ZADACI ZA OVERU PRISUSTVA NA VEŽBAMA

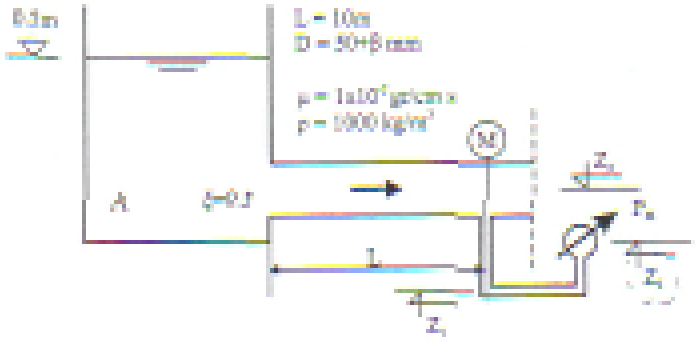
(Napomena: slike kotirati u metrima, a ne u opštim brojevima)

ZADATAK 7.1

Kroz instalaciju na slici teče voda od rezervoara A ka preseku M u cevi. Utvrđeno je da je Rejnoldsov broj Re = 50 000÷400*n. Ukoliko su prečnik cevovoda D = 50 + β mm i dužina cevovoda L=10 m, izračunati:

a) Brzinu vode i protok kroz instalaciju,
b) Koeficijent linijskog gubitka (λ) pod pretpostavkom da je tečenje turbulentno u hidraulički glatkoj cevi,
c) Linijski gubitak (ΔE_{lin}) duž cevi
d) Pritisak na manometru P_M.

Z_1 = -2.5m, Z_2 = -2.25m, Z_3 = -2.0m



ZADATAK 7.2

Za instalaciju iz zadatka 7.1 odrediti pri kom nivou u rezervoaru A će se uspostaviti laminarno tečenje (za Re = 2000) *ako se pritisak na mestu manometra, P_M, ne menja* (u odnosu na zadatak 7.1).

Skicirati u odgovarajućoj razmeri energetsku i piezometarsku liniju za zadatke 7.1 i 7.2.

ZADATAK 7.3

Za instalaciju iz zadatka 7.1 odrediti prečnik pri kom se uspostavlja laminarno tečenje (za Re = 2000). Nivo u rezervoaru A je na 0.5m i pritisak na manometru, P_M, je isti kao u zadatku 7.1.

Poredeći rezultate zadataka 7.1, 7.2 i 7.3 dati komentare:

- Pri kom režimu tečenja (laminarnom ili turbulentnom) je veća brzina u cevi?
- Da li su se pri prelasku sa turbulentnog na laminarno tečenje gubici energije povećali ili smanjili (uporediti rezultate 7.1 i 7.2)?

ZADACI KOJI SE OCENJUJU NA NAREDNOM ČASU

ZADATAK 7.4

U horizontalnoj položenoj kružnoj cevi ($D=\frac{\alpha+\beta}{4}$ mm) raspored brzina je dat izrazom:

$$v_r = v_{max}\left(1-\frac{4r^2}{D^2}\right)$$

gde je v_{max} = (α/10+2) m/s brzina u osovini cevi izmerena pomoću Pitot-ove cevi. Tečenje je ustaljeno i laminarno.

a) Odrediti h – nadvišenje u Pitot-ovoj cevi.
b) Izračunati protok kroz cev i srednju brzinu u cevi. Odrediti Re broj i proveriti pretpostavku o laminarnom tečenju.
c) Izračunati koeficijent trenja λ.
d) Izračunati čitanje na manometru (p_M).

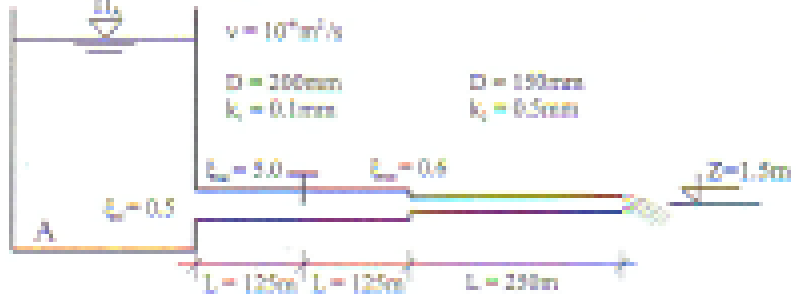
ZADATAK 7.5

Iz rezervoara A teče voda cevovodom promenljivog prečnika kao što je prikazano na slici. Dato je da je Π_A=2+β/5 m, Z_{kl} = 1.5 m, gubitak na ulazu ξ_{ul}=0.5, na zavrtanju ξ_{zav}=5.0 i na suženju $\xi_{suž}$=0.6.

- Izračunati protok kroz cev Q, pretpostavljajući turbulentno tečenje u hidraulički hrapavoj cevi.
- Proveriti režim tečenja i korigovati koeficijent linijskog gubitka ukoliko se pokaže da režim tečenja nije turbulentan u hidraulički hrapavoj cevi.
- Ako je korigovan koeficijent linijskog gubitka, sračunati ponovo protok kroz cev, Q.
- Proveriti režim za novo-sračunatim protokom; po potrebi korigovati koeficijent linijskog gubitka. Proračun nastaviti dok se veličina protoka u dve sukcesivne iteracije ne razlikuje za više od 1%.

Za izračunavanje koeficijenta linijskog gubitka λ koristiti formulu $\lambda = 0.115\left(\frac{k}{D}+\frac{60}{Re}\right)^{0.3}$.

