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Three-Dimensional Numerical Simulation of a Model Wind Turbine

N. Tabatabaei[1], M.J. Cervantes[1,2], C. Trivedi[2], J-O Aidanpää[1]

[1]Luleå University of Technology, Sweden

[2]Norwegian University of Science and Technology, Norway

Winterwind 2015

International Wind Energy Conference

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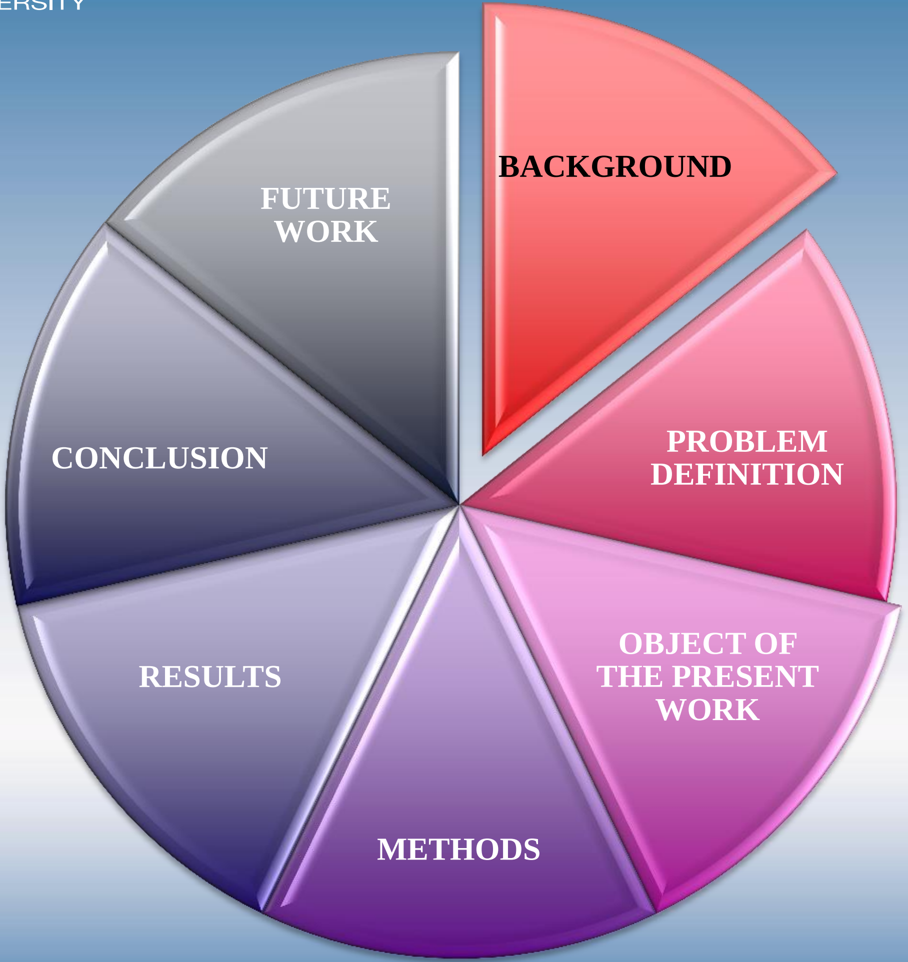
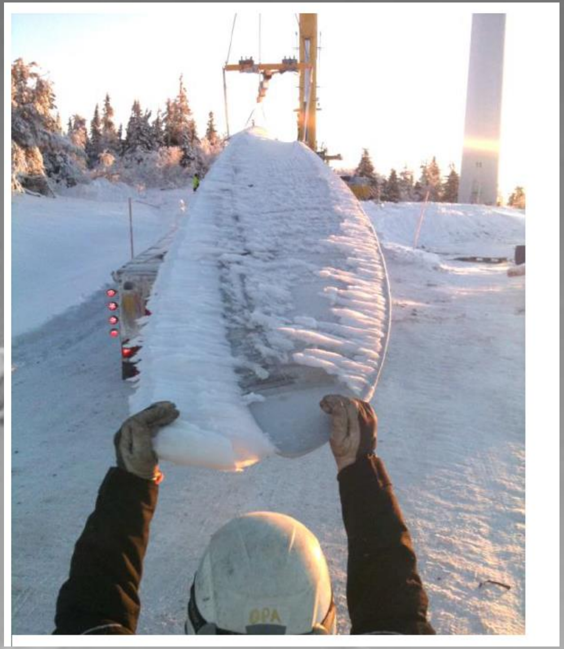

BACKGROUND
PROBLEM DEFINITION
OBJECT OF THE PRESENT WORK
METHODS
RESULTS
CONCLUSION
FUTURE WORK

Background

- Today, electricity generating wind turbines employ proven and tested technology, and provide a secure and sustainable energy supply
    - Loads acting on the blades are extracted from CFD simulations
    - Loads used to design and perform dynamic analysis of blades.

Wind Turbines Cold Weather Issues

- **Materials Failure at Low Temperatures**
- **Icing**
- **Presence of Snow**



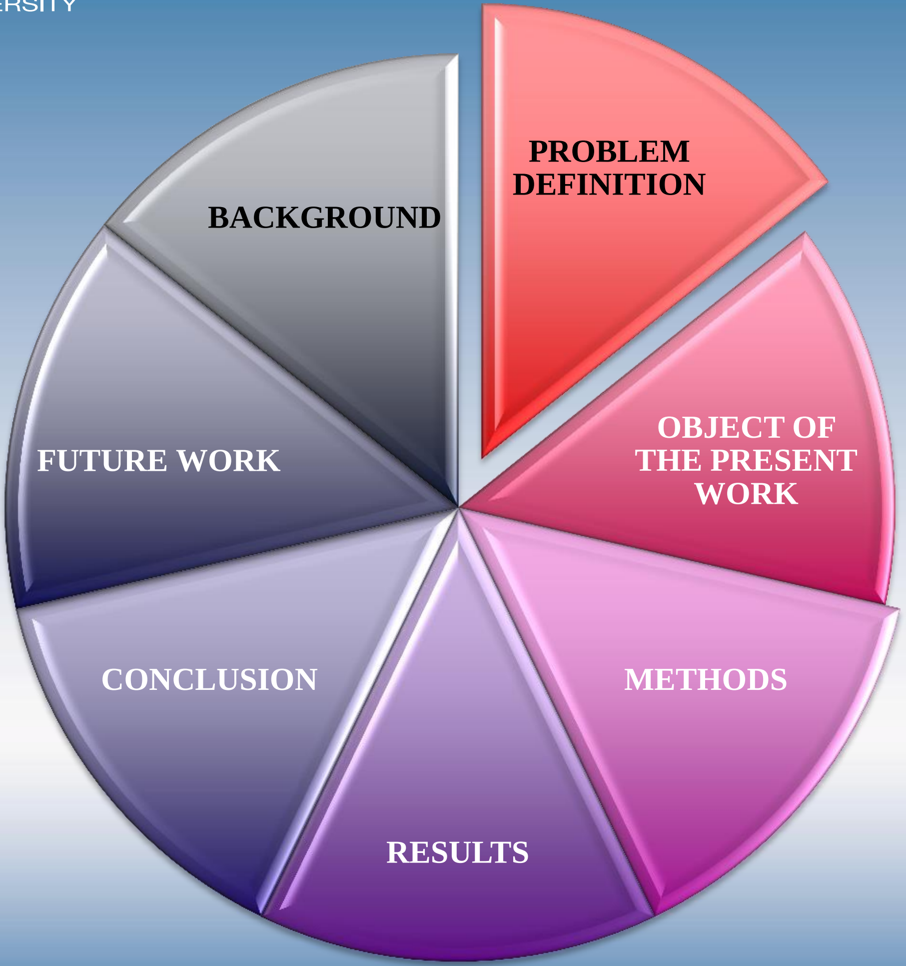
Windmills are now introduced in cold areas for which they are not designed. So, different problems are potential to occur such as cracks, separated flow, unbalance, etc.

Wind Turbines Cold Weather Issues

- **Materials Failure at Low Temperatures**
- **Icing**
- **Presence of Snow**

Operation issue
- Loss of income

Safety issue
- Ice may become projectiles
- Blades breaking due to cracks
- Blades burning due to heating systems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BACKGROUND

- What are the loads acting on wind turbines in the presence of ice on the blades?
- What are the consequences of these loads on the wind turbine dynamic?
- Can we modeled accurately such problem?

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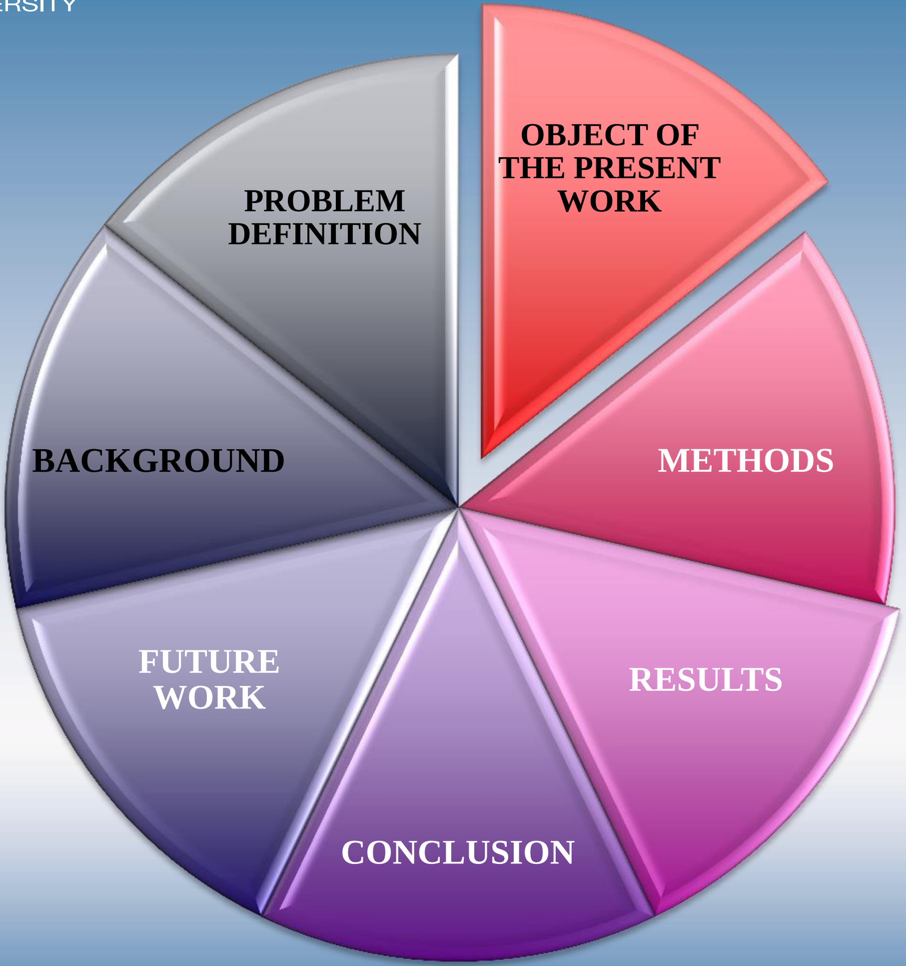

