ESAME 06/07/2018 SISTEMI ENERGETICI PER INGEGNERIA FISICA

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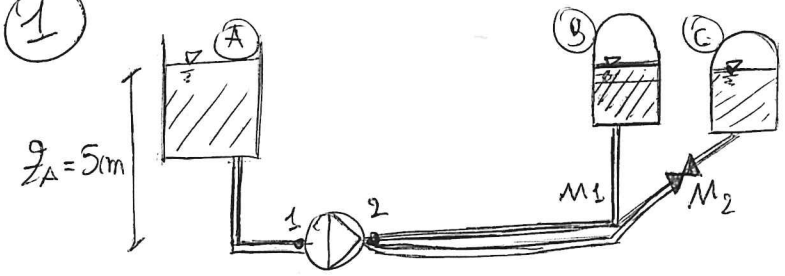


$P_A = 1\ atm \quad P_B = P_C = 6\ bar$

$L_{ASP} = 100m \quad D_{ASP} = 80\ mm$

$L_{M1} = 50\ m \quad D_{M1} = 40\ mm$

$L_{M2} = 50\ m \quad D_{M2} = 45\ mm$

$\dot{V} = 10\ \frac{m^3}{h}$ (PORTATA VOLUMETRICA)

TUBI LISCI: $f = \frac{0,079}{Re^{0,25}}$

* TUBO ASPIRAZIONE *

$$v_{ASP} = \frac{\dot{m}}{\rho \frac{\pi D_{ASP}^2}{4}} = 0,553\ m/s \qquad \dot{m} = \dot{V}\left[\frac{m^3}{h}\right] 3500 \left[\frac{s}{h}\right] \cdot \rho\left[\frac{kg}{m^3}\right] = 2,19\ kg/s$$

$$\frac{P_A}{\rho} + \cancel{\frac{v_A^2}{2}} + g z_A = \frac{P_1}{\rho} + \frac{v_1^2}{2} + \cancel{g z_1} + \cancel{Y_{ASP}} \qquad \begin{pmatrix} v_A = 0\ m/s \\ z_1 = 0\ m \end{pmatrix}$$

$$Y_{ASP} = f \frac{L_{ASP}}{D_{ASP}} \frac{v_{ASP}^2}{2} = \frac{0,079}{\left(\rho \frac{v_{ASP} D_{ASP}}{\mu}\right)^{0,25}} \cdot \frac{L_{ASP}}{D_{ASP}} \frac{v_{ASP}^2}{2} = 1,155\ J/kg$$

$$P_1 = \left(\frac{P_A}{\rho} + g z_A - \frac{v_1^2}{2} - Y_{ASP}\right)\rho = 1,377\ bar \qquad (\text{PRESSIONE ASPIRAZIONE POMPA})$$

* ANGOLO CHIUSURA VALVOLA * → PER EQUIDISTRIBUZIONE DELLA PORTATA SU M_1 E M_2

$$\dot{m}_{M1} = \dot{m}_{M2} = \frac{\dot{m}_{ASP}}{2} = 1,096\ kg/s$$

$$\frac{P_2}{\rho} + \frac{v_2^2}{2} + g z_2 = \frac{P_B}{\rho} + g z_B + Y_{M1}$$

$$\frac{P_2}{\rho} + \frac{v_2^2}{2} + g z_2 = \frac{P_C}{\rho} + g z_C + Y_{M2} + (K_C) \rightarrow \text{PERDITA DOVUTA ALLA VALVOLA}$$

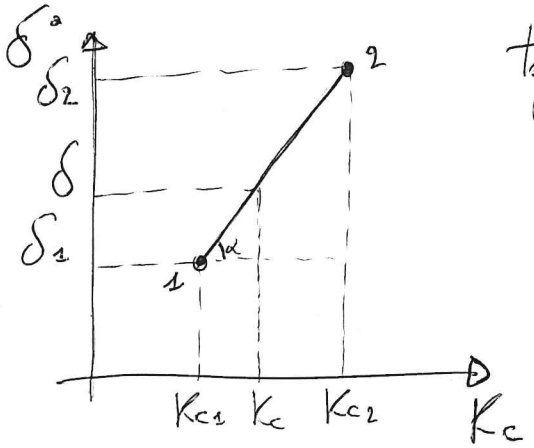
$$\frac{P_B}{\rho} + g z_B + \gamma_{M1} = \frac{P_C}{\rho} + g z_C + \gamma_{M2} + K_C$$

