Sveučilište u Zagrebu
Fakulteta strojarstva i brodogradnje

Validation of Finite Volume Immersed Boundary Method

Hrvoje Jasak, Damir Rigler, Željko Tuković

Zagreb, June 2014.

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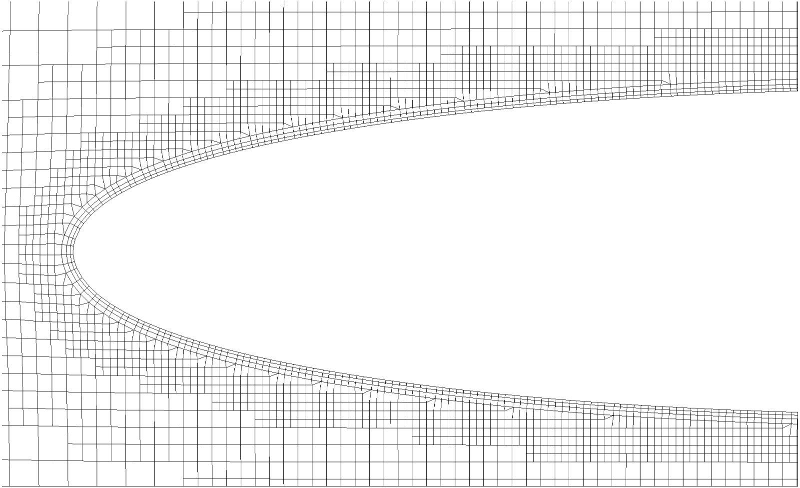
  - Surface-piercing hydrofoil (turbulent, free-surface flow)

– Conclusion

Body-Fitted Mesh

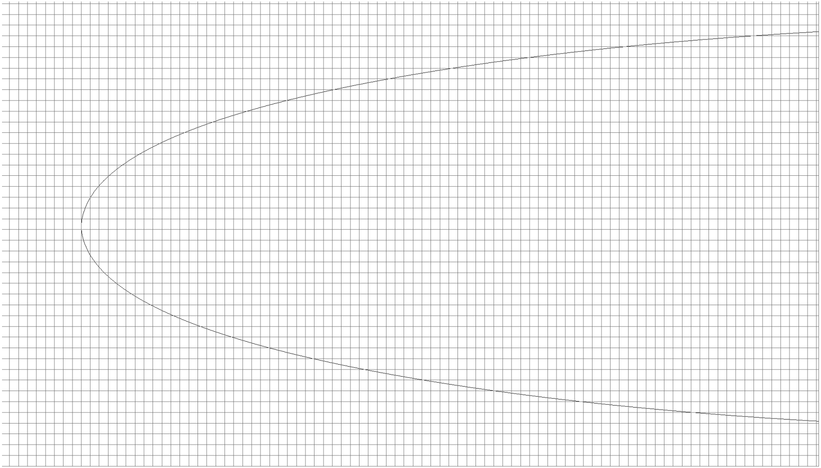
Finite Volume Method | Unstructured polyhedral mesh



Munk M3 airfoil, leading edge

Immersed Boundary Method

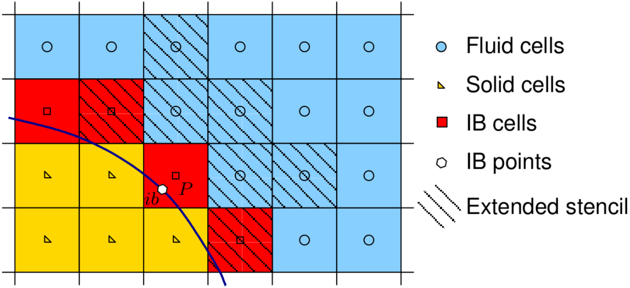
Finite Volume Method | Unstructured polyhedral mesh



Munk M3 airfoil, leading edge

Discrete forcing approach

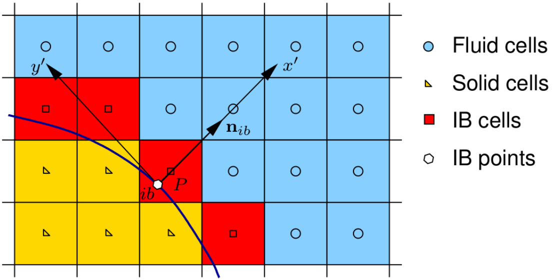
- Forcing function introduced in the cells near the Immersed Boundary
- Direct imposition of Boundary Conditions
- Quadratic interpolation



