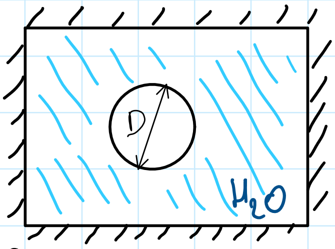
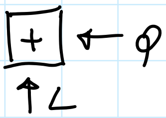
ESE_1

lunedì 11 ottobre 2021 18:30



PARETI ADIABATICHE



* DATI *

$D = 20\ cm \quad T_{cu_i} = 95°C \quad \rho_{cu} = 8938\ Kg/m^3$

$C_{cu} = 389,37\ \frac{J}{KgK} \quad M_{H_2O} = 50\ Kg$

$T_{H_2O_i} = 20°C \quad C_{H_2O} = 4186\ \frac{J}{KgK} \quad T_f\ ? \quad S = S_f - S_i\ ?$

* 1° Pr. TDN *

$\Delta U = Q + L$ } SISTEMA (H_2O + SFERA) → ADIABATICO $Q = 0$; NO SCAMBIO LAVORO $L = 0$

⇓

$$\Delta U_{TOT} = \Delta U_{Cu} + \Delta U_{H_2O} = 0$$

$$M_{cu} C_{cu} T_f + M_{H_2O} C_{H_2O} T_f = M_{H_2O} C_{H_2O} T_{H_2O_i} + M_{cu} C_{cu} T_{cu_i}$$

TEMPERATURA FINALE (SISTEMA ALL'EQUILIBRIO $T_{f_{H_2O}} = T_{f_{Cu}}$)

$$T_f = \frac{M_{H_2O} C_{H_2O} T_{H_2O,i} + M_{cu} C_{cu} T_{cu,i}}{M_{H_2O} C_{H_2O} + M_{cu} C_{cu}} = 24,89°C$$

$$M_{cu} = \rho_{cu} \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 = 37,44\ Kg \quad \text{(MASSA SFERA DI RAME)}$$

$$\Delta S_{universo} = \Delta S_{sistema} + \Delta S_{ambiente} \geq 0$$

$\Delta S_{ambiente} = 0$ (SISTEMA ADIABATICO)

$$\Delta S_{cu} + \Delta S_{H_2O} = M_{cu} C_{cu} \ln \boxed{\frac{T_f}{T_{cu,i}}} + M_{H_2O} C_{H_2O} \ln \boxed{\frac{T_f}{T_{H_2O,i}}} = 378\ \frac{J}{K}$$

T[K]!!!

ESE_2

lunedì 11 ottobre 2021 18:50

$V = cost = 3 m^3$

SISTEMA CHIUSO

* DATI *

$T_A = 25°C$; $P_A = 101325 Pa$; $MM_A = 28,84 \; Kg/Kmol$

$R_A^* = ?$ ρ_A (DENSITÀ IN COND. AMBIENTE) $= ?$

– RISCALDANDO A VOLUME COSTANTE $(T_f = 500°C)$ $\rightarrow Q = ?$; $P_f = ?$

$$R_A^* = \frac{R}{MM_A} = \frac{8314 \; J/Kmol K}{28,83 \; Kg/Kmol} = 288,3 \frac{J}{Kg K}$$

ARIA IN COND. AMBIENTE $\longrightarrow$ TRATTATA COME GAS PERFETTO

$$PV = n R T \xrightarrow[\text{PER } MM]{\text{DIVIDO E MOLTIPLICO}} PV = \underbrace{n \cdot MM}_{M = \text{MASSA GAS } [Kg]} \underbrace{\frac{R}{MM}}_{R^*} T$$

$$\downarrow$$

$$PV = M R^* T$$

$$\downarrow$$

$$P v = R^* T$$

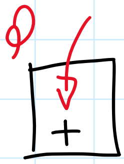
VOLUME SPECIFICO $\left[\frac{m^3}{Kg}\right]$ $v = \frac{1}{\rho}$

$$\rho_A = \frac{P}{R^* T} = \frac{101325 \; Pa}{288,3 \frac{J}{Kg K} (25 + 273,15) K} = 1,18 \; Kg/m^3$$ (DENSITÀ ARIA)

* RISCALDAMENTO ISO-V (TEMPERATURA FINALE $T_f = 500°C$) (SISTEMA CHIUSO)

$$\Delta U = Q + \cancel{L} \Rightarrow M c_v \Delta T = M c_v (T_f - T_i)$$

$$\Delta U = Q + \cancel{L} \Rightarrow \boxed{M} c_v \Delta T = M c_v (T_f - T_i)$$



NO SCAMBIO LAVORO

MASSA ARIA CONTENUTA NEL RECIPIENTE

$$M = \rho V = 1{,}18\ Kg/m^3 \cdot 3\ m^3 = 3{,}54\ Kg$$

$$c_v = \frac{5}{2} R^* = 720{,}75\ \frac{J}{Kg\,K}$$ (aria considerata gas perfetto biatomico)

CONSIDERARE $C_V = \frac{5}{2} R^*$ COME COST

$$Q = 1212\ KJ$$

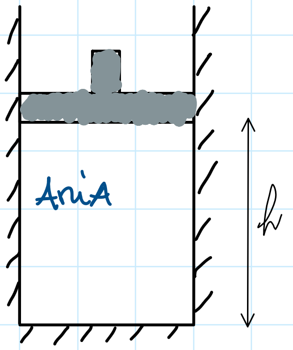
$$P_f V_f = \boxed{M} R^* T_f \Longrightarrow P_f = \frac{M R^* T_f}{V} = 262{,}7\ KPa$$

SISTEMA CHIUSO $M_f = M_i$ (LA MASSA NON CAMBIA)

$V_f = V_i$ (TRASFORMAZIONE ISO-V $\rightarrow V_f = 3\ m^3$)

ESE_3

martedì 12 ottobre 2021 16:58



Sistema Cilindro_Pistone chiuso

*** DATI ***

$M_{aria} = 0{,}01\ Kg$ $\quad P_i = 1\ atm$ $\quad S = 0{,}01\ m^2$ (cilindro)

$h = 1\ m$ $\quad R^* = \dfrac{R}{MM_{aria}} = \dfrac{8314\ J/KmolK}{28{,}84\ Kg/Kmol}$

$V_f\ [m^3] = \dfrac{V_i}{2}$ $\quad$ (TRASFORMAZIONE DI COMPRESSIONE ADIABATICA E REVERSIBILE) $\Downarrow$ ISO-S

$L = ?$ $\quad P_f = ?$

* I° Principio TDN *

$$\Delta U = Q + L = M c_v (T_2 - T_1)$$

? ?

$$T_i = ? \qquad P_i V_i = R^* M T_i \Rightarrow T_i = \frac{P_i V_i}{M R^*} = 351{,}5\ K$$

