HW1 SP01C

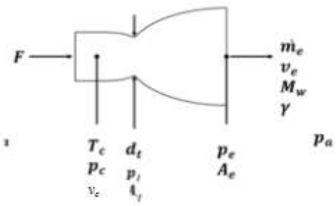
Wednesday, January 18, 2023 2:15 PM

1. **Name:** Veronica Loomis
2. **Given:** Rocket motor with a converging-diverging nozzle
3. **Find:**
    a. Starting with the conservation of energy equation for a control volume (see Appendix C), show a systematic derivation of the thrust equation that includes the velocity in the chamber entering the nozzle. State all the assumptions relevant to reducing and modifying the original equation and show the additional laws/equations that are inserted into the solution to arrive at Equation 4.23 in the textbook (with the added v_c term that is not included)

    $$v_e^2 = \frac{2\gamma R_u T_c}{\mathfrak{M}(\gamma - 1)}\left[1 - (p_e/p_c)^{(\gamma-1)/\gamma}\right]$$

    b. Comment on the definitions and equations for thermally perfect gas and calorically perfect gas assumptions and why real rocket nozzles operation behave differently.

4. **Schematic:**



Equations:

Motor with C/D nozzle

$$\dot{Q} - \dot{W} = \sum \dot{m}_e\left(h_e + \frac{V_e^2}{2} + gz_e\right) - \sum \dot{m}_i\left(h_i + \frac{V_i^2}{2} + gz_i\right) \quad [kW]$$

$$\downarrow$$

$$V_e^2 = \frac{2\gamma R_u T_c}{M(\gamma-1)}\left[1 - \left(P_e/P_c\right)^{(\gamma-1)/\gamma}\right] + V_c$$

Assume:

Adiabatic: $\dot{Q} = 0$

No shaft work: $\dot{W} = 0$

assume very low M

$$0 = h_e + \frac{V_e^2}{2} + g\cancel{z_e} - h_i - \cancel{\frac{V_i^2}{2}} - \cancel{gz_i}$$

these are the same

$$V_e^2 = 2(h_i - h_e)$$

$$h_x = \frac{\gamma R T_x}{\gamma - 1} \qquad R = \frac{R_u}{M} \rightarrow \text{script } M$$

$$V_e^2 = 2\left[\frac{\gamma R T_i}{\gamma-1} - \frac{\gamma R T_e}{\gamma-1}\right]$$

$$V_e^2 = \frac{2\gamma R}{\gamma-1}(T_i - T_e) \qquad T_i = T_c$$

$$V_e^2 = \frac{2\gamma R T_c}{\gamma-1}\left(1 - \frac{T_e}{T_c}\right)$$

$$\boxed{V_e^2 = \frac{2\gamma R T_c}{\gamma-1}\left[1-\left(\frac{P_e}{P_c}\right)^{(\gamma-1)/\gamma}\right]}$$

Answer

b)

Answer

Thermally perfect: Obeys $PV = nRT$

↳ can't always assume bc of gas particle interactions

Calorically perfect: C_v & C_p are constant w/in a temp range

↳ Generally invalid due to large temp changes involved

Comment:
It is convenient to assume thermally and calorically perfect since it makes the math easier, but oftentimes it is not truly the case