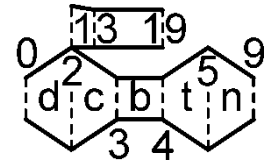


	2	3	4	5	9	13	19
	diff	comp	CC	Tur	No	Fan	No FAn
c_p	1004			1057			
γ	1.4			1.35			
π	1	21.5	0.955		0.98	1.53	0.99
$\eta, e_{c,t}$		0.92	0.95	0.9		0.96	
Tt			1349.8				
M0	0.85				QR	42800	kJ/kgK
T0	288	K	p0	101,300	Pa	η_m	0.98
alpha	5.053						
k	0.28571			0.25926			
R	286.857			274.037	kJ/kgK		



$$k = \frac{\gamma - 1}{\gamma} = \frac{0.4}{1.4} = 0.2867 \quad k_5 = \frac{\gamma_5 - 1}{\gamma_5} = \frac{0.35}{1.35} = 0.2593$$

$$R = k c_p = 0.2867 \cdot 1004 = 286.9 \text{ J/kgK} \quad R_5 = 0.2593 \cdot 1057 = 274.0 \text{ J/kgK}$$

$$a_0 = \sqrt{\gamma R T_0} = 1.4 \cdot 286.9 \cdot 288 = 340.1 \text{ m/s}$$

$$V_0 = M_0 \cdot a_0 = 0.85 \cdot 340.1 = 289.1 \text{ m/s}$$

Presa d'aria

$$\tau_r = \psi_0 = 1 + \frac{\gamma - 1}{2} M_0^2 = 1 + 0.2 \cdot 0.85 = 1.145$$

$$T_{t0} = T_{t2} = T_0 \tau_r = 288 \cdot 1.145 = 329.6 \text{ K}$$

$$p_{t0} = \tau_r^{\frac{1}{k}} p_0 = 1.145^{\frac{1}{0.2867}} 1.013 \cdot 10^5 = 162.5 \text{ kPa}$$

$$p_{t2} = p_{t0} \pi_d = 162.5 \cdot 1 = 162.5 \text{ kPa}$$

Compressore

$$\tau_c = \pi_c^{\frac{k}{e_c}} = 21.5^{\frac{0.2867}{0.92}} = 2.593$$

$$p_{t3} = p_{t2} \pi_c = 162.5 \cdot 21.5 \cdot 10^3 = 3493 \text{ kPa}$$

$$T_{t3} = T_{t2} \tau_c = 329.6 \cdot 2.593 = 854.7 \text{ K}$$

Camera di combustione

$$p_{t4} = p_{t3} \pi_b = 3.493 \cdot 0.955 \cdot 10^3 = 3336 \text{ kPa}$$

$$\tau_\lambda = \frac{c_{p5} T_{t4}}{c_p T_0} = \frac{1057 \cdot 1350}{288 \cdot 1004} = 4.934$$

$$f = \frac{\tau_\lambda - \tau_c \tau_r}{Q_R \eta_b / (c_p T_0) - \tau_\lambda} = \frac{4.934 - 2.593 \cdot 1.145}{42.8 \cdot 10^6 \cdot 0.95 / (288 \cdot 1004) - 4.934} = 0.01449$$

Fan

$$\tau_f = \pi_f^{\frac{k}{e_f}} = 1.53^{\frac{0.2867}{0.96}} = 1.135$$

$$p_{t13} = p_{t2}\pi_f = 162.5 \cdot 1.53 \cdot 10^3 = 248.6 kPa$$

$$T_{t13} = T_{t2}\tau_f = 329.6 \cdot 1.135 = 374.1 K$$

Turbina

$$\tau_t = 1 - \frac{\tau_r[(\tau_c - 1) + \alpha(\tau_f - 1)]}{\eta_m(1 + f)\tau_\lambda} = 1 - \frac{1.145[1.593 + 5.053 \cdot 0.135]}{0.98 \cdot 1.014 \cdot 4.934} = 0.4693$$

$$\pi_t = \tau_t^{\frac{1}{k_5 e_t}} = 0.4693^{\frac{1}{0.2593 \cdot 0.900}} = 0.03907$$

$$p_{t5} = p_{t4}\pi_t = 333.6 \cdot 0.03907 \cdot 10^3 = 130.3 kPa$$

$$T_{t5} = T_{t4}\tau_t = 1350 \cdot 0.4693 = 633.4 K$$

Ugello

$$p_{t9} = p_{t5}\pi_n = 130.3 \cdot 0.98 \cdot 10^3 = 127.7 kPa$$

$$\frac{p_{t9}}{p_9} = \frac{127.7}{101.3} = 1.261$$

$$\psi_9 = \left(\frac{p_{t9}}{p_9}\right)^{k_5} = 1.261^{0.2593} = 1.062$$

$$M_9 = \sqrt{\frac{2}{\gamma_5 - 1}[\psi_9 - 1]} = \sqrt{\frac{2}{.35}[1.062 - 1]} = 0.5950$$

