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A P P U N T I

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MATERIA: Fondamenti di Macchine - Formulario - Prof. Poggio

FORMULARIO FONDAMENTI DI MACCHINE

$$\boldsymbol{y = \frac{x - x_1}{x_2 - x_1}(y_2 - y_1) + y_1} \ interpolazione\ lineare$$

$$\boldsymbol{x = \frac{v - v_l}{v_v - v_l}} \ titolo\ in\ funzione\ del\ volume\ specifico$$

$$\boldsymbol{x = \frac{i - i_l}{i_v - i_l}} \ titolo\ in\ funzione\ del'entalpia$$

$$\boldsymbol{x = \frac{s - s_l}{s_v - s_l}} \ titolo\ in\ funzione\ del'entropia$$

Capitolo 1: *richiami di termodinamica*

$$\boldsymbol{m = \frac{c_p - c}{c_v - c}} \ relazione\ tra\ calori\ specifici\ e\ esponente\ politropica$$

<u>PRIMO PRINCIPIO</u>

<u>Forma lagrangiana</u>

$$Q_e + L_e = \Delta U^* + \Delta E_c + \Delta E_g + \Delta E_{cf}$$

$$L_e = -\int_1^2 pdv + L_w + \Delta E_c + \Delta E_g + \Delta E_{cf}$$

$$Q_e = \int_1^2 pdv - L_w + \Delta U^*$$

<u>Forma euleriana</u>

$$Q_e + L_e = \Delta i^* + \Delta E_c + \Delta E_g + \Delta E_{cf}$$

$$L_e = \int_1^2 vdp + L_w + \Delta E_c + \Delta E_g + \Delta E_{cf}$$

$$Q_e = \int_1^2 pdv - L_w + \Delta i^*$$

<u>RECUPERO E CONTRO RECUPERO</u>

<u>Contro recupero</u>

$$L_{i,is} = \Delta i_{is} = c_p(T_{2is} - T_1) = \boldsymbol{c_p T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right]}$$

$$L_i = \Delta i = c_p(T_2 - T_1) = \boldsymbol{c_p T_1 \left[\left(\frac{p_2}{p_1}\right)^{\frac{m-1}{m}} - 1\right]}$$

Capitolo 2: flusso di aeriformi nei condotti

$$\boldsymbol{c_s = \sqrt{k\frac{p}{\rho}} = \sqrt{kRT}}$$

$\boldsymbol{k = \frac{\ln^{p_2}/_{p_1}}{\ln^{\rho_2}/_{\rho_1}}}$ *espressione calcolo approssimato k nel caso di vapore da lettura diagramma Mollier*

$$\boldsymbol{Ma = \frac{c}{c_s}}$$

$$\frac{T^0}{T} = 1 + \frac{k-1}{2} * Ma^2$$

$$\frac{p^0}{p} = \left(1 + \frac{k-1}{2} * Ma^2\right)^{\frac{k}{k-1}}$$

$$\frac{\rho^0}{\rho} = \left(1 + \frac{k-1}{2} * Ma^2\right)^{\frac{1}{k-1}}$$

Se il fluido è incomprimibile

$$p^0 = p + \rho\frac{c^2}{2}$$

<u>ARRESTO ISOENTROPICO, GRANDEZZE TOTALI</u>

$$\boldsymbol{i^0 = i + \frac{c^2}{2}}$$

$$\boldsymbol{T^0 = T + \frac{c^2}{2c_p}}$$

$$\boldsymbol{p^0 = p\left(\frac{T^0}{T}\right)^{\frac{k}{k-1}}}$$

$$\boldsymbol{\rho^0 = \rho\left(\frac{T^0}{T}\right)^{\frac{1}{k-1}}}$$

<u>UGELLO O EFFUSORE</u>

$$c_{2is} = \sqrt{2(i_{1is}^0 - i_{2si})} = \sqrt{2c_p(T_{1is}^0 - T_{2is})} = \sqrt{\boldsymbol{2\frac{k}{k-1} * \frac{p_1^0}{\rho_1^0}\left[1 - \left(\frac{p_2}{p_1^0}\right)^{\frac{k-1}{k}}\right]}}$$

