Incompressible Navier-Stokes methods for wind turbine applications

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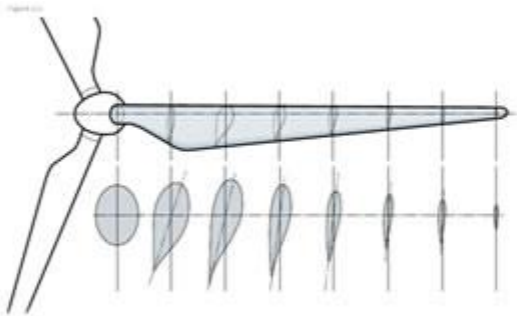
Outline

- Introduction
- Current tools
- CFD at ECN
- Test Cases
- Future Work

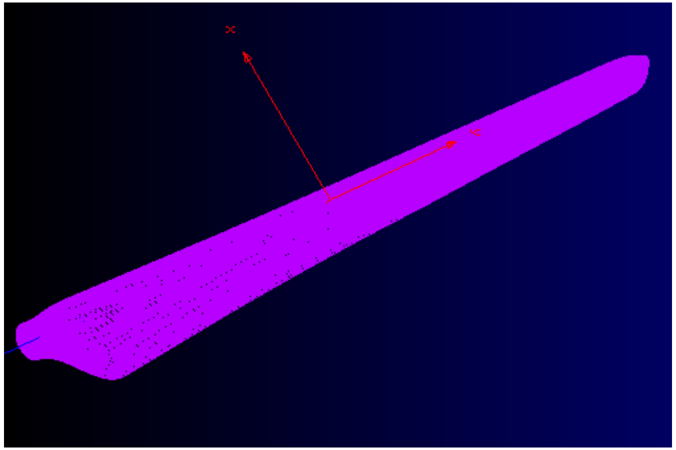
Introduction: Aerodynamics in wind energy applications

Aerodynamics plays an important role in harnessing wind energy.



Airfoils

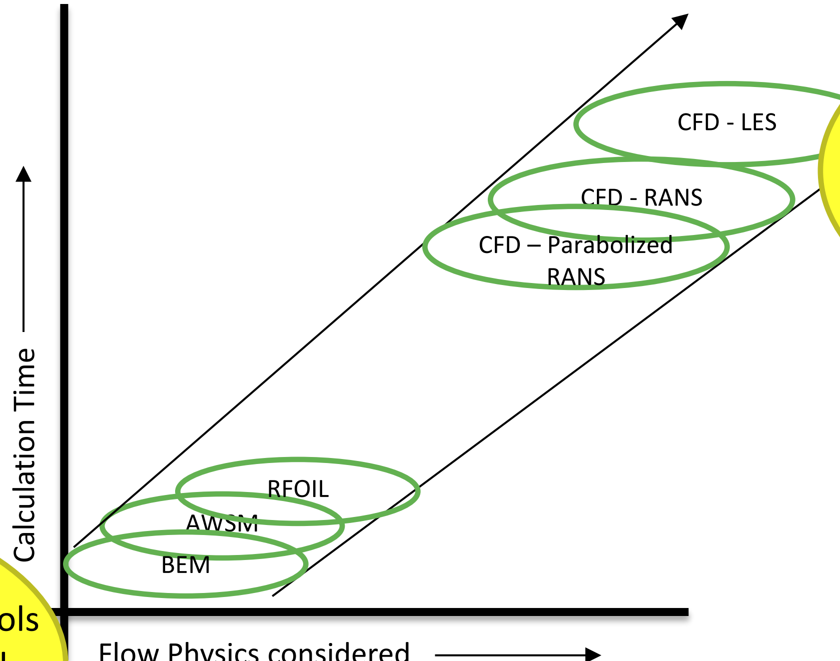
Blades



Wind turbines

Wind farms

Current Aerodynamic Tools



CFD simulations on the other hand, even though expensive, give very accurate results and model physics appropriately

Most of our performance predictions tools and design tools like BEM, AWSM, XFOIL, RFOIL rely on steady state approaches and simplifying assumptions.

