DEPARTMENT OF AEROSPACE ENGINEERING
III B.TECH. VI Semester.
CYCLE TEST-II

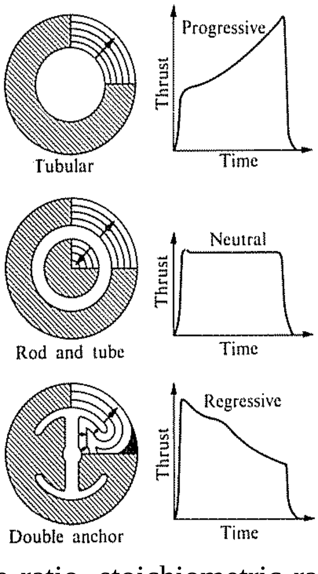
AS1012: Rocket Propulsion. **Date: 29-03-2016**
Time: 90 minutes **Max. Marks: 40**

Answer Any Four Questions
PART-A (4X4=16 Marks)

1. Enumerate the important factors that influence the burning rate of a solid propellant?
   Propellant burning rate is influenced by:
   - Combustion chamber pressure
   - Initial temperature of the propellant grain
   - Velocity of the combustion gases flowing parallel to the burning surface
   - Local static pressure
   - Motor acceleration and spin
   - Size of granules in the propellant
2. Name any four propellant ingredients and Binders used in a solid propellant rocket motor.
   Any four propellant ingredients and Binders used in a solid propellant rocket motor

3. What are the factors that affect the Ignitability of a solid propellant?

4. Draw with neat sketch explain Neutral Burning, Progressive burning and regressive burning of a solid propellant.



5. Define the following: Equivalence ratio, stoichiometric ratio, Enthalpy of formation and Enthalpy of Combustion.

Equivalence ratio

It is defined as the ratio of actual fuel to air mass ratio to that of stoichiometric fuel to air mass ratio.

$$\phi = \frac{\left(m_f / m_a\right)_{actual}}{\left(m_f / m_a\right)_{stoi}}$$

PART-B (2X12=24 Marks)

Answer any two questions

6. Considering a complete combustion of the following fuel i) isooctane with pure oxygen, ii)kerosene with air determine :(a) the mole fraction of fuel(b) the fuel-air ratio (c) the mole fraction of H_2O in the products and, (d) Heat of combustion of isooctane by assuming the following reaction takes place.

$$C_nH_m + x\left(O_2 + 3.78N_2\right) \rightarrow nCO_2 + \frac{m}{2}H_2O + \left(x \times 3.78\right)N_2$$

$$\Delta H^f{}_{octane} = -249.95kJ/mol$$

$$\Delta H^f{}_{CO_2} = -393.51kJ/mol$$

$$\Delta H^f{}_{H_2O} = -285.83kJ/mol$$

Solution

for case(*i*)

$$C_8H_{18} + xO_2 \rightarrow 8CO_2 + 9H_2O$$

$$where, x = n + \frac{m/2}{2} = n + \frac{m}{4} = 8 + 4.5 = 12.5$$

a) Mole fraction of fuel

$$MF_{C_8H_{18}} = \frac{1}{1+12.5} = 0.0741$$

b) fuel– air ratio

$$\frac{\dot{m}_f}{\dot{m}_a} = \frac{8*12+18}{12.5*16} = 0.57$$

c) *mole fraction of products*

$$Y_{CO_2} = \frac{8}{8+9} = 0.471$$

$$Y_{H_2O} = \frac{9}{8+9} = 0.529$$

d) *Heat of Combustion*

$$\Delta H = (8(-393.51) + 9(-285.83) - (-249.95)) = -5470.55KJ$$

for case(*ii*)

$$C_{12}H_{24} + x\left(O_2 + 3.76N_2\right) \rightarrow 12CO_2 + 12H_2O + x(3.76N_2)$$

$$where, x = n + \frac{m/2}{2} = n + \frac{m}{4} = 12 + 6 = 18$$

a) Mole fraction of fuel

$$MF_{C_8H_{18}} = \frac{1}{1+18(1+3.78)} = 0.01149$$

b) fuel– air ratio

$$\frac{\dot{m}_f}{\dot{m}_a} = \frac{12*12+24}{18(16+3.78*28)} = 0.0766$$

c) *mole fraction of products*

$$Y_{CO_2} = \frac{12}{12+12+68.04} = 0.1304$$

$$Y_{H_2O} = \frac{12}{12+12+68.04} = 0.1304$$

7. A solid rocket motor has the following operating characteristics:
Sea level thrust 15,000 N, Duration 15 sec, Chamber pressure 7.5 MPa Specific heat ratio 1.26, Chamber temperature 2800 K ,Burning rate 8 mm/sec at 7.5 MPa, Propellant density 1.67 gm/cc ,Molecular mass 28 kg/kmol. Assuming a neutral burning (with a cigarette burning grain) and an adapted nozzle operating at sea level, find the (a) Characteristic velocity, (b)Exhaust jet velocity (c)Thrust coefficient at optimum expansion, (d) specific impulse at sea level, (e) nozzle throat area, (f) weight of the propellant and (g) burning surface area