Nacrtati energetsku i pijezometarsku liniju u odgovarajućoj razmeri.
(*preporuka za razmeru: R_V = 1:50, R_H = 1:2500*).



Zadatak 7.1

$Re = 52400$

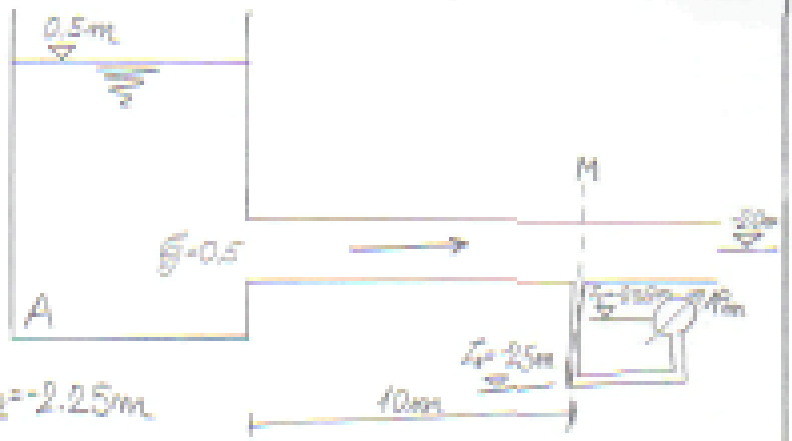
$D = 83.3\,mm$

$L = 10\,m$

$\nu = 1 \times 10^{-6}\,\frac{m^2}{s}$

$\mu = 10^{-3}\,\frac{kg}{ms}$

$\rho = 1000\,\frac{kg}{m^3}$



$Z_2 = -2.25\,m$

a) $Re = \frac{\rho D V}{\mu}$

$V = \frac{\mu Re}{D\rho} = \frac{10^{-3} \cdot 52400}{0.0833 \cdot 1000} = 0.629\,\frac{m}{s}$

$A = \frac{D^2 \pi}{4} = \frac{0.0833^2 \pi}{4} = 0.00545\,m^2$

$Q = A \cdot V = 0.629 \cdot 0.00545 = 0.003428\,\frac{m^3}{s} = 3.43\,\frac{l}{s}$

b) $\lambda = ?$

$\lambda = 0.115 \left(\frac{k}{D} + \frac{60}{Re}\right)^{\frac{1}{4}} = 0.115 \cdot \left(\frac{60}{52400}\right)^{\frac{1}{4}} = 0.021$

c) $\Delta E_{M} = \lambda \frac{L V^2}{2 D g} = 0.021 \cdot \frac{10 \cdot 0.629^2}{2 \cdot 0.0833 \cdot 9.81} = 0.051\,m$

d) $E_A = E_M + \Delta E_{A-M}$

$E_A = \Pi_A = 0.5\,m$

$\Delta E_{A-M} = \xi_{ok} \cdot \frac{V^2}{2g} + \Delta E_M = 0.5 \cdot \frac{0.629^2}{2 \cdot 9.81} + 0.051 = 0.061\,m$

$E_M = E_A - \Delta E_{A-M} = 0.5 - 0.061 = 0.439\,m$

$E_M = \Pi_M + \frac{V^2}{2g}$

$\Pi_M = E_M - \frac{V^2}{2g} = 0.439 - \frac{0.629^2}{2 \cdot 9.81} = 0.419\,m$

$\frac{p_M}{\rho g} + Z_2 = \Pi_M \qquad p_M = (\Pi_M - Z_M)\rho g$

$p_M = (0.419 + 2.25) \cdot 1000 \cdot 9.81 = 26.183\,kPa$

Задатак 7.2

$Re = 2000$

$P_M = 26.183\,kPa$

$\Pi_M = 0.419\,m$

$Re = \frac{\rho D V}{\mu}$, $V = \frac{Re\,\mu}{\rho D}$

$V = \frac{2000 \cdot 0.001}{0.0833 \cdot 1000} = 0.024\,\frac{m}{s}$

$\lambda = \frac{64}{Re} = \frac{64}{2000} = 0.032$

$E_A = E_M + \Delta E_{A-M}$

$E_A = \Pi_A$

$E_M = \Pi_M + \frac{V^2}{2g} = 0.419 + \frac{0.024^2}{2 \cdot 9.81} = 0.4191\,m$