CFD at ECN

- The **open-source** tool **SU²** is a density-based (compressible) **RANS** solver,
- Artificial Compressibility for incompressible applications – Very limited,
- Has **continuous and discrete adjoint** capabilities to design and optimization of airfoils/blades.
- Developing an **incompressible Navier-Stokes** for wind energy applications.

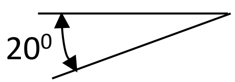
The goal of this PhD project: A **pressure-based solver within SU²** for highly separated flows and unsteady simulations (i.e., vortex generators, thick trailing edges, etc.)

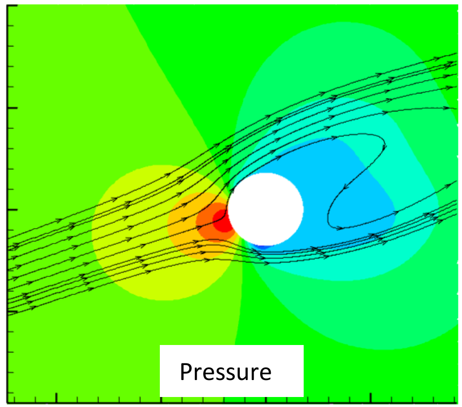
As a part of the project, we are developing a separate research code **iNS**, which mimics SU², to be used as a test bed for new ideas.

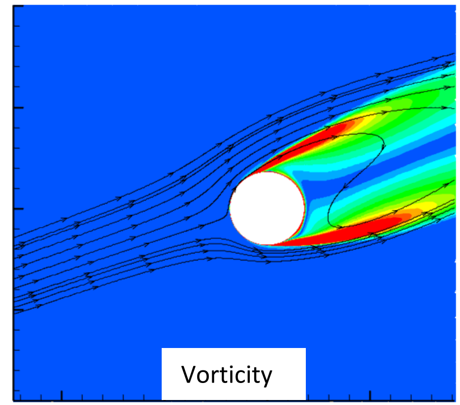
Test Cases

- SU2
  - Flow over cylinder with bumps to test capabilities of incompressible (artificial compressibility) solutions for wind energy application like VGs
  - Couette flow to test the ability to solve rotational flows
- iNS
  - Mimic SU2 – density based (artificial compressibility) implementation
  - Pressure based (incompressible) implementation

Sample Cases: Cylinders with bumps (SU², steady, artificial incomp)

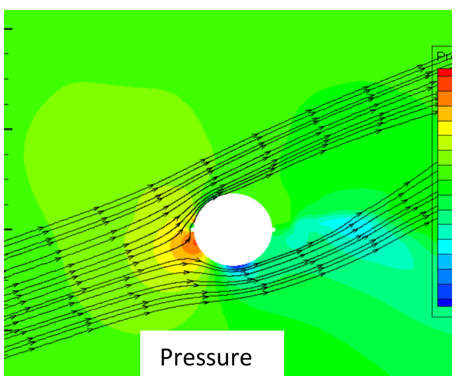


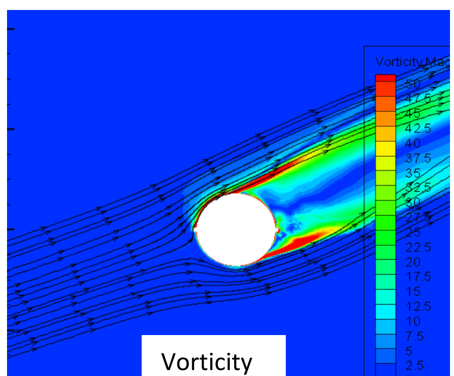




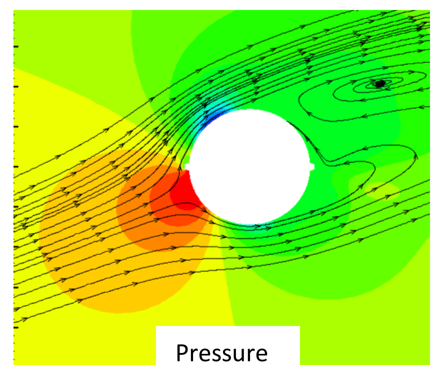
Cylinder at 30 m/s, 20 degree AoA
No bumps (clean)

