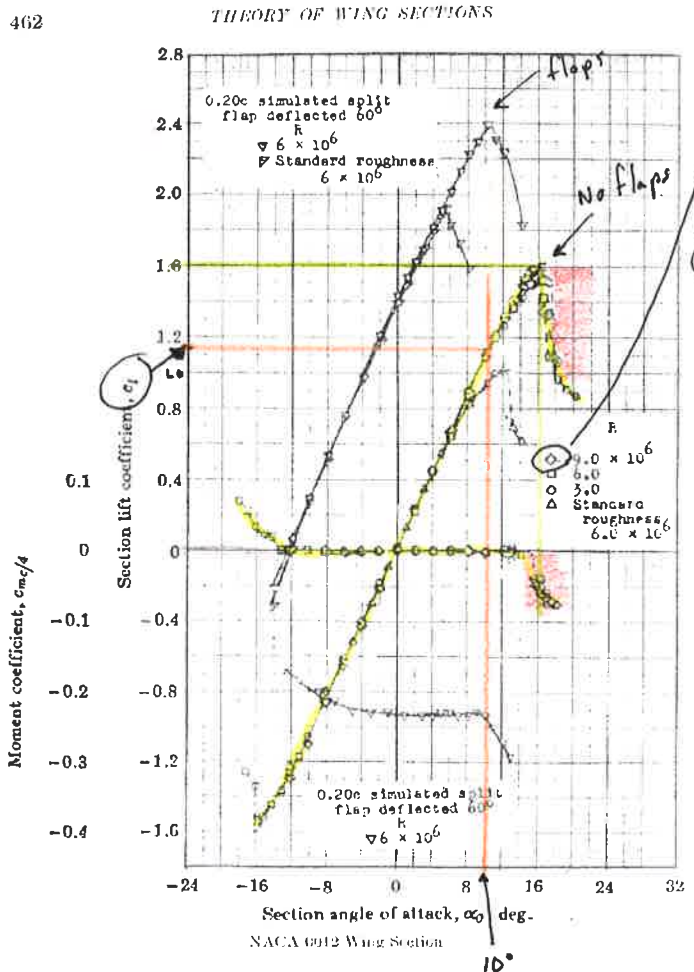
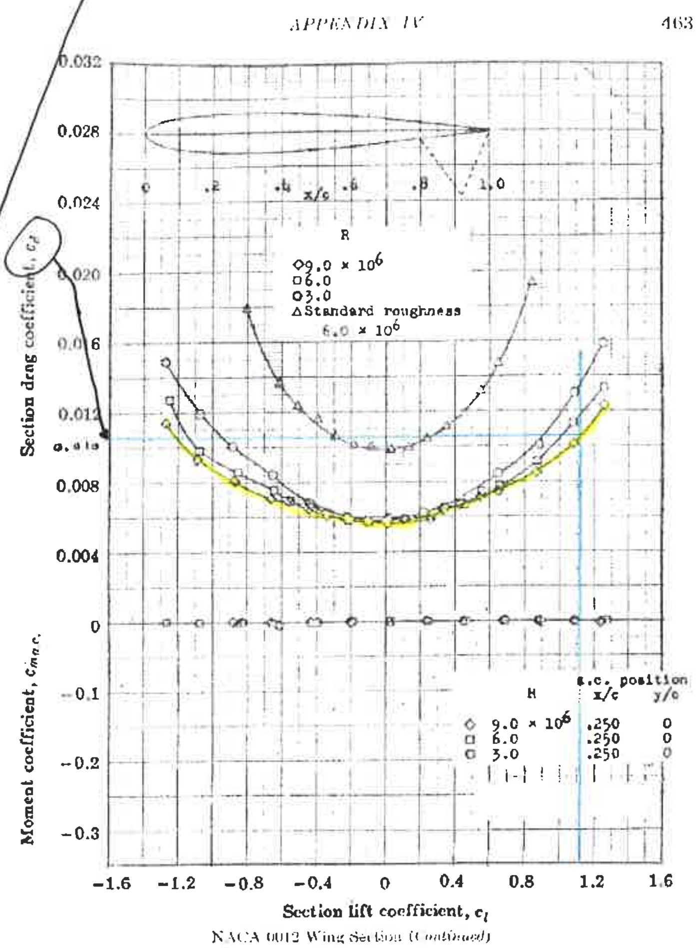
1) Chapter 2 in book ✓

2) For an NACA 0012 operating at a Reynolds number in excess of 10 million,

- Determine the lift, drag, and quarter chord moment coefficient at 10° AOA.
- Determine $C_{l\,max}$ and discuss lift and moment behavior near stall.





