Influence of jet flow on the aerodynamics of a floating model wind turbine

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ISOPE-2016 Conference, Rhodes, Greece
The 26th International Ocean and Polar Engineering Conference
Rhodes (Rodos), Greece, June 26−July 1, 2016: www.isope.org;

The research leading to these results has received funding from the European Community's Seventh Framework Programme under grant agreement No. 308974 (INNWIND.EU).

Overview

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- Introduction
- Approach
- Results
- Summary and conclusion

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Introduction – research project

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INNWIND.EU Project (www.Innwind.eu)

"high performance innovative design of a beyond-state-of-the-art 10-20MW offshore wind turbine"

Including:

- design of platforms for offshore installation
- validation of different simulation tools by model tests in wave tank

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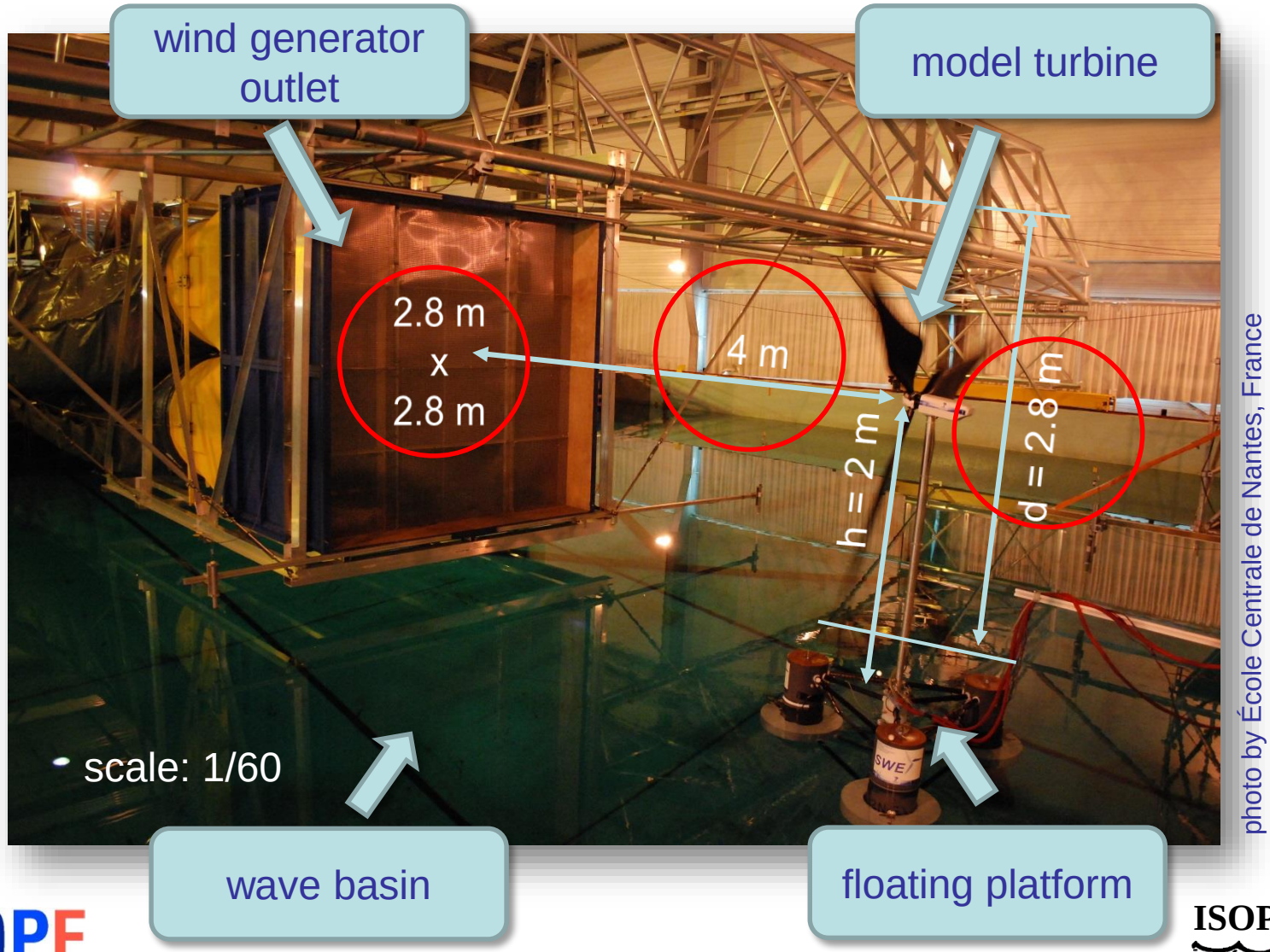
Introduction – experimental setup



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Introduction – main task

Wind generator outlet size ~ rotor diameter

Simulations:

- Most aerodynamic models (like BEM) *can't consider jet flow* and use *uniform inflow conditions*

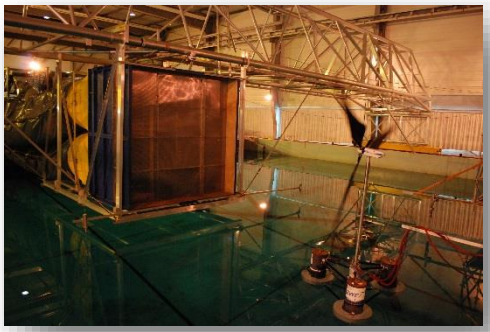

photo by École Centrale de Nantes, France

Is uniform inflow approach suitable?

- Approach needed that can consider jet flow as well as uniform inflow

→ CFD

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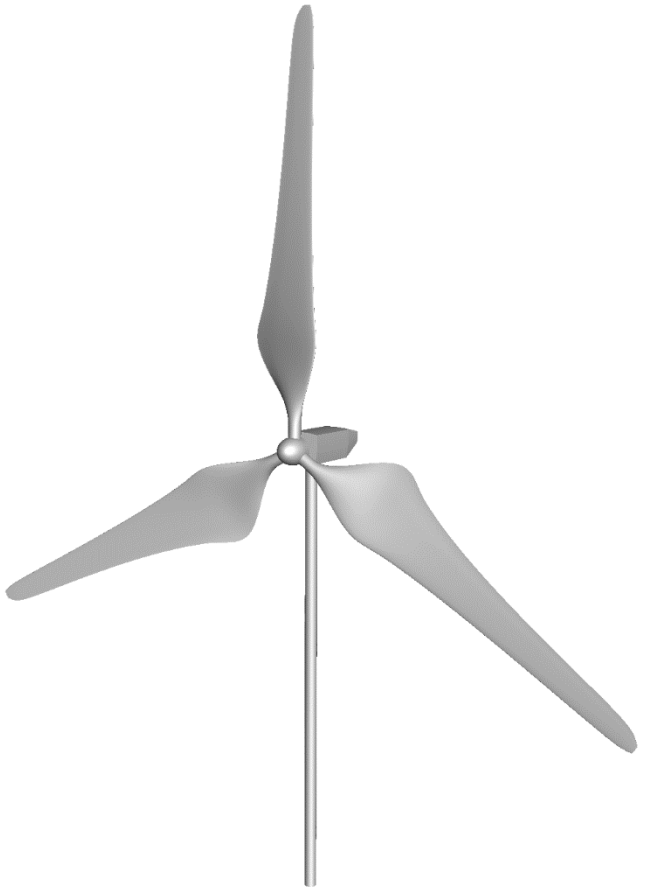
Introduction – model turbine (POLIMI)

Main function:

- provide realistic aerodynamic forces
  → thrust force

How?

