CFD Analysis of a Wind Turbine Airfoil at High Reynolds Numbers

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Wind Turbine Airfoil CFD Simulations

Wind Turbine Airfoil CFD Simulations

- Aerodynamic design of a wind turbine rotor:
  - is mostly based on fast Blade Element Momentum (BEM) Theory analysis
  - requires accurate **lift and drag polars** for a wide range of Reynolds numbers

- Because of the limited availability of wind tunnel data in limited Reynolds number ranges, obtaining **accurate numerical results** is of vital importance.

CFD Simulations for Airfoils

Numerical Solution Approaches:

- 2-D / 3-D
- Steady-State / Unsteady
- RANS / LES

Turbulence Models:

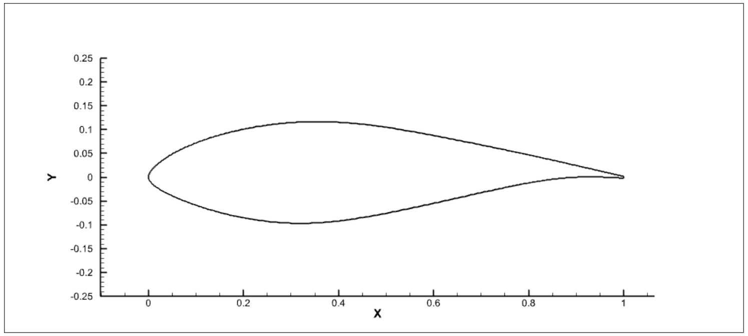
- RANS: SA, SST, Realizable
- Hybrid RANS/LES: DES, DDES, IDDES
- LES
- DNS (*usually low Reynolds numbers*)

Grid Characteristics:

- Structured / Unstructured / Hybrid / Block-structured / Multi-block
- 2-D Simulations: O type, C type, C-H type structured grids
- 3-D Simulations: Spanwise extension of 2-D grids

Orbay-Akcengiz, Sezer-Uzol, Grid Independence Study for a Thick Airfoil DU 00-W-212 At High Reynolds Numbers, WESC 2021.
Sezer-Uzol, Uzol, Orbay-Akcengiz, CFD Simulations for Airfoil Polars, Wind Energy Handbook, Springer, 2021.

Wind Turbine Airfoil CFD Simulations



DU 00-W-212 Airfoil

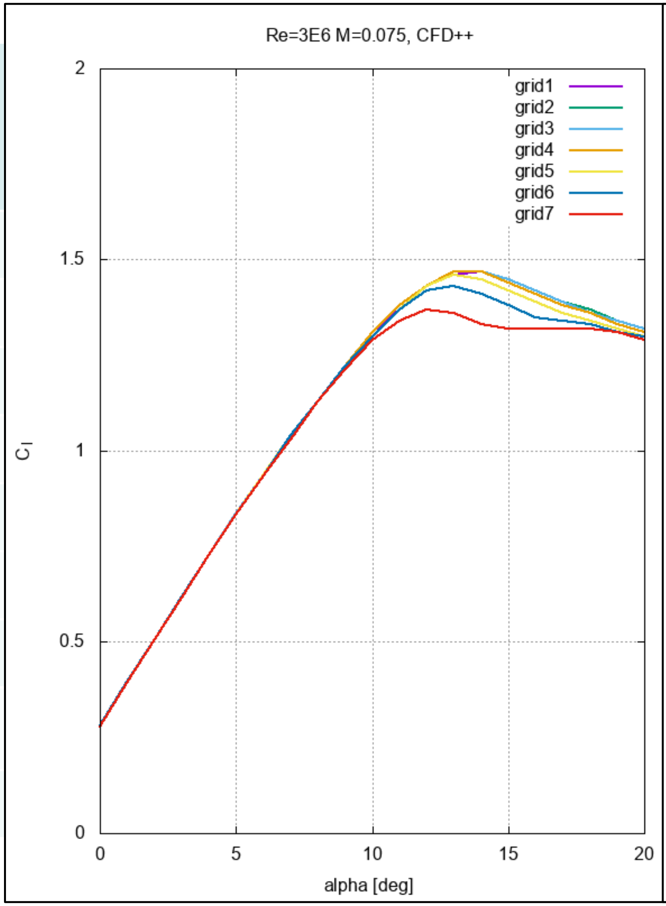
Wind Turbine Airfoil: DU 00-W-212

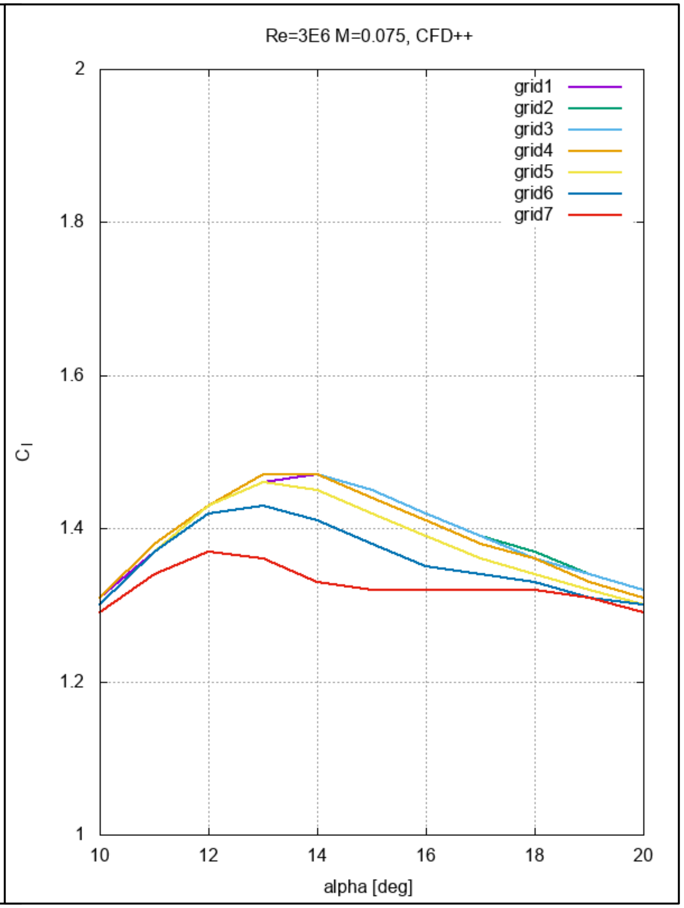
- CFD simulations by using SU2
  - Test Cases:
    - DU 00-W-212 airfoil
    - Reynolds numbers: 3M, 6M, 9M, 15M
    - Structured O-type grids
- Comparisons with experimental data, CFD++, and XFOIL
- Comparison of SU2 RANS SST and SA turbulence models
- Parallel performance analysis (TRUBA)
- Conclusions and future work

