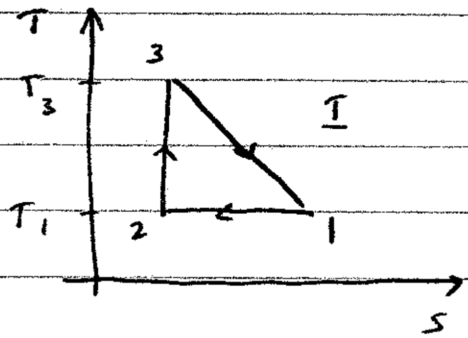
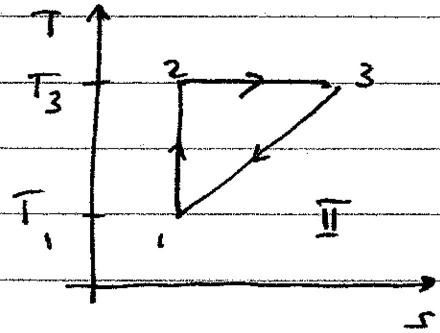
T1

Concepts: def. of entropy, thermal eff.





all processes internally reversible

$T\,ds = dq$

$$\eta_{th} = \frac{w_{net}}{q_A} = \frac{q_A + q_R}{q_A}$$

q is heat to system ($q_R < 0$) and $q = \int T\,ds$

$$\eta_{th}^{I} = 1 + \frac{\int_1^2 T\,ds}{\int_3^1 T\,ds} = 1 + \frac{\bar{T}_{12}(s_2 - s_1)}{\bar{T}_{31}(s_1 - s_3)} = 1 - \frac{\bar{T}_{12}}{\bar{T}_{31}}$$

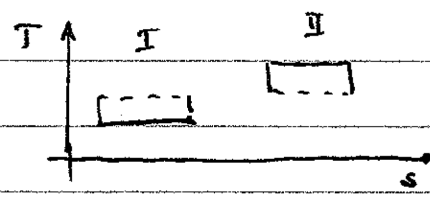
$$\eta_{th}^{I} = 1 - \frac{2T_1}{T_3 + T_1} \longrightarrow \underline{\eta_{th}^{I} = \frac{T_3 - T_1}{T_3 + T_1}}$$

$$\eta_{th}^{II} = 1 + \frac{\int_3^1 T\,ds}{\int_2^3 T\,ds} = 1 + \frac{\bar{T}_{31}(s_1 - s_3)}{\bar{T}_{23}(s_3 - s_2)} = 1 - \frac{\bar{T}_{31}}{\bar{T}_{23}}$$

$$\eta_{th}^{II} = 1 - \frac{T_3 + T_1}{2T_3} \longrightarrow \underline{\eta_{th}^{II} = \frac{T_3 - T_1}{2T_3}}$$

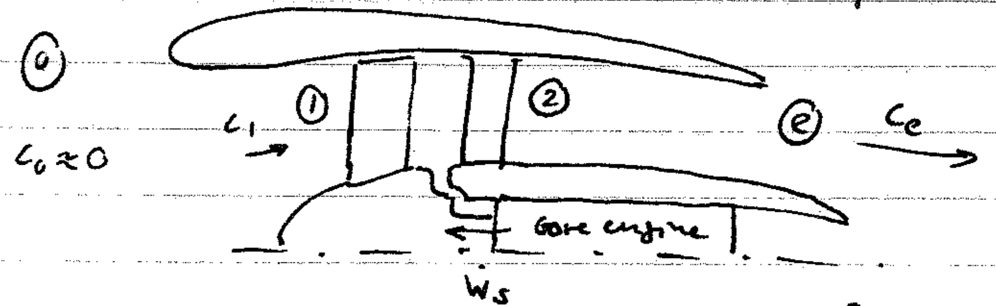
$\underline{\eta_{th}^{I} > \eta_{th}^{II}}$ because temperature ratio of heat sink to heat source (on average basis) lower for cycle I

$$\left.\frac{\bar{T}_R}{\bar{T}_A}\right|_{I} < \left.\frac{\bar{T}_R}{\bar{T}_A}\right|_{II}$$