- Froude scaled (1/60) + new design
- low Re airfoil (Re~45,000)
- matches thrust coefficient of full size turbine
- lower power coefficient



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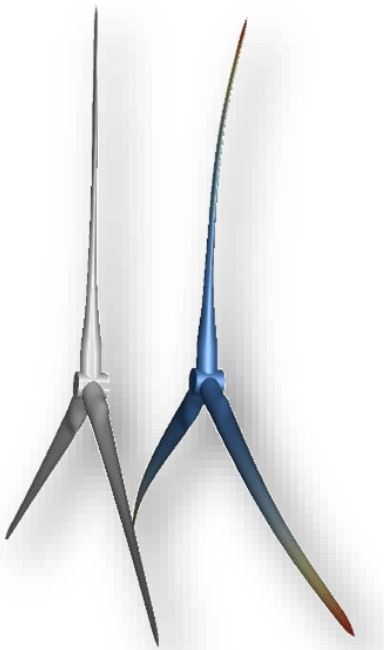
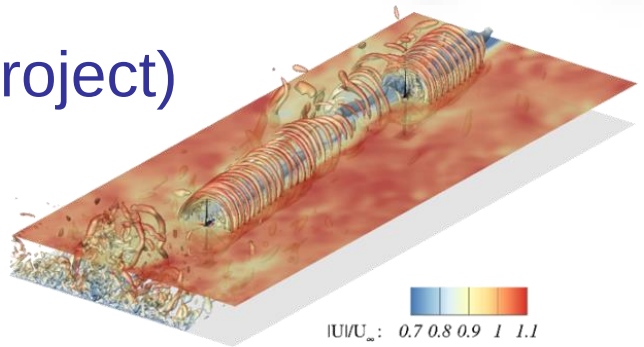
Approach – CFD solver

FLOWer by DLR (German Aerospace Center)

- block structured finite volume solver
- 2nd order in time and space
- chimera technique (overlapping grids)
- extended at IAG for wind turbine simulation
  - atmospheric turbulence and complex terrain
  - load control (e.g. flaps)
  - fluid structure coupling
- experimental validation (e.g. MEXICO project) and code to code validation (e.g. AVATAR project)





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Approach – CFD setup

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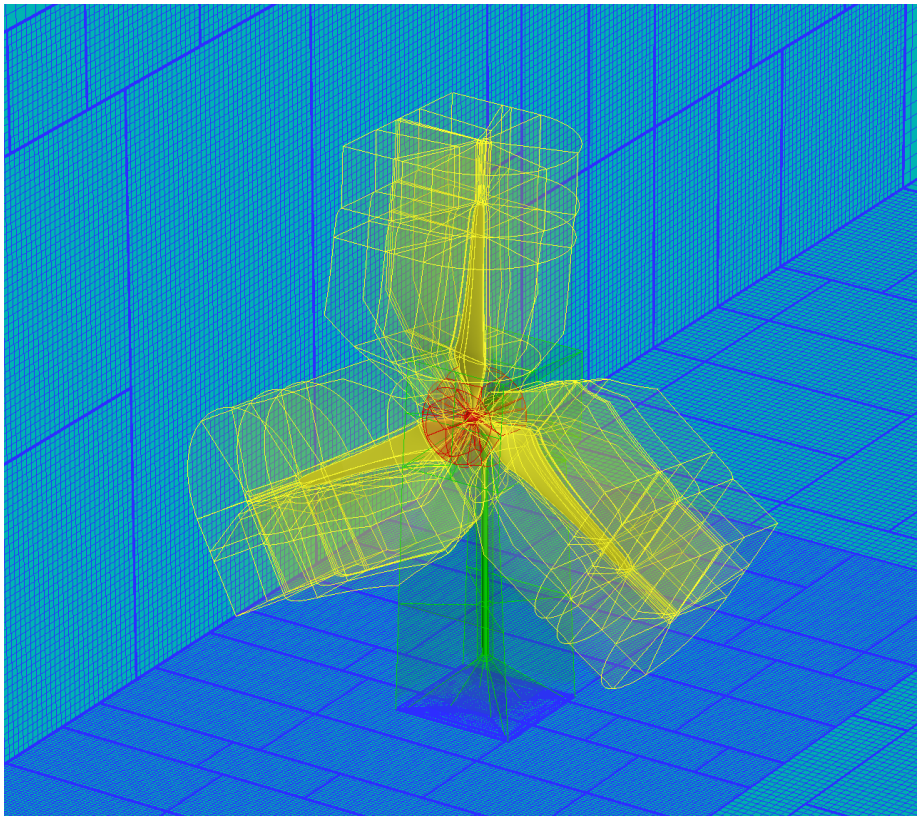
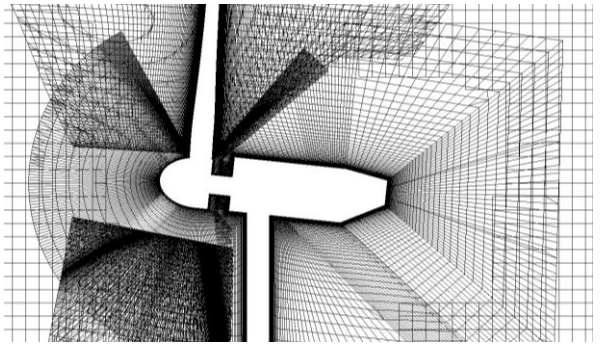
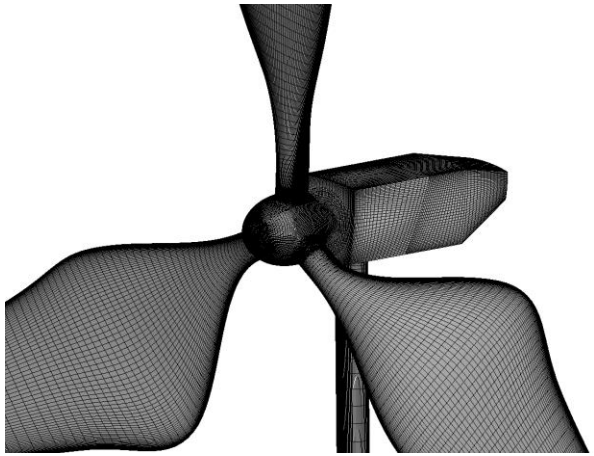
Turbine mesh – overlapping meshes