Compressione Iso-s $\quad PV^\gamma = cost \Longrightarrow P_i V_i^\gamma = P_f V_f^\gamma$

$\gamma = 7/5$ (× Gas Perfetto Biatomico → assumere come dato)

$$P_f = P_i \left(\frac{V_i}{V_f}\right)^\gamma = 101325 \cdot 2^{7/5} = 2{,}674\ bar$$

$$T_f = \frac{P_f V_f}{M R^*} = 463{,}7\ K$$

Lavoro Compressione

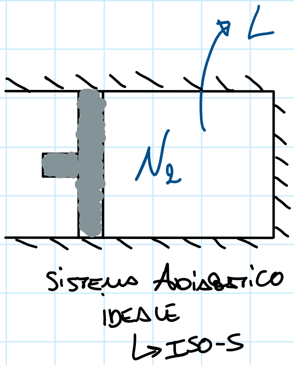
$$L = M \underbrace{c_v}_{\frac{5}{2}R^*} \Delta T_{f-i} = 809\ J \quad (\text{Adiabatica } Q = 0)$$

x Sistema Chiuso (alternativa calcolo di L)

$$L = \int_i^f -P\,dV \underset{PV^\gamma = cost}{=} -\int_i^f P_i V_i^\gamma \frac{dV}{V^\gamma} = -\int_i^f P_i V_i^\gamma V^{-\gamma} dV = -\frac{P_i V_i^\gamma}{-\gamma+1}\left[V^{-\gamma+1}\right]_i^f =$$

$$= \frac{P_i V_i^\gamma}{\gamma - 1}\left(V_f^{1-\gamma} - V_i^{1-\gamma}\right) = P_i \underbrace{V_i^\gamma}_{(P_f V_f^\gamma)/P_i} V_f^{1-\gamma} - P_i V_i^\gamma V_i^{1-\gamma} =$$

$$= \frac{1}{\gamma - 1}\left(P_f V_f - P_i V_i\right) = 809\ J$$ (stesso risultato)



* DATI *

$MM_{N_2} = 28{,}013\ Kg/Kmol \quad M_{N_2} = 1Kg$

$T_1 = 20°C\ ;\ V_1 = 0{,}859\ m^3 \longrightarrow V_2 = 0{,}2746\ m^3$

a) $T_2 = ?$ (FINE COMPRESSIONE) $L = ?$

ISO-S $\quad ds = 0 \Rightarrow c_p \frac{dT}{T} - R^* \frac{dP}{P} = 0 \Rightarrow c_p \ln\frac{T_2}{T_1} = R^* \ln\frac{P_2}{P_1}$

$\Rightarrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{R^*/c_p} \longrightarrow \left(\frac{T_2}{T_1}\right) = \left(\frac{V_1}{V_2}\right)^{\frac{R^*/c_p}{1-R^*/c_p}} \Rightarrow T_2 = 462K$

$P = \frac{MR^*T}{V}$ $\quad \left(\frac{R^*}{c_p} = \frac{2}{7}\ \text{dato}\right)$

* 1° PR. TDN *

$\Delta U = \cancel{Q} + L = Mc_v(T_2 - T_1) = M\frac{5}{2}R^*(T_2 - T_1) = 125{,}7\ KJ$

ADIABATICA

b) INTRODUCO NEL CILINDRO UNA MASSA DI Cu (1Kg) $\quad c_{cu} = 385\ J/KgK$

Hp: Cu e N_2 SEMPRE IN EQUILIBRIO TERMICO $\quad T_2 = ? \quad V_2 = ? \quad L = ? \quad c_x = ?$

SISTEMA ADIABATICO E REVERSIBILE $\quad \Delta s = 0 \quad \Delta S_{cu} + \Delta S_{N_2} = 0$

$\Delta S_{cu} = M_{cu} c_{cu} \ln\frac{T_2}{T_1}$

$\Delta S_{N_2} = M_{N_2} c_{P,N_2} \ln\frac{T_2}{T_1} - R^* M_{N_2} \ln\frac{P_2}{P_1}$

$\Delta S_{cu} = -\Delta S_{N_2}$

$M_{cu} c_{cu} \ln\frac{T_2}{T_1} = -M_{N_2}\left(c_{P_{N_2}} \ln\frac{T_2}{T_1} - R^* M_{N_2} \ln\frac{P_2}{P_1}\right)$

$\left(M_{cu} c_{cu} + M_{N_2} c_{P,N_2}\right) \ln\frac{T_2}{T_1} = R^* \ln\left(\frac{P_2}{P_1}\right) = R^* \ln\left(\frac{T_2 V_1}{T_1 V_2}\right)$

$$\left(M_{cu} c_{cu} + M_{N_2} c_{p,N_2}\right) \ln \frac{T_2}{T_1} = R^* \ln\left(\frac{P_2}{P_1}\right) = R^* \ln\left(\frac{T_2 V_1}{T_1 V_2}\right)$$

$P = \frac{MR^*T}{V}$

$$\frac{T_2}{T_1} = \left(\frac{T_2 V_1}{T_1 V_2}\right)^{\frac{R^*}{\underbrace{(M_{cu} c_{cu} + M_{N_2} c_{p,N_2})}_{a}}} \Longrightarrow \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\frac{R^*/a}{1 - R^*/a}}$$

$\rightarrow T_2 = 396\,K$

* I° PR. TDN * $\Delta U_{sistema} = \underbrace{\cancel{Q}}_{\text{Adiabatico}} + L = \Delta U_{N_2} + \Delta U_{cu} = M_{cu} c_{cu} \Delta T + M_{N_2} c_{v,N_2} \Delta T = 115{,}7\,KJ$

* Calcolo Indice Politropica n (Trasformazione Gas) $P_1 V_1^n = P_2 V_2^n$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\frac{R^*/a}{1 - R^*/a}} \qquad PV = MR^*T \qquad \frac{T_2}{T_1} = \frac{P_2 V_2}{P_1 V_1} \text{ (gas perfetti)}$$

$$\frac{P_2}{P_1} = \frac{V_1}{V_2}^{\frac{R^*/a}{1 - R^*/a} + 1} \rightarrow n = 1{,}263$$

* c_{x,N_2}?