$$\boldsymbol{c_2 = \varphi * c_{2is}}$$

$$\boldsymbol{\dot{m} = \rho_u A_u c_u = A_u \frac{p_1^0}{\sqrt{p_1^0/\rho_1^0}} * \sqrt{2\frac{k}{k-1}\left[\left(\frac{p_u}{p_1^0}\right)^{\frac{2}{k}} - \left(\frac{p_u}{p_1^0}\right)^{\frac{k+1}{k}}\right]} = A_u \frac{p_1^0}{\sqrt{p_1^0/\rho_1^0}} * f\left(k, \frac{p_u}{p_1^0}\right)}$$

Se $p_2 < p_{u,lim}$

$$\boldsymbol{\dot{m}_{cr} = \rho_r A_r c_{r,s} = A_r \frac{p_1^0}{\sqrt{p_1^0/\rho_1^0}} * \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = A_r \frac{p_1^0}{\sqrt{p_1^0/\rho_1^0}} * f(k)}$$

<u>Calcolo pressione limite</u>

Possibilità 1

$$\boldsymbol{A_r \sqrt{k\left(\frac{2}{k+1}\right)^{\frac{k+1}{k-1}}} = A_u \sqrt{2\frac{k}{k-1}\left[\left(\frac{p_u}{p_1^0}\right)^{\frac{2}{k}} - \left(\frac{p_u}{p_1^0}\right)^{\frac{k+1}{k}}\right]}}$$

Possibilità 2

$$\left(\frac{\dot{m} A_r}{\dot{m}_{cr} A_u}\right)^2 + \left(\frac{p_u - p_{u,cr}}{p_1^0 - p_{u,cr}}\right)^2 = 1$$

Con $\dot{m} = \dot{m}_{cr}$

Capitolo 3: introduzione alle turbomacchine

<u>RICHIAMI DI FLUIDODINAMICA</u>

$$\dot{m}_1 = \dot{m}_2 = \rho_1 A_1 c_1 \cos\theta_1 = \rho_2 A_2 c_2 \cos\theta_2$$

$$\vec{F} + p_1 A_1 \vec{n}_1 - p_2 A_2 \vec{n}_2 = \dot{m}(\vec{c}_2 - \vec{c}_1)$$

$$M_a = \dot{m}(r_2 c_{u2} - r_1 c_{u1})$$

<u>Lavoro interno</u>

$$C_{p \to f} = \dot{m}(r_2 c_{u2} - r_1 c_{u1})$$

$$\boldsymbol{C = \dot{m}(r_1 c_{u1} - r_2 c_{u2})}$$

$$\boldsymbol{P_i = C\omega = \dot{m}(u_1 c_{u1} - u_2 c_{u2})}$$

$$\boldsymbol{L_i = \frac{P_i}{\dot{m}} = (u_1 c_{u1} - u_2 c_{u2}) = \frac{(c_1^2 - c_2^2) + (w_2^2 - w_1^2) + (u_1^2 - u_2^2)}{2}}$$

$$\boldsymbol{\eta_{\theta i} = \frac{L_i}{L_{i,lim}} = \frac{L_i}{i_0^0 - i_{1,is}} = \frac{L_i}{c_{1,is}^2/2} = \frac{2\varphi^2 * L_i}{c_1^2} = \frac{2\varphi^2 * (1+\psi) * u * (c_1 \cos\alpha_1 - u)}{c_1^2} =}$$

$$\boldsymbol{\eta_{\theta i} = 2\varphi^2 * (1+\psi) * \sigma(\cos\alpha_1 - \sigma)}$$

TURBINA ASSIALE A REAZIONE

$$\chi = \frac{|\Delta i_{is,g}|}{|\Delta i_{is,d}| + |\Delta i_{is,g}|}; R = \frac{|\Delta i_g|}{|\Delta i^0|} = \frac{w_2^2 - w_1^2 + u_1^2 - u_2^2}{c_1^2 - c_2^2 + w_2^2 - w_1^2 + u_1^2 - u_2^2}$$

