Validation of a mesh generation tool for aerodynamic simulation of wind turbine in OpenFOAM

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Outline

- Motivations & Objectives
- Mesh and meshing tools
- Validation
- Conclusion
- Future work

Motivation & Objectives

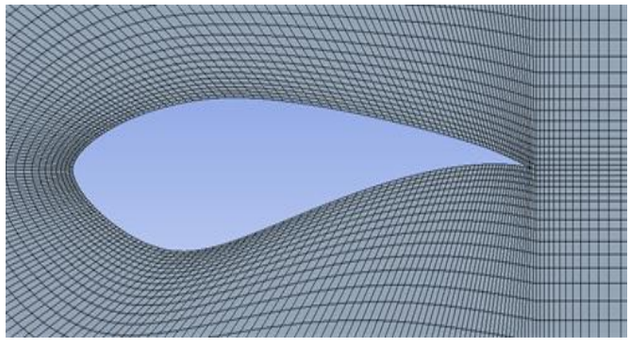
- CFD simulation are important parts of research and industrial projects
- CFD solutions require discretization
- Critical starting point
- Bottleneck in the analysis process
- Meshing has a significant impact on:
  - Convergence
  - Solution accuracy
  - CPU time required for simulations

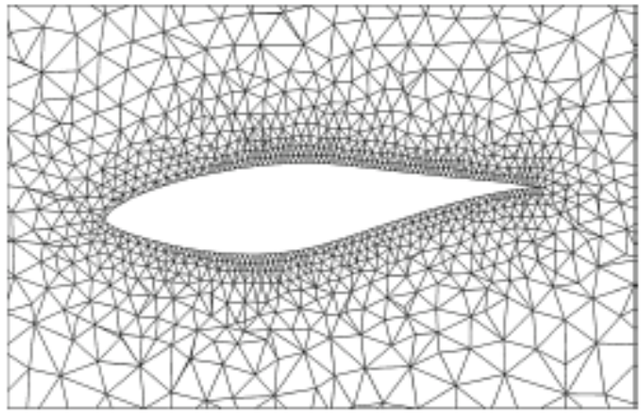
Motivation & Objectives

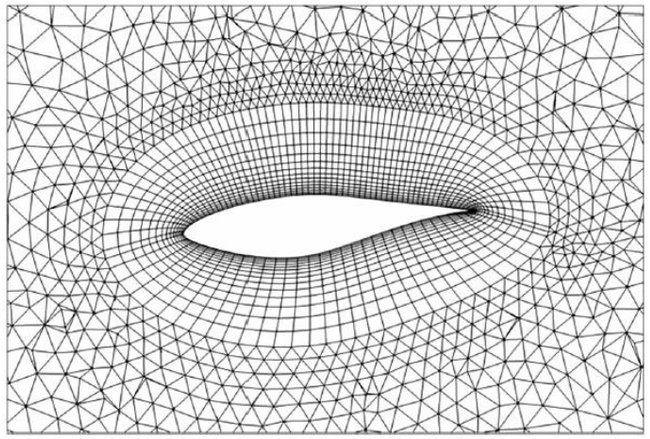
- Speed up the complex process of creating a structured mesh in OpenFOAM for blades, nacelle, tower, ...
- Implementing and optimizing new meshing process in OpenFOAM
- Testing the mesher to investigate its suitability and its requirement for wind turbine simulations

Mesh classification

- Structured:
  - Identified by regular connectivity
  - Hexahedral in 3D
  - Can effect on efficiently and convergence
- Unstructured:
  - Identified by irregular connectivity
  - Can be highly space inefficient
  - Tetrahedral in 3D
  - Faster to create
- Hybrid grids





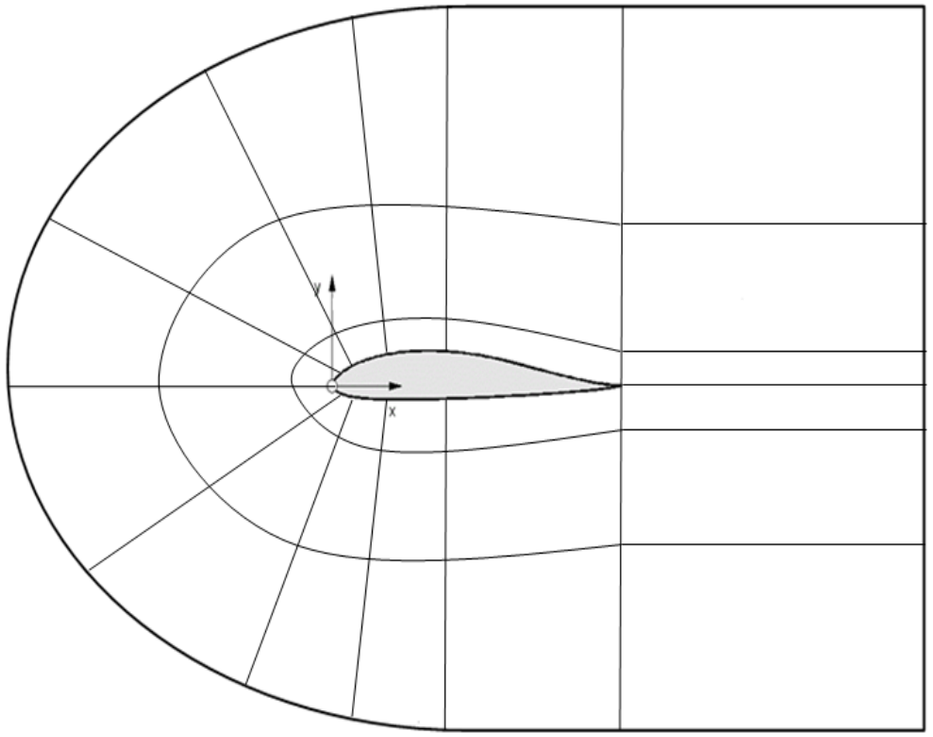


What is an appropriate mesh?