Trasf. Adiabatica $dQ = 0 = dQ_{cu} + dQ_{N_2} \Longrightarrow dQ_{cu} = -dQ_{N_2}$

$$M_{cu}\, c_{cu}\, \cancel{dT} = M_{N_2}\, c_{N_2}\, \cancel{dT} \Longrightarrow c_{N_2} = -c_{cu} \frac{M_{cu}}{M_{N_2}} = -385\ J/KgK$$

ESE_5

martedì 12 ottobre 2021 17:57

DATI

$P_1 = 1\,bar;\ T_1 = 25°C \rightarrow P_2 = 5\,bar;\ T_2 = 25°C$ aria (gas perfetto)

$c_v = \frac{5}{2}R^*;\ c_p = \frac{7}{2}R^*$

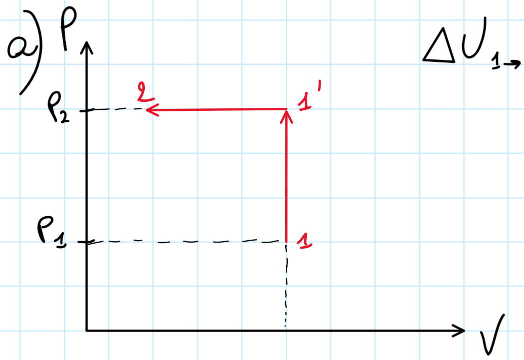
a) COMPRESSIONE ISO-V + SCAMBIO DI CALORE A P COSTANTE

b) COMPRESSIONE ISO-T

c) COMPRESSIONE ISO-S + SCAMBIO DI CALORE A V COSTANTE

TRASFORMAZIONI REVERSIBILI

a)



$$\Delta U_{1\to2} = \Delta U_{1\to1'} + \Delta U_{1'\to2} = M c_v (T_2 - T_1) = 0$$

25°C (dato) 25°C (dato)

$\underline{1\to1'}$ $V = cost$ $L = 0$ $\Delta U_{1\to1'} = M c_v (T_{1'} - T_1) = M c_v \left(\frac{P_2 V_{1'}}{R^*} - T_1\right) = 859\,KJ$

$V_1' = V_1 = \frac{R^* T_1}{P_1} = 0{,}86\,\frac{m^3}{kg}$

$$\Delta U_{1'\to2} = M c_v (T_2 - T_1) = M c_v \left(T_2 - \frac{P_2 V_1}{R^*}\right) = -859\,KJ$$

$$L_{1\to2} = \underbrace{L_{1\to1'}}_{ISO-V} + \underbrace{L_{1'\to2}}_{ISO-P} = 0 - M\int_{1'}^{2} P\,dV = -M P_2 (V_2 - V_1') = 343{,}5\,KJ$$

$$Q_{1\to2} = Q_{1\to1'} + Q_{1'\to2}$$

$$Q_{1\to1'} = \Delta U_{1\to1'} - L_{1\to1'} = 859\,KJ \quad (ISO-V)$$

$$Q_{1'\to2} = \Delta U_{1'\to2} - L_{1'\to2} = -859\,KJ - 343{,}5\,KJ = -1202{,}5\,KJ$$

$$Q_{1\to2} = 343{,}5\,KJ$$

$$\Delta S_{1\to2} = \Delta S_{1\to1'} + \Delta S_{1'\to2}$$

$$\Delta S_{1\to1'} = M c_p \ln\frac{T_{1'}}{T_1} - R^* M \ln\frac{P_{1'}}{P_1} = 1159{,}9\,J/K$$

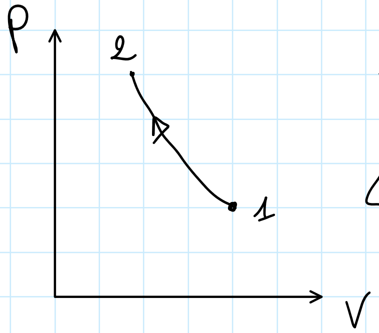
$$\Delta S_{1'\to2} = M c_p \ln\frac{T_2}{\ } - M R^* \cancel{\ln\frac{P_2}{\ }} = -1623{,}89\,J/K$$

$$\Delta S_{1'\to 2} = M c_p \ln \frac{T_2}{T_{1'}} - \cancel{M R^* \ln \frac{P_2}{P_1}} = -1623{,}89 \ J/K$$

ISO-P

$$\Delta S_{1\to 2} = -463{,}97 \ J/K$$

b) Compressione Iso-T



$$\Delta U_{1\to 2} = M c_v \Delta T = 0 \quad (T_2 = T_1)$$

$$L_{1\to 2} = -\int_1^2 P dV \overset{PV = MR^*T}{=} -MR^*T \int_1^2 \frac{dV}{V} =$$

$$= -MR^*T \ln \frac{V_2}{V_1} = 138{,}3 \ KJ$$

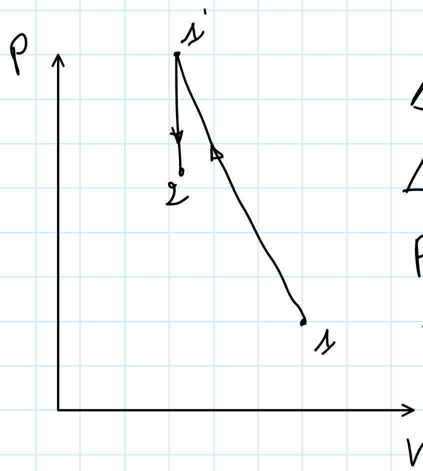
V_2: $0{,}172 \ m^3$; $V_1 = \frac{MR^*T}{P_1} = 0{,}8595 \ m^3$

$$\Delta U_{1\to 2} = Q_{1\to 2} + L_{1\to 2} = 0 \Rightarrow Q_{1\to 2} = -L_{1\to 2} = -138{,}3 \ KJ$$

$$\Delta S_{12} = \frac{Q_{1\to 2}}{T} = 464 \ J/K$$

T → ISO-T

c) Compressione Iso-S + Scambio Calore a V=cost



$$\Delta U_{1\to 2} = \Delta U_{1\to 1'} + \Delta U_{1'\to 2} = M c_v (T_2 - T_1) = 0$$

$$\Delta U_{1\to 1'} = M c_v (T_{1'} - T_1)$$

$$P_1 V_1^{\gamma} = P_{1'} V_{1'}^{\gamma} \quad (\text{ISO-S}) \rightarrow P_1' = 9{,}5 \ bar$$

$$T_1' = \frac{P_{1'} V_{1'}}{R^*} = \frac{P_{1'} V_2}{R^*} = 567 K$$

$$\Delta U_{1,1'} = 194 \ KJ$$

$$\Delta U_{1'\to 2} = M c_v (T_2 - T_{1'}) = -194 \ KJ$$

$$Q_{1\to 2} = Q_{1\to 1'} + Q_{1'\to 2}$$

$$Q_{1\to 1'} = 0 \quad (\text{Adiabatica})$$

$$Q_{1\to 2} = \Delta U_{1'\to 2} - L = -194 \ KJ$$

$$Q_{1\to 2} = \underbrace{\Delta U_{1'\to 2}}_{=0\ (\text{ISO-V})} - L = -194\ kJ$$

$$Q_{1\to 2} = -194\ kJ$$

$$L_{1\to 2} = L_{1\to 1'} + L_{1'\to 2}$$

$$L_{1\to 1'} = \underbrace{\Delta U_{1\to 1'}}_{=0} - Q_{1\to 1'} = 194\ kJ$$

$$L_{1\to 2} = 194\ kJ$$

$$\Delta S_{1\to 2} = \underbrace{\Delta S_{1\to 1'}}_{=0\ (1\to 1'\ \text{ISO-S})} + \Delta S_{1'\to 2}$$

$$\Delta S_{1'\to 2} = M c_p \ln\frac{T_2}{T_{1'}} - R^* M \ln\frac{P_2}{P_{1'}} = -464\ kJ$$

$$\Delta S_{1\to 2} = -464\ K$$

* TABELLA RIASSUNTIVA *

	A)	B)	C)
ΔU [kJ]	0	0	0
Q [kJ]	-343	-138	-194
L [kJ]	343	138	194
ΔS [kJ/K]	-464	-464	-464

