CFD Simulation of a Horizontal Axis Wind Turbine

Hamid Arastoopour and Emad Abbasi
Wanger Institute for Sustainable Energy Research, IIT

Applications of CFD in Wind Energy: From blade design to Wind Farms

- Airfoil design
- Blade design
- Full rotor sizing
- Acoustic analysis
- Wind farm configuration

Objective:

To Understand the behavior and performance of the wind turbine in the presence of rain droplets

***Case Studies**:*

1- Aerodynamic performance of the S809 airfoil with and without rain droplets

2- Full rotor simulation of NREL phase II experiments with and without rain droplets

Aerodynamic performance of the S809 without rain droplets

S809 Airfoil

- **Designed by NERL for HAWT application**

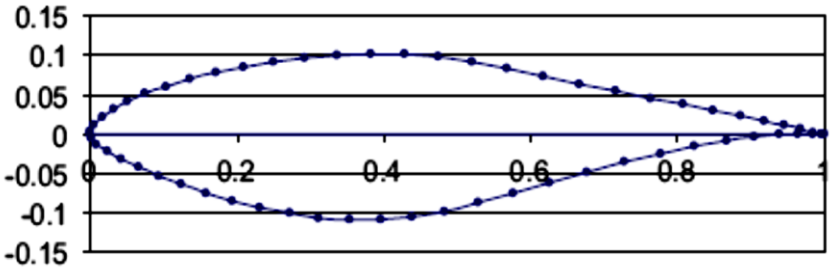
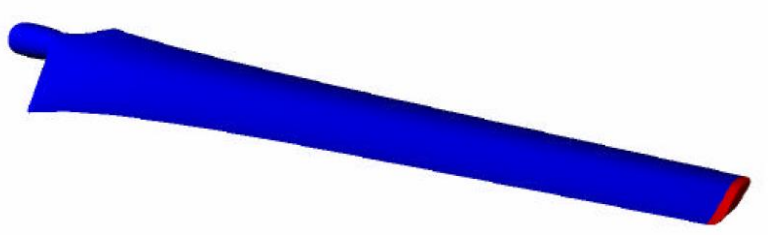


Fig. 1. S809 airfoil profile (unit: m).