$$f_{M1} \frac{L_{M1}}{D_{M1}} \frac{v_{M1}^2}{2} = f_{M2} \frac{L_{M2}}{D_{M2}} \frac{v_{M2}^2}{2} + K_C \frac{v_{M2}^2}{2}$$

$$v_{M1} = \frac{m_{M1}}{\left(\rho \frac{\pi D_{M1}^2}{4}\right)} = 1{,}11 \text{ m/s} \qquad v_{M2} = \frac{m_{M2}}{\rho \frac{\pi D_{M2}^2}{4}} = 0{,}873 \text{ m/s}$$

$$Re_{M1} = \frac{\rho v_{M1} D_{M1}}{\mu} = 29067{,}9 \qquad Re_{M2} = \frac{\rho v_{M2} D_{M2}}{\mu} = 25838$$

$$K_C = \left[\frac{2L_M}{v_{M1}^2}\right]\left[f_{M1} \frac{v_{M1}^2}{D_{M1} \cdot 2} - \frac{v_{M2}^2}{D_{M2} \cdot 2} f_{M2}\right] = \left[\frac{0{,}079}{2 \cdot Re_{M1}^{0{,}25}} \frac{v_{M1}^2}{D_{M1}} - \frac{v_{M2}^2}{2 D_{M2}} \frac{0{,}079}{Re_{M2}^{0{,}25}}\right] \Big/ \left[\frac{2L_M}{v_{M2}^2}\right]$$



$$tg\,\alpha = \frac{\delta_2 - \delta_1}{K_{C2} - K_{C1}} \qquad K_C = 5{,}19$$

$$\Downarrow$$

$$\delta = \delta_1 + tg\,\alpha \,(K_C - K_{C1}) = 28{,}2°$$

POTENZA RICHIESTA POMPA

$$\frac{P_A}{\rho} + \frac{v_A^2}{2} + g z_A = \frac{P_B}{\rho} + \frac{v_B^2}{2} + g z_B + \gamma_{ASP} + \gamma_{M1} - \ell_{POMPA,ID}$$

$$-\left(\frac{P_A}{\rho} - \frac{P_B}{\rho}\right) + \left(\gamma_{ASP} + \gamma_{M1}\right) = \ell_{POMPA,ID} = 633{,}93 \text{ J/Kg}$$

$$P_{ELETTRICA} = \dot{m}_{ASP} \frac{\left(\ell_{POMPA} + c_p \Delta T\right)}{\eta_{ORG-EL}} = 1{,}57 \text{ KW}$$

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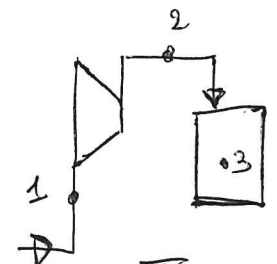


$T_1 = T_2 = T_3 = 10°C$

$V_3 = 0{,}5\ m^3$

$P_1 = 1\ bar$

$P_3 = 45\ bar$ (FINE RIEMPIMENTO)

$\dot{m}_1 = 0{,}1\ \frac{kg}{s}$ (PORTATA ASPIRATA DAL COMPRESSORE)

$$\dot{V}_1 = \frac{\dot{m}_1}{\rho_1} = \frac{\dot{m}_1}{\frac{P_1}{R^* T_1}} = 0{,}0841\ \frac{m^3}{s}$$

(GAS PERFETTO $R^* = \frac{R}{MM} =$)

ALLA FINE DEL RIEMPIMENTO

$$\rho_3 = \frac{P_3}{R^* T_3} = 53{,}5\ kg/m^3 \qquad M_3 = V_3\ \rho_3 = 26{,}8\ kg$$

