SECTION 2: Solid Propulsion

8. (20%) You are asked to design a simple rocket using a solid propellant motor with the following characteristics:

    Propellant: TP-H-3340 – 18% Al, 71% AP, 11% HTPB (Propellant B)
    Combustion Chamber Pressure: 5 MPa
    Ratio of Specific Heats (Products): 1.190
    Molecular Weight (Products): 31 g/mol

    For a thrust of 1700 N and a burn time of 30 seconds, calculate the thruster's mass flow and specific impulse. Assume ideal expansion at sea level.

Ideal: $F = \dot{m} V_e$

$$V_e = \sqrt{\frac{2\gamma \mathcal{R} T_o}{(\gamma-1)\, mw}\left\{1 - \left(\frac{P_e}{P_o}\right)^{\gamma-1/\gamma}\right\}}$$

$V_e = 2302.17\ m/s$

$$\boxed{\dot{m} = F/V_e = 0.738\ kg/s}$$

$$\boxed{I_{sp} = F/\dot{m} g_o = 234.68\ s}$$

Propellant B

$\gamma = 1.19$

$mw = 31\ kg/kmol$

$T_o = 3396\ K$

$\rho_p = 1800\ kg/m^3$

$c^* = 1527\ m/s$

$a = 0.399$

$n = 0.3$

Sea level:

$P_e = 0.1\ MPa$

9. (15%) For the conditions given in Problem #8, design the grain assuming an end-burner grain geometry for a rocket a burn time of 30 sec.

$M_{prop} = \dot{m}\, t_{burn} = 22.14\ kg$

$$\dot{m} = \rho_p \dot{r} A_b = 1800\ kg/m^3\ \frac{\left[0.399\ (5 MPa)^{0.3}\ cm/s\right]}{100\ cm/m}\ \frac{\pi D_g^2}{4} = 0.738\ kg/s$$

$$\boxed{D_g = 0.284\ m}$$

$$V = \frac{M_{prop}}{\rho_{prop}} = \frac{22.14\ kg}{1800\ kg/m^3} = 0.0123\ m^3 = \pi R_g^2 L_g$$

$$L_g = \frac{V}{\pi R_g^2} = \frac{0.0123\ m^3}{\pi\,(0.284 m/2)^2}$$

$$\boxed{L_g = 0.194 m}$$

SECTION 3: Liquid Propulsion

10. (15%) A thruster using liquid oxygen and liquid hydrogen propellants is being designed to have a combustion chamber pressure of 5.62 MPa and temperature of 3086 K. For a nozzle throat diameter of 10 cm, the propellant mass flow rate was measured to be 18.732 kg/sec. Is the measured value of the mass flow reasonable? Expain.

App. B: At $T_0 = 3086\,K$

$\gamma = 1.22$

$MW = 10.5\ kg/kmol$

$$C^*_{theory} = \frac{\sqrt{\gamma R T_0}}{\gamma\left(\frac{2}{\gamma+1}\right)^{\gamma+1/2(\gamma-1)}}$$

$$= \frac{\sqrt{1.22\ \ 8314.14/10.5\ \ (3086K)}}{1.22\left(\frac{2}{2.22}\right)^{2.22/0.44}}$$

$$C^*_{theory} = 2396.1\ m/s$$

$$C^*_{meas} = \frac{P_0 A_t}{\dot{m}} = \frac{5.62\times10^6\,Pa\ \left(\pi\,\frac{(0.1\,m)^2}{4}\right)}{18.732\ kg/s} = 2356.4\,m/s$$

$$\eta_{c^*} = \frac{C^*_{meas}}{C^*_{theory}} = 0.983$$ ✓ reasonable.

11. (15%) A nitrous oxide monopropellant thruster system is being used for satellite