

STRUJANJE VISKOZNOG FLUIDA

1. Krilo zrakoplova može se promatrati kao ravna ploča širine 10 m i duljine tetive 1,2 m. Na krilo nastrojava zrak brzinom 300 km/h sa standardnim karakteristikama za visinu 3000 m. Odrediti silu otpora trenja, debljinu graničnog sloja na izlaznom bridu i potrebnu snagu za savladavanje sile otpora uz sljedeće pretpostavke:
- granični sloj je laminaran na cijelom krilu,
 - granični sloj je turbulentan na cijelom krilu,
 - prijelaz laminarnog graničnog sloja u turbulentni događa se pri kritičnom Reynoldsovom broju $Re_{kr} = 500000$.

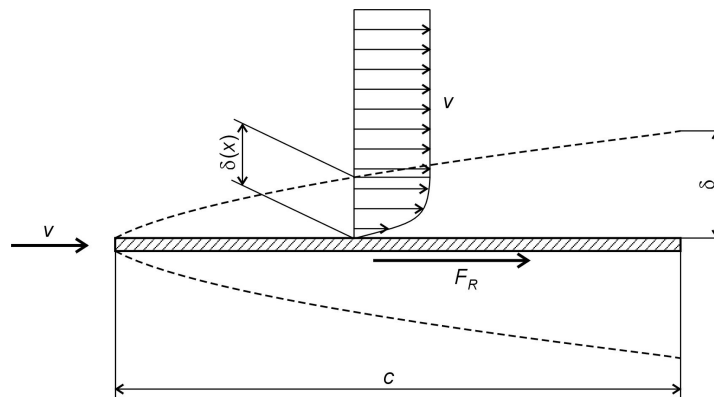
Rješenje: $H = 3000 \text{ m} \rightarrow T = 268,65 \text{ K}$
 $\rho = 0,90896 \text{ kg/m}^3$
 $\mu = 1,696 \cdot 10^{-5} \text{ Pas}$
 $\nu = 1,8659 \cdot 10^{-5} \text{ m}^2/\text{s}$

$$b = 10 \text{ m}$$

$$c = 1,2 \text{ m}$$

$$v = 300 \text{ km/h} = 83,33 \text{ m/s}$$

$$Re = \frac{v \cdot c}{\nu} = \frac{83,33 \cdot 1,2}{1,8659 \cdot 10^{-5}} = 5,35934 \cdot 10^6$$



$$a) \quad \bar{C}_f = \frac{1,328}{\sqrt{Re}} = \frac{1,328}{\sqrt{5,35934 \cdot 10^6}} = 5,736 \cdot 10^{-4}$$

$$F = 2 \cdot \bar{C}_f \cdot \frac{1}{2} \cdot \rho \cdot v^2 \cdot b \cdot c = 2 \cdot 5,736 \cdot 10^{-4} \cdot \frac{1}{2} \cdot 0,90896 \cdot 83,33^2 \cdot 10 \cdot 1,2 = 43,45 \text{ N}$$

$$P = F \cdot v = 43,45 \cdot 83,33 = 3621 \text{ W} \approx 3,6 \text{ kW}$$

$$\delta = 5,0 \cdot \sqrt{\frac{\nu \cdot x}{v}} = 5,0 \cdot \sqrt{\frac{1,8659 \cdot 10^{-5} \cdot x}{83,33}} = 0,002366 \cdot \sqrt{x}$$

$$x = c = 1,2 \text{ m} \rightarrow \delta = 0,002366 \cdot \sqrt{x} = 0,002366 \cdot \sqrt{1,2} = 0,00259 \text{ m} = 2,59 \text{ mm}$$

$$\text{b) } \overline{C}_f = \frac{0,074}{Re^{0,2}} = \frac{0,074}{(5,35934 \cdot 10^6)^{0,2}} = 0,003337$$

$$F = 2 \cdot \overline{C}_f \cdot \frac{1}{2} \cdot \rho \cdot v^2 \cdot b \cdot c = 2 \cdot 0,003337 \cdot \frac{1}{2} \cdot 0,90896 \cdot 83,33^2 \cdot 10 \cdot 1,2 = 252,80 \text{ N}$$

$$P = F \cdot v = 252,80 \cdot 83,33 = 21066 \text{ W} \approx 21 \text{ kW}$$

$$\delta = 0,371 \cdot x \cdot \left(\frac{\nu}{v \cdot x} \right)^{0,2} = 0,371 \cdot \left(\frac{\nu}{v} \right)^{0,2} \cdot x^{0,8} = 0,371 \cdot \left(\frac{1,8659 \cdot 10^{-5}}{83,33} \right)^{0,2} \cdot x^{0,8} = 0,01735 \cdot x^{0,8}$$

$$x = c = 1,2 \text{ m} \rightarrow \delta = 0,01735 \cdot x^{0,8} = 0,01735 \cdot 83,33^{0,8} = 0,0201 \text{ m} = 20,1 \text{ mm}$$

$$\text{c) } \overline{C}_f = \frac{0,074}{Re^{0,2}} - \frac{1700}{Re} = \frac{0,074}{(5,35934 \cdot 10^6)^{0,2}} - \frac{1700}{5,35934 \cdot 10^6} = 0,003020$$

$$F = 2 \cdot \overline{C}_f \cdot \frac{1}{2} \cdot \rho \cdot v^2 \cdot b \cdot c = 2 \cdot 0,003020 \cdot \frac{1}{2} \cdot 0,90896 \cdot 83,33^2 \cdot 10 \cdot 1,2 = 228,77 \text{ N}$$

$$P = F \cdot v = 228,77 \cdot 83,33 = 19064 \text{ W} \approx 19 \text{ kW}$$

– usporedba debljina laminarnog i turbulentnog graničnog sloja