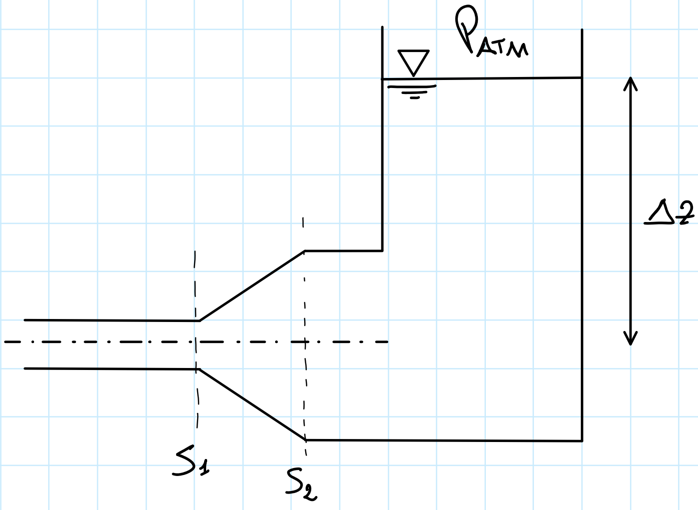
$= 0\ (T_1 = T_2)$

NON SONO FUNZIONI DI STATO

FUNZIONE DI STATO $\Delta S_{1\to 2}$ NON DIPENDE DALLA SEQUENZA DI TRASFORMAZIONI

ESE_6

mercoledì 13 ottobre 2021 09:17



* DATI *

$\Delta z = 3\,m$; $D_1 = 1{,}2\,m$

$D_2 = 2{,}4\,m$

$\dot{V}_{H_2O} = 3{,}3\,m^3/s$ $\quad \rho_{H_2O} = 1000\,Kg/m^3$

· SPINTA ORIZZONTALE ESERCITATA DAL FLUIDO SUL DIFFUSORE

FLUSSO IDEALE

PERDITA PER ATTRITO $Y = 0{,}6\ J/Kg$

· PORTATA MASSICA (REGIME STAZIONARIO) (PRINCIPIO CONS. MASSA)

$$\dot{m}_1 = \dot{m}_2 = \dot{m} = \frac{\dot{V}}{v_{H_2O}} = \dot{V}\rho_{H_2O} = 3300\ Kg/s \quad (H_2O \text{ liq} \rightarrow \rho = \text{cost})$$

· PR. CONS. ENERGIA

$$\cancel{l} + q = \left(U_2 + \frac{P_2}{\rho} + \frac{V_2^2}{2} + \cancel{g z_2}\right) - \left(U_1 + \frac{P_1}{\rho} + \frac{V_1^2}{2} + \cancel{g z_1}\right)$$

NO ORGANI MOBILI

CONDOTTO ORIZZONTALE $z_2 = z_1$

· x FLUIDO INCOMPRIMIBILE $\rho = \text{cost}$ $\quad Y = (U_2 - U_1) - Q$

perdite ← per attrito

a) 0 (FLUSSO IDEALE)

b) 0,6 [J/Kg]

$$P_2 - P_1 = \frac{V_1^2 - V_2^2}{2}\rho - Y\rho$$

$$V_1 = \frac{\dot{V}_1\left[\frac{m^3}{s}\right]}{A_1\,[m^2]} = \frac{\dot{V}_1}{\frac{\pi D_1^2}{4}} = 2{,}92\ m/s \quad ; \quad V_2 = \frac{\dot{V}_2}{A_2} = 0{,}73\,m/s$$

SEZ. CIRCOLARE

$P_2 - P_1 = \Delta P$

a) 3997 Pa ($Y = 0$)

b) 3397 Pa ($Y = 0{,}6\ J/Kg$)

↘ b) 3397 Pa ($Y = 0{,}6$ J/Kg)

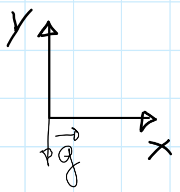
- <u>Cons. Quantità di Moto</u>

$$M\vec{g} + \int_{S_1}\left(-p\vec{n} + \cancel{\tau\vec{t}}\right)ds + \int_{S_2}\left(-p\vec{n} + \cancel{\tau\vec{t}}\right)ds + \int_{S_3}\left(-p\vec{n} + \tau\vec{t}\right)ds = \dot{m}\vec{V}_2 - \dot{m}\vec{V}_1$$

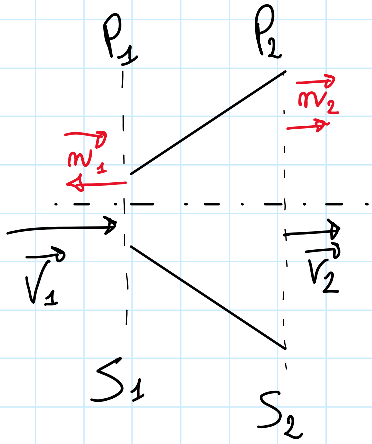
MONODIMENSIONALITÀ

$$\vec{G} - \vec{\Pi}_1 - \vec{\Pi}_2 + \vec{R}_3 = \vec{M}_2 - \vec{M}_1 \qquad -\vec{R}_{3,x} = ?$$

FORZA ESERCITATA DALLA PARETE SUL FLUIDO



$$\vec{G}_x = 0$$ (LA FORZA PESO NON HA COMPONENTE LUNGO X)



$$-\vec{R}_{3,x} = -\vec{\Pi}_{1,x} - \vec{\Pi}_{2,x} - \vec{M}_{2,x} + \vec{M}_{1,x}$$

$$|\Pi_2| = P_2 S_2$$

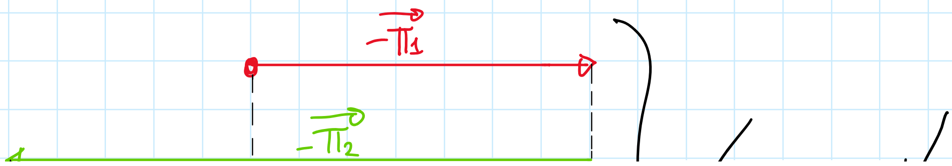
$$P_2 = P_{ATM} + \rho g \Delta z = 101325\,\text{Pa} + 1000 \cdot 9{,}81 \cdot 3 = 130755\,\text{Pa}$$