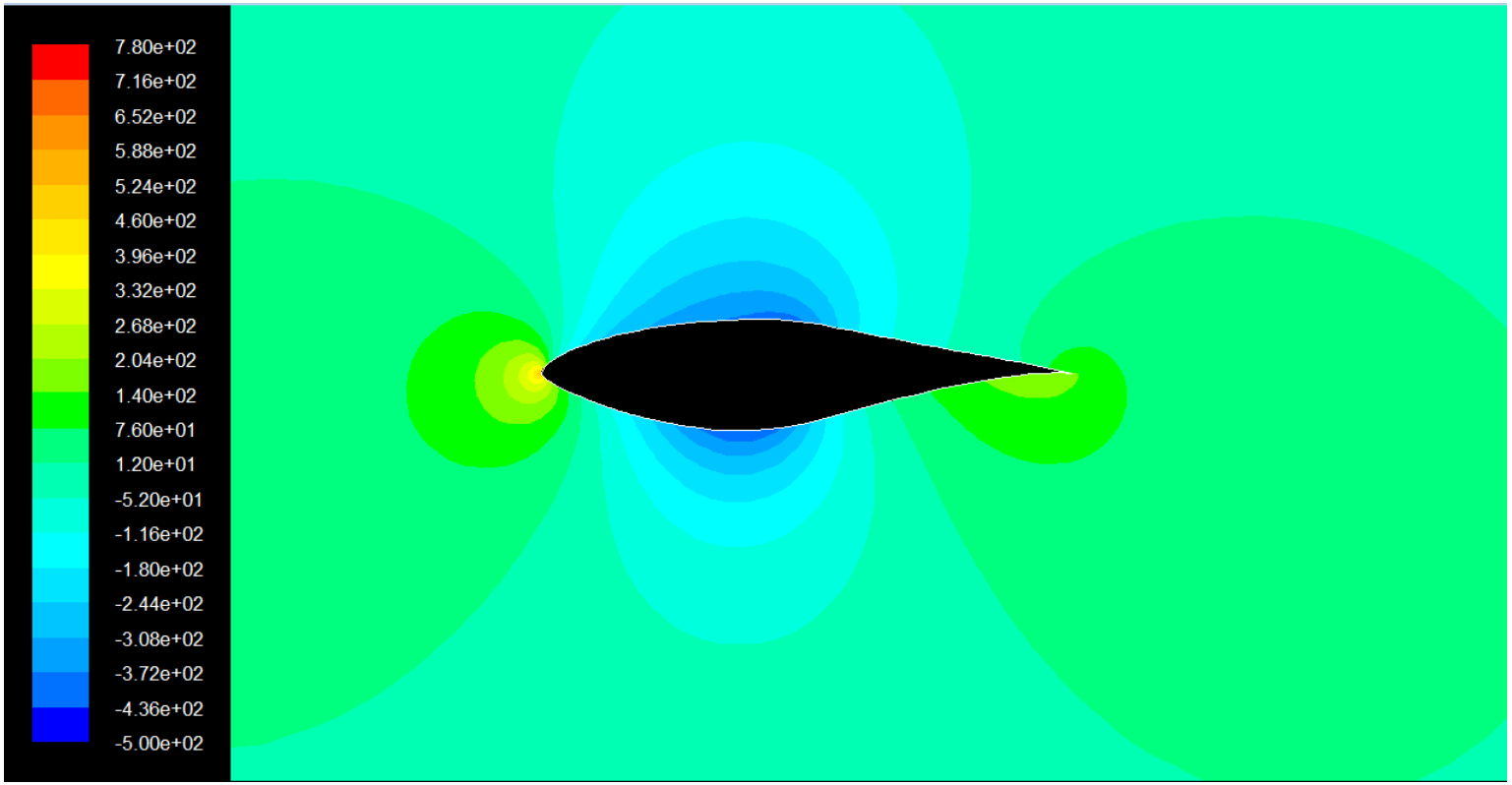


Laminar Flow Airfoil for Wind Turbine Applications

- Re= 2,000,000, Angle of Attack = **0° to 20°**
- **Experiments:**
- 2D: Tested in the low-turbulence wind tunnel at Delft University of Technology, (Somers, 1989)
- 3D: Used as the profile for the NREL Phase IV full wind turbine experiment, (Simms, 2001)
- Transitional and Fully Turbulent
- Grid = 200,000 Nodes
- Turbulent model: k-ω SST