- $C_l \approx 1.14$

  $C_d \approx 0.0105 = 105$ counts

  $C_m \approx 0^-$

- $C_{l\,max} \approx 1.6$

  At AOAs greater than 16° (stall), the lift dramatically decreases and the moment becomes nose down. The stall is "sharp"/sudden. with little prior warning.

3) Variable Density Wind Tunnel

- Match Re and M for $1/10^{th}$ scale model

$$Re \equiv \frac{\rho V L}{\mu} \quad \text{and} \quad M \equiv \frac{V}{a} = \frac{V}{\sqrt{\gamma R T}}$$ ← see 1.2.3

For the $\underbrace{\text{full size}}_{fs = \text{full size}}$ and $\underbrace{\text{model}}_{wt = \text{wind tunnel}}$, the Re and M must be identical

$$Re_{fs} = Re_{wt} = \frac{\rho_{fs} V_{fs} L_{fs}}{\mu_{fs}} = \frac{\rho_{wt} V_{wt} \cancel{L_{wt}}^{\frac{L_{fs}}{10}}}{\mu_{wt}}$$

$$M_{fs} = M_{wt} = \underbrace{\frac{V_{fs}}{\sqrt{\gamma R T_{fs}}} = \frac{V_{wt}}{\sqrt{\gamma R T_{wt}}}}_{\text{since changing temperature is only a weak change in speed, } \underline{\text{assume constant T}}}$$

$$\Rightarrow V_{fs} = V_{wt}$$

Substitute into Re equation with $\rho = \frac{P}{RT}$

$$\frac{P_{fs} V_{fs} L_{fs}}{R T \mu_{fs}} = \frac{P_{wt} V_{wt} L_{fs}}{R T \mu_{wt} 10}$$

$\mu = f(T)$ so canceled

Canceled out

$$P_{fs} = \frac{P_{wt}}{10} \quad \Rightarrow \quad P_{wt} = 10 \cdot P_{fs}$$

$$\boxed{P_{wt} = 147 \text{ psi}}$$

- Water ?

The speed of sound in water $\approx 5000\ \text{ft/s}$, air $\approx 1100\ \text{ft/s}$

$$M_{fs} = M_{wt} = \frac{V_{fs}}{1100} = \frac{V_{wt}}{5000} \Rightarrow V_{wt} = 4.5\, V_{fs}$$

Re #,

$$Re_{fs} = Re_{wt} = \frac{\rho_{fs} V_{fs} L_{fs}}{\mu_{fs}} = \frac{\overset{1000\rho_{fs}}{\rho_{wt}}\ \overset{4.5 V_{fs}}{V_{wt}}\ \overset{L_{fs}/10}{L_{wt}}}{\mu_{wt}}$$

$$\mu_{H_2O} \approx 1\,cp = \overbrace{1\ mPa\text{-}s}^{1\times10^{-3}\ Pa\text{-}s}$$

$$\mu_{air} \approx \underbrace{20\ \mu Pa\text{-}s}_{20\times10^{-6}\ Pa\text{-}s}$$

$$\Rightarrow \frac{\mu_{H_2O}}{\mu_{air}} = \frac{1\times10^{-3}\ Pa\text{-}s}{20\times10^{-6}\ Pa\text{-}s} = 50$$

Re

$$\frac{\rho_{fs} V_{fs} L_{fs}}{\mu_{fs}} = \frac{1000\,\rho_{fs} \cdot 4.5 V_{fs}\ \frac{L_{fs}}{10}}{50\,\mu_{fs}} = 9\,\frac{\rho_{fs} V_{fs} L_{fs}}{\mu_{fs}}$$

Not equal !

Our assumption of using water and matching the Ma and Re led to the false statement that $1 = 9$. The assumptions over constrained the physics. $\boxed{\text{Not feasible}}$

Dropping the M requirement would work.

