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Ideal Turbojet assuming calorically perfect gas.

$M_0 = 2$; $h = 11000\,m$; $T_0 = 216{,}5\,K$; $P_0 = 22600\,Pa$

$T_{T4} = 1373\,K$; $\tau_c = \frac{T_{T3}}{T_{T2}} = 2$; $\varepsilon_i = 0{,}075$; $\varepsilon_b = 0{,}06$; $\varepsilon_n = 0{,}02$

$\eta_{cp} = 0{,}88$; $\eta_{tp} = 0{,}93$; $\phi = 0{,}98$; $\gamma = 1{,}4$

0: Free stream

$$\theta_0 = \frac{T_{T0}}{T_0} = \left(1 + \frac{\gamma - 1}{2} M_0^2\right) = \underline{1{,}8}$$

$$\delta_0 = \frac{P_{T0}}{P_0} = \theta_0^{\frac{\gamma}{\gamma-1}} = \underline{7{,}8244}$$

0 - 2: intake

$$\theta_2 = \frac{T_{T2}}{T_0} = \theta_0 = \underline{1{,}8} \qquad \delta_2 = (1 - \varepsilon_i)\,\delta_0 = \underline{7{,}2375}$$

2 - 3: compressor

$$\theta_3 = \frac{T_{T3}}{T_0} = \tau_c \cdot \theta_0 = \underline{3{,}6} \qquad \pi_c = \tau_c^{\frac{\gamma}{\gamma-1}\cdot \eta_{cp}} = \underline{8{,}4561}$$

3 - 4: Burner

$$\pi_b = \frac{P_{T4}}{P_{T3}} = (1 - \varepsilon_b) = \underline{0{,}94}$$

$$h_f = h_{f_0} - \Delta h_{f_c} = 40{,}07609 \cdot 10^6 \; J/kg$$

$$h_{f_0} = 4{,}3095 \cdot 10^7 \; J/kg$$

$$\Delta h_{f_c} = r_i \left[-1607{,}2 + 4{,}47659 \cdot T_{T4} + 4{,}00997 \cdot 10^{-3}\, T_{T4}^2 - 6{,}12432 \cdot 10^{-7} \cdot T_{T4}^3\right] = 3{,}018900 \cdot 10^6 \; J/kg$$

($r_i = 287{,}15\ J/kgK$, $T_{T4} = 1373\,K$)

$$\alpha = \frac{c_p\,(T_{T4} - T_{T3})}{h_f} = 0{,}01488$$

$T_{T4} = 1373\,K$, $T_{T3} = 779{,}4\,K$, $h_f = 40{,}07609 \cdot 10^6$

$$c_p = \frac{\gamma r}{\gamma - 1} = 1005{,}025 \quad ; \quad T_{T3} = \tau_c \cdot T_{T2} = \tau_c \cdot T_0 \cdot \theta_0 = 779{,}4\,K$$

$\gamma = 1{,}4$, $r = 287{,}15$; $\tau_c = 2$, $T_0 = 216{,}5\,K$, $\theta_0 = 1{,}8$

4-5: High pressure turbine ($\alpha = 0$)

$$\tau_t = 1 - \frac{\theta_0}{\theta_4}(\tau_c - 1) = 0{,}71616$$

$\theta_0 = 1{,}8$, $\tau_c = 2$

$$\theta_4 = \frac{T_{T4}}{T_0} = \frac{1373\,K}{216{,}5\,K} = 6{,}34180$$

$$\pi_t = \tau_t^{\frac{\gamma}{\gamma-1} \cdot \frac{1}{\eta_{tp}}} = 0{,}28468$$