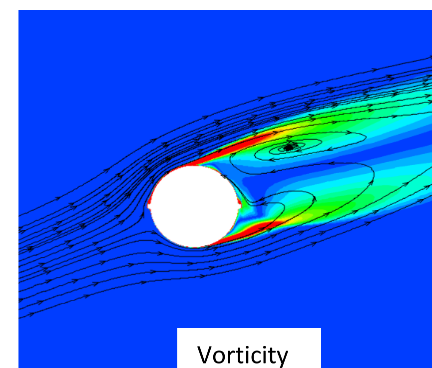
Cylinder with bumps in fully turbulent field, 30 m/s AoA = 20



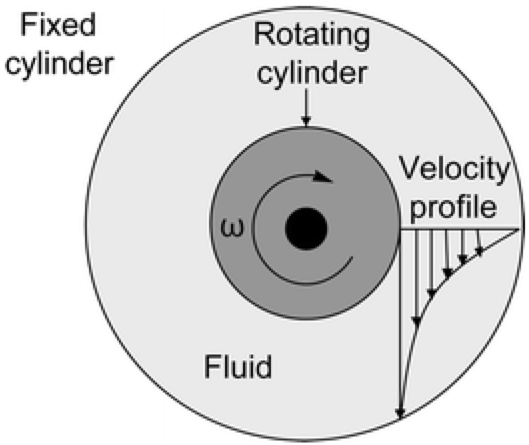


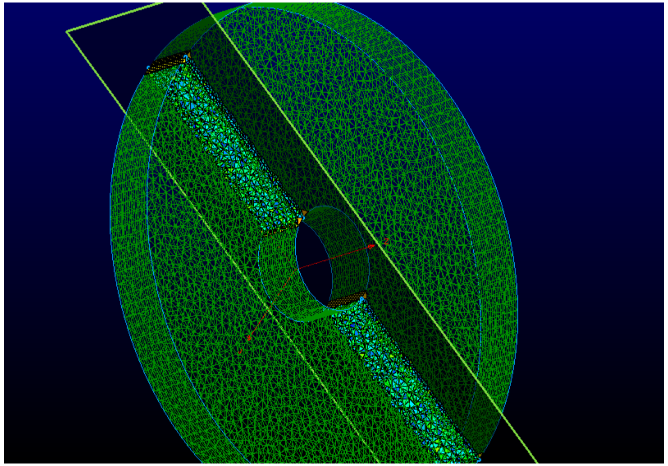
Cylinder with bumps in flow with transition, 30 m/s AoA = 20





SU² test case:
Couette Flow - A rotating body in a fluid





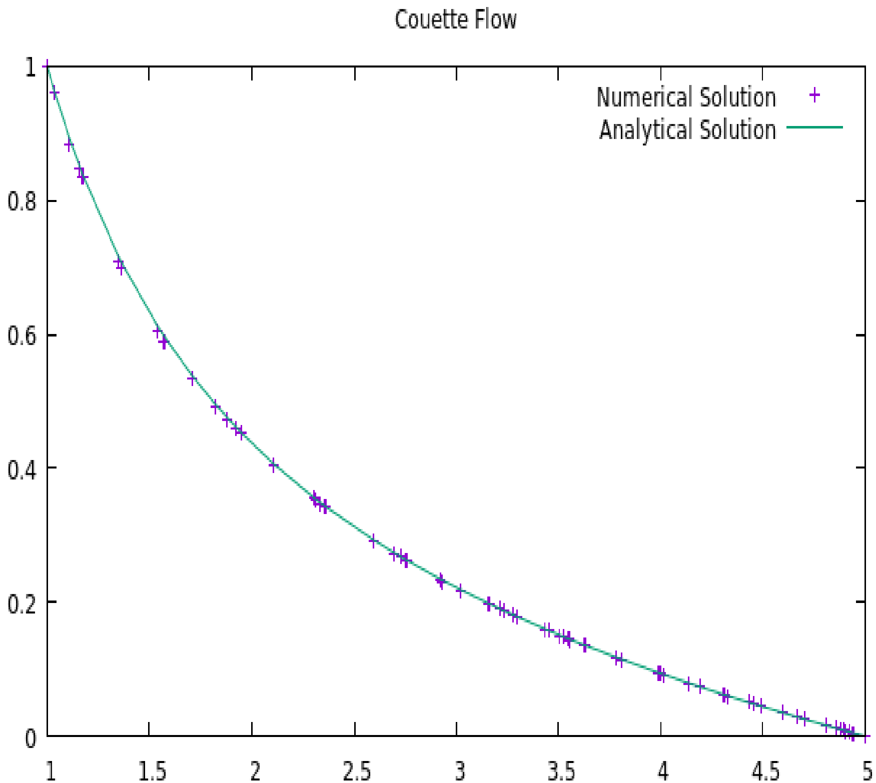
Case Setup
Steady State
Rotating wall
Artificial Compressibility
Re = 1