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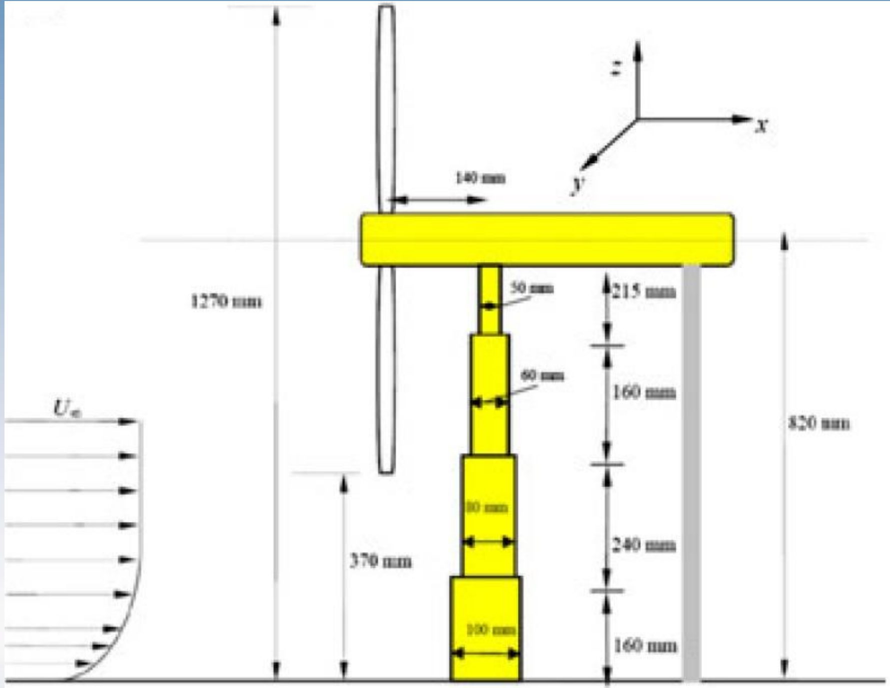
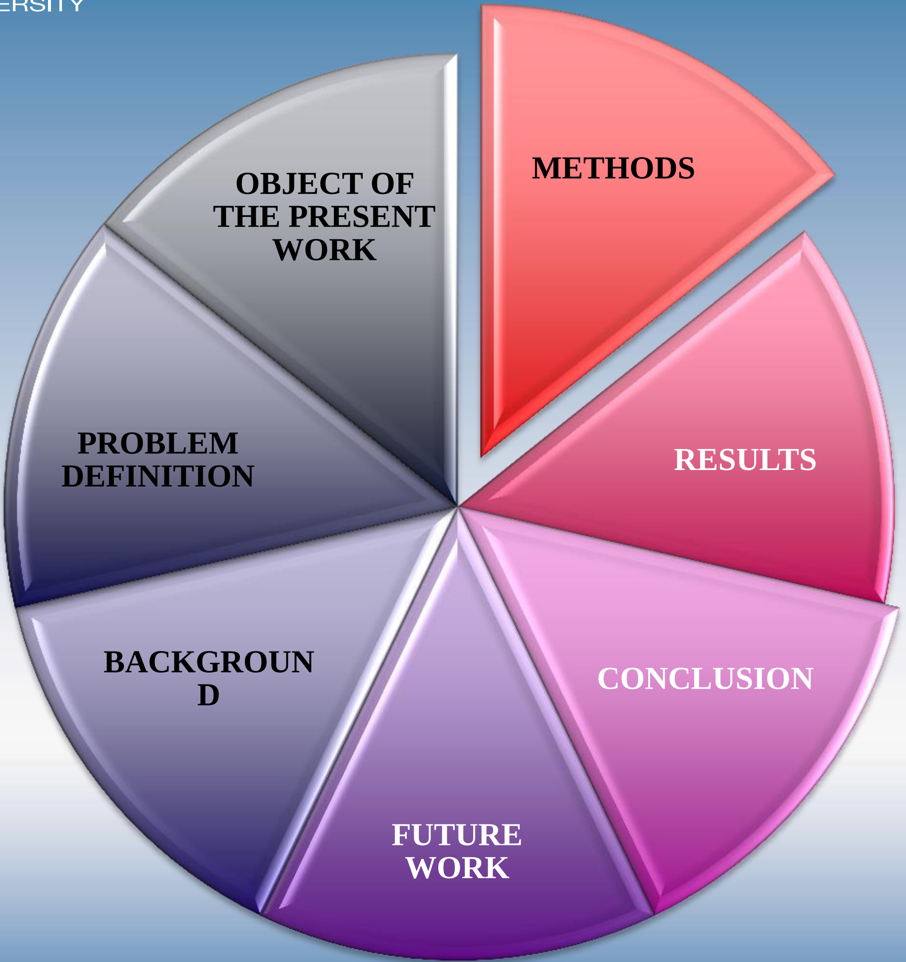
- Numerical simulation of an upwind 3 blades wind turbine model tested at NTNU, Norway:
    - 3 blades and the rotor sits on top of a stepped tower consisting of 4 cylinders of different diameters
    - Airfoil selected is the 14% thick NREL S826
    - The tunnel has a test section of 1.9 m (height) 2.7 m (width) 12.0 m (length).

The model wind turbine



Schematic diagram of the model

Model mounted in the wind tunnel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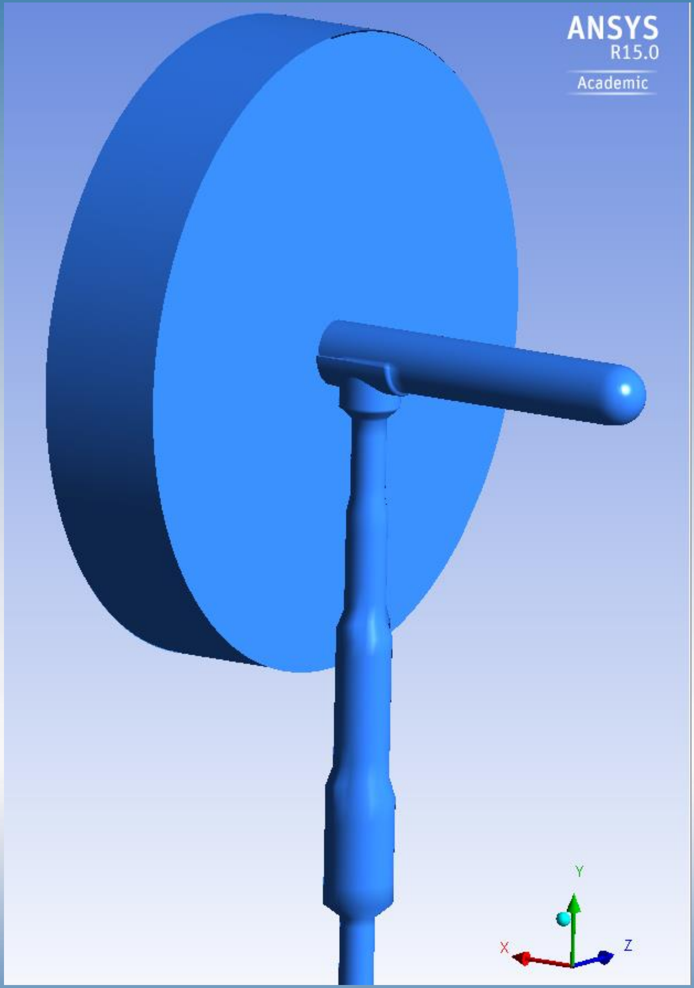

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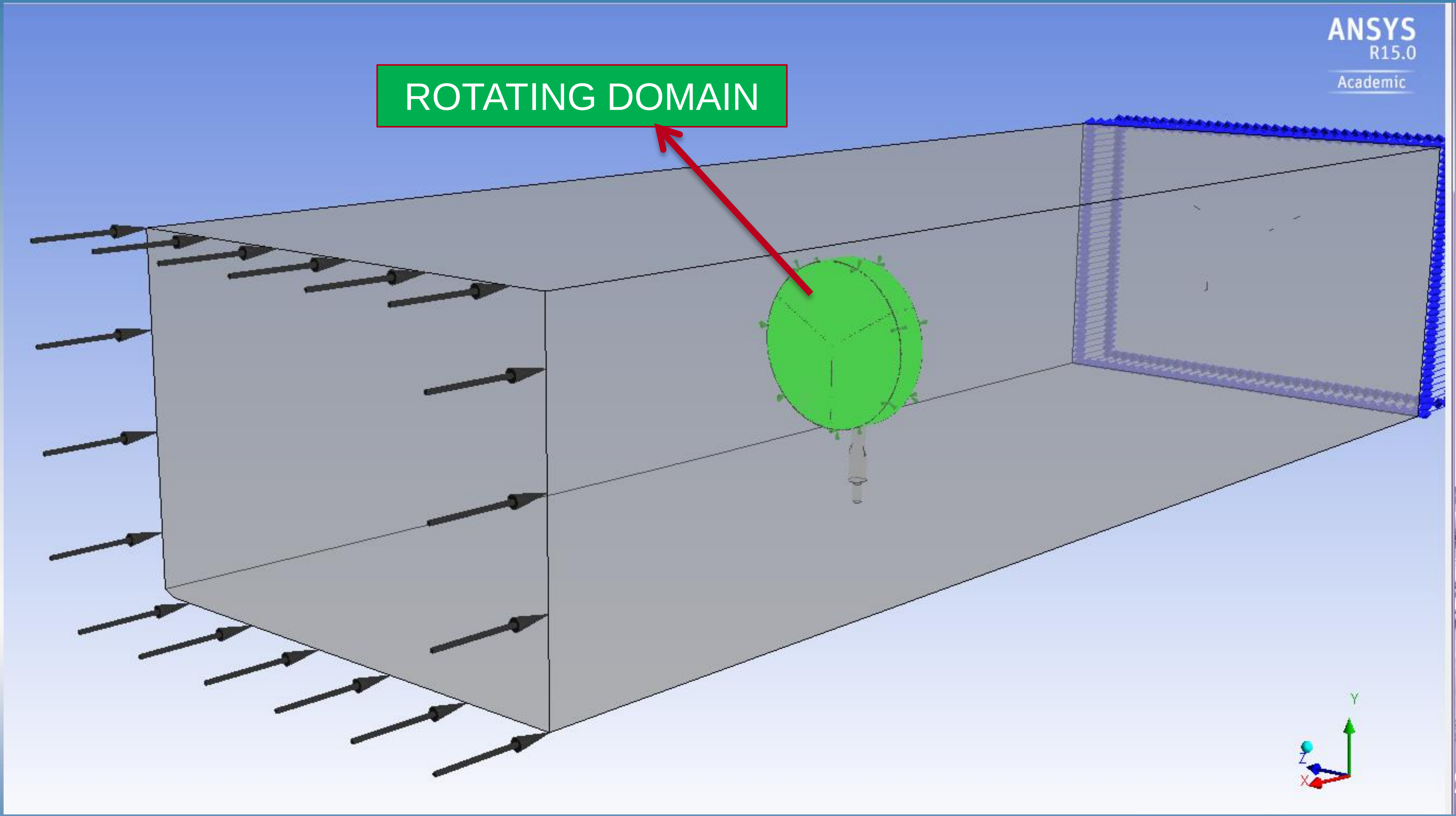
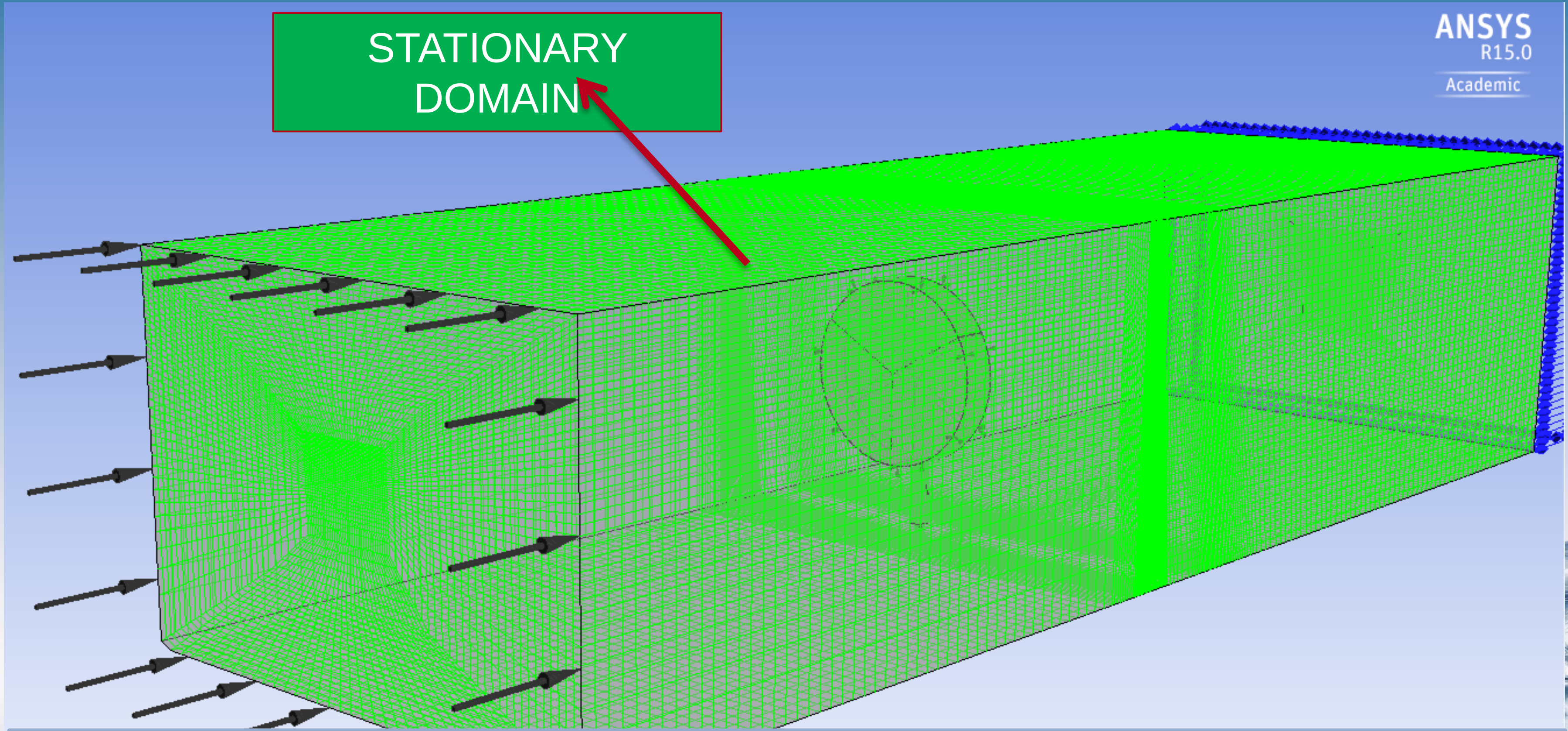
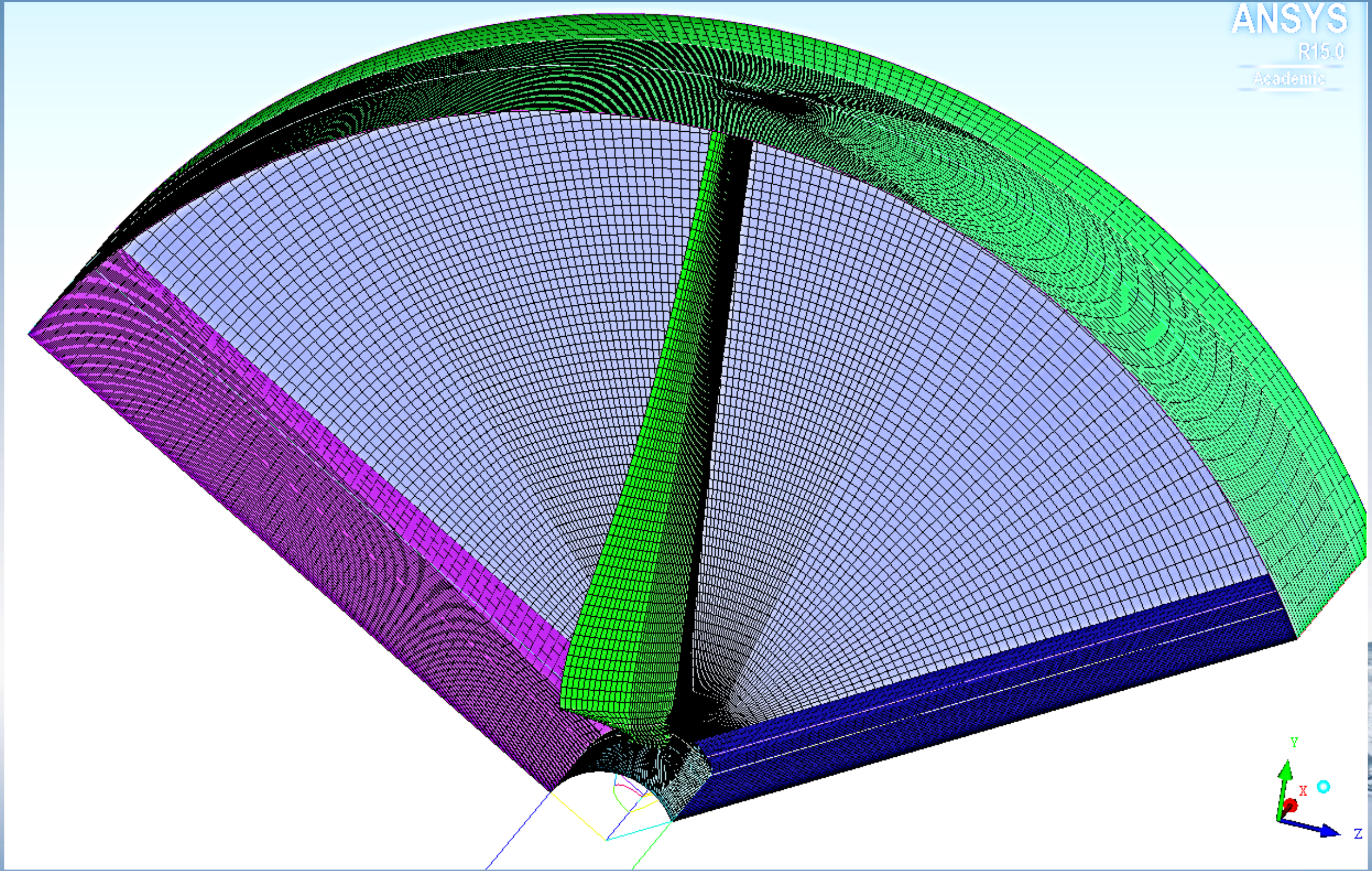