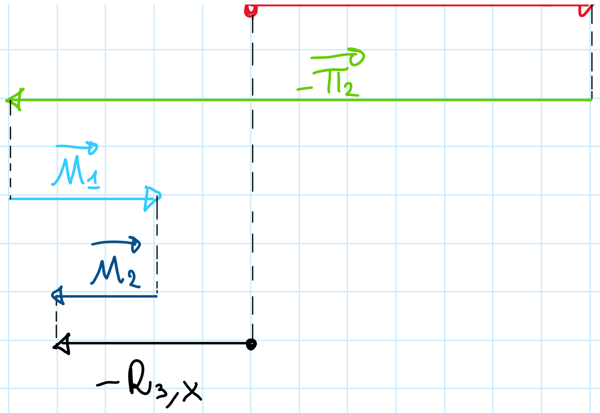
$$|\Pi_1| = P_1 S_1$$

$P_1 = P_2 - \Delta P$
- a) 126764 Pa ($Y = 0$ [J/Kg])
- b) 127364 Pa ($Y = 0{,}6$ [J/Kg])

$$|M_2| = \dot{m} V_2 = 2407{,}2\ N$$

$$|M_1| = \dot{m} V_1 = 9628{,}9\ N$$



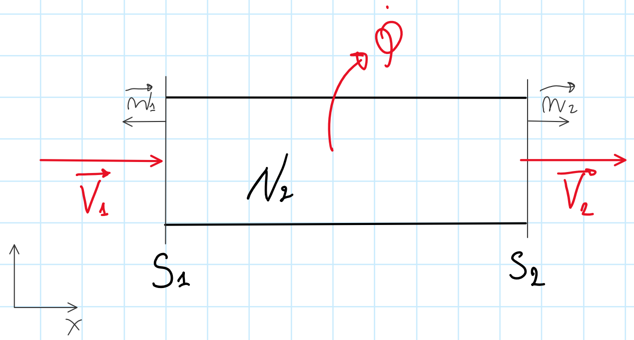


Somma Vettoriale

(vettori non in scala)

$|-R_{3,x}|$ → a) $-440,9\ N$

$|-R_{3,x}|$ → b) $-440,2\ N$



DATI

$\dot m_1 = 0{,}05\ kg/s \qquad S_1 = S_2 = 0{,}0156\ m^2$

$T_1 = 75°C \qquad T_2 = 40°C \qquad P_1 - P_2 = 6{,}75\ mbar$

$P_2 = P_{ATM} = 1\ atm$

$-R_{3,x}$? (Forza esercitata dal fluido sulla parete da parte del fluido)

- Regime Stazionario

* Cons. Massa $\Longrightarrow \dot m_{in} = \dot m_{out}$ $\quad (\dot m_1 = \dot m_2 = \dot m)$ (Nessun termine di accumulo)

$$\dot m_1 = \rho_1 V_1 S_1 = \rho_2 V_2 S_2 \ [kg/s]$$

* Cons. Q. Moto

$$M\vec g - P_1 S_1 \vec n_1 - P_2 S_2 \vec n_2 + \boxed{\int_{S_3} \left(-p\vec n + \tau \vec t\right) ds} = \dot m \left(\vec V_2 - \vec V_1\right)$$

↳ $\vec R_3$ (Forza esercitata dalla parete sul fluido)

⇓

$$\vec G - \vec \Pi_1 - \vec \Pi_2 + \vec R_3 = \vec M_2 - \vec M_1$$

$$P_1 = P_2 + \Delta P = 101325\ Pa + \frac{6{,}75}{1000} \cdot 10^5\ Pa = 102000\ Pa$$

$$\dot m_1 = \boxed{\rho_1} V_1 S_1 = 0{,}05\ kg/s$$

↳ Aria trattata come gas ideale $\frac{P}{\rho} = \overbrace{\left(\frac{R}{MM}\right)}^{R^*} \overbrace{T}^{[K]} \Longrightarrow \rho_1 = \frac{P_1}{T_1 R^*} = 1{,}017\ kg/m^3$

⇓

$$V_1 = \frac{\dot m}{S_1 \rho_1} = 3{,}15\ m/s$$

$$\rho_1 V_1 \cancel{S_1} = \rho_2 V_2 \cancel{S_2} \Longrightarrow V_2 = V_1 \frac{\rho_1}{\rho_2} = 2{,}85\ m/s$$

- Componente Tangenziale della Forza Esercitata dalla Parete su Fluido $\vec R_{3,x}$

$$-R_{3,x} = -\int_{S_3} \tau \vec t\, ds \quad (\text{da valutare})$$

- $-R_{3,x} = G_x - \Pi_{1,x} - \Pi_{2,x} - M_{2,x} + M_{1,x}$

  $G_x = 0$ (FORZA PESO NON HA COMPONENTE LUNGO X)

- $|M_2| = \dot{m} V_2 = 0{,}1425\,N$ • $|\Pi_1| = P_1 S_1 = 1591{,}2\,N$
- $|M_1| = \dot{m} V_1 = 0{,}1575\,N$ • $|\Pi_2| = P_2 S_2 = 1580{,}67\,N$

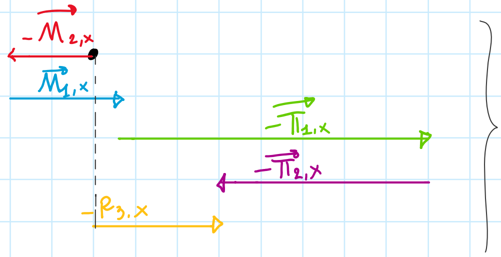
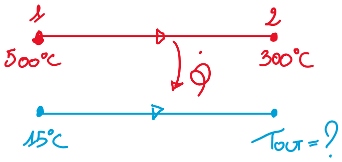


diagramma vettoriale (non in scala)



DATI

$\dot{m}_{N_2} = 3\,kg/s \qquad \dot{m}_{H_2O} = 3\,kg/s$

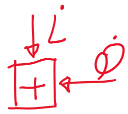
$T_1 = 500°C \quad T_2 = 300°C \quad T_{IN,H_2O} = 15°C$