- Mesh density: high enough to capture all relevant flow features.
- Mesh density: CPU time?
- Length/volume ratios of adjacent cells: fine enough to resolve the boundary layer flow.
- Skewness- Orthogonaltiy
- Tet vs Hex
- Boundary layer mesh
- Aspect ratio and grading

Meshing with OpenFOAM

- blockMesh
  - Structured mesh
  - Block decomposition of the computational domain
  - Simple geometries
  - Time consuming procedure



Meshing with OpenFOAM

- snappyHexMesh
  - Unstructured mesh
  - Meshes directly to surfaces from STL
  - Can be a time consuming procedure
  - Problem with sharp edges:
    - Trailing edge of blades

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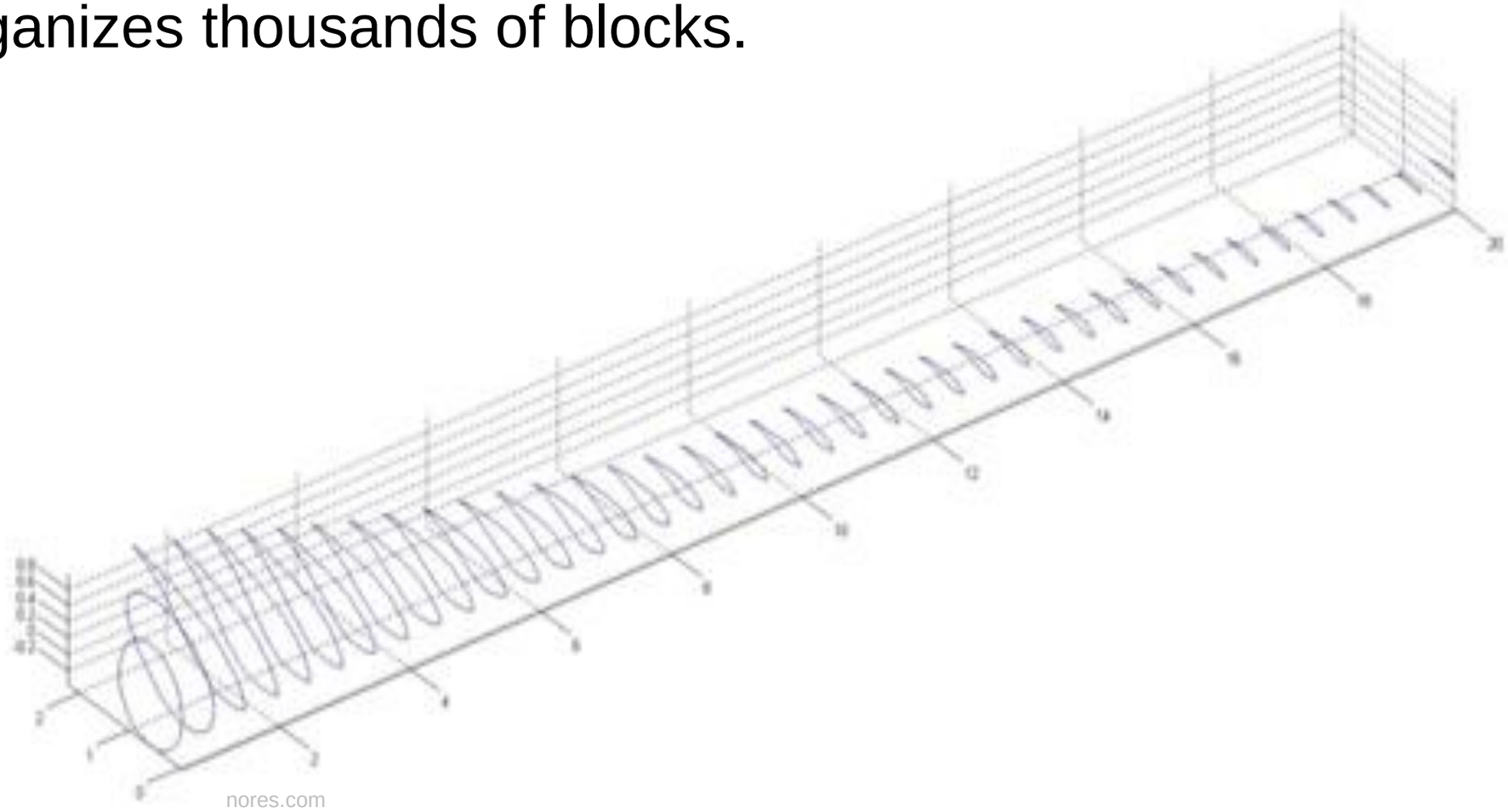
New Meshing tool

- Automatized structured mesh generation
- Key feature: organizes thousands of blocks.