ROTATING DOMAIN
ANSYS
R15.0
Academic
Y
Z
X



ICEM CFD 15. is used to model and provide the appropriate grid in the flow domains
The wind entrance and exit have been considered 4 and 5 diameters upstream and downstream of the rotor plane respectively.


ANSYS
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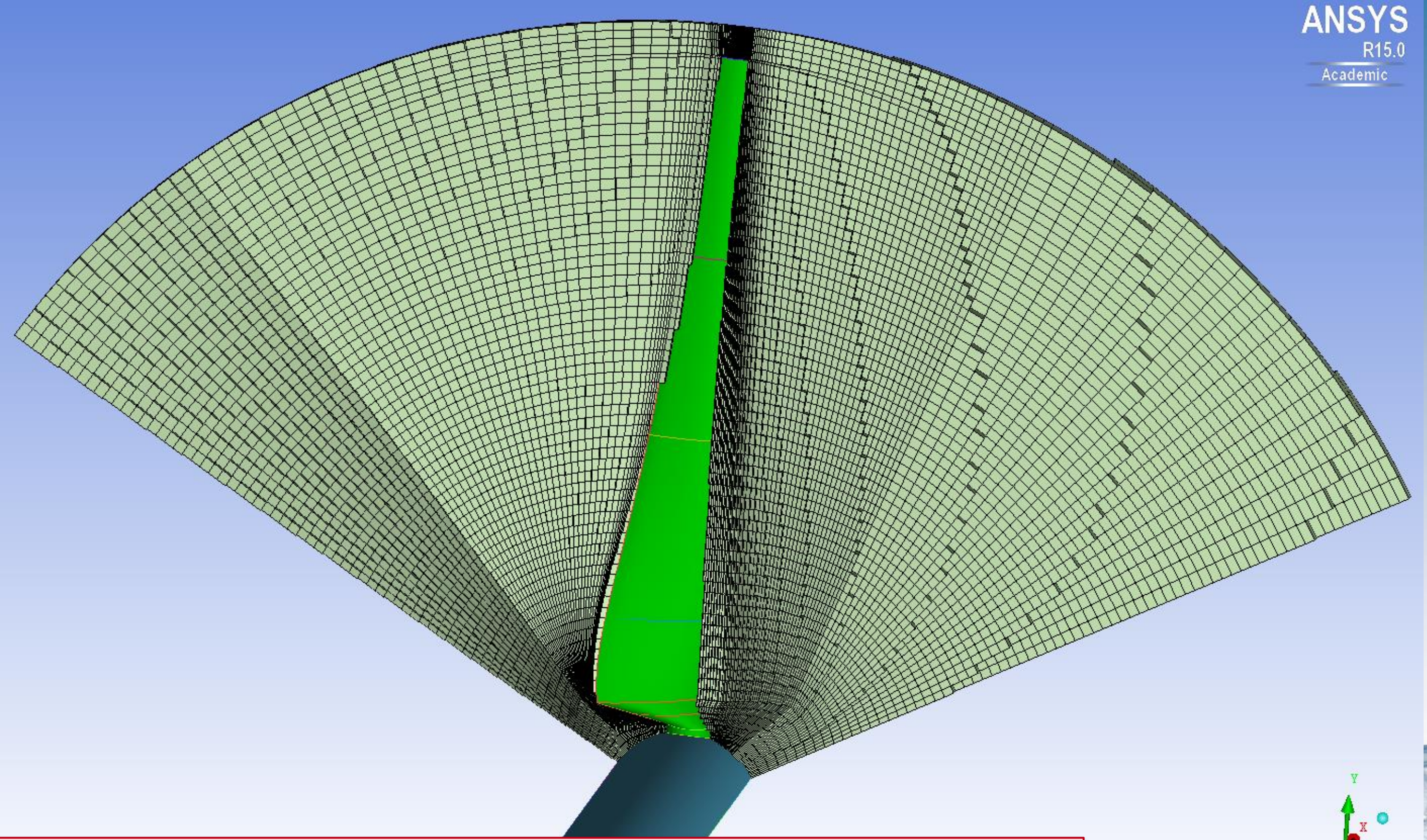
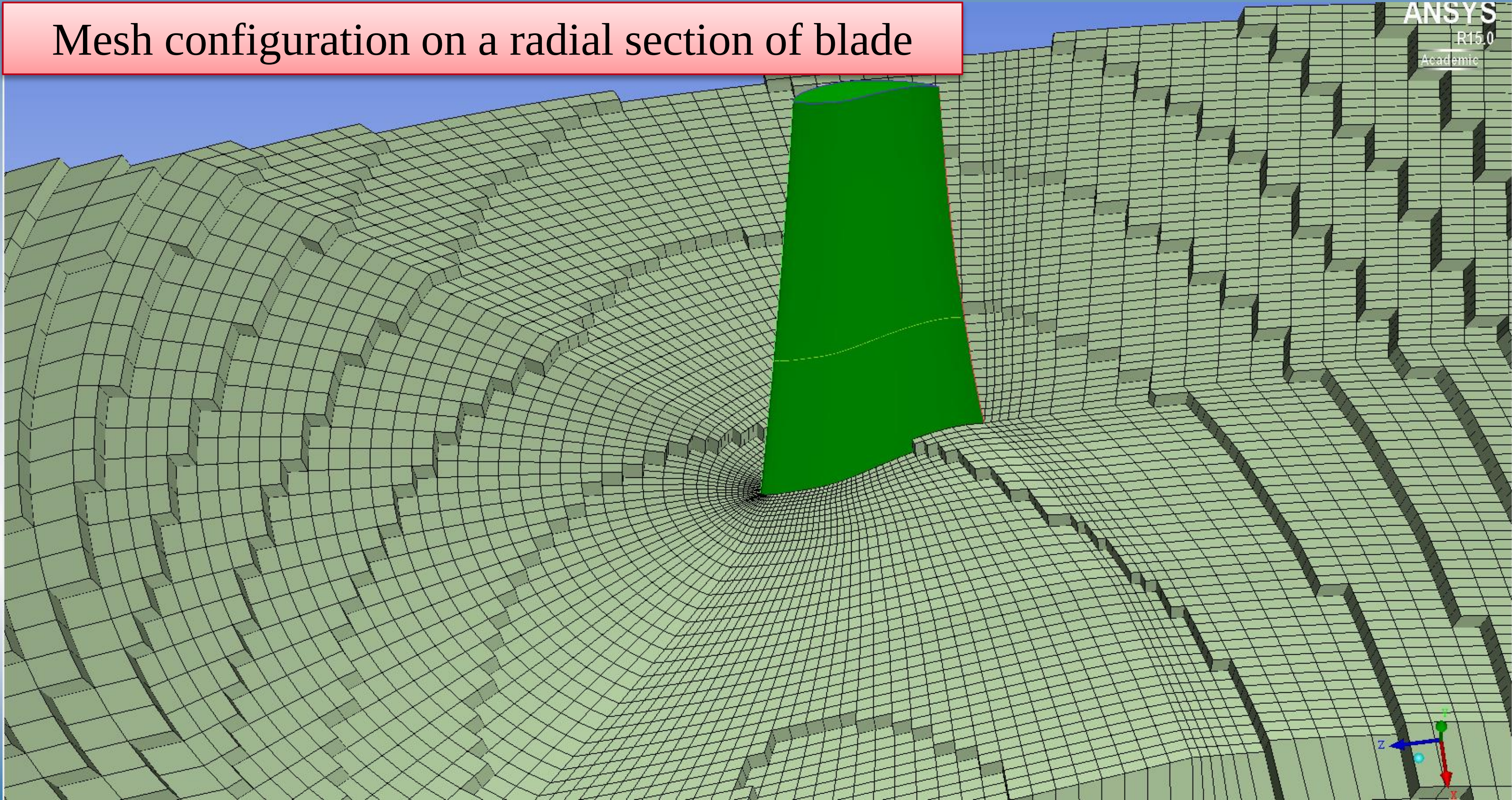


