Numerical simulations of the NREL S826 performance characteristics

Kristian F. Sagmo, Lars Sætran, Jan Bartl
krissag@stud.ntnu.no

NTNU

Introduction

The project work at hand makes use of the Computational Fluid Dynamics (CFD) software package STAR-CCM+ developed by CD-Adapco, and assesses some CFD turbulence's models ability to accurately predict performance characteristics of the NREL S826 airfoil.

Experiments on the Airfoil characteristics have already been conducted at both NTNU by Aksnes[1] and DTU by Sarlak[2], providing a large amount of data for CFD validation. Simulations were set up in a similar manner as the experiments done at NTNU's windtunnel.

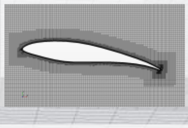

Figure 1: Exploded view of the 2D Mesh around the wing profile. cells shown are 6 mm. Chord 0.45 m.

Method

Simulations were set up in a similar manner as the experiments done at NTNU's windtunnel. After a mesh refinement study using both the Spalart-Allmaras and the Menter SST k-omega turbulence models, Reynolds dependency was investigated for low Reynolds numbers. 3D simulations were conducted using NTNU's supercomputer "Vilje" to asses effects not present in 2D simulations.

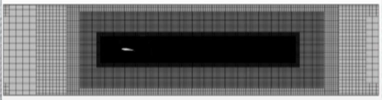

Figure 2: The 2D mesh .This mesh profile was also used for the 3D domain illustrated to the right in Figure 6.

Results and Discussion

Following the process of verification outlined in Roache[3] the grid convegence study presented in Figure 3 resulted in discretization error estimates of 6.7 % and 8.5 % for the Spalart-Allmaras and Realizable k-epsilon 2D simulations, respecively.

In Figure 4 the results for the airfoils drag coefficient is presented with experimental data, and in Figure 3 the 3D simulation results are presented.

Considering the estimated discretzation error bands and the differing results obtained by the DTU and NTNU experiments the Spalart.-Allmaras turbulence model can be said to make good predictions for lift and drag. The 2D simulations utilizing the Realizable k-épsilon model used Star-CCM+'s default k and épsilon values. This resulted in lower effective viscosity throughout the domain and lower drag prediction relative to the user specified Spalart-Allmaras turbulence parameters. The drastic difference in drag prediction highlights the importance in specifying turbulence model parameters and underlines that there really is no one RANS based turbulence model that can handle diverse flow problems without some tuning as pointed out by Versteeg et. al[3]. The 3D simulations with the Realizable k-épsilon model uses the same turbulence specifications as the Spalart-Allmaras 2D simulations.

Lift and drag coefficients were also simulated for Reynolds numbers of 50, 70 and 200 thousand, but revealed no abrubt changes in the lift and drag coefficients. This is in accordance with findings by experiments conducted at NTNU(?) but not with experiments conducted at DTU.

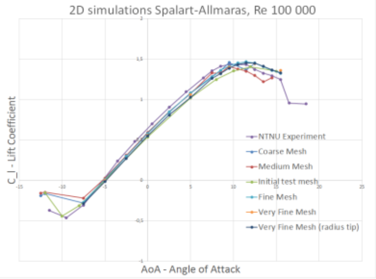

Figure 3: Lift coefficients with different mesh refinement levels. The results from the finest meshes overlap, but the solution has changed from the initial grid setup.

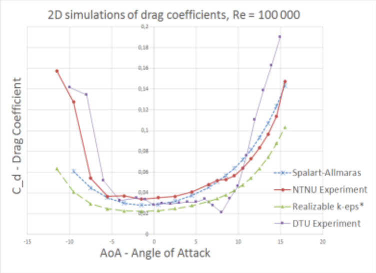

Figure 4: Drag coefficients for two different turbulence models in 2D, plotted with experimental data. under estimation of drag by the k-épsilon model is explained by the differing turbulence length scales set.

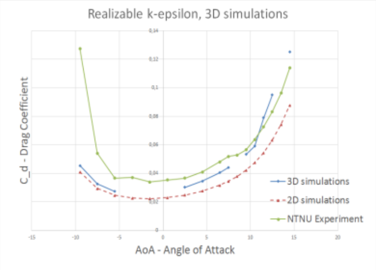

Figure 5: Drag coefficients comparing 2D and 3D simulation results. 3D effects makes for a sharper increase in drag in the stall región.

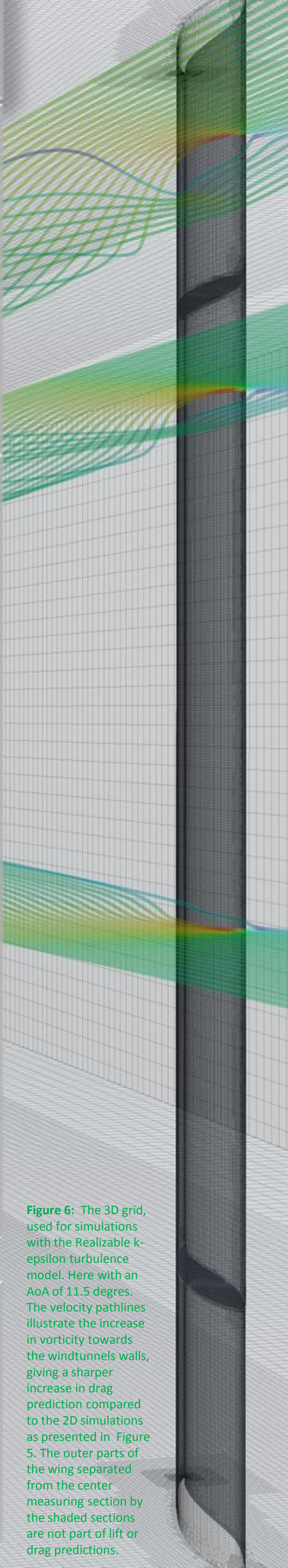

Figure 6: The 3D grid, used for simulations with the Realizable k-epsilon turbulence model. Here with an AoA of 11.5 degrees. The velocity pathlines illustrate the increase in vorticity towards the windtunnels walls, giving a sharper increase in drag prediction compared to the 2D simulations as presented in Figure 5. The outer parts of the wing separated from the center measuring section by the shaded sections are not part of lift or drag predictions.

Conclusions

It was found that 2D RANS based simulations with the Spalart-Allmaras and the Realizable k-épsilon give a reasonable estimate for lift and drag coefficients for the NREL S826 airfoil at low Reynolds numbers. The 3D simulations confirms that flow can not be considered 2D, even around the forcé measuring section of the wing, when entering the stall región. This has been previously been pointed out by Manolesos[4] among others.

Simulation results displaying Reynolds number independency and the varying results from the experiments suggest that Reynolds dependency effects might be due to unsteady flow effects. Therefore, it would be interesting to see the results from transient RANS simulations, or perhaps DES/LES simulations.

References

[1] Nikolai Yde Aksnes, *Performance characteristics of the NREL S826 airfoil - Reynolds Independency.* Master Thesis, NTNU Trondheim, 2015.

[2] H. Sarlak C., *Large Eddy Simulations of turbulent flows in Wind Energy.* Doctoral Thesis, DTU, January 2014.

[3] H.K. Versteeg & Malalasekera, *An Introduction to Computational Dynamics.*

[4] M. Manolesos, *Stall Cells, what do we know about them?* Conference Paper FORWIND Seminar, July 2015.