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Aerospace Engineering Department

Gas Dynamics

(AE 325)

Term Project

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INTRODUCTION:

In this report, I will use computer software for the calculation of compressible flow properties.
I will list all the equations that are needed to calculate all the properties and then construct big tables of the following:

1. Isentropic flow
2. Normal shock waves (we can find also properties of oblique and expansion waves)
3. One-Dimensional adiabatic flow with friction

All calculations will be carried according to the value of value of specific heat ratio

$\gamma = C_P/C_V = 1.4$

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1. Isentropic flow:

We will calculate the following five parameters:

1. Mach number (M)
2. Pressure ratio (P_0/P)
3. Temperature ratio (T_0/T)
4. Density ratio (ρ_0/ ρ)
5. Area ratio (A/A^*)

And obtain the other four properties and Prandtle-Mayer angle for (M>1)

We will input the value of the Mach number (M) and we will calculate the parameters:

- To calculate the temperature ratio **(T_0/T)**

We use this equation:

$(T_0/T) = [1+(\gamma - 1) M^2 /2]$

- To calculate the pressure ratio **(P_0/P)**

We use this equation:

$(P_0/P) = [1+(\gamma - 1) M^2 /2]^{(\gamma/ \gamma-1)}$

- To calculate the density ratio **(ρ_0/ ρ)**

We use this equation:

$(\rho_0/ \rho) = [1+(\gamma - 1) M^2 /2]^{(1/ \gamma-1)}$

- To calculate **(a_0/ a)**

We use this equation:

$(a_0/ a) = (\gamma R T_0/ \gamma R T)^{1/2} = (T_0/T)^{1/2}$

- To calculate the area ratio **(A/A^*)**

We use this equation:

$(A/A^*) = [2/(\gamma+1) + (\gamma-1)/(\gamma+1) M^2]^{1/(\gamma-1)} * [2/(\gamma+1)+(\gamma-1)/(\gamma+1)M^2]^{1/2}$

- To calculate the Prandtle-Mayer angle for (M>1) **(θ)**

We use this equation:

$\theta = [(\gamma+1)/ \gamma-1)]^{1/2} * \tan^{-1} [(\gamma-1)/ \gamma+1)*(M-1)]^{1/2} - \tan^{-1} (M^2-1)^{1/2}$

Were θ is in degress.

2. Normal shock waves:

We will calculate the following six parameters:

1. Mach number ahead of the shock wave (M_1)
2. Mach number behind of the shock wave (M_2)
3. Stagnation pressure ratio across the shock wave (P_{02}/P_{01})
4. Static pressure ratio across the shock wave (P_2/P_1)
5. Static temperature ratio across the shock wave (T_2/T_1)

And obtain tabulated results for (M_1), (P_2/P_1), (ρ_2/ρ_1), (T_2/T_1), (P_{02}/P_{01}), (P_{02}/P_1), and (M_2)

We will input (M_1):

- To calculate **(M_2)**

We use this equation:

$$M_2 = \{[(M_1)^2 + (2/(\gamma-1))]/[(2\gamma/(\gamma-1))*(M_1)^2 - 1]\}^{1/2}$$

- To calculate **(P_2/P_1)**

We use this equation:

$$(P_2/P_1) = [2\gamma (M_1)^2 - (\gamma-1)] / (\gamma+1)$$

- To calculate **(T_2/T_1)**

We use this equation:

$$(T_2/T_1) = [(\gamma+1)/(\gamma-1) + P_2/P_1] / [(\gamma+1)/(\gamma-1) + P_1/P_2]$$

- To calculate **(ρ_2/ ρ_1)**

We use this equation:

$(\rho_2/ \rho_1) = [(\gamma+1)* (P_2/P_1)+1] / [(\gamma+1)/ (\gamma-1)+ P_2/P_1]$

- To calculate **(P_{02}/P_{01})**

We use this equation:

$$(P_{02}/P_{01}) = \{(\gamma-1)/2 * (M_1)^2 /[1+(\gamma-1)/2 * (M_1)^2]\}^{(\gamma/ \gamma-1)} *$$

$$\{2 \gamma (\gamma+1) * (M_1)^2 - [(\gamma-1)/ (\gamma+1)\}^{(-1/ \gamma-1)}$$

- To calculate **(P_{02}/P_1)**

We use this equation:

$$(P_{02}/P_1) = \{[1+(\gamma-1)/2 *(M_2)^2]^{(\gamma/ \gamma-1)}\} *\{[2 \gamma (M_1)^2 - (\gamma-1)] / (\gamma+1)\}$$

3. One-Dimensional adiabatic flow with friction:

We will calculate the following parameters:

1. Mach number (M)
2. Friction factor term (4 f L/D)
3. Pressure ratio (P/P^*)
4. Temperature ratio (T/T^*)
5. Density ratio (ρ/ ρ^*)
6. Stagnation pressure ratio (P_0/P_0^*)
7. Velocity ratio (V/V^*)

We will input (M) and we will calculate the other properties by using the following equations:

- To calculate (P/P^*)

We use this equation:

$$(P/P^*) = 1/M \{[(\gamma+1)/2]/[1+(\gamma+1)*M^2/2]\}^{1/2}$$

- To calculate (T/T^*)

We use this equation:

$$(T/T^*) = [(\gamma+1)/2]/[1+(\gamma-1)*M^2/2]$$

- To calculate (P_0/P_0^*)

We use this equation:

$$(P_0/P_0^*) = (P/P^*)\{[1+(\gamma-1)*M^2/2]/[(\gamma+1)/2]\}^{(\gamma/\gamma-1)}$$

- To calculate (ρ/ρ^*)

We use this equation:

$$(\rho/\rho^*) = 1/M \{[(\gamma+1)/2]/[1+(\gamma+1)*M^2/2]^{1/2} * \{[1+(\gamma-1)*M^2/2]/[(\gamma+1)/2]\}$$

- To calculate (V/V^*)

We use this equation:

$$(V/V^*) = 1/M (T/T^*)^{1/2} = 1/M \{[(\gamma+1)/2]/[1+(\gamma-1)*M^2/2]\}^{1/2}$$

- To calculate $(4 f L^*/D)$

We use this equation:

$$(4 f L^*/D)=[(1-M^2)/(\gamma M^2)]+[(\gamma+1)/(2\gamma)] \ln\{[(\gamma+1) M^2]/[2(1+1/2(\gamma-1)M^2)]$$

CONCLUSION:

Actually the usage of constructing these tables is very helpful in solving the problems and finding the solution in short time instead of going through all the equations above and calculating all the properties, which of course will take longer time more effort, and possible wrong answers. But the tables guarantee correct answers, since they were found by a computer program.

REFERENCES:

The equations above that I used to calculate the properties are found in many books. I will list them below as references.

1. J. D. Anderson, Modern Compressible Flow with Historical Perspective (3 rd Ed.), McGraw-Hill International Editions, 2003.

2. Michel A. Saad, Compressible Fluid Flow (2 nd Ed.), Prentice Hall, 1993.

3. M. Haluk Askel and O. Cahit Eralp, Gas Dynamics, Prentice Hall, 1993.

4. Ascher. H. Shapiro, The Dynamics and Thermodynamics of Compressible Fluid Flow, Volume 1, John Wiley & Sons, 1953.