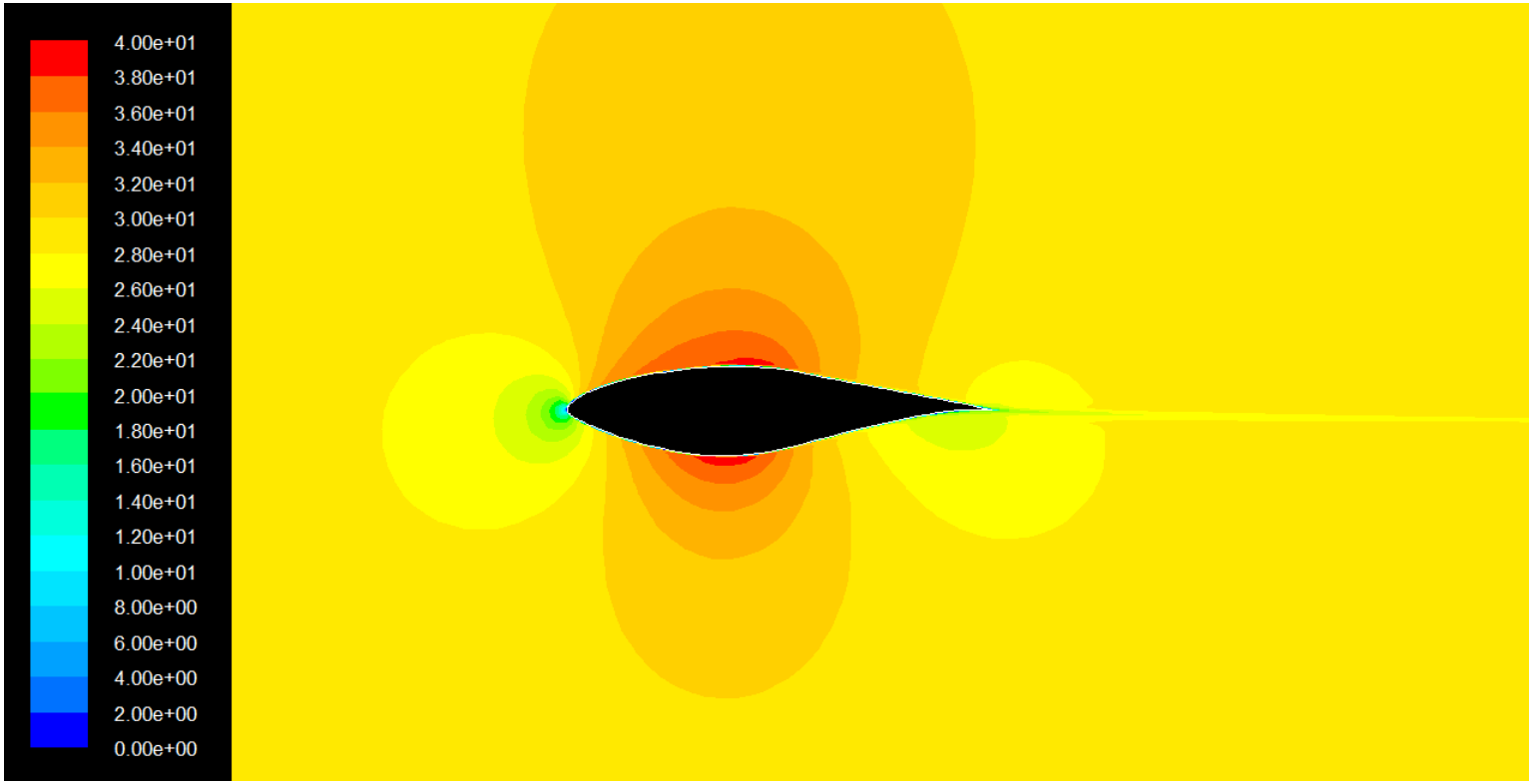
2d simulation results

Static Pressure Contours , Angle of attack: 0 degree



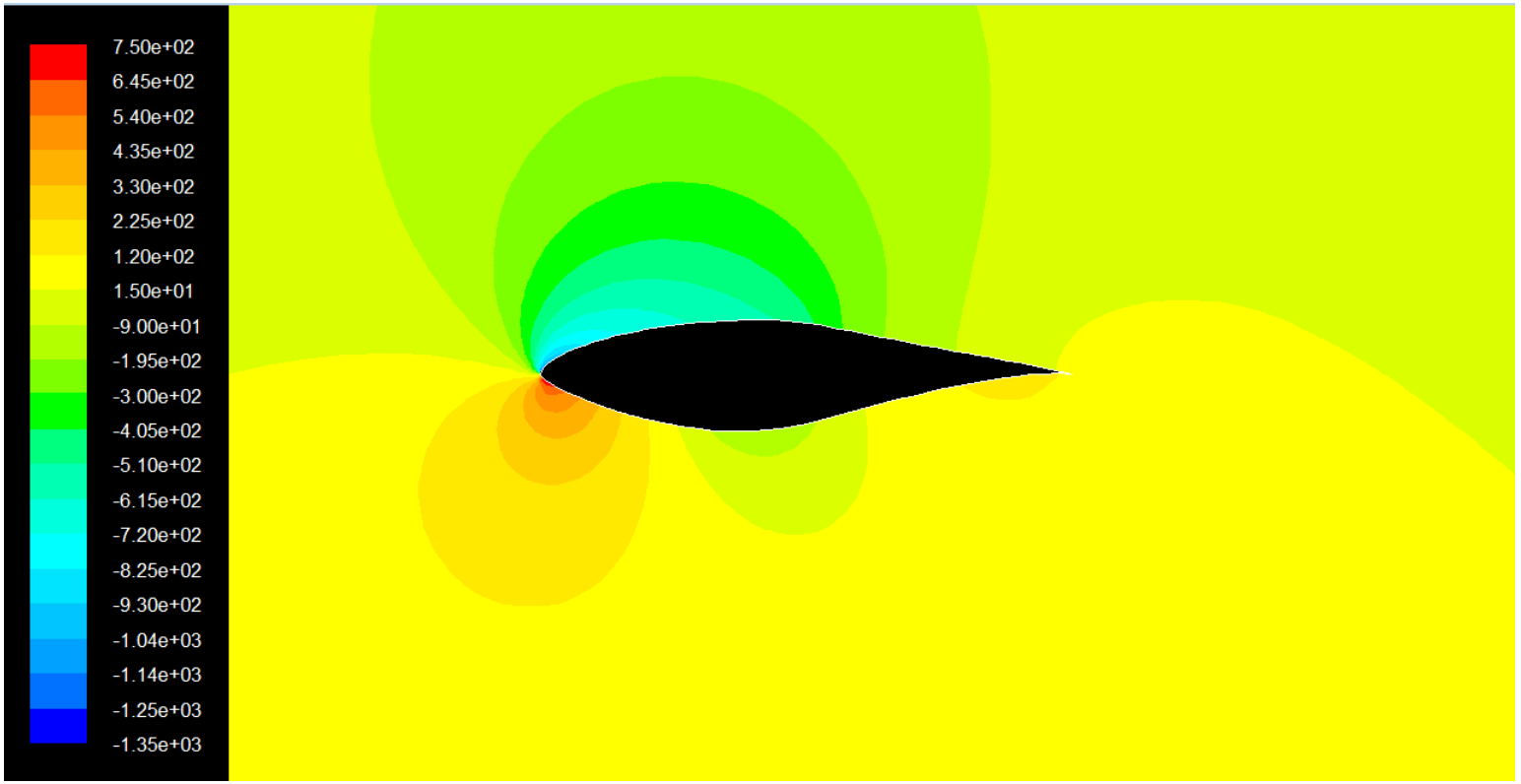
2d simulation results

