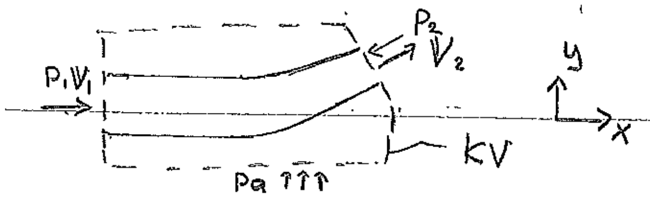
MTF052 Strömningsmekanik 101022



3.40 stationärt 1-dim

$$\sum \mathbb{F} = (\dot m \mathbb{V})_{ut} - (\dot m \mathbb{V})_{in}$$

räkna med övertryck $p_1^{ö} = p_1 - p_a = 50\,kPa$

$$\hat{x}: p_1^{ö} A_1 - p_2^{ö} A_2 \cos 30° + F_x = \dot m (u_2 \cos 30° - u_1) \quad (1)$$

$$\hat{y}: -p_2^{ö} A_2 \sin 30° + F_y = \dot m u_2 \sin 30° - 0 \quad (2)$$

$$u_1 = \frac{\dot m}{\rho \frac{\pi D_1^2}{4}} = 0{,}78\ m/s \quad (4)$$

$$u_2 = \frac{\dot m}{\rho \frac{\pi D_2^2}{4}} = 2{,}39\ m/s \quad (5)$$

$$F_x = \dot m (u_2 \cos 30° - u_1) - p_1^{ö} A_1 + p_2^{ö} A_2 \cos 30° \quad (6)$$

$$F_y = \dot m u_2 \sin 30° + p_2^{ö} A_2 \sin 30° \quad (7)$$

bernoulli: $p_1^{ö} + \frac{\rho u_1^2}{2} = p_2^{ö} + \frac{\rho u_2^2}{2}$

$$p_2^{ö} = p_1^{ö} + \frac{\rho}{2}(u_1^2 - u_2^2) \quad (8)$$

sätt in (8) i (6) & (7)

$$F_x = \dot m (u_2 \cos 30° - u_1) - p_1^{ö} A_1 + \left(p_1^{ö} + \frac{\rho}{2}(u_1^2 - u_2^2)\right) A_2 \cos 30° =$$

$$= -137\ N \qquad \underline{\underline{F_{Fx} = 137\ N}}$$

$$F_y = \dot m u_2 \sin 30° + \left(p_1^{ö} + \frac{\rho}{2}(u_1^2 - u_2^2)\right) A_2 \sin 30° =$$

$$= 33.4\ N \qquad \underline{\underline{F_{Fy} = -33{,}4\ N}}$$

Svar: $(137, -33{,}4)$ N

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

70 km/h = 19.4 m/s
90 km/h = 25 m/s

C_D fås vid dynamisk likf. dvs
$Re_m = Re_b$

$$\frac{U_m D_m \rho_m}{\mu_m} = \frac{U_b D_b \rho_b}{\mu_b}$$

$$U_m = U_b \frac{D_b}{D_m} \frac{\rho_b}{\rho_m} \frac{\mu_m}{\mu_b} =$$

$$= U_b \frac{D}{\frac{D}{10}} \frac{\rho_l}{\rho_v} \frac{\mu_v}{\mu_l} = U_b \cdot 0{,}666$$

ur diagram fås:

	bilhast	modellhast	kraft
①	19,4 m/s	12,9 m/s	1,1 kN
②	25 m/s	16,6 m/s	1,65 kN

$$F_b = \frac{1}{2} \rho_l A_b C_D U_b^2 \quad (1)$$

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

$$C_D = \frac{2 F_m}{A_m \rho_v U_m^2} \qquad \text{sätt in i (1)}$$

$$F_b = \frac{\rho_l}{\rho_v} \frac{A_b}{A_m} \left(\frac{U_b}{U_m}\right)^2 F_m$$

