AA 311 | Luke Verlangieri | HW3

$\boxed{4.34}$

Given

Wingspan 17.5 m

Chord length 3 m

Sea level

$V_\infty = 200$ m/s

Assumptions

Rectangular wing

Laminar flow

Flat plate

Assume Incompressible flow

Find

$\delta_{\text{trailing edge}}$

$D_{f,\text{total}}$

Properties

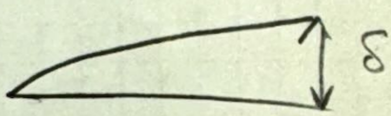
$\delta_{\text{Laminar}} = \frac{5.2x}{\sqrt{Re_x}}$ $C_F = \frac{1.328}{Re_L^{1/2}}$

$Re_x = \frac{\rho_\infty V_\infty \cdot x}{\mu_\infty}$ $q = \rho \frac{V^2}{2}$

$S = L \cdot W$

$D_{f\,\text{Laminar}} = S \cdot q \cdot C_F$

Schematic



Analysis

Appendix A: Figure 4.41

@ sea level $\rho_\infty = 1.225 \frac{kg}{m^3}$ $\mu_\infty \approx 1.75 \times 10^{-5} \frac{kg}{(m)(s)}$

$$Re_L = \frac{(\rho_\infty \cdot V_\infty \cdot L)}{\mu_\infty} = \frac{(1.225\ kg/m^3)(200\ m/s)(3\ m)}{1.75 \times 10^{-5}\ kg/(m)(s)}$$

$\rightarrow Re_L = 4.2 \times 10^7$

$$\boxed{\delta_{\text{Boundary}} = \frac{(5.2 \cdot L)}{(Re_L)^{1/2}} = \frac{(5.2 \cdot 3m)}{(4.2 \cdot 10^7)} = \underline{2.407 \cdot 10^{-3}}}$$

$$q = \rho V^2/2 = (1.225 \tfrac{kg}{m^3})(200^2 \tfrac{m^2}{s^2} \cdot \tfrac{1}{2}) = 24500 \tfrac{N}{m^2}$$

$$S = (3m)(17.5m) = 52.5\ m^2$$

$$C_F = \frac{1.328}{Re_L^{1/2}} = \frac{1.328}{(4.2 \cdot 10^7)^{1/2}} = 0.0002049$$

2 sides

$$\boxed{D_{\text{total}} = 2 \cdot S \cdot q \cdot C_F = 2 \cdot 52.2\ m^2 \cdot 24500 \tfrac{N}{m^2} \cdot 0.0002049 = 527.1\ N}$$

4.43 Given : Flat plate. $L = 4m$ $Re_{cr} = 5 \cdot 10^5$

Assumptions : Sea level Incompressible flow $D_F \propto V_\infty^n$

Find : D_F when ($V_\infty = 20$ m/s and 40 m/s), n

Properties : $Re_x = \dfrac{\rho_\infty V_\infty \cdot x}{\mu_\infty}$ $D_F = S \cdot q \cdot C_F$

$$C_{F_L} = \frac{1.328}{\sqrt{Re_x}} \quad C_{F_T} = \frac{0.074}{\sqrt[5]{Re_x}} \quad q = \rho_\infty \cdot \frac{V_\infty^2}{2}$$

Analysis $\mu_\infty = 1.789 \cdot 10^{-5} \frac{N}{m \cdot s}$ $\rho_\infty = 1.225 \frac{kg}{m^3}$

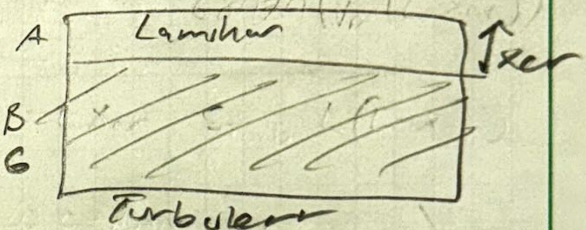
$$x_{cr} = \frac{(Re_{cr})(\mu_\infty)}{(\rho_\infty)(V_\infty)} = \frac{(5 \cdot 10^5)(1.789 \cdot 10^{-5} \frac{N}{m \cdot s})}{(1.225 \frac{kg}{m^3})\ V_\infty} = \frac{1}{V_\infty} 7.302$$