$$Given:$$
$$T = 15000N$$
$$t_b = 15s$$
$$P_c = 7.5MPa$$
$$\gamma = 1.26$$
$$T_c = 2800K$$
$$r = 8mm/s \to 7.5MPa$$
$$\rho_b = 1670kg/m^3$$
$$Molecular\ mass = 28kg/kmole$$
$$Solution:$$
$$C^* = \frac{\sqrt{RT_c}}{\sqrt{\gamma}\left[\frac{2}{\gamma+1}\right]^{\frac{\gamma+1}{2(\gamma-1)}}} = \frac{\sqrt{\frac{8314}{22}\times 2500}}{\sqrt{1.26}\left[\frac{2}{1.26+1}\right]^{\frac{1.26+1}{2(1.26-1)}}} = 1381.67m/s$$
$$V_j = \sqrt{\frac{2\gamma RT_c}{\gamma-1}\left[1-\left(\frac{P_e}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]}$$
$$V_j = \sqrt{\frac{2\times 1.26\times\frac{8314}{28}\times 2800}{1.26-1}\left[1-\left(\frac{1.01325\times 10^5}{7.5\times 10^6}\right)^{\frac{1.26-1}{1.26}}\right]} = 2177.85m/s$$
$$C_{F0} = \frac{V_j}{C^*} = 1.5762$$
$$C_{F0} = \sqrt{\frac{2\gamma^2}{\gamma-1}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{(\gamma-1)}}\left[1-\left(\frac{P_e}{P_c}\right)^{\frac{\gamma-1}{\gamma}}\right]} = 1.5762$$
$$F = C_F P_c A_t \to A_t = \frac{F}{C_F P_c} = \frac{15000}{1.5762\times 7.5\times 10^6} = 1.2688\times 10^{-3} m^2$$

$$I_{sp} = \frac{V_j}{g_0} = 222s$$

$$I_{sp} = \frac{F}{\dot{w}_p} \rightarrow \dot{w}_p = \frac{F}{I_{sp}} = \frac{15000}{222} = 67.56N / s$$

$$w_p = \dot{w}_p t_b = 67.56 \times 15 = 1013.51N$$

$$\dot{m}_p = \frac{\dot{w}_p}{g_0} = \frac{67.56}{9.81} = 6.8876kg / s$$

$$A_b = \frac{\dot{m}_p}{\rho_b r} = \frac{6.8876}{1670 \times 6 \times 10^{-3}} = 0.5155m^2$$

8. The grain in a solid propellant rocket is a hollow cylinder bonded to the casing so that it burns only on its inner cylindrical surface. Its density is 1600 kg/m3, and its burning rate is characterized by r=0.0153 P $^{0.7}$ mm/s where P is in Mpa. At a point where diameter of 0.65m, generates the pressure p1= 0.7 Mpa, the grain d/D = 0.4 and L/D = 1.67, L being the grain length and, d and D being its inner and outer diameters .Throat diameter is 60 mm. Determine the rate of change of chamber pressure, assuming the gas temperature stays constant at 2750 K and that the gas specific heat ratio is 1.24 and D = 1.5 m. Take R= 307 J/KgK.

$$Given:$$

$$\rho_b = 1600 kg/m^3$$

$$r = 0.0153 P^{0.7}$$

$$P_{c1} = 0.7 MPa \rightarrow at\, 0.65 m\, diameter$$

$$d/D = 0.4$$

$$L/D = 1.67$$

$$D = 1.5 m$$

$$\gamma = 1.24$$

$$T_c = 2750 K$$

$$R = 307 J/kgK$$

$$solution:$$

$$L = 1.67$$

$$C^* = \frac{\sqrt{RT_c}}{\sqrt{\gamma}\left[\frac{2}{\gamma+1}\right]^{\frac{\gamma+1}{2(\gamma-1)}}} = \frac{\sqrt{307 \times 2750}}{\sqrt{1.24}\left[\frac{2}{1.24+1}\right]^{\frac{1.24+1}{2(1.24-1)}}} = 1400 m/s$$

$$p_{c1} = \left(\frac{A_{b1} a \rho_p c^*}{A_t}\right)^{\frac{1}{1-n}}$$

$$\rightarrow A_t = \left(\frac{A_{b1} a \rho_p c^*}{P_c^{1-n}}\right) = 3.0922 m^2$$

$$p_{ci} = \left(\frac{A_{bi} a \rho_p c^*}{A_t}\right)^{\frac{1}{1-n}} = .5361 MPa$$

$$p_{co} = \left(\frac{A_{bo} a \rho_p c^*}{A_t}\right)^{\frac{1}{1-n}} = 11.3693 MPa$$

$$\Delta P = p_{co} - p_{ci} = 10.8332 MPa$$