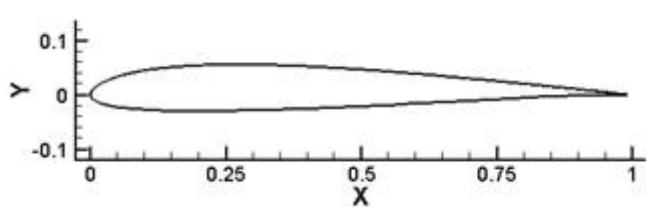
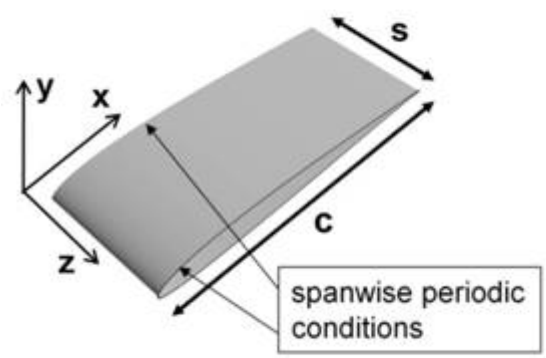
# Problem C3.3. Transitional Flow over a SD7003 Wing

**Overview**
This test case is aimed at characterizing the accuracy and performance of high-order solvers for the prediction of complex unsteady transitional flows over a wing section under low Reynolds number conditions. Of particular interest is the evaluation of so-called Implicit Large-Eddy Simulation (or ILES) approaches for handling, in a seamless fashion, the mixed laminar, transitional and turbulent flow regions encountered in low-Re applications. The unsteady flow is characterized by laminar separation, the formation of a transitional shear layer followed by turbulent reattachment. In a time-averaged sense, a laminar separation bubble (LSB) is formed over the airfoil.

**Governing Equations**
The governing equations are the full 3D compressible Navier-Stokes equations with a constant ratio of specific heats of 1.4 and Prandtl number of 0.72. Solutions obtained employing the fully incompressible Navier-Stokes equations are also desired. Given the low value of Reynolds number being considered, emphasis is placed on ILES approaches; however, methodologies which incorporate dynamic sub-grid-scale (SGS) models are also of interest in terms of comparing computational cost, accuracy and robustness.

**Geometry**
The wing section is based on the Selig SD7003 airfoil profile shown in Fig. 1. This airfoil which was originally designed for low-Reynolds number operation ($Re_c \sim 10^5$), has a maximum thickness of 8.5% and a maximum camber of 1.45% at x/c = 0.35. The original sharp trailing edge has been rounded with a very small circular arc of radius r/c ~ 0.0004 in order to facilitate the use on an O-mesh topology. The precise profile geometry will be provided to all participants. The flow is considered to be homogeneous in the spanwise direction with periodic boundary conditions being imposed over a width s/c = 0.2.




**Flow Conditions**
Mach number M=0.1
Reynolds number based on wing chord, $Re_c = 60,000$.
Angle of attack:
Case 1(MANDATORY): $\alpha = 8$ deg., which corresponds to a relatively short LSB

Case 2 (OPTIONAL): $\alpha$ = 4 deg., which corresponds to a relatively long LSB

**Boundary Conditions**

Far field boundary: subsonic inflow and outflow. This boundary should be located very far from the wing at a distance of ~ 100 chords

Airfoil surface: no slip isothermal wall conditions with $T_{wall}/T_{inf} = 1.002$

**Data Requirements**

**A. Time-averaged data**

The term “time-averaged” or “mean” denotes in this context data which is both time-averaged and spanwise-averaged taking advantage of the imposed homogenous conditions in the spanwise direction. The time-averaging needs to be performed over a sufficiently long period of time (> 10 convective times) after start-up transients are eliminated. Please indicate the length of time used for averaging and provide a time history of selected variables (e.g., Cl, Cd, etc.) used to monitor the establishment of a stationary state.

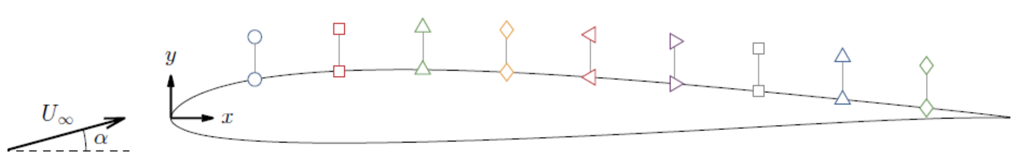
Mean data requested includes the following:

1. Surface pressure coefficient (Cp)
2. Skin-friction coefficient (Cf)
3. Mean aerodynamic coefficients (Cl, Cd and $Cm_{0.25c}$)
4. Separation and reattachment locations
5. Separation bubble length and max. height
6. Profiles of u-component of velocity along a vertical line (x=constant) at chordwise stations x/c=0.1, 0.2,…., 0.9. Note that (x,y; u,v) refer to the airfoil coordinate system.
7. Profiles of u-velocity fluctuations ($\langle u'^2 \rangle$) at the same stations as in (6).
8. Provide a Tecplot or other standard graphics file(s) containing the u-velocity, pressure (Cp) and u-fluctuations. This will facilitate a cross-comparison of the airfoil near-field for all simulations.

Items 1-7 should be provided in an easily readable ASCII format.

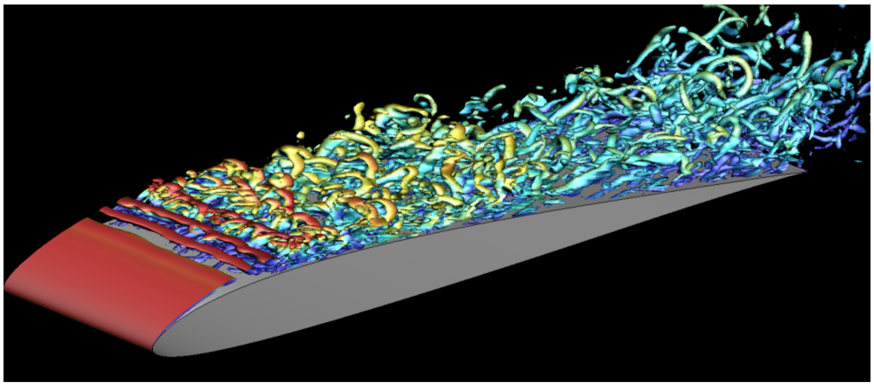
Additional item if available:

9. Frequency spectra for u-velocity at selected points. I would suggest the x-stations in (6) at a distance 0.005c above the airfoil surface. This item is intended to demonstrate the existence of a broad spectrum (downstream of reattachment) and its decay characteristics.



**B. Instantaneous data**

Please provide a 3D plot of the iso-surface of the Q-criterion (Q=500) at a selected instant in time. This will be used to qualitatively compare the overall flow structure (see sample figure).



**C. Other computational details**

1. Grid spacing in wall units at x/c= 0.8 (i.e., $\Delta s^+$, $\Delta n^+$, $\Delta z^+$, where s, n and z denote streamwise, normal and spanwise directions)
2. Max. grid spacing along the airfoil surface and spacing at the airfoil leading edge
3. Time step used
4. A measure of computational cost (e.g., CPU time per iteration, computer system and no. of processors)