H. Jasak and Ž. Tuković *Immersed Boundary Method in OpenFOAM*, Delft 2013: 5th Dutch OpenFOAM Users Day.

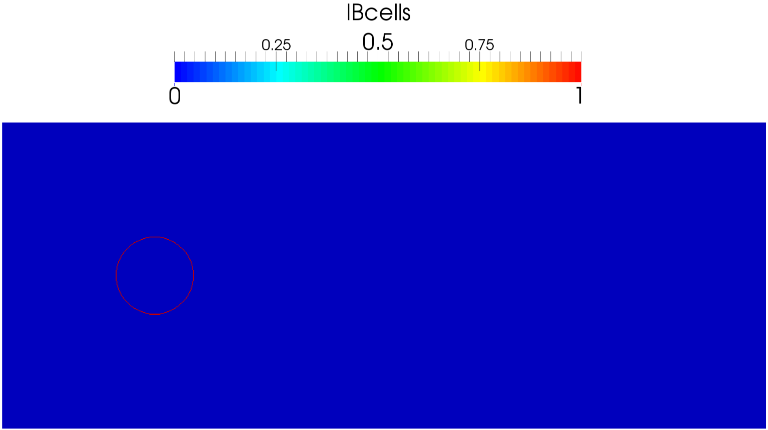
Wall functions

- RANS wall functions
  Determine region of turbulent boundary layer from near-wall k and y. Assume velocity profile on the wall.
- Immersed Boundary wall function
  Determine sampling point. Interpolate k and determine y. From those values assume velocity profile on the wall. Apply only to tangential velocity component.



H. Jasak and Ž. Tuković *Immersed Boundary Method in OpenFOAM*, Delft 2013: 5th Dutch OpenFOAM Users Day.

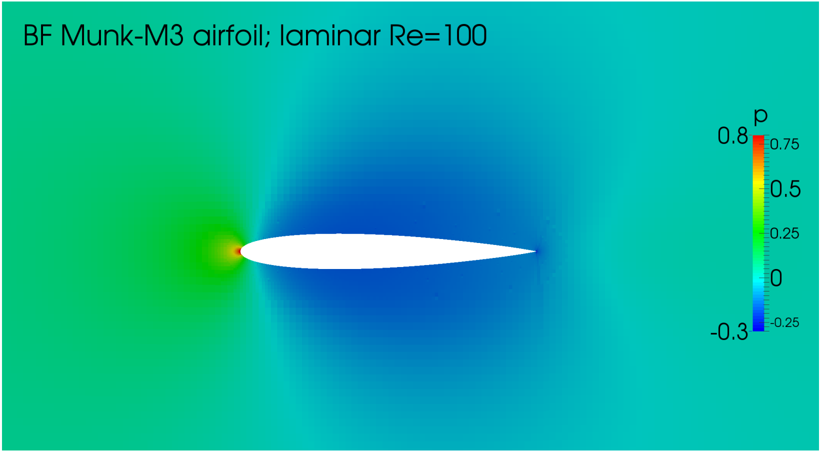
Immersed Boundary cells visualization



Cylinder in channel

Munk M3 airfoil - laminar flow

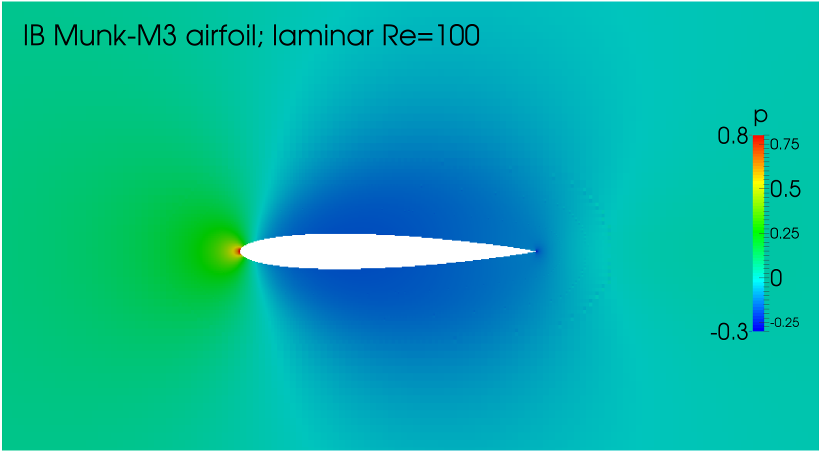
Body Fitted Mesh - pressure field



$Re = 100 \mid v_\infty = 1\,[m/s] \mid \nu = 0.01\,[m^2/s] \mid L = 1\,[m]$

Munk M3 airfoil - laminar flow

Immersed Boundary Method - pressure field



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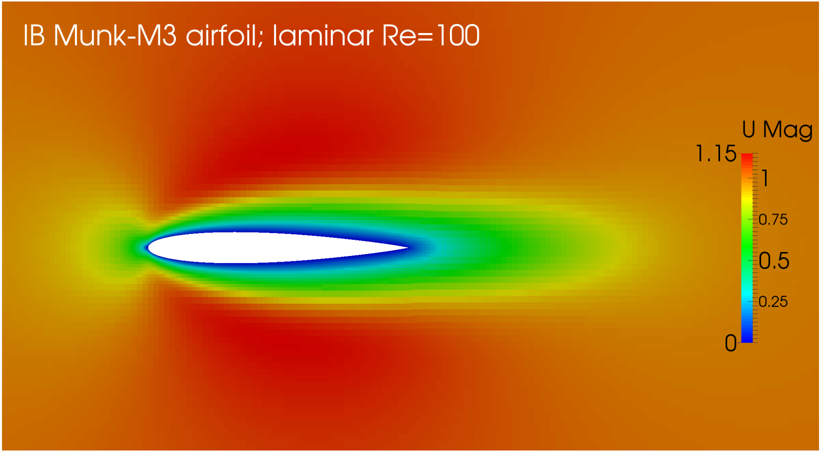
Munk M3 airfoil - laminar flow

