Universidad Europea de Madrid

Advanced Fluid Mechanics Course

Homework 6

Boundary Layer Approximation

Due on November 21, 2016

***Problem 1***

1. How does momentum influence airflow over an airfoil?
2. Why in a certain point of an airfoil the boundary layer is to be separated from the surface wall? Explain.
3. Why the kinetic energy is decreasing along the upper surface of an airfoil?
4. why we cannot apply the BL equations on the separation bubble, which equations can be applied to obtain the characteristic of the BL?
5. How you can reenergize the boundary layer on upper surface to delay the separation point?
6. In what way, is the Euler equation an approximation of the Navier-Stoke equation? Where in a flow field Euler equation an appropriate approximation?
7. What is the main difference between the steady incompressible Bernoulli equation for irrational regions of flow and the steady incompressible Bernoulli equation for rotational but inviscid regions flow?
8. It was mentioned that the boundary layer approximation “Bridges the gap” between the Euler equation and Navier-Stoke equation. Explain your answer.
9. We usually think of boundary layers as occurring along solid walls. However, there are other flow situations in which the boundary layer approximation is also appropriate. Name three such flows and explain why boundary layer approximation is appropriate.
10. Air flow parallel to a speed limit sign along the highway at speed V=5 m/s. The temperature of the air is 25Celsius and the width W of the sign parallel to the flow direction is 0.45m Is the boundary layer on the sign laminar or turbulent or transitional? Explain.
11. Without writing any equations, give a verbal description of boundary-layer displacement thickness.

***Problem 2***

Equation of the boundary layer thickness for turbulent flow assumes that the boundary layer on the plate is turbulent from the leading edge onward. Devise a scheme for determining the boundary-layer thickness more accurately when the flow is laminar up to a point Re*x*,crit and turbulent thereafter. Apply this scheme to the computation of the boundary-layer thickness at *x =*2.0 m in 50 m/s flow of air at 20°C and 1 atm past a flat plate. Compare your result with Equation. Assume Re *x*,crit =1.5x106.

***Problem 3***

A light aircraft has tapered wing with root and tip chord-lengths of 2.2m and 1.8 m respectively and wingspan of 16m. Estimate the skin friction drag of the wing when the aircraft is travelling at 55m/s. On the upper surface the point of minimum pressure is located at 0,375 chord-length from the leading edge. The dynamic viscosity and density of air may be taken as 1.8E-5 Kg s/m and 1.2 Kg/m3 respectively

***Problem 4***

1. A semi-infinite flat plate is placed in air freestream of velocity U which is parallel to the plate. Calculate (i) the boundary layer velocity profile on the plate. (ii) Boundary thickness (iii) Shear stress on the wall. (iv) Skin friction coefficient.
2. If the plate is placed at angle of attack of 10 degree, set up only the equations for solving the velocity profile.

***Problem 5***

A flat plate is placed in a uniform airstream of 20 m/s and zero incidence. What is the displacement thickness at the trailing edge, if the total length of the plate is 0.5m, 1m and 1.5m?.For each length, calculate de the overall drag coefficient and shear stress of the pate.

***Problem 6***

The streamwise velocity component of a steady, incompressible, laminar, flat plate boundary layer, boundary layer thickness δ is approximated by the simple linear expression u=Uy/δ for y<δ, and u=U for y>δ. Generate expressions for displacement thickness ad momentum thickness as a function of δ, based on the linear approximation. Compare the approximate values of $\frac{δ^{\*}}{δ}$ and $\frac{θ}{δ}$ to the values of $\frac{δ^{\*}}{δ}$ and $ \frac{θ}{δ}$ obtained from the Blasius solution.

