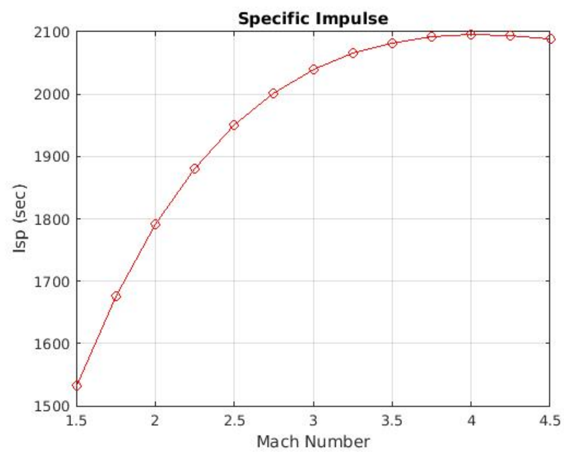
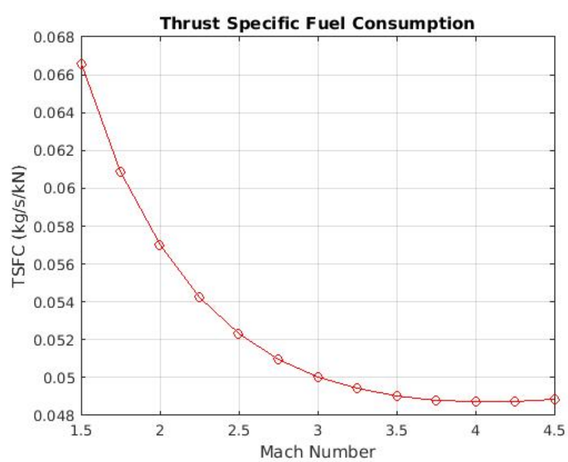
ASE 376K Homework # 3

Use the equations at the bottom of this question and any other you need to write a computer program to perform a Ramjet Analysis to plot **<u>TSFC and Isp</u>** as a function of different parameters – you can use Excel, Matlab, Python or any other programming language of your choice. <u>Label the axis and Label the plots.</u> Explain briefly what you see in the plots.

1. Plot TSFC and Isp vs M, from 1.5 to 4.5 in steps of 0.25
   - Set all inefficiencies to 1.
   - Incoming static temperature = 220K.
   - T04 (Tmax) = 3400K
   - Perfectly expanded nozzle, so pa=pe
   - Heat of combustion, Qr = 45 MJ/kg
   - Cp = 1005 J/kg/K, R = 287 J/kg/K, g = 1.4

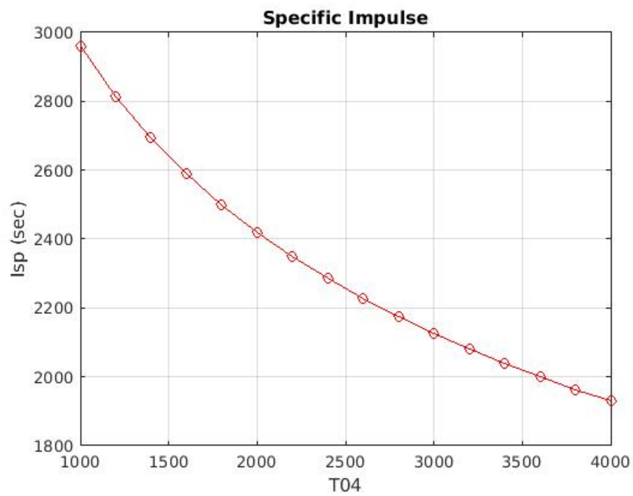


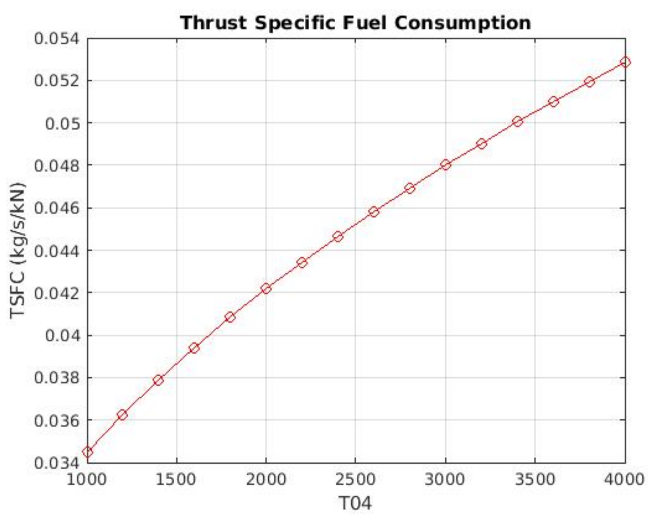
Specific impulse increases with Mach number, peaking at Mach 4.0, and tapering off.