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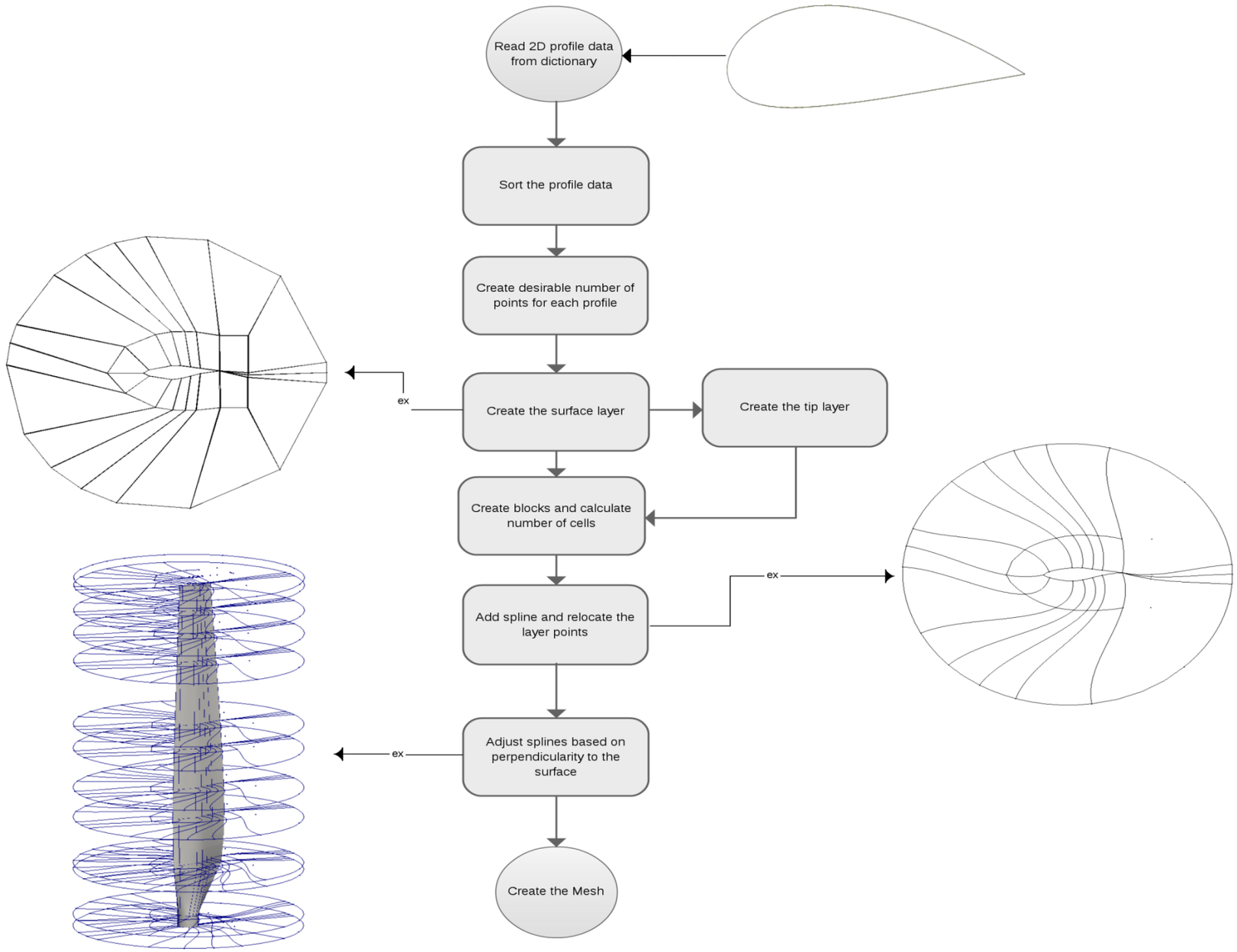
What is accomplished by the developed code?



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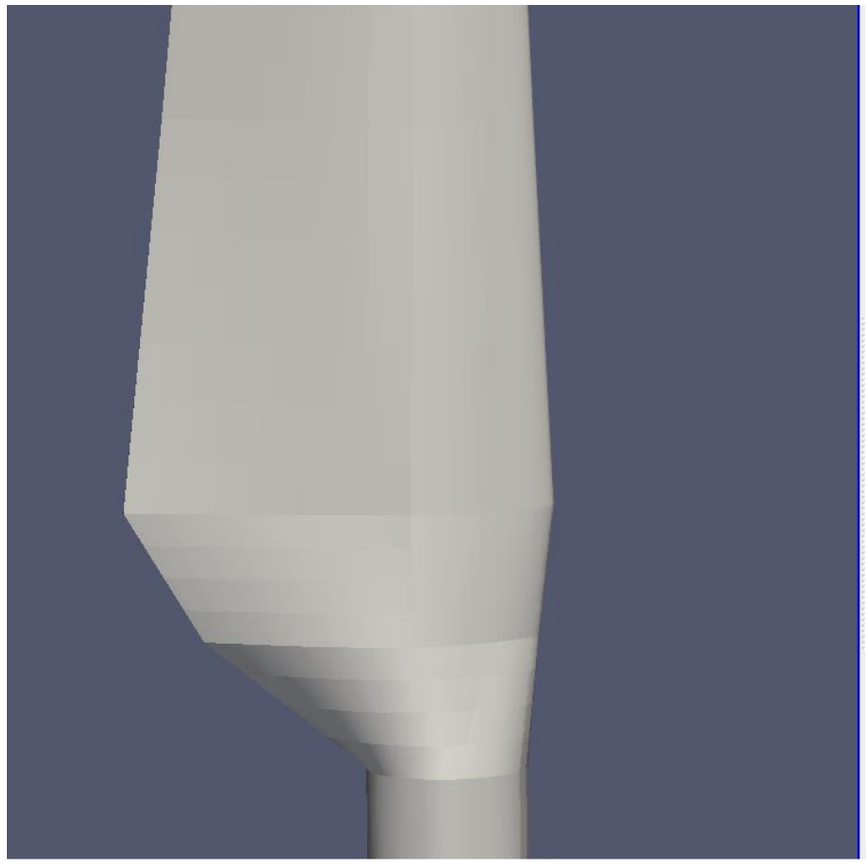
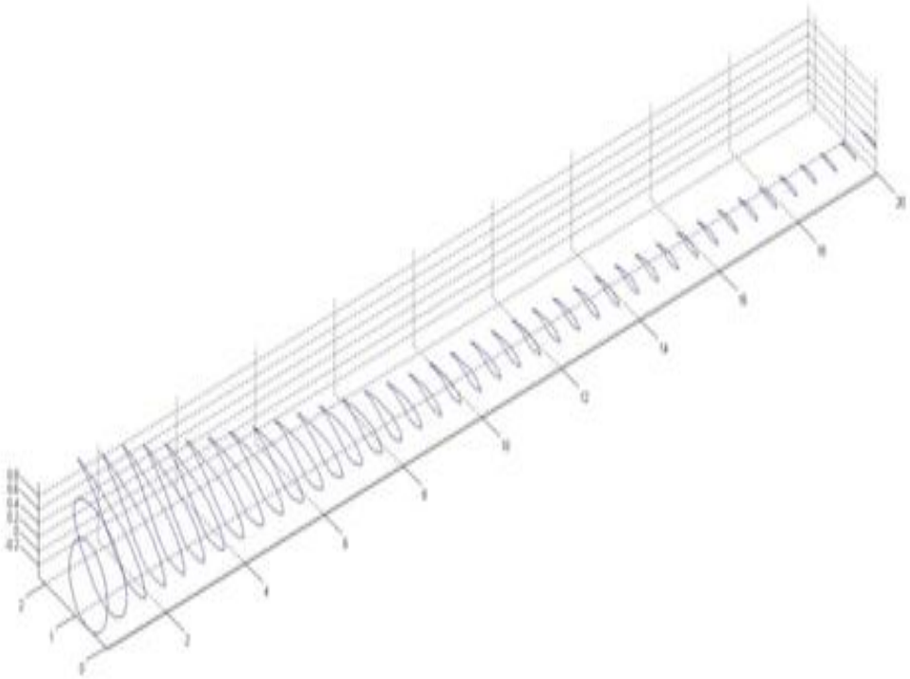
Smoothing rotor-blade geometry