$c_{H_2O} = 4{,}186\ kJ/kg/K \quad c_{p,N_2} = a + bT + cT^2 = f(T) \quad T[K]$

$\dot{\Phi} = ? \quad T_{OUT,H_2O} = ?$

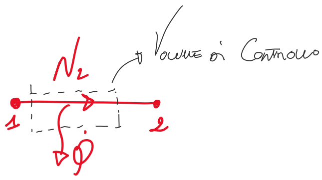
CONS. ENERGIA (REGIME STAZIONARIO)

$$\dot{m}_{N_2}\left(h_1 + \frac{V_1^2}{2} + g z_1\right) + \dot{L} + \dot{\Phi} = \dot{m}_{N_2}\left(h_2 + \frac{V_2^2}{2} + g z_2\right) \quad [W] \quad (\text{generale})$$



- No organi mobili $\longrightarrow \dot{L} = 0$
- $g(z_2 - z_1)$ trascurabile
- $\frac{V_1^2}{2} - \frac{V_2^2}{2}$ trascurabile

$$\dot{\Phi} = \dot{m}_{N_2}\underbrace{(h_2 - h_1)}_{\Delta h_{12}(T)}$$

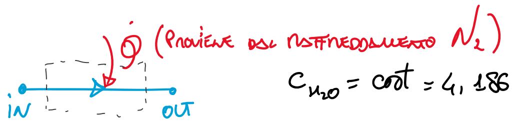


$$dh = c_p(T)\,dT \Longrightarrow \Delta h = \int_1^2 c_p(T)\,dT = \int_1^2 (a + bT + cT^2)\,dT =$$

$$= a(T_2 - T_1) + \frac{b}{2}(T_2^2 - T_1^2) + \frac{c}{3}(T_2^3 - T_1^3) = -223{,}4\ \frac{kJ}{kg}$$

$$\dot{\Phi} = \dot{m}\,\Delta h_{12} = -670{,}3\ kW \quad (\text{Potenza termica uscente dal flusso } N_2)$$

- **CONS. ENERGIA H_2O**

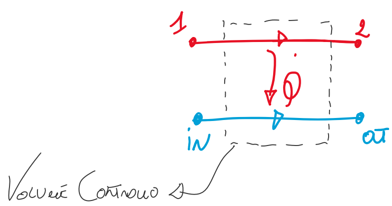


$c_{H_2O} = \text{cost} = 4{,}186\ kJ/kgK$

$$\dot{\Phi}_{H_2O} = \dot{m}_{H_2O}(h_{OUT} - h_{IN}) = \dot{m}_{H_2O}\,c\,(T_{OUT} - T_{IN})$$

$$\Downarrow$$

$$T_{OUT} = \frac{\dot{\Phi}_{H_2O}}{\dot{m}_{H_2O}\,c} + T_{IN} = 68{,}38°C$$



$$\dot{m}_{N_2} h_1 + \dot{m}_{H_2O} h_{IN} - \dot{m}_{N_2} h_{N_2} - \dot{m}_{H_2O} h_{IN} = 0$$

$h_{OUT} \rightarrow T_{OUT,H_2O}$ (Stesso risultato)

ESE_9

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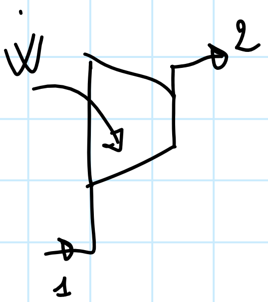

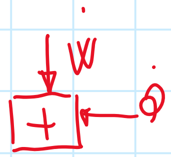

Rapporto di Compressione $\beta = \frac{P_2}{P_3} = 3$

$\dot V_1 = 5000\ m^3/h$ Aria $\rightarrow$ Gas Perfetto

$\gamma = c_p/c_v = 1{,}39$ $\quad T_1 = 20°C$ $\quad P_1 = P_{amb}$

$T_2 = ?$ $\quad \dot W = ?$

• Compressione Ideale (Adiabatica Reversibile) $\longrightarrow$ Iso-s

$P v^\gamma = cost$ (Iso-s $\rightarrow$ Politropica $n = \gamma$) $\rightarrow$ (Possibile ricavare la stessa relazione applicando $Tds = dh - vdP$ x gas perfetto ($dh = c_p dT$))

$$P_1 v_1^\gamma = P_2 v_2^\gamma \Longrightarrow \frac{P_1}{P_2} = \left(\frac{v_2}{v_1}\right)^\gamma .$$

$$v = R^* \frac{T}{P} \left[\frac{m^3}{kg}\right]$$

Sostituisco nella relazione.

$$\frac{P_1}{P_2} = \left(\frac{\frac{R^* T_2}{P_2}}{\frac{R^* T_1}{P_1}}\right)^\gamma \Longrightarrow \left(\frac{P_1}{P_2}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^\gamma$$

$$T_2 = \left(\frac{P_1}{P_2}\right)^{(1-\gamma)/\gamma} \cdot T_1 = 398{,}8\,K = 125{,}8\,°C$$

T[K]!!!

Bil. Energia (Regime Stazionario)

$$\dot Q + \dot W + \left(h_1 + \frac{V_1^2}{2} + g z_1\right)\dot m = \dot m\left(h_2 + \frac{V_2^2}{2} + g z_2\right)$$

$\dot Q = 0$ (Adiabatica)

$g z_1 \simeq g z_2$ (Diff. Quota Trascurabile)

$$\dot W = \dot m (h_2 - h_1)$$

$gz_1 \simeq gz_2$ (DIFF. QUOTA TRASCURABILE)

$\frac{V_2^2}{2} - \frac{V_1^2}{2}$ (TRASCURABILE)

$\dot{W} = \dot{m}(h_2 - h_1)$

$$\dot{W} = \dot{m}(h_2 - h_1) \overset{\text{GAS PERFETTO}}{=} c_p^T (T_2 - T_1) \cdot \dot{m}$$

$\gamma = \frac{c_p}{c_v}$; $c_p = c_v + R^*$ (VALIDA SOLO PER GAS PERFETTI)

$\Downarrow$

$c_p = \frac{c_p}{\gamma} + R^* \Rightarrow c_p = \frac{\gamma R^*}{\gamma - 1} = 1027{,}5 \ J/kg/K$

$\dot{m}_1 = \dot{m}_2 = \dot{m}$ (CONS. MASSA $\rightarrow$ REGIME STAZIONARIO)

$\dot{V}_1 = 5000 \frac{m^3}{h} \cdot \frac{1}{3600} \frac{h}{s} = 1{,}39 \ m^3/s$

$\dot{m}_1 = \dot{V}_1 \rho_1$

$\rightarrow$ GAS PERFETTO $1{,}2 \ kg/m^3$

$\dot{W} = \dot{m} c_p (T_2 - T_1) = 181 \ kW$ ($+$ ENTRANTE $\rightarrow$ COMPRESSORE MACCHINA OPERATRICE)

ESE_10

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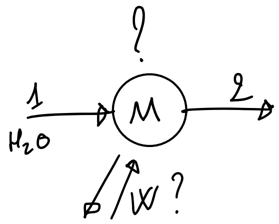

DATI

$z_1 = z_2$ H_2O liq ≡ FLUIDO INCOMPRIMIBILE

$P_1 = 1 atm$ $P_2 = 3 bar$ $V_1 = 8 m/s$ $V_2 = 10 m/s$

POTENZA SCAMBIATA $= |\dot{W}| = 350 kW$

$\Delta T_{12} = 0{,}01 °C$ MACCHINA MOTRICE ? / OPERATRICE ?