Velocity Magnitude Contours , Angle of attack: 0 degree



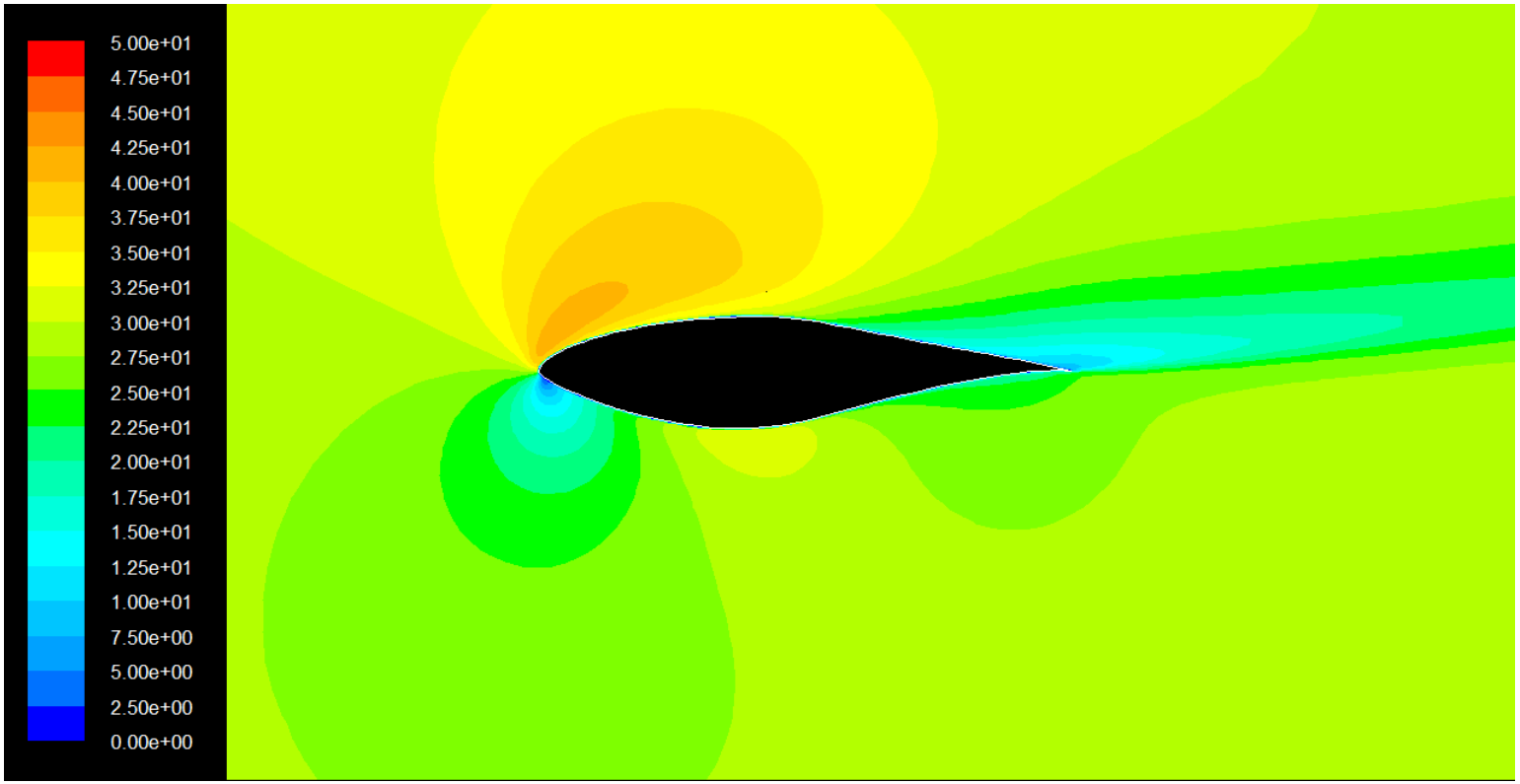
2d simulation results

Static Pressure Contours , Angle of attack: 9.22 degree