$$M_9 < 1 \rightarrow p_9 = p_0 \text{ (OK)}$$

$$T_9 = T_{t9}/\psi_9 = T_{t5}/\psi_9 = 633.4/1.062 = 596.5 K$$

$$a_9 = \sqrt{\gamma_5 R_5 T_9} = 1.35 \cdot 274.0 \cdot 596.5 = 469.8 m/s$$

$$V_9 = M_9 \cdot a_9 = 0.5950 \cdot 469.8 = 279.5 m/s$$

$$\frac{V_9}{a_0} = \frac{279.5}{340.1} = 0.8219 < M_0 \text{ (??)}$$

Ugello Fan

$$p_{t19} = p_{t13}\pi_{nf} = 248.6 \cdot 0.99 \cdot 10^3 = 246.1 kPa$$

$$\frac{p_{t19}}{p_{19}} = \frac{246.1}{101.3} = 2.429$$

$$\psi_{19} = \left(\frac{p_{t19}}{p_{19}}\right)^k = 2.429^{0.2867} = 1.289$$

$$M_{19} = \sqrt{\frac{2}{\gamma - 1}[\psi_9 - 1]} = \sqrt{\frac{2}{0.4}[1.289 - 1]} = 1.201$$

$$M_{19} > 1 \rightarrow p_9 \neq p_0 \text{ (Ugello strozzato)}$$

$$\psi_{19} = 1 + \frac{\gamma - 1}{2} 1 = 1.200$$

$$T_{19} = T_{t19}/\psi_9 = T_{t13}/\psi_{19} = 374.1/1.200 = 311.7K$$

$$p_{19} = p_{t19}/\psi_9^{\frac{1}{\gamma}} = 246.1 \cdot 1.200^{\frac{-1}{0.2867}} \cdot 10^3 = 130.0kPa$$

$$\frac{p_0}{p_{19}} = \frac{101.3}{130.0} = 0.7792$$

$$a_{19} = \sqrt{\gamma R T_{19}} = 1.4 \cdot 286.9 \cdot 311.7 = 353.8m/s$$

$$V_{19} = M_{19} \cdot a_{19} = 1 \cdot 353.8 = 353.8m/s$$

$$\frac{V_{19}}{a_0} = \frac{353.8}{340.1} = 1.040$$

$$\frac{V_{19.e}}{a_0} = \frac{V_{19}}{a_0} \left(1 + \frac{1 - \frac{p_0}{p_{19}}}{\gamma M_{19}^2} \right) = 1.040 \left(1 + \frac{1 - 0.7792}{1.4 \cdot 1^2} \right) = 1.204$$

Spinta

$$\frac{F_{u.c}}{\dot{m}_0 a_0} = (1 + f) \frac{V_{9.e}}{a_0} - M_0 = 1.014 \cdot 0.8219 \cdot 1 - 0.85 = -0.01621$$

$$\frac{F_{u.f}}{\dot{m}_0 a_0} = \alpha \left(\frac{V_{19.e}}{a_0} - M_0 \right) = 5.053 \cdot (1.204 - 0.85) = 1.7912$$

$$\frac{F_u}{\dot{m}_0 a_0} = \left(\frac{F_{u.c}}{\dot{m}_0 a_0} + \frac{F_{u.f}}{\dot{m}_0 a_0} \right) = -0.01621 + 1.7912 = 1.775$$

$$\frac{F_u}{\dot{m}_{air} a_0} = \frac{1}{\alpha + 1} \left(\frac{F_{u.c}}{\dot{m}_0 a_0} + \frac{F_{u.f}}{\dot{m}_0 a_0} \right) = \frac{1}{6.053} (-0.01621 + 1.7912) = 0.2932$$

$$TSFC = \frac{f}{F_u/\dot{m}_0} = \frac{0.01449 \cdot 10^3}{1.775 \cdot 340.1} = 0.02401 \frac{g}{s N}$$

$$\eta_{th} = \frac{a_0^2 [(1 + f) V_{9.e}^2/a_0^2 + \alpha V_{19.e}^2/a_0^2 - (1 + \alpha) M_0^2]}{2f Q_R} =$$

$$\eta_{th} = \frac{340.1^2 [1.014 \cdot 0.8219^2 + 5.053 \cdot 1.204^2 - 6.053 \cdot 0.85^2]}{2 \cdot 0.01449 \cdot 42.8 \cdot 10^6} = \frac{4.213 \cdot 10^5}{1.240 \cdot 10^6} =$$

$$\eta_{th} = 0.3396$$

$$\eta_p = \frac{2 \frac{F_u}{\dot{m}_0 a_0} a_0 V_0}{a_0^2 [(1 + f) V_{9.e}^2/a_0^2 + \alpha V_{19.e}^2/a_0^2 - (1 + \alpha) M_0^2]} = \frac{2 \cdot 1.775 \cdot 340.1 \cdot 289.1}{4.213 \cdot 10^5} =$$

$$\eta_p = 0.8283$$

$$\eta_0 = \eta_{th} \eta_p = 0.3396 \cdot 0.8283 = 0.2813$$