Problem C2.2. Steady Turbulent Transonic flow over an Airfoil

Overview

This problem is aimed at testing high-order methods for a two-dimensional turbulent flow under transonic conditions with weak shock-boundary layer interaction effects. The test case is the RAE2822 airfoil Case 9, for which an extensive experimental database exists [CMcDF79]. The test case has also been investigated numerically by many authors using low order methods. It was also used in the ADIGMA project (test case MTC5). The target quantities of interest are the lift and drag coefficients and the skin friction distribution at one free-stream condition, as described below.

Governing Equations

The governing equation is the 2D Reynolds-averaged Navier-Stokes equations with a constant ratio of specific heats of 1.4 and Prandtl number of 0.71. The dynamic viscosity is also a constant. The choice of turbulence model is left up to the participants; recommended suggestions are 1) the Spalart Allmaras model, and 2) the Wilcox k-omega model or EARSM.

Flow Conditions

The flow conditions are based on the experimental data base provided in [CMcDF79]. Only Case 9 is retained for this workshop. The original flow conditions in the wind tunnel experiment are $M_\infty = 0.730$, angle of attack $\alpha = 3.19^o$, Reynolds number (based on the reference chord) $Re = 6.5x10^6$. However, in order to take into account the wind tunnel corrections for comparison with experimental data the computations for the workshop have to be made with corrected flow conditions, namely Mach number $M_\infty = 0.734$, angle of attack $\alpha = 2.79^o$, with the same Reynolds number, see [A1982]. Laminar to turbulent transition is fixed at 3% of the chord, on both pressure and suction side. No further wind tunnel effects are to be modeled.

Geometry

The airfoil geometry is given in [CMcDF79]. Originally the geometry is defined with a set of points. These points are then used to define a high-order geometry, which will be available online at the workshop web site.

Boundary Conditions

Adiabatic no-slip wall on the airfoil surface, free-stream at the farfield (subsonic inflow / outflow). A sensitivity study must be performed to find a far field boundary location whose effect on the lift and drag coefficient is less than 0.01 counts, i.e., 1e-6.

Grids

Participants may use their own grids for the convergence study. However, the geometry definition provided at the workshop web site should be used such that all the participants will use the same geometry. The workshop will also provide sample high-order computational meshes.

Requirements

1. Perform a convergence study of drag and lift coefficient, c_l and c_d, using one or more of the following three techniques:
   a. Uniform mesh refinement of the coarsest mesh

b. Quasi-uniform refinement of the coarsest mesh, in which the meshes are not necessarily nested but in which the relative grid density throughout the domain is constant.
c. Adaptive refinement using an error indicator (e.g. output-based).

Record the degrees of freedom and the work units for each data point, where the CPU t=0 corresponds to initialization with free-stream conditions on the coarsest mesh.

2. Submit three sets of data to the workshop contact for this case
   a. c_l & c_d error versus work units
   b. c_l & c_d error versus $1/\sqrt{nDOFs}$
   c. Skin friction distribution on pressure and suction side of the airfoil, compared to the experiments.

   Include a description of the coarsest mesh resolution and of the strategy used for refinement.

References

[CMcDF79] Cook, P.H., M.A. McDonald, M.C.P. Firmin, "Aerofoil RAE 2822 - Pressure Distributions, and Boundary Layer and Wake Measurements," Experimental Data Base for Computer Program Assessment, AGARD Report AR 138, 1979.

[A1982] NACA0012 Oscillating and Transient Pitching, AGARD-R-702, 1982.