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AME-60639
Advanced Aerodynamics

Homework 6

The tapered symmetric wing shown below is placed at an angle of attack $\alpha = 5^o$ to a free stream velocity of $100m/s$. The chord length is given in meters by

$$c(y) = 3 - \frac{y}{(b/2)}$$

where $b = 18m$ is the wing span. The wing is designed to fly at elevations where the air density $\rho = 1.20kg/m^3$ and the speed of sound is about 330 m/s. The cross-section of the wing at the root is a NACA 4412 profile and changes linearly to a NACA 0012 at the tip.

1. Explain why the flow around the wing may be considered to be incompressible.

2. Although we want to calculate the characteristics of the finite wing, it is interesting to examine the characteristics of each cross-section as the profile of a two-dimensional infinite-span wing. Use the thin airfoil theory to calculate the two-dimensional characteristics such as the circulation Γ, the angle of zero-lift α_{L_0}, and the aerodynamic coefficients : $c_\ell, c_{m,le}, x_{cp}$ and c_{mac}, compare and plot their variations from root to tip. Compare the pressure distributions obtained from the two methods at three locations of the wing: root, middle of root-tip, and tip. Comment on the results.

3. Check the relationship between the angle of zero-lift, α_{L_0} and the sectional profile camber, m.

4. The finite wing theory introduces the new variable $y = -(b/2)cos\theta$, and give the expression

$$\alpha - \alpha_{L_0}(\theta) = \frac{2b}{\pi c(\theta)} \sum_1^N A_n sinn\theta + \sum_1^N nA_n \frac{sinn\theta}{sin\theta}.$$

   Determine how many collocation points you need to calculate the A_n 's with a reasonable accuracy. Compare the results with the following choice: two points, one at the centerline $y = 0$ $(\theta = \pi/2)$ and the other at $y = 0.3535b(\theta = 3\pi/4)$.

5. Calculate the lift coefficient, C_L, the induced angle of attack, α_i, along the span, and the induced drag coefficient, $C_{D,i}$. Compare the results with those obtained from two-dimensional methods.

6. Compare C_L, $C_{D,i}$ and α_i with those of an elliptical wing with the same span and chord length at the root.

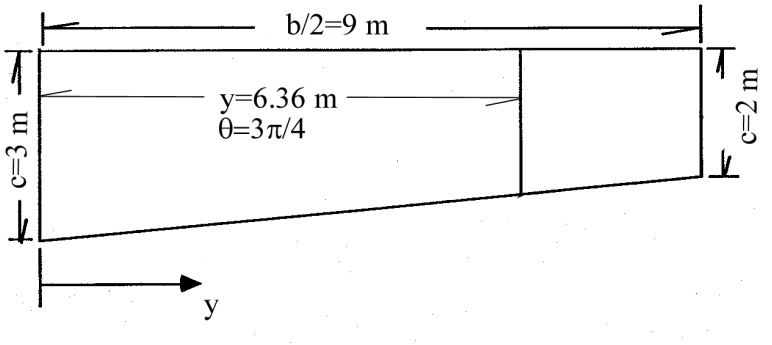

Figure 1: Tapered Wing Geometry