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Approach – CFD setup

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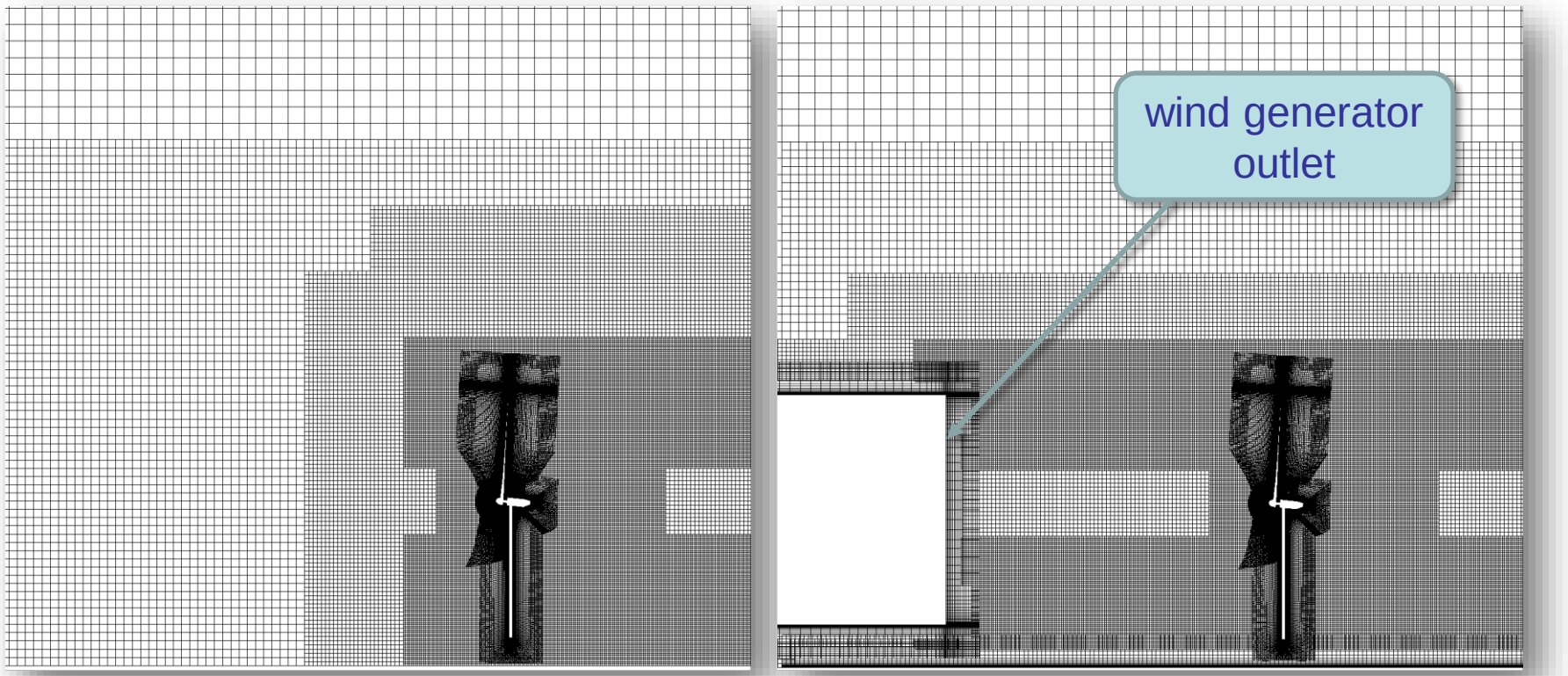
uniform inflow (29M cells)

jet flow (35M cells)



only sections of grids shown

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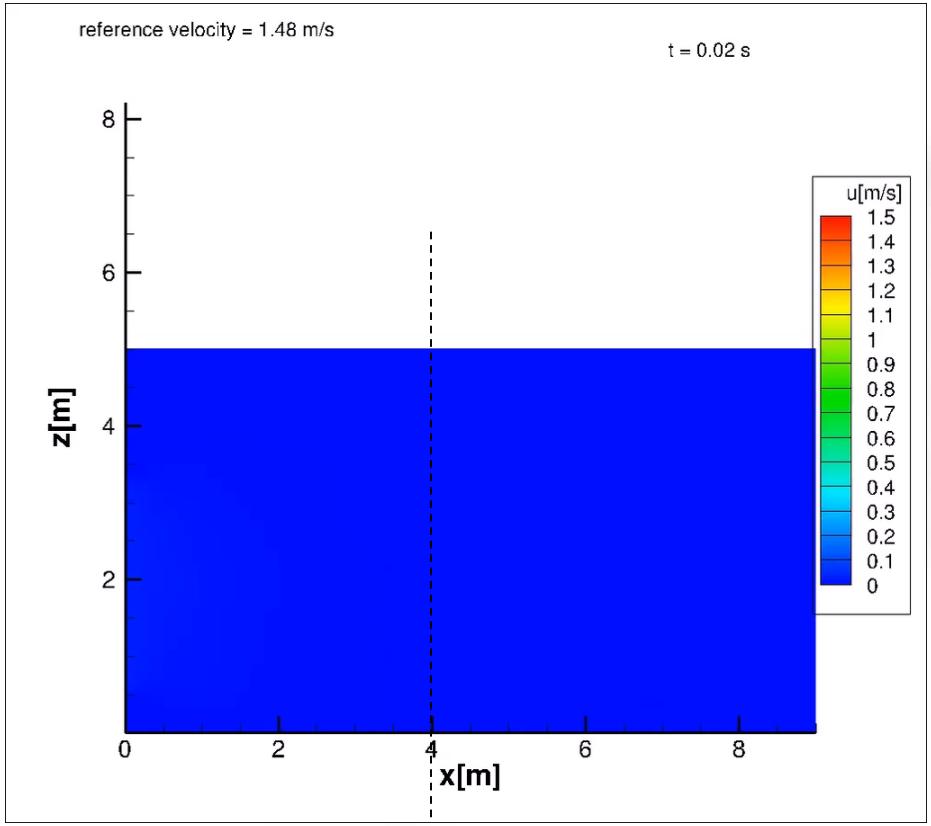
Approach – CFD setup

- rated wind speed
  1.48 m/s corr. to 11.4 m/s
- 70.9 rpm
- fixed turbine
  (no floating motion)
- fully turbulent
- time step ~ 0.75° azimuth
- prescribed velocity at wind generator outlet