$\eta_{ion} = ?$ $\dot{m} = ?$ $D_1 = ?$

* CONS. ENERGIA * (REGIME STAZIONARIO)

$$l + q + u_1 + \frac{P_1}{\rho_1} + \frac{V_1^2}{2} + g z_1 = u_2 + \frac{P_2}{\rho_2} + \frac{V_2^2}{2} + g z_2$$

$\boxed{+} \leftarrow q$, $\downarrow l$

* FLUIDO INCOMPRIMIBILE $\rho_1 = \rho_2$ $\quad \Upsilon = u_2 - u_1 - q$ $\begin{cases} = 0 \text{ MACCHINA IDEALE} \\ > 0 \text{ MACCHINA REALE} \end{cases}$

* MACCHINA ADIABATICA $q = 0$

→ CONSIDERO MACCHINA IDEALE

$$l_{ID} = \left(\frac{P_2 - P_1}{\rho}\right) + \left(\frac{V_2^2 - V_1^2}{2}\right) = 217 \frac{J}{kg} > 0$$ MACCHINA OPERATRICE (es. POMPA)

→ CONSIDERO MACCHINA REALE (ADIABATICA)

$$\Upsilon = u_2 - u_1 = c\,(T_2 - T_1) = 41{,}86 \frac{J}{kg} \quad \left(c_{H_2O\,liq} = 4186 \left[\frac{J}{kg K}\right]\right)$$

$$l_{REALE} = l_{ID} + \Upsilon = 258{,}535 \; J/kg$$

↓ (IRREVERSIBILITÀ AUMENTANO IL LAVORO NECESSARIO AL FUNZIONAMENTO DELLA MACCHINA OPERATRICE)

$$\dot{W} = 350 kW = \dot{m}\, l_{REALE} \longrightarrow \dot{m} = 1353 \; kg/s$$

* CONS. MASSA *

$$\dot{m} = cost = \rho_1 V_1 A_1 = \rho_2 V_2 A_2 \Longrightarrow A_1 = \frac{\dot{m}}{\rho_1 V_1} = 0{,}168 m^2$$

DENSITÀ ACQUA LIQUIDA $\simeq 1000 \; kg/m^3$

$$D_1 = \sqrt{\frac{4 A_1}{\pi}} = 0{,}464 m$$

RENDIMENTO IDRAULICO POMPA (MACCHINA OPERATRICE)

IL LAVORO RICHIESTO DALLA POMPA È SUPERIORE A QUELLO TRASFERITO AL FLUIDO $\left(Y \left[\frac{J}{kg}\right] \text{ IRREVERSIBILITÀ} \right)$

$$* \quad \eta_{idr} = \frac{l_{id}}{l_{reale}} < 1$$

(POMPA → MACCHINA OPERATRICE)

** INDICA LA QUALITÀ DELLA TRASFORMAZIONE

$$|l_{reale\,pompa}| = |l_{ideale\,pompa}| + Y \; [J/kg]$$

TURBINA → MACCHINA MOTRICE

$$* \quad \eta_{idr\,turbina} = \frac{l_{reale}}{l_{id}} < 1$$

$$** \quad |l_{reale\,turb}| = |l_{ideale\,turb}| - Y \; [J/kg]$$

IL LAVORO PRODOTTO DALLA TURBINA È INFERIORE ALL'ENERGIA IDEALE MESSA A DISPOSIZIONE DAL FLUIDO

$$\eta_{idr\,pompa} = \frac{l_{ideale}}{l_{reale}} = 0{,}838$$

ESE_11

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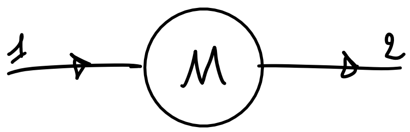
Dati



Aria (Gas Perfetto); $c_p = 1004$ J/kgK

$R^* = 287$ J/kgK $T_1 = 25°C$ $P_1 = 1$ bar

macchina Adiabatica e Ideale

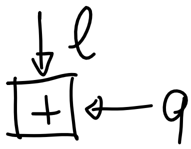
$V_1 = 100$ m/s $P_2 = 5$ bar $V_2 = 110$ m/s $|\dot{W}| = 1$ MW

macchina → operatrice / motrice ?

$s_1 = ?$ $s_2 = ?$ $\dot{m} = ?$

$\dot{m}_1 = \dot{m}_2 = \dot{m}$ (cons. massa)

$$l + \cancel{q} + h_1 + \frac{V_1^2}{2} + g z_1 = h_2 + \frac{V_2^2}{2} + g z_2$$



Adiabatica

$g(z_1 - z_2) = 0$

$$l = (h_2 - h_1) + \frac{V_2^2 - V_1^2}{2} = \underbrace{c_p (T_2 - T_1)}_{\text{gas perfetto}} + \frac{V_2^2 - V_1^2}{2}$$

→ > 0 Operatrice (compressore)

→ < 0 Motrice (turbina)

- Adiabatica + Ideale (Reversibile): 1 → 2 ISO-S

$T ds = dh - v dP$

↓ ISO-S $ds = 0$

$dh = v dP$

↓ Gas Perfetto

$$c_p dT = \frac{R^*}{P} T dP \longrightarrow c_p \frac{dT}{T} = R^* \frac{dP}{P} \rightarrow c_p \ln\frac{T_2}{T_1} = R \ln\frac{P_2}{P_1}$$

p T p · T_1 p_1

$$T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{R^*/c_p}$$ (TRASFORMAZIONE POLITROPICA $n = \gamma = \frac{c_p}{c_v}$)

$$T_2 = 472,3\,K = 199,17\,°C$$

aria (fluido comprimibile)

$$l = 175920,6\ J/Kg > 0$$ (OPERATRICE, COMPRESSORE)

$$\dot{W} = \dot{m}\, l \implies \dot{m} = \frac{\dot{W}}{l} = 5,68\ Kg/s$$

DATO: 1 MW

PORTATA MASSICA: $\dot{m} = \rho V S$

$$\rho = \frac{p}{R^* T} = \frac{\dot{m}}{\dot{V}}$$

$\rho_1 = 1,168\ Kg/m^3$

$\rho_2 = 3,688\ Kg/m^3$

$S_1 = 0,0486\ m^2$

$S_2 = 0,014\ m^2$

ESE_12

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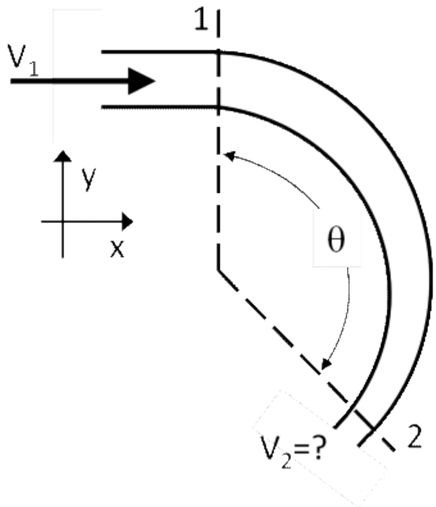