Mesh configuration on a sector of domain

Mesh configuration on a radial section of blade



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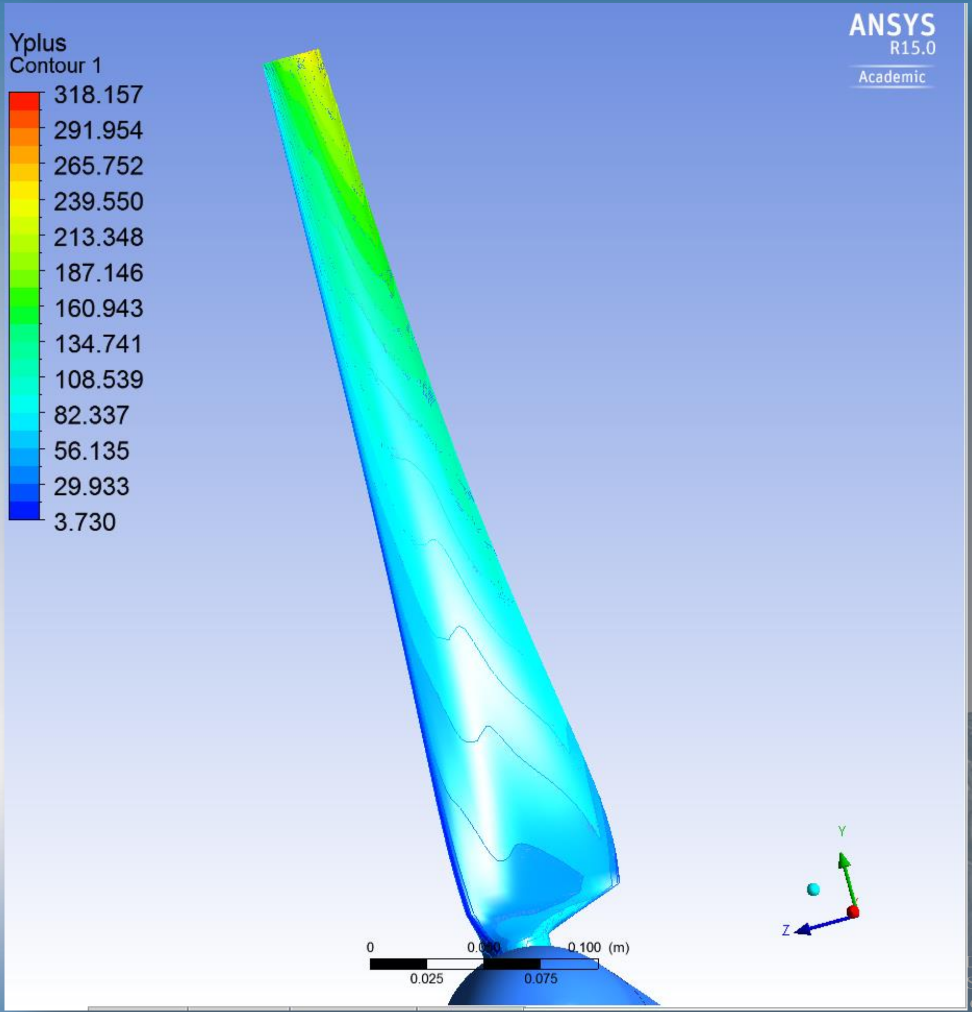
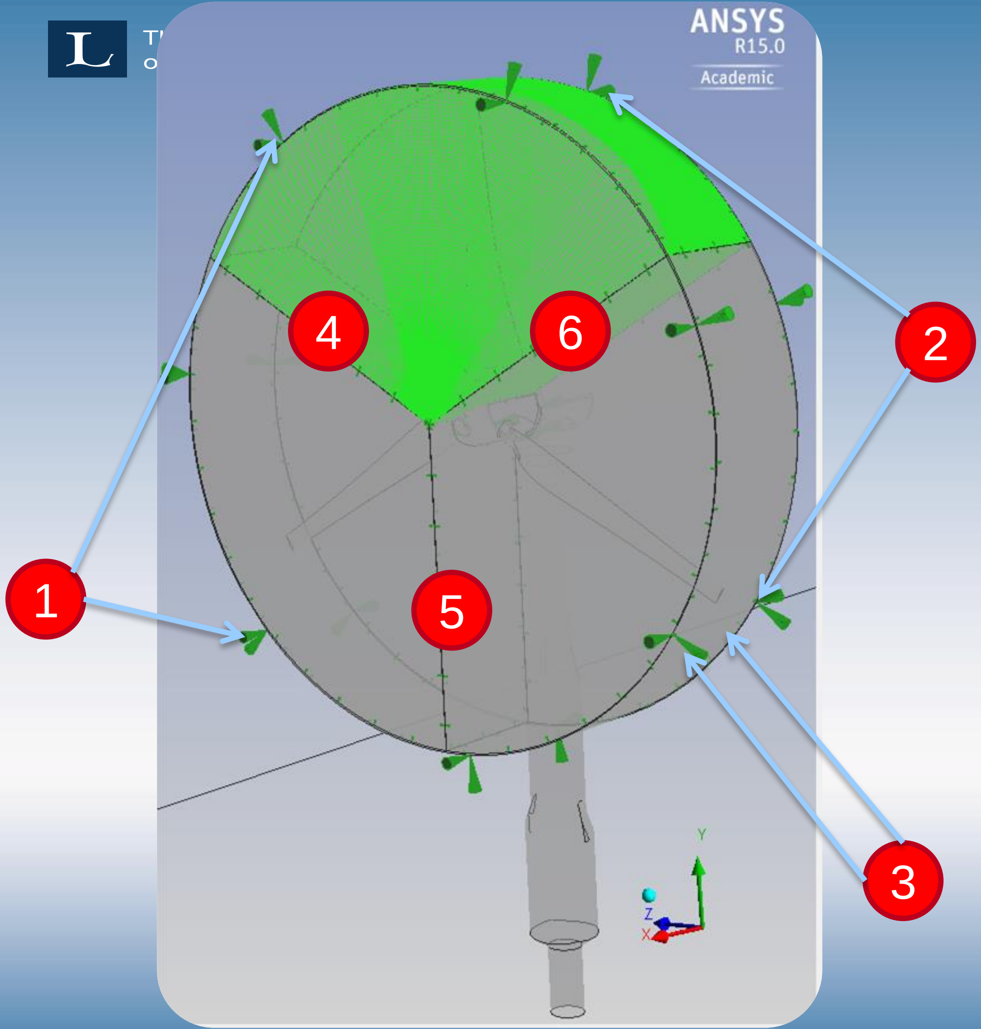
Turbulence model :

Shear Stress Transport

Mesh information	
Domain	Nodes
ROTATING	1,900,000
STATIONARY	1,500,000
All Domains	3,400,000





GGI INTERFACES:

- Connection of sectors of the rotating domain(4-6)
- Connection of rotating and stationary domain(1-3)

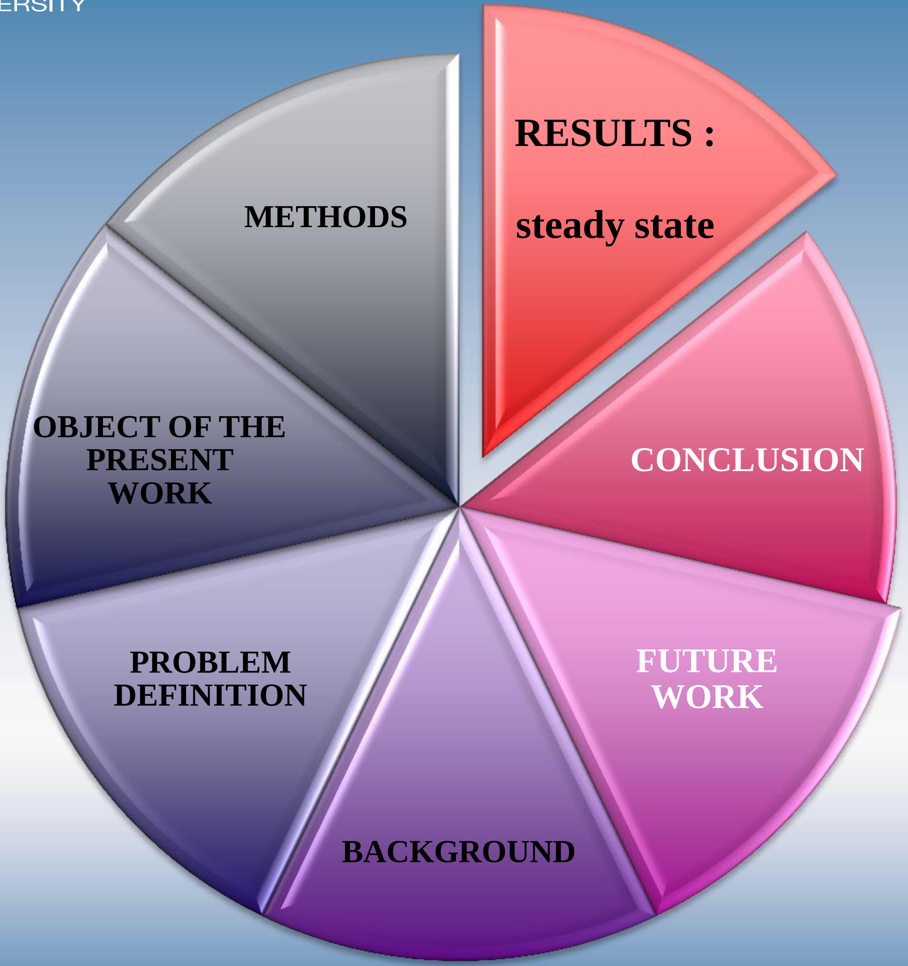
SIMULATION METHODS

Steady state

- Assumption of “Frozen Rotor” for the interface of rotating and stationary domains.
- Physical time step equals 1% of L/U_∞

Transient

- ”transient rotor stator” interface of rotating and stationary domains.
- Passes each degree in 2 time steps


RESULTS :
steady state
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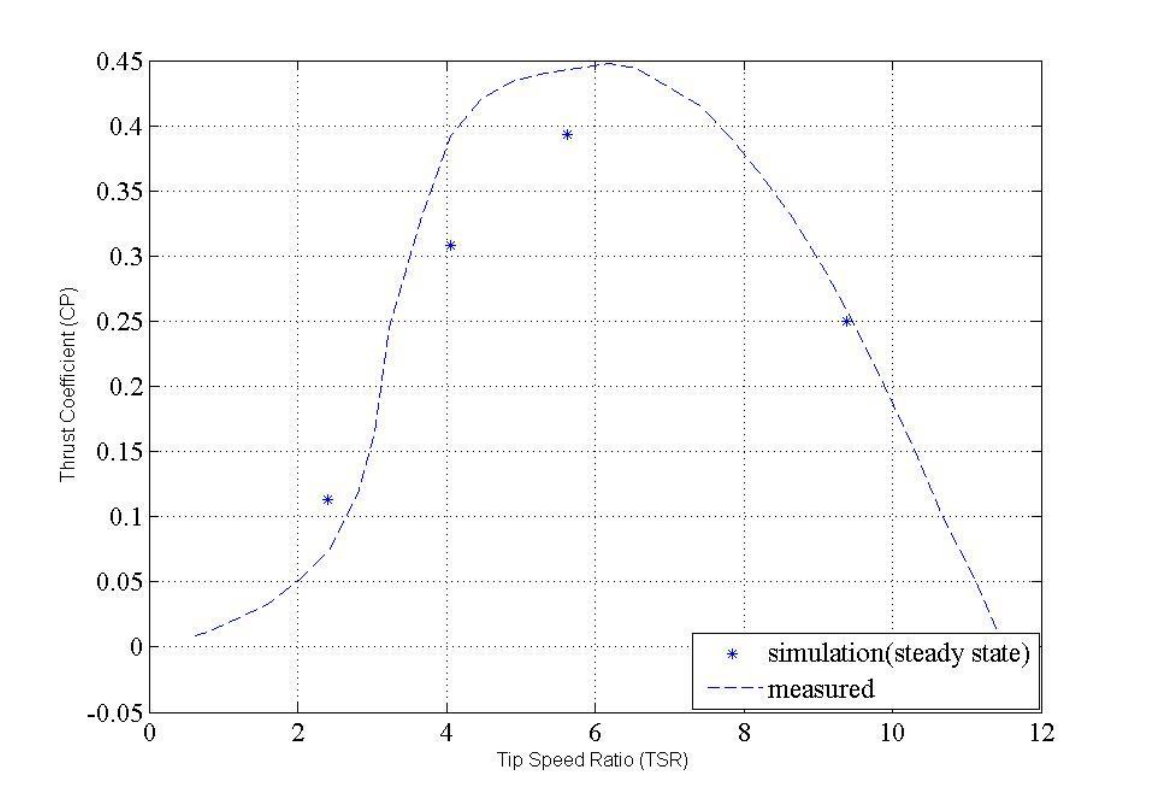
Turbine performance: Power coefficient



✓ *Comparison between the NTNU measured data and LTU steady state simulation shows good agreement.*

