Birla Institute of Technology and Science Pilani-KK Birla Goa Campus
FIRST SEMESTER 2022-23
ME F317 Engines, Motors, and Mobility
Mid Semester Examination (Closed Book)

DATE: 05/11/2022 **Time: 4:00 PM - 5:30 PM** **Maximum Marks: 60**

Instructions:

- Write all steps while answering the problems.
- All the parts of a question must be answered together at a single place.
- Recheck will not be considered for the part of answer where pencil will be used.
- All symbols used in the question paper have their standard meaning.

Q.1. Write the 9 points which differentiate the actual cycle from air standard cycle. **[09]**

Q.2. (i) For the various compression ratios varying from 4 to 10, draw the figure showing the effect of fuel ratio on the exhaust gas temperature. **[02]**
(ii) At a given compression ratio, by making mixture rich in fuel, whether exhaust gas temperature increases or decreases? Justify your answer within 1 or 2 lines. **[02]**
(iii) For a given compression ratio, when will you observe the maximum exhaust gas temperature? Why; justify your answer within 1 or 2 lines. **[02]**
(iv) At a given compression ratio, by making mixture lean in fuel, whether exhaust gas temperature increases or decreases? Justify your answer within 1 or 2 lines. **[02]**
(v) At a given air fuel ratio, with increase in compression ratio, whether the exhaust gas temperature decreases or increases? Why; justify your answer within 2 lines. **[03]**

Q.3. SI engine with compression ratio 6 uses a fuel with calorific value 42 MJ/kg. Air fuel ratio is 15:1. Pressure and temperature at the start of compression stroke are 1 bar and 57^0C respectively. Determine the maximum pressure in the cylinder if the index of compression is 1.3 and Cv = 0.678 + 0.00013T where T is in Kelvin. Compare this value with that obtained when Cv = 0.717 kJ/kg.K. **[15]**

Q.4. A four cylinder four stroke SI engine running at 1200 rpm gives 18.87 kW as brake power. When 1 cylinder missed firing the average torque was 100 NM. Calculate the indicated thermal efficiency if the CV of the fuel is 42 MJ/kg. The engine uses 0.335 kg of fuel per kW/h. What is the mechanical efficiency of the engine? **[12]**

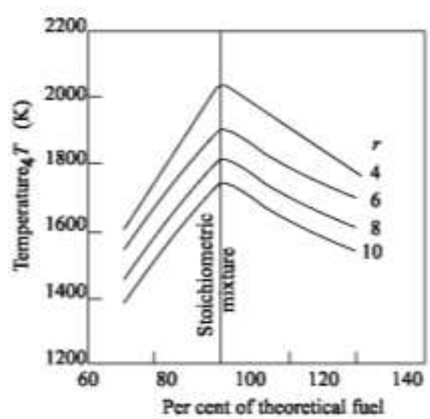
Q.5. Find out the speed at which a four cylinder engine using natural gas can develop a brake power of 50 kW working under following conditions.
Air-gas ratio = 9:1, calorific value of the fuel = 34 MJ/m^3, compression ratio = 10:1, volumetric efficiency = 70%, indicated thermal efficiency = 35%, mechanical efficiency = 80%, and the total volume of the engine is 2 liters. **[13]**

ANSWER KEY

Q.1. Actual cycle considers following points which are NOT considered in air standard cycle. [Each point carries 1 mark]

1. It considers Fuel air ratio alongwith Compression ratio.
2. It considers effect of Residual gases on Volumetric efficiency.
3. It considers variation of Specific heat with Temperature.
4. It considers effect of Dissociation and Re-association.
5. It considers number of Moles.
6. The progressive combustion rather than the instantaneous combustion.
7. The heat transfer to and from the working medium
8. The substantial exhaust blowdown loss, i.e., loss of work on the expansion stroke due to early opening of the exhaust valve.
9. Gas leakage, fluid friction etc., in actual engines.