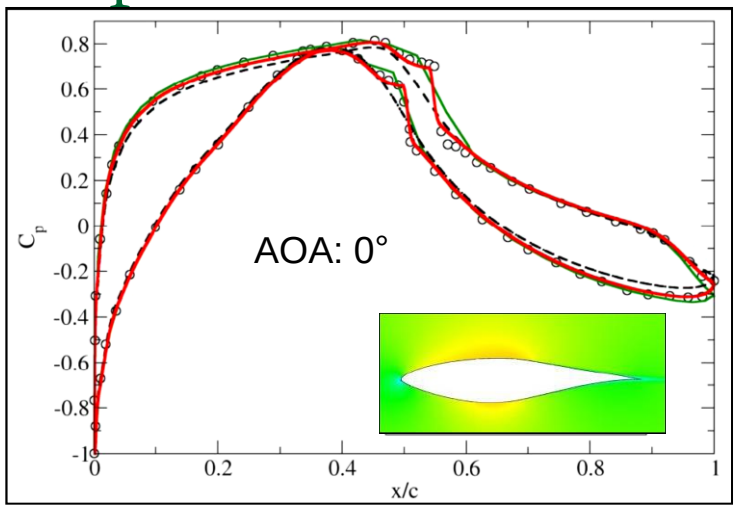


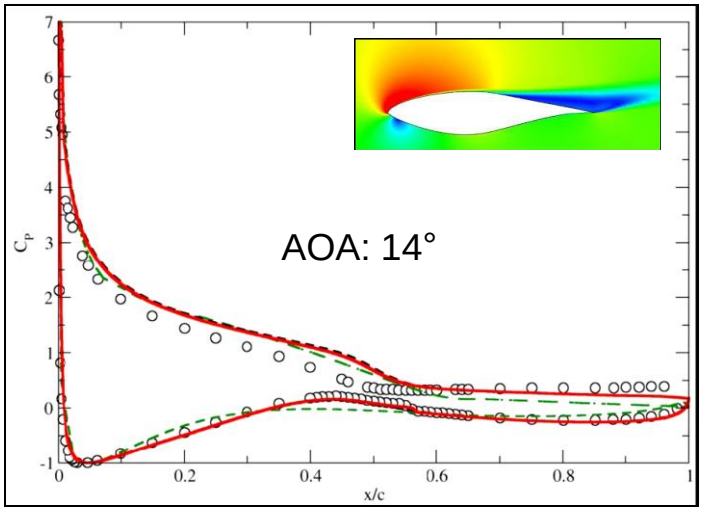
2d simulation results

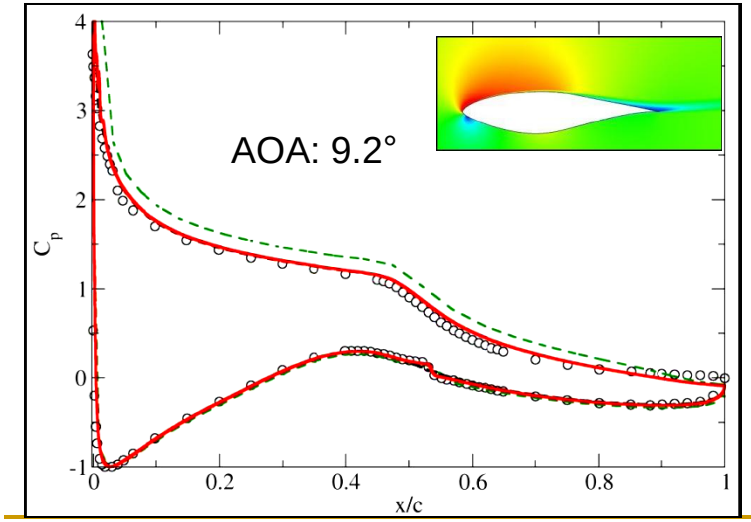
Velocity Magnitude Contours , Angle of attack: 9.22 degree