Body Fitted Mesh - velocity field



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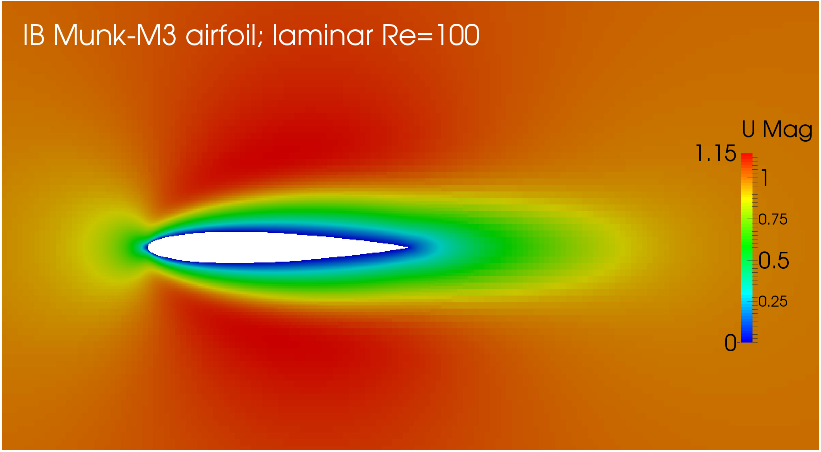

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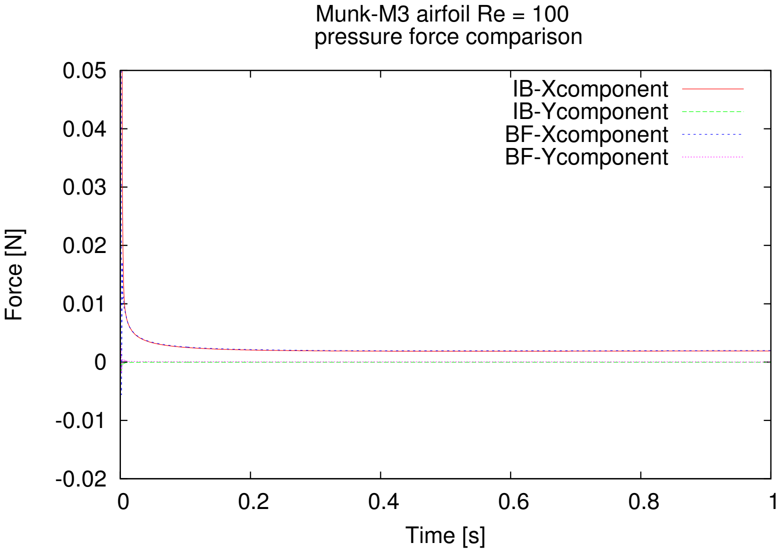
Munk M3 airfoil - laminar flow



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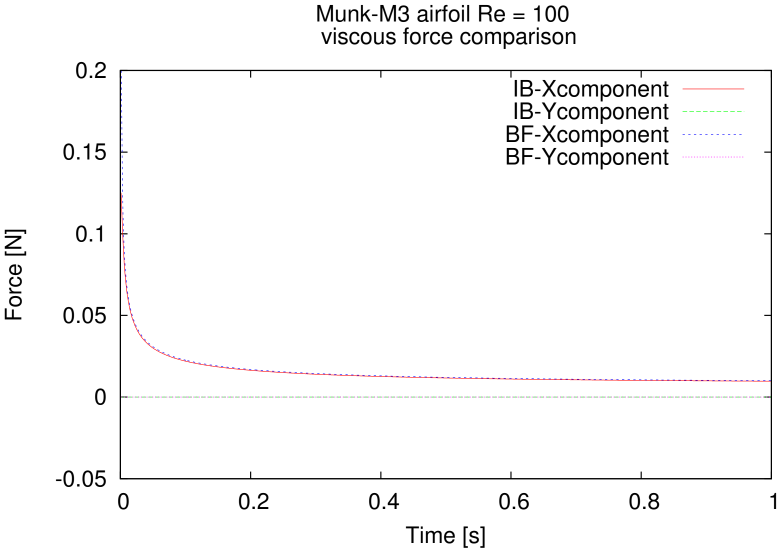

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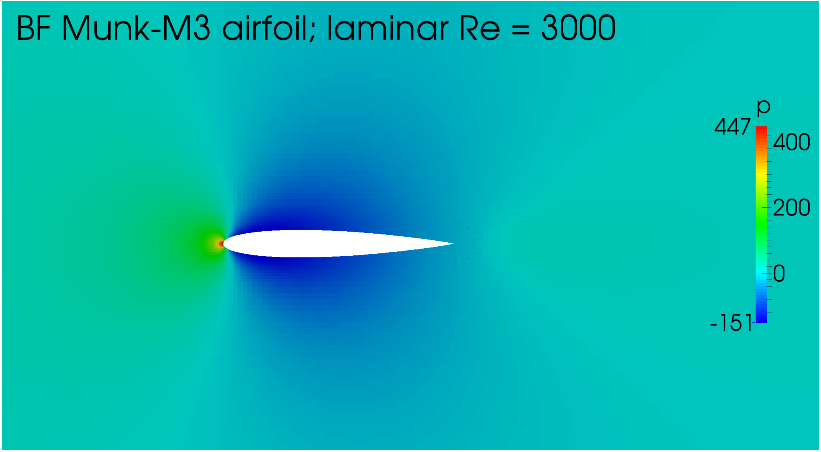
Munk M3 airfoil - laminar flow