Smoothing rotor-blade geometry

- Few number of slices in spanwise direction
- Blade geometry should be free of sudden changes and kinks which cause undesired effects
- A polynomial based, recursive method
- Will give accurate results by using appropriate linear combination of values at grid nodes

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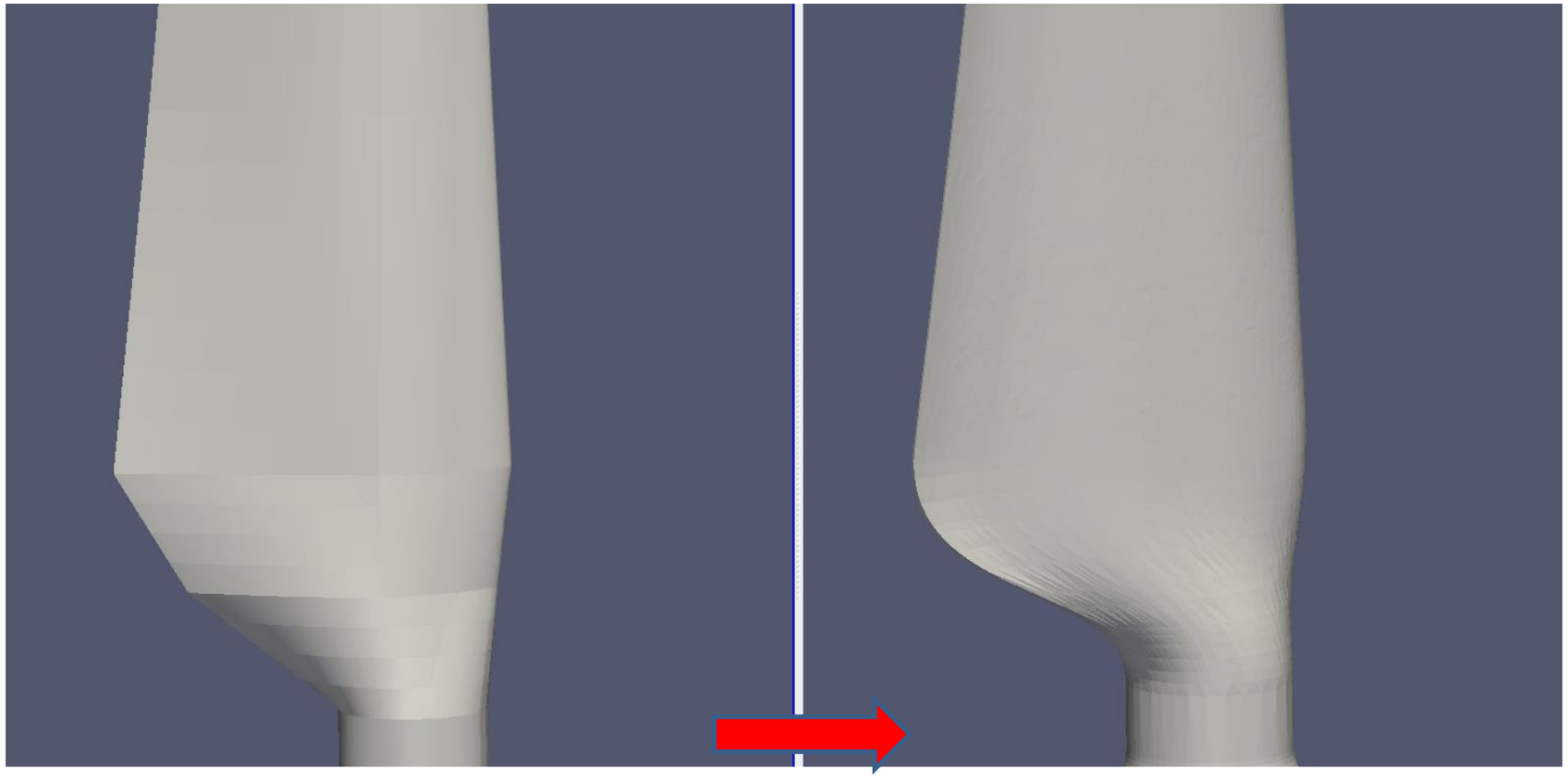
Smoothing rotor-blade geometry



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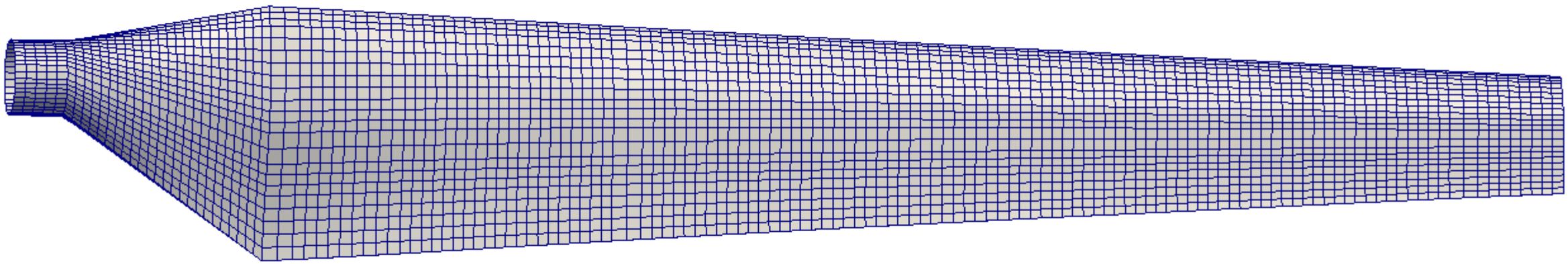
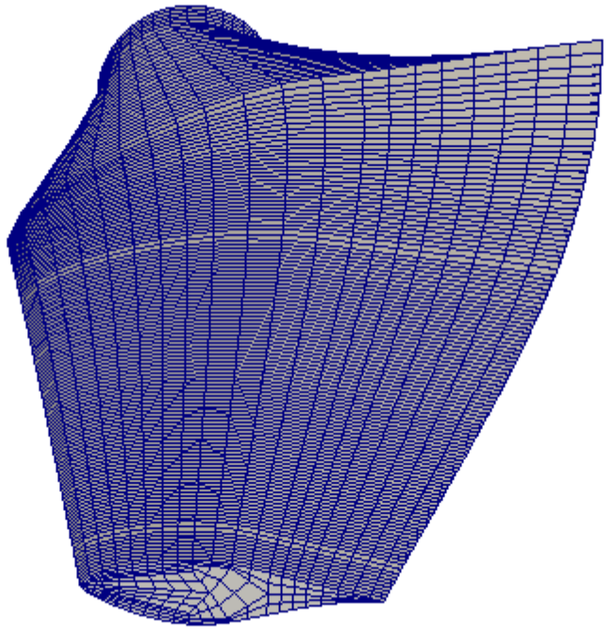
Final Mesh





