Assignment #8

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Goal

1. Plot specific thrust as a function of flight mach number for a variety of area ratios in a real ramjet.
2. For the chosen design of part 2 (i.e. the chosen area ratio), redo the specific thrust calculation using the real properties of the working fluid for fuel air ratio, exit temperature, and exit mach number computation.

Governing Equations and Methodologies

$$P_{4t} = P_4\left(1 + \frac{\gamma_4 - 1}{2} M_4^2\right)^{\frac{\gamma_4}{\gamma_4 - 1}}$$

$$T_{3t} = T_{4t} = T_4\left(1 + \frac{\gamma_4 - 1}{2} M_4^2\right)$$

$$\frac{A_4}{A^*} = \frac{\left(1 + \frac{\gamma_4 - 1}{2} M_4^2\right)^{\frac{\gamma_4 + 1}{2(\gamma_4 - 1)}}}{\pi_n\left(\frac{\gamma^* + 1}{2}\right)^{\frac{\gamma^* + 1}{2(\gamma^* - 1)}} M_4} \frac{\sqrt{\gamma^*}}{\sqrt{\gamma_4}}$$

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Governing Equations and Methodologies

$$f = \frac{Cp_3 T_{3t} - Cp_2 T_{0t}}{(Q_R - Cp_3 T_{3t})}$$

$$P_0 \pi_d \pi_b \pi_n \frac{\left(1 + \frac{\gamma_0 - 1}{2} M_0^2\right)^{\frac{\gamma_0}{\gamma_0 - 1}}}{\left(1 + \frac{\gamma_4 - 1}{2} M_4^2\right)^{\frac{\gamma_4}{\gamma_4 - 1}}} = P_4$$

Governing Equations and Methodologies

Pressure Specific Thrust:

$$\frac{T}{\dot{m}}_{Momentum} = (1+f)(P_4 - P_0)\frac{RT_4}{P_4 M_4 \sqrt{\gamma_4 R T_4}}$$

Momentum Specific Thrust:

$$\frac{T}{\dot{m}}_{Pressure} = \boldsymbol{a_0 M_0 \left[(1+f)\frac{M_4\sqrt{\gamma_4 T_{3t}}}{M_0\sqrt{\gamma_0 T_0}} \frac{1}{\left(1+\frac{\gamma_4 - 1}{2}M_4^2\right)^{\frac{1}{2}}} - 1 \right]}$$

Governing Equations and Methodologies

Total Specific Thrust (Noramilized):

$$\frac{T}{\dot{m}(1+f)}_{Total} = \frac{T}{\dot{m}(1+f)}_{Momentum} + \frac{T}{\dot{m}(1+f)}_{Pressure}$$

Specific Thrust As A Function Of Flight Mach Number For A Variety Of Area Ratios In A Real Ramjet | Part 1

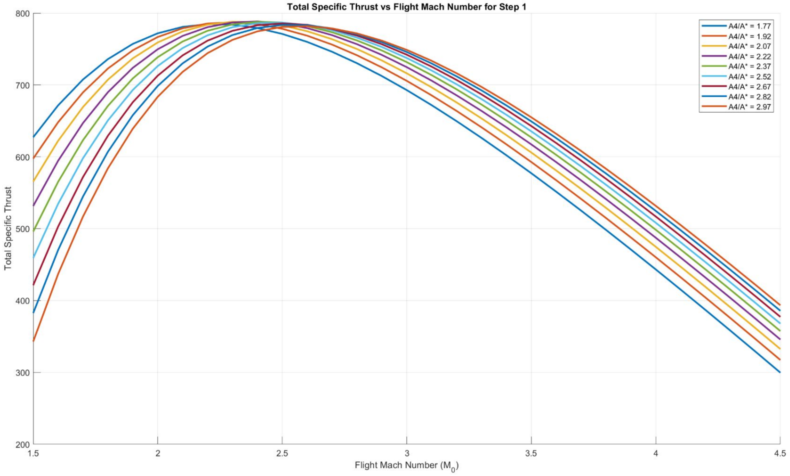

Figure 0. Specific thrust vs Flight Mach Number (M0) for a real ramjet. The maximum function value corresponds to ~788 Ns/kg @ an area ratio of 2.22, implying that the area ratio for use in step 2 is 2.22.

