AEM 408 – Propulsion

Problem Statement: A ramjet is to propel an aircraft at Mach 3 at high altitude where the ambient pressure is 8.5 kPa and the ambient pressure T_a is 220 K. The turbine inlet temperature T is 2540 K. If all components of the engine are ideal – that is, frictionless – determine

1. The thermal efficiency
2. The propulsion efficiency
3. The overall efficiency

Let the specific heat ratio be $\gamma = 1.4$ and make the approximations appropriate to f<<1.

Solution:

Find T_{0_2}

$$T_{0_2} = T_a\left(1 + \frac{\gamma - 1}{2}M^2\right) = 220\left(1 + \frac{1.4 - 1}{2}3^2\right) = 616\ K$$

Find T_e

$$\frac{T_e}{T_{0_4}} = \frac{T_a}{T_{0_2}}$$

$$T_e = \frac{T_a}{T_{0_2}} * T_{0_4} = \frac{220}{616} * 2540 = 907.1\ K$$

Find u_e

****$M_e = M$ because the ramjet is assumed to be ideal**

$$u_e = M_e\sqrt{\gamma R T_e} = 3\sqrt{1.4 * 287 * 907.1} = 1811\ m/s$$

Find u

$$u = M\sqrt{\gamma R T_a} = 3\sqrt{1.4 * 287 * 220} = 891.9\ m/s$$

1. **Propulsion Efficiency**

$$n_p = \frac{2\frac{u}{u_e}}{1+\frac{u}{u_e}} = \frac{2\frac{891.9}{1811}}{1+\frac{891.9}{1811}}$$

$$n_p = 0.660$$

2. **Thermal Efficiency**

$$n_{th} = \frac{\frac{1}{2}({u_e}^2 - u^2)}{C_p(T_{0_4} - T_{0_2})} = \frac{\frac{1}{2}(1811^2 - 891.9^2)}{1005(2540 - 616)}$$

$$n_{th} = 0.642$$

3. **Overall Efficiency**

$$n_o = n_p * n_{th} = 0.66 * 0.642$$

$$n_o = 0.424$$