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Validation using CFD simulation for NREL VI

- NREL rotor with 0° yaw angle and 3° tip pitch angle for 6 different incoming wind velocities

http://www.nrel.gov/wind/

Validation using CFD simulation for NREL VI

- Simulation conducted on the *FLOW* * cluster, with 92 CPU cores
- Steady-State simulation
- Total gird size: 7 Million
- **k-ω SST** turbulence model
- Convergence achieved within10 hours CPU time >15000 iterations

* The Facility for Large-Scale cOmputations in Wind energy research (FLOW)

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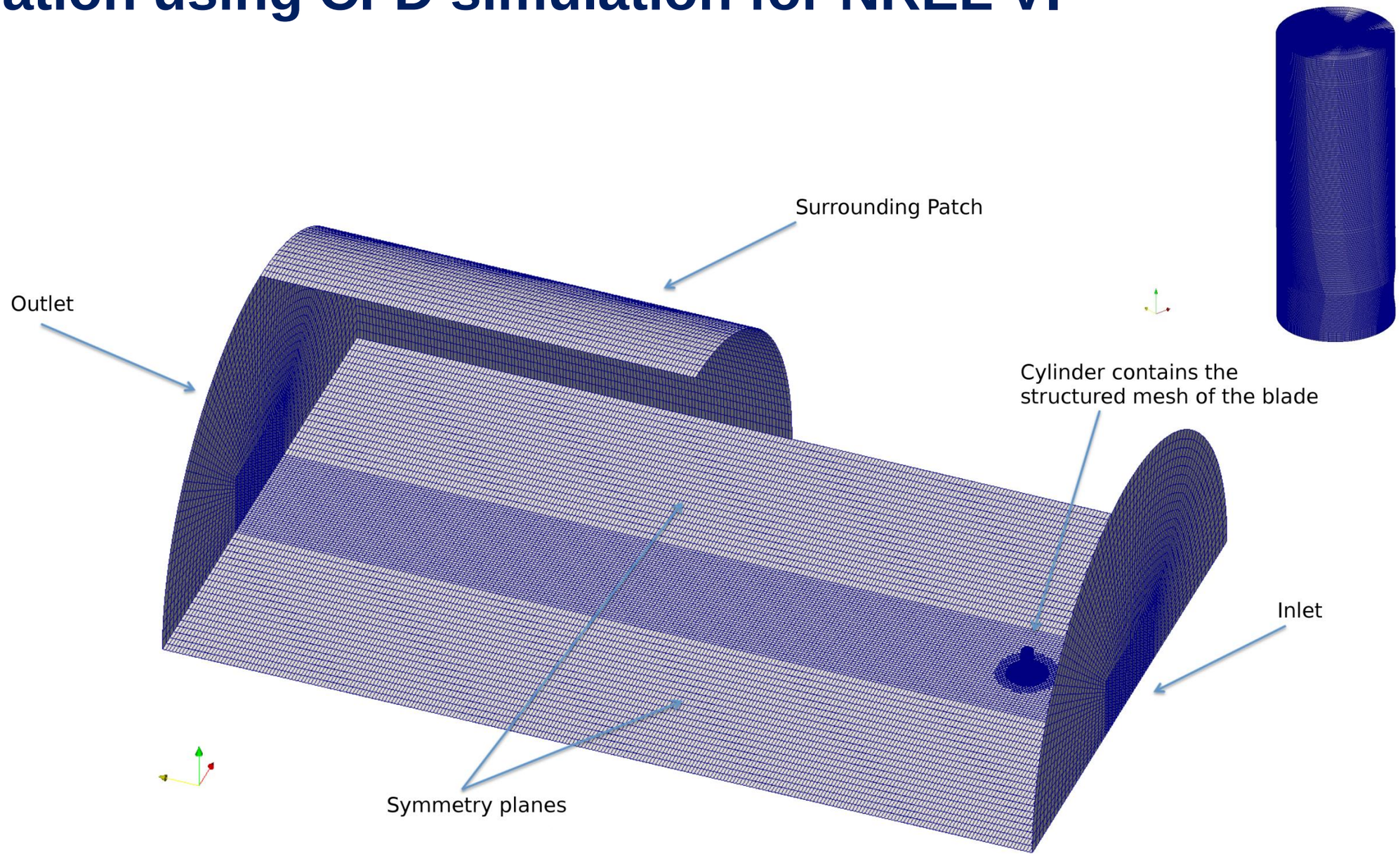
Validation using CFD simulation for NREL VI



