AE3235 Thermodynamics and Gas Turbines

Governing equations

If $M = 0$

$$T_a = T_0$$

$$P_a = P_0$$

If $M \neq 0$

$$T_0 = T\left(1 + \frac{\gamma - 1}{2} M^2\right)$$

$$P_0 = P\left(\frac{T_0}{T}\right)^{\frac{\gamma}{\gamma-1}}$$

Compression

$$T_2 = T_1\left[1 + \frac{1}{\eta}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]\right]$$

Mass flow

$$\dot{m}_{a_{duct}} + \dot{m}_{a_{core}} = \dot{m}_a$$

$$BPR = \frac{\dot{m}_{a_{duct}}}{\dot{m}_{a_{core}}}$$

Fuel flow

$$\dot{m}_{fuel} = \frac{\dot{m}_{air} \cdot c_{pg} \cdot \Delta T_{cc}}{\eta_{cc} \cdot H_f}$$

Expansion

$$\frac{T_2}{T_1} = 1 - \eta\left[1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right] \rightarrow P_2 = P_1\left[\frac{1}{\eta}\left(\frac{T_2}{T_1} - 1\right) + 1\right]^{\frac{\gamma}{\gamma-1}}$$

$$W \cdot \eta_{mech} = c_{pa} \cdot \dot{m} \cdot (T_2 - T_1)$$

$$c_{pa} \cdot \dot{m} \cdot \Delta T_{comp} = \eta_{mech} \cdot c_{pg} \cdot \left(\dot{m}_{a_{core}} + \dot{m}_{fuel}\right) \cdot \Delta T_{turb}$$

Critical pressure ratio

$$\varepsilon_{kr} = \frac{P_1}{P_2} = \left[\frac{1}{1 - \frac{\gamma - 1}{\eta_{is} \cdot (\gamma + 1)}}\right]^{\frac{\gamma}{\gamma-1}}$$

With ε_{kr}, one can check if the nozzle is choked or not

If $\frac{P}{P_a} < \varepsilon_{kr}$ the nozzle is **NOT choked**

$$P_j = P_a$$
$$P_0 = P_{2.1}$$

T_j is found with isentropic relationship

$$c_j = \sqrt{2 \cdot C_p \cdot \Delta T}$$
$$F_N = \dot{m} \cdot (c_j - c_0)$$
$$A_j = \frac{\dot{m} \cdot R \cdot T_j}{P_j \cdot c_j}$$

$\frac{P}{P_a} > \varepsilon_{kr}$ the nozzle is **choked**

$$P = \rho \cdot R \cdot T$$
$$P_s = \frac{P}{P_a} = \frac{P}{\varepsilon_{kr}}$$

$$TR_{cr} = \frac{\gamma + 1}{2}$$
$$T_j = \frac{T}{TR_{cr}}$$

$$c_j = \sqrt{\gamma \cdot R \cdot T_j}$$
$$A_j = \frac{\dot{m} \cdot RT_{cr}}{P_j \cdot c_j}$$
$$F_N = \dot{m}_j(c_j - c_0) + A_j(P_j - P_0)$$

Specific thrust

$$F_s = \frac{F_N}{\dot{m}}$$

Thrust specific fuel consumption

$$TSFC = \frac{\dot{m}_{fuel}}{F_N}$$

$$CD = \frac{A_{eff}}{A_{goniometric}}$$

First stage of an axial turbine.

$$T_0 = T_{st} + \frac{1}{2C_p}V^2$$

$$Sp\ Power = C_p \Delta T$$

$$\eta_{is} = \frac{\Delta T}{\Delta T_{is}}$$

$$\Delta T_{is} = T_0 \left(1 - \left(\frac{1}{\varepsilon}\right)^{\frac{\gamma - 1}{\gamma}}\right)$$