$$= \frac{\rho_l}{\rho_v} \left(\frac{D}{\frac{D}{10}}\right)^2 \left(\frac{U_b}{U_m}\right)^2 F_m$$

$$= \frac{\rho_l}{\rho_v} 10^2 \left(\frac{U_b}{U_m}\right)^2 F_m \quad (2)$$

(2) ⇒

$$F_b^{90} = 450\ N$$

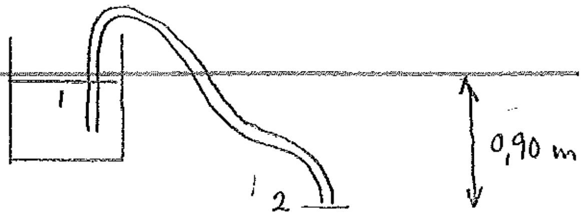
$$F_b^{70} = 299\ N$$

$$P = F \cdot U$$

$$\Delta P = F_b^{90} \cdot U_b^{90} - F_b^{70} \cdot U_b^{70} =$$

$$= 5{,}4\ kW$$

Bernoullis utvidgade (3.68 b):



$$p_1 + \rho\frac{V_1^2}{2} + \rho g z_1 = p_2 + \rho\frac{V_2^2}{2} + \rho g z_2 + \Delta p_f$$

$p_1 = p_2$, $V_1 \approx 0$, $z_1 - z_2 = 0{,}9$ $\Rightarrow$

$0{,}9\,\rho g = \rho\frac{V_2^2}{2} + \Delta p_f$ där $\Delta p_f = f\,\rho\frac{V^2}{2}\frac{L}{d}$ (6.10b) ($\cancel{6.30b}$), $f = f\left(Re, \frac{\varepsilon}{d}\right)$, $\frac{\varepsilon}{d} = 1{,}25\cdot10^{-4}$

$\therefore$ $\boxed{0{,}9\,g = \frac{V_2^2}{2}\left(1 + f\frac{L}{d}\right)}$ (1)

$\nu = 1\cdot10^{-6}\ m^2/s$, $L = 8{,}5\,m$, $d = 0{,}008\,m$

Antag laminärt, (~~6.46~~) (6.13) $\Rightarrow$

$f = \frac{64}{Re} \Rightarrow 0{,}9\,g = \frac{V_2^2}{2}\left(1 + \frac{L}{d}\cdot\frac{64\nu}{d\,V_2}\right)$

$\Rightarrow$ $V_2 = 1{,}73\ m/s \Rightarrow Re = 13840 > 2300$

$\therefore$ Turbulent strömn, antagandet var fel.

Använd t.ex (~~6.64a~~) (6.49)

$$\frac{1}{f^{1/2}} \approx -1{,}8\log\left[\frac{6{,}9}{Re_d} + \left(\frac{\varepsilon/d}{3{,}7}\right)^{1{,}11}\right] \quad (2)$$

Iterera; $Re = 13840$, $(2) \Rightarrow f = 0{,}0285$

Ins i (1) $\Rightarrow V_2 = 0{,}752 \Rightarrow Re = 6017$

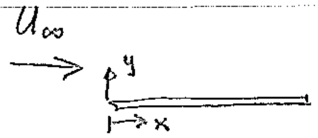
$(2) \Rightarrow f = 0{,}0358$, $(1) \Rightarrow V_2 = 0{,}673 \Rightarrow Re = 5381$

etc $\Rightarrow V_2 = 0{,}66\ m/s$ $Re = \frac{Vd}{\nu} = 5285 > Re_{kr}$

$$Q = V_2\frac{\pi d^2}{4} = 3{,}32\cdot10^{-5}\ m^3/s$$

Svar: $Q = 2{,}0$ liter/min

(Det går lika bra att använda Moody-diagramme
ε/d är litet $\Rightarrow$ $\approx$ slätt rör.)