$\tau_t = 0{,}71616$, $\gamma = 1{,}4$, $\eta_{tp} = 0{,}93$

5-98 From afterburner to nozzle

$$\theta_9 = \theta_4 - \theta_0(\tau_c - 1) = 4{,}5418$$

$\theta_4 = 6{,}34180$, $\theta_0 = 1{,}8$, $\tau_c = 2$

$$\delta_9 = \frac{P_{t9}}{P_0} = (1-\varepsilon_i)(1-\varepsilon_b)(1-\varepsilon_n)\,\theta_0^{\frac{\gamma}{\gamma-1}}\,\tau_c^{\frac{\gamma}{\gamma-1}\cdot\eta_{cp}}\left[1 - \frac{\theta_0}{\theta_4}(\tau_c - 1)\right]^{\frac{\gamma}{\gamma-1}\cdot\frac{1}{\eta_{tp}}} \Rightarrow$$

$\varepsilon_i = 0{,}075$, $\varepsilon_b = 0{,}06$, $\varepsilon_n = 0{,}02$, $\theta_0 = 1{,}8$, $\tau_c = 2$, $\gamma = 1{,}4$, $\eta_{cp} = 0{,}88$, $\theta_4 = 6{,}34180$, $\eta_{tp} = 0{,}93$

$$\Rightarrow \delta_9 = 16{,}05022$$

Exhaust velocity

$$v_9 = \phi \sqrt{\theta_4\left[1 - \frac{1 + \varepsilon_T}{\theta_0\,\tau_c^{\eta_{cp}}\left[1 - \frac{\theta_0}{\theta_4}(\tau_c - 1)\right]^{\frac{1}{\eta_{tp}}} - 1}\right] - \theta_0(\tau_c - 1)}$$

$\phi = 0{,}98$, $\varepsilon_T = 0{,}04428$, $\theta_0 = 1{,}8$, $\tau_c = 2$, $\eta_{cp} = 0{,}88$, $\theta_4 = 6{,}34180$, $\eta_{tp} = 0{,}93$

$$\varepsilon_T = \frac{\gamma - 1}{\gamma}(\varepsilon_i + \varepsilon_b + \varepsilon_n) = 0{,}04428$$

$\gamma = 1{,}4$, $\varepsilon_i = 0{,}075$, $\varepsilon_b = 0{,}06$, $\varepsilon_n = 0{,}02$

$$v_9 = 1{,}54695$$

$$V_9 = v_9 \cdot \sqrt{2 c_p T_0} = 1020{,}495\ \frac{m}{s}$$

$c_p = 1005{,}025$, $T_0 = 216{,}5\,K$

thermal efficency

$$\eta_{th} = \frac{V_9^2 - V_0^2}{\theta_4 - \theta_3} = \frac{\overset{1{,}54695}{V_9}{}^2 - (\overset{1{,}8}{\theta_0} - 1)}{\underset{6{,}34180}{\theta_4} - \underset{2}{\tau_c}\,\underset{1{,}8}{\theta_0}} = \underline{0{,}58102 \rightarrow 58{,}102\,\%}$$

specific thrust

$$f = \underset{1{,}54695}{V_9} - (\underset{1{,}8}{\theta_0} - 1)^{\frac{1}{2}} = \underline{0{,}65252}$$

$$\Psi = f \cdot \sqrt{2\underset{1005{,}25}{C_p}\underset{216{,}5K}{T_0}} = \underline{430{,}455\ \frac{m}{s}}$$

Propulsive efficency

$$\eta_{pr} = \frac{2}{1 + \underset{1{,}54695}{V_9}\,(\underset{1{,}8}{\theta_0} - 1)^{-1/2}} = \underline{0{,}73272 \rightarrow 73{,}272\,\%}$$

overall efficency

$$\eta_0 = \eta_{th} \cdot \eta_{pr} = \underline{0{,}42572 \rightarrow 42{,}572\,\%}$$

thrust specific fuel consumption

$$C_{TS} = \frac{V_0}{\underset{\rightarrow 0{,}42572}{\eta_0}} = \underline{2{,}1009}\ \frac{g}{kN \cdot s}$$

$$V_0 = \sqrt{\underset{1{,}8}{\theta_0} - 1} = 0{,}89442$$