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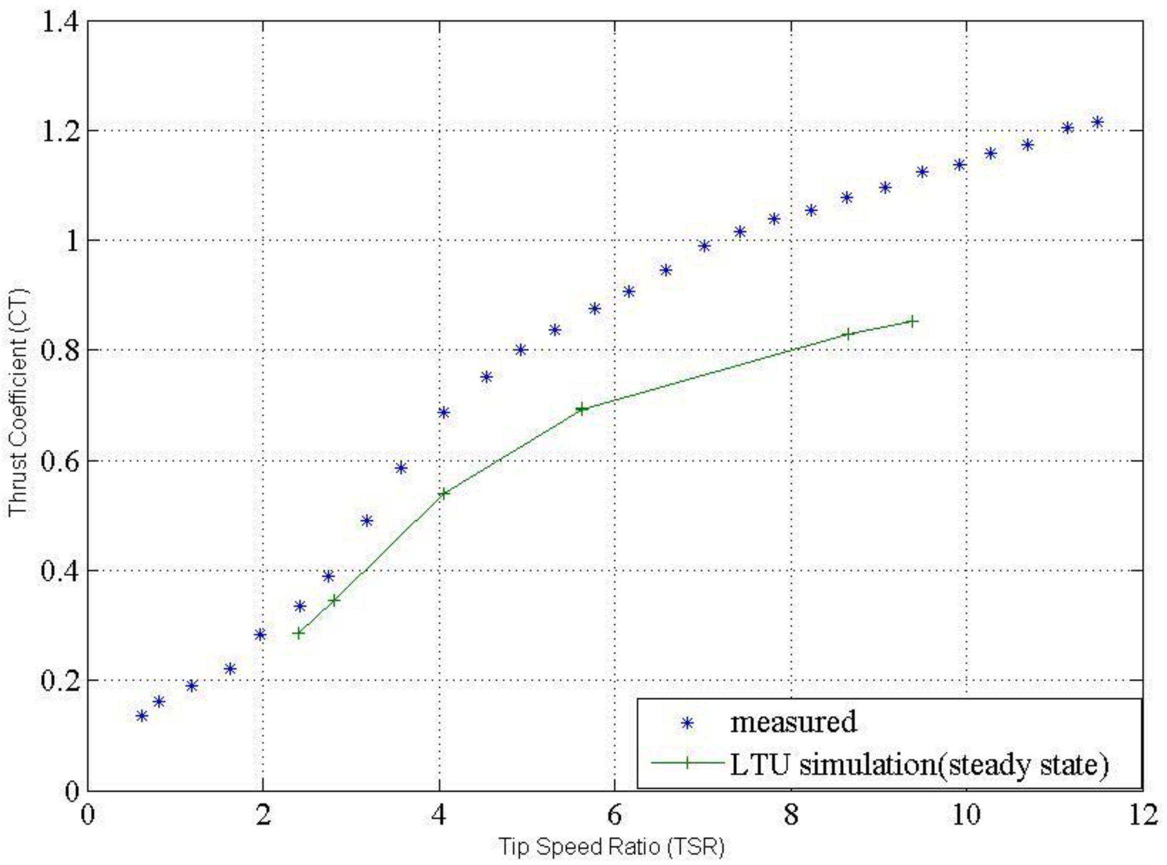
Turbine performance: Thrust Coefficient



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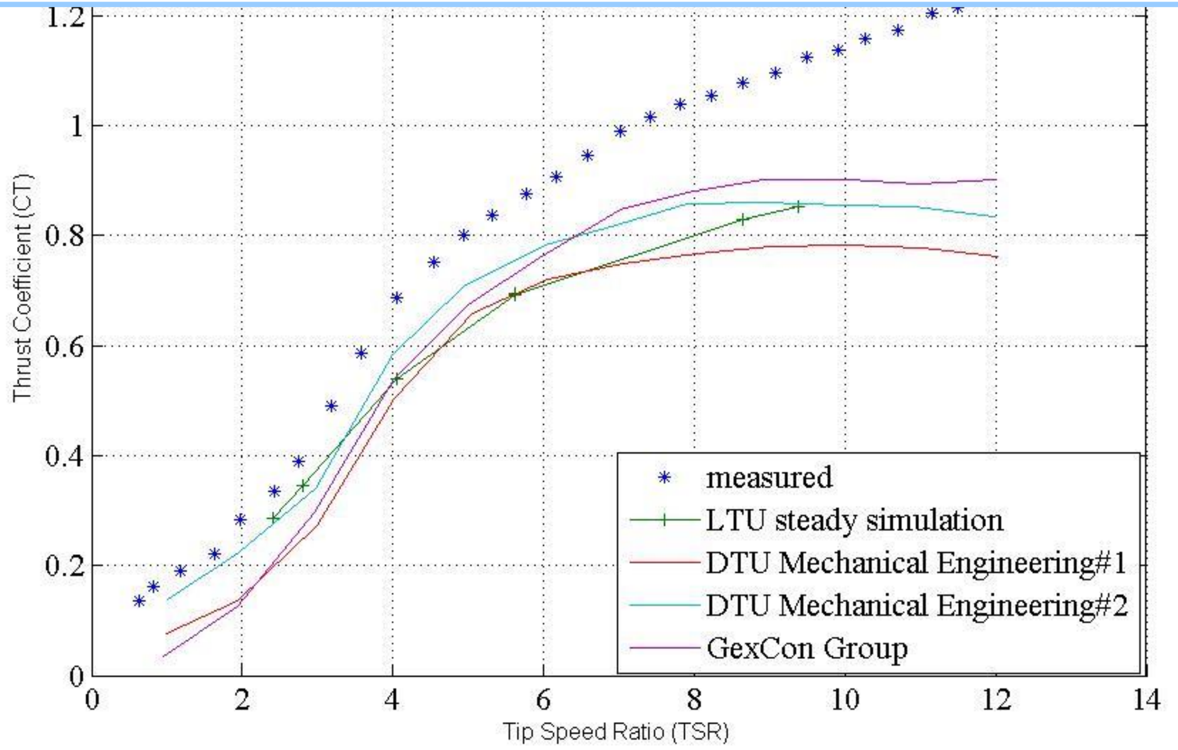
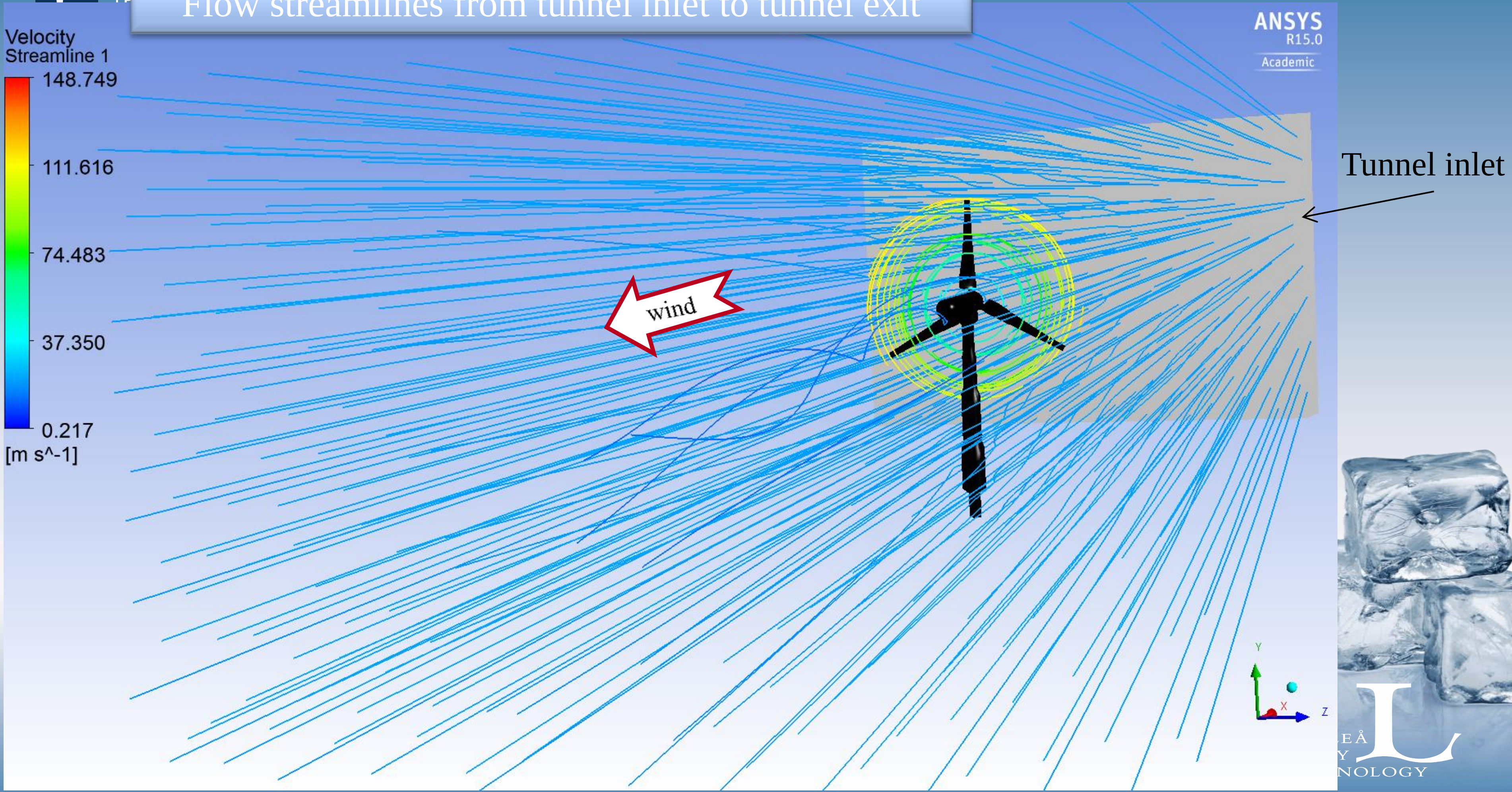
Turbine performance: Thrust Coefficient

- ✓ *The comparison shows Steady state simulation underestimates the Thrust coefficients of the turbine,*
- ✓ *Which is seen similarly in some other numerical simulations of this model wind turbine*

