Quiz II

Answer all Questions

1. A hollow cylindrical propellant grain of outer diameter 600 mm has the initial propellant surface in the shape of a diverging cone. The axis of the cone coincides with the axis of the cylindrical chamber containing the grain. The port diameter of the conical surface increases from 200 mm at the head end of the grain to 300 mm at the nozzle end. The length of the grain is 750 mm. The throat diameter is 45 mm. The ends of the grain are inhibited from burning. Determine:
   i. Initial equilibrium value of pressure developed by the grain
   ii. Maximum pressure developed
   iii. Web thickness
   iv. Mass of the propellant sliver

   You can assume the burn rate law for the propellant to be given by $r = a\, p^n$. The value of a_{70} = 5 mm/s and n=0.3. The characteristic velocity (C*) for the propellant is 1500 m/s. The density of the solid propellant is 1700 kg/m^3.

2. A liquid propellant rocket developing a thrust of 500 N uses MMH and N_2O_4 for the propellant at a mixture ratio of 1.65. The chamber pressure is 0.7 MPa. The value of the characteristic velocity C* of the propellant at the above chamber pressure and the mixture ratio of 1.65 is 1800 m/s. The thrust coefficient C_F of the rocket is 1.5. Determine:

   i. Throat area of the nozzle

   ii. Mass flow rate of MMH and N_2O_4

   iii. The diameter of the injection holes to be provided in the injector for the MMH and N_2O_4 if 10 doublet injector elements are used. The injection pressure of MMH and N_2O_4 is 1 MPa. The discharge coefficient of the orifices is 0.95 for both MMH and N_2O_4. The density of MMH is 868 kg/m^3 and the density of N_2O_4 is 1400 kg/m^3.

3. A liquid propellant rocket uses hydrazine for fuel and N_2O_4 for oxidizer. The rate of hydrazine injection is 4 g/s and that of N_2O_4 is 6 g/s. The mean diameter of hydrazine and N_2O_4 droplets formed in the spray is 0.3 mm and the mean axial velocity of the droplets

in the combustion chamber is 50 m/s. The mean length of the combustion chamber is 50 cm.

The evaporation of the droplets can be assumed to be given by the law: $d^2 = d_0^2 - \lambda t$, where d is the diameter of the droplets at time t and d_0 is the initial diameter. The evaporation constant λ is 3 mm^2/s for hydrazine droplets and 5 mm^2/s for N_2O_4 droplets. Determine:

i. Mixture ratio at injection

ii. Mixture ratio of the vaporized propellant.

iii. If the characteristic velocity C* in m/s is expressed in terms of mixture ratio by the expression $C^* = 2000 - 100(|R - 1.4|)$, what is the value of C* efficiency due to incomplete vaporization.

4. In a simplified model of combustion of a solid composite propellant, you can assume the final diffusion flame to stand off at a distance of 120 μm from the surface and to be at a temperature of 3000 K . The steady state temperature of the burning surface is 700 K. The specific heat of the propellant is 800 J/(kg K) and the thermal conductivity of the gas above the propellant is 0.05 W/(m K). The overall heat required at the surface to bring about the pyrolysis and gas release is 50 kJ/kg. Determine the burn rate of the propellant.

You can assume the density of the propellant as 1500 kg/m^3 and the density of the gas above the propellant as 12 kg/m^3. The temperature of the unburned propellant is 300 K. You can also assume a linear profile for the temperature distribution between the flame and the propellant surface.