

ОТВОРЕНИ ТОКОВИ - 03

$\alpha = 5$
 $\beta = 30$

Задатак 9.1 - отпори трења

$$\left. \begin{aligned} \rho_1 &= 1000 \text{ kg/m}^3 \\ \mu_1 &= 10^{-2} \text{ g/cm}^2 \end{aligned} \right\} \text{ вода}$$

$$\left. \begin{aligned} \rho_2 &= 1,2 \text{ kg/m}^3 \\ \mu_2 &= 2 \cdot 10^{-4} \text{ g/cm}^2 \end{aligned} \right\} \text{ ваздух}$$

$$u_1 = u_2 = u = 7 \frac{\text{m}}{\text{s}}$$



$$k = 0,5 \text{ mm}$$



а) режими?

б) сила трења

F по 1m

ширине плоче

в) силица τ, δ

$$Re_{crit} \in (1,5 \div 3) \cdot 10^6$$

$$Re(L) = \frac{\rho u L}{\mu}$$

$$L = 6 \text{ m}$$

а) 1) вода

$$Re_1(6\text{m}) = \frac{\rho_1 u L}{\mu_1} = \frac{1000 \text{ kg/m}^3 \cdot 7 \frac{\text{m}}{\text{s}} \cdot 6 \text{ m}}{10^{-2} \text{ g/cm}^2} = \frac{1 \text{ g/cm}^3 \cdot 7 \cdot 10^2 \frac{\text{cm}}{\text{s}} \cdot 600 \text{ cm}}{10^{-2} \text{ g/cm}^2}$$

$$\rightarrow Re_1 = 42000000 > Re_{crit}$$

$$\rightarrow Re_1(0,1 \cdot L) = 4200000 > Re_{crit}$$

\rightarrow усваја се да је слој
целим дужином
турбулентан

2) ваздух

$$Re_2(6\text{m}) = \frac{\rho_2 u L}{\mu_2} = \frac{1,2 \text{ kg/m}^3 \cdot 7 \frac{\text{m}}{\text{s}} \cdot 6 \text{ m}}{2 \cdot 10^{-4} \text{ g/cm}^2} = \frac{1,2 \cdot 10^{-3} \frac{\text{g}}{\text{cm}^3} \cdot 700 \frac{\text{cm}}{\text{s}} \cdot 600 \text{ cm}}{2 \cdot 10^{-4} \text{ g/cm}^2}$$

$$\rightarrow Re_2 = 2520000 \in Re_{crit} \rightarrow \text{целим дужином плоче слој је ламинаран}$$

б) $C_f(x) = 0,026 \cdot \left(\frac{k}{x} + \frac{50}{Re(x)} \right)^{1/5} \rightarrow$ турбулентан режим

$$C_{f1} = 0,026 \cdot \left(\frac{0,0005 \text{ m}}{6 \text{ m}} + \frac{50}{42000000} \right)^{1/5} \rightarrow C_{f1} = 3,981 \cdot 10^{-3}$$

$$C_{f2} = \frac{0,7}{\sqrt{Re_2}}$$

$$C_f(x) = \frac{0,7}{\sqrt{Re(x)}} \rightarrow \text{ламинаран режим}$$

$$C_{f2} = \frac{0,7}{\sqrt{2520000}} \rightarrow C_{f2} = 0,4 \cdot 10^{-3}$$

$$C_{F1}(L) = 0,032 \cdot \left(\frac{k}{L} + \frac{50}{Re(L)} \right)^{1/5}$$

$$C_{F1} = 0,032 \cdot \left(\frac{0,0005}{6} + \frac{50}{42 \cdot 10^6} \right)^{1/5} = 4,9 \cdot 10^{-3}$$

$$C_{F2}(L) = \frac{1,4}{\sqrt{Re_2(L)}}$$

$$C_{F2}(L) = \frac{1,4}{\sqrt{2,52 \cdot 10^6}} = 9,88 \cdot 10^{-3}$$

$$F = C_F \cdot \frac{1}{2} \rho u^2 A$$

$$F_1 = C_{F1} \cdot \frac{1}{2} \rho_1 u^2 \cdot 2BL$$

$$F_1 = 4,9 \cdot 10^{-3} \cdot \frac{1}{2} \cdot 1000 \frac{\text{kg}}{\text{m}^3} \cdot \left(7 \frac{\text{m}}{\text{s}} \right)^2 \cdot 2 \cdot 1 \text{m} \cdot 6 \text{m}$$

