AE 234/711 Aircraft Propulsion
Quiz 6

Compare the specific fuel consumption of a turbojet and a ramjet that are being considered for flight at $M = 1.5$ at an altitude of 15 km. Consider the following for the ambient air properties: $T = 205\ K$, $p = 11.6\ kPa$, $c_p = 1\ kJ/kg - K$.

Assume the compressor and turbine efficiencies to be 0.90. Let the fuel heating value be $45\ MJ/kg$.

The turbojet compressor has a pressure ratio of 12 and the maximum allowable temperature is 1400 K. For the ramjet the maximum temperature is 2500 K.

For simplicity, assume there is no pressure loss in the combustor. Also assume no losses in the diffuser (intake) and the nozzle. Assume that the nozzle is perfectly expanded.

$$R = \frac{\gamma - 1}{\gamma} c_p \qquad c_a = \sqrt{\gamma R T_a} = 286 \text{ m/s}, V_a = M_a c_a = 430 \text{ m/s}$$

At the end of intake/diffuser: $T_{t2} = 297$ K, $p_{t2} = 42.6$ kPa

Perfect Expansion in nozzle $\implies$ Exit velocity is determined by nozzle pressure ratio:

$$V_e = \sqrt{2\left(h_{t5} - h_e\right)} \equiv \sqrt{2c_p T_{t5}\left[1 - \left(\frac{p_a}{p_{t5}}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$

- Ramjet:

    - No compressor $\implies T_{t3} = T_{t2}$ and $p_{t3} = p_{t2}$
    - $f = c_p \left(T_{t4} - T_{t3}\right)/Q_r = 0.049$
    - No turbine $\implies T_{t5} = T_{t4}$ and $p_{t5} = p_{t4}$
    - $V_e = 1246$ m/s $\implies \mathcal{T}/\dot{m}_a = 0.88$ kN/kg $\implies$ TSFC $= 55.8$ gm/kN $-$ s

- Turbojet:

    - $\pi_c = 12 \implies T_{t3} = 638.7$ K and $p_{t3} = 511$ kPa
    - $f = c_p \left(T_{t4} - T_{t3}\right)/Q_r = 0.017$
    - $w_t = w_c = 341.5$ kJ/kg $\implies \pi_t = 3.02$
    - $\rightarrow T_{t5} = 1064.2$ K and $p_{t5} = 172.7$ kPa
    - $V_e = 1070$ m/s $\implies \mathcal{T}/\dot{m}_a = 0.66$ kN/kg $\implies$ TSFC $= 25.7$ gm/kN $-$ s