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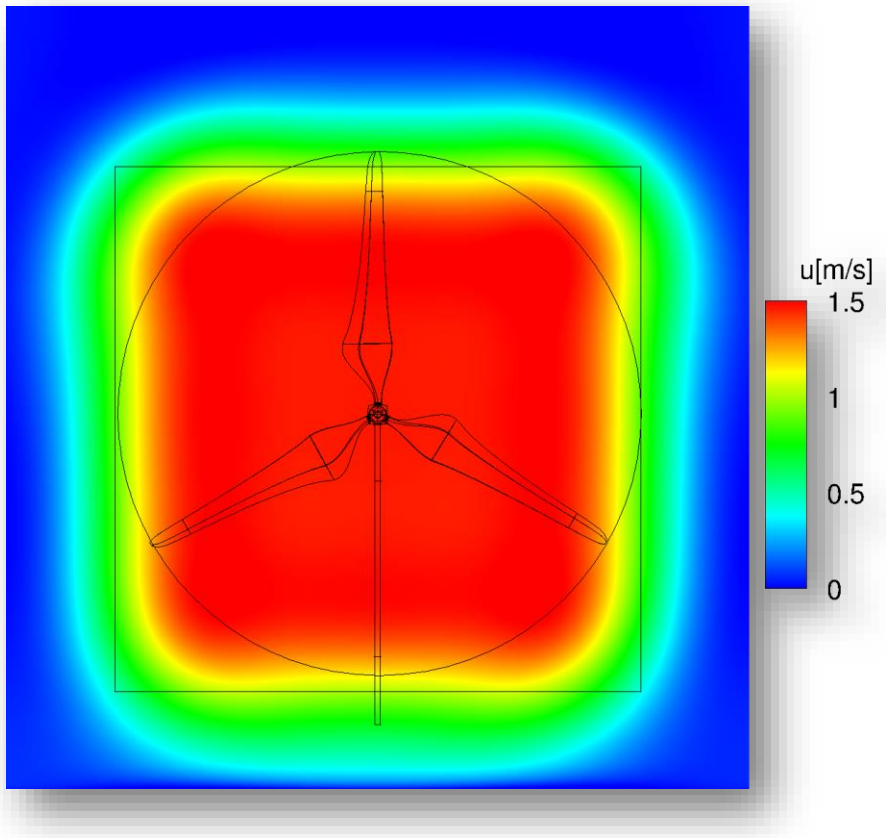

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Results – flow field

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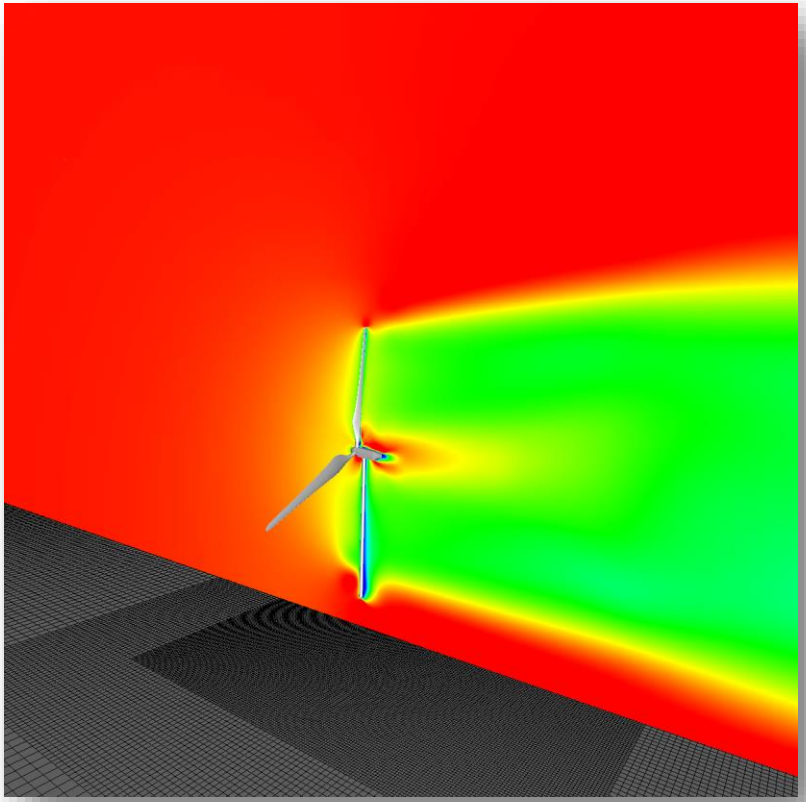
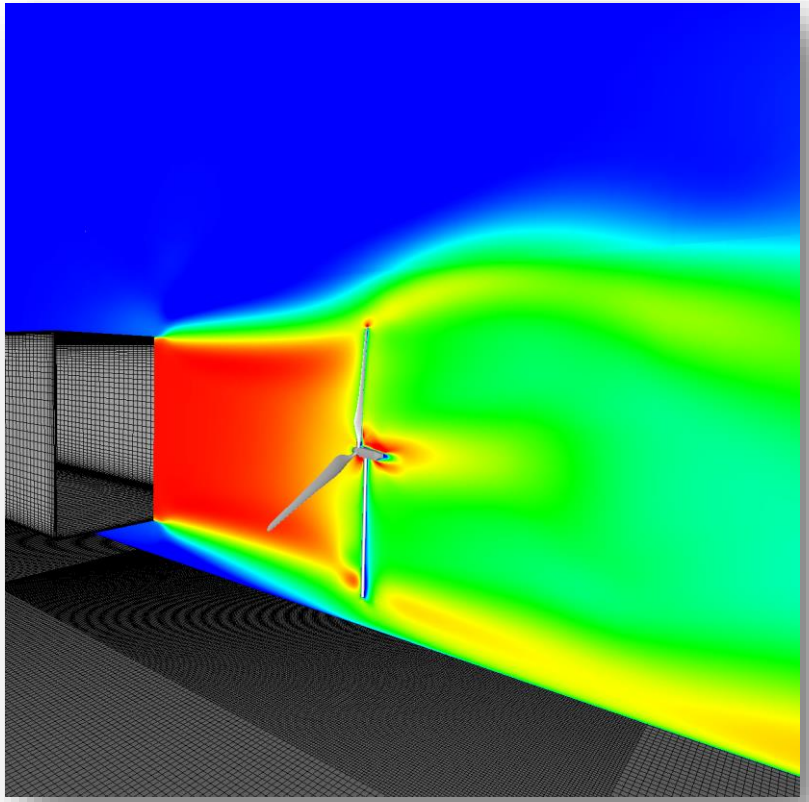
uniform inflow