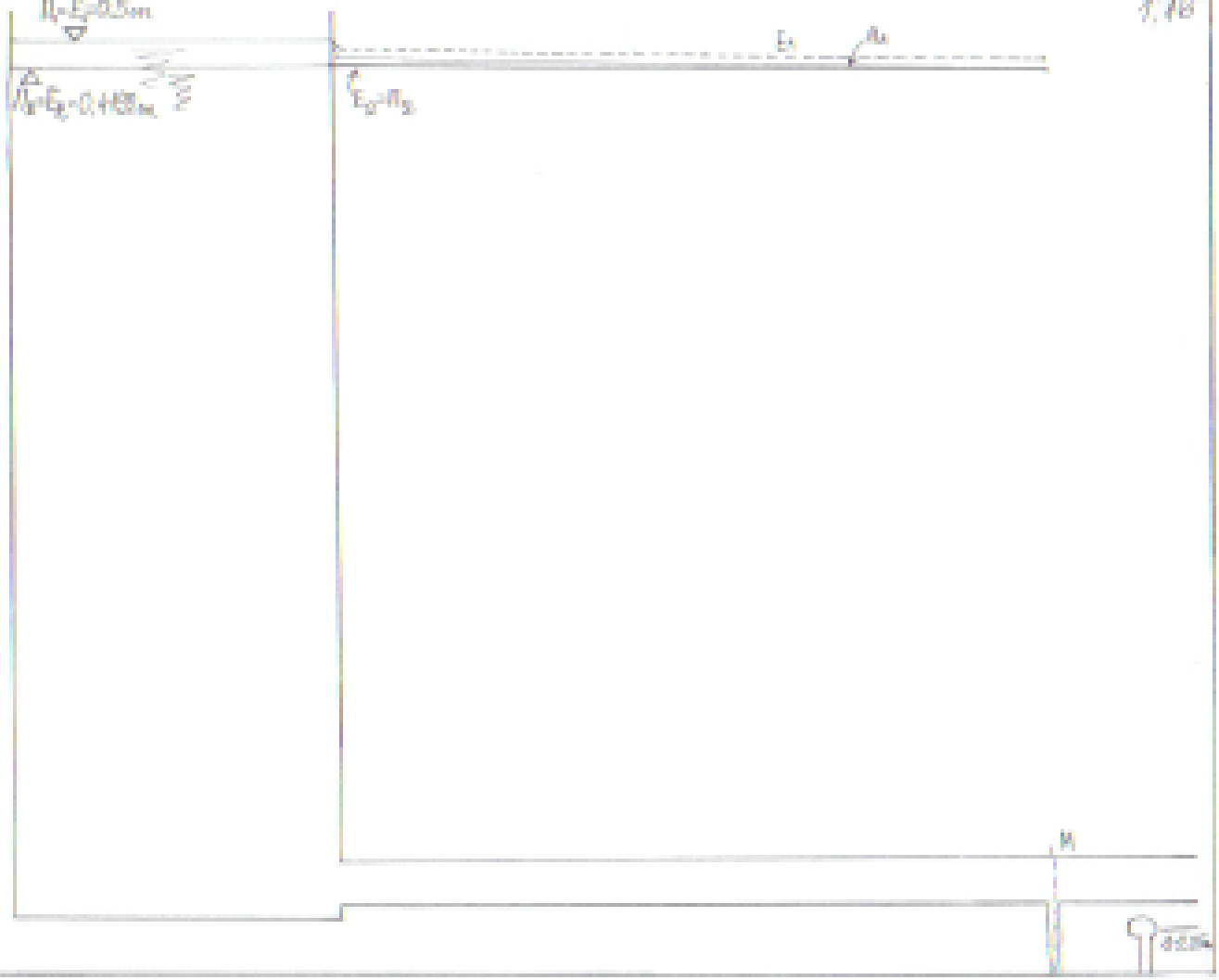
$\Delta E_{A-M} = \xi \frac{V^2}{2g} + \lambda \frac{L V^2}{2Dg} = 0.5 \cdot \frac{0.024^2}{2 \cdot 9.81} + 0.032 \cdot \frac{10 \cdot 0.024^2}{2 \cdot 0.0833 \cdot 9.81} =$

$= 0.00001678 + 0.00011279 = 0.0001\,m$

$\Pi_A = E_M + \Delta E_{A-M} = 0.4191 + 0.0001\,m = 0.4192\,m$

$\frac{V_1^2}{2g} = 0.02\,m$

$\frac{V_2^2}{2g} = 0.000029\,m \approx 0\,m$



Задатак 7.3

$Re = 2000$

$\Pi_A = 0.5m$

$P_M = 26.183 kPa$

$\Pi_M = 0.419m$

$\lambda = \frac{64}{Re} = \frac{64}{2000} = 0.032$

$Re = \frac{\rho D V}{\mu}$

$DV = \frac{Re\,\mu}{\rho} = \frac{2000 \cdot 0.001}{1000} = 0.002$

$E_A = E_M + \Delta E_{A-M}$

$E_A = 0.5m$

$E_M = 0.419 + \frac{V^2}{2g} = 0.419 + 0.051 V^2$

$\Delta E_{A-M} = \zeta \frac{V^2}{2g} + \lambda \frac{L V^2}{2Dg} = 0.0255 V^2 + 0.0163 \frac{V^2}{D}$

