

1. (50 points) A non-afterburning turbojet is being designed for operation at an altitude of 15 km and a Mach number of 1.8. The maximum stagnation temperature at the inlet of the turbine is 1500 K. The fuel is a jet fuel having a LHV of 43124 kJ/kg and f_{st} is 0.06. The following efficiencies apply at this Mach number:

$$\begin{array}{lll} \eta_d = 0.9 & \eta_b = 0.98 & \eta_t = 0.92 \\ \eta_c = 0.9 & r_b = 0.97 & \eta_n = 0.98 \end{array}$$

Use a gamma value of 1.4 up to the burner, and a value of 1.3 for the rest of the engine. Assume R is 0.287 kJ/kgK throughout the engine. Plot the specific thrust, TSFC, η_{th} , η_p , and η_o as a function of r_c , the total pressure ratio across the compressor. Is there an optimum r_c that minimizes TSFC? Is there an optimum r_c that maximizes specific thrust? Consider a range of r_c from 2 to 60. Assume the exhaust is ideally expanded. Also plot the nozzle area ratio as a function of r_c .

$$kJ := 10^3 \cdot J$$

$$\begin{array}{llllll} nd := 0.9 & nt := 0.92 & alt := 15 \text{ km} & hc := 43124 \frac{kJ}{kg} & R := 0.287 \frac{kJ}{kg \cdot K} \\ nc := 0.9 & nn := 0.98 & M_{flt} := 1.8 & fst := 0.06 & cp_{in} := 1004.5 \frac{J}{kg \cdot K} \\ nb := 0.98 & rb := 0.97 & T_{04} := 1500 \text{ K} & \gamma_{in} := 1.4 & \gamma_b := 1.3 \\ & & & & cp_b := \frac{\gamma_b}{\gamma_b - 1} \cdot R = 1.244 \frac{kJ}{kg \cdot K} \end{array}$$

Outside Engine

$$\begin{array}{llll} P_a := 18750 \text{ Pa} = 2.719 \text{ psi} & T_a := 216.65 \text{ K} & U := M_{flt} \cdot \sqrt{\gamma_{in} \cdot R \cdot T_a} = 1188 \text{ mph} \\ T_{0a} := T_a \cdot \left(1 + \frac{\gamma_{in} - 1}{2} \cdot M_{flt}^2 \right) = 357.039 \text{ K} & P_{0a} := P_a \cdot \left(1 + \frac{\gamma_{in} - 1}{2} \cdot M_{flt}^2 \right)^{\frac{\gamma_{in}}{\gamma_{in} - 1}} = 15.625 \text{ psi} \end{array}$$

Inlet/Diffuser

$$\begin{array}{llll} T_{02} := T_{0a} & T_{02a} := nd \cdot (T_{02} - T_a) + T_a & P_{02} := P_a \cdot \left(\frac{T_{02a}}{T_a} \right)^{\frac{\gamma_{in}}{\gamma_{in} - 1}} & \gamma = 0.577 \end{array}$$

Compressor

Note: Mathcad usually starts vector indices at 0

$$rc := 2, 3..60 \quad P_{03}(z) := z \cdot P_{02} \quad \text{define a FUNCTION rather than a vector}$$

$$T_{03a}(z) := T_{02} \cdot \left(\frac{P_{03}(z)}{P_{02}} \right)^{\frac{\gamma_{in} - 1}{\gamma_{in}}} \quad T_{03}(z) := \frac{T_{03a}(z) - T_{02}}{nc} + T_{02} \quad w_{c_in}(z) := cp_{in} \cdot (T_{03}(z) - T_{02})$$

Combuster

$$fb(z) := \frac{T_{04} - T_{03}(z)}{\frac{nb \cdot hc}{cp_b} - T_{04}} \quad fb(2) = 0.033$$

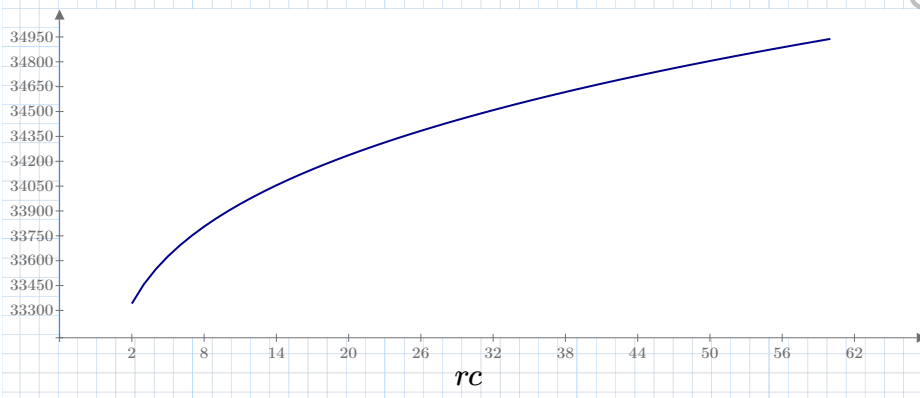
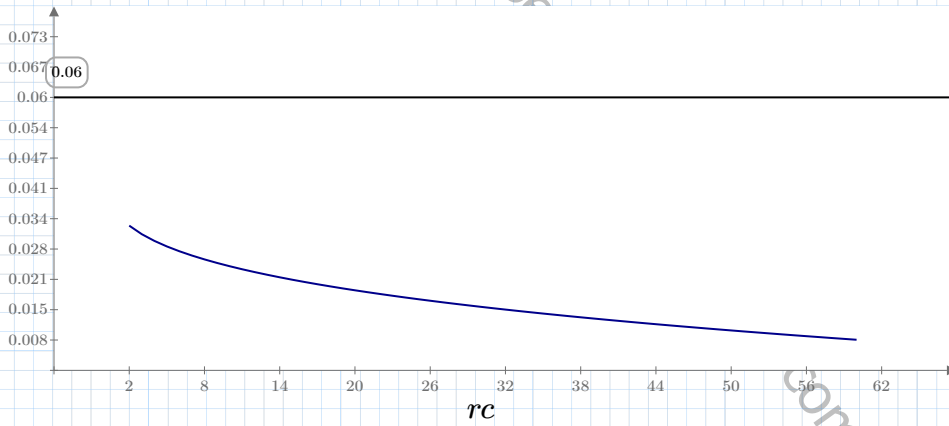
$fb(2) = 0.033$ I assume your loop wants to return $to4(z)$

```
fb = (t04 - t03) / ((nb*hc)/cp - t04)
for i = 1:length(fb)
    if fb(i) > fs
        fb(i) = fs
        t04(i) = 1 / (1 + fb(i)) * ((nb*hc)/cp + t03)
    end
end
```

My fb is (similar to the first line of code)

$$fb(rc) := \frac{T_{04} - T_{03}(rc)}{\left(\frac{nb \cdot hc}{cp_b}\right) - T_{04}}$$

$$T_{04}(z) := \text{if} \left(fb(z) > fst, \frac{1}{1 + fst} \cdot \left(\frac{nb \cdot hc}{cp_b} + T_{03}(z) \right), \frac{1}{1 + fb(z)} \cdot \left(\frac{nb \cdot hc}{cp_b} + T_{03}(z) \right) \right)$$



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