induction factor: 27.2%

jet flow



induction factor: 27.8%

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Results – flow field

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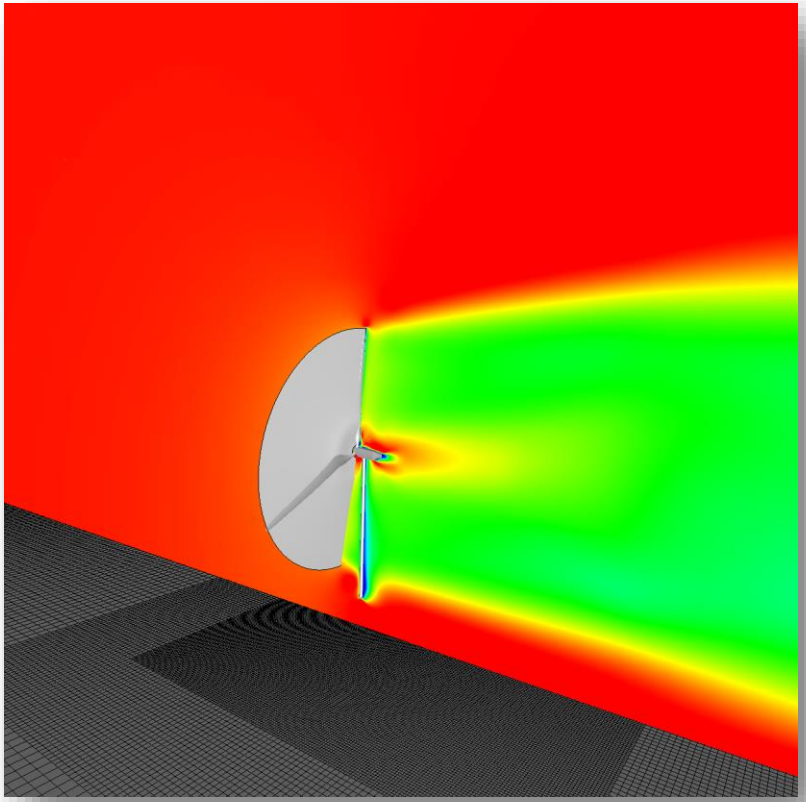
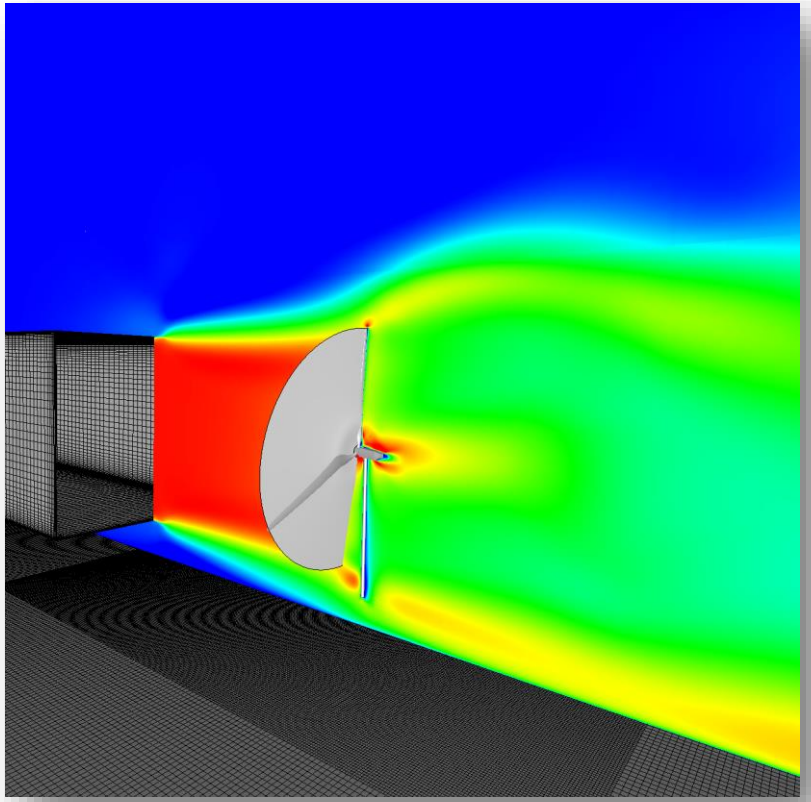
uniform inflow



induction factor: 27.2%

jet flow



induction factor: 27.8%

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Results – velocity in rotor plane

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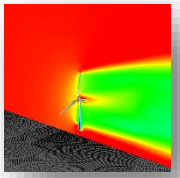
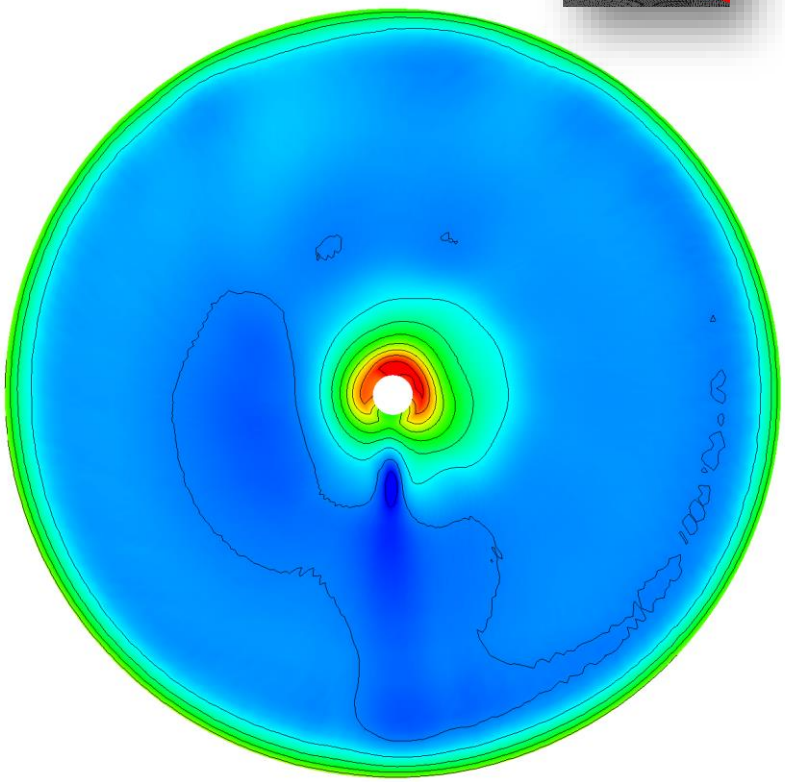
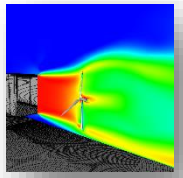
uniform inflow