$$\Rightarrow \boxed{F_1 = 1,441 \text{ kN}}$$

$$F_2 = C_{F2} \cdot \frac{1}{2} \rho_2 u^2 \cdot 2BL$$

$$F_2 = 9,88 \cdot 10^{-3} \cdot \frac{1}{2} \cdot 1,2 \frac{\text{kg}}{\text{m}^3} \cdot \left(7 \frac{\text{m}}{\text{s}} \right)^2 \cdot 2 \cdot 1 \text{m} \cdot 6 \text{m}$$

$$\Rightarrow \boxed{F_2 = 0,310 \text{ N}}$$

b) Шангенујални напони на почетку, средини и крају плоче:

$$\tau(x) = c_T \cdot \frac{1}{2} \rho u^2$$

$$\tau_1 = c_{T1} \cdot \frac{1}{2} \rho_1 u^2 = 3,981 \cdot 10^{-3} \cdot \frac{1}{2} \cdot 1000 \frac{\text{kg}}{\text{m}^3} \cdot \left(7 \frac{\text{m}}{\text{s}} \right)^2$$

$$\boxed{\tau_1 = 97,534 \text{ Pa}}$$

$$\tau_2 = c_{T2} \cdot \frac{1}{2} \rho_2 u^2 = 0,4 \cdot 10^{-3} \cdot \frac{1}{2} \cdot 1,2 \frac{\text{kg}}{\text{m}^3} \cdot \left(7 \frac{\text{m}}{\text{s}} \right)^2$$

$$\boxed{\tau_2 = 0,012 \text{ Pa}}$$

$$\delta_1(0) = 0,38 \cdot \frac{0}{(Re(0))^{1/5}} = 0$$

$$\delta_1(3 \text{ m}) = 0,38 \cdot \frac{3 \text{ m}}{\left(\frac{\rho_1 u L}{\mu} \right)^{1/5}}$$

$$\Rightarrow \delta_1(3 \text{ m}) = 0,062$$

$$\delta_1(6 \text{ m}) = 0,38 \cdot \frac{6 \text{ m}}{Re_1^{1/5}} = 0,38 \cdot \frac{6 \text{ m}}{(42 \cdot 10^6)^{1/5}}$$

$$\Rightarrow \delta_1(6 \text{ m}) = 0,068$$

$$\delta_2(0) = 4,9 \cdot \frac{0}{\sqrt{Re_2(0)}} = 0$$

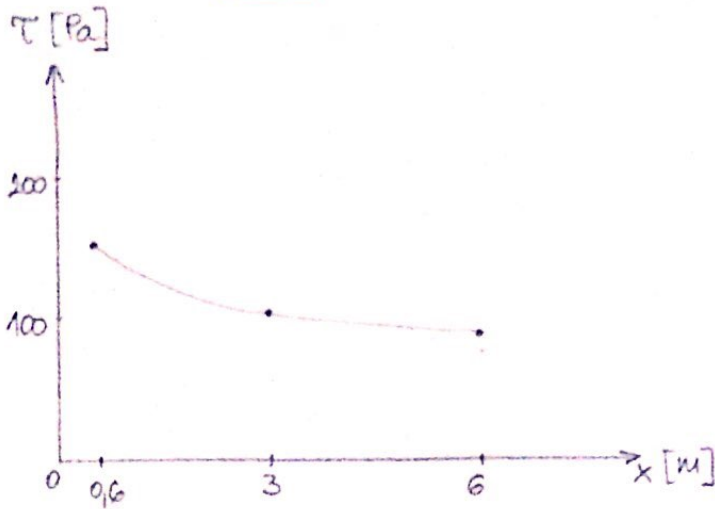
$$\delta_2(3 \text{ m}) = 4,9 \cdot \frac{3 \text{ m}}{\sqrt{\frac{\rho_2 u L}{\mu_2}}}$$

$$\Rightarrow \delta_2(3 \text{ m}) = 0,0041$$

$$\delta_2(6 \text{ m}) = 4,9 \cdot \frac{6 \text{ m}}{\sqrt{Re_2(6 \text{ m})}}$$