GIVET: $x = 1\,m$, $\tau_{w1} = 8{,}2\cdot10^{-3}\,Pa$
$y = 1\,mm$, $U_{\infty 2} = 45\ m/s$

Luft av normaltillstånd $\Rightarrow \begin{cases}\rho = 1{,}189\ kg/m^3 \\ \nu = 15{,}2\cdot10^{-6}\ m^2/s\end{cases}$

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) $\Rightarrow$ $c_{f,lam} = \frac{0{,}664}{\sqrt{Re_x}}$ $\Rightarrow$

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

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

$\Rightarrow Re_{x,lam} = \frac{U_{\infty,lam}\cdot x}{\nu} = 2{,}01\cdot10^5$ $\therefore$ OK.

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

$\Rightarrow U_{\infty,turb} = \left(\tau_{w,1}\cdot\frac{2}{\rho}\cdot\frac{1}{0{,}027}\left(\frac{x}{\nu}\right)^{1/7}\right)^{7/13} = 1{,}635\,m/s$

$\Rightarrow Re_{x,turb} = \frac{U_{\infty,turb}\cdot x}{\nu} = 1{,}08\cdot10^5$ ej OK

$\therefore$ Laminärt gränsskikt $\Rightarrow$

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

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

c) $U_{\infty 2} = 45\,m/s \Rightarrow Re_{x,2} = \frac{U_{\infty 2}\cdot x}{\nu} = 3{,}0\cdot10^6$ $\therefore$ turbulent.

(7.43) $\Rightarrow \tau_{w,2} = \frac{1}{2}\rho U_{\infty,2}^2\cdot 0{,}027\left(\frac{\nu}{U_{\infty,2}\cdot x}\right)^{1/7} \approx$
$\approx 3{,}87\ Pa$

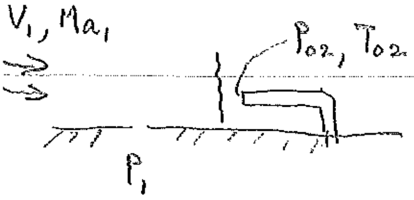
d) (7.34) $\Rightarrow$ $u^* = \sqrt{\frac{\tau_{w,2}}{\rho}} = 1{,}0836\,m/s$

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

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

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

koll: $\frac{u^* y}{\nu} = \frac{1{,}0836\cdot 0{,}001}{15{,}2\cdot10^{-6}} = 71$



Givet: $p_1 = 35$ kPa

$T_{02} = 340^\circ C = 613$ K

$p_{02} = 260$ kPa

Sökt: Ma_1, V_1

Gissa $Ma_1 = 2{,}0$ Tabell B1 $\Rightarrow \dfrac{p_1}{p_{01}} = 0{,}1278$

$\Rightarrow p_{01} = 273\,865$ Pa

$Ma_1 = 2{,}0$, Tabell B2 $\Rightarrow \dfrac{p_{02}}{p_{01}} = 0{,}7209 \Rightarrow p_{02} = 197\,430$ Pa

För lågt.

Gissa $Ma_1 = 2{,}3$ B1 $\Rightarrow \dfrac{p_1}{p_{01}} = 0{,}08 \Rightarrow p_{01} = 437\,500$

$Ma_1 = 2{,}3$ B2 $\Rightarrow \dfrac{p_{02}}{p_{01}} = 0{,}5833 \Rightarrow$

$\Rightarrow p_{02} = 255\,193 \approx 260$ kPa, OK

(noggrannare iterering $\Rightarrow Ma_1 = 2{,}29$)

$Ma_1 = 2{,}3$ B1 $\Rightarrow \dfrac{T_1}{T_{01}} = 0{,}4859 \Rightarrow$

$T_{01} = T_{02}$ (adiabatiskt)

$\therefore T_1 = 0{,}4859 \cdot 613 = 298$ K

$V_1 = Ma_1 a_1 = 2{,}3\sqrt{\kappa R T_1} =$

$= 2{,}3\sqrt{1{,}4 \cdot 287 \cdot 298} = 796$ m/s

Svar: $Ma_1 = 2{,}3$ $V_1 = 796$ m/s