ESAME "SISTEMI ENERGETICI PER ING. FISICA"
04/07/2019

(1) CICLO A VAPORE RANKINE SURRISCALDATO + RIG. A SUPERFICIE

$$\dot{m}_2 = \dot{m}_1 = \dot{m}_6 = \dot{m}_5 = 350\ kg/s$$

$$\dot{m}_3 = 0{,}1 \cdot \dot{m}_2 = 35\ kg/s = \dot{m}_3^*$$

$$\dot{m}_4 = \dot{m}_2 - \dot{m}_3 = 315\ kg/s \quad \text{(Bilancio massa sulla Turbina)}$$

$$\left.\begin{aligned} P_2 &= 150\ bar = P_1 = P_6 \\ P_3 &= 20\ bar = P_3^* \\ P_4 &= P_5 = 0{,}1\ bar \end{aligned}\right\} \text{no } \Delta P \text{ negli scambiatori}$$

Punti ciclo Termodinamico (cfr. diagramma T-s)

$$h_2 = h(P_2, T_2) = 3296{,}4\ \frac{kJ}{kg} \qquad s_2 = 6{,}496\ \frac{kJ}{kg\,K}$$

$$h_3 = h(P_3;\ s_3 = s_2) = 2876{,}4\ \frac{kJ}{kg} \qquad T_3 = 239{,}7\ °C \quad \text{(espansione isoentropica)}$$

$$h_3^* = h(P_3^* = P_3;\ x_3^* = 0) = 908{,}62\ \frac{kJ}{kg} \qquad T_3^* = 212{,}4\ °C$$

$$h_4 = h(P_4;\ s_2 = s_4) = 2056{,}5\ \frac{kJ}{kg} \qquad T_4 = 45{,}8\ °C$$

$$h_5 = h(P_5 = P_4;\ x_5 = 0) = 191{,}8\ \frac{kJ}{kg} \qquad T_5 = 45{,}8\ °C$$

$$P_{TV} = \dot{m}_2 (h_2 - h_3) + (m_2 - m_3)(h_3 - h_4) = 405{,}25\ MW$$

$$P_{pompa} = \dot{m}_5 (h_6 - h_5) = 3{,}52\ MW$$

$$\dot{Q}_{IN} = \dot{m}_1 (h_2 - h_1) = 1121{,}07\ MW$$

$$\eta_{EL} = \frac{P_{TV} - P_{pompa}}{\dot{Q}_{IN}} = \frac{P_{NETTA}}{\dot{Q}_{IN}} = 0{,}3583$$

BILANCIO RIGENERATORE

$$\dot{m}_6 h_6 + \dot{m}_3 h_3 = \dot{m}_3^{\#} h_3^{\#} - \dot{m}_2 h$$

$$\Downarrow$$

$$h_1 = 398{,}64\ \frac{kJ}{kg}$$

$$T_1 = 93{,}3°C$$

(2) $\gamma_{N_2} = 1{,}4 \quad \Theta = \frac{\gamma - 1}{\gamma} = 0{,}2857$ (GAS PERFETTO BIATOMICO)

$\beta_1 = 5 \quad \beta_2 = 5$

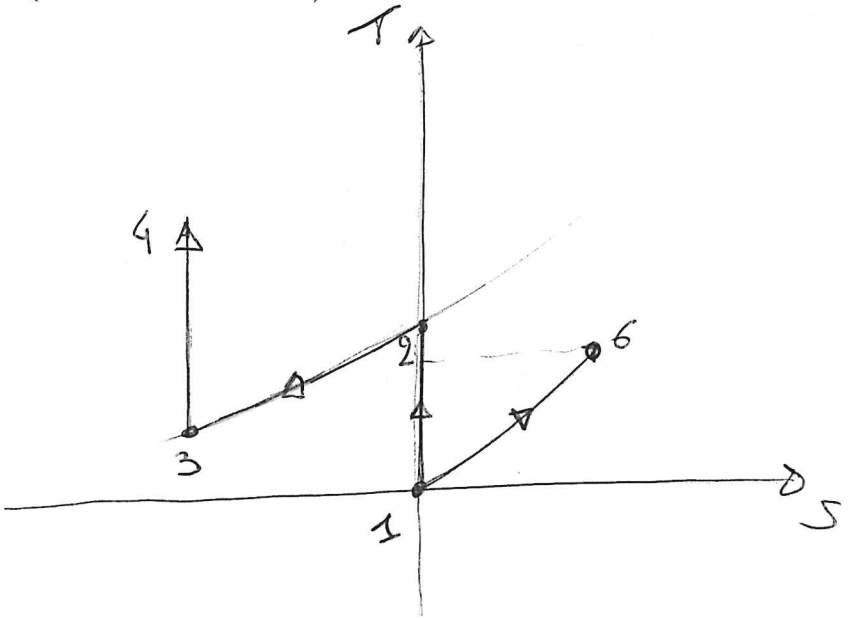
$$T_{2,IS} = T_1 \beta_1^{\Theta} = 472\ K \qquad S_2 = S_1 \text{ (ISOENTROPICA)}$$

$$T_{4,IS} = T_3 \beta_2^{\Theta} = 496\ K \qquad S_4 = S_3 = c_p \ln \frac{T_3}{T_1} - R^* \ln \beta = -426{,}9\ \frac{J}{kgK}$$