Ipotesi importante: triangoli di velocità simmetrici implica

$|w_2| = |c_1|;\ |w_1| = |c_2|;\ \alpha_1 + \beta_2 = \pi; \alpha_2 + \beta_1 = \pi$

Funzionamento ideale

$$i_0^0 - i_{2,is} = (i_0^0 - i_{1,is}) + (i_{1,is} - i_{2,is}) = \frac{c_{1,is}^2}{2} + \frac{w_{2,is}^2}{2} - \frac{w_1^2}{2}$$

$$\boldsymbol{L_i = u_1 c_{u1} - u_2 c_{u2}}$$

Se $u_1 = u_2 = u$

$$\boldsymbol{L_i = u(c_{u1} - c_{u2}) = u(c_{1,is}\cos\alpha_1 - c_2\cos\alpha_2)}$$

$$\boldsymbol{\eta_{\theta i} = \frac{L_i}{L_{i,lim}} = \frac{L_i}{i_0^0 - i_{2,is}} = \frac{L_i}{(i_0^0 - i_{1,is}) + (i_{1,is} - i_{2,is})} = \frac{u(c_{1,is}\cos\alpha_1 - c_2\cos\alpha_2)}{\frac{c_{1,is}^2}{2} + \frac{w_{2,is}^2}{2} - \frac{w_1^2}{2}}}$$

$$\boldsymbol{-c_2\cos\alpha_2 = c_{1,is}\cos\alpha_1 - u; w_{2,is}^2 - w_1^2 = u(2c_{1,is}\cos\alpha_1 - u)}$$

$$\boldsymbol{L_i = u(2c_{1,is}\cos\alpha_1 - u) = u^2(2\frac{\cos\alpha_1}{\sigma} - 1)}$$

$$\boldsymbol{\eta_{\theta i} = \frac{2u(2c_{1,is}\cos\alpha_1 - u)}{c_{1,is}^2 + u(2c_{1,is}\cos\alpha_1 - u)} = 2\frac{(2\cos\alpha_1 - \sigma) * \sigma}{1 + (2\cos\alpha_1 - \sigma) * \sigma}}$$

$$\boldsymbol{\sigma_{opt} = \left(\frac{u}{c_1}\right)_{opt} = \cos\alpha_1;\ \ \eta_{\theta i,max} = \frac{2(\cos\alpha_1)^2}{(\cos\alpha_1)^2 + 1};\ L_{i,opt} = u^2}$$

Funzionamento reale

$$i_0^0 - i_{2,is} = (i_0^0 - i_{1,is}) + (i_{1,is} - i_{2,is})$$

$$(i_0^0 - i_{1,is}) = \frac{c_{1,is}^2}{2} = \frac{c_1^2}{2\varphi^2}$$

$$(i_{1,is} - i_{2,is}) \cong (i_1 - i_{2,is}^*) = \frac{w_{2,is}^2}{2} - \frac{w_1^2}{2} = \frac{w_2^2}{2\psi^2} - \frac{w_1^2}{2}$$

$$\frac{\boldsymbol{w_{2,is}^2}}{\mathbf{2}} - \frac{\boldsymbol{w_2^2}}{\mathbf{2}} = (\mathbf{1} - \boldsymbol{\psi^2})\boldsymbol{w_1^2} \; stadi\ ad\ azione\ |w_1| = |w_{2is}|$$

$$\boldsymbol{\eta_{\theta i}} = \frac{\boldsymbol{L_i}}{\boldsymbol{i_0^0} - \boldsymbol{i_{2,is}}} \; quando\ l'energiacinetica\ è\ persa, total\ to\ static\ efficiency$$

$$\boldsymbol{\eta_{\theta i}} = \frac{\boldsymbol{L_i}}{\boldsymbol{i_0^0} - \boldsymbol{i_{2,is}^0}} \; quando\ l'energiacinetica\ è\ recuperata, total\ to\ total\ efficiency$$