Grid Generation

- Grids are generated by using Pointwise Grid Generation Software.
- **Grid independence study** was performed by using CFD++ (*WESC 2021*)

Grid. No (O-type)	Number of Grid Cells on airfoil	Total Number of Grid Cells
Grid 1	1536	322560
Grid 2	1086	222630
Grid 3	**768**	**154368**
Grid 4	543	106232
Grid 5	384	73153
Grid 6	271	50677
Grid 7	192	35136
Grid 8	136	23986
Grid 9	96	16356





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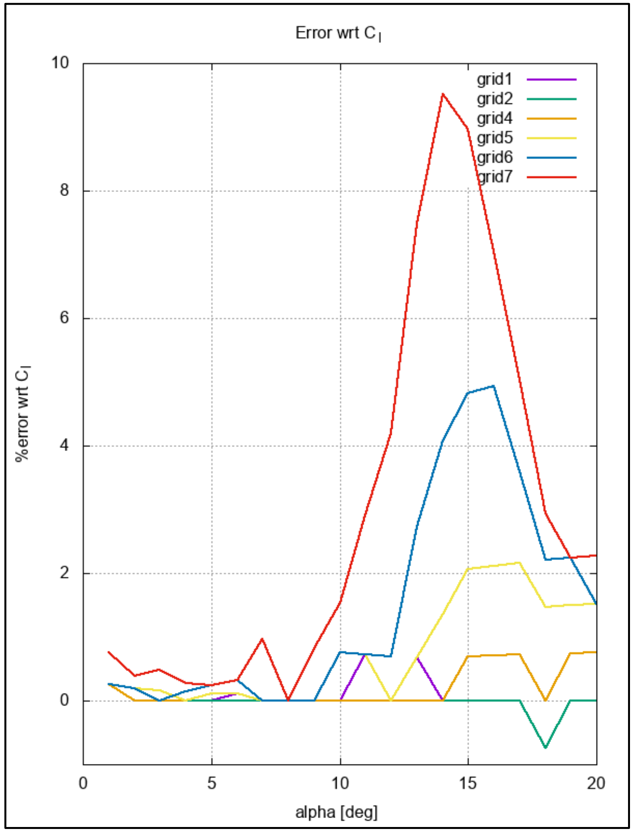