$0.5 = 0.419 + 0.051 V^2 + 0.0255 V^2 + 0.0163 \frac{V^2}{D}$

$0.081 = 0.0765 V^2 + 0.0163 \frac{V^2}{D}$

$D = \frac{0.002}{V}$

$0.081 = 0.0765 V^2 + 0.0163 \frac{V^2}{\frac{0.002}{V}}$

$0.081 = 0.0765 V^2 + 8.15 V^3$

$8.15 V^3 + 0.0765 V^2 - 0.081 = 0$

$V_1 = 0.1 \frac{m}{s}$

$0.00815 + 0.000765 - 0.081 = -0.072085$

$V_2 = 0.25 \frac{m}{s}$

$0.1953125 + 0.0019125 - 0.081 = 0.056125$

$V_3 = 0.2 \frac{m}{s}$

$0.0652 + 0.00306 - 0.081 = -0.01274$

$V_4 = 0.225 \frac{m}{s}$

$0.092833593 + 0.003872812 - 0.081 = 0.015706405$

$V_5 = 0.2125 \frac{m}{s}$

$0.078201988 + 0.003451453 - 0.081 = 0.00066$

$V_6 = 0.21$

$0.075417715 + 0.003373665 - 0.081 = -0.002208592$

$V_7 = 0.2117 \frac{m}{s}$

$0.077325045 + 0.003428492 - 0.081 = -0.000246436$

$V_u = 0.212 \frac{m}{s}$

$(8.15V^3 + 0.0765V^2 - 0.081) : (V - 0.212) = 8.15V^2 + 1.8043V + 0.3825$

$8.15V^3 - 1.7278V^2$

$1.8043V^2$

$1.8043V^2 - 0.3825V$

$0.3825V - 0.081$

$0.3825V - 0.08109$

0

$8.15V^2 + 1.8043V + 0.3825 = 0$

$V_{kritz} = \frac{-1.8043 \pm \sqrt{3.255193849 - 12.4995}}{16.3} \notin R$

$V = 0.212 \frac{m}{s}$

$D = \frac{0.002}{0.212} = 0.00943\,m = 9.43\,mm$

- Турбулентно
- Смавнили

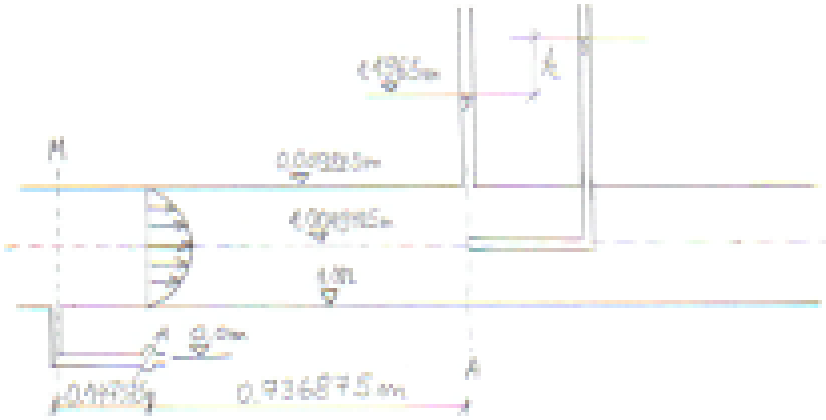
Zadatak 7.4

$D = 9.825\,mm = 0.009825\,m$

$u_{max} = 2.6\,\frac{m}{s}$ ✓

$u_r = u_{max}\left(1 - \frac{4r^2}{D^2}\right) = 2.6\left(1 - \frac{4r^2}{0.009825^2}\right) = 2.6(1 - 41437.63r^2)$

$= 2.6 - 107737.83r^2$



$L_1 = 0.147375\,m \approx 0.147\,m$

$L_2 = 0.736875\,m \approx 0.737\,m$

$\mu = 0.001\,\frac{kg}{ms}$

$\rho = 800\,\frac{kg}{m^3}$

a) $h = \frac{u_{max}^2}{2g} = \frac{2.6^2}{2 \cdot 9.81} = 0.345\,m$

b) $Q = \int_A u\,dA = \int_0^{R} u(r)\,2r\pi\,dr = \int_0^{0.0049125} (2.6 - 107737.83r^2)\,2 \cdot r \cdot \pi \cdot dr =$

$= 2\pi \int_0^{0.0049125} (2.6 - 107737.83r^2)\,r\,dr = 16.336 \int_0^{0.0049125} r\,dr - 676936.75 \int_0^{0.0049125} r^3\,dr =$

$= 16.336 \frac{r^2}{2}\Big|_0^{0.0049125} - 676936.75 \frac{r^4}{4}\Big|_0^{0.0049125} =$

$= 0.000197115 - 0.000098559 = 0.000098555\,\frac{m^3}{s} = 0.098\,\frac{l}{s}$

$A = \frac{D^2 \pi}{4} = \frac{0.009825^2 \pi}{4} = 0.000075814 m^2$

$V = \frac{Q}{A} = \frac{0.000098555}{0.000075814} = 1.2999 \frac{m}{s} \approx 1.3 \frac{m}{s}$

$Re = \frac{\rho D V}{\mu} = \frac{800 \cdot 0.009825 \cdot 1.3}{0.001} = 10218$ није ламинарно

c) $\lambda = 0.115 \left(\frac{60}{Re}\right)^{\frac{1}{4}} = 0.115 \cdot \left(\frac{60}{10218}\right)^{0.25} = 0.032$

d) $E_M = E_A + \Delta E_{M-A}$

$E_A = \Pi_A + \frac{V^2}{2g} = 1.1965 + \frac{1.3^2}{2 \cdot 9.81} = 1.283 m$

$\Pi_A = 1.1965 m$

$\Delta E_{~~M~~-A} = \lambda \frac{L}{D} \frac{V^2}{2g}$

$L = 90 \cdot 0.009825 = 0.88425 m$

$\Delta E_{M-A} = 0.032 \cdot \frac{0.88425 \cdot 1.3^2}{2 \cdot 0.009825 \cdot 9.81} = 0.248 m$