$$P_{w,dischi} = k_d \rho_1 d_m^2 u^3;\ P_{w,ventilante} = k_v \rho_1 d_m u^3 l_1 \varepsilon$$

$$\Delta i_{w,d} = \frac{P_{w,dischi}}{\dot{m}} \propto u^2; \Delta i_{w,v} = \frac{P_{w,ventilante}}{\dot{m}} \propto \varepsilon * u^2$$

$$\sum P_m = P_{w,dischi} + P_{w,ventilante} + P_{w,cuscinetti} + P_{w,ausiliari}$$

$$\eta_m = 1 - \frac{\sum P_m}{P_i}$$

$$\sum \dot{m}_f = \dot{m}_{f,giochi} + \dot{m}_{f,fughe};\ \eta_f = 1 - \frac{\sum \dot{m}_f}{\dot{m}}$$

$$u = \pi d_m n;\ \pi d_m = \frac{u}{n} = \frac{c_{1,is}\sigma_{opt}}{n} = \frac{\varphi c_1 \sigma_{opt}}{n}$$

$$v_1 \dot{m} = \xi \pi d_m l_1 c_1 \sin\alpha_1 = \frac{\xi l_1 \varphi^2 c_{1,is}^2\, \sigma_{opt} \sin\alpha_1}{n} = \frac{\xi l_1 \varphi^2 2\, \sigma_{opt} \sin\alpha_1}{n} \Delta i_{is}$$

$$l_1 = \left[\frac{n}{\xi \varphi^2 2\, \sigma_{opt} \sin\alpha_1}\right] * \frac{v_1 \dot{m}}{\Delta i_{is}} = [costante] * \frac{v_1 \dot{m}}{\Delta i_{is}}$$

<u>Parzializzazione</u>

$$\boldsymbol{v_1 \dot{m}} = (\mathbf{1} - \boldsymbol{\varepsilon}) \boldsymbol{\xi \pi d_m l_1 c_1} \sin \boldsymbol{\alpha_1}$$

$$(\mathbf{1} - \boldsymbol{\varepsilon}) = \frac{\boldsymbol{v_1 \dot{m}}}{\boldsymbol{\xi \pi d_m l_1 c_1} \sin \boldsymbol{\alpha_1}} = \frac{\boldsymbol{v_1 \dot{m}}}{\boldsymbol{\xi \Delta i_{is} l_{1,min}}} \; dove\ l_{1,min} = max\{10mm; 0.01 \div 0.02\ d_m\}$$

Capitolo 5: turbocompressori

<u>GENERALITA' SUI TURBOCOMPRESSORI</u>

$$L_i = u'' c_u'' - u' c_u';\ L_i = c_p (T_2 - T_1);\ L_i = \int_1^2 v dp + L_w$$

$$\boldsymbol{\eta_{is}} = \frac{\boldsymbol{L_{i,is}}}{\boldsymbol{L_i}} = \frac{\left[\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}} - 1\right]}{\left[\left(\frac{p_2}{p_1}\right)^{\frac{m-1}{m}} - 1\right]} = \frac{\left[(\boldsymbol{\beta})^{\frac{\boldsymbol{k-1}}{\boldsymbol{k}}} - \mathbf{1}\right]}{\left[(\boldsymbol{\beta})^{\frac{\boldsymbol{m-1}}{\boldsymbol{m}}} - \mathbf{1}\right]}$$

$$\dot{m}v'' = \xi\pi l'' d'' w_r'' = \xi\pi \frac{l''}{d''} d''^2 \varphi u''$$

$$\varphi \propto \frac{\dot{m}v_1 v''}{d''^2 u''^{v_1}} \cong \frac{\dot{m}RT_1}{p_1 d''^2 u''} \propto \frac{\dot{m}\sqrt{RT_1}}{p_1 d''^2}\frac{\sqrt{RT_1}}{nd''}; \ \frac{\boldsymbol{\dot{m}\sqrt{RT_1}}}{\boldsymbol{p_1 d''^2}} \propto \frac{\boldsymbol{nd''}}{\boldsymbol{\sqrt{RT_1}}} * \boldsymbol{\varphi}$$

