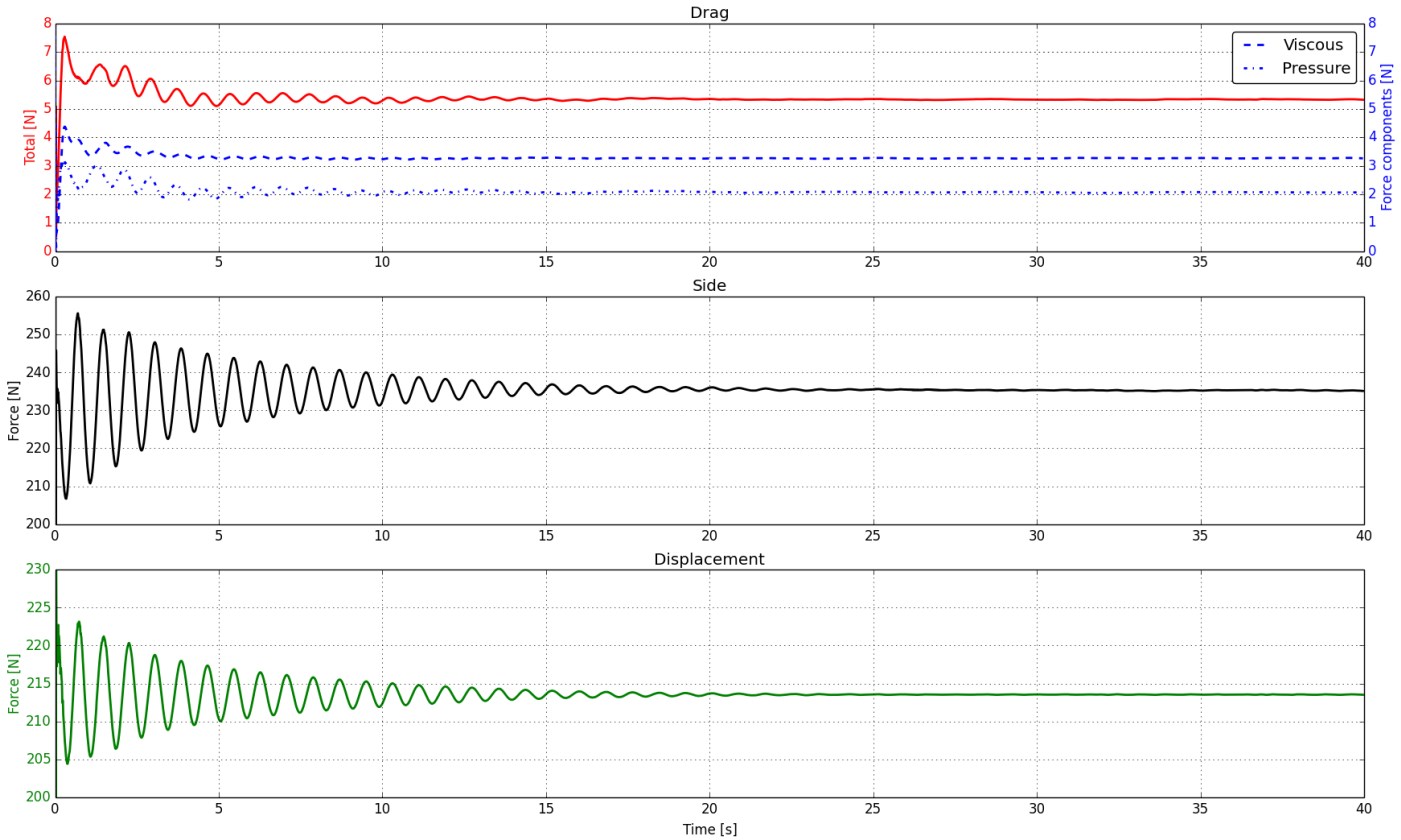