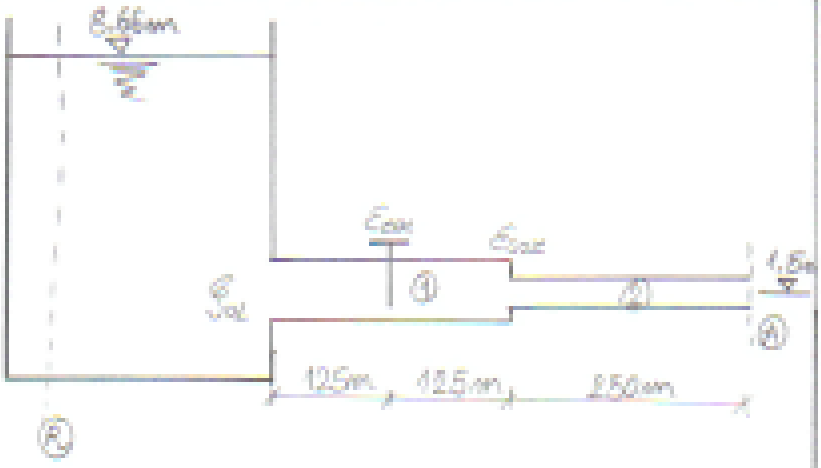
$E_M = 1.283 + 0.248 = 1.531 m$

$\Pi_M = E_M - \frac{V^2}{2g} = 1.531 - \frac{1.3^2}{2 \cdot 9.81} = 1.445 m$

$\frac{p_M}{\rho g} + Z_M = \Pi_M$, $Z_M = 0$

$p_M = \Pi_M \rho g = 1.445 \cdot 800 \cdot 9.81 = 11339.3 Pa \approx 11.34 kPa$

Задатак 7.5



$\Pi_A = 8.66m$

$z_{1c} = 1.5m$

$\zeta_{ex} = 0.5$

$\zeta_{con} = 5$

$\zeta_{con} = 0.6$

$L_1 = 250m$

$L_2 = 250m$

$D_1 = 200mm = 0.2m$

$K_1 = 0.1mm = 0.0001m$

$D_2 = 150mm = 0.150m$

$K_2 = 0.5mm = 0.0005m$

$\nu = 10^{-6} \frac{m^2}{s}$

а) ТУРБУЛЕНТНО ТЕЧЕЊЕ У ХИДРАУЛИЧКИ ХРАПАВОЈ ЦЕВИ

$\Rightarrow \lambda = \lambda\left(\frac{k}{D}\right)$

$\lambda_1 = 0.115\left(\frac{K_1}{D_1} + \frac{60}{Re}\right)^{0.25} = 0.115\left(\frac{K_1}{D_1}\right)^{\frac{1}{4}} = 0.115\left(\frac{0.0001}{0.2}\right)^{\frac{1}{4}} = 0.017$

$\lambda_2 = 0.115\left(\frac{K_2}{D_2}\right)^{\frac{1}{4}} = 0.115 \cdot \left(\frac{0.0005}{0.155}\right)^{\frac{1}{4}} = 0.028$

$E_R = E_A + \Delta E_{R-A}$

$E_R = \Pi_R = 8.66m$

$E_A = \Pi_A + \frac{V_2^2}{2g} = 1.5 + 0.051 V_2^2$

$\Pi_A = z_{1c} = 1.5m$

$\Delta E_{R-A} = \zeta_{ex}\frac{V_1^2}{2g} + \lambda_1\frac{L_1 V_1^2}{2D_1 g} + \zeta_{con}\frac{V_1^2}{2g} + \zeta_{con}\frac{V_2^2}{2g} + \lambda_2\frac{L_2 V_2^2}{2D_2 g} =$

$= 0.025 V_1^2 + 1.083 V_1^2 + 0.254 V_1^2 + 0.030 V_2^2 + 2.3785 V_2^2 =$

$= 1.363 V_1^2 + 2.4091 V_2^2$

$Q: A_1V_1 = A_2V_2$

$A_1 = \frac{D_1^2\pi}{4} = \frac{0.2^2\pi}{4} = 0.0314\,m^2$

$A_2 = \frac{D_2^2\pi}{4} = \frac{0.15^2\pi}{4} = 0.0177\,m^2$

$V_1 = \frac{A_2}{A_1}V_2 = \frac{0.0177}{0.0314}V_2 = 0.5637V_2$

$8.66 = 1.5 + 0.051V_2^2 + 1.3634V_1^2 + 2.4091V_2^2$

$8.66 = 1.5 + 0.051V_2^2 + 1.3634(0.5637V_2)^2 + 2.4091V_2^2$

$7.16 = 2.8933V_2^2$

$V_2^2 = 2.4746$

$V_2 = 1.573\,\frac{m}{s}$

$V_1 = 0.5637 \cdot 1.573 = 0.887\,\frac{m}{s}$

$Q = A_1V_1 = 0.0314 \cdot 0.887 = 0.02784\,\frac{m^3}{s} = 27.84\,\frac{l}{s}$

б) $Re_1 = \frac{V_1D_1}{\vartheta} = \frac{0.887 \cdot 0.2}{10^{-6}} = 177400$

$Re_2 = \frac{V_2D_2}{\vartheta} = \frac{1.573 \cdot 0.15}{10^{-6}} = 235950$

$\lambda_1' = 0.115\left(\frac{K_1}{D_1} + \frac{60}{Re_1}\right)^{\frac{1}{3}} = 0.115\left(\frac{0.0004}{0.2} + \frac{60}{177400}\right)^{\frac{1}{3}} = 0.115(0.0005 + 0.00034)^{\frac{1}{3}} =$

$= 0.0136 > \lambda_1 (0.017)$

$\lambda_1' = 0.0136$

$\lambda_2' = 0.115\left(\frac{K_2}{D_2} + \frac{60}{Re_2}\right)^{\frac{1}{3}} = 0.115\left(\frac{0.0005}{0.15} + \frac{60}{235950}\right)^{\frac{1}{3}} = 0.115(0.00333 + 0.000254)^{\frac{1}{3}} =$