Q.2. (i) [2 M]



(ii) Decreases [1 M]. With increase in fuel, for a given amount of stoichiometric air supplied, partial combustion or incomplete combustion increases causing decrease in T4. [1 M]

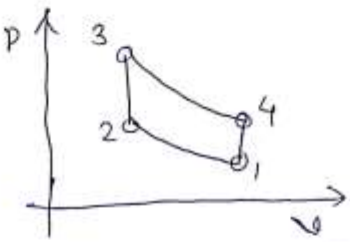
(iii) At stoichiometric mixture (SM) [1 M]. Re-association will more effectively takes place at SM with complete combustion of fuel causing T4 maximum than other air fuel ratios. [1 M]

(iv) Decreases [1 M]. With decrease in fuel, for a given amount of stoichiometric air supplied, re-association takes place with complete combustion of fuel but due to decrease in amount of fuel combusted causing net effect as decrease in T4. [1 M]

(v) Decreases [1 M]. This is because, with increase in compression ratio, stroke length increases which causes (a) more expansion of the hot gases [1 M] (b) increased surface area of the cylinder to lose more heat to the cooling medium (water or air) [1 M].

Q.3.

Solution →



$$\boxed{P_2} = P_1\left(\frac{V_1}{V_2}\right)^n = 1 \times 6^{1.3} = \boxed{10.27\ bar} \rightarrow \text{(I)} \rightarrow \text{(2M)}$$

hence $T_2 = T_1\left(\frac{P_2 V_2}{P_1 V_1}\right) = 330\left(\frac{10.27}{1} \times \frac{1}{6}\right)$

$$\boxed{T_2 = 565\ K} \rightarrow \text{(II)} \rightarrow \text{(2M)}$$

Now $Q = m_f C_f = m_{mixture}\ C_{v\,mixture}\ dT_{mixture}$

For constant Cv ⇐

$\therefore Q = 1 \times 42000 \frac{kJ}{kg} = (1+15)\,kg \times 0.717 \times (T_3 - T_2)$

If $T_2 = 565\ K$, $\boxed{T_3 = 4226\ K} \rightarrow \text{(III)} \rightarrow \text{(2M)}$

hence $P_3 = P_2 \frac{T_3}{T_2} = 10.27 \times \frac{4226}{565}$

$$\boxed{P_3 = 76.81\ bar} \rightarrow \text{(IV)} \rightarrow \text{(2M)}$$

→ For constant Cv value

Now For varying Cv,

$Q = m_f C_f = m_{mix} \cdot C_{v\,mix} \cdot dT_{mix}$

$= 1\,kg \times 42000 \frac{kJ}{kg} = (1+15)\,kg\left[0.678 + 0.00013 \times \left(\frac{T_3 + 565}{2}\right)\right](T_3 - 565)$ (565 = T_2)

Solving, $\boxed{T_3 = 3375\ K} \rightarrow \text{(V)} \rightarrow \text{(5M)}$

Hence $P_3 = P_2 \frac{T_3}{T_2} = 10.27 \times \frac{3375}{565}$

$$\boxed{P_3 = 61.35\ bar} \rightarrow \text{(VI)} \rightarrow \text{(2M)}$$

→ with varying Cv

Q.4.

Q: 4

Brake power developed by 4 cylinders 18.87 kW

hence, $4(IP - FP) = BP = 18.87 \rightarrow (1)$ → 2 Marks

BP developed when 3 cylinders fired,

$$= \frac{2\pi NT}{60} = \frac{2\pi \times 1200 \times 100}{60} = 12.57 \text{ kW}$$

$$= 3IP - 4FP = 12.57 \rightarrow (2)$$ → 2 M

Hence, Subtracting eq^n (2) from (1), → 2 M

$$IP = 6.3 \text{ kW} \rightarrow (3)$$ → 2 M

hence IP of engine having 4 cylinders

$$= 4 \times IP = 4 \times 6.3 = 25.2 \text{ kW} \rightarrow (4)$$

Therefore, Indicated thermal efficiency when 4 cylinders fired $= \frac{IP}{CV \times m_f}$

