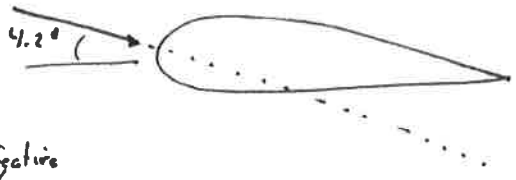
HW 7

1) Estimate C_L for a constant chord AR = 8 wing, using the NACA 4414 airfoil. Operating AOA is 5 degrees.

- From XFOIL, α_{zL} for the 4414 is $-4.2°$



- Calculate effective aero AOA

$$\alpha = AOA + \alpha_{zL} = 5 - (-4.2°) = 9.2°$$

- Estimate C_{L_α} slope parameter from Fig 7.14

$$\tau \approx 0.22$$

$$C_{L_\alpha} \approx \frac{2\pi}{1 + \frac{2\pi}{\pi AR}(1+\tau)} = \frac{2\pi}{1 + \frac{2\pi}{8\pi}(1.22)}$$

$$C_{L_\alpha} \approx 4.8 \ \frac{1}{rad}$$

- C_L lift coeff

$$C_L = C_{L_\alpha}\,\alpha$$

$$= 4.8 \ \frac{1}{rad} \left| 9.2° \right| \frac{\pi \ rad}{180°} =$$

$$\boxed{C_L \approx 0.77}$$

2) Estimate the thrust and power consumed by induced drag for a 1.268×10^6 lbf A380 at 150 kts.

Geometry from wikipedia!

$b = 79.75\text{m} = 261.7\text{ ft}$

$S = 9100\text{ ft}^2$

$\lambda \approx 0.25$

$AR = \frac{b^2}{S} = 7.5$

- Induced drag

$$C_{D_i} = \frac{C_L^2}{\pi AR}(1+\delta)$$

- Compute C_L

$$C_L = \frac{L}{\frac{1}{2}\rho V^2 S} = \frac{1.268\times10^6\ \text{lbf} \mid 2 \mid \text{ft}^3}{0.00237\ \text{slug} \mid 150^2\ \text{kt}^2 \mid 9100\ \text{ft}^2}$$

$$\frac{\text{slug ft} \mid 1^2\ \text{kt}^2\ \text{s}^2}{\text{lbf s}^2 \mid 1.68^2\ \text{ft}^2}$$

$$= 1.85$$

- Look up δ

Fig 7.14a

$\delta \approx 0.025$ for $\lambda = 0.25$ and $AR \approx 8$

$$C_{D_i} = \frac{1.85^2 \mid \mid 1.025}{\pi \mid 7.5} = 0.1489 \quad !!$$

-  $\Rightarrow$ 

$$T_i = D_i = \frac{1}{2} \mid 9100\ \text{ft}^2 \mid 150^2\ \text{kt}^2 \mid 0.00237\ \frac{\text{slug}}{\text{ft}^3} \mid 0.1489 \mid \frac{\text{lbf s}^2}{\text{slug ft}} \mid \frac{1.68^2\ \text{ft}^2}{1^2\ \text{kt}^2\ \text{s}^2}$$

$$= \boxed{102\,000\ \text{lbf}}$$

- $P = F \cdot V = 102000\ \text{lbf} \mid 150\ \text{kt} \mid \frac{1.68\ \text{ft}}{\text{kt s}} \mid \frac{\text{s hp}}{550\ \text{ft lbf}}$

$$= \boxed{46700\ \text{hp}}$$

3) Linearly twisted AR = 8 constant chord wing with min drag (using prl 2)

Create input file hw7.txx

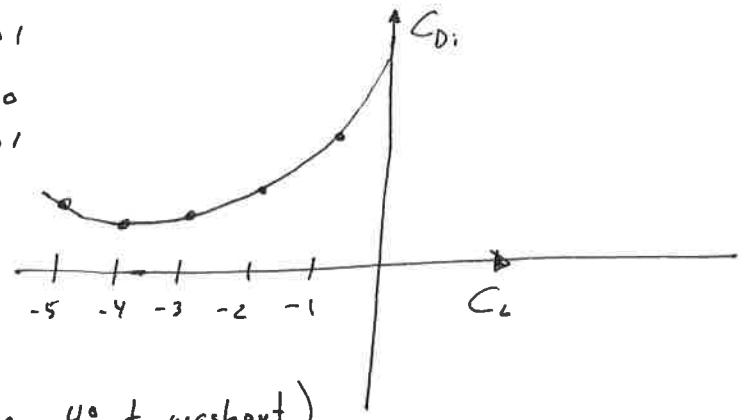
```
% geofile (header line)
% chord # <integer>
3
% half span ratio, chord, twist [deg]
-1.0   0.25   -1
 0.0   0.25    0
 1.0   0.25   -1
```

vary these

span chord twist

Add washout by varying twist at tips. plot C_{D_i} vs C_L. This requires finding the AOA to achieve $C_L = 0.5$. (Iteration within prl 2)

twist	C_L	C_{D_i} $\times 10^{-2}$
-1	0.5	1.04
-2	⋮	1.02
-3	⋮	1.01
-4		1.00
-5		1.01



A twist of -4° (i.e. 4° at washout) minimizes C_{D_i} at $C_L = 0.5$

Elliptical would be $C_{D_i} = \frac{C_L^2}{\pi AR} = \frac{0.5^2}{\pi 8} = 0.009947$

Linear twist at a specific C_L works <u>really</u> well. (0.5% higher than elliptical!)

Off design has only slightly more induced drag. AR is <u>the</u> driving factor for C_{D_i}

The untwisted wing has ≈ 4 counts more drag at $C_L = 0.5$. This would be marginally noticeable in a flight test.