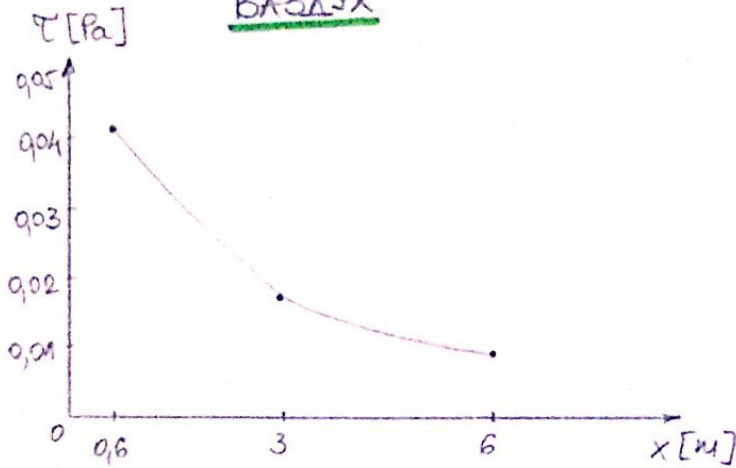
$$\Rightarrow \delta_2(6 \text{ m}) = 0,018$$

БОЛА

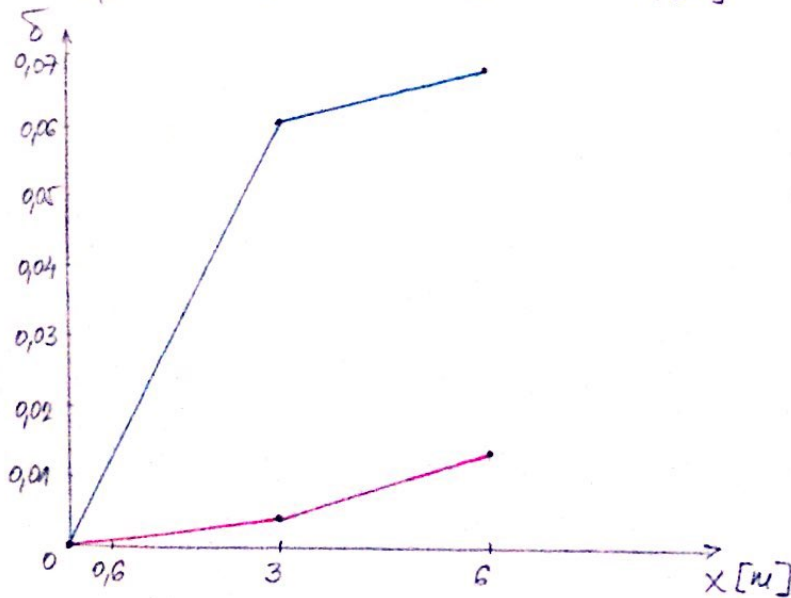


$\sigma_1(0,6) = 0,006$
 $\tau_1(0,6) = 147 \text{ Pa}$
 $\sigma_1(3) = 0,005$
 $\tau_1(3) = 122,5 \text{ Pa}$
 $\sigma_1(6) = 3,981 \cdot 10^{-3}$
 $\tau_1(6) = 97,534 \text{ Pa}$

БАЗЛУХ



$\sigma_2(0,6) = 0,0014$
 $\tau_2(0,6) = 0,041 \text{ Pa}$
 $\sigma_2(3) = 0,00062$
 $\tau_2(3) = 0,018 \text{ Pa}$
 $\sigma_2(6) = 0,00044$
 $\tau_2(6) = 0,012 \text{ Pa}$

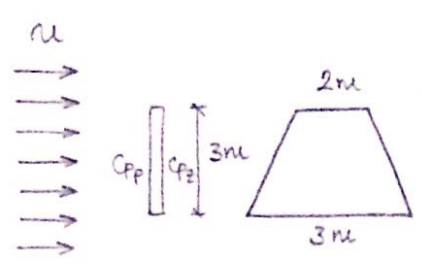


— БОЛА
— БАЗЛУХ

Задача 9.2 - отпори објекта

$\alpha = 5$
 $\beta = 30$

- $\rho_{\text{ваз}} = 1,2 \text{ kg/m}^3$
- $U_{\text{ваз}} = 3,5 \text{ m/s}$
- $C_{F,p} = 1,3$
- $C_{F,z} = -2,1$
- $C_F = ?$
- $F_0 = ?$



$$p = C_F \cdot \frac{1}{2} \rho U^2$$

$$p_p = 1,3 \cdot \frac{1}{2} \cdot 1,2 \text{ kg/m}^3 \cdot (3,5 \text{ m/s})^2 \Rightarrow \boxed{p_p = 9,555 \text{ Pa}}$$