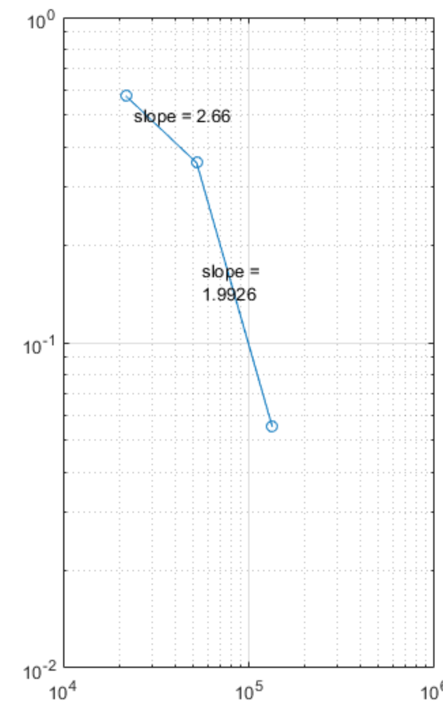
Mesh details
Tet Cells
No. of cells ~ 22k, 53k and 113k

Consists of a fluid region enclosed between a rotating inner wall and a fixed outer wall. Results compared against analytical solution

$$u_\theta(r) = r_0\omega_0 \frac{r_1/r - r/r_1}{r_1/r_0 - r_0/r_1} + r_1\omega_1 \frac{r/r_0 - r_0/r}{r_1/r_0 - r_0/r_1}$$

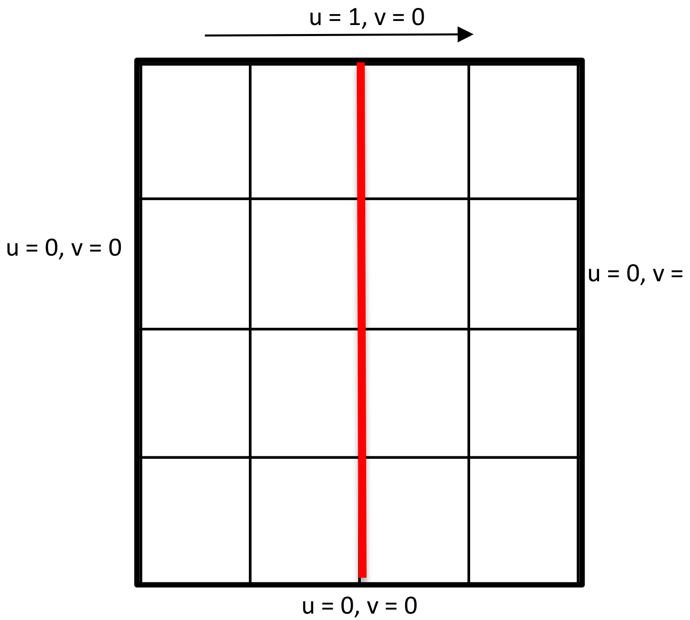
SU² test case:
Couette Flow - A rotating body in a fluid