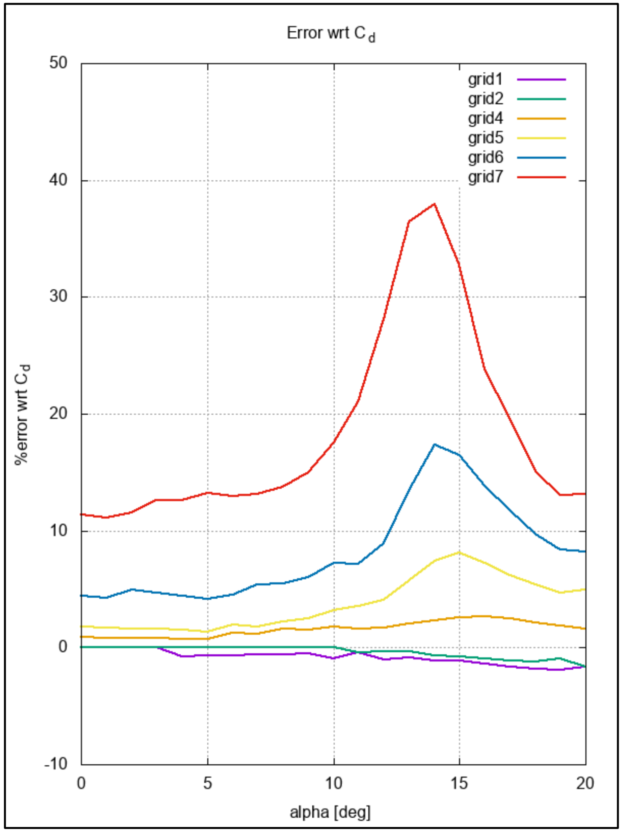

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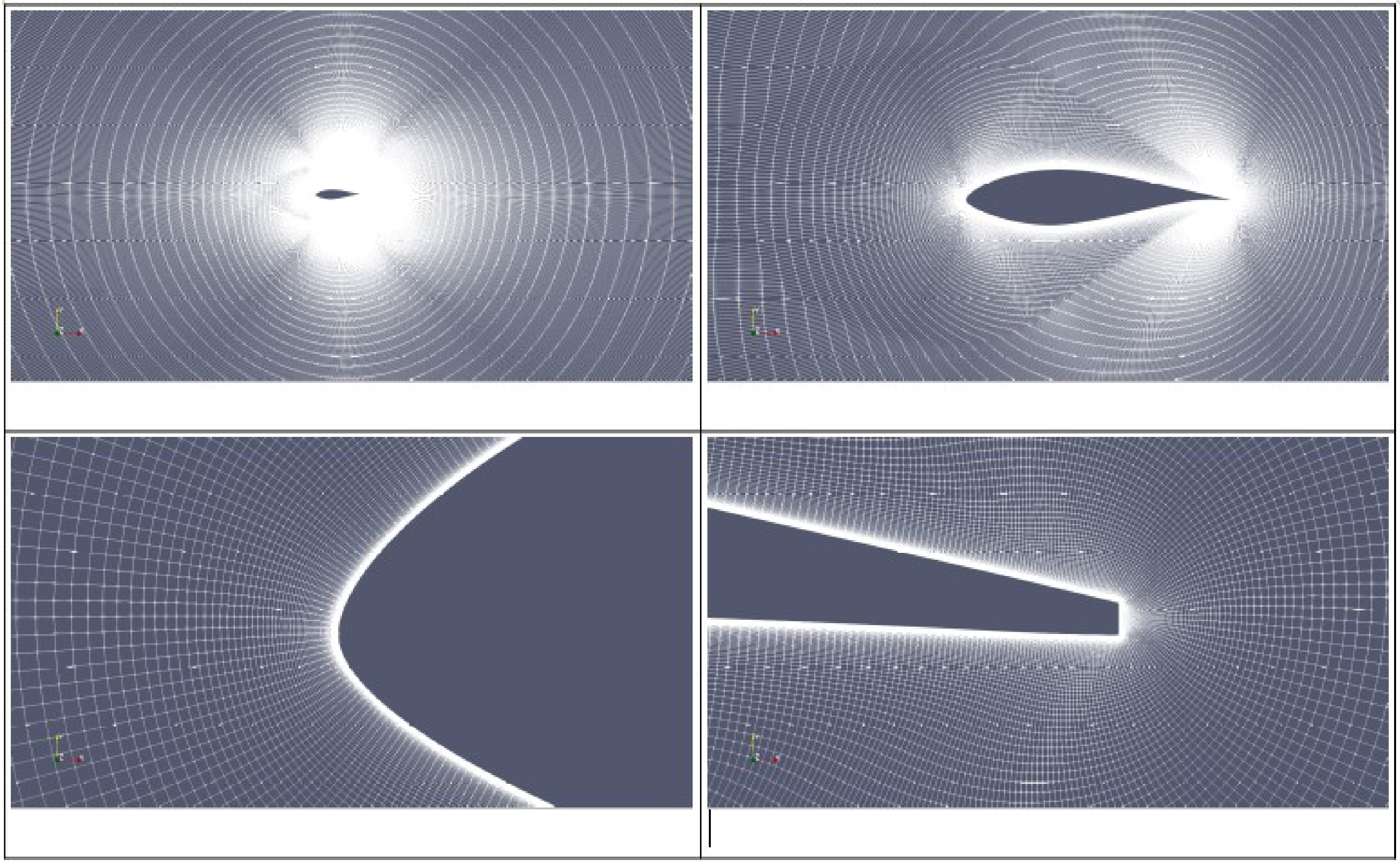


Grid 3: DU-00-W-212

CFD Simulations by using SU2 7.1.1

Numerical Approach:

- Turbulence Models: Spalart Allmaras and k-ω SST
- Convective Numerical Methods: Roe, Scalar Upwind & MUSCL
- Weighted least squares for spatial gradients
- Euler implicit time discretization (CFL = 100-200)
- Multi Grid W-cycle (9 level)
- FGMRES linear solver (Gaus Siedel)

BCs:

- Farfield BC on the circular outer domain
- Adiabatic Wall BC on airfoil body surface

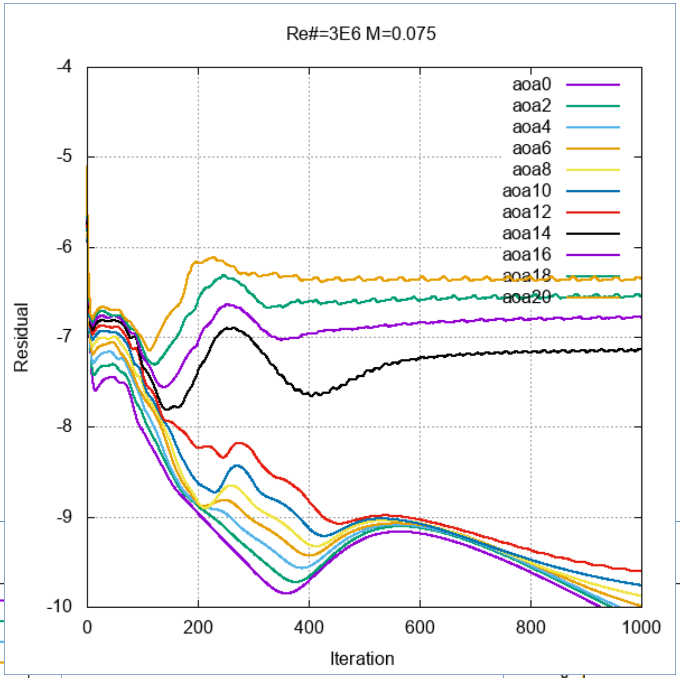
Freestream:

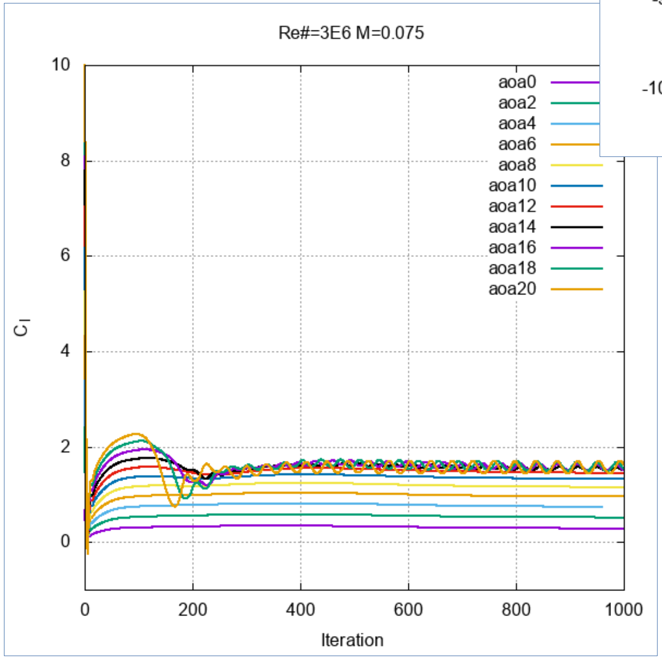
- P_∞, T_∞, M_∞ : Selected according to Re

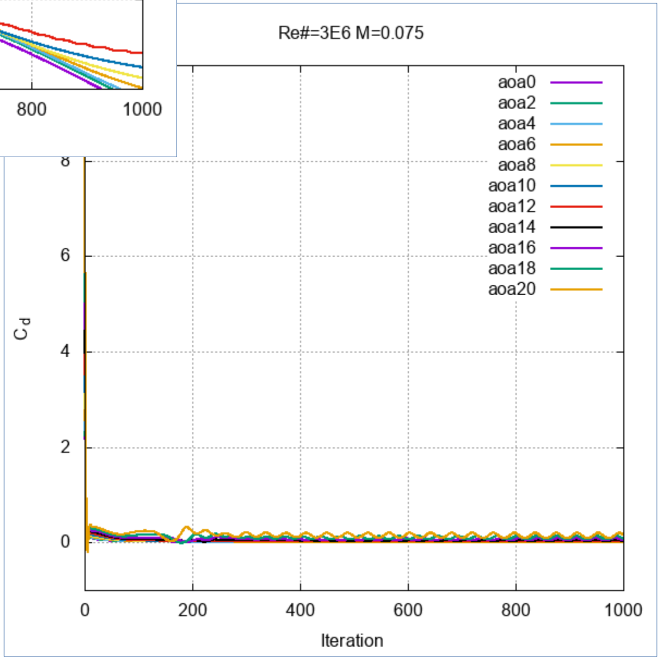
RESULTS

Convergence History:

Case 1:
Re = 3M
M = 0.075

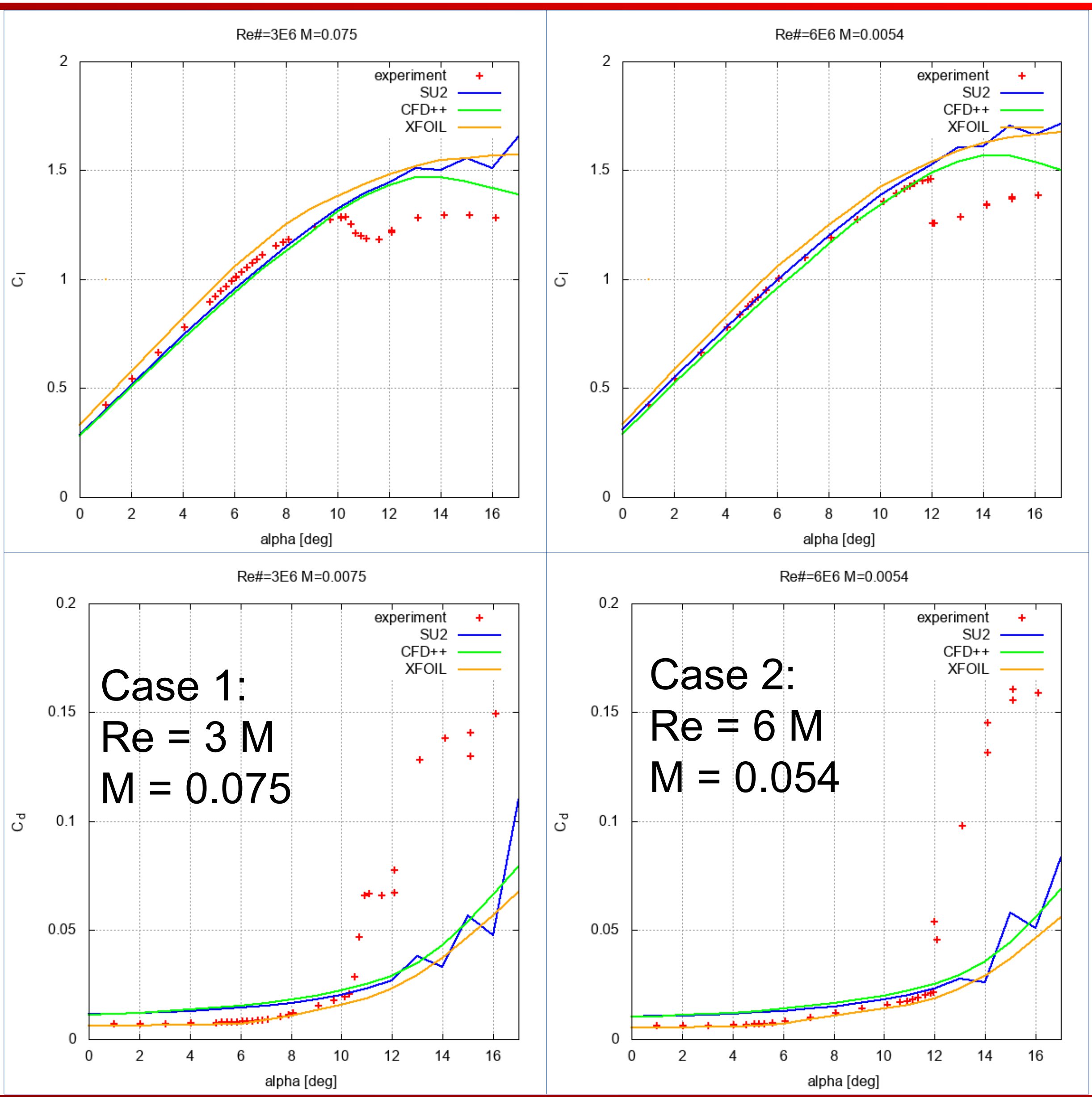






RESULTS

Different Re numbers:



RESULTS

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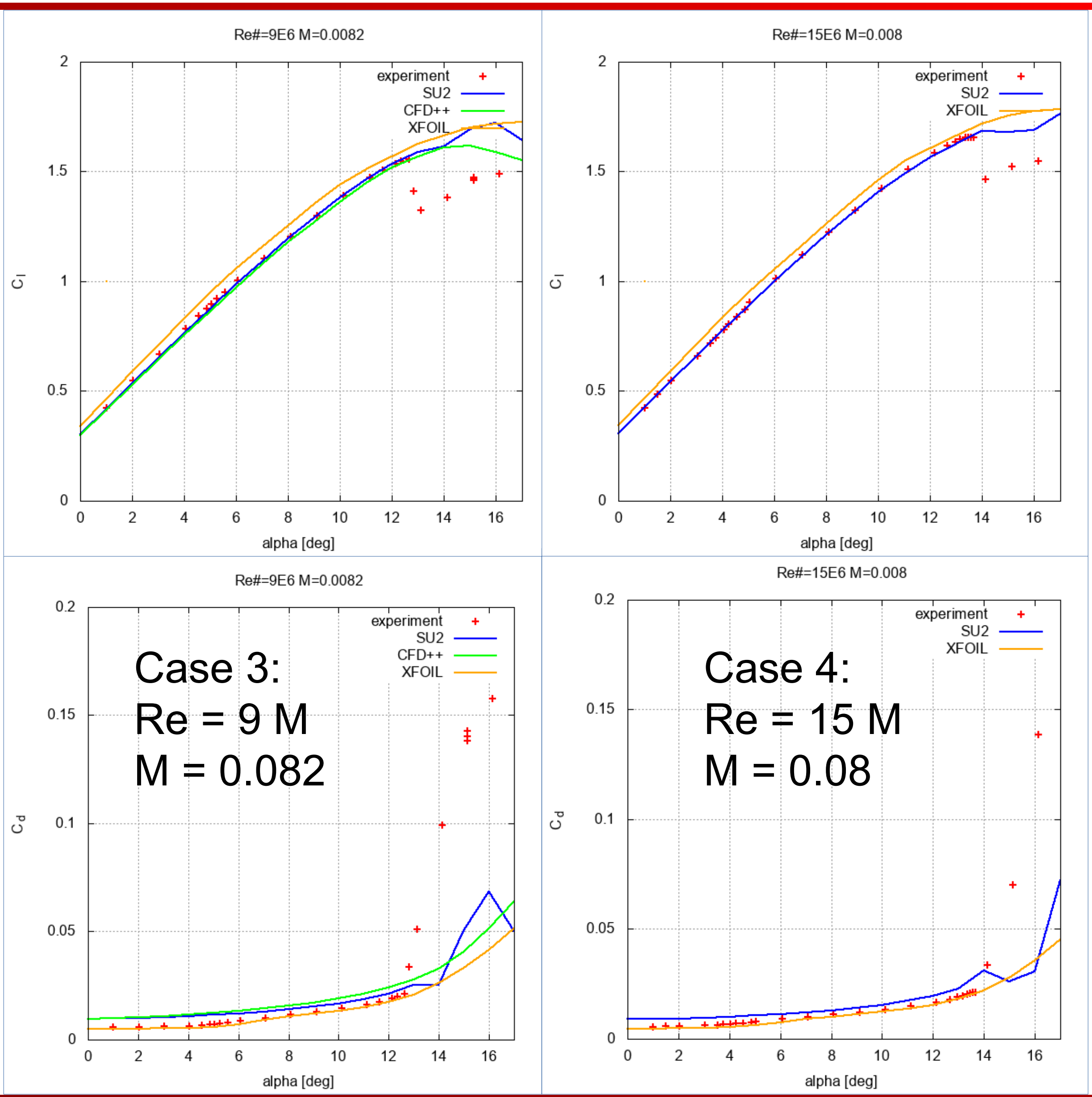