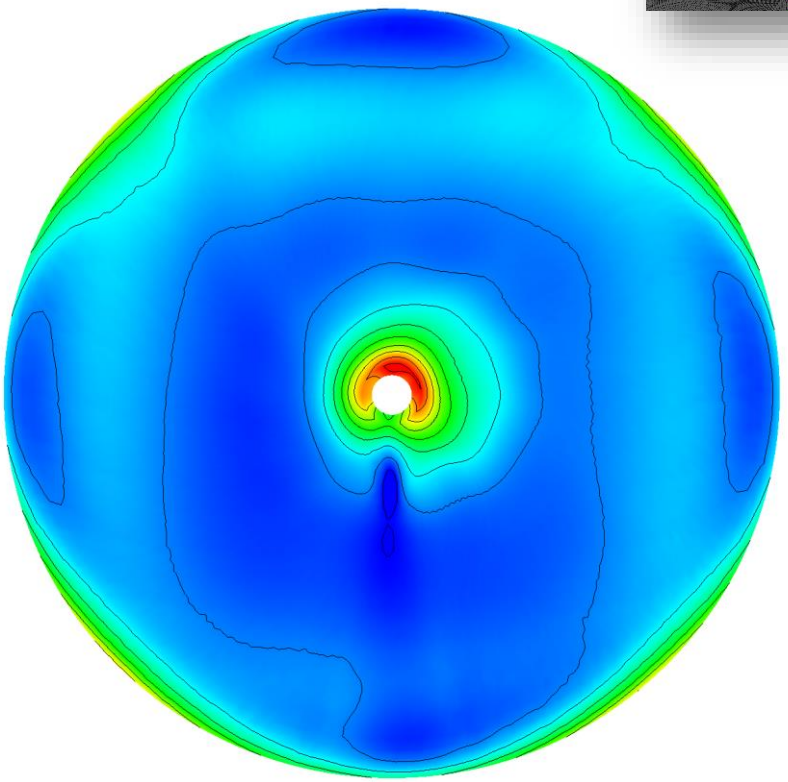




induction factor: 27.2%

jet flow





induction factor: 27.8%

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Results

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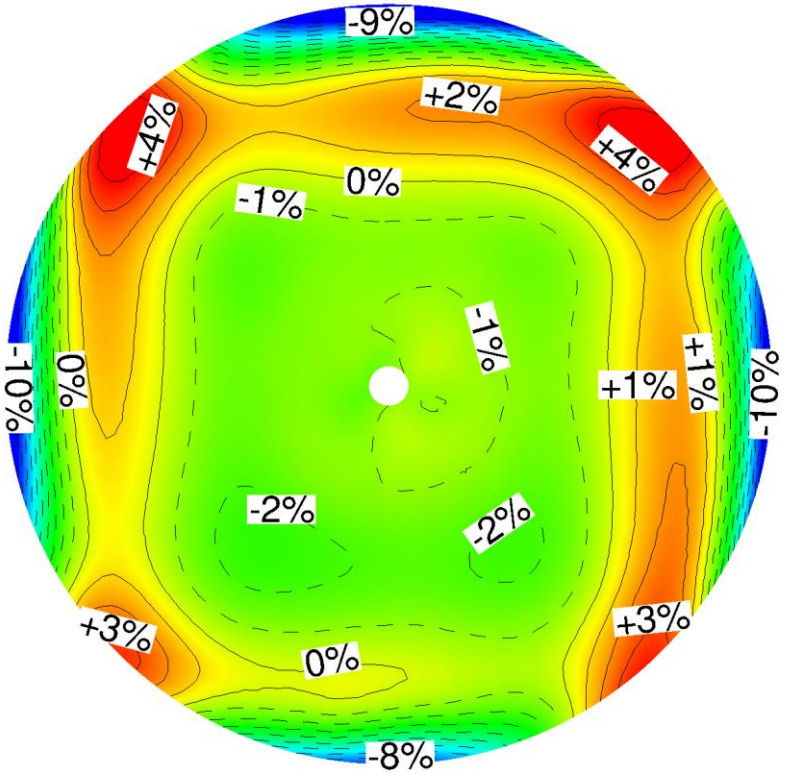
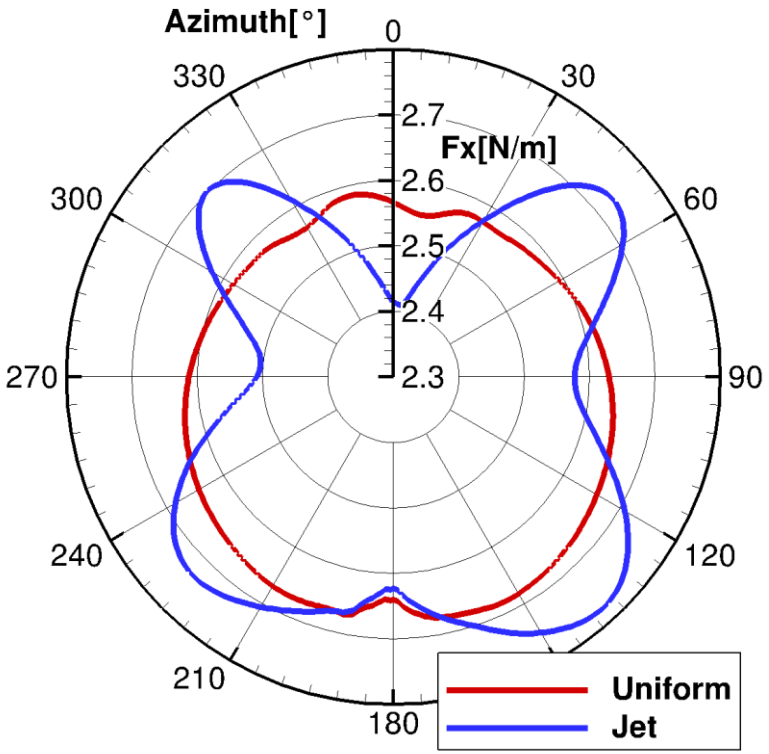
velocity difference