$$F_p = p_p \cdot A = 9,555 \text{ Pa} \cdot (2+3) \text{ m} \cdot 3 \text{ m} \cdot \frac{1}{2} \Rightarrow \boxed{F_p = 71,662 \text{ N}}$$

$$p_z = -2,1 \cdot \frac{1}{2} \cdot 1,2 \text{ kg/m}^3 \cdot (3,5 \text{ m/s})^2 \Rightarrow \boxed{p_z = -15,435 \text{ Pa}}$$

$$F_z = p_z \cdot A = -15,435 \cdot (2+3) \text{ m} \cdot 3 \text{ m} \cdot \frac{1}{2} \Rightarrow \boxed{F_z = -115,762 \text{ N}}$$

→ сила отпора цроче:

$$F_0 = F_p + F_z = (71,662 - 115,762) \text{ N} \Rightarrow \boxed{F_0 = -44,1 \text{ N}}$$

Задача 9.3

$\alpha = 5/\beta = 30$

$\rho_{\text{вода}} = 1,0 \text{ kg/cm}^3$

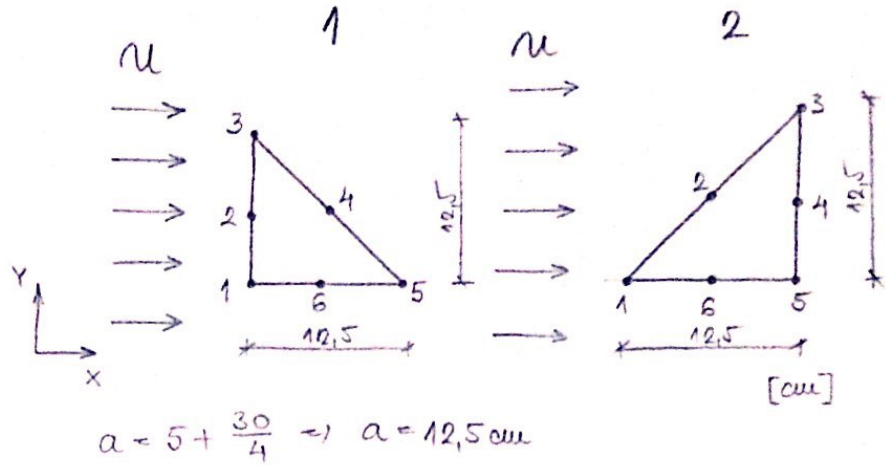
$\mu_{\text{вода}} = 10^{-2} \text{ g/cm}^2$

а) F_0 и h в высоте построения сечения

б) $C_{Fx}, C_{Fy} = ?$

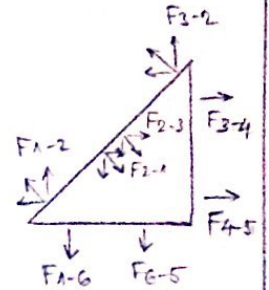
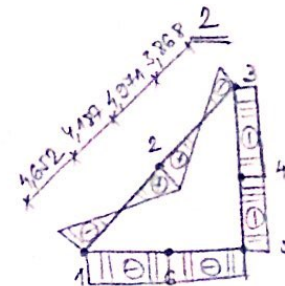
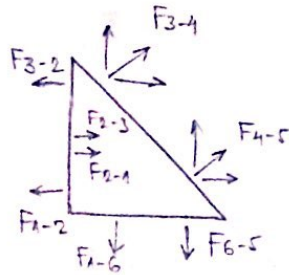
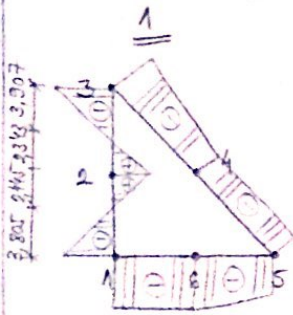
в) $U_{obj} = U_{вод} / 5 \frac{m}{s}$

$F_{obj} = ?$



$U_{вод} = 1,25 \frac{m}{s}$

а) сила давления и h в высоте построения сечения



ТАЧКА: 1 2 3 4 5 6
 $C_p: -1,4 \quad 0,9 \quad -1,5 \quad -1,2 \quad -1,2 \quad -1,4$

ТАЧКА: 1 2 3 4 5 6
 $C_p: -1,0 \quad 0,9 \quad -0,7 \quad -0,8 \quad -0,9 \quad -1,0$