RESULTS

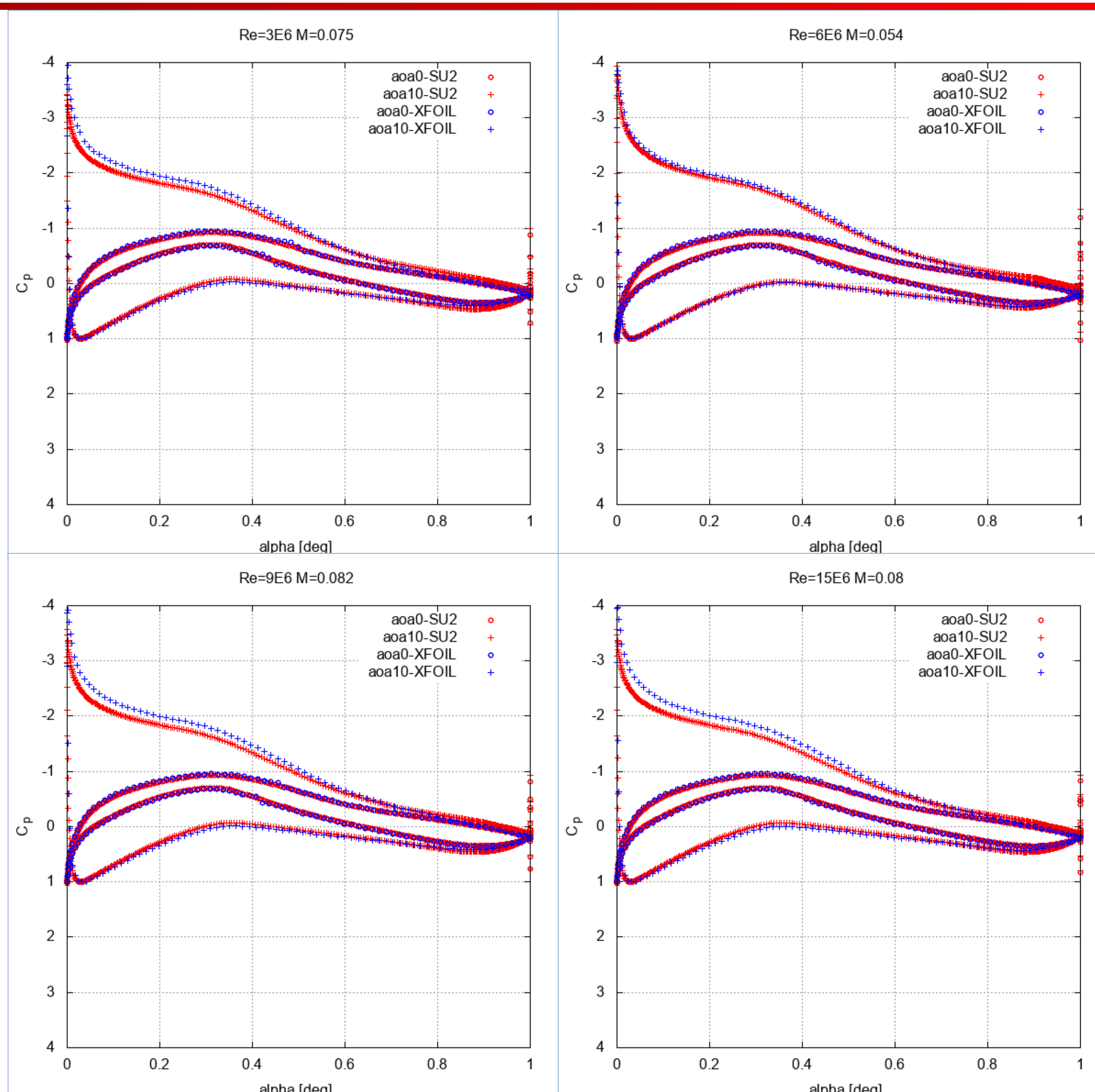
Different AOA Cp Distributions:

Re = 3 M, 6M

AOA = 0°, 10°

Re = 9 M, 15 M

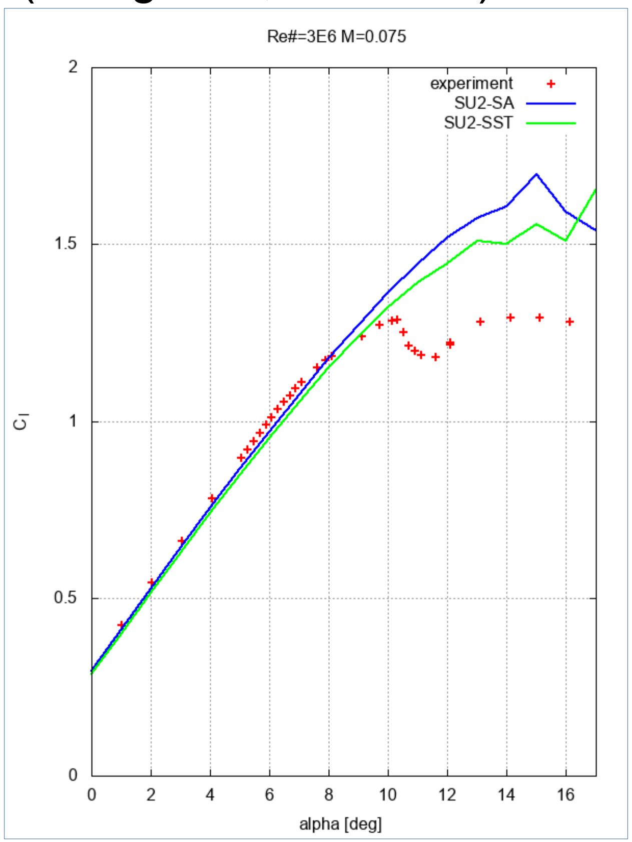
AOA = 0°, 10°

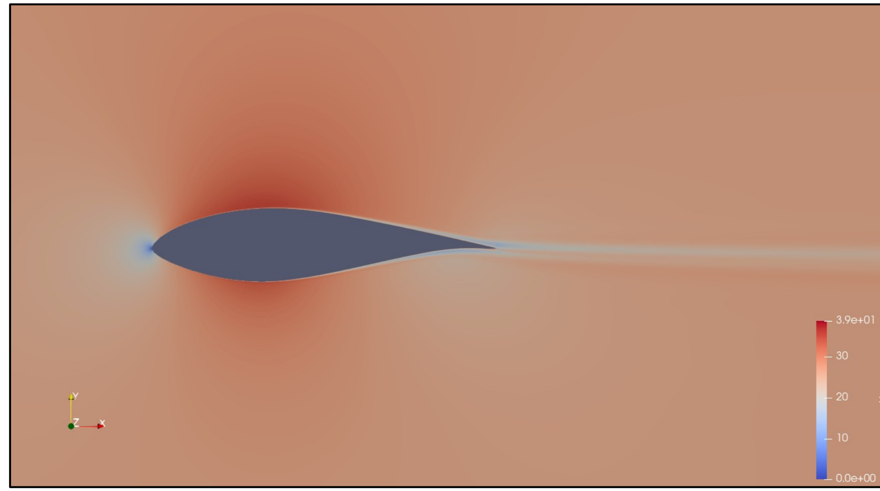


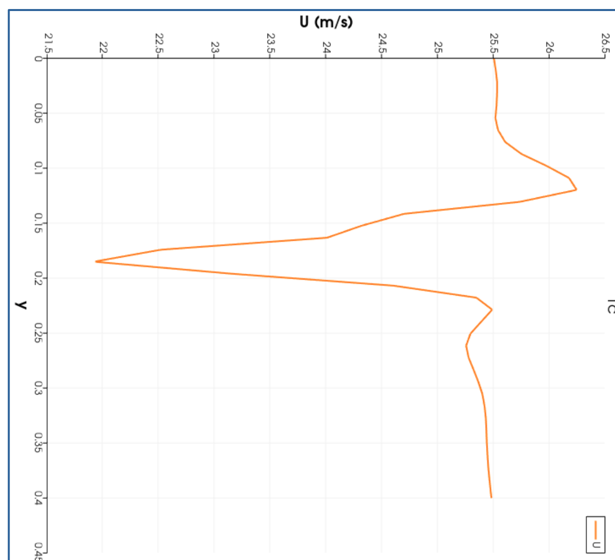
RESULTS

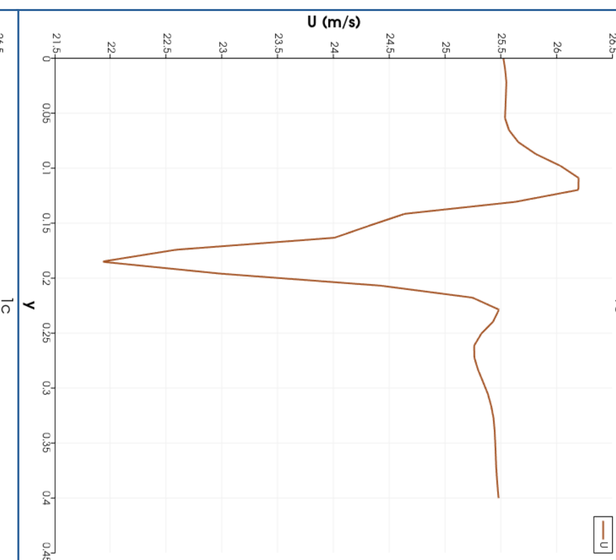
Different Turbulence Models:

Re = 3 M & M = 0.075 @ AOA = 0°
(orange SA, red SST)