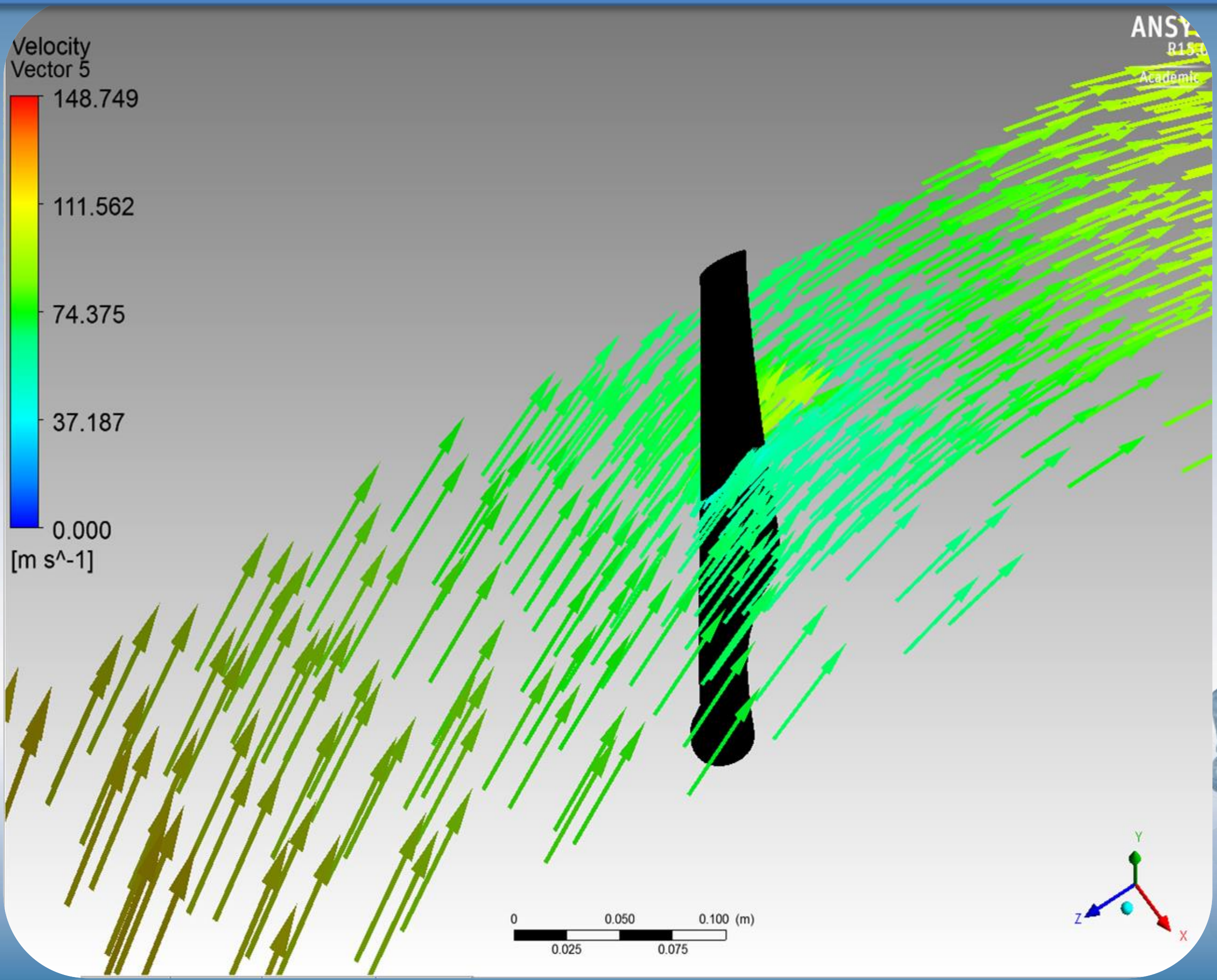


Flow streamlines from tunnel inlet to tunnel exit



Flow vectors passing over different blade sections TSR=5,6

Half height



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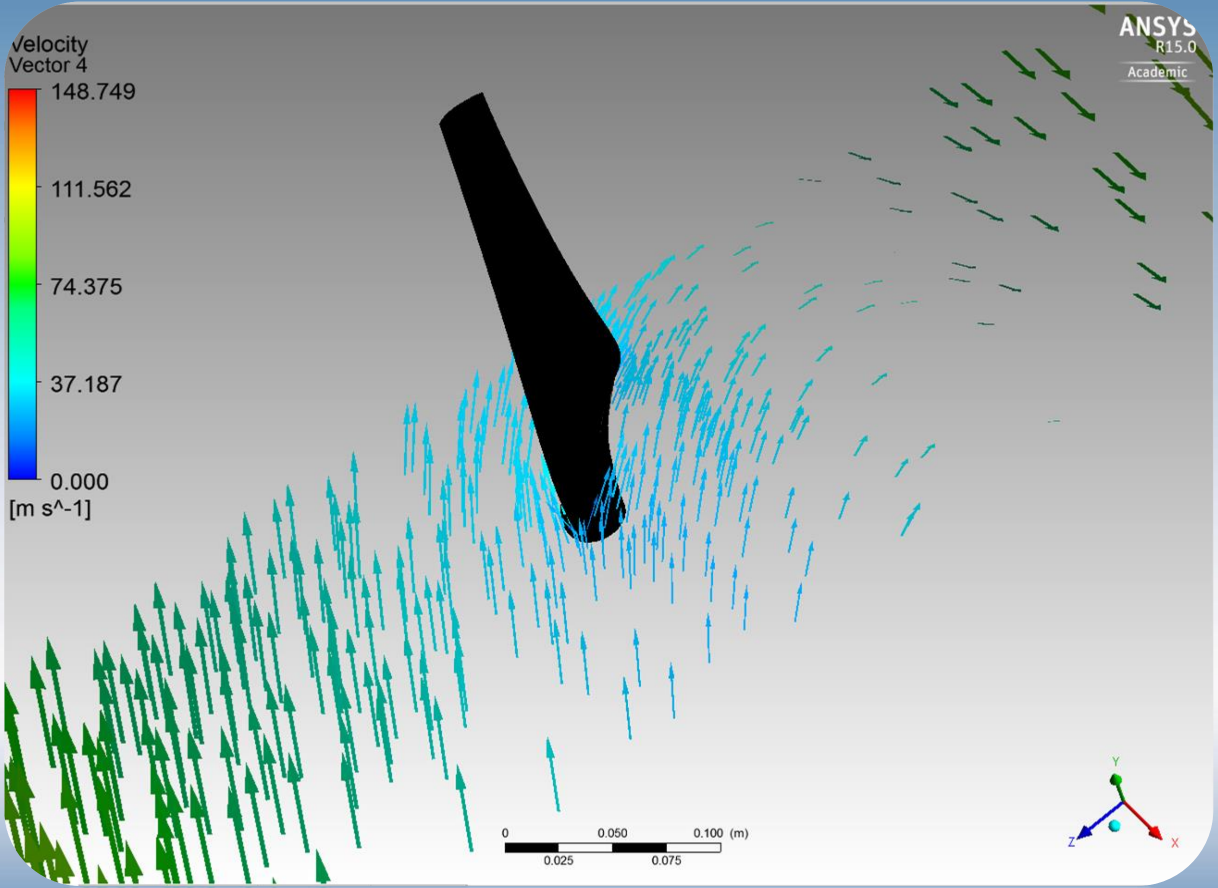
Flow vectors passing over different blade sections TSR=5,6

Near hub sectoin



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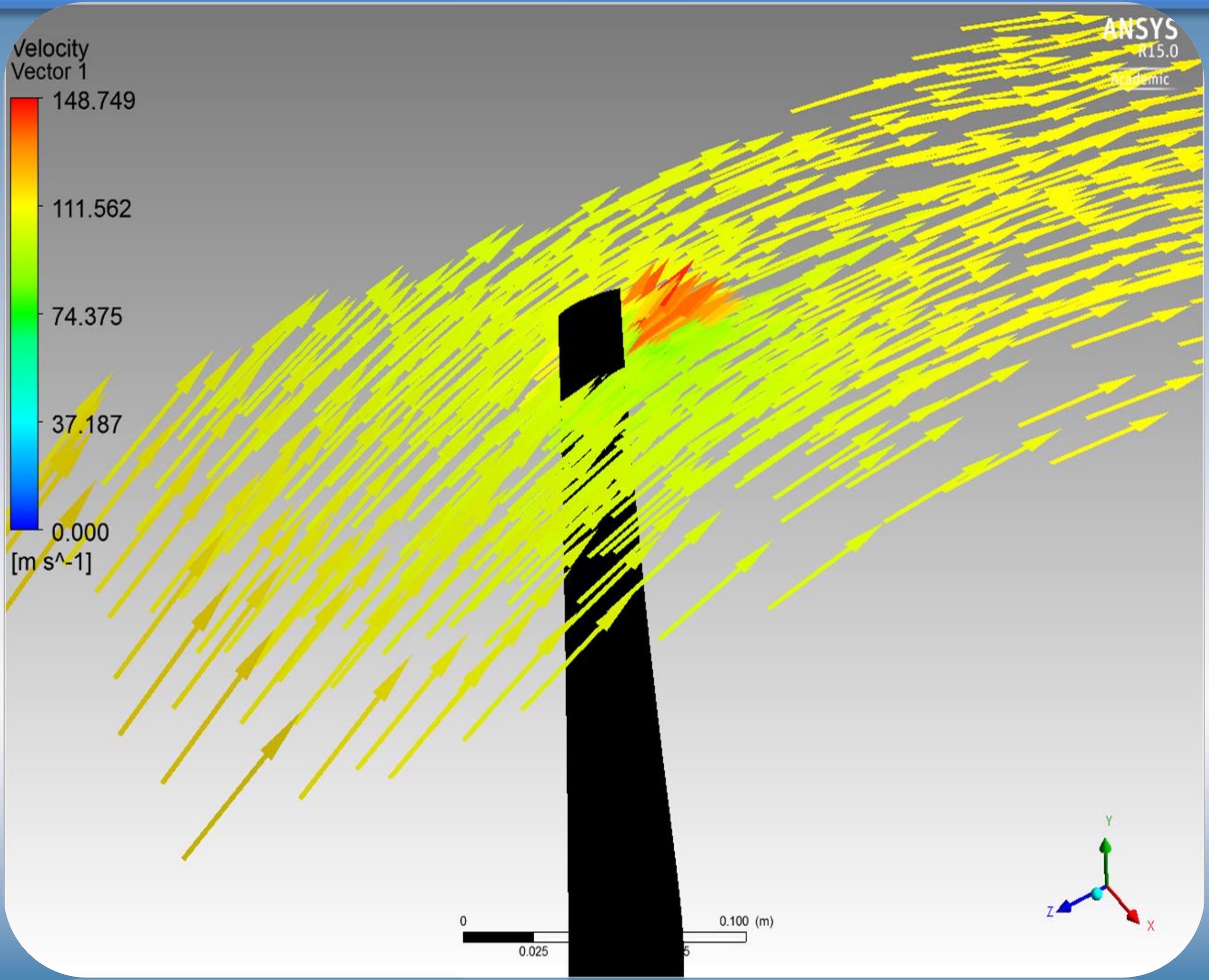
Flow vectors passing over different blade sections TSR=5,6



Near tip section

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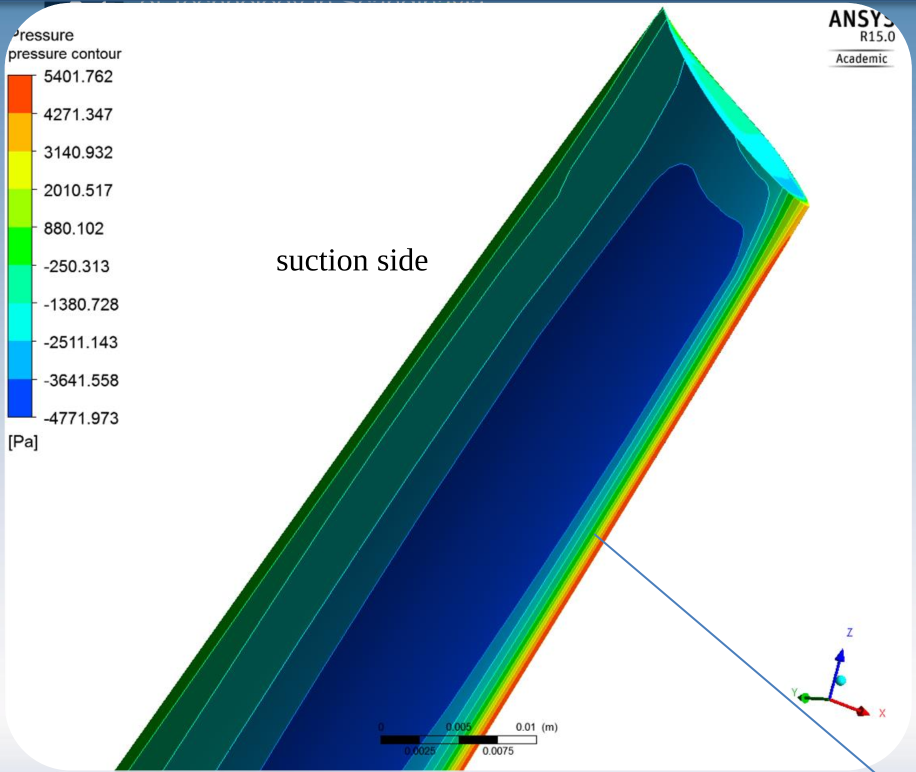
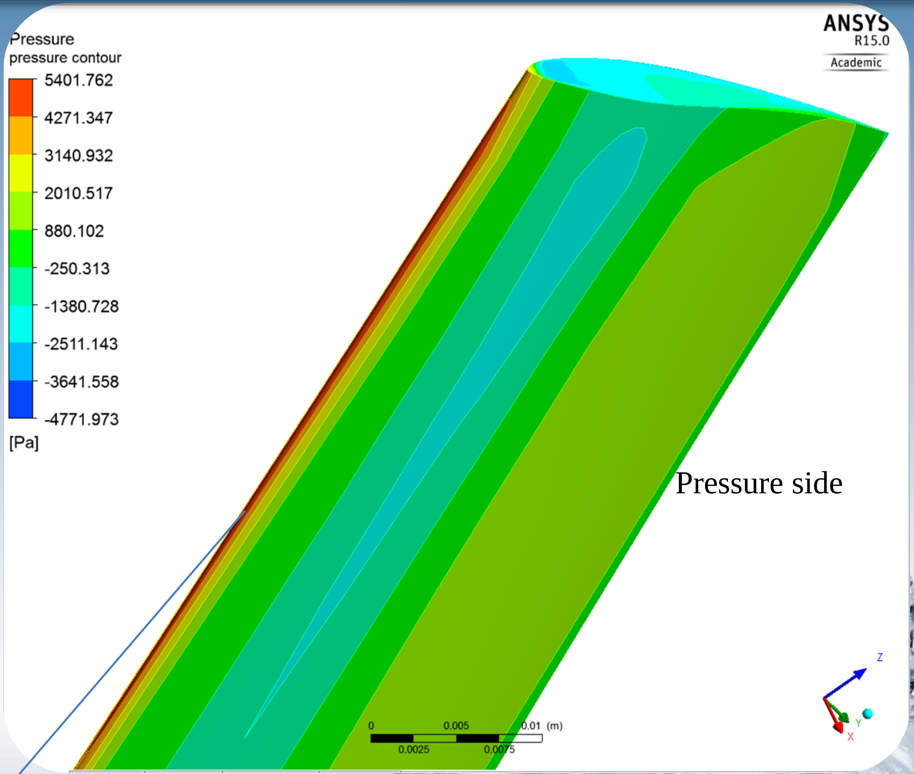
Pressure contour over the blade surfaces TSR=9,4





