MTF052 Strömningsmekanik 2014-01-17

(2.8)

~~(2.13)~~ $\nabla p = \rho(\mathbf{g} - \mathbf{a}) + \mu \nabla^2 \mathbf{V}$

Ingen relativrörelse mellan elementen

$\nabla p = \rho(\mathbf{g} - \mathbf{a})$

z-axeln uppåt $\Rightarrow \frac{dp}{dz} = \rho(-g - a)$ (1)

 $p_2 = 100$ kPa, vi söker p_1

i) $a = 7g$

(1) $\Rightarrow \frac{dp}{dz} = \rho(-8g)$

$p_2 - p_1 = -8\rho g(z_2 - z_1)$

$p_1 = p_2 + 8\rho g(z_2 - z_1) =$

$= 100 \cdot 10^3 + 8 \cdot 1000 \cdot 9{,}81 \cdot 0{,}05 = \underline{\underline{103{,}9 \text{ kPa}}}$

b) $a = -g$

(1) $\Rightarrow \frac{dp}{dz} = \rho \cdot 0$

$\Rightarrow p = \text{konst} \Rightarrow p_1 = p_2 = \underline{\underline{100 \text{ kPa}}}$

c) $V = \text{konst} \Rightarrow a = 0$

(1) $\Rightarrow \frac{dp}{dz} = -\rho g$

$p_1 = p_2 + \rho g(z_2 - z_1) = \underline{\underline{100{,}5}}$ kPa

(samma som om muggen stått still, dvs hydrostatiskt, om man bortser från vakeffekter. I verkligheten minsk trycket p_2 också pga avlösning)

vatten 20°C: $\mu = 1{,}005 \cdot 10^{-3}$ $\rho = 1000$

luft 20°C: $\mu = 18{,}1 \cdot 10^{-6}$ $\rho = 1{,}2$

C_D fås vid dynamisk likf.

dvs $Re_m = Re_p$

$$\frac{U_m D_m \rho_m}{\mu_m} = \frac{U_p D_p \rho_p}{\mu_p}$$

$$U_m = U_p \frac{D_p}{D_m} \frac{\rho_p}{\rho_m} \frac{\mu_m}{\mu_p} =$$

$$= U_p \frac{D}{\frac{D}{12}} \frac{\rho_L}{\rho_V} \frac{\mu_V}{\mu_L} = U_p \cdot 0{,}8$$

Ur diagram fås:

	fordonhast	modellhast	kraft
①	20 m/s	16 m/s	1,5 kN
②	25 m/s	20 m/s	2,4 kN

$F_p = \frac{1}{2} \rho_L A_p C_D U_p^2$ (1)

$F_m = \frac{1}{2} \rho_V A_m C_D U_m^2 \Rightarrow$

$C_D = \frac{2 F_m}{A_m \rho_V U_m^2}$ sätt in (1)

$$F_p = \frac{\rho_L}{\rho_V} \frac{A_p}{A_m} \left(\frac{U_p}{U_m}\right)^2 F_m =$$

$$= \frac{\rho_L}{\rho_V} \left(\frac{D}{D/12}\right)^2 \left(\frac{U_p}{U_m}\right)^2 F_m$$

$$= \frac{\rho_L}{\rho_V} 144 \left(\frac{U_p}{U_m}\right)^2 F_m \quad (2)$$

(2) $\Rightarrow$

$F_p^{25} = 648$ N

$F_p^{20} = 405$ N

$P = F \cdot U$

$\Delta P = F_p^{25} \cdot 25 - F_p^{20} \cdot 20 =$

8,1 kW

Givet: $L = 25\,m$ Olja av $30°C$ $\rho = 980\ kg/m^3$

$d = 0{,}15\,m$

$p_0 = 250\,kPa$ i centrum $\nu = 1{,}0 \cdot 10^{-6}\ m^2/s$

$p = 225\,kPa$

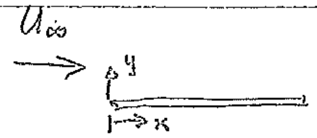
Lösning: $p_0 = p + \dfrac{\rho w_{mitt}^2}{2} \Rightarrow w_{mitt} = \sqrt{\dfrac{2(p_0 - p)}{\rho}} = 7{,}14\ m/s$

$$Re = \frac{w \cdot d}{\nu} = k \cdot \frac{w_{mitt} \cdot d}{\nu} = k \cdot \frac{7{,}14 \cdot 0{,}15}{10^{-6}} = k \cdot 1{,}07 \cdot 10^6$$

Strömningen är alltså turbulent med $k \approx 0{,}82$

$$\dot{m} = \rho A W = 980 \cdot \frac{\pi \cdot 0{,}15^2}{4} \cdot 0{,}82 \cdot 7{,}14 = 101\ kg/s$$

Svar: $\dot{m} = 100\ kg/s$



GET: $x = 1\,m$, $\tau_{w1} = 8{,}2 \cdot 10^{-3}\,Pa$

$y = 1\,mm$ $U_{\infty 2} = 45\ m/s$

Luft av normaltillstånd $\Rightarrow \begin{cases} \rho = 1{,}189\ kg/m^3 \\ \nu = 15{,}2 \cdot 10^{-6}\ m^2/s \end{cases}$

