T7

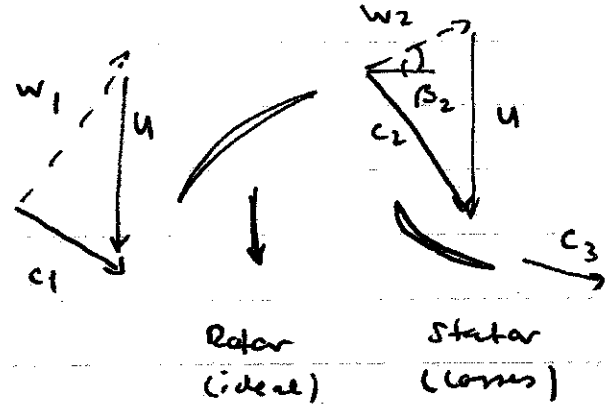
16. Unified Sp 09

25

repeating stage:

$T_1 = 300K$

$\eta_{ad} = 0.85$



$c_1 = 140 m/s$

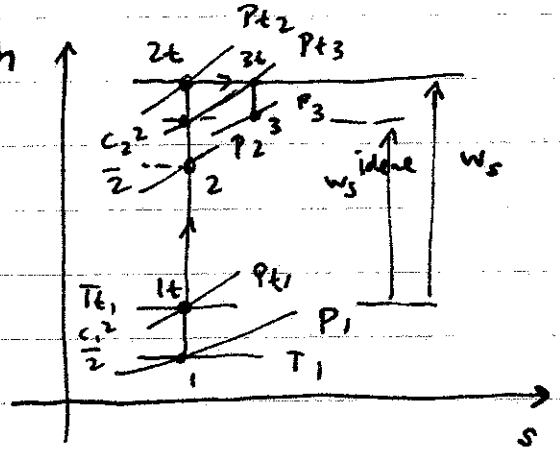
$c_2 = 240 m/s$

$w_1 = 240 m/s$

$w_2 = 140 m/s$

$\beta_2 = 30°$

a)



$$\eta_{ad} = \frac{w_s^{ideal}}{w_s} = \frac{\left(P_{t3}/P_{t1}\right)^{\frac{k-1}{k}} - 1}{T_{t3}/T_{t1} - 1}$$

$c_{x_2} = 121.2 m/s$ $\quad \alpha_2 = 59.5°$

$c_{\theta_2} = 207.1 m/s$ $\quad u = 277.1 m/s$

symmetry: $c_{\theta_1} = 70.0 m/s$

$(w_{\theta_2} = c_{\theta_1})$

b) Euler turbine eqn: $h_{t_2} - h_{t_1} = u(c_{\theta_2} - c_{\theta_1})$, $h_{t_3} - h_{t_2}$ (1st law stator)

$$T_{t_1} = T_1 + \frac{c_1^2}{2c_p} = 309.8K, \quad w_s = h_{t_2} - h_{t_1} = 37.99 kJ/kg$$

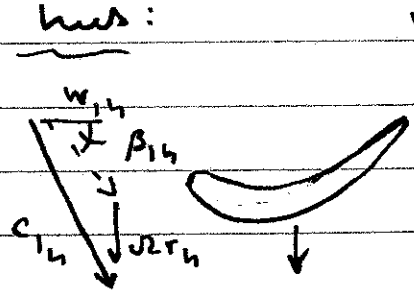
$$T_{t_3} = T_{t_2} = 347.6 K$$

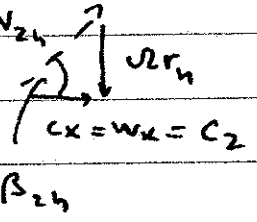
$$\Pi = \frac{P_{t3}}{P_{t1}} = \left(\eta_{ad}\left(\frac{T_{t3}}{T_{t1}} - 1\right) + 1\right)^{k/k-1}, \quad \underline{\Pi = 1.41}$$

c) $\dot{W}_c = \dot{m} c_p (T_{t_3} - T_{t_1})$

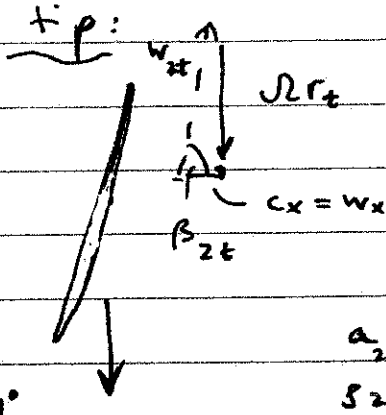
$\underline{\dot{W}_c = 379.9 kW}$

hub:





tip:



estimate: $\beta_{1h} = 25°$

$\beta_{2h} = 60°$ $\beta_{2t} = 80°$

$a_2 = 470\ m/s$

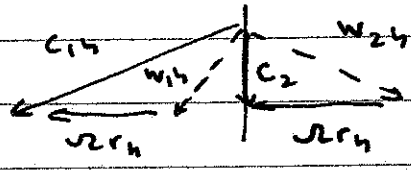
$\rho_2 = 0.59\ kg/m^3$

a) $w_{2t} = a_2 = \dfrac{\Omega r_t}{\sin\beta_{2t}}$ $\Omega = 2\pi f = 314.15\ rad/s$