High pressure on leading edge near to blade tip

Streamlines over the critical speed points TSR=9,4

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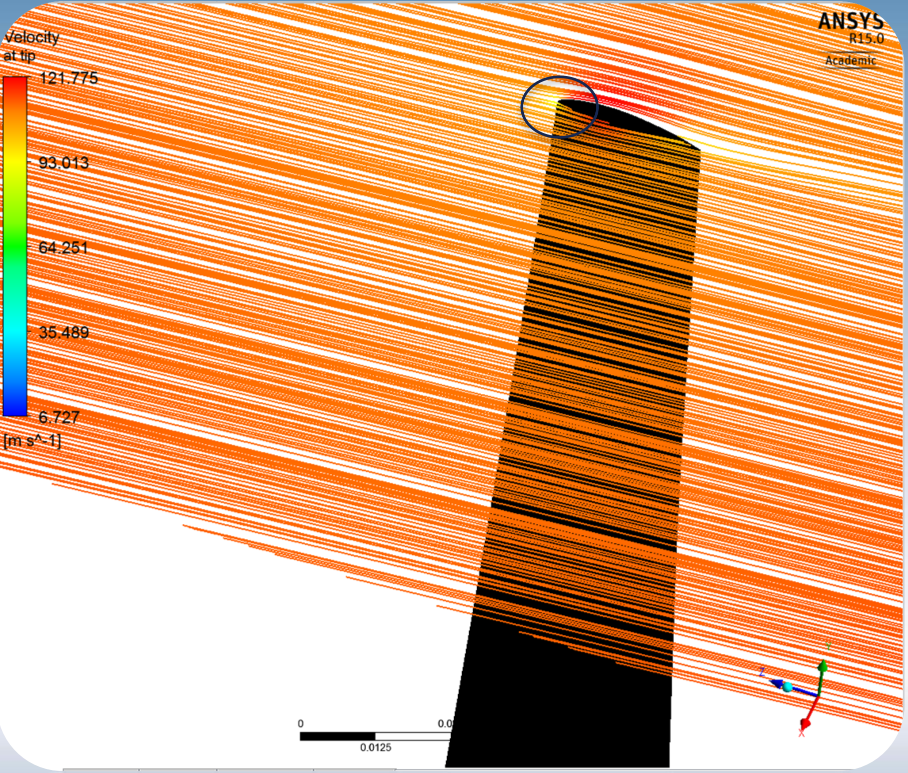
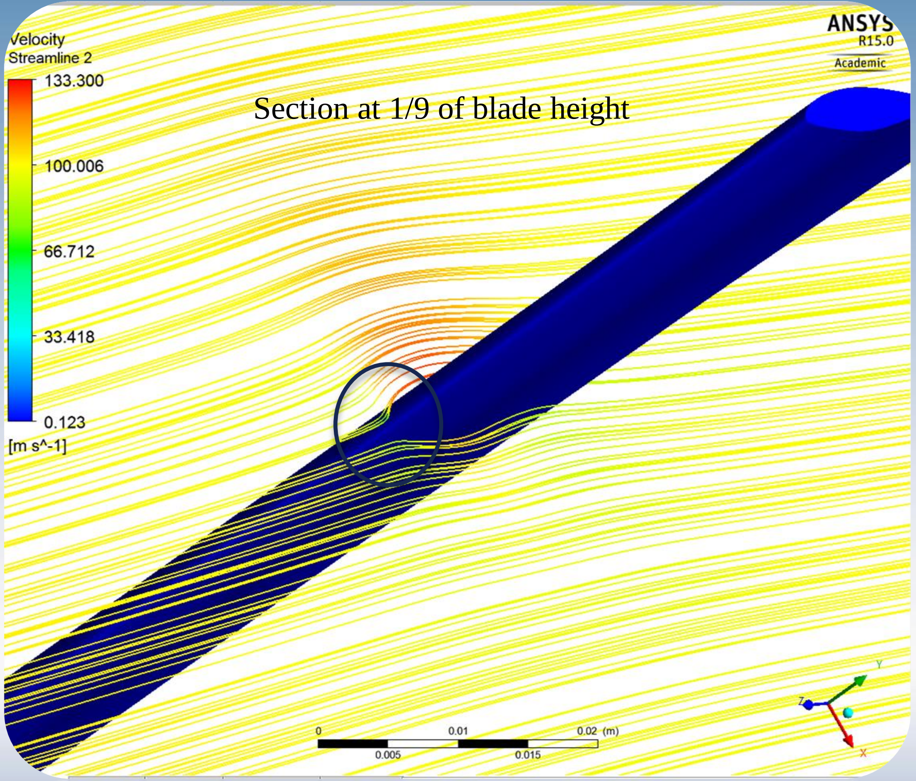
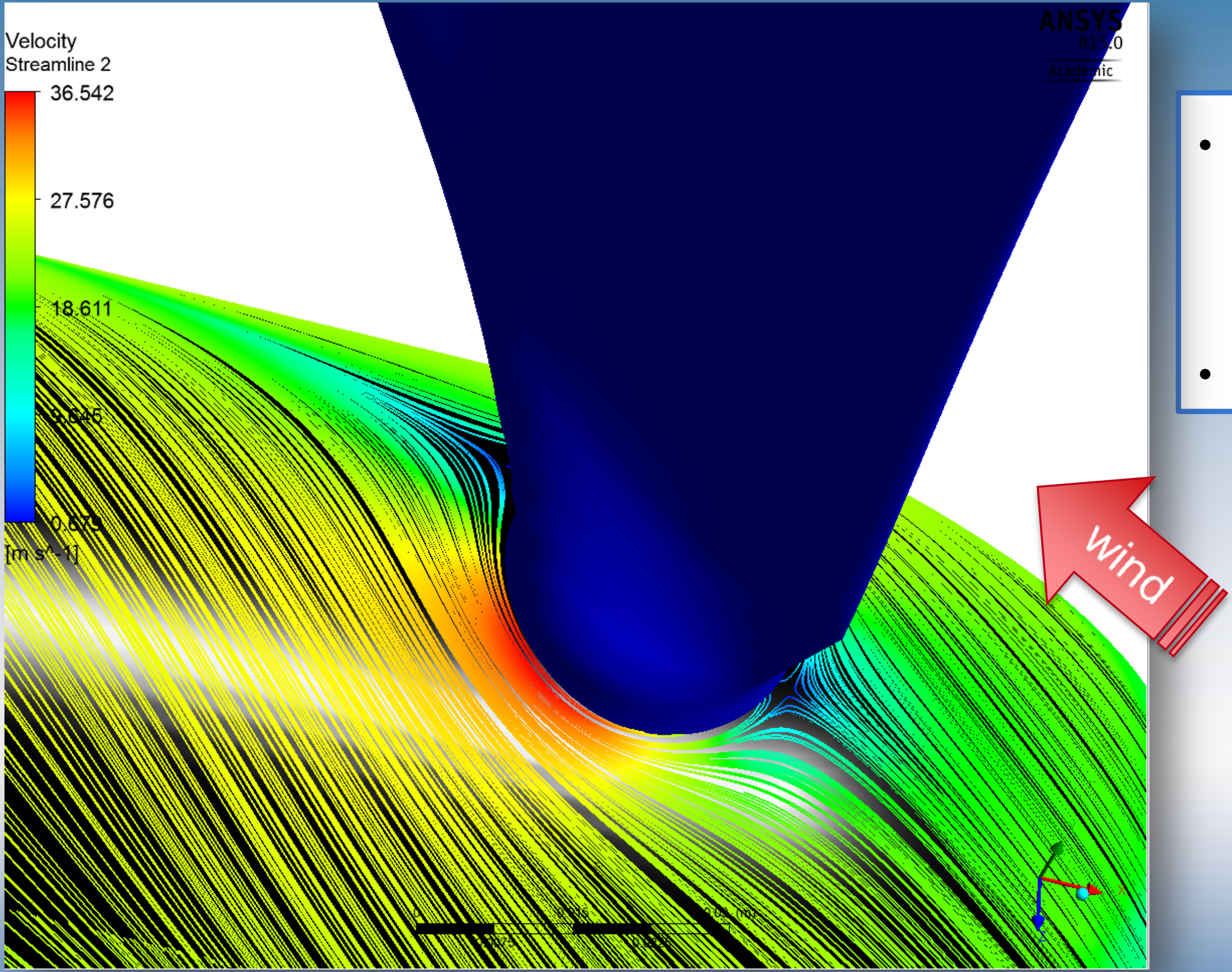




No separation at high speed points near the tip



- Streamlines on blade hub where it sits on the shaft.
- No separation is observed

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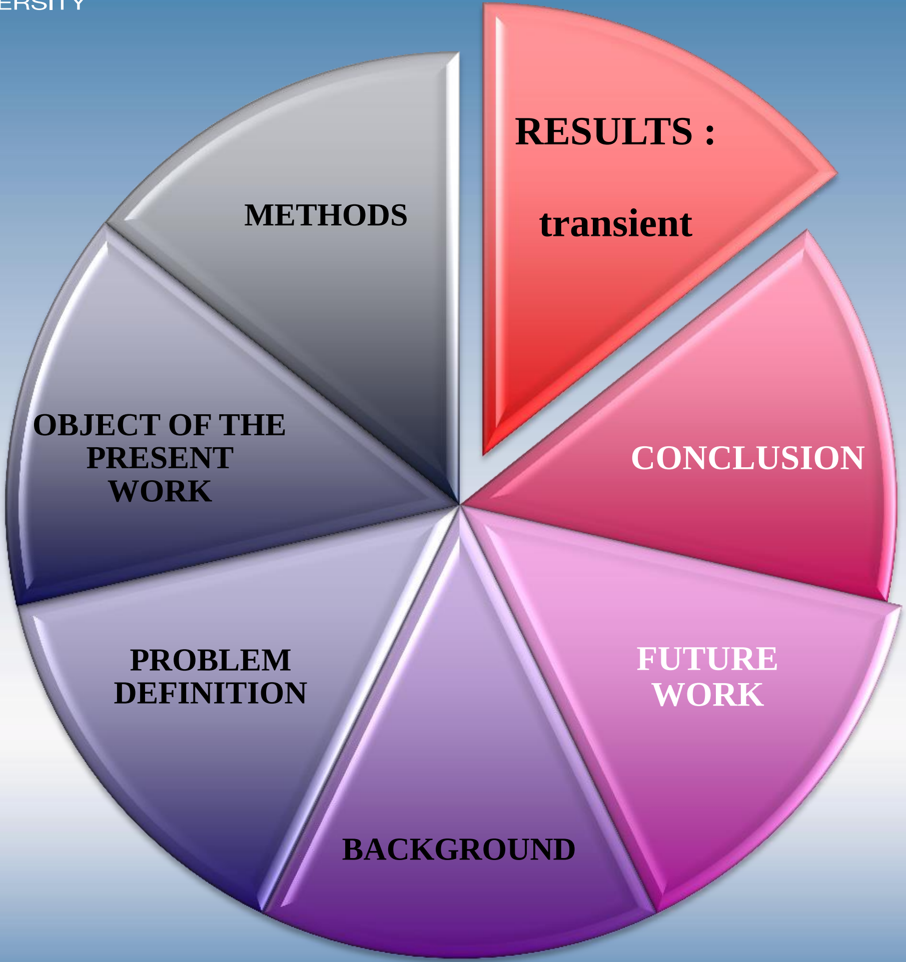

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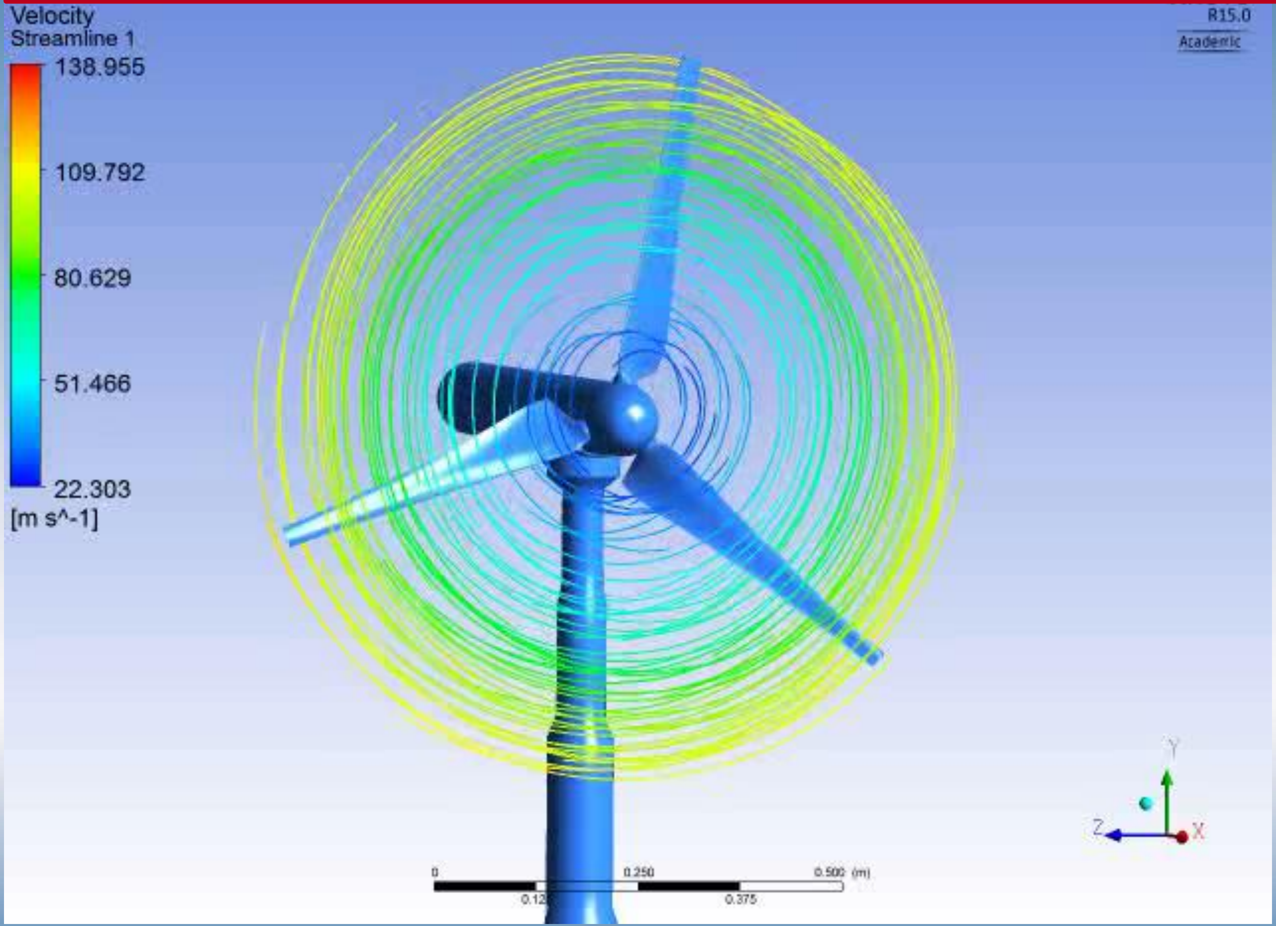
Streamlines showing the velocity variations during the transient simulation