SÖKT: a) $U_{\infty 1}$ b) $u_1(x,y)$

c) τ_{w2} d) $u_2(x,y)$

LÖSNING: a) Bestäm om gränsskiktet är laminärt eller turbulent;

(7.25) $\Rightarrow$ $C_{f,lam} = \dfrac{0{,}664}{\sqrt{Re_x}} \Rightarrow$

$$\Rightarrow \tau_{w,lam} = \frac{1}{2}\rho U_{\infty,lam}^2 \cdot 0{,}664 \sqrt{\frac{\nu}{U_{\infty,lam} \cdot x}} \Rightarrow$$

$$U_{\infty,lam} = \left(\tau_{w,1} \frac{1}{0{,}664} \cdot \frac{2}{\rho} \sqrt{\frac{x}{\nu}}\right)^{2/3} = 3{,}05\,m/s$$

$$\Rightarrow Re_{x,lam} = \frac{U_{\infty,lam} \cdot x}{\nu} = 2{,}01 \cdot 10^5 \ \therefore OK.$$

(7.43) $\Rightarrow C_{f,turb} = \dfrac{0{,}027}{Re_x^{1/7}} \Rightarrow \tau_{w,turb} = \dfrac{1}{2}\rho U_{\infty,turb}^2 \cdot 0{,}027 \left(\dfrac{\nu}{U_{\infty,turb} \cdot x}\right)^{1/7}$

$$\Rightarrow U_{\infty,turb} = \left(\tau_{w,1} \cdot \frac{2}{\rho} \cdot \frac{1}{0{,}027} \left(\frac{x}{\nu}\right)^{1/7}\right)^{7/13} \approx 1{,}63\,m/s$$

$$\Rightarrow Re_{x,turb} = \frac{U_{\infty,turb} \cdot x}{\nu} \approx 1{,}08 \cdot 10^5 \ \text{ej OK}$$

$\therefore$ Laminärt gränsskikt $\Rightarrow$

$\underline{\underline{U_{\infty 1}}} = U_{\infty,lam} = \underline{\underline{3{,}05\ m/s}}$

b) Lam. g.s. se Tab. 7.1 s. 397 med

$$y \cdot \sqrt{\frac{U_{\infty,lam}}{\nu x}} = 0{,}448 \Rightarrow \frac{u}{U_{\infty,lam}} \approx 0{,}15$$

efter interpolation $\Rightarrow \underline{\underline{u_1(x,y) = 0{,}46\ m/s}}$

c) $U_{\infty 2} = 45\,m/s \Rightarrow Re_{x,2} = \dfrac{U_{\infty 2} \cdot x}{\nu} = 3{,}0 \cdot 10^6$ turbulent.

(7.43) $\Rightarrow \underline{\underline{\tau_{w,2}}} = \dfrac{1}{2}\rho U_{\infty,2}^2 \cdot 0{,}027 \left(\dfrac{\nu}{U_{\infty,2} \cdot x}\right)^{1/7}$

$\approx \underline{\underline{3{,}87\ Pa}}$

d) (7.34) $\Rightarrow u^* = \sqrt{\dfrac{\tau_{w,2}}{\rho}} = 1{,}0836\ m/s$

$$\frac{u(x,y)}{u^*} = \frac{1}{\kappa} \ln \frac{y u^*}{\nu} + B$$

med $\kappa = 0{,}41$ och $B = 5{,}0$

$\Rightarrow \underline{\underline{u_2(x,y)}} = \underline{\underline{30{,}0\ m/s}}$

koll: $\dfrac{u^* y}{\nu} = \dfrac{1{,}0836 \cdot 0{,}001}{15{,}2 \cdot 10^{-6}} = 71$

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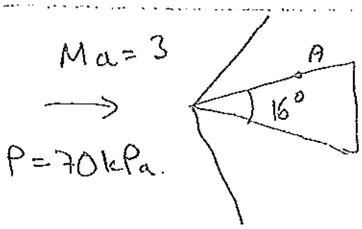
a) 

Luft ⇒ $k = 1{,}4$

För $Ma_1 = 3$; $\theta = 8^\circ$ ger ekv (9.86)

$$\tan\theta = \frac{2\cot\beta\,(Ma_1^2\sin^2\beta - 1)}{Ma_1^2\,(k + \cos 2\beta) + 2}$$

Iterering ⇒ $\beta = 25{,}61^\circ$

$$\frac{P_A}{P_1} = \frac{1}{k+1}\cdot\left[2k\cdot Ma_1^2\sin^2\beta - (k-1)\right] \quad (9.83a)$$

$\Rightarrow \underline{P_A = 126 \text{ kPa}}$

b) En normal stöt formas

$\Rightarrow P_B = P_{02}$

Tabell B1 ⇒ $P_{01} = P/0{,}0272 = 2574$ kPa

Tabell B2, $Ma = 3$ ⇒ $P_{02}/P_{01} = 0{,}3283$

$P_{02} = P_B = 0{,}3283 \cdot 2574$ kPa $= \underline{845 \text{ kPa}}$.