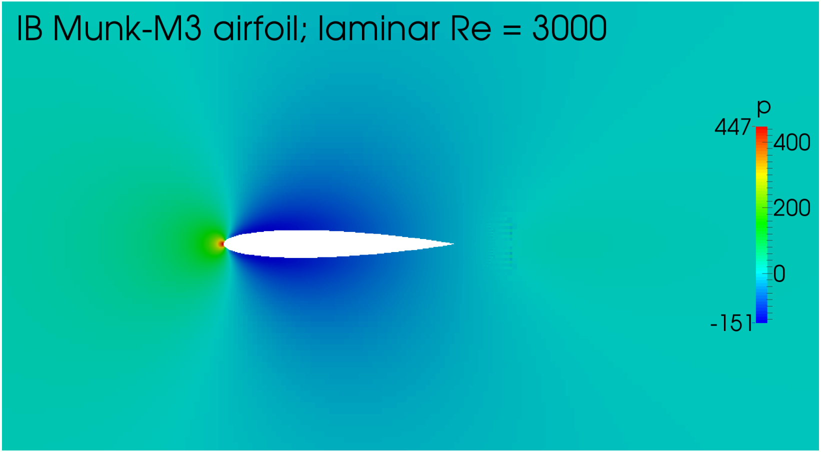
Body Fitted Mesh - pressure field



$Re = 3000 \mid v_\infty = 30\,[m/s] \mid \nu = 0.01\,[m^2/s] \mid L = 1\,[m]$

Munk M3 airfoil - laminar flow

Immersed Boundary Method - pressure field



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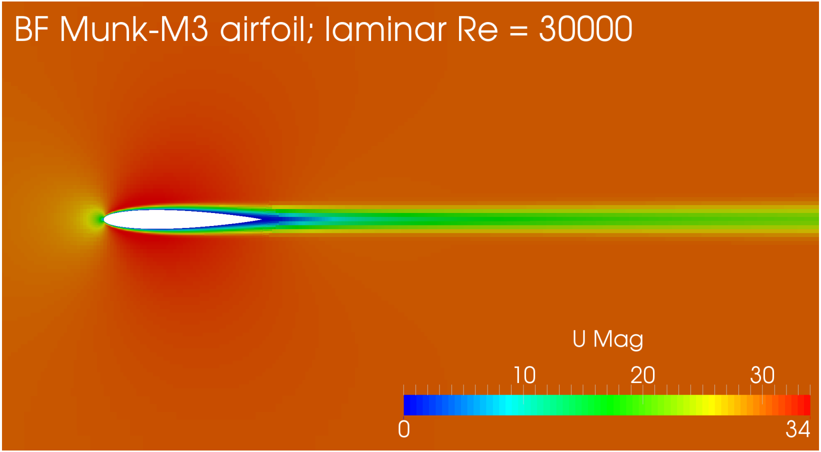
Munk M3 airfoil - laminar flow

Body Fitted Mesh - velocity field



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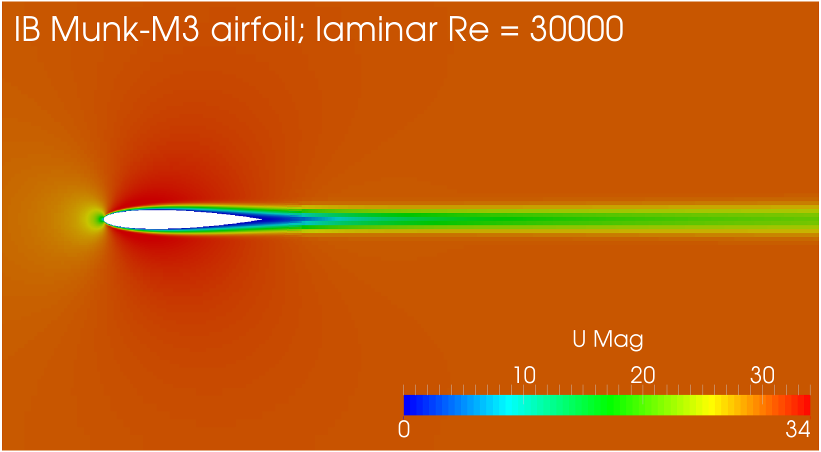
Munk M3 airfoil - laminar flow