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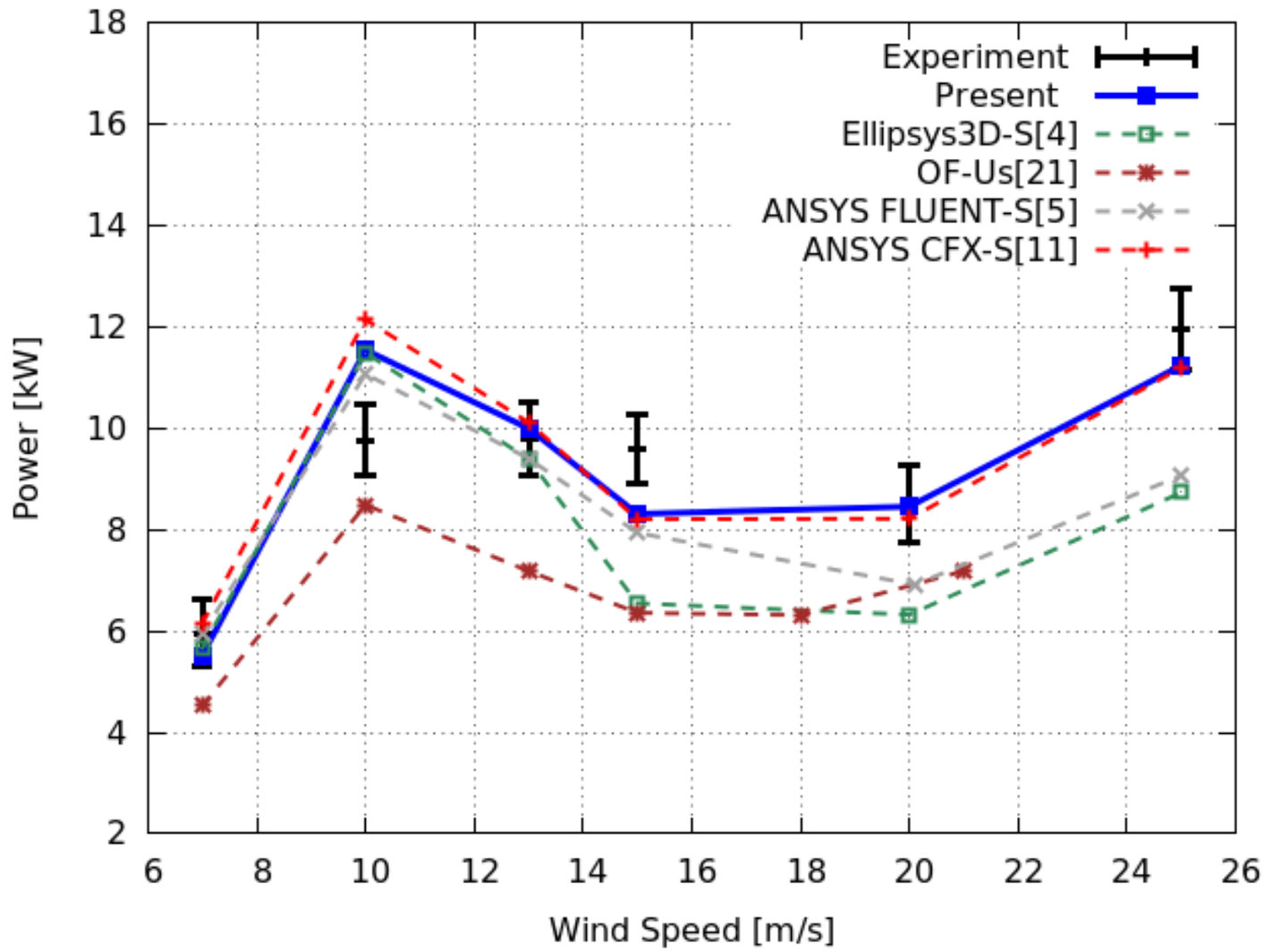
Validation using CFD simulation for NREL VI -Power output



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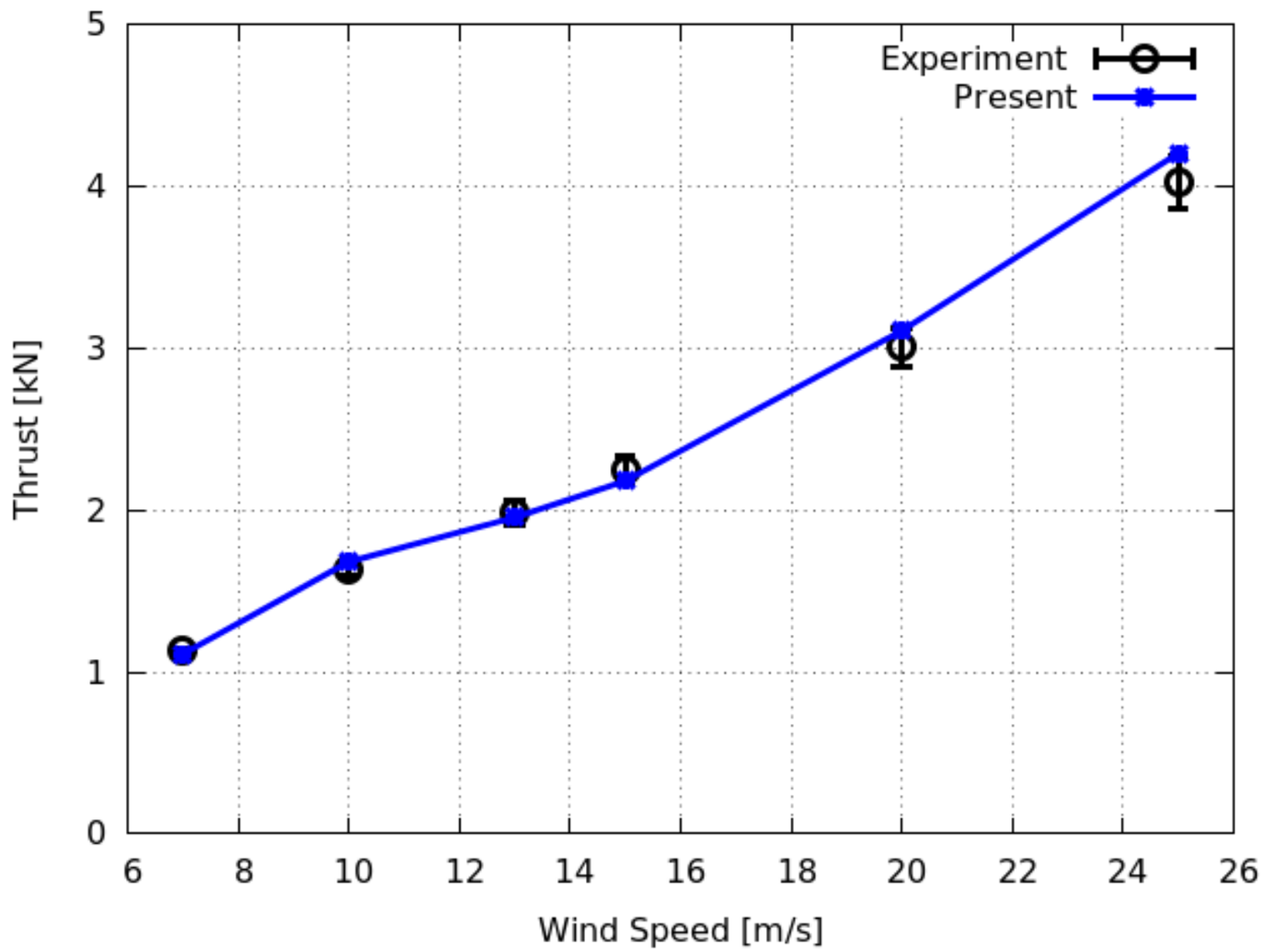
Validation using CFD simulation for NREL VI -Thrust