Ipotesi similitudine geometrica (le dimensioni sono tra loro in rapporti di scala costanti) e similitudine fluidodinamica ovvero triangoli di velocità simili in punti corrispondenti della macchina $\{\varphi = costante\ implica\ \psi, \zeta, \psi - \zeta, \eta_{y,c}\ sono\ costanti\}$

$$\boldsymbol{(\beta - 1) \propto \left[\frac{nd''}{\sqrt{RT_1}}\right]^2;\ \frac{\dot{m}\sqrt{RT_1}}{p_1 d''^2} \propto \frac{nd''}{\sqrt{RT_1}};\ (\beta - 1) \propto \left[\frac{\dot{m}\sqrt{RT_1}}{p_1 d''^2}\right]^2}$$

$$\eta_{is} = \frac{\beta^{\frac{k-1}{k}} - 1}{\beta^{\frac{k-1}{k} * \frac{1}{\eta_{y,c}}} - 1}$$

Capitolo 6: turbopompe

$$L_i = u'' c_u'' - u' c_u';\ L_i = \int_1^2 v dp + L_w + \Delta E_c + \Delta E_g = v\Delta p + L_w + \Delta E_c + \Delta E_g$$

$$L_i = \frac{p_1 - p_2}{\rho} + \frac{c_2^2 - c_1^2}{2} + g(z_2 - z_1) + L_w$$

<u>PREVALENZA</u>

$$\boldsymbol{H = \left(\frac{p_2}{g\rho} + \frac{c_2^2}{2g} + z_2\right) - \left(\frac{p_1}{g\rho} + \frac{c_1^2}{2g} + z_1\right) = H_2^0 - H_1^0}$$

$$L_i - L_w = \frac{p_1 - p_2}{\rho} + \frac{c_2^2 - c_1^2}{2} + g(z_2 - z_1)$$

$$L_i - L_w = g\left[\left(\frac{p_2}{g\rho} + \frac{c_2^2}{2g} + z_2\right) - \left(\frac{p_1}{g\rho} + \frac{c_1^2}{2g} + z_1\right)\right] = gH; \boldsymbol{H = \frac{L_i - L_w}{g}}$$

$$\eta_y = \frac{L_i - L_w}{L_i} = \frac{gH}{L_i}; H = \frac{\eta_y L_i}{g} = \frac{\eta_y(u'' c_u'' - u' c_u')}{g}$$

<u>Potenza e rendimento</u>

$$P_i = L_i(\dot{m} + \dot{m}_f) = \frac{gH}{\eta_y}(\dot{m} + \dot{m}_f)$$

$$\eta_v = \frac{\dot{m}}{\dot{m} + \dot{m}_f}$$

$$L_i = \frac{p_1 - p_a}{\rho} + \frac{c_1^2 - c_a^2}{2} + g(z_1 - z_a) + L_{w,a};\ L_i = g(H_1^0 - H_a^0) + L_{w,a}$$

$L_{w,a} = gY_a; L_i = 0$

$(H_1^0 - H_a^0) = -Y_a$

Fase di mandata $2 \to m$

$$L_i = \frac{p_m - p_2}{\rho} + \frac{c_m^2 - c_2^2}{2} + g(z_m - z_2) + L_{w,m};\ L_i = g(H_m^0 - H_2^0) + L_{w,m}$$