4) $S = 174\ ft^2$

- Determine $C_{L_{max}}$ from $W = 3400\ lbf$ and $V_{min} = 54\ kts$ $\underline{SSL}$

$$L = W = \tfrac{1}{2}\rho V^2 S C_L \Rightarrow C_{L_{max}} = \frac{2W}{\rho V^2 S}$$

Convert airspeed

$$V = \frac{54\ kt}{} \cdot \frac{nm}{\cancel{kt}\ hr} \cdot \underbrace{\frac{6076\ ft}{nm} \cdot \frac{hr}{3600\ s}}_{1.68\ \frac{ft}{s}\frac{1}{kt}} = 91.1\ ft/s$$

$$C_{L_{max}} = \frac{2 \cdot 3400\ \cancel{lbf}}{} \cdot \frac{\cancel{ft^3}}{0.00237\ \cancel{slug}} \cdot \frac{\cancel{s^2}}{91.1^2\ \cancel{ft^2}} \cdot \frac{}{174\ \cancel{ft^2}} \cdot \frac{\cancel{slug}\ \cancel{ft}}{\cancel{lbf}\ \cancel{s^2}}$$

$$\boxed{C_{L_{max}} = 1.98}$$

- Determine drag in pounds at $120\ kt$ at SSL and $W = 3100\ lbf$

$$V = 120\ kt \cdot 1.68\ \frac{ft}{s\ kt} = 201\ ft/s$$

$$C_L = \frac{2W}{\rho V^2 S} = \frac{2 \cdot 3100\ \cancel{lbf}}{} \cdot \frac{\cancel{ft^3}}{0.00237\ \cancel{slug}} \cdot \frac{\cancel{s^2}}{201^2\ \cancel{ft^2}} \cdot \frac{}{174\ ft^2} \cdot \frac{slug\ ft}{lbf\ s^2}$$

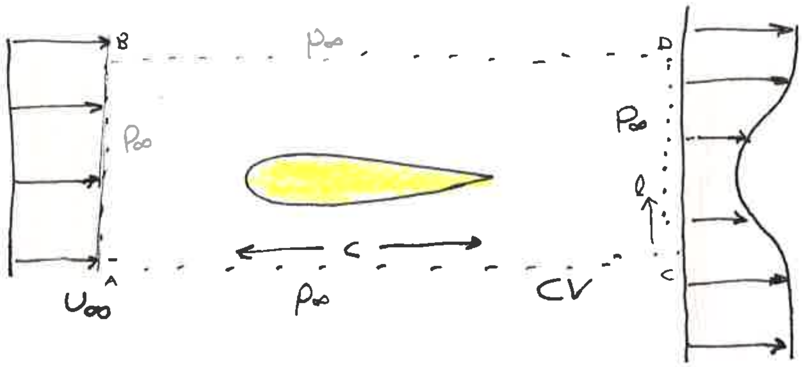
$$= 0.372$$

$$C_D = 0.0358 + 0.054 \cdot 0.372^2 = 0.0433$$

$$D = q S C_D = \frac{1}{2} \cdot \frac{0.00237\ slug}{ft^3} \cdot 174\ ft^2 \cdot 0.0433 \cdot \frac{lbf\ \cancel{s^2}}{slug\ ft} \cdot \frac{201^2\ ft^2}{\cancel{s^2}}$$

$$\boxed{D = 360\ lb}$$

5) Determine the drag coefficient.



$$U_2 = U_\infty \left(1 - 0.5 \cos \frac{\pi y}{2H}\right)$$

$$H = 0.025c$$

From lesson 6 notes

$$D = \int_C^D \rho_2 U_2 (U_1 - U_2)\, dl \qquad \text{with} \quad U_1 = U_\infty$$

$$U_2 = U_\infty\left(1 - 0.5 \cos \frac{\pi y}{2H}\right)$$

Compute $U_1 - U_2$:

$$= U_\infty - U_\infty\left(1 - 0.5 \cos \frac{\pi y}{2H}\right) = U_\infty\left(1 - 1 + 0.5 \cos \frac{\pi y}{2H}\right)$$

$$= U_\infty\left(0.5 \cos \frac{\pi y}{2H}\right)$$

Drag

$$D = \int_{-H}^{H} \rho_2 U_\infty \left(1 - 0.5 \cos \frac{\pi y}{2H}\right)\left(U_\infty\, 0.5 \cos \frac{\pi y}{2H}\right) dl$$

$$= \underbrace{\rho_2 U_\infty^2}_{2q} \int_{-H}^{H} \Big(\underbrace{0.5 \cos \frac{\pi y}{2H}}_{\frac{2H}{\pi}} - \underbrace{0.25 \cos^2 \frac{\pi y}{2H}}_{-\frac{H}{4}} \Big) dl$$

Coeff of drag:

$$0.025c = \frac{1}{40}\cancel{c}$$

$$C_d = \frac{D}{qc} = \frac{2\cancel{q}\,(\cancel{h})\left(\frac{2}{\pi} - \frac{1}{4}\right)}{\cancel{q}\,\cancel{c}} = \frac{2}{40}\left(\frac{2}{\pi} - \frac{1}{4}\right)$$

$$\boxed{C_d = 0.0193}$$