$$= \frac{25.2 \times 10^3 \text{ W}}{42 \times 10^3 \frac{kJ}{kg} \times 0.335 \frac{kg}{kW\text{-}hr}}$$

$$= \frac{25.2 \text{ W}}{42 \frac{kJ}{kg} \times 0.335 \frac{kg}{kW\text{-}hr} \times 18.87 \text{ kW}}$$

$$= \frac{0.0949 \text{ W}}{1 \frac{kJ}{hr}}$$

$$= \frac{0.0949 \times 3600 \text{ W}}{1000 \frac{J}{sec}}$$

$$= 0.34164$$

$$\eta_{ITH} = 34.16\,\%$$ → 3 M

Hence η_{mech} (4 cylinder firing) $= \frac{BP}{IP} = \frac{18.87}{25.2} = 74.88\%$ → 1 M

Q.5.

Indicated thermal efficiency = ITE = IP / Energy
Where IP i.e Indicated Power provided to the piston / Input fuel energy in kW or Kj

ITE = IP in KW / (mass of fuel/sec in kg/s) * (Calorific value of fuel in kJ/kg)
ITE = [BP/Mechanical Efficiency] / Mf Cf.
Now, Mf Cf for engine = [BP/ME] / ITE.

Mf Cf for 1 cylinder = [50 kW /0.8] / 0.35 * (**K=4**) = 44.64 kW / cylinder
Mf (kg/sec) Cf (kJ / kg) = 44.64 kJ / sec
Mf (kg/**sec**) * Cf (kJ / kg) = 44.64 kJ / sec
Mf (kg/**sec**) * Cf (kJ / kg) = 44.64 kJ / **sec**. … (time basis) **(eq.1)** **…….[2 M]**
Mf (kg) * Cf (kJ / kg) = 44.64 kJ **for Many number of cycles**
(Mf .Cf) kJ = 44.64 kJ
1.19 kJ = 44.64 kJ is NOT possible i.e hence there must be (refer below how to get 1.19 kJ for Mf. Cf)

[1.19 /cycle] * no. of cycles = 44.64 (refer below how to get 1.19/cycle)

Hence no. cycles or no. of power strokes = ps

ps = 44.64 kJ/ [Mf.Cf] kJ … for diesel or petrol where Mf in kg and Cf in kJ/kg
ps = 44.64 kJ/ [Vf .Cf] kJ for gas fuels where Vf in m^3 and Cf in m^3/kg …. **(eq.2)**

Hence, ps = 44.64 /1.19 = 37.51 (refer below how to get 1.19/cycle)
Thus number of power strokes (ps) = 37.51 obtained using eq.1 and 2 where basic eq. 1 is having the basis of time in second.
Hence number of power strokes **per second (in a cylinder)** = 37.51 **…….[2 M]**
Hence power strokes **per minutes** = n = 37.51 * 60 = (N/2)
Hence number of revolutions per minutes = N = 2* 37.51 * 60 RPM
Hence **N= 4500 rpm** (Approximately) **…….[3 M]**

[Now **vf** (m^3) = va / (a/f) = va / 9 = (vs* vol eff) / 9 **….(eq.3)**
Where vs = vt –vcl
vs = (*2000* ***cc*** */ 4*) – (*vt* /CR) = (*500*) – (*500*/10) = 450 cc = 450 * 10^{-6} m^3= vs …. [**2 M]**

From eq 3, **vf** (m^3) = va / (a/f) = va / 9 = (vs* vol eff) / 9
vf (m^3) = (450 * 10^{-6} * 0.7) / 9
vf (m^3) = 35* 10^{-6} …………….**(eq.4)** …. [**2 M]**

Now vf (m^3) .Cf (kJ/ m^3) = 35* 10^{-6} m^3. 34*10^3 (kJ/m^3)
=1.19 kJ /cycle …………….**(eq.5)** …. [**2 M]**
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