$L_{w,m} = gY_m; L_i = 0$

$(H_m^0 - H_2^0) = -Y_m$

$(H_m^0 - H_2^0) + (H_1^0 - H_a^0) = -(Y_a + Y_m)$

$Y_a + Y_m = Y$

$H = (H_m^0 - H_a^0) + Y$

Quando $c_m = c_a \approx 0$ e $p_m = p_a = p_{atm}$

$H_m^0 - H_a^0 = z_m - z_a = H_g;\ H_e = H_g + Y;\ H_e = H_g + kQ^2$

<u>Circuito chiuso</u>

$H_e = H_g + kQ^2;\ H_g = 0;\ H_e = kQ^2$

<u>AVVIAMENTO TURBOPOMPE</u>

$\Delta p = \rho g H$

<u>CAVITAZIONE</u>

$p_{min} > p_v$

$$L_i = \frac{p_1 - p_a}{\rho} + \frac{c_1^2 - c_a^2}{2} + g(z_1 - z_a) + gY_a$$

Risultano $L_i = 0; \frac{c_a^2}{2}\ trascurabile, z_a\ origine\ del\ sistema\ di\ riferimento, \Delta p = \lambda\rho\frac{w'^2}{2g}$

$$\frac{p_1}{\rho g} = \frac{p_a}{\rho g} - \frac{c_1^2}{2g} - z_1 - Y_a - \lambda\frac{w'^2}{2g}$$

$$\boldsymbol{\frac{p_a - p_v}{\rho g} - z_1 - Y_a \geq \frac{c_1^2}{2g} + \lambda\frac{w'^2}{2g}}$$

$\boldsymbol{NPSH_{disp} > NPSH_{min}}$

$$\eta_\varphi = \frac{m_m}{m_a};\ \eta_\tau = \frac{T_{Bad}}{T_B};\ \lambda_v = \eta_\tau * \eta_\varphi(1-\delta_1) * \left[1-\mu\left(\frac{\beta_i^{\frac{1}{m\prime}}}{\eta_\tau}-1\right)\right]$$

$$L_c = \int_B^C Vdp - \int_A^D Vdp = \boldsymbol{\frac{m}{m-1}p_1'V_B\left[\beta_i^{\frac{m-1}{m}}-1\right]} - \boldsymbol{\frac{m'}{m'-1}p_1'V_A\left[\beta_i^{\frac{m\prime-1}{m\prime}}-1\right]}$$

$$P_i = n*i*L_c;\ P_{ass} = \frac{P_i}{\eta_m} = \frac{n*i*L_c}{\eta_m}$$

<u>REGOLAZIONE COMPRESSORIO VOLUMETRICI</u>

<u>Laminazione all'aspirazione</u>

Utile con $\beta > 3$

$$\dot{m} = \lambda_v * i * n * V * \rho_1 \propto \boldsymbol{\lambda_v * \rho_1}$$

$$\boldsymbol{\frac{\dot{m}'}{\dot{m}} = \frac{p_1'}{p_1} * \frac{1-\mu\left[\beta'^{\frac{1}{k}}-1\right]}{1-\mu\left[\beta^{\frac{1}{k}}-1\right]}}\ da\ risolversi\ iterativamente$$

<u>Variazione del volume di spazio morto</u>

Nel caso ideale

$$\boldsymbol{\frac{\dot{m}'}{\dot{m}}} = \frac{\lambda'_v}{\lambda_v} = \boldsymbol{\frac{1-\mu'\left[\beta^{\frac{1}{k}}-1\right]}{1-\mu\left[\beta^{\frac{1}{k}}-1\right]}};\ \boldsymbol{\mu' = \mu + \frac{V_{add}}{V}}$$

$$\boldsymbol{L_{c,id} = \frac{k}{k-1}p_1\lambda_{v,id}V\left[\beta^{\frac{k-1}{k}}-1\right] \propto \lambda_{v,id} \propto -\mu\left[\beta^{\frac{1}{k}}-1\right]}$$