$= 0.0281 \approx \lambda_2 \approx 0.028$

$\lambda_2' = 0.0281$

$\Delta E_{2-4} = \xi_{вх}\frac{V_2^2}{2g} + \lambda_2'\frac{l_2}{2D_2}\frac{V_2^2}{2g} + \xi_{пов}\frac{V_1^2}{2g} + \xi_{вых}\frac{V_2^2}{2g} + \lambda_2\frac{l_4}{2D_4}\frac{V_2^2}{2g}$

$$\Delta E'_{k-A} = 0.0255 V_1'^2 + 1.2467 V_1'^2 + 0.9548 V_1'^2 + 0.0306 V_2'^2 + 2.387 V_2'^2 =$$

$$= 1.529 V_1'^2 + 2.4176 V_2'^2$$

$$V_1' = 0.5637 V_2'$$

$$E_{kl} = E_{A} + E'_{k-A}$$

$$8.66 = 1.5 + 0.051 V_2'^2 + 1.529 V_1'^2 + 2.4176 V_2'^2$$

$$7.16 = 2.95445 V_2'^2$$

$$V_2'^2 = 2.423$$

$$V_2' = 1.557 \frac{m}{s}$$

$$V_1' = 0.5637 \cdot 1.557 = 0.878 \frac{m}{s}$$

$$Q' = A_1 V_1 = 0.0314 \cdot 0.878 = 0.02755 \frac{m^3}{s} = 27.55 \frac{l}{s}$$

$$\frac{Q - Q'}{Q} = \frac{0.02784 - 0.02755}{0.02784} = 0.0104 = 1.04\%$$

$$\frac{Q - Q'}{Q'} = 1.05\%$$

$$Re_1' = \frac{V_1' D_1}{\nu} = \frac{0.878 \cdot 0.2}{10^{-6}} = 175600$$

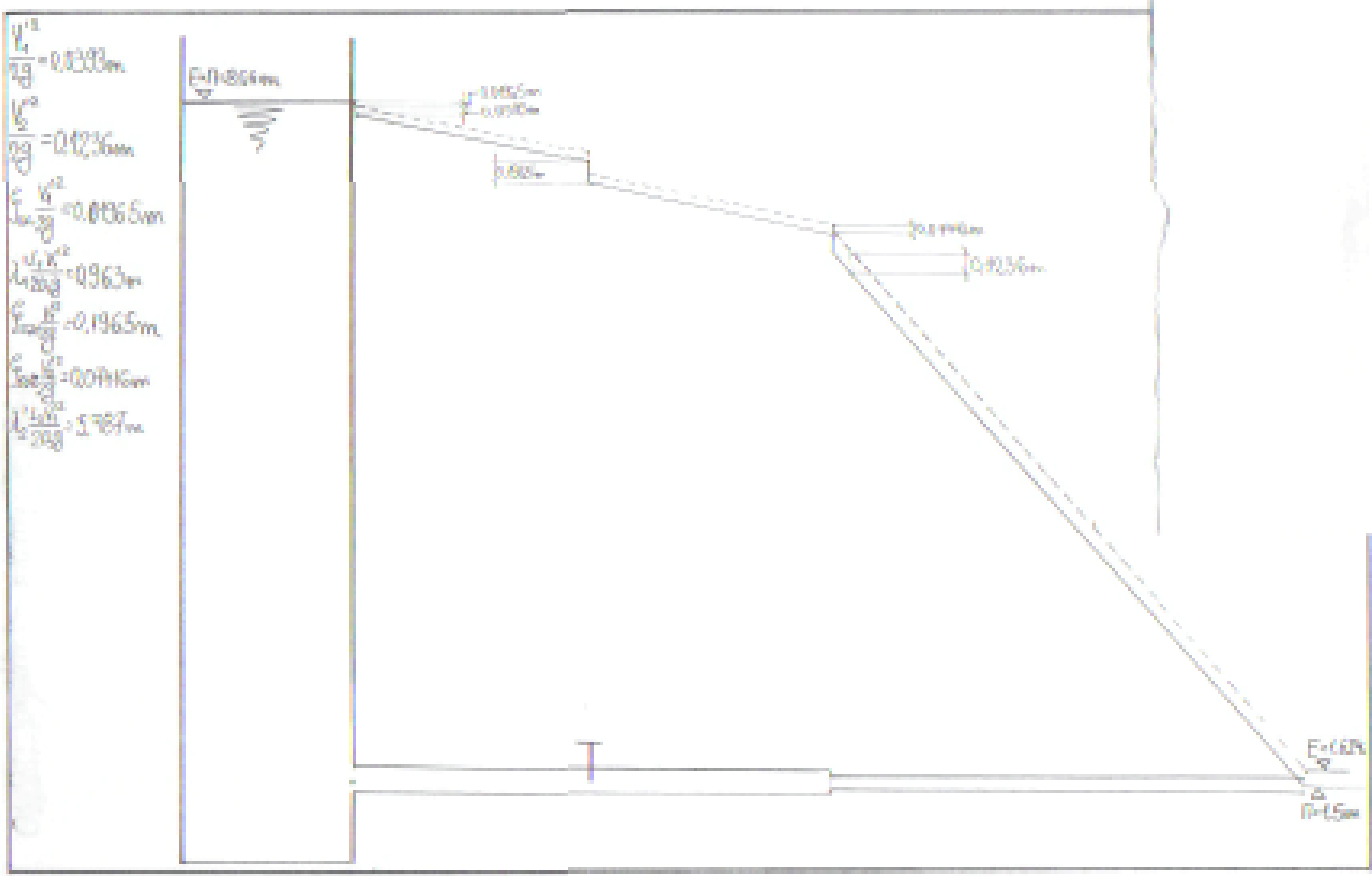
$$Re_2' = \frac{V_2' D_2}{\nu} = \frac{1.557 \cdot 0.15}{10^{-6}} = 233550$$