Immersed Boundary Method - velocity field



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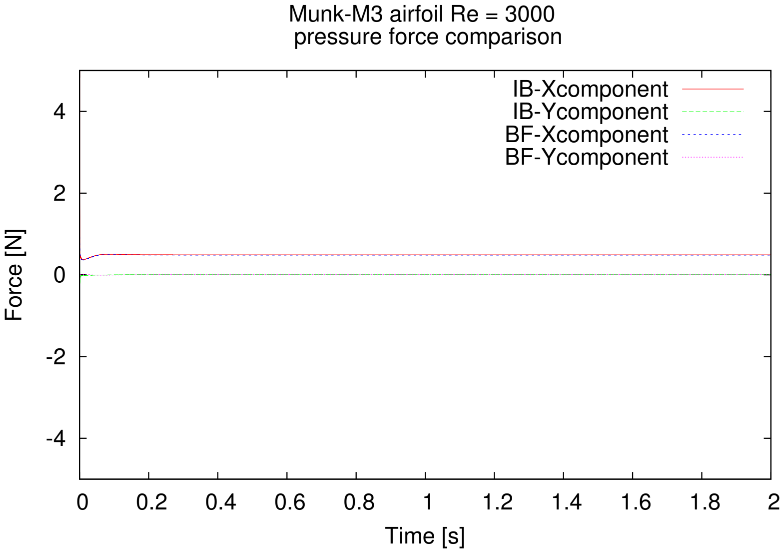

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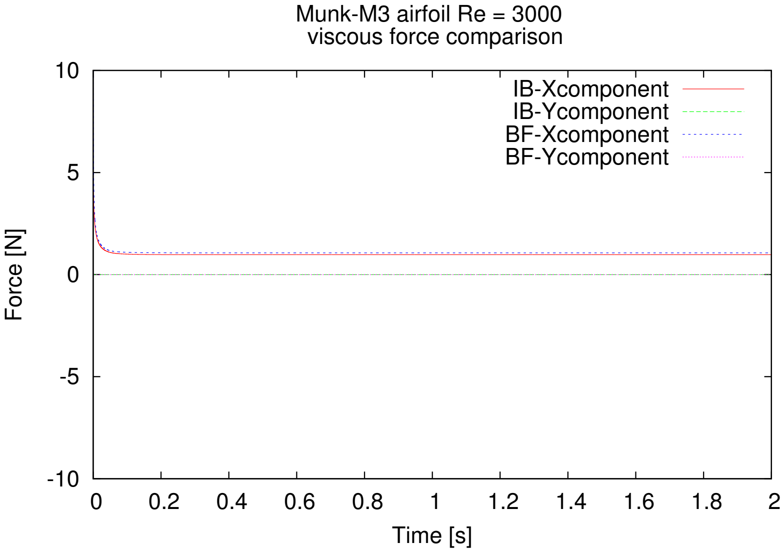

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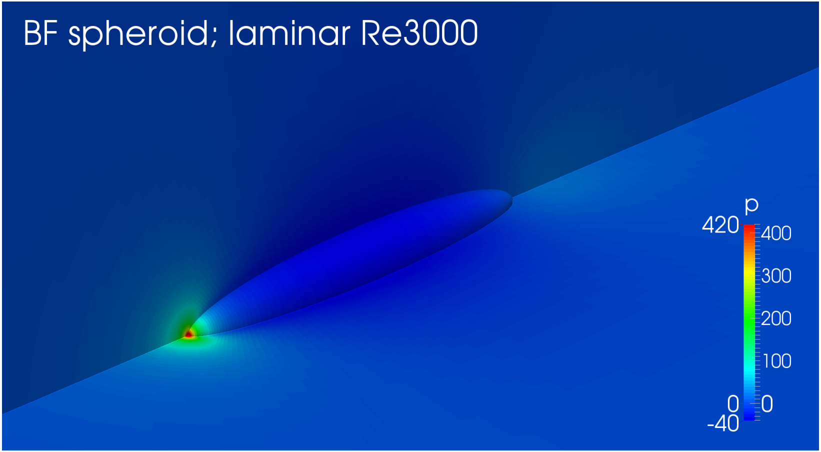
Spheroid - laminar flow

Body Fitted Mesh - pressure field



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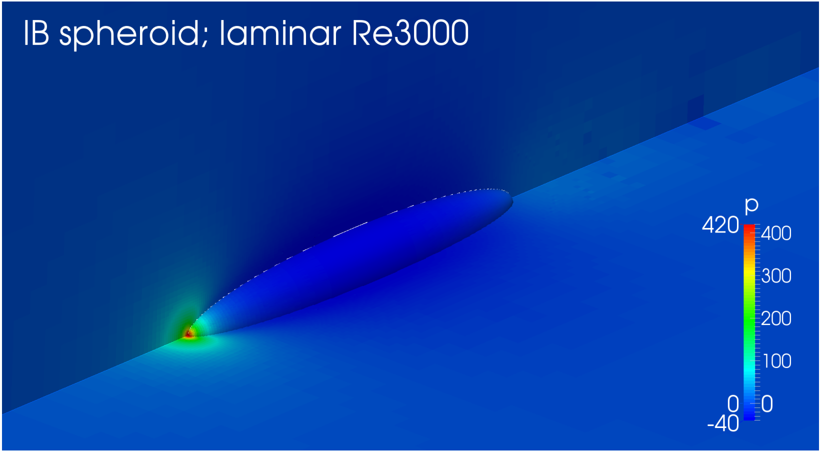
Spheroid - laminar flow

