Engineering Software

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Engineering Assumptions

When dealing with energy conversion and considering ideal (isentropic) operation and the working fluid is air, the following assumptions are valid:

Compressible Flow
Single species consideration
Basic equations hold (continuity, momentum and energy equations)
Specific heat is constant

Basic Conservation Equations

Continuity Equation

$m = \rho v A$ [kg/s]

Momentum Equation

$F = (vm + pA)_{out - in}$ [N]

Energy Equation

$q - w = (h + v^2/2 + gh)_{out - in}$ [kJ/kg]

Basic Engineering Equations

Ideal Gas State Equation

$pv = RT$ [kJ/kg]

Perfect Gas

c_p = constant [kJ/kg*K]

Kappa

$\chi = c_p/c_v$ [/]

For air: χ = 1.4 [/], R = 0.2867 [kJ/kg*K] and

c_p = 1.004 [kJ/kg*K]

Compressible Flow Engineering Equations

Sonic Velocity

$$v_s = (\chi RT)^{1/2} \text{ [m/s]}$$

Mach Number

$$M = v/v_s \text{ [/]}$$

Compressible Flow Engineering Equations

Energy Equation

$$q - w = (h + v^2/2 + gh)_{out\ -\ in}\ [kJ/kg]$$

When q = 0 and w = 0 (for isentropic expansion), it follows:

$$(h + v^2/2 + gh)_{in} = (h + v^2/2 + gh)_{out}$$

Furthermore,

in = Total and/or Stagnation Condition (t) and v = 0

out = Static Condition

Also, gh = 0

Compressible Flow Engineering Equations

Therefore,

$$h_t = h + v^2/2$$

$$c_p T_t = c_p T + v^2/2$$

$$T_t = T + v^2/(c_p 2)$$

$$T_t = T(1 + v^2/(T c_p 2))$$

$$T_t/T = (1 + v^2/(T c_p 2))$$

$$c_p - c_v = R$$

$$\mathrm{X} = c_p/c_v$$

Compressible Flow Engineering Equations

$$1 - c_v/c_p = R/c_p$$

$$(X - 1)/X = R/c_p$$

$$(X - 1)/(XR) = 1/c_p$$

Hence,

$$T_t/T = (1 + v^2/(Tc_p 2))$$

$$T_t/T = (1 + ((X - 1)v^2)/(TXR2))$$

$$v_s^2 = \chi RT$$

Compressible Flow Engineering Equations

$$T_t/T = (1 + ((X - 1)v^2)/(v_s{}^2 2))$$

$$M^2 = (v/v_s)^2$$

$$T_t/T = (1 + M^2(X - 1)/2)$$

Compressible Flow Engineering Equations

Knowing the following:

$$T_t/T = (p_t/p)^{(\chi-1)/\chi}$$

$$p_t/p = (T_t/T)^{\chi/(\chi-1)}$$

$$p_t/p = (1 + M^2(\chi - 1)/2)^{\chi/(\chi-1)}$$

Compressible Flow Engineering Equations

Isentropic Flow

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

$$p_t/p = (1 + M^2(\gamma - 1)/2)^{\gamma/(\gamma-1)} \text{ [/]}$$

$$h_t = (h + v^2/2) \text{ [kJ/kg]}$$

$$T_t = (T + v^2/(2c_p)) \text{ [K]}$$

$$\text{Thrust} = vm + (p - p_a)A \text{ [N]}$$