Numerical investigations on an airfoil undergoing pitching motion

Numerical investigations on an airfoil undergoing pitching motion

F. Geng[1], I.M. Kalkman [1], A.S.J. Suiker [1], B. Blocken[1, 2]

[1] Eindhoven University of Technology , the Netherlands

[2] KU Leuven, Belgium

e-mail: f.geng@tue.nl

1 The message

For a NACA 0012 airfoil pitching in the deep dynamic stall regime with the angle of attack $\alpha(t) = 10° + 15° \sin(\omega t)$, flow characteristics around the airfoil are numerically investigated by means of 2D Unsteady Reynolds-Averaged Navier-Stokes (URANS) and 2.5D Large Eddy Simulation (LES) methods.

2 Research objectives

- Obtain aerodynamic load coefficients in static and dynamic stall situations
- Quantify the sensitivity of CFD results to the model parameters adopted
- Evaluate the capabilities of 2D URANS and 2.5D LES models for predicting aerodynamic forces

CFD results and experimental measurements depicted in Figure 4 show a reasonable agreement for airfoil at both static and pitching state. It also indicates that the pitching motion postpones stall occurrence to a higher angle of attack by comparing dynamic load coefficients with their static counterparts.

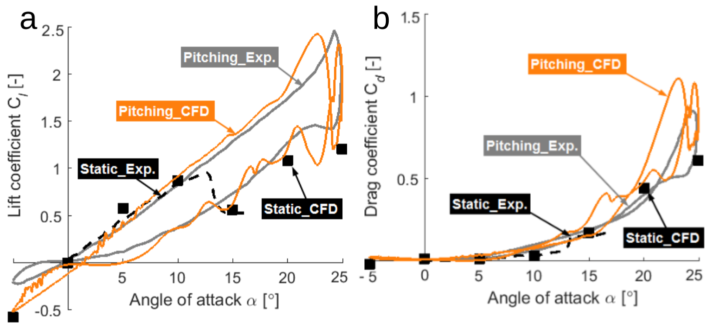

Figure 4: Aerodynamic loads: (a) lift coefficient; (b) drag coefficient

3 2D URANS calculation

Turbulence model: Transition SST

The computational domain is chosen as a rectangular domain comprising a circular subdomain with the radius of 3 chord lengths (c), resulting in a grid with about 1.2×10^5 quadrilateral cells. The diagram of computational domain and boundary conditions is shown in Figure 1.

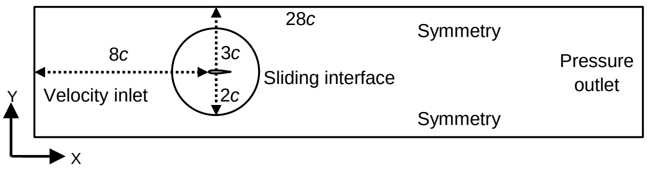

Figure 1: 2D computational domain and boundary conditions

Pressure-velocity coupling is taken care of by the SIMPLE algorithm and second order discretization schemes are used for both spatial and temporal discretization. Iterations are terminated only when all scaled residuals have fallen below 1×10^{-5}. Figure 3 shows the non-dimensional stream-wise velocity magnitude at point P as a function of height for six monitoring angles of attack.

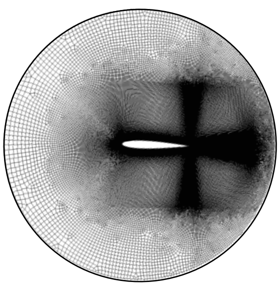

Figure 2: Rotational subdomain

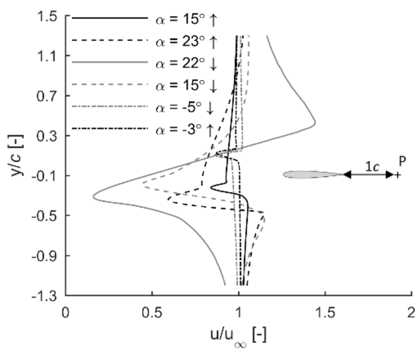

Figure 3: Streamwise velocity

4 2.5D LES calculation

Subgrid scale model: Smagorinsky

2.5D model is different from 3D in that only 0.5c is modeled in the spanwise direction, as periodic boundary conditions are imposed at the sides of the domain shown in Figure 4. The total number of cells is 4.2 million. Mesh details close to the airfoil wall are shown in Figure 5.

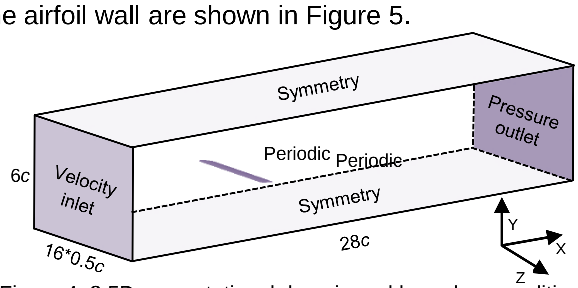

Figure 4: 2.5D computational domain and boundary conditions

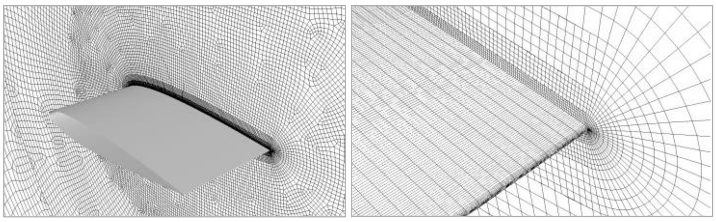

Figure 5: Non-conformal mesh close to the airfoil

Figure 6 shows iso-surfaces of Q-criterion ($Q = 5\times10^5$ [s^{-2}]) colored with instantaneous streamwise velocity at $\alpha = 24°$↓.

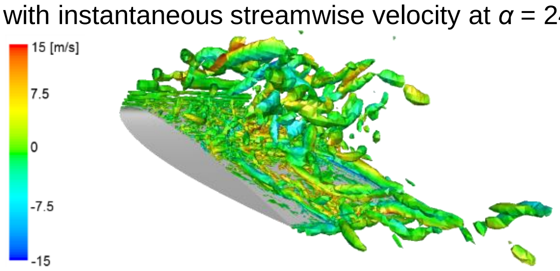

Figure 6: Turbulence structures for LES of flow around a pitching airfoil