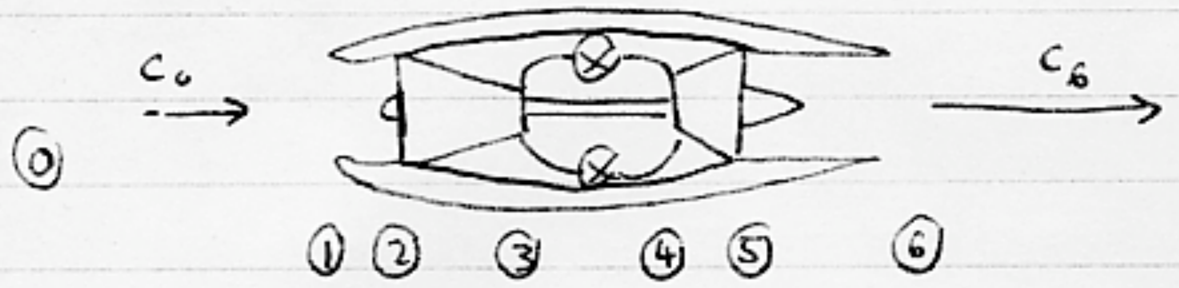
T14 16.Unified Fall 07



$p_0 = 0.55\,bar = p_6$

$T_0 = 255\,K$

$c_0 = 280\,m/s$

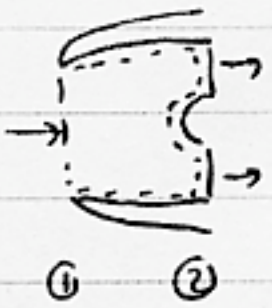
$\Pi = \frac{p_{t_3}}{p_{t_2}} = 14$, $T_{t_4} = 1450\,K$

Assume: – ideal components, $p_{t4} = p_{t3}$
– neglect fuel mass flow and PE effects
– $c_{p_C} = 1004.5\,\frac{J}{kgK}$, $\gamma_C = 1.4$ $c_{p_T} = 1243.6\,J/kgK$, $\gamma_T = 1.3$

a) $T_{t_0} = T_0 + \frac{c_0^2}{2c_{p_C}}$, 1st law: $h_{t_0} = h_{t_1}$ $\underline{T_{t_1} = 294\,K}$

$p_{t_0} = p_0\left(\frac{T_{t_0}}{T_0}\right)^{\gamma/\gamma-1}$ adiab. rev: $p_{t_0} = p_{t_1}$ $\underline{p_{t_1} = 0.9\,bar}$

b)



1st law: $\frac{dE_{cv}}{dt} = \Sigma\dot{Q} + \Sigma\dot{W} + \Sigma\dot{m}(h + \frac{c^2}{2} + gz)$

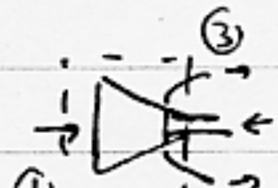
$0 = \dot{m}(h_1 + \frac{c_1^2}{2}) - \dot{m}(h_2 + \frac{c_2^2}{2}) \rightarrow h_{t_1} = h_{t_2}$, $\underline{T_{t_2} = T_{t_1}}$

reversible (inviscid) flow: $\underline{p_{t_1} = p_{t_2}}$

c) $p_{t_3} = \Pi \cdot p_{t_2} = 12.6\,bar$ $\underline{T_{t_3}} = \Pi^{\frac{\gamma-1}{\gamma}} \cdot T_{t_2} = \underline{625\,K}$

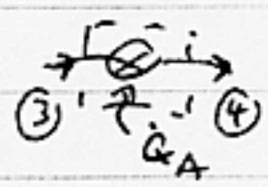
d) $\eta_B = 1 - \frac{T_0}{T_{t_3}} \cdot \frac{T_6/T_0 - 1}{T_{t4}/T_{t3} - 1}$ * (see next page for derivation)

e)



$0 = +\dot{W}_c + \dot{m}h_{t_1} - \dot{m}h_{t_3}$; $\underline{w_c} = \frac{\dot{W}_c}{\dot{m}} = h_{t_3} - h_{t_1} = \underline{332.5\,\frac{kJ}{kg}}$

f)



$0 = \dot{Q}_A + \dot{m}h_{t_3} - \dot{m}h_{t_4}$ $\underline{q_A} = h_{t_4} - h_{t_3} = c_{p_T}(T_{t_4} - T_{t_3}) = \underline{1.03\,MJ/kg}$

g) shaft power balance $w_C = w_T = c_{p_T}(T_{t4} - T_{t5})$ $T_{t5} = \frac{-c_{pC}(T_{t3} - T_{t1})}{c_{pT}} + T_{t4}$

$\underline{T_{t5} = 1183\,K}$ $\underline{p_{t5}} = p_{t_4}\left(\frac{T_{t5}}{T_{t4}}\right)^{\gamma_T/\gamma_T-1} = \underline{5.22\,bar}$

h) $\frac{p_{t6}}{p_6} = \frac{p_{t5}}{p_0} = \left(1 + \frac{\gamma_T-1}{2}M_6^2\right)^{\gamma_T/\gamma_T-1}$; $M_6 = \sqrt{\frac{2}{\gamma_T-1}\left[\left(\frac{p_{t5}}{p_0}\right)^{\frac{\gamma_T-1}{\gamma_T}} - 1\right]} = 2.13$,

$\rightarrow$ ad. rev. expansion in nozzle

$T_6 = T_{t_6}\left(1 + \frac{\gamma_T-1}{2}M_6^2\right)^{-1}$

$T_{t6} = T_{t5}$ (1st law)

$T_6 = 704\,K$

$\underline{c_6} = M_6\sqrt{\gamma RT_6} = \underline{1092\,\frac{m}{s}}$