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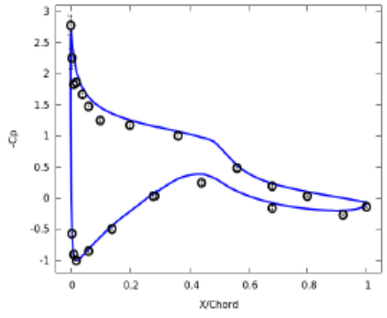
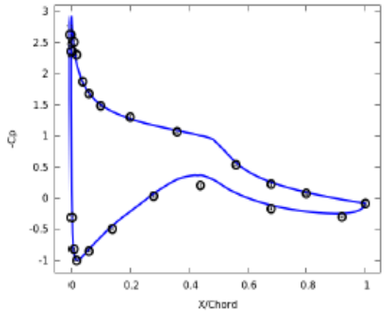
Validation using CFD simulation for NREL VI -Cp

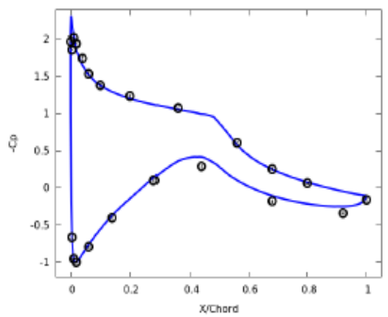
7 m/s



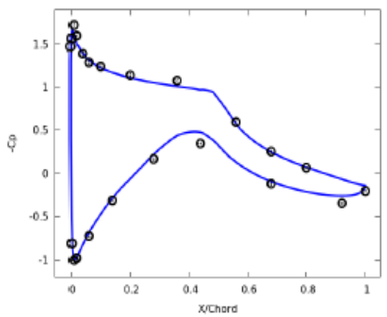
(a) $r/R = 30$ %



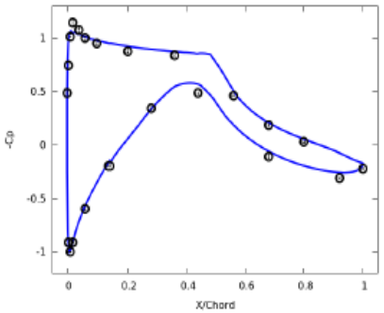
(b) $r/R = 47$ %



(c) $r/R = 63$ %

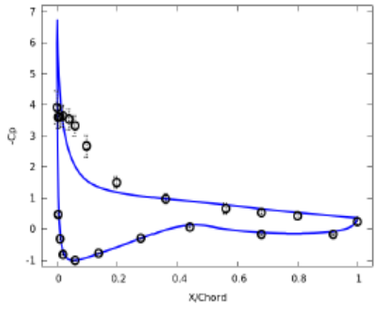


(d) $r/R = 80$ %



(e) $r/R = 95$ %

10 m/s



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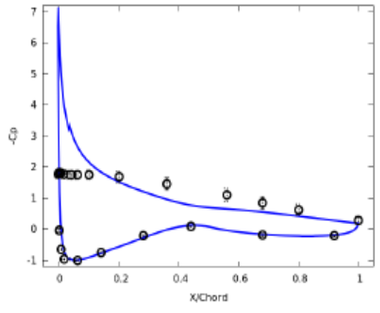
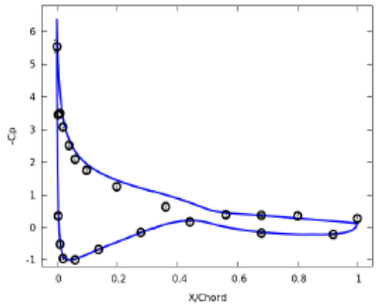


(b) $r/R = 47$ %



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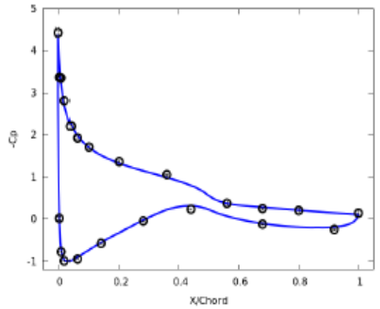

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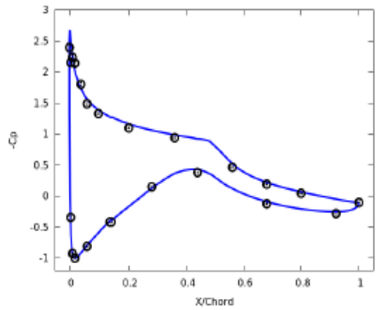

(e) $r/R = 95$ %

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Validation using CFD simulation for NREL VI -Cn & Ct

