Numerical simulations of the NREL S826 performance characteristics

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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 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.

Results and Discussion

NTNU[7] but not with experiments conducted at DTU:

Following the process of verification outlined in Roache[3] the grid convergence 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, respectively.

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 discretization 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-epsilon model used Star-CCM+’s default k and epsilon 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 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-epsilon 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 abrupt changes in the lift and drag coefficients. This is in accordance with findings by experiments conducted at

Conclusions

It was found that 2D RANS based simulations with the Spalart-Allmaras and the Realizable k-epsilon give a reasonable estimate for lift and drag coefficients for the NREL S826 airfoil at low Reynolds numbers. The 3D simulations confirm that flow can not be considered 2D, even around the force measuring section of the wing, when entering the stall region. 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.

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 assess effects not present in 2D simulations.

References


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

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

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-epsilon 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 region.

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 part of the wing separated from the center measuring section by the shaded sections are not part of lift or drag predictions.