

MAE 563 - AIRCRAFT PROPULSION PROJECT

ANALYSIS TOOL

Module 1 - Conditions at section 1 - Atmospheric conditions

$$P_s := 101.3 \text{ kPa} \quad z_{star} := 8404 \text{ m}$$

$$T_s := 288 \text{ K} \quad R := 286.9 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

$$\rho_s := 1.23 \frac{\text{kg}}{\text{m}^3} \quad \gamma := 1.4$$

$$z := 4300 \text{ m} \quad x := 0.8, 0.84..5 \quad M_1 := x =$$

$$T_1 := T_s \cdot \left(1 - \frac{(\gamma - 1)}{\gamma} \cdot \frac{z}{z_{star}} \right)$$

$$T_{t1} := T_1 \cdot \left(1 + \frac{(\gamma - 1)}{2} \cdot M_1^2 \right)^{\frac{\gamma}{\gamma - 1}}$$

$$P_1 := P_s \cdot \left(1 - \frac{(\gamma - 1)}{\gamma} \cdot \frac{z}{z_{star}} \right)^{\frac{\gamma}{\gamma - 1}}$$

$$P_{t1} := P_1 \cdot \left(1 + \frac{(\gamma - 1)}{2} \cdot M_1^2 \right)^{\frac{\gamma}{\gamma - 1}}$$

$$a_1 := \sqrt{\gamma \cdot R \cdot T_1}$$

$$V_1 := M_1 \cdot a_1$$

Module 2 - Conditions at section 2 - Inlet/Diffuser section

$$M_2 := 0.15 \quad c_p := 1004 \frac{\text{J}}{\text{kg} \cdot \text{K}}$$

$$\eta_d := 0.92 \quad T_{t2} := T_{t1}$$

$$T_2 := \frac{T_{t2}}{1 + \frac{(\gamma - 1)}{2} \cdot M_2^2}$$

$$P_{t2} := P_1 \cdot \left(1 + n_r \cdot \frac{(\gamma - 1)}{M_1^2} \right)^{\frac{\gamma}{\gamma - 1}}$$

$$\begin{bmatrix} 0.8 \\ 0.84 \\ 0.88 \\ 0.92 \\ 0.96 \\ 1 \\ 1.04 \\ 1.08 \\ 1.12 \\ \vdots \end{bmatrix}$$

1 2 3 4 5 6 7 8 9 10 11 12

$$P_2 := \frac{P_{t2}}{\left(1 + \frac{(\gamma-1)}{2} M_2^2\right)^{\frac{\gamma}{\gamma-1}}}$$

$$a_2 := \sqrt{\gamma \cdot R \cdot T_2}$$

$$V_2 := M_2 \cdot a_2$$

$$\Delta s_{12} := c_p \cdot \ln \left(\frac{T_{t2}}{T_{t1}} \right) - R \cdot \ln \left(\frac{P_{t2}}{P_{t1}} \right)$$

Module 3 - Conditions at section 3 - Combustor section

$$b := 0.179 \frac{J}{kg \cdot K^2} \quad a := 986 \frac{J}{kg \cdot K}$$

$$M_2 := 0.15 \quad T_{t3} := 2400 \text{ K}$$

$$\gamma_0 := 1.3 \quad P_3 := P_2$$

$$q_{23} := a \cdot (T_{t3} - T_{t2}) + \frac{1}{2} \cdot b \cdot (T_{t3}^2 - T_{t2}^2)$$

$$C := \frac{T_{t3}}{T_{t2}} \cdot \frac{\left(1 + \frac{(\gamma_0-1)}{2} \cdot M_2^2\right)}{\left(1 + \gamma_0 \cdot M_2^2\right)^2} \cdot M_2^2$$