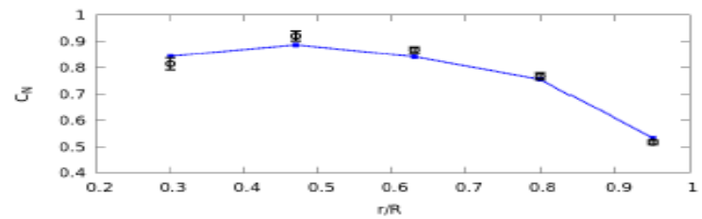
(a) $7m/s$

(b) $10m/s$

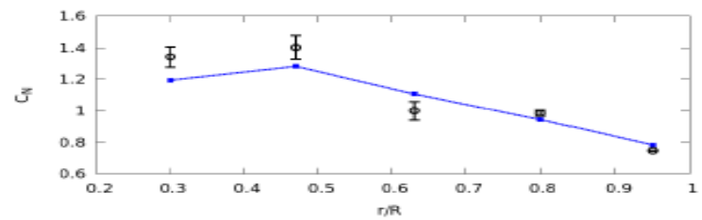
(c) $15m/s$

(d) $20m/s$

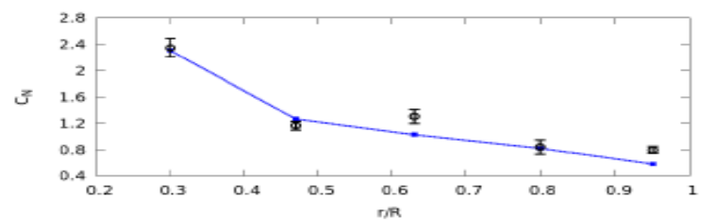
(e) $25m/s$



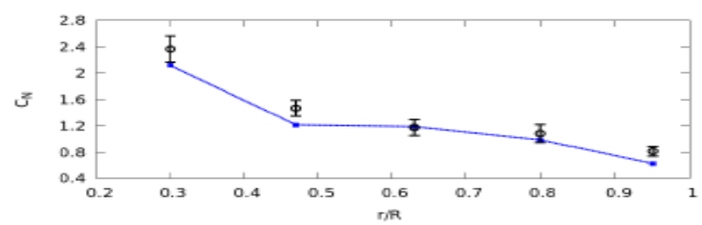
(a) $7m/s$



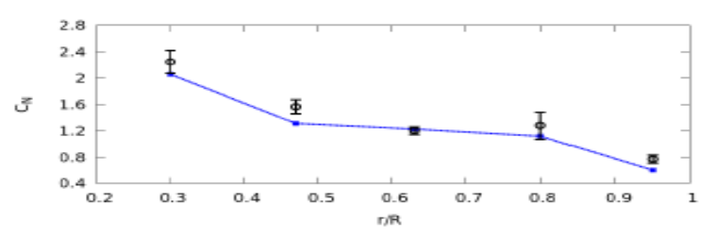
(b) $10m/s$



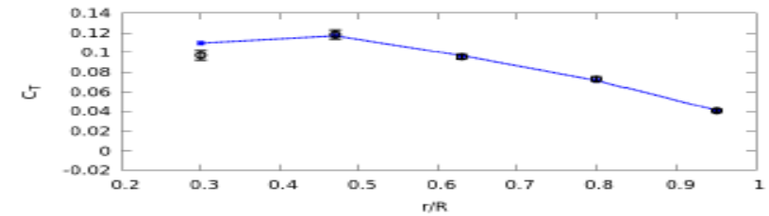
(c) $15m/s$



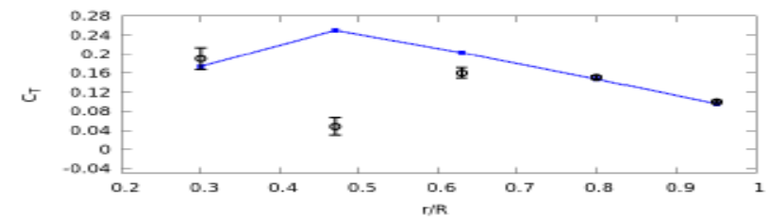
(d) $20m/s$



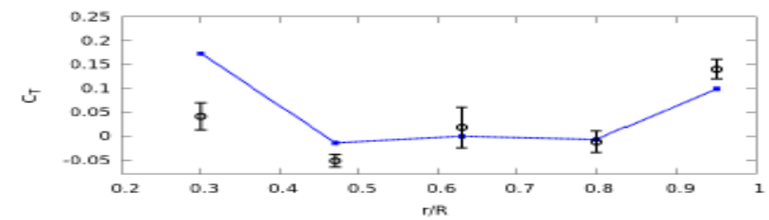
(e) $25m/s$



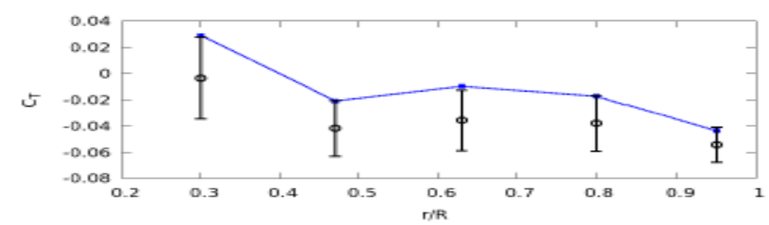
(a) $7m/s$



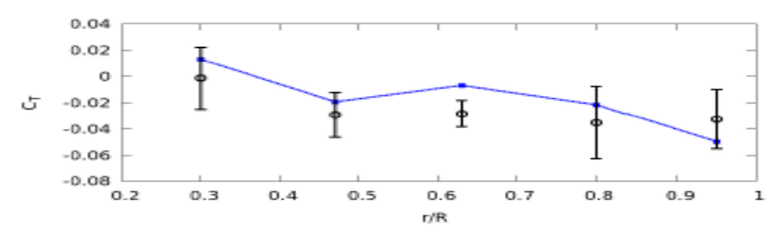
(b) $10m/s$



(c) $15m/s$



(d) $20m/s$



(e) $25m/s$

Conclusion

- The automatized mesh-generator developed so far can be used in combination with OpenFOAM as a tool for investigating blade aerodynamics and load calculations.
- The quality of blocks and the effects of the grid on the results has been investigated in different cases
- The block-generator allows implementation of smooth and complex geometries by only using coordinates of few number of points.
- Simulation results show the good quality of generated mesh

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Future works

- Implementing smoothing function for the mesh
- Improving the quality of mesh by testing with different Wind turbine blades types

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Smart Blades Project

- Development and Design of Intelligent Rotor Blades -

A joint research project of DLR, ForWind and Fraunhofer - IWES

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

* The Facility for Large-Scale cOmputations in Wind energy research (FLOW)

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Thank you for your attention

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