TSFC decreases with Mach number, with the lowest value occurring at Mach 4.0. This engine has an ideal operating Mach number around 4.0 for most efficient operation.

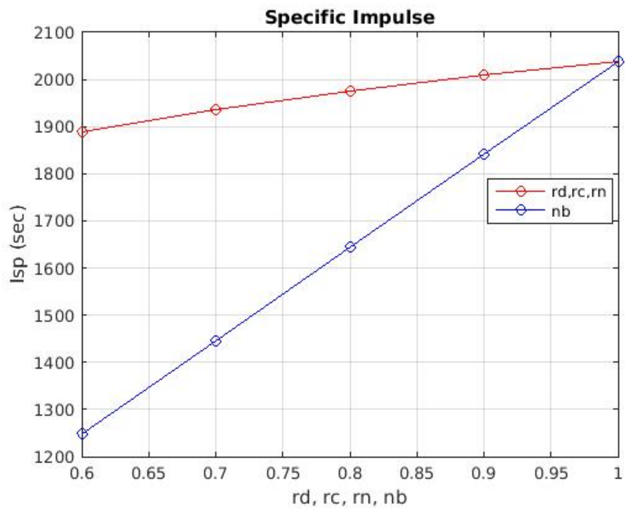
2. Plot TSFC and Isp vs T_{04} (i.e., maximum allowable temperature at the exit of the combustor), vary from 1000K to 4000K in steps of 200K.
    - Set all inefficiencies to 1.
    - Incoming static temperature = 220K.
    - Perfectly expanded nozzle, so pa=pe
    - Heat of combustion, Qr = 45 MJ/kg
    - Cp = 1005 J/kg/K, R = 287 J/kg/K, g = 1.4
    - incoming Mach number of 3

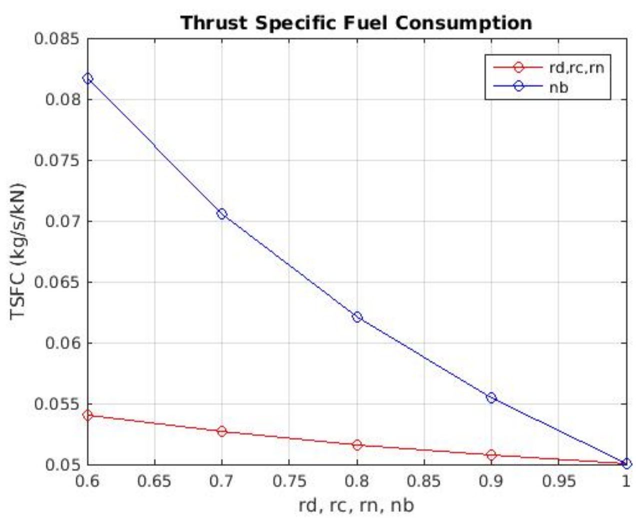




Increasing the maximum allowable temperature allows for burning more fuel, but not necessarily in the most efficient manner. In fact, TSFC keeps increasing continuously with increasing T04.

3. Plot TSFC and Isp vs r_d, and h_b individually by varying them one at a time from 0.6 to 1 (in steps of 0.1). Hold the other inefficiencies at 1. For example, if you are looking at the effect of r_d, make all other at 1 and vary r_d from 0.6 to 1.
   - incoming Mach number of 3.
   - perfectly expanded nozzle, so pa=pe
   - T04 (Tmax) < 3400K
   - Incoming static temperature, 220K
   - Heat of combustion, Qr = 45 MJ/kg
   - Cp = 1005 J/kg/K, R = 287 J/kg/K, g = 1.4





Increasing the efficiency clearly improves the Impulse since more thrust can be obtained from the same fuel consumption. Increasing efficiency also helps reduce TSFC.

$$\frac{\mathcal{T}}{\dot{m}_a} = (1 + f)\sqrt{\frac{2\gamma R T_{04}(m - 1)}{(\gamma - 1)m}} - \mathrm{M}\sqrt{\gamma R T_a} + \frac{p_e A_e}{\dot{m}_a}\left(1 - \frac{p_a}{p_e}\right),$$

in which

$$m = \left(1 + \frac{\gamma - 1}{2}\mathrm{M}^2\right)\left(r_d r_c r_n \frac{p_a}{p_e}\right)^{(\gamma-1)/\gamma}.$$

$$f = \frac{(T_{04}/T_{0a}) - 1}{(\eta_b Q_R/c_p T_{0a}) - (T_{04}/T_{0a})},$$