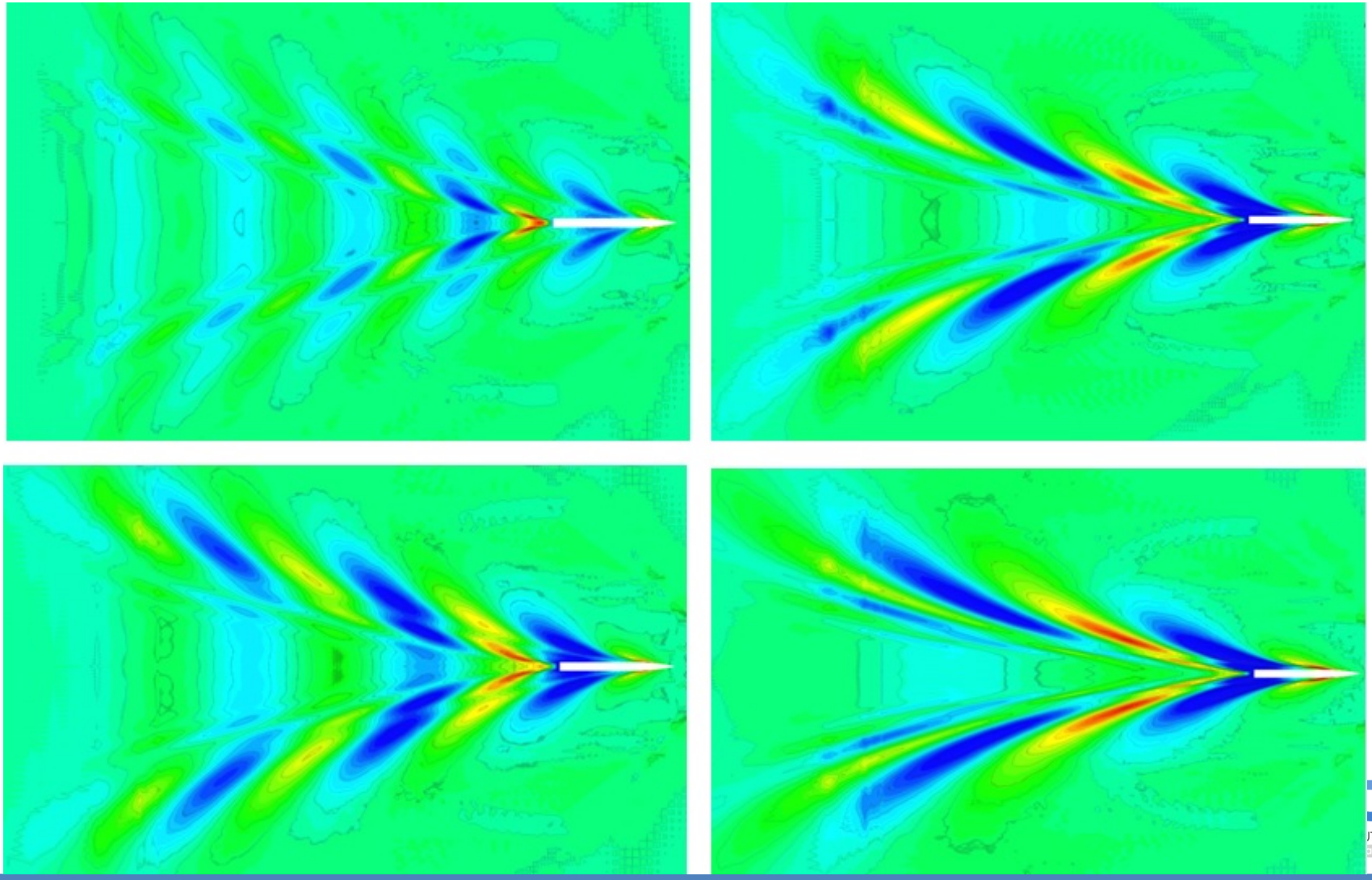
Results
Forces @ Fr = 0.4