Maximum Specific Thrust As A Function Of Varying A4/A* Area Ratios | Part 1

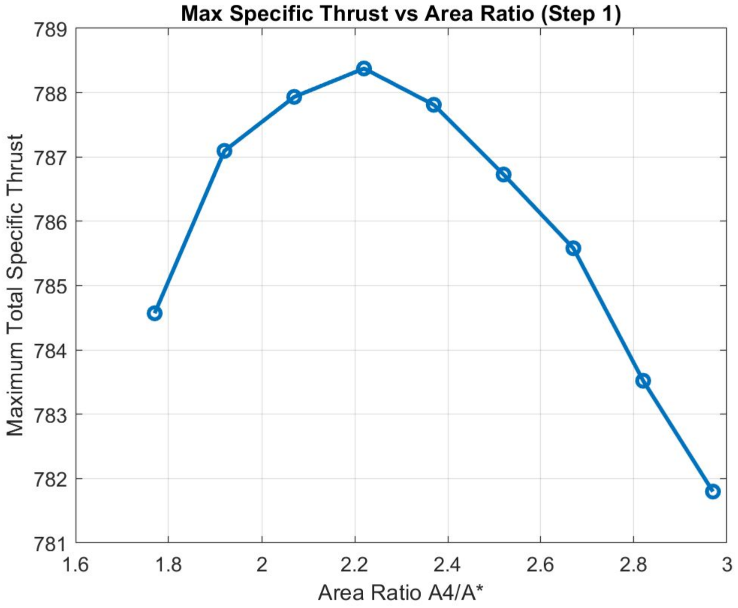

Figure 1. Maximum Total Specific Thrust vs Area Ratio A4/A* used to determine best area ratio during step 2. Here, the area ratio A4/A* ~ 2.22 has the highest maximum specific thrust and will thus be used for subsequent real ramjet analysis.

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Total Specific Thrust vs Flight Mach Number for a Real Ramjet Operating with a 2.22 A4/A* Area Ratio | Part 2

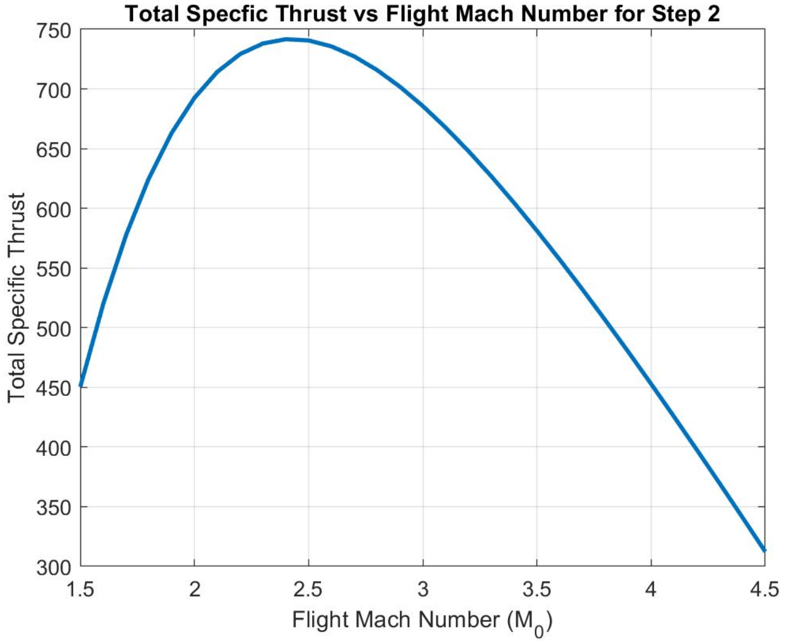

Figure 2. Flight Mach Number vs Total Specific Thrust (normalized) for a real ramjet with a area ratio of 2.22 as picked by the previous figure. Additionally, real gas properties were realized (i.e. cp and gamma vary with temperature).

Conclusions

1. The optimal area ratio for a real ramjet with constant gas properties (i.e. step 1) was found to be A4/A* = 2.22/
2. Maximum specific thrust for this ratio is ST = 788 Ns/kg
3. When analyzing this ideal area ratio at varying gas properties (i.e. step 2) the maximum specific thrust falls to ST = 742 Ns/kg, a 5.83% decline relative to the maximum thrust measured when the gas properties where constant (i.e. step 1).

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