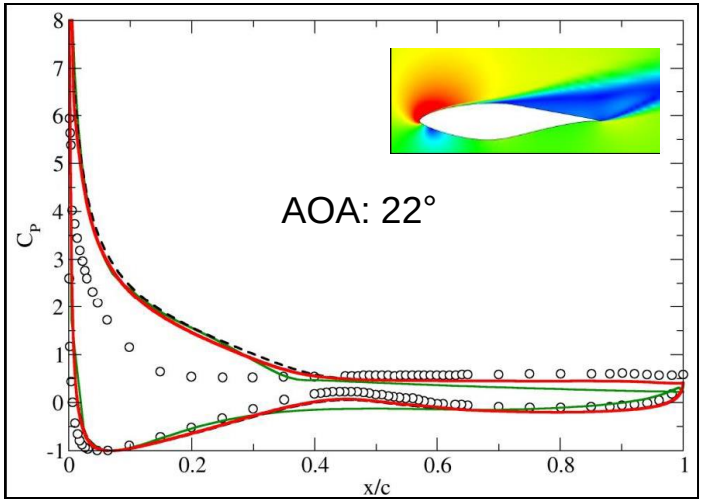


Pressure Coefficient distribution: Experiment vs. Simulation

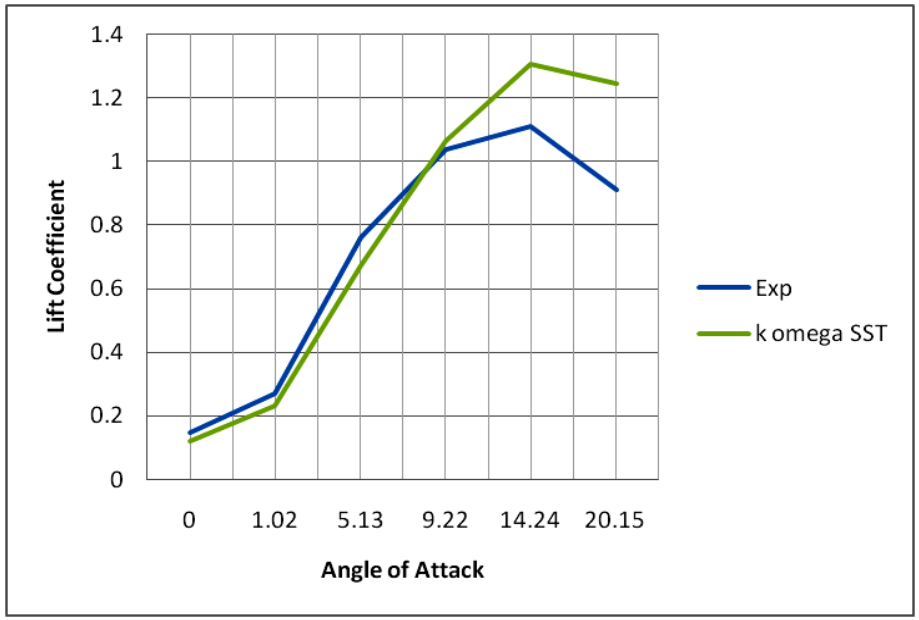


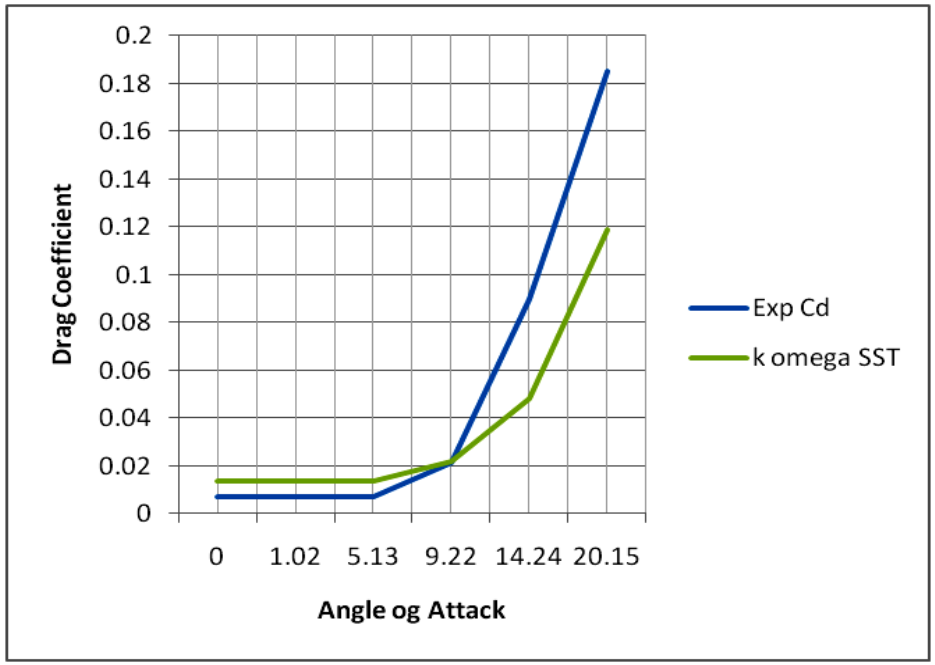






Lift and Drag Coefficient: Experiment vs. Simulation





WISER
WANGER INSTITUTE FOR SUSTAINABLE ENERGY RESEARCH

ILLINOIS INSTITUTE OF TECHNOLOGY