$$\lambda_1'' = 0.115 \left(\frac{0.0001}{0.2} + \frac{60}{175600} \right)^{\frac{1}{4}} = 0.115 (0.0005 + 0.000342)^{\frac{1}{4}} = 0.01958 = 0.0196$$

$$\lambda_2'' = 0.115 \left(\frac{0.0005}{0.15} + \frac{60}{233550} \right)^{\frac{1}{4}} = 0.115 (0.0033 + 0.000257)^{\frac{1}{4}} = 0.02608 = 0.0261$$

$$\lambda_1' = \lambda_1''$$

$$\lambda_2' = \lambda_2''$$


E=0.1856m
E=1.68m
D=1.5m

ZADACI ZA OVERU PRISUSTVA NA VEŽBAMA

(Napomena: slike kostruisati u razmeri, a ne u opštim brojevima)

ZADATAK 8.1

Posmatra se otpor trenja na ravnu ploču dužine L=18 m velike širine (problem je ravanski), koja je postavljena paralelno sa fluidnom strujom.

a) Oko ploče, brzinom U = (α+β)/25 m/s, struji vazduh gustine ρ_{vaz}= 1.2 kg/m^3 i dinamičke viskoznosti $\mu = 1.78\times10^{-4}$ gr/cm/s.
   - Pokazati da je granični sloj celom dužinom laminaran.
   - Odrediti silu trenja F koja deluje po 1 metru širine ploče.
   - Odrediti tangencijalni napon τ i debljinu graničnog sloja δ u tačkama A, B i C.
   - Skicirati dijagram promene tangencijalnog napona i debljine graničnog sloja duž ploče.

b) Oko ploče, brzinom U =(α+β)/2 m/s, struji voda gustine ρ_{voda}= 1.0 kg/dm^3 i dinamičke viskoznosti $\mu = 1\times10^{-2}$ gr/cm/s.
   - Pokazati da je granični sloj turbulentan na više od 90% dužine ploče.
   - Odrediti silu trenja F koja deluje po 1 metru širine ploče.
   - Odrediti tangencijalni napon τ i debljinu graničnog sloja δ u tačkama A, B i C.

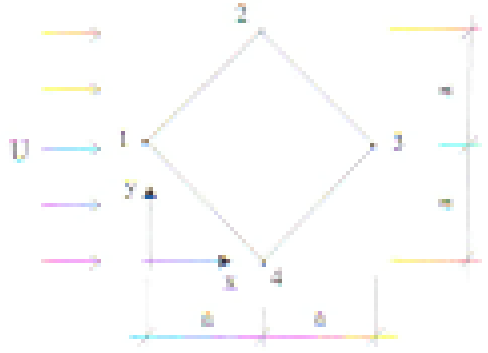
ZADATAK 8.2

Na modelu se ispituje uticaj vetra na stub [redacted] poprečnog preseka čije su dimenzije date na skici (a=(α+β)cm, a visina stuba je 1.2m). Brzina ravnomerne vazdušne struje je U = (α+β)/5 m/s (gustina vazduha je ρ = 1.2 kg/m^3). U označenim tačkama su izmereni pritisci, a dobijeni koeficijenti pritiska Cp su dati u tabeli.

a) Sračunati pritisko u označenim tačkama.

b) Sračunati silu otpora oblika u pravcima X i Y, kao i odgovarajuće koeficijente sile otpora (kao merodavna površina poprečnog preseka se uzima maksimalna površina poprečnog preseka stuba, normalnog na pravac strujanja).

c) Koristeći koeficijente sile izračunate pod b), sračunati ukupnu silu otpora koja će delovati na stub u prirodi koji je 5 puta veći od modela, a koji se nalazi u vodi brzine U_v = (α/3) m/s (gustina vode je ρ = 1.0 kg/dm^3).



a = α + β [cm]

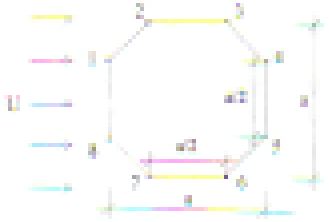
tačka	1	2	3	4
Cp	1.0	0.1	-0.6	0.1

ZADACI KOJI SE OCENJUJU NA NAREDNOM ČASU

ZADATAK 8.3

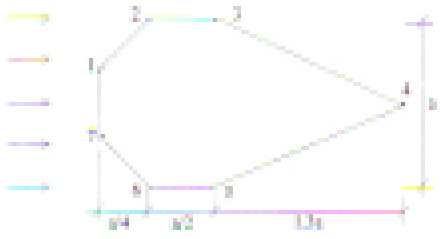
Razmatraju se dva poprečna preseka mostovskih stubova. Biće usvojena povoljnija varijanta, tj. onaj oblik koji daje manju silu otpora toku. Jedna varijanta je stub romboidnog, dok je druga varijanta stub složenog preseka. Koeficijenti pritiska su dati u odgovarajućim tabelama. Pokazati koja je varijanta bolja (daje manji otpor) pri laboratorijskim merenjima sa vazduhom (ρ_{vaz}=1.2 kg/m^3) brzine U=20 m/s.

