Ref. No.: Ex/PE/PE/B/T/421A/2022

B.E. Power Engineering 4th Year 2nd Semester 2022 Examination

Subject: Combustion

Full Marks: 70 **Time:**

Answer any five questions

1. A group of students were conducting an experiment in the laboratory with flames. They took a tubular burner of circular cross-section, passed a mixture of fuel (propane) and air through it and ignited a flame. They found the colour of some part of the flame to be yellow. The teacher explained that the flame is yellow because the fuel-air mixture is rich.
   (i) What do you mean by a rich fuel-air mixture? Name a parameter which can directly show from its value whether a fuel-air mixture is rich or not and define it. [2+1+2]
   (ii) Why is a flame burning rich fuel-air mixture yellow in colour? [3]
   (iii) The students measured the fuel flow rate issued through the burner to be 21 cm^3/s. What should be the minimum flow of air through the burner so that the mixture is not rich? [3]
   (iv) What will be the colour of the flame if the fuel-air mixture is not rich and why? [3]

2. Mr. Sharma is a chemist at a thermal power plant. The plant used natural gas as the fuel consisting of 90% methane and 10% ethane. His manager asked him to determine the efficiency of the plant when the generation was 200 MW and the gas burning rate was 9.7 kg/s. Mr. Sharma found his calorimeter to be defective and could not measure the heating value of the fuel. He instead calculated the lower heating value and reported the efficiency to the manager.
   (i) Determine the lower heating value of the fuel. [6]
   (ii) Determine the efficiency of the plant as calculated by Mr. Sharma. [3]
   (iii) Do you also think that the LHV and not the HHV should be taken for efficiency calculation in this case? – Explain from the definition of the terms. [5]

   Given: Heat of formation of CH_4 = -74850 kJ/kmol, C_2H_6= -84680 kJ/kmol, CO_2=-393520 kJ/kmol $H_2O(v)$= -285830 kJ/kmol $H_2O(l)$=-241820 kJ/kmol.

3. Flame temperature is the temperature of the burnt gas in the reaction zone and adiabatic flame temperature is a thermodynamic parameter which can be computed easily. Fuel burns more efficiently in a flame if the temperature of the flame remains high.
   (i) Define adiabatic flame temperature and state its significance. [2+2]
   (ii) How much increase in the adiabatic flame temperature will occur if the air is preheated to 225°C rather than supplying it at ambient temperature of 25°C? The furnace operates at an air-fuel ratio of 16.5 (by mass) with the fuel injected at the reference temperature. Consider the product mixture as a single component and assume the following simplified thermodynamic parameters.

   T_{ref}=298 K, $C_{p,fuel}$=$C_{p,air}$=$C_{p,prod}$=1150 J/kg K, Heat of formation of fuel=4.2×10^7J/kg and that of air and products are zero. [6]

(iii) How does the adiabatic flame temperature of a fuel-air mixture vary with the equivalence ratio of the mixture and why? [4]

4. Suman is a student doing a project on combustion. He has to compute the combustion rate of different fuels when burning in air. His advisor asks him to find out the chemical mechanisms of combustion of the fuels.
   (i) Suman finds for any fuel both global mechanism and detailed mechanism exist in the literature. What do you think is the difference between the two mechanisms? [3]
   (ii) His advisor explains to him why a global mechanism is not probable in real combustion. Can you explain the same considering a fuel like propane? [3]
   (iii) A detailed mechanism has many reactions and Suman found that most of the reactions are of the same molecularity. Define the term molecularity. What is the molecularity of most of the reactions in a detailed chemical mechanism? [3]
   (iv) The advisor also explains to Suman that a detailed chemical mechanism works like a chain reaction and there can be various types of reaction in a reaction chain. What are the types of reaction in a chain reaction and how are they differentiated? [5]

5. A constant volume chamber is used to determine the laminar burning velocity of a fuel-air mixture. A spark igniter having two electrodes is used in the chamber to ignite the fuel-air mixture filled in the chamber.
   (i) It is found that following ignition the flame propagates through the mixture only within a range of air-fuel ratio for the mixture. Why is it so? [3]
   (ii) It is also found that within the flammable range of mixture the flame propagates fastest at a particular air-fuel ratio. Explain this behavior. [4]
   (iii) In a spark igniter, successful ignition is possible with the supply of the minimum ignition energy. Determine an expression of minimum ignition energy for spark ignition. [7]

6. Draw the flame stability diagram of an open laminar premixed flame on a burner and explain the different regimes through which the flame passes with the increase in flow velocity of the fuel-air mixture for a (i) stoichiometric fuel-air mixture, (ii) rich fuel-air mixture beyond the rich flammability limit.
   Also explain why certain regimes of case (i) are not observed in case (ii) and vice versa. [14]

7. Consider a co-flow burner having two coaxial tubes one inside the other. Both the tubes are of small thickness and the outer tube wall is extended above the burner exit in the form of a shield. Methane is flown through the inner tube and air is passed through the outer tube at higher than stoichiometric flow rate.
   (i) Which type of flame will establish on the burner? Why is the flame so called? [1+2]
   (ii) Describe the microstructure of the flame using suitable temperature distributions across the flame. How can you measure the flame height from the temperature distribution? [6]
   (iii) Explain the stabilization mechanism of the flame. [5]