PART A

Wednesday, March 17, 2021 7:52 AM

$\eta_{c_R} = .85$

$M_0 = .8$

$\pi_c = 15$

$M_2 = .5$

Altitude = sea level (T_0 = 288K, P_0 = 101325 N/m^2)

A_1 (inlet face area) = 0.00318 m^2 $\pi_b = 1.0$ $\eta_c = .90$

RPM_{design} = 60,000 RPM T_{t4} = 1500K $\pi_d = .9904$

$\tau_r = \frac{T_{t2}}{T_0}$

$A_1 = A_0$ -> design

$T_{t2} = T_0\left(1 + \frac{\gamma-1}{2} M_0^2\right)$

$P_{t2} = \left(1 + \frac{\gamma-1}{2} M_0^2\right)^{\frac{\gamma}{\gamma-1}} P_0 = P_{t1}$ $P_{t2} = P_{t1}\pi_d$

$\dot{m} = \rho u A$

$\tau_c = 1 + \frac{\pi_c^{\frac{\gamma-1}{\gamma}} - 1}{\eta_c}$

$P_{t3} = P_{t4}$

$\tau_t = 1 - \frac{T_{t2}}{T_{t4}}(\tau_c - 1)$

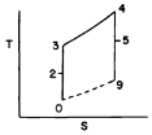

Fig. 5.20 Temperature-entropy diagram.

$M_8 = 1.0 \Rightarrow T_8 = \cancel{T_{t4}}$

Mach number=	1	Mach angle=	90	P-M angle=	0
p/p_0=	0.52828178	rho/rho_0=	0.63393814	T/T_0=	0.83333333
p/p^*=	1	rho/rho^*=	1.00000000	T/T^*=	1

TT

$\frac{N_{L2}}{\sqrt{\theta_2}}$

$M_4 = M_8 = 1 \Rightarrow T_8 \Rightarrow P_8$

$T_{t8} = \cancel{T_{t4}} T_{t4}\tau_t$

Velocities -> temps. -> machs ->

$\rho_0 u_0 A_0$

$\frac{P_0}{RT_0} M_0\sqrt{\gamma R T_0} A_0 = \frac{101325}{287 \cdot 288} \cdot 8\sqrt{1.4(287)288}\,(.00318) = \dot{M} = 1.0609 kg/s$

$\tau_r = 1 + \frac{\gamma-1}{2} M_0^2 = 1 + .2(.8)^2 = 1.128$

$T_{t3} = \tau_c T_{t2} = 2.374(324.864) = 771.227 K$

$T_{t0} = \tau_r T_0 = 324.864\ K = T_{t2}$

$P_{t0} = P_0[\tau_t]^{\frac{\gamma}{\gamma-1}} = 154458.752\ pa$

$P_{t2} = \pi_d P_{t0} = 152970.996\ p.$

$\dot{m}_{corr_2} = \frac{\dot{m}\sqrt{T_{t2}/T_{tsp}}}{P_{t2}/P_{tsp}} = .746\ kg/s$

$\tau_c = 1 + \frac{\pi_c^{\frac{\gamma-1}{\gamma}} - 1}{\eta_c}$, $\eta_c = .85$ $\Rightarrow \tau_c = \frac{1.15^{\frac{.4}{1.4}} - 1}{.85} = 2.374$

T_{t4} 1500

$$\frac{T_{t4}}{T_{t2}} = \frac{1500}{324.864} = 4.617$$

$$\tau_t = 1 - \frac{T_{t2}}{T_{t4}}(\tau_c - 1) = 1 - \frac{1}{4.617}(2.374 - 1) = .702$$

$$\pi_t = \left(1 - \frac{1-\tau_t}{\eta_t}\right)^{\gamma/(\gamma-1)} = \left[1 - \frac{1-.702}{.9}\right]^{1.4/.4} = .2448$$

$$T_{t8} = \tau_t T_{t4} = 1053\,K$$

$$P_{t8} = \pi_t P_{t4} = 561709.496\ pa$$

$$P_{t4} = P_{t3} = \pi_c P_{t2} = 2294564.433\ pa$$

$$M_8 = 1 \Rightarrow \frac{T_{t8}}{T_8} = 1 + \frac{\gamma-1}{2} M_8^2 \Rightarrow \frac{T_{t8}}{1.2} = T_8 = 877.5$$

$$u_8 = M_8\sqrt{\gamma R T_8} = 593.784\ m/s$$

$$u_0 = M_0\sqrt{\gamma R T_0} = 272.139\ m/s$$

$$T = \dot{m}(1+f)(u_8 - u_0) + (P_8 - P_0)A_8$$

$$f = \frac{\tau_r\left(T_{t4}/T_{t2} - \tau_c\right)}{\frac{h}{c_p T_0}} = .01644 \Rightarrow \dot{m}_f = .0174$$