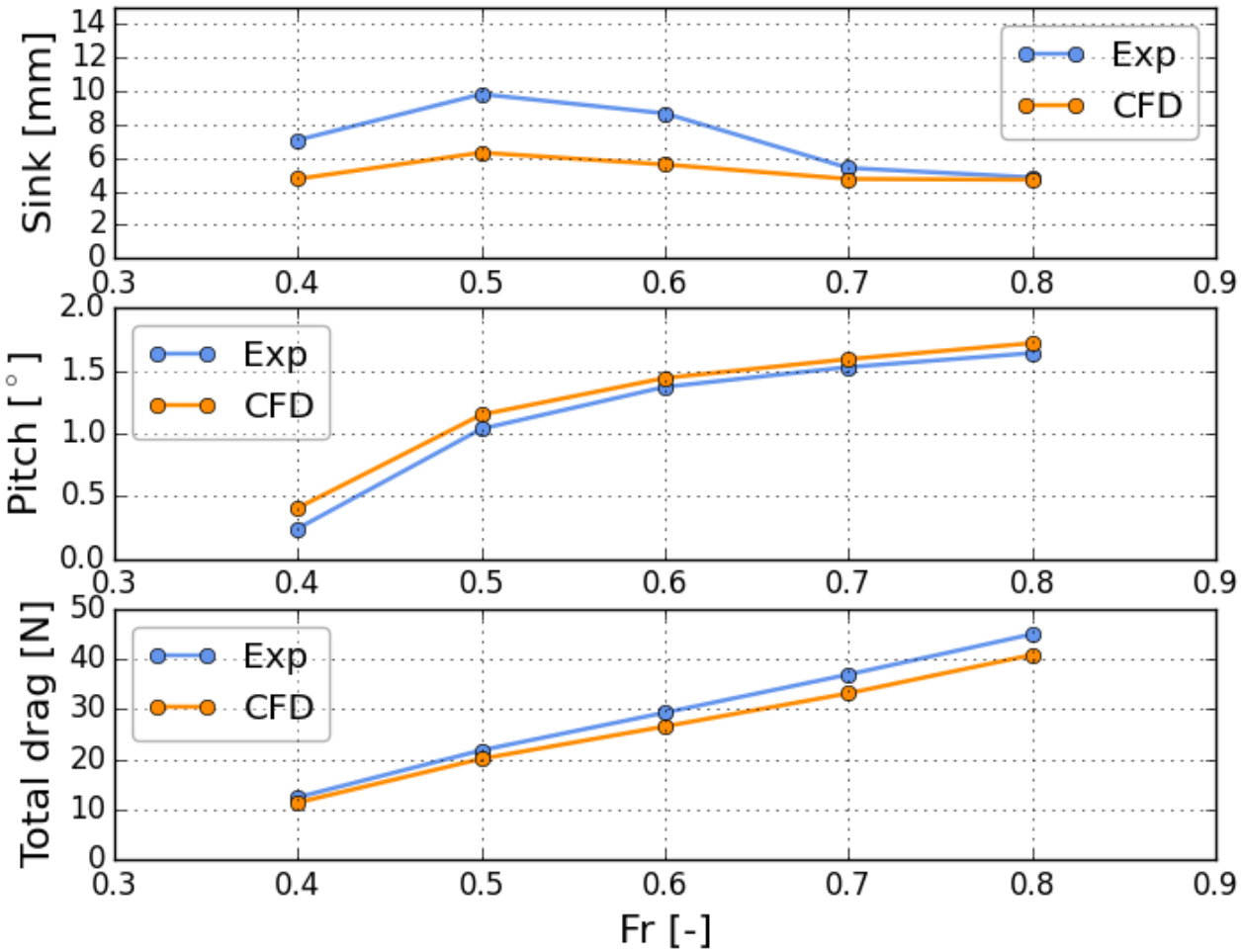
Results
Elevation



Results
Attitude @ Fr = 0.8

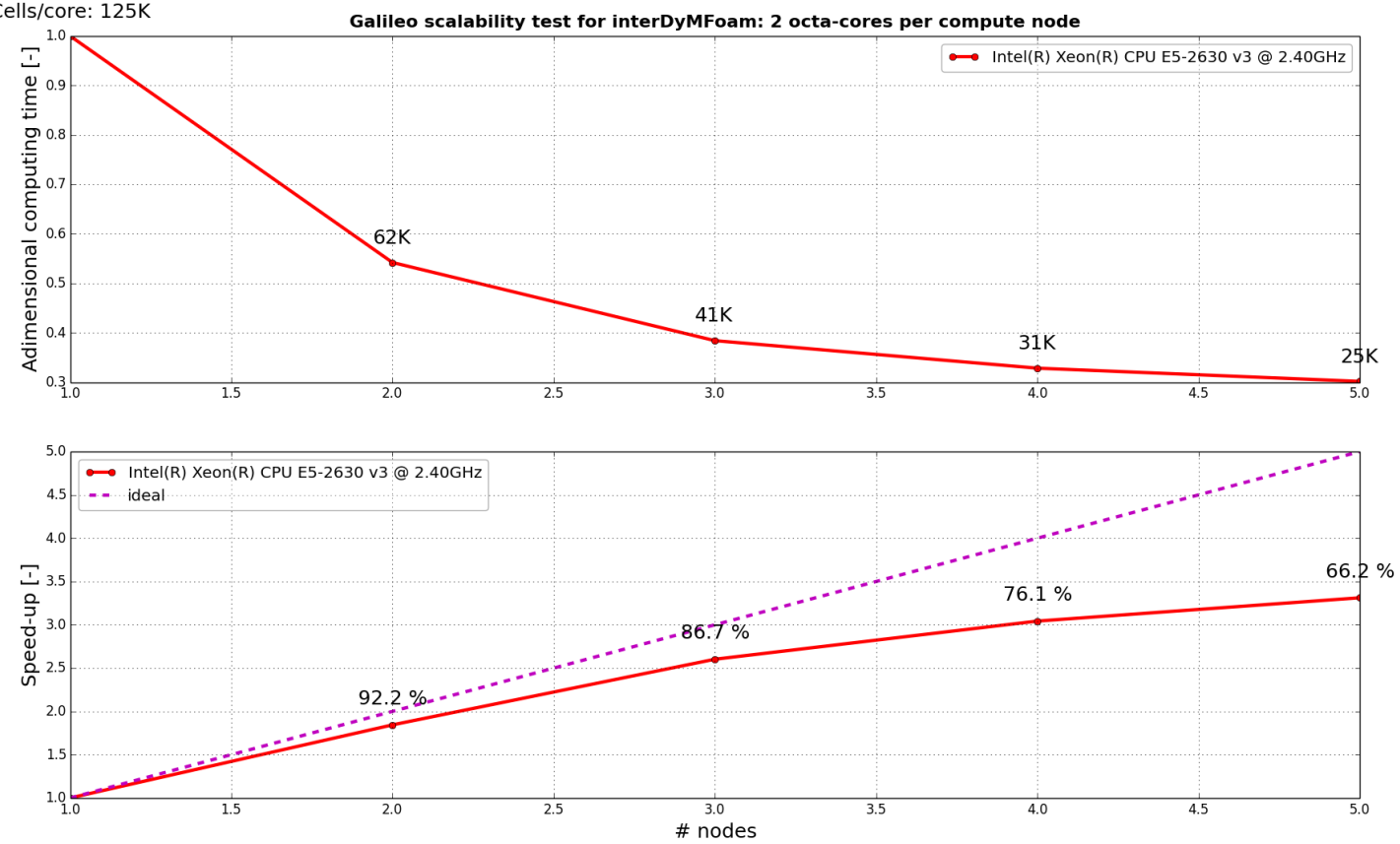
Figure : In red the final attitude

Results
CFD vs Exeriment



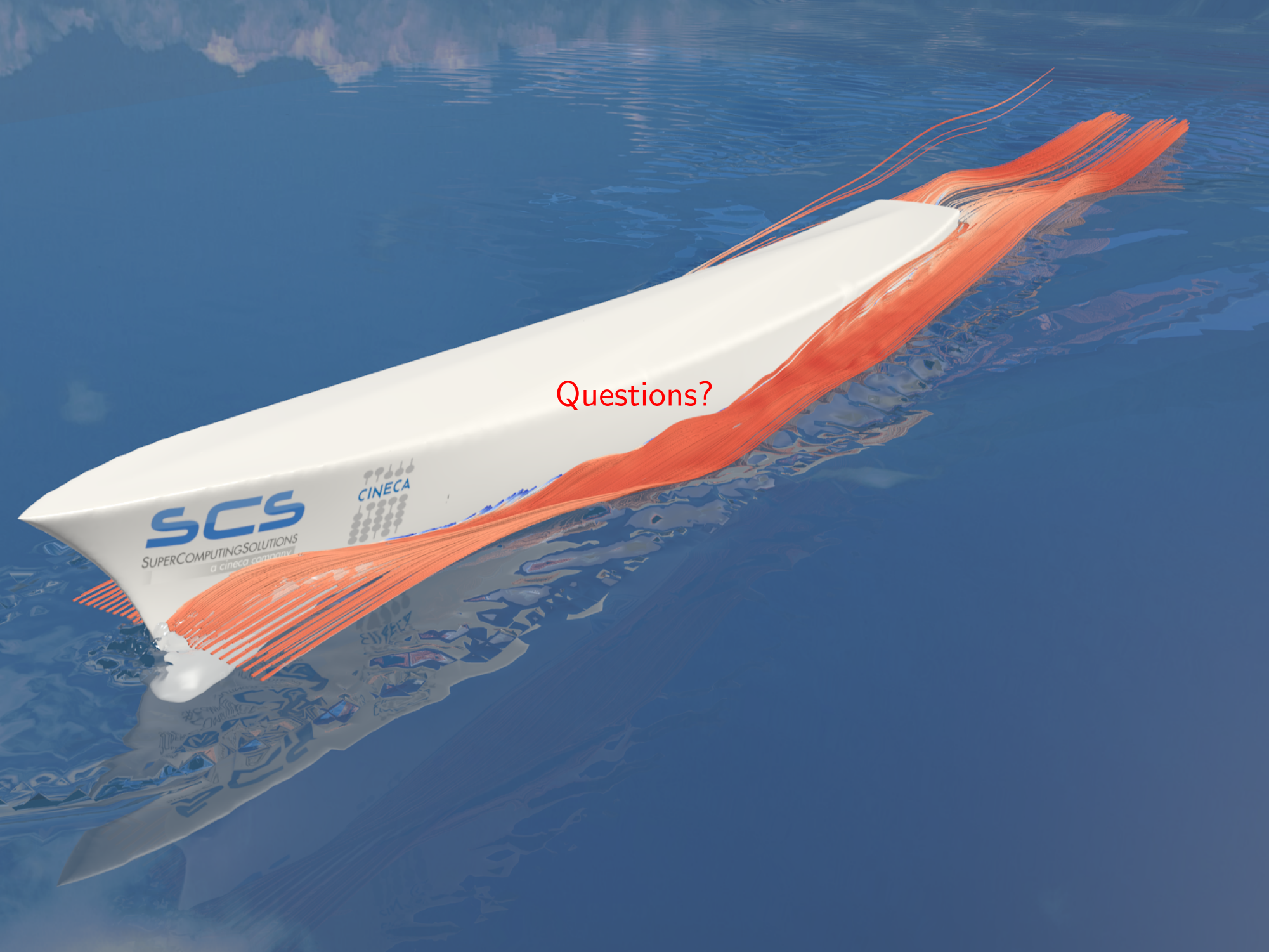
Scalability

Cells/core: 125K



Conclusions

- Open-source softwares can be competitive with respect to the commercial ones.
  - Open-source: high costs to set it properly, low cost of simulation (cost/corehour, no license)
  - Commercial codes: low costs for the setup, high cost of simulation (cost/corehour, license)
- OpenFOAM, coupled with HPC facilities, can drastically reduce the cost and the time-to-results of each simulation.
- High automatization can further improve the productivity.
- Absence of license is a DoF to scale up to maximum efficiency.


Questions?
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