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 $M_3 := \begin{cases} \text{for } i \in 0..105 \\ \quad \begin{cases} \text{for } j \in 0..1000 \\ \quad \begin{cases} x_j \leftarrow \frac{\left(1 + \frac{(\gamma_0-1)}{2} y_j^2\right)}{\left(1 + \gamma_0 \cdot y_j^2\right)^2} \cdot y_j^2 \\ \text{if } C_i = x_j \\ \quad \begin{cases} M_i \leftarrow y_j \\ \text{else} \\ \quad \begin{cases} j \leftarrow j+1 \end{cases} \end{cases} \end{cases} \end{cases} \end{cases} = 0$ 

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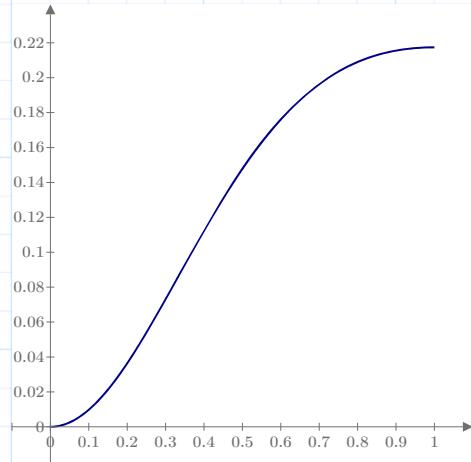
On Iteratively solving x for different M_3 , we try and match the value of C to x. The value of x is greatest for $M_3 = 1$, if C is greater than this value for $M_3 = 1$ then the flow is thermally choked.

$$y := 0, 0.001..1 = \begin{bmatrix} 0 \\ 0.001 \\ 0.002 \\ 0.003 \\ 0.004 \\ 0.005 \\ 0.006 \\ 0.007 \\ 0.008 \\ 0.009 \\ 0.01 \\ 0.011 \\ \vdots \end{bmatrix}$$

|| return M

$$x(y) := \frac{\left(1 + \frac{(\gamma_0 - 1)}{2} y^2\right)}{(1 + \gamma_0 \cdot y^2)^2} \cdot y^2 \quad x(.635) = 0.184$$

$y2 := 0, 0.01..1$



$x(y2)$

$y2$

$$x = \frac{\left(1 + \frac{(\gamma_0 - 1)}{2} y^2\right)}{(1 + \gamma_0 \cdot y^2)^2} \cdot y^2$$

explicit, solve, y

$$\begin{aligned} & \sqrt{\frac{\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} - 2 \cdot \gamma_0 \cdot x + 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}} \\ & -\sqrt{\frac{\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} - 2 \cdot \gamma_0 \cdot x + 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}} \\ & \sqrt{\frac{\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} + 2 \cdot \gamma_0 \cdot x - 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}} \\ & -\sqrt{\frac{\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} + 2 \cdot \gamma_0 \cdot x - 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}} \end{aligned}$$

$$y(x) := \sqrt{\frac{\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} + 2 \cdot \gamma_0 \cdot x - 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}}$$

$y(.184) = 0.635$

Constraintless Values

$x := .1$

$$y = \sqrt{\frac{-\sqrt{1 - 2 \cdot \gamma_0 \cdot x - 2 \cdot x} + 2 \cdot \gamma_0 \cdot x - 1}{2 \cdot x \cdot \gamma_0^2 - \gamma_0 + 1}}$$

Solver

$\mathbf{a}(y) := \mathbf{find}(x)$

$$\mathbf{a}(.635) = 0.184$$

$answer :=$
$$\begin{cases} \text{for } i \in 0 .. \text{last}(C) \\ \quad \left| \begin{array}{l} y \leftarrow C_i \\ ans_i \leftarrow \mathbf{a}(y) \end{array} \right. \\ \text{return } ans \end{cases}$$

$answer =$

$$\begin{bmatrix} 0.031 \\ 0.031 \\ 0.03 \\ 0.029 \\ 0.029 \\ 0.028 \\ 0.027 \\ 0.027 \\ 0.026 \\ 0.025 \\ 0.024 \\ 0.024 \\ \vdots \end{bmatrix}$$