Assuming Turbulent flow total

$$Re_L = \frac{\rho_\infty V_\infty L}{\mu_\infty} = 2.739 \cdot 10^5 \cdot V_\infty$$

$$C_{f_L} = \frac{0.074}{\sqrt[5]{2.739 \cdot 10^5 \cdot V_\infty}} \quad C_{A_{Turb}} = \frac{0.074}{\sqrt[5]{5 \cdot 10^5}} \rightarrow 0.00536$$

$$q = 0.6125 \cdot V_\infty^2$$



$$D_B = D_L - D_A = L \cdot q \left(L \cdot \frac{0.074}{\sqrt[5]{2.739 \cdot 10^5 \cdot V_\infty}} - x_{cr} C_{A_{Turb}} \right)$$

Assuming Laminar

$$C_{A_{laminar}} = \frac{1.328}{\sqrt{Re_{cr}}} = \frac{1.328}{\sqrt{5 \cdot 10^5}} = 0.00188$$

$$D_A = L \cdot q \left(x_{cr} \cdot C_{A_{laminar}} \right) \qquad \underline{D_{F\ total} = 2 \cdot (D_A + D_B)}$$

Because we have equations for D_A and D_B in terms of known and V_∞ this can be thrown into python.

$$\boxed{\begin{aligned} D_F(V_\infty = 20 \text{ m/s}) &= 23.557 N \\ D_F(V_\infty = 40 \text{ m/s}) &= 85.73 N \end{aligned}}$$

$$D_F \propto V_\infty^n$$

$$\frac{D_{F2}}{D_{F1}} = \left(\frac{V_{\infty 2}}{V_{\infty 1}}\right)^N$$

$$N = \frac{\log(D_{F2}/D_{F1})}{\log(V_{\infty 2}/V_{\infty 1})}$$

$$\rightarrow N = \frac{\log(85.73\,N/23.557\,N)}{\log(40/20)}$$

$$\boxed{\rightarrow N = 1.864}$$

in this case N is 93.2% of 2. It would be a decent approximation to say $D \propto V_\infty^2$, However 6.8% is a fall amount, and I would not consider any measurement using that valid for this n.

4.63 Given: mach 0.6 at 20,000 ft, boundary layer bleed duct at 2.89 m downstream from the nose.

Find: The nessecary height of the rectangular entrance of the BL (δ)

Assumpions: Turbulent, Incompressible, flat plate

Properties

$M = \frac{V}{A}$ $\quad \delta_T = \frac{0.37x}{\sqrt[5]{Re_x}}$ $\quad Re_x = \frac{\rho_\infty V_\infty \cdot x}{\mu_\infty}$

$C_{F\,Turb} = \frac{0.074}{\sqrt[5]{Re_x}}$ $\quad a = \sqrt{\gamma R T}$ $\quad \gamma = 1.4$ $\quad R = 287\ J/kg \cdot k^\circ$

Analysis

$20{,}000\,ft \cong 6096\,m \rightarrow 248.55\,k^\circ = T_\infty$
$0.65283\ kg/m^3 = \rho_\infty$ } Appendix A
$1.52 \cdot 10^{-5} \approx \mu_\infty$ ← Figure 4.41

$a = \sqrt{\gamma R T}$

$= \sqrt{1.4 \cdot (287 \frac{J}{kg \cdot k}) \cdot (248.55\,k^\circ}$

$a = 316.02\ m/s$

$V_\infty = M \cdot a = 0.6 \cdot 316.02\ m/s$
$= 189.61\ m/s$

$$Re_L = \frac{V_\infty \rho_\infty \cdot L}{\mu_\infty} = \frac{(189.61)(0.65283)(2.89)}{1.52 \cdot 10^{-5}} = 2.352 \cdot 10^7$$

$$\boxed{\delta_L = \frac{0.37 \cdot L}{\sqrt[5]{Re_L}} = \frac{0.37 \cdot (2.89\,m)}{\sqrt[5]{2.352 \cdot 10^7}} = 0.0359\,m}$$

TOPS

```python
import math

R_cr = 5 * (10**5)
mu = 1.789 * pow(10, -5)
rho = 1.225
L = 4

def drag(v):
    x_cr = (R_cr * mu)/(rho * v)
    q = (rho * (v**2))/2
    R_l = (rho * v * L)/mu
    c_len_turb = 0.074/(R_l**(1/5))
    drag_turb_len = q * c_len_turb * L * L
    c_a_T = 0.074/(R_cr**(1/5))
    drag_turb_a = q * L * x_cr * c_a_T
    c_a_L = 1.328/(R_cr**(1/2))
    d_b = drag_turb_len - drag_turb_a
    d_a = L * q * (x_cr * c_a_L)
    return 2 * (d_b + d_a)

print(drag(20))
print(drag(40))

n = (math.log(drag(40)/drag(20))/math.log(40/20))

print(n)
```

Here is the code I used for Question 4.43