Carnot: more "waste" heat in cycle II for same net work

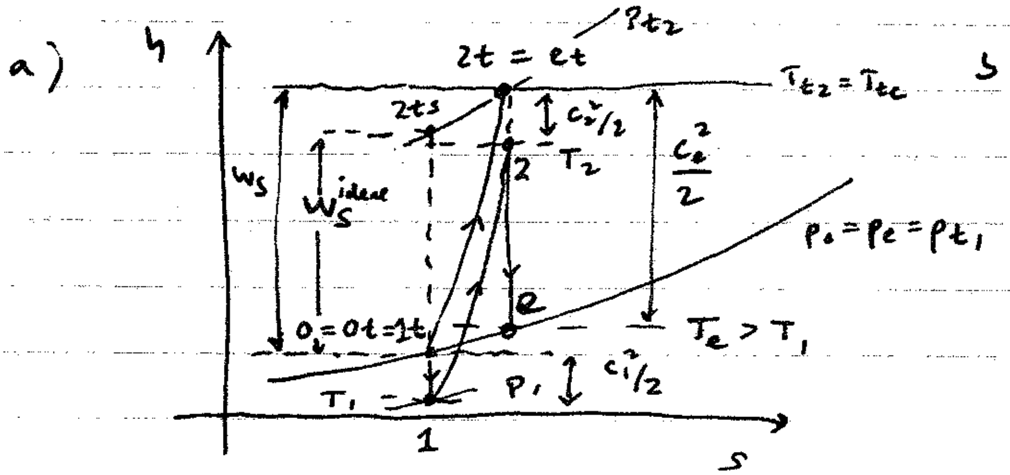
T2 (h-s diagrams, Gibbs, integral mom. equation) 16. Unified Sp09 ZS



$c_1 = c_2$ $p_e = p_0$

Assume:
- adiabatic non-ideal fan,
- core mass flow negligible

a)



b) 1st Law CV entire sys:

$\dot W_s = \dot m (h_{te} - h_{t0})$

$h_{t0} = h_{t1}$, $h_{te} = h_{t2}$

$\dot m = \dfrac{\dot W_s}{c_p (T_{t2} - T_{t1})}$

$T_{t1} = T_{t0} = T_0 = 300K$

use adiab. eff to find T_{t2}: $\eta_{fan}^{ad} = \dfrac{w_s^{ideal}}{w_s} = \dfrac{T_{t2s} - T_{t1}}{T_{t2} - T_{t1}}$, $\dfrac{T_{t2s}}{T_{t1}} = \left(\dfrac{p_{t2}}{p_{t1}}\right)^{\frac{\gamma-1}{\gamma}}$

so $T_{t2} = T_{t1}\left(1 + \dfrac{1}{\eta_{fan}^{ad}}\left[\left(\dfrac{p_{t2}}{p_{t1}}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]\right)$; $T_{t2} = 335.6\ K$; $\underline{\dot m = 699\ kg/s}$

c) $T_{t2} = T_2 + \dfrac{c_2^2}{2c_p}$, $c_1 = c_2 = \sqrt{2c_p(T_0 - T_1)}$, $\underline{T_2} = T_{t2} - \dfrac{c_2^2}{2c_p} = \underline{320.5\ K}$

$c_1 = c_2 \rightarrow T_{t1} = T_0 = T_1 + \dfrac{c_1^2}{2c_p}$

$M_2 = \dfrac{c_2}{\sqrt{\gamma R T_2}}$ $\underline{M_2 = 0.485}$

d) Gibbs: $T_t ds = dh_t - v_t dp_t \,\Big|\, \int_1^2$; $s_2 - s_1 = c_p \ln\left(\dfrac{T_{t2}}{T_{t1}}\right) - R \ln\left(\dfrac{p_{t2}}{p_{t1}}\right)$

no other interaction (ad. fan): $\Delta S_{tot} = \Delta S_{gen} = \Delta S_{fan} = s_2 - s_1$, $\underline{\Delta s_{gen} = 16.1\ J/kg\text{-}K}$

e) Integral mom. eqn.:

$T = \dot m (c_e - c_0) = \dot m c_e$;

$\underline{T = 173.7\ kN}$

isentropic expansion in nozzle

$p_{te} = p_{t2} = p_e\left(1 + \dfrac{\gamma-1}{2} M_e^2\right)^{\gamma/\gamma-1}$, $p_e = p_{t1}$

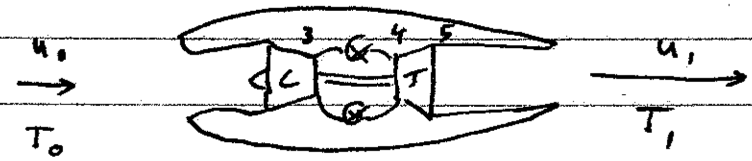
$M_e = \sqrt{\left[\left(\dfrac{p_{t2}}{p_{t1}}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]\dfrac{2}{\gamma-1}} = 0.71$

$T_e = T_{t2}\left(1 + \dfrac{\gamma-1}{2} M_e^2\right)^{-1} = 304.8K$

$c_e = M_e\sqrt{\gamma R T_e}$, $c_e = 248.5\frac{m}{s}$

T3

16. Unified sp 09 ZS

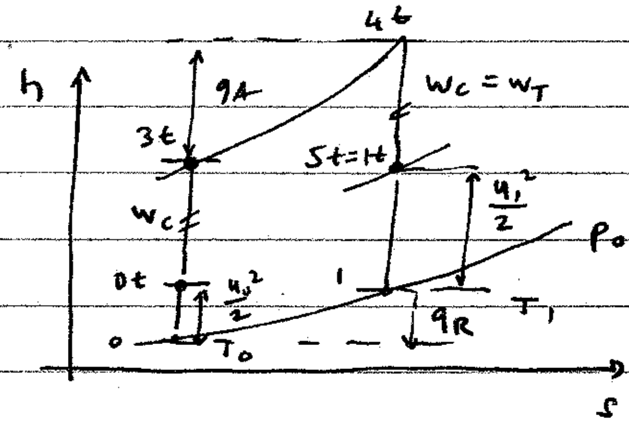


know: u_0, u_1, T_0, T_1, c_p

assume: ideal cycle
steady level flight
ideal gas, c_p = const

Concepts: ideal Brayton cycle
h-s diagrams
overall, prop. eff.

a)



b) $\underline{q_R = c_p (T_1 - T_0)}$ from 1st law

c) $q_A - q_R = q_{net} = w_{net}$, $\quad w_{net} = \frac{u_1^2}{2} - \frac{u_0^2}{2}$; $\quad \underline{q_{net} = \frac{u_1^2}{2} - \frac{u_0^2}{2}}$

d) $\eta_{th} = \frac{w_{net}}{q_A} = \frac{w_{net}}{q_R + w_{net}} = \frac{1}{1 + q_R/w_{net}}$

$$\underline{\eta_{th} = \left(1 + \frac{2c_p (T_1 - T_0)}{u_1^2 - u_0^2}\right)^{-1}}$$

e) $\eta_0 = \eta_{prop} \cdot \eta_{th}$; $\quad \eta_{prop} = \frac{\text{thrust power}}{\text{mech. power}} = \frac{\dot{m}(u_1 - u_0) u_0}{\dot{m}(u_1^2/2 - u_0^2/2)}$

$$\eta_{prop} = \frac{2}{1 + \frac{u_1}{u_0}}$$

$$\eta_0 = \frac{\frac{2}{1 + u_1/u_0}(u_1^2 - u_0^2)}{u_1^2 - u_0^2 + 2c_p (T_1 - T_0)} \; ; \quad \underline{\eta_0 = \frac{2u_0 \cdot (u_1 - u_0)}{u_1^2 - u_0^2 + 2c_p (T_1 - T_0)}}$$