(MASSA CONTENUTA NELLA BOMBOLA)

$$c_v = \frac{5}{2} R^* \qquad c_p = c_v + R^* = \frac{7}{2} R^* = 1033{,}25\ J/kg$$

$$t = \frac{M_3}{\dot{m}_1} = 268\ s$$

(TEMPO PER RIEMPIRE LA BOMBOLA)

$$\rightarrow P_{compr} = \dot{m}_1 \frac{R}{MM} T_1 \ln \frac{P_3}{P_1}$$

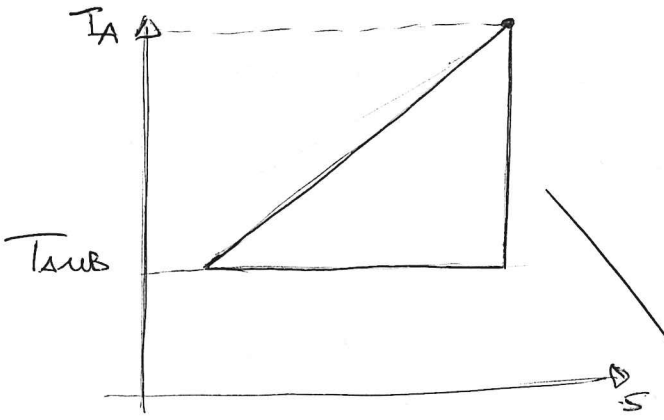
(COMPRESSIONE ISOTERMA) $E_{compr} = P_{compr} \cdot t$

ENERGIA SOTTRATTA IN QUESTO MODO ALLA ENERGIA CONSUMATA DAL COMPRESSORE NEL PROCESSO DI RIEMPIMENTO POICHÉ LA PRESSIONE DI SCARICO DEL COMPRESSORE AUMENTA COSTANTEMENTE (LA BOMBOLA SI RIEMPIE) MENTRE NELLA REALTÀ FORNITA LA PRESSIONE DI SCARICO È SEMPRE QUELLA MASSIMA

$\rightarrow$ NEL CASO IN CUI $z = 0{,}99$ $\dot{m}_1 = 0{,}1\ kg/s$ (RIMANE LO STESSO)

$$M_3 = V_3 \cdot \rho_{3\,REALE} = V_3 \cdot \left(\frac{P_3}{R^* T_3} / z\right) = 27\ kg$$

(3) $\dot{m}_F = 125\ kg/s$ $\quad T_A = 325°C$ $\quad T_{AMB} = 25°C$



$$\eta_{MAX} = 1 - \frac{T_{AMB}}{T_{ml}} = 1 - \frac{T_{AMB}}{\frac{T_A - T_B}{\ln \frac{T_A}{T_B}}} = 0{,}308$$

$$P_{MAX} = \dot{m}_F c_{p_F} \left(T_A - T_{AMB} \right) \cdot \eta_{MAX} = 12322\ kW$$

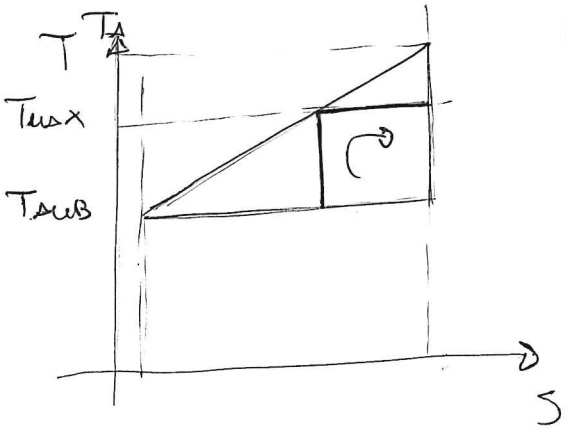
→ LA MASSIMA POTENZA SI OTTIENE CON UN CICLO TRIANGOLARE

* CICLO REALE * $\eta_{II} = 0{,}60$

$$\eta_{REALE} = \eta_{MAX} \cdot \eta_{II} \qquad \dot{Q}_{IN} = \dot{m}_F c_p \left(T_A - T_B \right)$$