Full rotor simulation of NREL phase II experiments without rain droplets

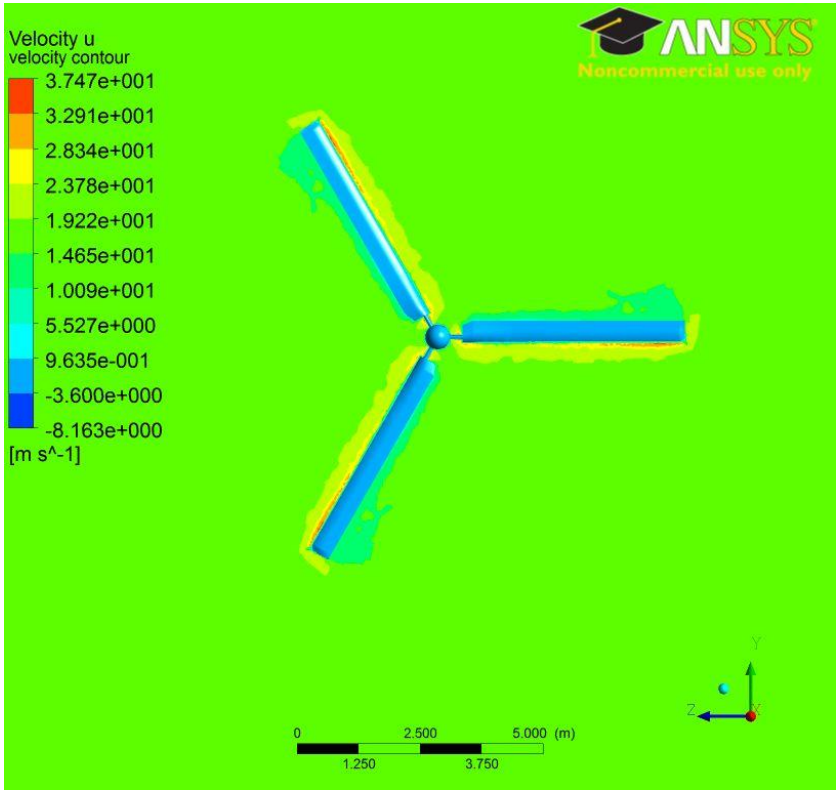
Experimental set up:

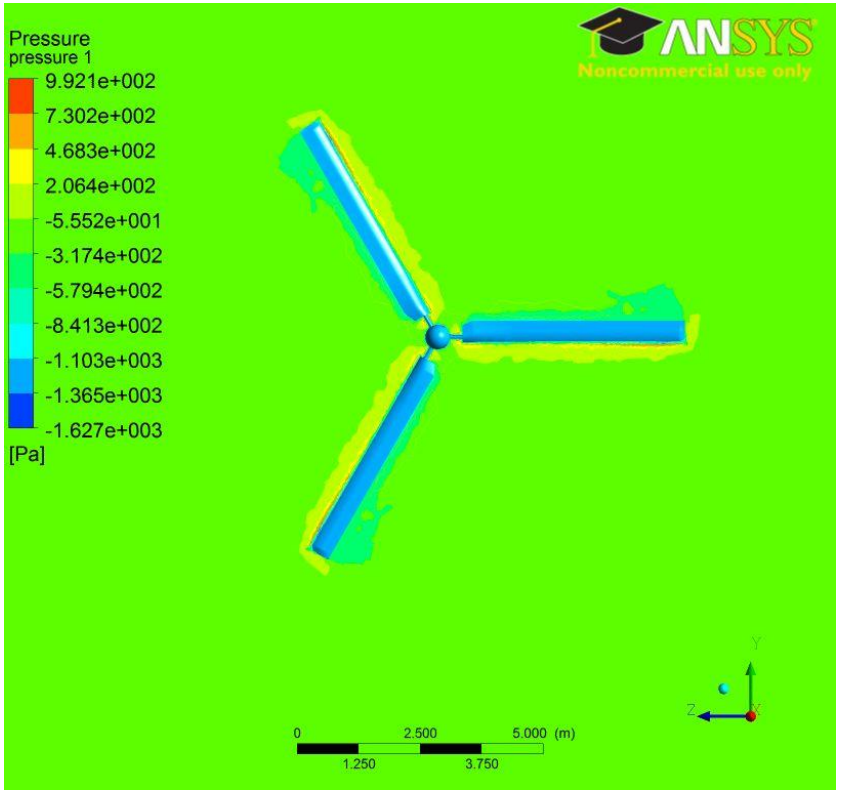
- Blade: NREL in house
- Number of blades: 3
- Blade span (from flange to tip) = 4.521 m
- Rotor diameter = 10 m
- Airfoil profile: NREL S809
- Phase II: Blade without twist and taper
- The rotor operates at a nominal 72 rpm.