$$\dot{m} = \rho_8 u_8 A_8 \Rightarrow \frac{\dot{m} R T_8}{P_8 u_8} = .0055\,m^2$$

$$T = \dot{m}(u_8 - u_0) + (P_8 - P_0)A_8 =$$

$$A_2 = \frac{\dot{m}}{\rho_2 u_2} = \frac{\dot{m} R T_2}{P_2 M_2 \sqrt{\gamma R T_2}}$$

$$\frac{P_{t2}}{\left(1 + \frac{\gamma-1}{2}M_2^2\right)^{\left(\frac{\gamma}{\gamma-1}\right)}} = P_2 = 128957.483\ pa$$

$$\frac{T_{t2}}{1 + \frac{\gamma-1}{2}M_2^2} = T_2 = 309.394$$

$$\frac{P_{t8}}{P_8} = \left(1 + \frac{\gamma-1}{2}M_8^2\right)^{\frac{\gamma}{\gamma-1}} \Rightarrow P_8 = 296740.847$$

$$\rho_8 = 1.178$$

$\rho_2 = \frac{P_2}{RT_2} = 1.452\ kg/m^3$

$u_2 = M_2\sqrt{\gamma R T_2} = 176.291\ m/s$

$u_3 = u_2$

$A_2 = \frac{\dot{m}}{\rho_2 u_2} = 0.00414$

$A_4 = \frac{\dot{m}}{\rho_4 u_4}$

$\frac{P_{t4}}{(1+(\gamma-1)/2)^{\frac{\gamma}{\gamma-1}}} = P_4 = \frac{2294564.933}{(1.2)^{1.41.4}} = 1212176.865\ pa$

$\frac{T_{t4}}{1.2} = T_4 = 1250K$

$\rho_4 = \frac{P_4}{RT_4} = 3.379$

$u_4 = \sqrt{\gamma R T_4} = 708.696 m/s$

$A_4 = \frac{1.0609}{3.379 \cdot 708.696} = 4.43E\text{-}4\ m^2$

$A_3 = \frac{\dot{m}}{\rho_3 u_3} \quad u_2 = U$

$T_3 = T_{t3} - T_{t2} + T_{t2} = 753.757$

$M_3 = \frac{u_3}{\sqrt{\gamma R T_3}} = .3199$

$P_3 = \frac{P_{t3}}{(1+M_3^2 \cdot .2)^{\frac{\gamma}{\gamma-1}}} = \frac{2294564.933}{[1+.2(.3199)^2]^{1.41.4}}$

$= 2137470.78\ pa$

$\rho = \frac{P_3}{RT_3} = 9.855\ kg/m^3$

$A_3 = \frac{1.0609}{} = 6.107E\text{-}4\ m^2$

$\frac{\dot{m}\sqrt{T_{t4}/T_{tSP}}}{P_{t4}/P_{tSP}} = .107$

$\frac{N_t}{\sqrt{\theta_4}} = 26290.683 \qquad \frac{N_t}{\sqrt{\theta_2}} = 56493.288$

$\dot{m}_{corr_2}\frac{1}{\pi_c}\frac{N_c}{\sqrt{\theta_2}} = 2809$

$\dot{m}_{corr_4}\frac{N_t}{\sqrt{\theta_4}} = 2810$

$\dot{m}_{corr_8} = \frac{\dot{m}\sqrt{T_{t8}/T_{tSTD}}}{P_{t8}/P_{tSP}} = .366$

$\frac{\dot{m}_{corr8}}{\dot{m}_{corr2}} = .491$

$\sqrt{T_{t4}/T_{t2}}\cdot\tau_t \quad \frac{1}{\pi_c \pi_t} = .491$

γRT_3

$A_3 = \frac{1.0609}{9.855 \cdot 176.291} = 6.107E-4\ m^2$

$A_5 = \frac{\dot{m}}{\rho_5 u_5}$

$P_5 = \frac{P_{t5}}{(1+.2M^2)^{\frac{\gamma}{\gamma-1}}} = 309258.738\ pa$

$u_5 = .8\, u_4 = 566.957$

$T_5 = \frac{.18 u_4^2}{c_p} T_4 + T_{t5} - T_{t4} = 860.6\ k$

$\rho_5 = \frac{P_5}{RT} = 1.252\ kg/m^3$

$M_5 = \frac{u}{\sqrt{\gamma R T_5}} = .9641$

$A_5 \approx .001494\ m^2 \Rightarrow A_8 = .001492\ m^2$