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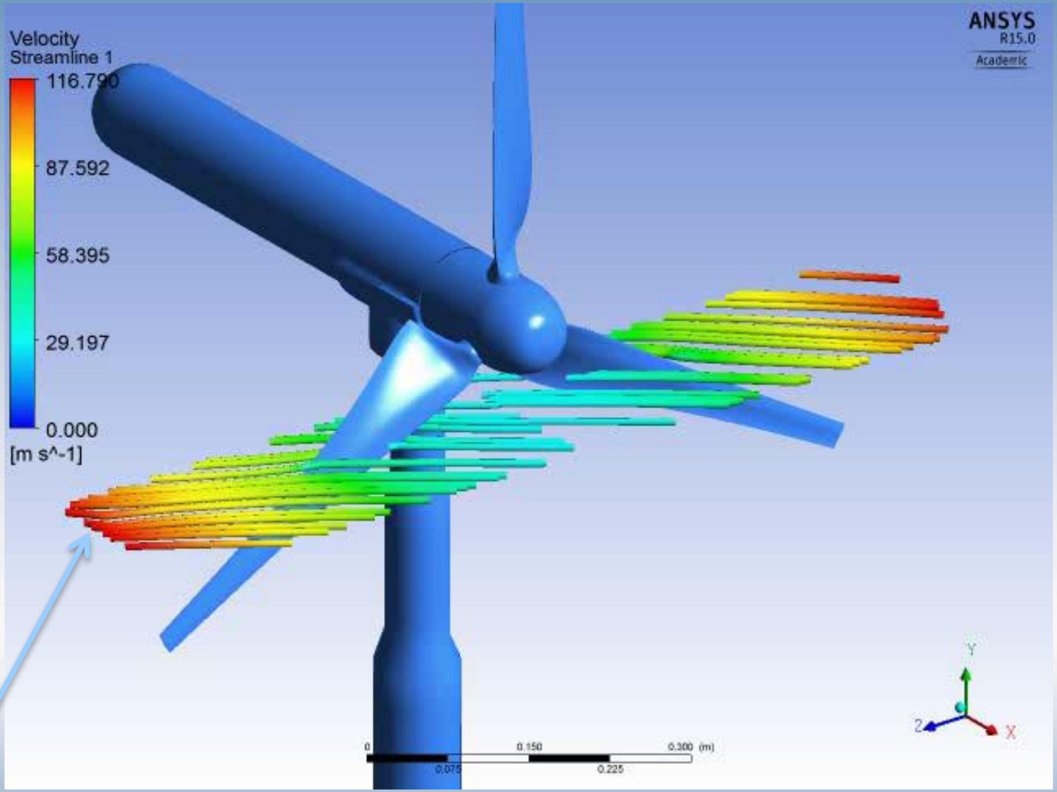
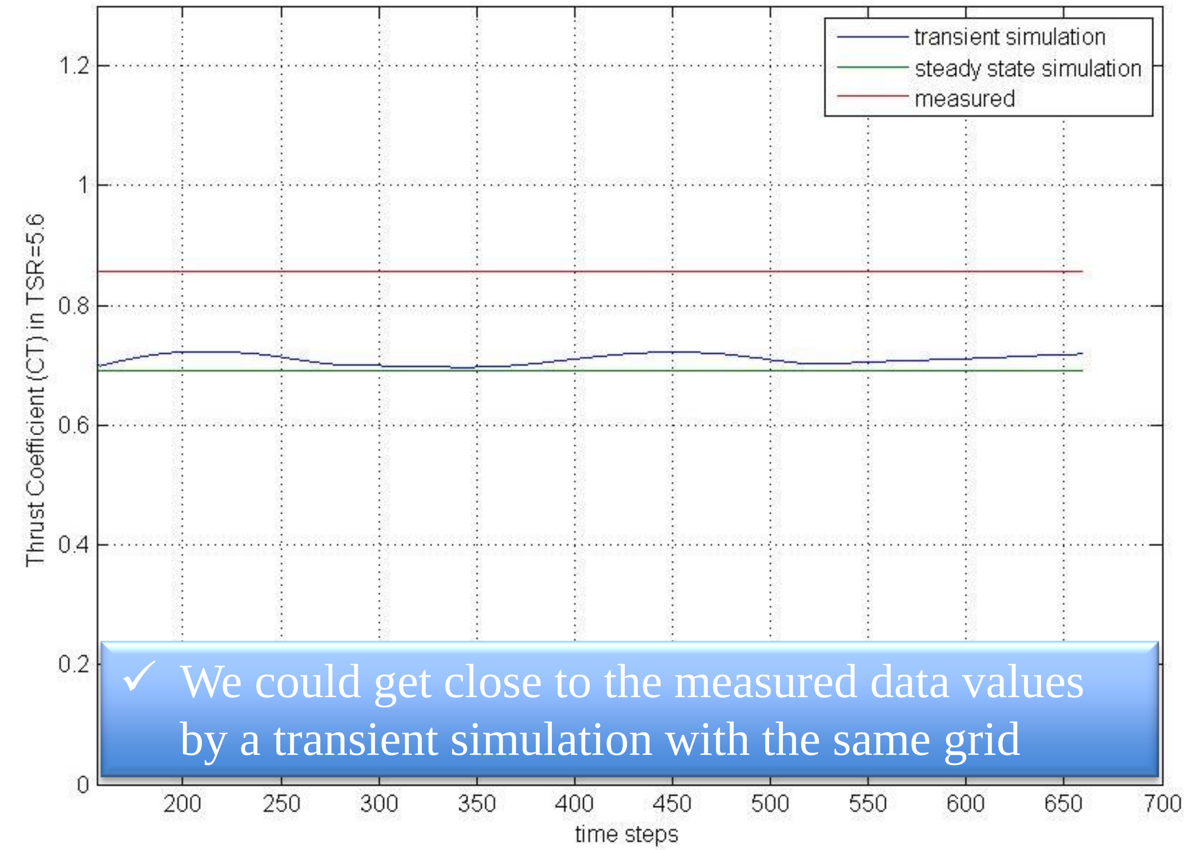
Streamlines showing the velocity variations during the transient simulation

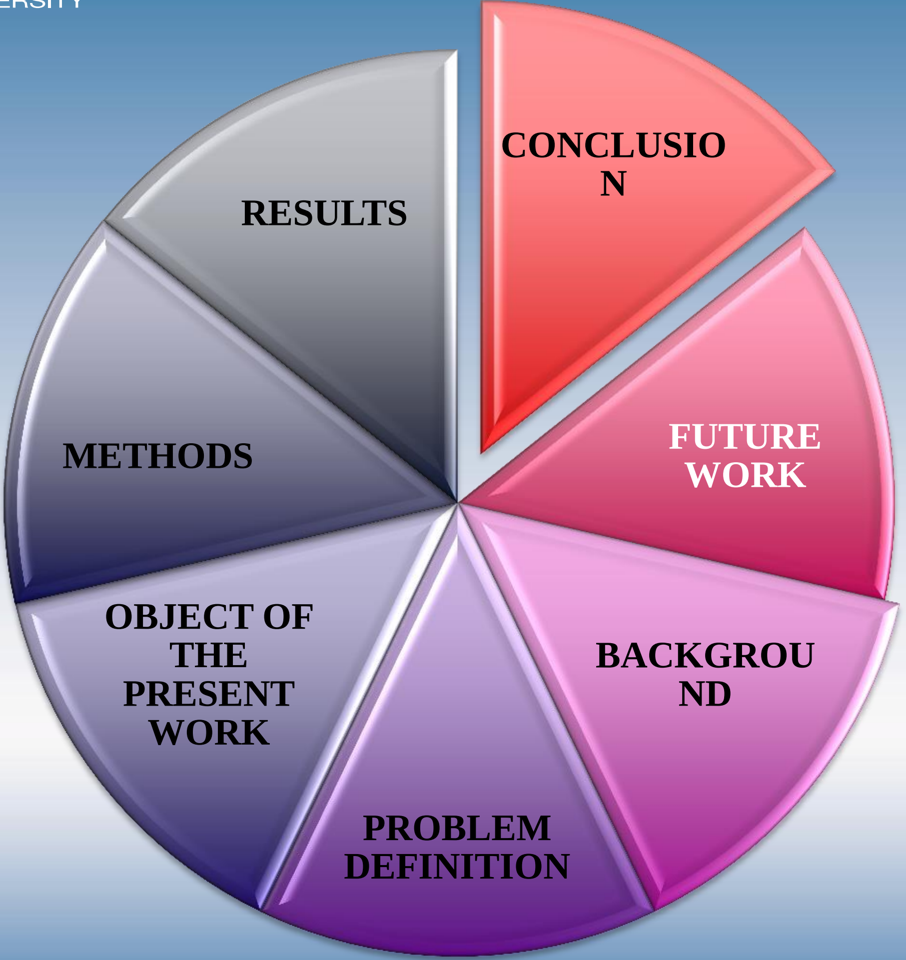


a fixed plane in which flow velocity changes during the rotation

Thrust Coefficient resulted from transient simulation



- ✓ We could get close to the measured data values by a transient simulation with the same grid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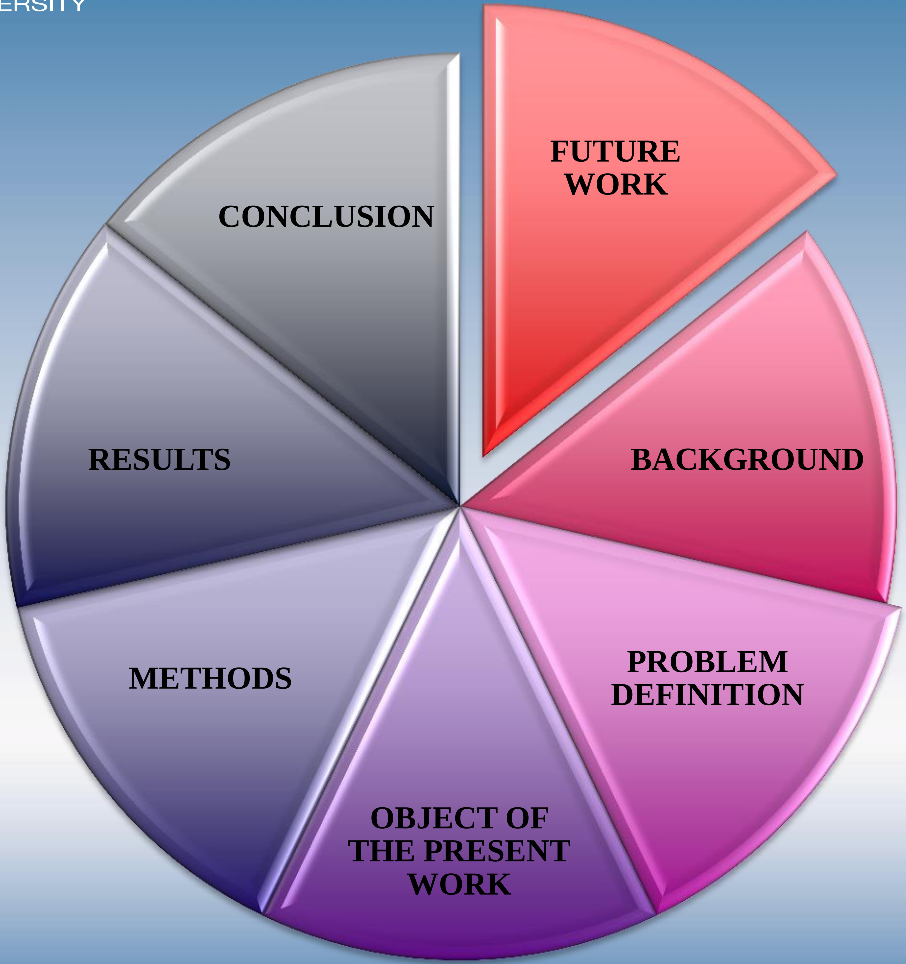
CONCLUSION:

The performance of the model turbine and wake formed by the rotor is predicted through a numerical study.

The power generation and the thrust force are calculated reasonably well.

The aim of this project has been to launch a reliable simulation of a wind turbine, to model icing in next step.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FUTURE WORKS:

Evaluation of CFD methods to simulate wind turbine accurately.

- Improve the quality and density of the mesh to get more precise results.
- Assess the need of turbulence modeling

3D simulation with various ice-configuration to support dynamic modeling

- Yield 3-D ice shapes over the blade bodies and study its effects on the wind turbine performance.

A coupled method fluid-structure interaction (FSI)

Thank you for your consideration