$p_1 = C_{p1} \cdot \frac{1}{2} \rho U^2 = -1,4 \cdot \frac{1}{2} \cdot 1000 \cdot 1,25^2 \text{ Pa}$

$\Rightarrow p_1 = -1,094 \text{ kPa}$

$p_2 = C_{p2} \cdot \frac{1}{2} \rho U^2 = 0,9 \cdot \frac{1}{2} \cdot 1000 \cdot 1,25^2 \text{ Pa}$

$\Rightarrow p_2 = 0,703 \text{ kPa}$

$p_3 = C_{p3} \cdot \frac{1}{2} \rho U^2 = -1,5 \cdot \frac{1}{2} \cdot 1000 \cdot 1,25^2 \text{ Pa}$

$\Rightarrow p_3 = -1,172 \text{ kPa}$

$p_4 = C_{p4} \cdot \frac{1}{2} \rho U^2 = -1,2 \cdot \frac{1}{2} \cdot 1000 \cdot 1,25^2 \text{ Pa}$

$\Rightarrow p_4 = -0,938 \text{ kPa}$

$p_5 = C_{p5} \cdot \frac{1}{2} \rho U^2 = p_3 \Rightarrow p_5 = -0,938 \text{ kPa}$

$p_6 = p_1 = -1,094 \text{ kPa}$

$p_1 = -0,781 \text{ kPa}$

$p_2 = 0,703 \text{ kPa}$

$p_3 = -0,547 \text{ kPa}$

$p_4 = -0,625 \text{ kPa}$

$p_5 = -0,703 \text{ kPa}$

$p_6 = -0,781 \text{ kPa}$

$1,875 : \frac{12,5}{2} = 1,172 : x_1$

$x_1 = 3,907 \text{ cm}$

$1,797 : \frac{12,5}{2} = 1,094 : x_2$

$x_2 = 3,805 \text{ cm}$

$1,25 : \frac{17,672}{2} = 0,547 : x_3$

$x_3 = 3,868 \text{ cm}$

$1,481 : \frac{17,672}{2} = 0,781 : x_4$

$x_4 = 4,652 \text{ cm}$

1	2
[Pa] [m]	
$F_{12} = -1,094 \cdot 10^3 \cdot 3,805 \cdot 10^{-2} \cdot \frac{1}{2} = -20,813 \text{ N/m}$	$F_{12} = -0,781 \cdot 4,652 \cdot 10 \cdot \frac{1}{2} = -18,166 \text{ N/m}$
$F_{21} = 0,703 \cdot 2,445 \cdot 10^1 \cdot \frac{1}{2} = 8,594 \text{ N/m}$	$F_{21} = 0,703 \cdot 4,187 \cdot 10 \cdot \frac{1}{2} = 14,717 \text{ N/m}$
$F_{23} = 0,703 \cdot 2,343 \cdot \frac{10}{2} = 8,236 \text{ N/m}$	$F_{23} = 0,703 \cdot 4,971 \cdot 10 \cdot \frac{1}{2} = 17,473 \text{ N/m}$
$F_{32} = -1,172 \cdot 3,907 \cdot \frac{10}{2} = -22,895 \text{ N/m}$	$F_{32} = -9,547 \cdot 3,868 \cdot 10 \cdot \frac{1}{2} = -10,579 \text{ N/m}$
$F_{34} = (-1,173 - 0,938) \cdot 8,239 \cdot \frac{10}{2} = -93,296 \text{ N/m}$	$F_{34} = (-9,547 - 9,625) \cdot 6,25 \cdot 10 \cdot \frac{1}{2} = -36,625 \text{ N/m}$
$F_{45} = -0,938 \cdot 8,239 \cdot 10 = -82,910 \text{ N/m}$	$F_{45} = (-9,625 - 0,703) \cdot 6,25 \cdot 10 \cdot \frac{1}{2} = -41,500 \text{ N/m}$
$F_{65} = (-0,938 - 1,094) \cdot 6,25 \cdot \frac{10}{2} = -63,500 \text{ N/m}$	$F_{65} = (-0,703 - 0,781) \cdot 6,25 \cdot 10 \cdot \frac{1}{2} = -46,375 \text{ N/m}$
$F_{16} = -1,094 \cdot 6,25 \cdot 10 = -68,375 \text{ N/m}$	$F_{16} = -0,781 \cdot 6,25 \cdot 10 = -48,812 \text{ N/m}$