Immersed Boundary Method - pressure field



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Spheroid - laminar flow

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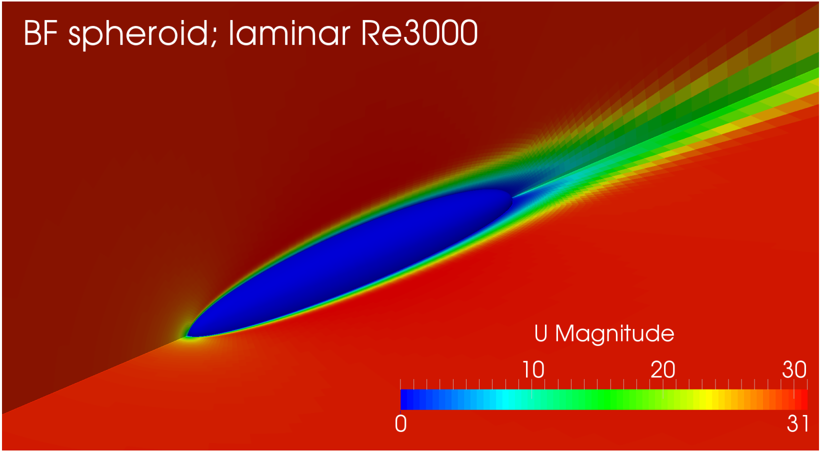

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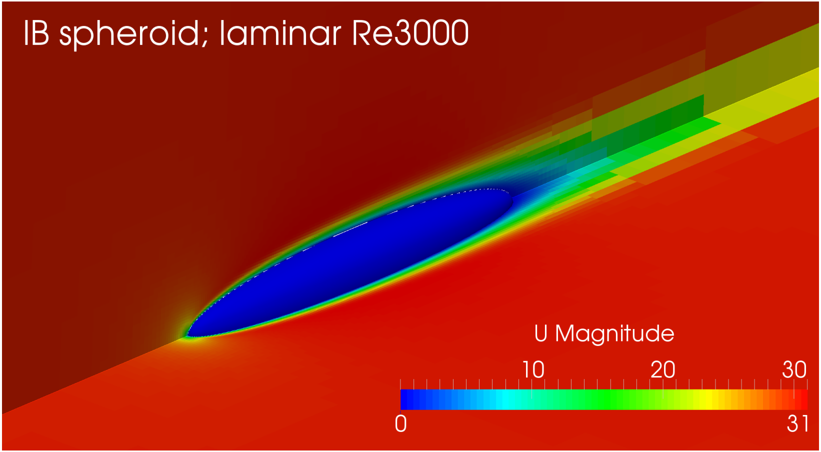

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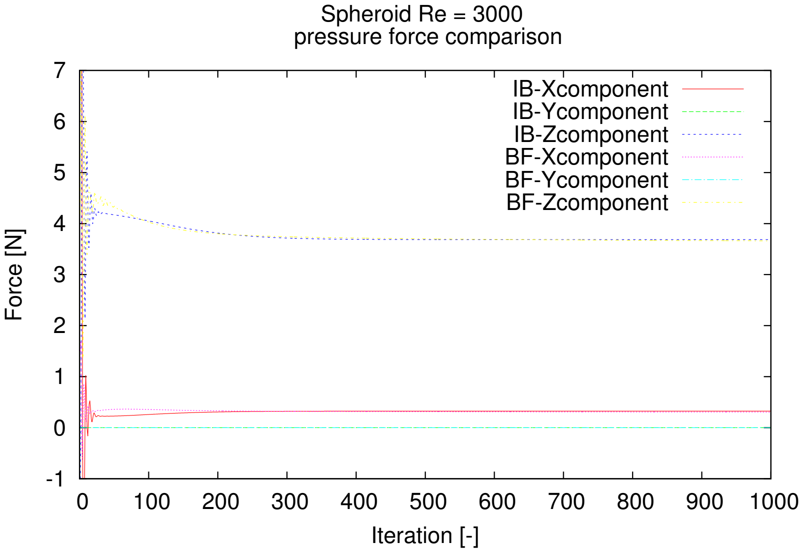

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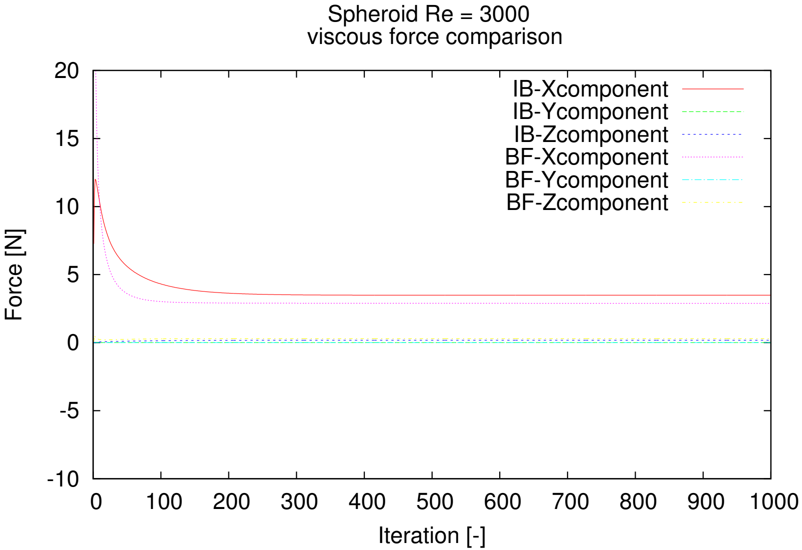