Za potrebe projektovanja realnog mostovskog stubu izračunati silu na stub sa povoljnijim oblikom. Na osnovu sračunate sile na modelu, odrediti koeficijent sile C_x, i C_y. Primenit koeficijent sile za računanja vaših sile na objektu ako su laboratorijski modeli rađeni u razmeri 1:50 i ukoliko se vodu kreće brzinom U=1.2 m/s.



tačka	1/8	2/7	3/6	4/5
C_p	0.8	0.5	-0.2	-0.9

$$\delta = \frac{\alpha + \beta}{20}$$



tačka	1	2	3	4	5	6	7
C_p	-0.9	0.5	-0.1	-0.5	-0.1	0.5	0.8

Задатак 8.1

$L = 10m$

a) $U = 1.572 \frac{m}{s}$

$\rho_{ваз} = 1.2 \frac{kg}{m^3}$

$\mu = 1.78 \cdot 10^{-5} \frac{kgr}{0ms} = 0.0000178 \frac{kg}{m \cdot s}$

$Re(x) = \frac{\rho U x}{\mu} = \frac{1.2 \cdot 1.572 \cdot x}{0.0000178} = 105977.53x$

- $Re(L) = Re(10) = 105977.53 \cdot 10 = 1059775.3 < 1.5 \cdot 10^6 < Re_{крит} \Rightarrow$ слој струјом дуњином ламинарни

$\delta(x) = 4.9 \frac{x}{\sqrt{Re(x)}} = \frac{4.9x}{\sqrt{105977.53x}} = 0.015052\sqrt{x}$

$C_x(x) = \frac{0.7}{\sqrt{Re(x)}} = \frac{0.7}{\sqrt{105977.53x}} = \frac{0.00215}{\sqrt{x}}$

- $C_f = \frac{1.4}{\sqrt{Re(L)}} = \frac{1.4}{\sqrt{1059775.3 \cdot 10}} = 0.00136$

$F = C_f \cdot \frac{1}{2} \rho U^2 A = 0.00136 \cdot \frac{1}{2} \cdot 1.2 \cdot 1.572^2 \cdot 2 \cdot 1 \cdot 10 = 0.0403N$

- Тачка A

$x = 0$

$\delta(0) = 0.015052\sqrt{0} = 0$

$C_x(0) = \frac{0.00215}{\sqrt{0}} = +\infty$

$\tau(0) = C_x \frac{1}{2} \rho U^2 = +\infty$

Тачка B

$x = 5$

$\delta(5) = 0.015052\sqrt{5} = 0.03366m = 3.37cm$

$C_x(5) = \frac{0.00215}{\sqrt{5}} = 0.000962$

$\tau(5) = 0.000962 \cdot \frac{1}{2} \cdot 1.2 \cdot 1.572^2 = 0.0043 Pa$

Точка C

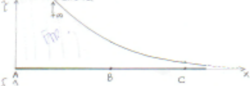
$x = 9$

$\delta(9) = 0.015052\sqrt{9} = 0.0452\,m \approx 4.52\,cm$

$C_f(9) = \frac{0.00215}{\sqrt{9}} = 0.000239$

$\tau(9) = 0.000239 \cdot \frac{1}{2} \cdot 1.2 \cdot 1.572^2 = 0.00035\,Pa$

• Промена на слоја



b) $u = 19.65\,\frac{m}{s}$ $\quad k = 0.2\,mm = 0.0002\,m$

$\rho = 1000\,\frac{kg}{m^3}$

$\mu = 1 \cdot 10^{-2}\,\frac{g}{cms} = 0.001\,\frac{kg}{ms}$

$Re(x) = \frac{\rho u x}{\mu} = \frac{1000 \cdot 19.65\,x}{0.001} = 19650000\,x$

• $Re(0.1L) = Re(1) = 19650000 > 3 \cdot 10^6 > Re_{crit} \Rightarrow$ на видео од ge слојот турбулентен

• $C_f = 0.032\left(\frac{k}{L} + \frac{50}{Re(L)}\right)^{\frac{1}{5}} = 0.032\left(\frac{0.0002}{10} + \frac{50}{19650000 \cdot 10}\right)^{\frac{1}{5}} = 0.003685$

$F = C_f \frac{1}{2} \rho u^2 A = 0.003685 \cdot \frac{1}{2} \cdot 1000 \cdot 19.65^2 \cdot 2 \cdot 10 \cdot 1 = 14229.16\,N = 14.23\,kN$

$\delta(x) = 0.38\,\frac{x}{\sqrt[5]{19650000\,x}} = 0.0132167\sqrt{x}$

$C_f(x) = 0.026\left(\frac{0.0002}{x} + \frac{50}{19650000\,x}\right)^{\frac{1}{5}} = 0.0047455\left(\frac{1}{x}\right)^{\frac{1}{5}}$

Точка A

$x=0$

$\delta(0)=0$

$C_x(0)=+\infty$

$\tau(0)=+\infty$

Точка B

$x=5$

$\delta(5)=0.013216\sqrt{5}=0.02955\,m\approx 2.96\,см$

$C_x(5)=0.0047455\left(\frac{1}{5}\right)^{\frac{1}{3}}=0.00344$

$\tau(5)=0.00344\cdot\frac{1}{2}\cdot 1000\cdot 19.65^2=664.02\,Па$

Точка C

$x=9$

$\delta(9)=0.013216\sqrt{9}=0.039648\,m\approx 3.96\,см$

$C_x(9)=0.0047455\left(\frac{1}{9}\right)^{\frac{1}{3}}=0.003058$

$\tau(9)=0.003058\cdot\frac{1}{2}\cdot 1000\cdot 19.65^2=590.38\,Па$