$$\Sigma F_{Y1} = F_{34} \frac{\sqrt{2}}{2} + F_{45} \frac{\sqrt{2}}{2} - F_{65} - F_{16}$$

$$\Sigma F_{Y1} = \left(\frac{\sqrt{2}}{2} (-93,296 - 82,910) \right) + 63,500 + 68,375 \text{ N/m}$$

$$\Sigma F_{Y1} = 7,278 \text{ N/m}$$

$$\Sigma F_{X1} = F_{23} + F_{21} - F_{32} - F_{12} + F_{34} \frac{\sqrt{2}}{2} + F_{45} \frac{\sqrt{2}}{2}$$

$$\Sigma F_{X1} = \left(8,236 + 8,594 + 22,895 + 20,813 - 93,296 \frac{\sqrt{2}}{2} - 82,910 \frac{\sqrt{2}}{2} \right) \text{ N/m}$$

$$\Sigma F_{X1} = -64,088 \text{ N/m}$$

$$\Sigma F_{Y2} = F_{32} \frac{\sqrt{2}}{2} + F_{12} \frac{\sqrt{2}}{2} - F_{16} - F_{65} - F_{23} \frac{\sqrt{2}}{2} - F_{21} \frac{\sqrt{2}}{2}$$

$$\Sigma F_{Y2} = \left(-10,579 \frac{\sqrt{2}}{2} - 18,166 \frac{\sqrt{2}}{2} + 48,812 + 46,375 - 17,473 \cdot \frac{\sqrt{2}}{2} - 14,717 \cdot \frac{\sqrt{2}}{2} \right) \text{ N/m}$$

$$\Sigma F_{Y2} = 55,718 \text{ N/m}$$

$$\Sigma F_{X2} = F_{34} + F_{45} - F_{12} \frac{\sqrt{2}}{2} - F_{32} \frac{\sqrt{2}}{2} + F_{23} \frac{\sqrt{2}}{2} + F_{21} \frac{\sqrt{2}}{2}$$

$$\Sigma F_{X2} = \left(-36,625 - 41,500 + 18,166 \frac{\sqrt{2}}{2} + 19,579 \frac{\sqrt{2}}{2} + 17,473 \frac{\sqrt{2}}{2} + 14,717 \frac{\sqrt{2}}{2} \right) \text{ N/m}$$

$$\Sigma F_{X2} = -35,037 \text{ N/m}$$

→ Мања је сила отпора струја у варијанти 1, према томе је положај 1 повољнији

$$b) C_{Fx} = \frac{F_x}{\frac{1}{2} \rho u^2 A_P} = \frac{-64,088 \text{ N}}{\frac{1}{2} \cdot 1000 \frac{\text{kg}}{\text{m}^3} \cdot (1,25 \frac{\text{m}}{\text{s}})^2 \cdot 0,125 \cdot 1 \text{ m}^2} \Rightarrow C_{Fx} = 0,656$$

$$C_{Fy} = \frac{F_y}{\frac{1}{2} \rho u^2 A_P} = \frac{7,278 \text{ N}}{\frac{1}{2} \cdot 1000 \frac{\text{kg}}{\text{m}^3} \cdot (1,25 \frac{\text{m}}{\text{s}})^2 \cdot 0,125 \text{ m}^2} \Rightarrow C_{Fy} = 0,074$$

g) $F = ?$

$$U_{obj} = \frac{U_{mod}}{5} = u^* = \frac{1,25 \frac{m}{s}}{5} \Rightarrow u^* = 0,25 \frac{m}{s}$$

$$F^* = \rho^* \left(\frac{1}{2} \right) S^* (u^*)^2 \cdot A^* \rightarrow \text{все размерные величины}$$

имеют размер 1

$$\rho^* = 1 \frac{kg}{dm^3}$$

$$L^* = 5 \text{ m}$$

$$A^* = L^* = 5 \text{ m}^2$$

$$\rightarrow F^* = (0,25)^2 \cdot 5$$

$$\rightarrow F^* = 0,312$$

$$F_{xobj} = F_{mod} \cdot F^* = -64,088 \cdot 0,312 \text{ N/m} \rightarrow \boxed{F_{xobj} = -19,996 \text{ N/m}}$$

$$F_{yobj} = F_{mod} \cdot F^* = 7,278 \cdot 0,312 \text{ N/m} \rightarrow \boxed{F_{yobj} = 2,271 \text{ N/m}}$$