Gas Tables Calculator

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Abstract

The aim of this report is to presents concise formulations for isentropic flow, normal shock, and oblique shock relations for a perfect gas with ratio of specific heats γ. Equations are only summarized for quick reference from class notes itself.

Objectives

- Develop equations to find various parameters with a single given parameter in isentropic flow, normal shock, and oblique shock.
- To write a code for all the relations and make a calculator.

Isentropic Flow Relations

- Mach Angle (μ):

$$\mu = \sin^{-1}\left(\frac{1}{M}\right) \tag{1}$$

- Prandtl–Meyer Angle (ν):

$$\nu(M) = \sqrt{\frac{\gamma+1}{\gamma-1}}\ \tan^{-1}\left(\sqrt{\frac{\gamma-1}{\gamma+1}\,(M^2-1)}\right) - \tan^{-1}\left(\sqrt{M^2-1}\right) \tag{2}$$

- Static pressure to Stagnation pressure (p/p_0):

$$\frac{p}{p_0} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-\frac{\gamma}{\gamma-1}} \tag{3}$$

- Static density to Stagnation density (ρ/ρ_0):

$$\frac{\rho}{\rho_0} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-\frac{1}{\gamma-1}} \tag{4}$$

- Static temperature to Stagnation temperature (T/T_0):

$$\frac{T}{T_0} = \left(1 + \frac{\gamma-1}{2}M^2\right)^{-1} \tag{5}$$

- Pressure Ratio at Critical Mach Number (p/p^*):

$$\frac{p}{p^*} = \left(\frac{\gamma+1}{1+\frac{\gamma-1}{2}M^2}\right)^{\frac{\gamma}{\gamma-1}} \tag{6}$$

- Density Ratio at Critical Mach Number (ρ/ρ^*):

$$\frac{\rho}{\rho^*} = \left(\frac{\gamma+1}{1+\frac{\gamma-1}{2}M^2}\right)^{\frac{1}{\gamma-1}} \tag{7}$$

- Temperature Ratio at Critical Mach Number (T/T^*):

$$\frac{T}{T^*} = \frac{\gamma + 1}{2 + \ (\gamma - 1)M^2} \tag{8}$$

- Area Ratio at Critical Mach Number (A/A^*):

$$\frac{A}{A^*} = \frac{1}{M} \left(\frac{2}{\gamma + 1} \left(1 + \frac{\gamma - 1}{2} M^2 \right) \right)^{\frac{\gamma+1}{2(\gamma-1)}} \tag{9}$$

Normal Shock Equations

Upstream Mach Number is denoted as M_1 and specific heat ratio is γ.

- Downstream Mach Number (M_2):

$$M_2 = \sqrt{\frac{(\gamma - 1)M_1^2 + 2}{2\gamma M_1^2 - (\gamma - 1)}} \tag{10}$$

- Total Pressure Ratio (p_{02}/p_{01}):

$$\frac{p_{02}}{p_{01}} = \left(\frac{(\gamma + 1)M_1^2}{2 + (\gamma - 1)M_1^2} \right)^{\frac{\gamma}{\gamma-1}} \left(\frac{\gamma + 1}{2\gamma M_1^2 - (\gamma - 1)} \right)^{\frac{1}{\gamma-1}} \tag{11}$$

- Static Pressure Ratio (p_1/p_{02}):

$$\frac{p_1}{p_{02}} = \left(1 + \frac{\gamma + 1}{2}(M_1^2 - 1) \right)^{-1} = \left(1 + 0.5(\gamma - 1) \left(\frac{2\gamma M_1^2 - (\gamma - 1)}{(\gamma + 1)M_1^2} \right) \right)^{-\frac{\gamma}{\gamma-1}} \tag{12}$$

- Static Pressure Ratio (p_2/p_1):

$$\frac{p_2}{p_1} = \frac{2\gamma M_1^2}{\gamma + 1} - \frac{\gamma - 1}{\gamma + 1} \tag{13}$$

- Density Ratio (ρ_2/ρ_1):

$$\frac{\rho_2}{\rho_1} = \frac{p_2}{p_1} \cdot \frac{T_1}{T_2} = \frac{(\gamma + 1)M_1^2}{2 + (\gamma - 1)M_1^2} \tag{14}$$

- Temperature Ratio (T_2/T_1):

$$\frac{T_2}{T_1} = \frac{(2\gamma M_1^2 - (\gamma - 1))\,(2 + (\gamma - 1)M_1^2)}{(\gamma + 1)^2 M_1^2} \tag{15}$$

Oblique Shock Equations

- Upstream Mach Number is denoted as M1, specific heat ratio is γ, Turn Angle is θ and Wave Angle is β.
- Turn Angle (θ) with respect to wave angle (β):

$$\tan\theta = \frac{2\cot\beta(M_1^2\sin^2\beta - 1)}{M_1^2(\gamma + \cos 2\beta) + 2}$$

- Normal Mach Number Upstream (Mn1):

$$M_{n1} = M \cdot \sin(\beta)$$

- Downstream Mach Number (M2):

$$M_2 = \sqrt{\frac{2 + (\gamma - 1)M_{n1}^2}{2\gamma M_{n1}^2 - (\gamma - 1)}} \cdot \frac{1}{\sin(\beta - \theta)}$$

- Normal Mach Number Downstream (Mn2):

$$M_{n2} = M_2 \cdot \sin(\beta - \theta)$$

- Static Pressure Ratio (p2/p1):

$$\frac{p_2}{p_1} = 1 + \frac{2\gamma}{\gamma + 1} \cdot (M_{n1}^2 - 1)$$

- Density Ratio ($\rho 2/\rho 1$):

$$\frac{\rho_2}{\rho_1} = \frac{M_{n1}^2(\gamma + 1)}{2 + (\gamma - 1)M_{n1}^2}$$

- Temperature Ratio (T2/T1):

$$\frac{T_2}{T_1} = \frac{1 + \frac{2\gamma}{\gamma+1}(M_{n1}^2 - 1)}{\frac{M_{n1}^2(\gamma+1)}{2+(\gamma-1)M_{n1}^2}}$$

- Stagnation Pressure Ratio (p02/p01):

$$\frac{p_{02}}{p_{01}} = \frac{p_2}{p_1} \cdot \left(\frac{1 + \frac{\gamma-1}{2}M_2^2}{1 + \frac{\gamma-1}{2}M_{n1}^2}\right)^{\frac{\gamma}{\gamma-1}}$$

Librareis Used

- I didn't use much libraries, instead I used reference to solve reverse mach relation using numerical analysis
- Compressible Aerodynamics Calculator here was a good resource to learn about the values to convert from, and to verify your my results.
- Apart from that I implemented the calculator in Typescript, because of its typesafety I was able to detect early on.
- Now Typescript's or in general browser side languages are frontend first, therefore I had to make the fronted first, Which results in both gui and calculator backend.