Mechanics of Fluids: Computer Assignment

Due: Thurs, April 24th, 2013

Potential Flow over a Cylinder and Method for Separation Estimation

The goal of this computer assignment is to estimate the separation location for a laminar boundary layer flow over a cylinder. The problem is in two parts:

1. Determine the potential flow field over the cylinder (2-D flow domain)
2. Determine the distribution of momentum thickness and the estimated separation location using Thwaites' Method.

A cylinder in a cross flow (Section 8.5 in the textbook) is formed by the superposition of a uniform stream in the x direction with velocity U , a doublet of strength $\lambda = UR^2$ (R=radius), and with a potential flow vortex of strength K.

Analysis*

a. Determine an equation for the stream function and velocity potential function.
b. Determine the value of the stream function defining the bod.
c. Determine the stagnation point as a function of K.
d. Plot contour plots of the stream function and velocity-potential function for values of K/(UR)=0.0, 1.0, 2.0, and 3.0 (check against Fig. 8.14 in book)

*Feel free to use matlab program I passed out in class to help you out here.

Numerical (You can use any reasonable programming language – C/C++, Matlab, Fortran, Java,…)

Input values for U , R, and K and the number of points N on the surface. Divide the surface into N segments on the bottom surface and N segments on the top surface. Report N used in this

a. Calculate and plot (for K/(Ua)=0,1.0):
   (1) Velocity magnitude on the surface, u_e , as a function of x/R.
   (2) Pressure on surface as a function of x/R.
b. Numerically integrate pressure to calculate (let span, b=1m) (for K/(Ua)=0,1.0):
   (1) Lift coefficient: $C_L = \frac{Lift}{0.5\rho U^2 b(2R)}$
   (2) Drag coefficient: : $C_D = \frac{Drag}{0.5\rho U^2 b(2R)}$
c. Viscous Estimation:
   a. Estimate the separation location on the upper and lower surfaces (for K/(Ua)=0,1.0). We will estimate this as the first point where dP/ds>0.
   b. Recalculate the drag coefficients (for K/(Ua)=0). This time assume that pressure aft of the separation point remains unchanged from the point at separation.
   c. How does this model scale with Re? How does the result compare to data?

See Sample Report for scoring.