$$P_{REALE} = \eta_{REALE} \dot{Q}_{IN} = 7690\ kW$$

* TEMPERATURA MASSIMA DEL CICLO DI CARNOT CHE MASSIMIZZA LA POTENZA *



$$\dot{Q}_{IN} = \dot{m}_F c_p \left(T_A - T_{MAX} \right)$$

$$\eta_{CARNOT} = 1 - \frac{T_{AMB}}{T_{MAX}}$$

$$P_{CARNOT} = \dot{Q}_{IN} \cdot \eta_{CARNOT} = \dot{m}_F c_p \left(T_A - T_{MAX} \right) \left(1 - \frac{T_{AMB}}{T_{MAX}} \right)$$

$$= \left(\dot{m}_F c_p T_A - \dot{m}_F c_p T_{MAX} \right) \left(1 - \frac{T_{AMB}}{T_{MAX}} \right) = \dot{m}_F c_p T_A - \dot{m}_F c_p \frac{T_A \cdot T_{AMB}}{T_{MAX}} -$$

$$- \dot{m}_F c_p T_{MAX} + \dot{m}_F c_p T_{AMB}$$

$$\frac{\partial P_{CARNOT}}{\partial T_{MAX}} = \dot{m}_F c_p \frac{T_A \cdot T_{AMB}}{T_{MAX}^2} - \dot{m}_F c_p = 0 \quad \left(\text{CALCOLIAMO PER MASSIMA POTENZA} \right)$$

$$\Downarrow$$

$$T_{MAX} = \sqrt{T_{AMB} \cdot T_A} = 422{,}3\ K$$

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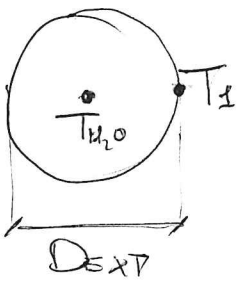

$D_{EXT} = 70\,mm \qquad L = 400\,m$

$T_{H_2O} = T(P_{SAT} = 50\,bar)$ (LA T DEL FLUIDO È QUELLA IN CONDIZIONI SATURE (ENTRA LIQ. SATURO ED ESCE VAP. SATURO))

RESISTENZA CONVETTIVA INTERNA E RESISTENZA CONDUTTIVA TRASCURABILE

$T_{H_2O} = T_1$ (SUP. ESTERNA DEL TUBO) $= 263,34°C$

* COEFF. SCAMBIO CONVETTIVO ESTERNO **

$T_{Film} = \frac{T_1 + T_{AMB}}{2} = 139,67°C$

$c_p = 1013,245\ J/kgK \qquad \mu = 2,353 \cdot 10^{-5}\ Pa \cdot s \qquad K = 0,03476\ \frac{W}{mK} \qquad Pr = 0,686$

$Re = \frac{\rho v D_{EXT}}{\mu} = \frac{\frac{p}{\frac{R}{MM} T_{Film}} v D_{EXT}}{\mu} = 2564,64$ (SCELTA CORRELAZIONE)

$Nu = c\, Re^{e} Pr^{1/3} \Rightarrow Nu = \frac{h D_{EXT}}{K} = 23,27$

$\Rightarrow h = \frac{Nu K}{D_{EXT}} = 11,557\ W/m^2K$

* POTENZA TERMICA DISSIPATA VERSO L'AMBIENTE **

$\Phi_{AMB} = \Phi_{conv} + \Phi_{rad} = h \pi D_{EXT} L_{TUBO} (T_1 - T_{AMB}) + A_{TUBO} \varepsilon \sigma (T_1^4 - T_{AMB}^4)$

$= 348,247\ kW$

$$\Phi_{ASSORBITA} = \Phi_{INC} \cdot \alpha = 1080 \text{ KW}$$

$$\Phi_{H_2O} = \Phi_{ASSORBITA} - \Phi_{AUB} = 731,75 \text{ KW}$$

$$\dot{m}_{H_2O} = \frac{\Phi_{H_2O}}{\Delta h_{EVAP}(P_{SAT} = 50 \text{ bar})} = 0,446 \text{ kg/s}$$

$$\Delta h_{EVAP}(P_{SAT} = 50 \text{ bar}) = 1639,56 \frac{\text{KJ}}{\text{kg}}$$