Version NS/3

EGT3
ENGINEERING TRIPOS PART IIB

Tuesday 22 April 2014   2.00 to 3.30

Module 4A13

COMBUSTION AND IC ENGINES

*Answer not more than **three** questions.*

All questions carry the same number of marks.

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM
CUED approved calculator allowed
Attachment: None

You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.

1 (a) Describe what we mean by *lean flammability limit*. [25%]

(b) An approximate theory suggests that the lean flammability limit occurs when the flame temperature T_f becomes less than 1600 K.

A burner as shown in Fig. 1 is constructed to burn very lean mixtures of methane (CH_4) and air by preheating the reactant mixture. The fresh reactants at an equivalence ratio ϕ enter the burner at a temperature $T_{\text{in}} = 300$ K. The reactants reach a temperature of T_R immediately before the flame zone because of heat transfer from the hot products flowing out of the burner at $T_{\text{out}} = 1000$ K, as shown in Fig. 1. Assume that the specific heat capacity at constant pressure for the reactants and products is constant and equal to 1.2 $\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$. The lower heating value of CH_4 is 50 $\text{MJ}\,\text{kg}^{-1}$.

Calculate the leanest possible equivalence ratio for this burner. [55%]

(c) Although the flame temperature is low for the burner in Fig. 1, a finite amount of NO is measured at the exit. Discuss the origin of this NO. [20%]

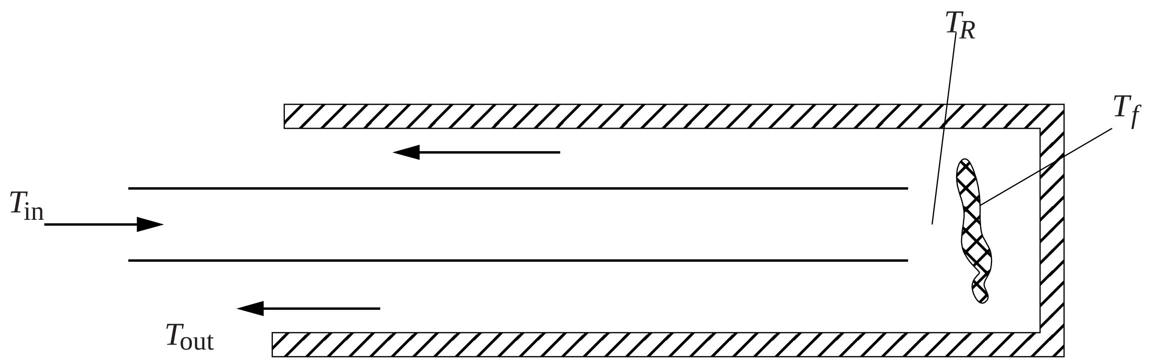

Fig. 1

2 (a) Describe briefly flame *blow-off* using a carefully drawn graph for the physics of a well-stirred reactor. [20%]

(b) Using carefully drawn graphs, explain the variation of laminar flame speed, s_l, of methane-air mixture with equivalence ratio, reactant temperature and pressure for a lean mixture. [20%]

(c) A flame arrestor, a metal plate with small circular holes, is to be installed at the entry of a combustion chamber burning methane-air mixture at 298 K and 1 bar, to prevent the potential of flame flashback. The flame quenching occurs as a result of a balance between heat generation by the flame and loss to the arrestor. If the flame resides inside the holes just before quenching, show that the hole diameter, d, must be less than or equal to $2\sqrt{2}\delta$. The symbol $\delta = \alpha/s_l$ is the laminar flame thickness and α is the thermal diffusivity of the reactant mixture. [40%]

(d) If the operating pressure was changed to 5 bar, would the hole diameter increase or decrease? Justify your answer clearly. State your assumptions, if you make any. [20%]

3 Discuss possible ways in which the CO_2 emissions associated with road transport might be reduced, considering both

(a) IC-engined vehicles, and [70%]

(b) other prime movers. [30%]

For your answers, consider both well-to-tank and tank-to-wheel aspects. Include brief justifications.

4 (a) Briefly discuss the advantages and disadvantages of using air-standard cycles to model real IC engines. [10%]

(b) A normally aspirated 4-cylinder gasoline engine has a peak indicated power output of 61 kW at 5500 rpm, and a peak indicated torque of 128 Nm at 3250 rpm. It is operating in ambient conditions of 1 bar and 20 °C. The fuel calorific value is 44 MJ kg^{-1}, and the air fuel ratio is 14.6 : 1.

(i) Explain why the peak torque occurs at a lower rpm than the maximum power, and calculate the torque at the maximum power condition and the power at the maximum torque condition. [20%]

(ii) If the indicated fuel conversion efficiency is 40% at the peak torque condition, determine the *isfc* in kg per kWh. Would you expect the *isfc* to be higher or lower at the maximum power condition? [20%]

(iii) If the volumetric efficiency based on ambient conditions is 90% at the maximum torque condition, and the cylinder bore and stroke are equal, determine the displacement of the engine. [25%]

(iv) It is suggested that a 3-cylinder version of this engine would be preferable. Briefly list the arguments for and against this suggestion. [25%]

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List of Answers

1. (b) $\phi_{\text{lean}} = 0.276$

4. (b)(i) At maximum power condition $T = 105.9$ N m, At maximum torque condition $P = 43.6$ kW

   (ii) $isfc = 0.205$ kg/kWh

   (iii) Bore = stroke = 73.5 mm and engine displacement is 1.25 litres