MCL721 Advanced automotive Prime Movers
Sample Problem set #3
(27/01/2019)

1. A petrol engine with a compression ratio of 6 is operating at a fuel-air-ratio (FAR) of 1:15. The pressure and temperature at beginning of compression stroke is 1 bar and 57°C respectively. If the specific heat of the charge at constant volume is approximated by an expression as C_v = (0.678 + 0.00013 T) KJ/kg-K, where T is temperature in Kelvin, calculate the maximum pressure in the engine. Compare this with assumption of constant C_v = 0.717 KJ/kg-K. Use the fuel as iso-octane (C_8H_{18}) with a calorific value of 42 MJ/kg. Assume compression process with air (c_p/c_v = 1.3).

2. While an engine was delivering 30% of its maximum power, the exhaust gas composition measurements were done. The results revealed following values in moles or volumetric fractions:
   CO_2 = 11%, H_2O = 11.5%, CO = 0.5%, O_2 = 2%, N_2 = 74.5% and Unburned hydrocarbons expressed in terms of CH_2 = 0.5%.
   a) Is the engine a diesel of spark-ignition engine? Is there enough oxygen in the exhaust to burn the fuel completely?
   b) Calculate the combustion efficiency of the engine. What portions of input fuel energy ($m_f\, Q_{HV}$) exit the engine in terms of unburned hydrocarbon and CO individually?

   The fuel is $(CH_2)_n$ with a heating value of 44 MJ/kg. Atomic weights: C = 12, H = 1, O = 16, N = 14. Heating values of CO is 10 MJ/kg.

3. A gas engine, running on a gaseous mixture of butane, C_4H_{10} and air has the following conditions in the cylinder prior to constant-volume adiabatic combustion: pressure, 6.48 x 10^5 N/m^2; temperature, 600 K. Calculate the enthalpy, internal energy and specific volume (m^3/kg) of the mixture, if its composition corresponds to a equivalence ratio (ϕ) of 0.5, without any exhaust residual gas. The internal energy of air and butane at 600 K are 12,596 KJ/kmol and 38,424 KJ/kmol respectively.
   Calculate the pressure and temperature at the end of combustion, if the internal energy of combustion of butane at 298 K is $\Delta\widehat{u^o_{comb}}$ = -2.659 MJ/gmol and the sensible internal energy of products after combustion are (in KJ/kmol): 6293 at 298 K, 54,227 at 2075 K, 54,380 at 2080 K.

4. Hydrogen is a possible future fuel for spark-ignited engines promising much cleaner combustion (less emissions). It comes with a higher heat density (Q_{HV} = 120 MJ/kg) compared to the gasoline (Q_{HV} = 44 MJ/kg) on mass basis. However, a disadvantage is that due to lesser molecular weight it displaces more air in the intake manifold, hence leading to lesser air intake which is proportional to the partial pressure of the air. For H_2 and gasoline fuel (C_8H_{18}), compare the following for the same SI engine running at same rpm and operating at unity equivalence ratio (φ = 1):
   a. Stochiometric air to fuel ratio
   b. Partial pressure of air in the intake manifold
   c. Heat content in the fuel-air mixture entering the engine per cycle

   For comparison, engine parameters such as displaced volume, rpm etc. can be kept in symbolic form. Assume total mixture pressure and temperature in intake manifold after fuel injection and complete vaporization of gasoline are same as that with H_2.