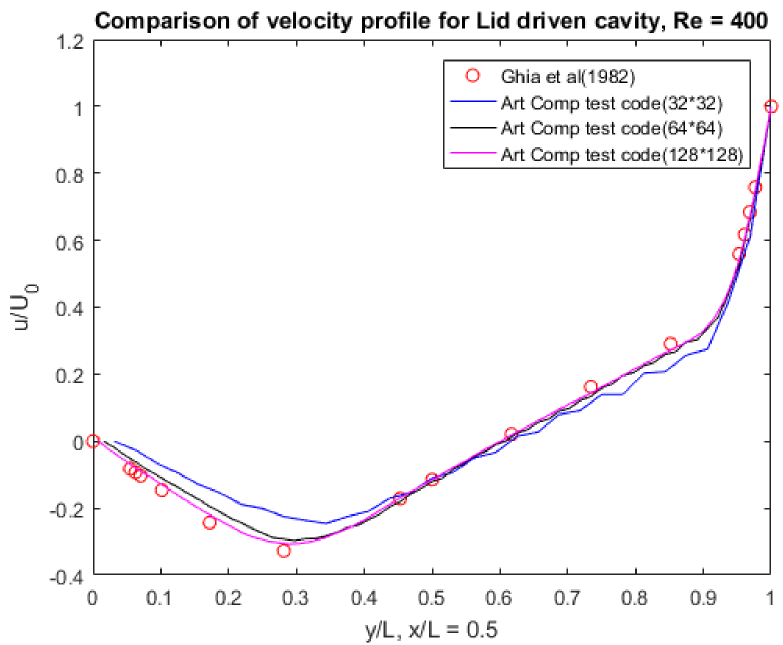


Incompressible Navier-Stokes Research Code(iNS)

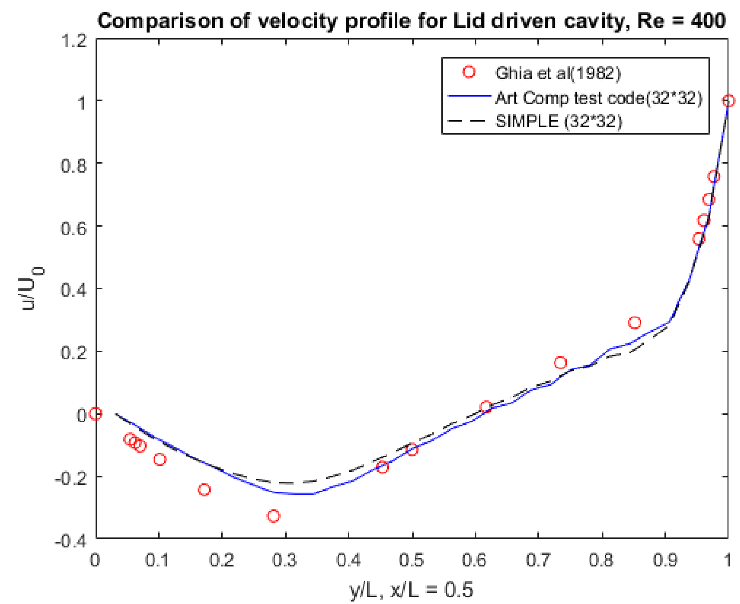
- A Navier-Stokes research code(iNS) with density based and pressure based approaches is being developed.
- Results for a Lid driven cavity is presented.
- A square domain where all the walls are fixed and the top wall is moving.
- Velocity profile along the centerline (shown in red) is presented.
- Results compared against benchmarked standard solution.



Incompressible Navier-Stokes Research Code



Density-based, iNS
Mimics SU2



Pressure-based, iNS
(latest, under development)

Future Work

- Use iNS as a test bed to test and develop better pressure-based methods.
- Implement ideas from iNS for the pressure-based solver SU^2 to get more accurate results for VGs, unsteady flows etc.
- Develop Atmospheric boundary layer models and wind farm simulation tools within SU^2.

Thank you!

Thank you for your attention

This presentation is prepared and given by:

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