Delft University of Technology

AE1101 - Introduction to Aerospace Engineering
Studio Classroom solutions

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Technische Universiteit Delft

Problem (1) : Wing

The lift and drag coefficient at $\alpha = 6^\circ$

From the graph: $C_l = 0 : \alpha = -1.5^\circ$

$C_l = 1.05 \quad \alpha = 8^\circ$

For the airfoil $a_0 = \frac{dC_l}{d\alpha} = \frac{1.05 - 0}{8 - (-1.5)} = 0.11 / \text{degr.}$

(Note: theory for thin airfoils: $a_0 = 2\pi / \text{rad.} = 0.1097 / \text{degr.}$)

Lift gradient $a = \frac{dC_L}{d\alpha}$ for the wing:

$$a = \frac{a_0}{1 + \frac{57.3 * a_0}{\pi A e}} = \frac{0.11}{1 + \frac{57.3 * 0.11}{\pi * 5 * 0.9}}$$

$$= 0.076 / \text{degr.}$$

at 6°: wing $C_L = a * (\alpha - \alpha_{C_l = 0})$

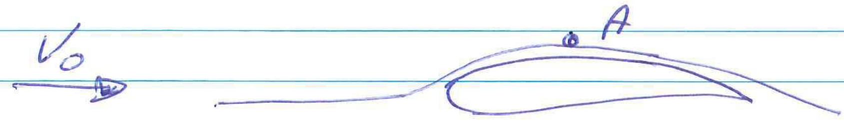
$$= 0.076 * (6 - (-1.5)) = 0.57$$

$$C_D = C_{D_0} + \frac{C_L^2}{\pi A e} = 0.004 + \frac{0.57^2}{\pi * 5 * .9}$$

$$= 0.027$$

In de Onderwijs- en examenregeling is vastgelegd dat tentamenuitslagen binnen 20 werkdagen zullen worden gepubliceerd.
The Education and Examination regulations stipulate that examination results will be made known within 20 working days.

Problem 2



Given: $V_A = 75 \, m/s$ $\quad p_0 = 70121 \, N/m^2$

$V_0 = 200 \, km/hr$ $\quad \rho_0 = 0.90926 \, kg/m^3$

$T_0 = -4.5 \, °C$

a) Incompressible?

Incompressible when $M_0 < 0.3$

$M_0 = \frac{V_0}{a_0}$ $\quad a_0$? $\quad a_0 = a = \sqrt{\gamma R T_0}$

$T_0 = 273.15 - 4.5 = 268.65 \, K$

$\gamma = 1.4$

$R = 287 \, J/kg\,K$

$\rightarrow a = 328.6 \, m/s$

$M_0 = \frac{200/3.6}{328.6} = 0.17 \Rightarrow$ Incompressible!

b) P_A?

Bernoulli: $p_0 + \frac{1}{2}\rho V_0^2 = p_A + \frac{1}{2}\rho V_A^2$

$$P_A = p_0 + \frac{1}{2}\rho (V_0^2 - V_A^2)$$

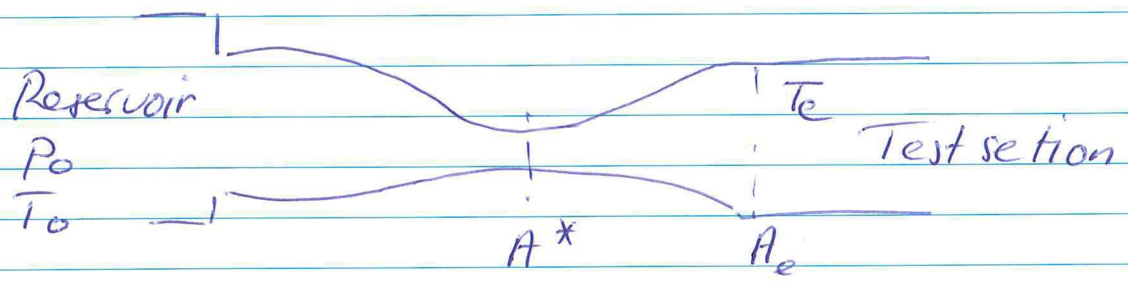
$$= 70121 + \frac{1}{2} * 0.90926 (55.6^2 - 75^2)$$

$$= 70121 - 1154 = 68967 \, N/m^2$$

c) $C_{p_A} = \frac{P_A - P_0}{q_0} = \frac{68967 - 70121}{0.5 * 0.90926 * 55.6^2}$

$= -0.82$

Problem 3



$\gamma = 1.4$ $\quad\quad R = 287\ J/kgK$

$M_e = 3$

$T_e = 288.15 K$
$p_e = 101325\ N/m^2$
$\rho_e = 1.225\ kg/m^3$

} standard sea level cond.

a) P_o ?

Assume isentropic flow

$$\frac{P_0}{P_e} = \left(1 + \frac{\gamma - 1}{2} \cdot M_e^2\right)^{\gamma/\gamma-1}$$

$$P_o = P_e * \left(1 + \frac{\gamma-1}{2} M_e^2\right) = 1.01325 * 10^5 * (2.8)^{3.5}$$

$$= 3.72 * 10^6\ N/m^2$$

b) T_o ?

$$\frac{T_0}{T_e} = \left(1 + \frac{\gamma-1}{2} M_e^2\right)$$

$T_e = 288.15 K$

$$T_0 = 288.15 * \left(1 + \frac{1.4-1}{2} 3^2\right)$$

$$= 806.54 K$$

c) V_e ?

We know $M_e = 3$

$M_e = \frac{V_e}{a_e}$ $a_e = \sqrt{\gamma R T_e}$

$= \sqrt{1.4 * 287 * 288.15}$

$= 340.3$ m/s

$V_e = M_e . a_e = 3 * 340.3 = 1020.9$ m/s.

d) V^* ?

$M^* = 1 \Rightarrow V^* = a^*$

so a^* ? $a^* = \sqrt{\gamma R T^*}$, so T^* ?

$\frac{T_0}{T^*} = 1 + \frac{\gamma - 1}{2} M^{*2}$

$M^* = 1$

$T^* = \frac{806.54}{1 + \gamma - 1/2} = 672.1 K$

$a^* = \sqrt{1.4 * 287 * 672.1} = 519.7$ m/s

e) $\frac{A^*}{A_e}$?

Continuity : $\rho^* A^* V^* = \rho_e A^e V_e$ *

$\rho_e = 1.225$ kg/m³

$V_e = 1021$ m/s

$V^* = 519.7$ m/s

$$\frac{\rho_0}{\rho^*} = \left(1 + \frac{\gamma - 1}{2} M^*\right)^{1/\gamma - 1}$$

$$\frac{\rho_0}{\rho_e} = \left(1 + \frac{\gamma - 1}{2} M_e^{2}\right)^{1/\gamma - 1}$$

$$\rho_0 = \rho_e \left(1 + \frac{0.4}{2} 3^2\right)^{1/0.4} = 1.225 * 2.8^{2.5} = 16.07 \ kg/m^3$$

$$\rho^* = \frac{\rho_0}{\left(1 + \frac{\gamma - 1}{2} M^{*2}\right)^{1/\gamma - 1}}$$

$$M^* = 1$$

$$\rho^* = 10.19 \ kg/m^3$$

$$\frac{A^*}{A_e} = \frac{\rho_e V_e}{\rho^* V^*} = \frac{1.225 * 1021}{10.19 * 519.9} = 0.236$$