<u>COMPRESSORI VOLUMETRICI ROTATIVI A PALETTE</u>

$$\eta_v < 1;\ \lambda_v = 1$$

$$\rho = \frac{V}{V_i}$$

$$\boldsymbol{\dot{m} = i * V * n * \rho_1}$$

$$P_a = \frac{P_i}{\eta_m} = \frac{i*n*L_c}{\eta_m}$$

$$L_c = \int_B^i Vdp + \frac{V}{\rho}(p_2-p_1) = \boldsymbol{\frac{m}{m-1}p_1V[\rho^{m-1}-1] + \frac{V}{\rho}p_1(\beta-\rho^m)}$$

$$P_i = L_i * \dot{m} = n*i*L_c$$

$$\eta_i = \frac{P_{it}}{\dot{Q}_1} = \frac{L_{it}}{Q_1};\ \eta_i = \eta_{i,id} * \eta_{i,is\,t};\ \eta_i = \frac{i_e - i_f}{i_e - i_b} \cong \frac{\boldsymbol{i_e - i_f}}{\boldsymbol{i_e - i_a}}$$

$$P_i = P_{it} - P_{ip} \cong P_{it}$$

$$\eta_{is,t} = \frac{L_{it}}{L_{i,is\,t}} = \frac{\boldsymbol{i_e - i_f}}{\boldsymbol{i_e - i_{f,is}}}$$

$$\boldsymbol{\eta_o = \frac{P_u}{P_i}}$$

$$\boldsymbol{\dot{F} = \dot{m}_f * H_{if}}$$

$$\eta_b = \frac{\dot{Q}_1}{\dot{F}} = \frac{\boldsymbol{\dot{m}_v * Q_1}}{\boldsymbol{\dot{m}_f * H_{if}}}$$

$$d = \frac{\dot{m}_a}{\dot{m}_f}\ dosatura$$

$$x = \frac{m_v}{m_l + m_v}$$

<u>Con rigenerazione e ri-surriscaldamento</u>

$$\boldsymbol{Q_1} = i_e - i_{b'} + y(i_j - i_g) \cong \boldsymbol{i_e - i_{a'} + y(i_j - i_g)}$$

$$\boldsymbol{L_i \cong L_{it} = i_e - i_g + (1 - y) * (i_j - i_f)}$$

<u>CICLI A GAS (TURBOGAS)</u>

<u>Funzionamento ideale</u>

$$P_{i,id} = \dot{m} * L_{i,id}; P_{i,id} = P_{i,t} - P_{i,c}$$

$$\boldsymbol{P_{i,c} = \dot{m} * L_{i,c}}$$

$$\boldsymbol{P_{i,t} = \dot{m} * L_{i,t}}$$

$$Q_1 - Q_2 = L_{i,id}$$

$$\boldsymbol{\eta_{i,id} = 1 - \beta_c^{\frac{1-k}{k}}};\ \eta_{i,id} = \frac{L_{i,id}}{Q_1}$$

$$Q_1 = c_p(T_3 - T_2) = \boldsymbol{c_p\left(T_3 - T_1 * \beta_c^{\frac{k-1}{k}}\right)}$$

$$L_{i,id} = \eta_{i,id} * Q_1 = \boldsymbol{\left(1 - \beta_c^{\frac{1-k}{k}}\right) c_p \left(T_3 - T_1 * \beta_c^{\frac{k-1}{k}}\right)}$$

$$\eta_o = \frac{P_u}{P_i}$$

$$\boldsymbol{P_i = \dot{m}_a \left[\left(\frac{\alpha+1}{\alpha}\right) L_t - L_c\right]}$$

$$\boldsymbol{L_i = \left[\left(\frac{\alpha+1}{\alpha}\right) L_t - L_c\right]}$$

$$\boldsymbol{P_u = \eta_o \dot{m}_a \left[\left(\frac{\alpha+1}{\alpha}\right) L_t - L_c\right]}$$

$$\boldsymbol{L_u = \eta_o \left[\left(\frac{\alpha+1}{\alpha}\right) L_t - L_c\right]}$$

$$\eta_{tot} = \frac{P_u}{\dot{F}} = \boldsymbol{\alpha \frac{L_u}{H_{if}} = \alpha\eta_o \frac{L_i}{H_{if}}}$$

<u>Calcolo di α</u>

$$\alpha = \frac{\boldsymbol{c_{pg}(T_3 - T_0) - H_{if}\eta_b}}{\boldsymbol{c_{pa}(T_2 - T_0) - c_{pg}(T_3 - T_0)}};\ \boldsymbol{T_0 = 25°C}$$