BILANCIO ALLO SCAMBIATORE

$$\dot{m}_5 c_p (T_6 - T_5) = \dot{m}_3 c_p (T_2 - T_3) \qquad T_6 = T_2 - 10° = 462\ K$$

$$\dot{m}_5 = \frac{\dot{m}_3 c_p (T_2 - T_3)}{c_p (T_2 - 10° - T_5)} = 4{,}847\ \frac{kg}{s} \qquad s_6 = c_p \ln \frac{T_6}{T_1} - R^* \ln 1 = 455\ \frac{J}{kgK}$$



(3) BILANCIO TRA PELO LIBERO DEL SERBATOIO 1 E USCITA 2

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + g z_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + g z_2 + \Upsilon$$

$P_1 = P_2 = 1\ atm$

$V_1 = 0\ m/s$

$z_1 - z_2 = 5\ m\ (dato)$

$$\Upsilon = f \frac{L}{D} \frac{V_2^2}{2}$$

$$\Downarrow$$

$$V_2 = \left[\left(g \Delta z_{12} \right) / \left(\frac{1}{2} \left(1 + f \frac{L}{D} \right) \right) \right]^{0,5} = 6,143\ m/s$$

$$\dot{m}_2 = \rho A V_2 = 9,046\ kg/s$$

(X MANTENERE IL LIVELLO NEL SERBATOIO 3 INALTERATO, LA PORTATA ENTRANTE DALLA POMPA DEVE ESSERE UGUALE A $\dot{m}_2$)

$\dot{m}_{POMPA} = \dot{m}_2$

- LA PORTATA SI DISTRIBUISCE IN MODO UGUALE TRA GLI 8 TUBI

$$\frac{\dot{m}_{POMPA}}{8} = \dot{m}_{MANDATA} = 1,131\ kg/s \qquad V_M = \frac{\dot{m}_{MANDATA}}{\rho A_M} = 4,8\ m/s$$

$$\Upsilon_{M,DISTR} = f_M \frac{L_M}{D_M} \frac{V_M^2}{2} = 138\ J/kg \quad (L_M = 20\ m)$$

$$\Upsilon_{M,CONC} = K_C \frac{V_M^2}{2} = 69\ J/kg \quad (K_C = 6)$$

$$\Upsilon_{TOT} = 207,26\ J/kg$$

$$\Upsilon_{TOT} = \Upsilon_{M,DISTR} + \Upsilon_{M,CONC}$$

$$\frac{P_3}{\rho} + \frac{V_3^2}{2} + g z_3 + l_{1D} = \frac{P_4}{\rho} + \frac{V_4^2}{2} + g z_4 + \Upsilon_{TOT}$$

$V_3 = 0$, $V_4 = 0$, $z_4 = 0$

$$l_{1D} = \frac{(P_4 - P_3)}{\rho} - g z_3 + \Upsilon_{TOT} = 255,2\ J/kg$$

$$P_{EL,pompa} = \frac{\dot{m}_{pompa} \cdot l_{1D}}{\eta_{idr} \cdot \eta_{acc-el}} = 3{,}37 \text{ kW}$$

$$E = P_{EL,pompa} \cdot \Delta h = 20{,}2 \text{ kWh}$$

- SE SI AUMENTASSE 2, IL LIVELLO DEL BACINO DIMINUIREBBE E LA POTENZA DELLA POMPA AUMENTEREBBE POICHÉ NEL BILANCIO, $z_3 \downarrow$

(4) $$\dot{Q}_{GENERATA} = \dot{q}_{GEN} \cdot \frac{\pi}{4}\left(D_3^2 - D_2^2\right) \cdot L = 2{,}31 \text{ MW}$$

$$R_{CONV,EXT} = \frac{1}{h_{EXT} \cdot A_{EXT}} = \frac{1}{h_{EXT} \cdot 2\pi D_{EXT} \cdot L} = 2{,}95 \cdot 10^{-3} \frac{K}{W}$$

$$R_{CONV,INT} = \frac{1}{h_{INT} \cdot A_{INT}} = 1{,}6977 \frac{K}{W}$$

$$R_{COND} = \frac{\ln D_4/D_3}{2\pi K L} = 3{,}52 \cdot 10^{-5} \text{ K/W}$$

$$\dot{Q}_{EXT} = h_{EXT} \cdot A_{EXT}\left(T_4 - T_\infty\right) = 18{,}7 \text{ kW}$$

T_4: 80°C, T_∞: 25°C

$$\dot{Q}_{FLUIDO} = \dot{Q}_{GEN} - \dot{Q}_{EXT} = 2{,}29 \text{ MW}$$

$$\dot{Q}_{FLUIDO} = h_{INT} A_{INT}\left(T_2 - T_1\right) \Longrightarrow T_2 = 303\,^\circ\text{C}$$

T_1: 264°C (da diagramma T-s)

$$\dot{Q}_{EXT} = T_4 + R_{34} \cdot \dot{Q}_{EXT} = T_3 = 86{,}6\,^\circ\text{C}$$

$$\dot{m}_{H_2O} \cdot \Delta h_{H_2O} = \dot{Q}_{FLUIDO} \Longrightarrow \dot{m}_{H_2O} = 1{,}998 \text{ kg/s}$$

(4)