$r_t = \dfrac{a_2 \sin\beta_{2t}}{\Omega}$ $\underline{r_t = 1.47\ m}$

$c_x = a\cos\beta_{2t} \longrightarrow \underline{c_x = 81.6\ m/s}$

b)



$c_2 = c_x$ $\Omega r_h = c_2 \tan\beta_{2h}$

$r_h = \dfrac{c_2 \tan\beta_{2h}}{\Omega}$ $\underline{r_h = 0.45\ m}$

$\dot{m} = \rho_2 c_2 A_2$, $A_2 = \pi(r_t^2 - r_h^2)$ $\underline{\dot{m} = 296.2\ kg/s}$

c) Euler at hub: $w_T = \Delta h_t = \Omega r_h (c_{\theta_1})_h$

$c_{\theta_{1h}} = \Omega r_h + c_x \tan\beta_{1h} = 179.4\ m/s$

$w_T = 25.3\ kJ/kg$ $\underline{\dot{W}_T = 7.5\ MW}$

(note: in a single rotor!)

T9

16. Unified Sp 09

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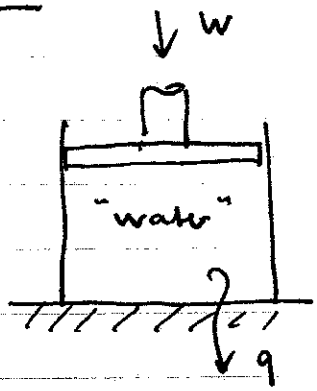
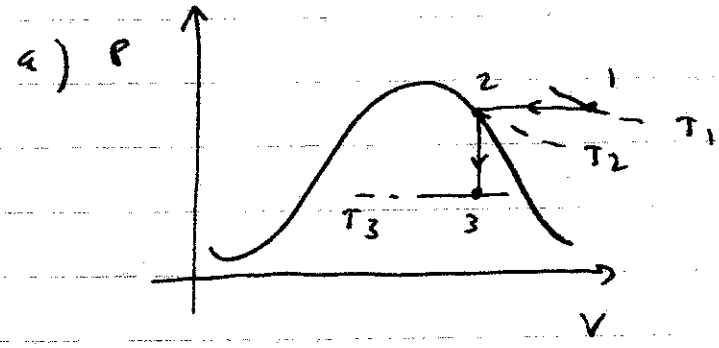


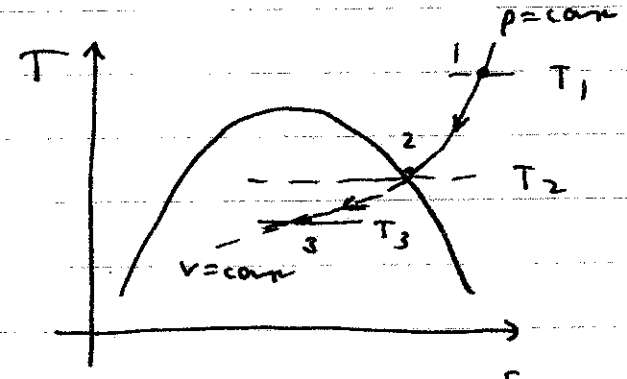
$T_1 = 400°C$, $p_1 = 10\,bar$ → dry vapor

1-2 : isobaric compression to sat. vapor @ 10 bar

2-3 : isochoric cooling to 150°C

a)





b) 1-2 : $w = \int_{v_1}^{v_2} p\,dv$

2-3 : $w = 0$ $(dv = 0)$

tables: $v_1 = 0.2066\ m^3/kg$

$v_2 = v_g(10\,bar) = 0.194\ m^3/kg$

$w_{1-3} = w_{1-2} = p_1 (v_2 - v_1)$

$w_{1-3} = -112.6\ kJ/kg$

work done on system

c) 1st law : $du = dq - dw$ $\left| \int_1^3 \right.$

$u_3 - u_1 = q - w_{1-3}$ $\quad q = u_3 - u_1 + w_{1-3}$

tables: $u_1 = 2957.3\ kJ/kg$

$u_3 = x_3 u_g(T_3) + (1 - x_3) u_f(T_3)$

$x_3 = 0.492$ → $u_3 = 1581.3\ kJ/kg$

find: $q = -1488.6\ kJ/kg$ rejected

$v_3 = v_2 = x_3 v_g(T_3) + (1 - x_3) v_f$

$x_3 = \dfrac{v_2 - v_f(T_3)}{v_g(T_3) - v_f(T_3)}$

$v_f(T_3) = 0.001\ m^3/kg$

$v_g(T_3) = 0.3928\ m^3/kg$