CFD simulations

- Full turbulence and transition turbulence are implemented at different wind velocities and constant 72 rpm rotational speed
- Incompressible flow
- Full turbulence: SST k-w model (turbulence)
- Transition turbulence: transition SST k-w model (transition)

3D simulation results:
Pressure and velocity contours

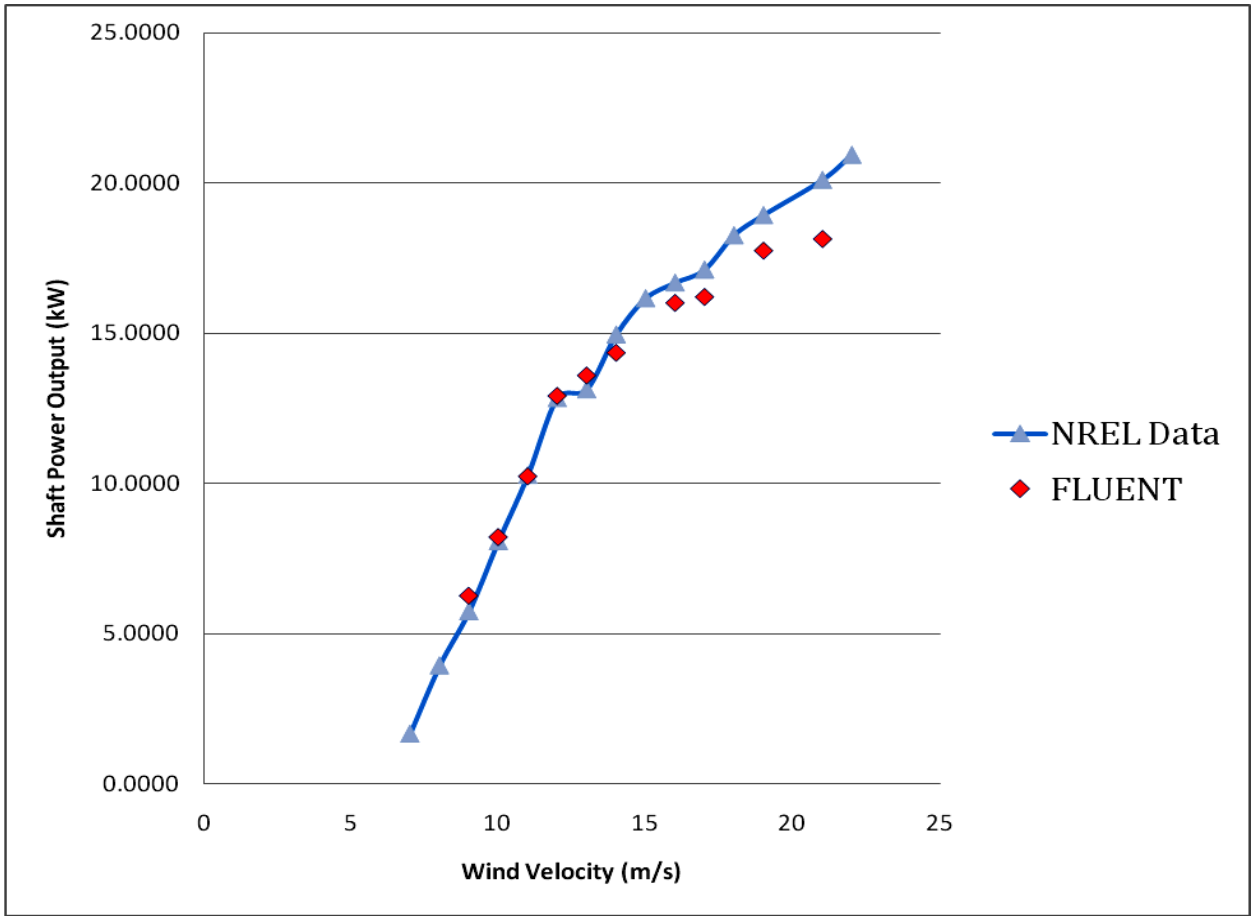




WISER
WANGER INSTITUTE FOR SUSTAINABLE ENERGY RESEARCH

ILLINOIS INSTITUTE OF TECHNOLOGY

Output power



Ongoing research

- Considering the effect of change in the air density due to the rain on both aerodynamics and output power of the wind turbine
- Simulation of both 2D and 3D cases in the presence of water droplets:
  - Using Lagrangian-Eulerian model
  - To understand the interactions between droplets and the blades
  - Water layer formation over the blades

Questions?