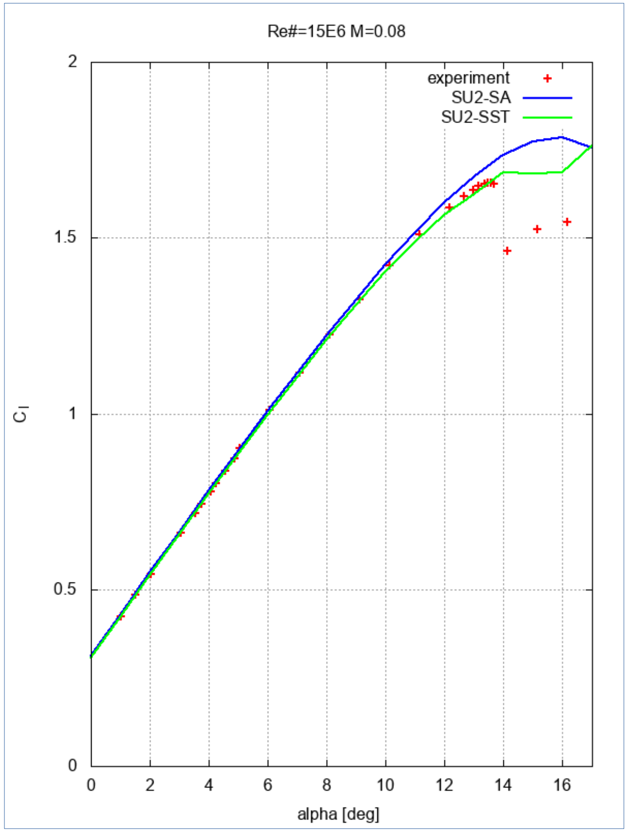


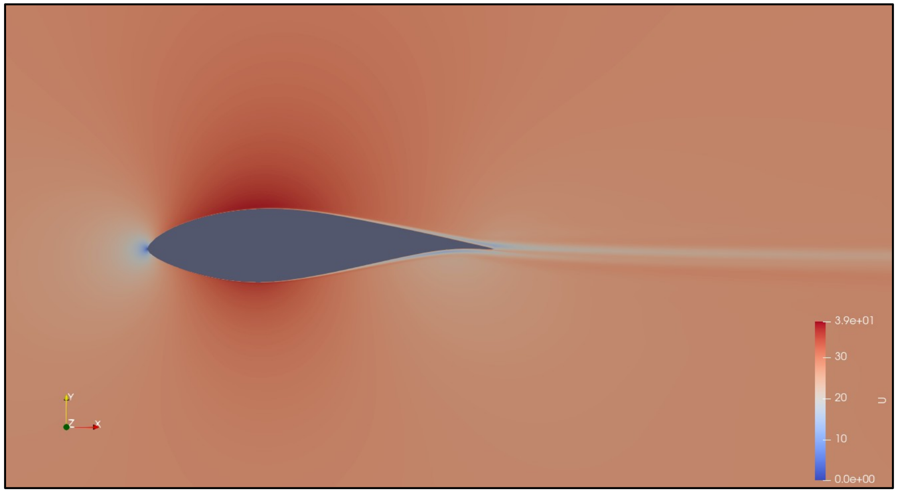


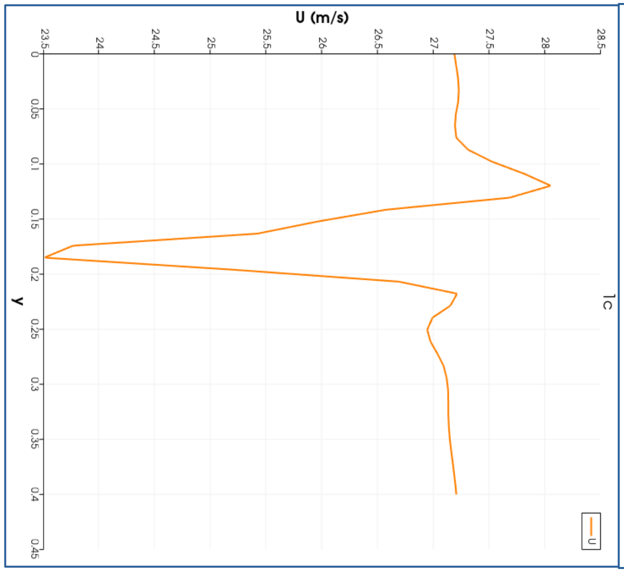
RESULTS

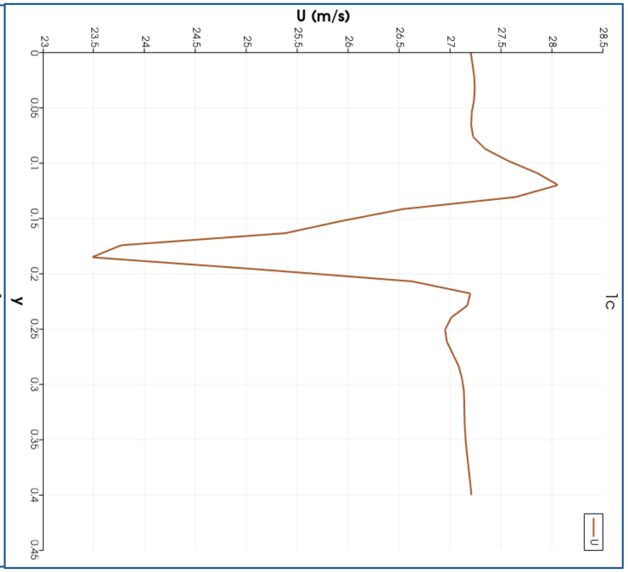
Different Turbulence Models:

Re = 15 M & M = 0.08 @ AOA = 0°
(orange SA, red SST)





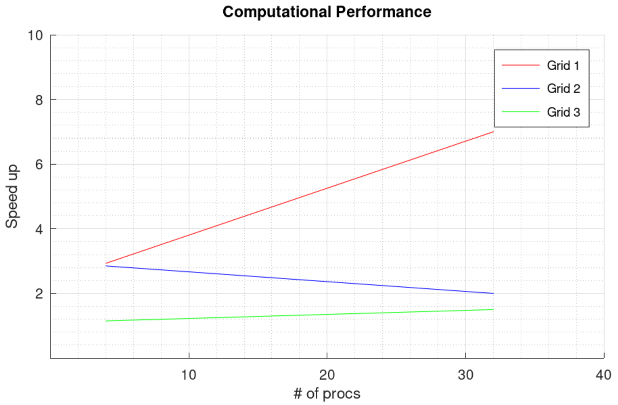




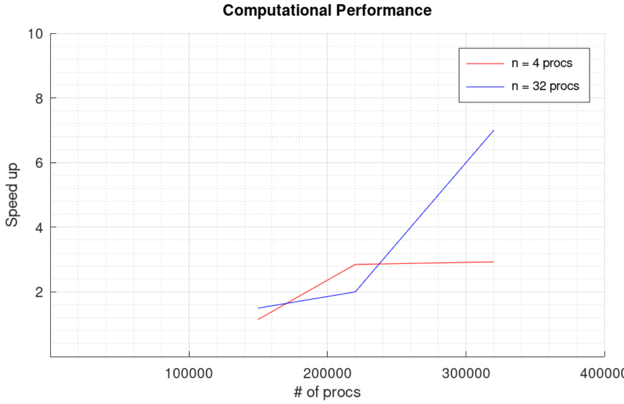
RESULTS

Parallel Performance Analysis

Computational Performance: Speed up			
Grid No	**# of Cells**	**# of Procs n = 4**	**# of Procs N=2, n = 16**
1	~320K	2.93	7
2	~220K	2.85	2
3	~150K	1.15	1.5



Computational Resources			
Cluster	**# of Nodes**	**# of CPU x Cores**	**Theoretical Tflops**
Barbun	120	2 CPU x 20 cores Xeon Scalable 6148 2.40 GHz	2.048
Hamsi	144	2 CPU x 28 cores Xeon(R) Gold 6258R 2.70GHz	3.234



Summary/Conclusions

- For the wind turbine airfoil DU 00-W-212, CFD analysis of Reynolds numbers of 3M, 6M, 9M and 15M are performed by using SU2 and the results are compared with the experimental data and with the results obtained by using CFD++ and XFOIL.
- Previously, a grid independence study was performed by using CFD++ with 9 different structured O-grids (*Orbay-Akcengiz and Sezer-Uzol WESC 2021*).
- For the same selected fine grid, 2-D steady-state RANS CFD simulations are performed by using SU2 with SA and k-omega SST turbulence models.
- Parallel performance analysis done by using the facilities of TRUBA, and still continue.
- Further studies will be performed for more accurate predictions at higher angles of attack in the stall region using transition models, 3-D simulations, unsteady simulations, and DES.

Acknowledgement

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- Also, CFD Education Materials and Test Cases are currently being prepared through EuroCC@Turkey Project, 2020-2022.

Q & A

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