\+ = higher in jet case

spanwise thrust at r/R=90%



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Results – Thrust

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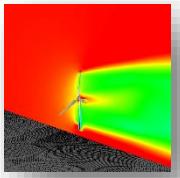
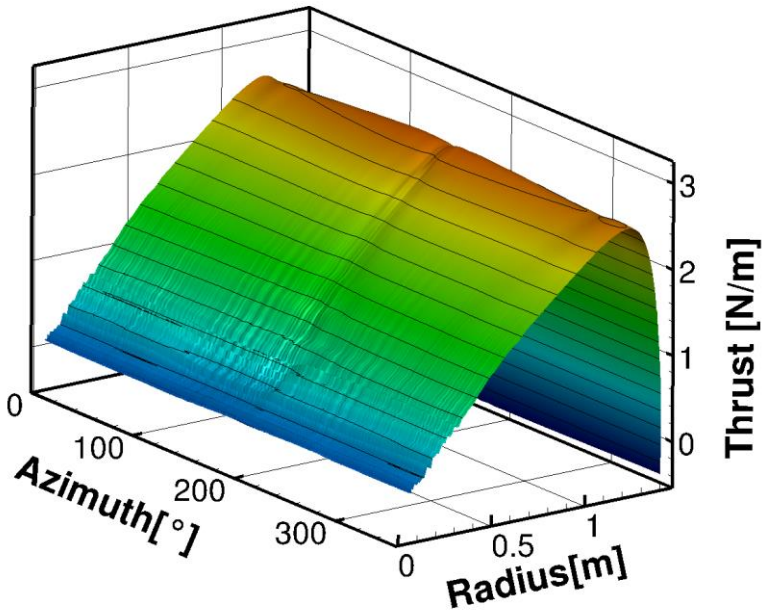
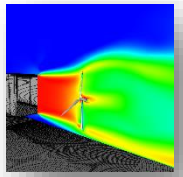
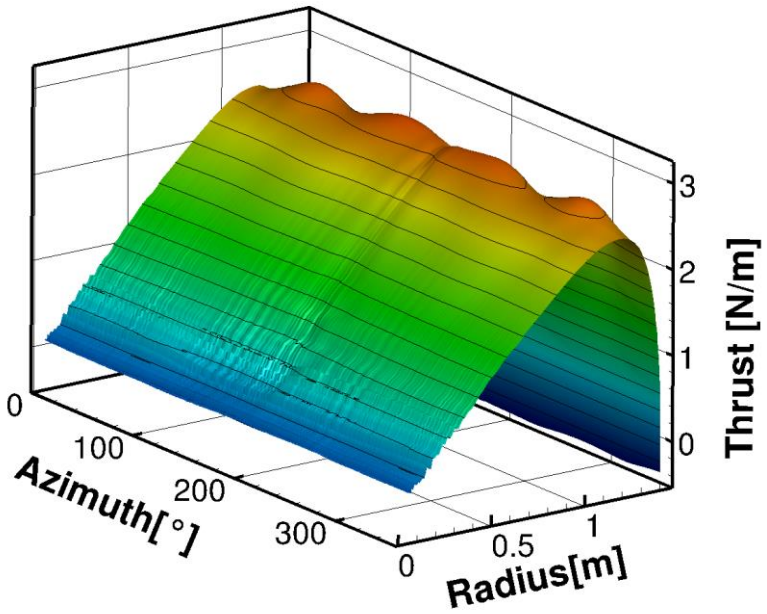
uniform inflow





jet flow





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Results – Thrust

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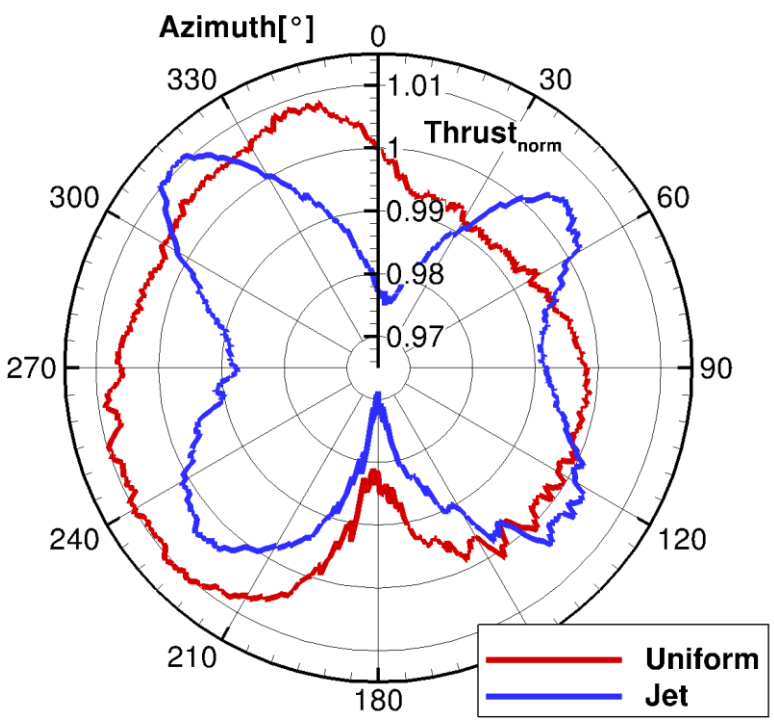
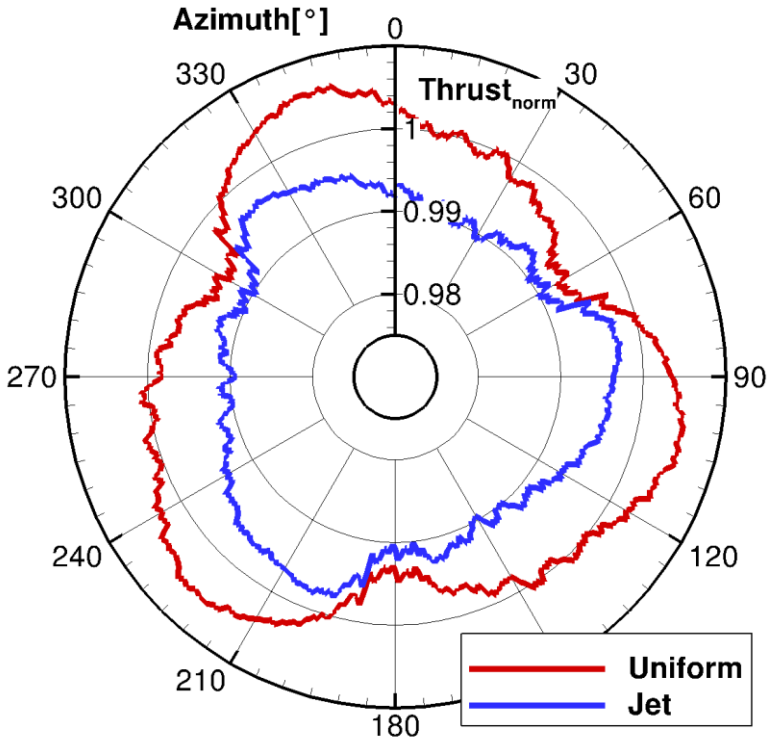
blade thrust