*** DATI ***

$\dot{V}_1 = 0{,}424\, m^3/s$ (ACQUA LIQUIDA)

$D_1 = 0{,}3\, m \quad D_2 = 0{,}2\, m$

$P_1 = 96{,}4\, kPa$ (FLUSSO IDEALE: $\mu = 0$)

$\theta = 135°C \quad -R_3$? (TUBO SU PIANO ORIZZONTALE)

*** CONS. Q. MOTO ***

$$\vec{G} - \vec{\Pi}_1 - \vec{\Pi}_2 + \vec{R}_3 = \dot{m}\,(\vec{V}_2 - \vec{V}_1)$$

$\underbrace{\dot{V}_1}_{\text{DATO}} = V_1 \underbrace{A_1}_{\frac{\pi D_1^2}{4}} \Rightarrow V_1 = 6\, m/s$; $\boxed{V_2 = V_1 \frac{A_1}{A_2}} = 13{,}5\, m/s$ ($\rho = cost$)

CONS. MASSA

COMPONENTI SPINTA $R_3 = \vec{M}_2 - \vec{M}_1 + \vec{\Pi}_1 + \vec{\Pi}_2 - \vec{G}$ (SPINTA PARETE SU FLUIDO) REGIME STAZIONARIO

① IL PESO $\vec{G}$ È VERTICALE (NESSUNA COMPONENTE SUL PIANO ORIZZONTALE)

② $|\vec{M}_1| = \dot{m}\,|\vec{V}_1| = \underbrace{\rho A_1 V_1}_{\text{PORTATA MASSICA}} \cdot V_1 = 2543\, N$

$|\vec{M}_2| = \dot{m}\,|\vec{V}_2| = \rho A_2 V_2 \cdot V_2 = 5722\, N$

$P_2 = P_1 + \rho\, \frac{V_1^2 - V_2^2}{2} = 23314{,}6\, Pa$ (eq. CONS. ENERGIA FLUIDI $\rho = cost$, $z_1 = z_2$)

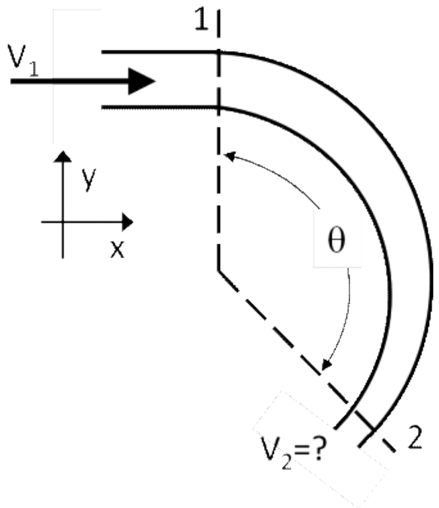
$|\Pi_2| = P_2 A_2 = 732{,}45\, N$

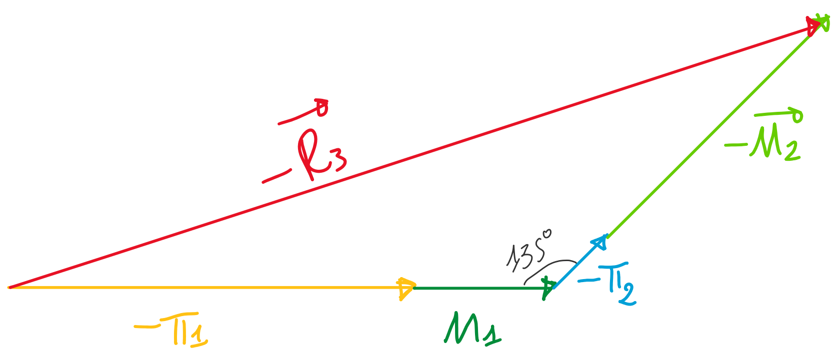
$|\Pi_1| = P_1 A_1 = 6814\,N$

(3) SU PIANO ORIZZONTALE X-Y LE COMPONENTI DELLA SPINTA SONO:

$$\underbrace{-\vec{R_3}}_{\text{SPINTA FLUIDO SULLA PARETE}} = \vec{M_1} - \vec{M_2} - \vec{\Pi_1} - \vec{\Pi_2}$$

($\vec{G}$ solo direzione lungo z)





$$|-R_{3,x}| = |\Pi_1|+|M_1| + (|\Pi_2|+|M_2|)\cos(180° - \theta) = 13922\ N$$

$$|-R_{3,y}| = (|\Pi_2|+|M_2|)\operatorname{sen}\theta = 4564\ N$$

$$|-R_{3,z}| = -|G|$$

$$|-R_{3,xy}| = \sqrt{|R_{3,x}|^2+|R_{3,y}|^2} = 14651\ N$$

$\underline{\theta_{MAX}\ ?}$ (ANGOLO DELLA CURVA CHE IMPLICA LA MASSIMA SPINTA SUL PIANO X-Y)

$a = |\Pi_1|+|M_1|$; $b = |\Pi_2|+|M_2|$ (sostituzione solo per semplificare)

$$R_{3,oriz} = \left[(a - b\cos\theta)^2 + (b\operatorname{sen}\theta)^2\right]^{1/2} = (a^2+b^2-2ab\cos\theta + b\operatorname{sen}^2\theta)^{1/2} =$$

$$= (a^2+b^2-2ab\cos\theta)^{0,5}$$

$$\frac{dR_{3,\text{minima}}}{d\theta} = \frac{1}{2}\left(a^2+b^2-2ab\cos\theta\right)\cdot\left(2ab\,\text{sen}\,\theta\right) = 0$$

$$\Downarrow$$

$$\theta_{MAX} = 180°$$

$$\left.\frac{dR_{3,\text{minima}}}{d\theta}\right|_{\theta_0} = 0 = f'(x_0) \Longrightarrow \theta_0 \quad \text{Punto Stazionario}$$

$f'(x) > 0$ SE $0 < x < \pi$

$f'(x) < 0$ SE $\pi < x < 2\pi$