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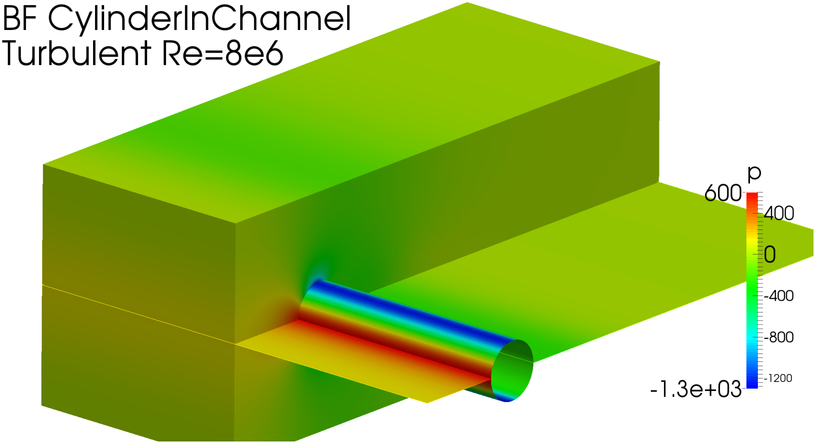
Cylinder in channel - turbulent flow

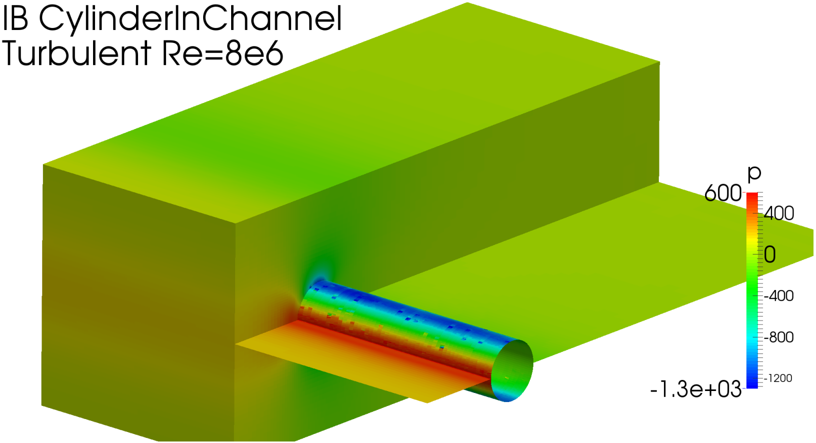
Body Fitted Mesh - pressure field



$$Re = 8 \cdot 10^6 \mid v_\infty = 30\,[m/s] \mid \nu = 3.75 \cdot 10^{-6}\,[m^2/s] \mid L = 1\,[m]$$

Cylinder in channel - turbulent flow

Immersed Boundary Method - pressure field



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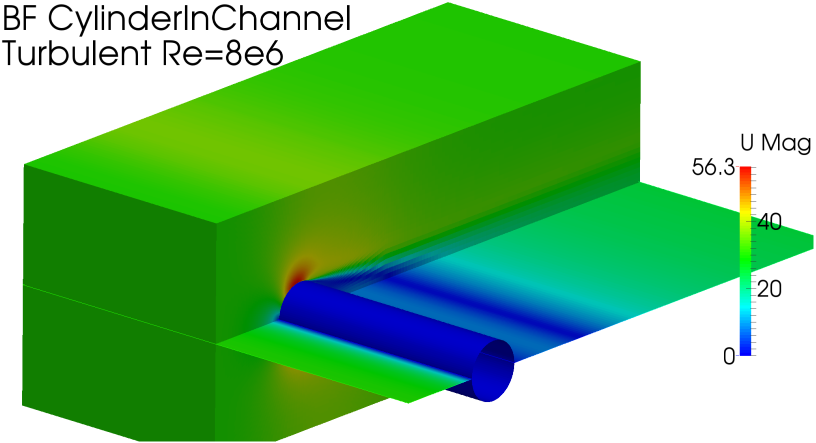
Cylinder in channel - turbulent flow

Body Fitted Mesh - velocity field



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Cylinder in channel - turbulent flow

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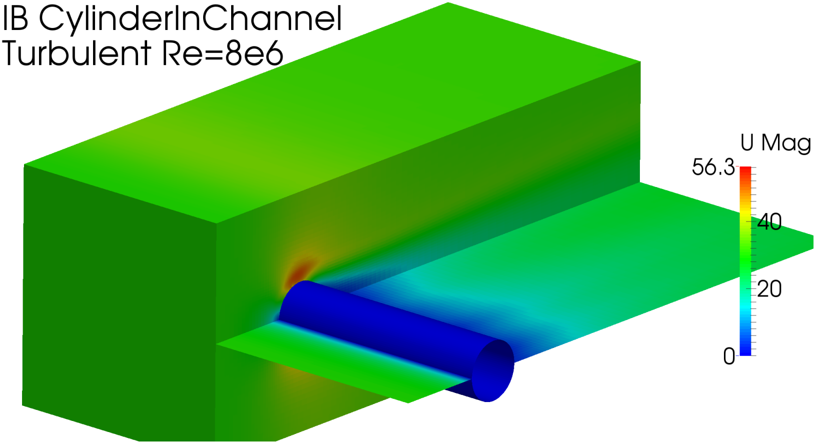