Rotor thrust



Average Thrust 0.7% lower for jet case

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Results – Thrust FFT

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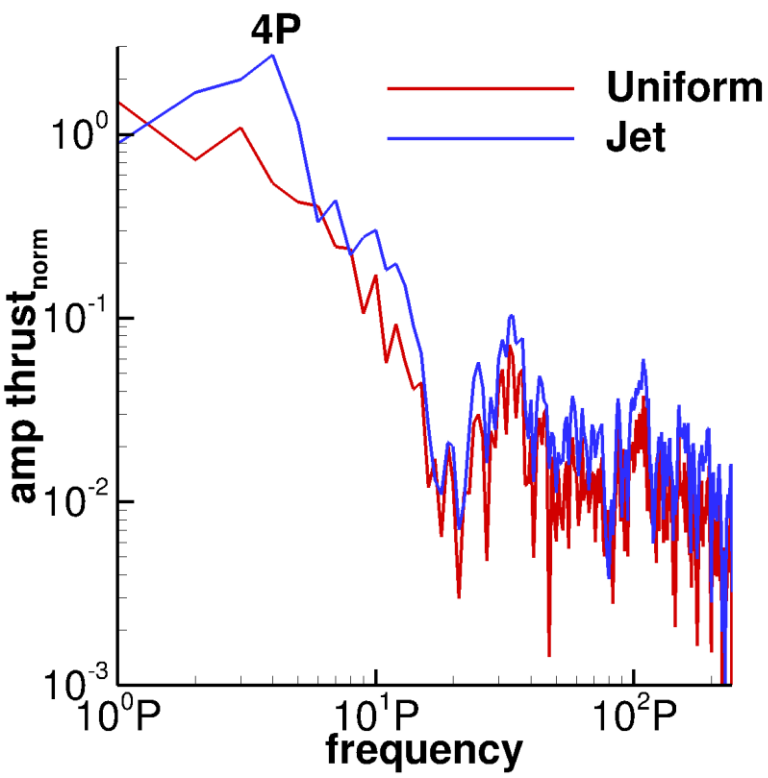
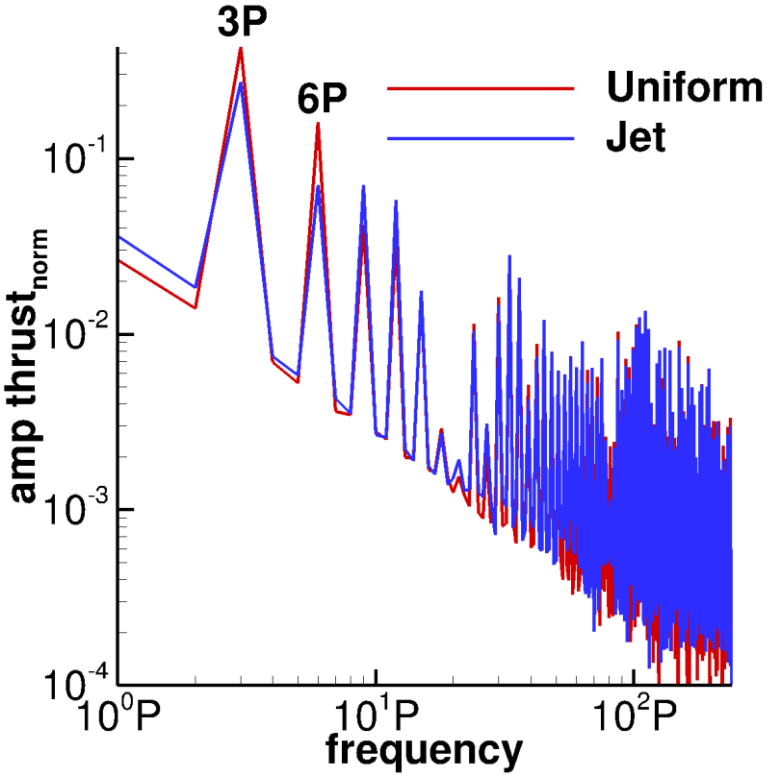
Blade thrust



Rotor thrust



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Summary and conclusion

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- CFD simulation of model wind turbine in uniform inflow and jet flow
- rotor thrust comparable, blade thrust different

Is uniform inflow approach suitable?

Yes but, …

- only if turbine is placed in the center of the jet (and at this position)
- influence might be higher when turbine is moving (floating motion)
- real jet might be less perfect then simulated one (inhomogeneous, turbulence)

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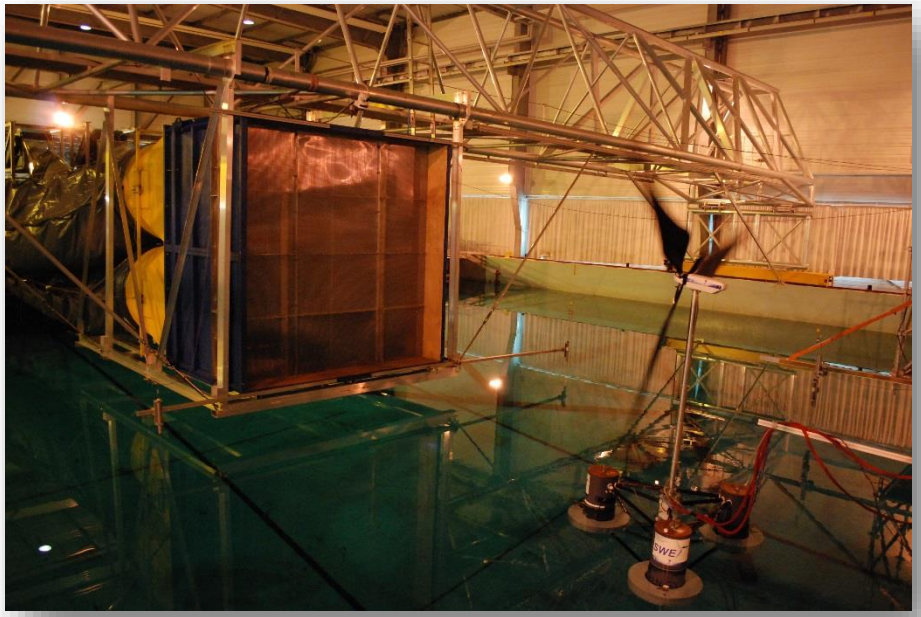
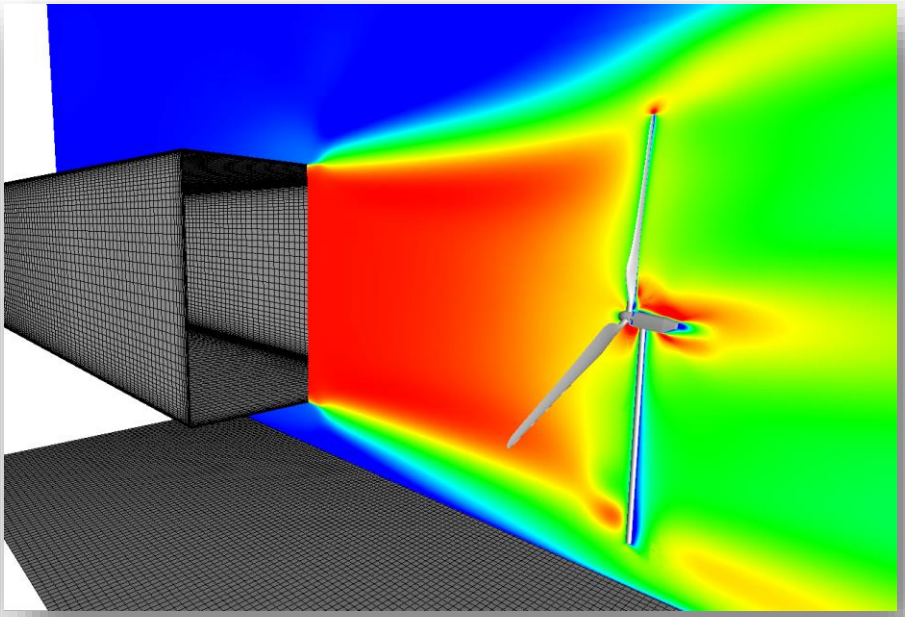
Thank you!





Questions?

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