

AME 321 Homework 6

Problem 1. A delta wing has an aspect ratio of 2.0. By means of helium bubbles in the flow, the vortices are observed to be bursting 2/3 of the midspan chord back from the apex. What would you estimate the angle of attack of the wing to be?

Answer: from equation (3.86) we get $\Lambda = \arctan 4/A = 63.46^\circ$, then from the equation (3.96) for the resultant angle and figure 3.76 (using middle of band) we can find that the angle of attack for the burst point to be at 2/3 of chord is $\alpha \approx 21^\circ$.

Problem 2. The landing weight of Concorde is approximately 245 00 lb. The planform has a curved, swept leading edge. However, the wing can be approximated as a delta wing with an aspect ratio of 1.7. The wing span is 25.5 m. If the airplane lands at a speed that is 20% above the stalling speed, what is the landing speed and the angle of attack of the wing when landing at SSL conditions? Neglect the effects of vortex bursting in determining α but not in finding the landing speed.

Answer: $\Lambda = \arctan 4/A = 67^\circ$, $S = b^2/A$, from figure 3.78 we have $C_{Lmax} \approx 1.35 = 2W/(\rho V_s^2 S)$, so the stalling speed is $V_s = 58.7$ m/s. The landing speed is $V_{land} = 1.2V_s = 70.4$ m/s, and $C_L = 0.939$. Using figure 3.73 to get the coefficients for the equation 3.92, we find (numerically) that the angle of attack for landing speed $\alpha \approx 20^\circ$.

Problem 3. A flat plate aligned with the flow has a length of $l = 4$ m and a width of $w = 10$ m. Calculate its skin friction drag at an airspeed of $V = 40$ m/s for SSL conditions. Assume a transition Reynolds number of $Re_{tr} = 10^6$.

Answer: for completely turbulent flow: $Re = Vl/\nu = 10.95 \cdot 10^6$ and $C_{f0} = 0.455(\log(Re))^{-2.58} = 0.00296$, then $q = \rho V^2/2 = 980$ Pa, and $D_0 = qSC_{f0} = 116$ N; drag up to transition point if the flow is turbulent: $C_{f1} = 0.455(\log(10^6))^{-2.58} = 0.00447$ and $D_1 = qSC_{f1} = 16$ N. Also, the transition point is $x = Re_{tr}\nu/V = 0.365$ m; drag up to the transition point if the flow is laminar: $C_{f2} = 1.328Re_{tr}^{-1/2} = 0.00133$ and $D_2 = 4.76$ N.

The net drag is $D = D_0 - D_1 + D_2 = 104.76$ N.

Problem 4. For the plate in the previous problem, calculate the displacement thickness 1 m back from the leading edge.

Answer: as the location (1 m) is behind the transition point, then the flow is turbulent: $\delta^* = 1/8(0.37x(Vx/\nu)^{-0.2}) = 2.39$ mm.

Problem 5. Estimate the roughness height that would cause premature transition on the plate in the third problem.

Answer: the roughness height should be of order of δ^* , we can use figure 4.44 as an estimate of Reynolds number based on a roughness height length scale. As the projection

fineness is not given, we assume that d/k is large, the Reynolds number is independent of this ratio and use the value of $\sqrt{Re_k} = 12$, or $Re_k = 144 = Vh/\nu$, so $h = \delta^* = 0.05$ mm. Then, for laminar boundary layer, $\delta^* = 1/3(5.2\sqrt{x\nu/\bar{V}}) \Rightarrow x = 2.3$ mm. So, the roughness height can be estimated as the displacement thickness δ^* at 2.3 mm from the leading edge of the plate.