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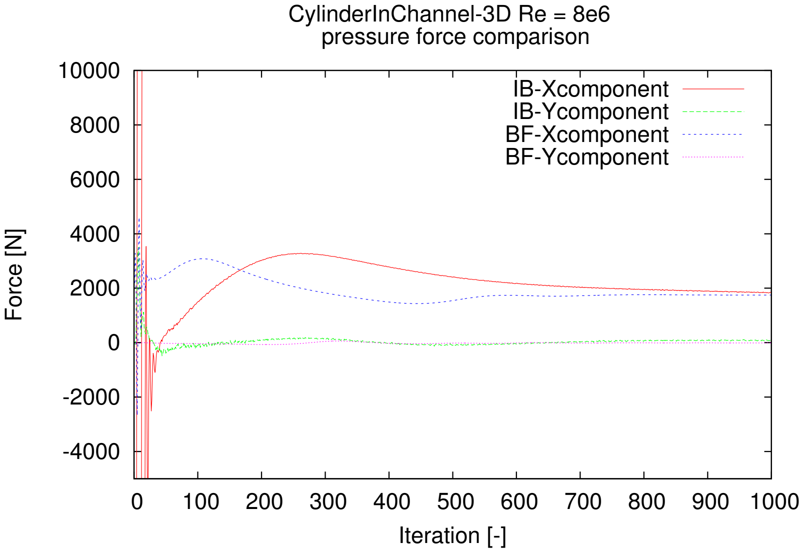

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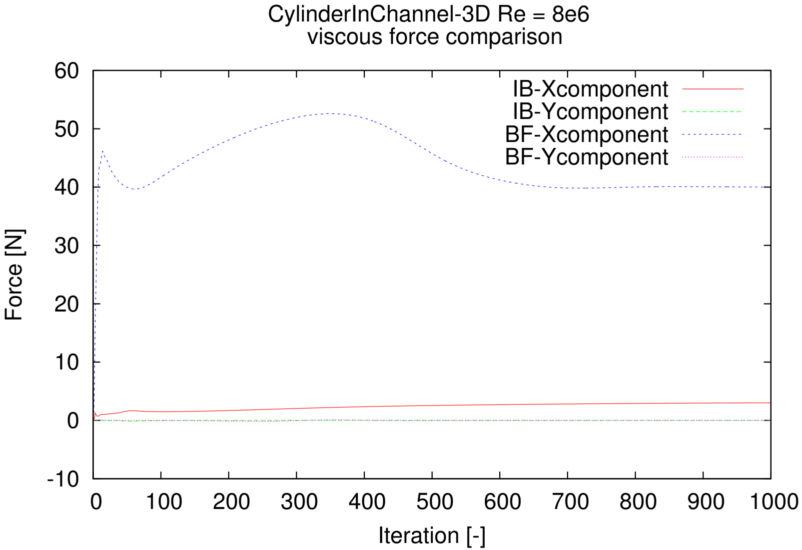

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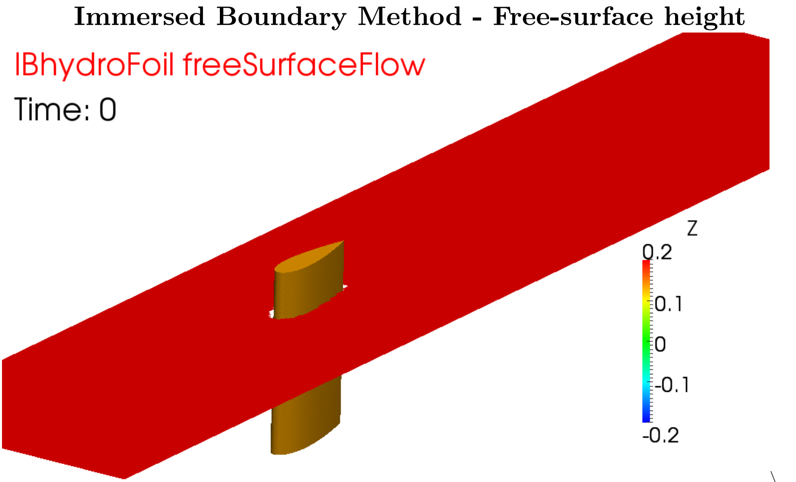
Surface-piercing hydrofoil



$Re = 3\,059\,708 \mid v_\infty = 1.887\,[m/s] \mid \nu = 1.1417004e-06\,[m^2/s] \mid L = 1.21\,[m]$

Advantages & Disadvantages

Advantages:

- Simple mesh generation
- Simple to use
- High Re flow functionality

Disadvantages:

- Accuracy in some cases
- Surface mesh quality important

Wish list:

- Parallelization
- Turbulent viscous forces calculation fix
- Implementation of advanced turbulence models

Thank you