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MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

INTERNAL COMBUSTION ENGINES

1 CHAPTER Introduction and Basic Concepts

Practice Questions : Level-I

Q.1 The brake thermal efficiency of a diesel engine is 30%. If air to fuel ratio by weight is 20 and calorific value of fuel is 41800 kJ/kg. Find brake mean effective pressure at STP (15°C and 760 mm Hg).

Solution:

$$\therefore \quad \text{Brake thermal efficiency} = \frac{B.P.}{\text{Thermal power}}$$

$$0.3 = \frac{B.P.}{m_f \times C.V.} = \frac{B.P.}{\frac{m_a}{20} \times 41800}$$

$$m_a = \frac{B.P. \times 20}{0.3 \times 41800} = \frac{B.P.}{627} \text{ kg/s} \quad \ldots\text{(i)}$$

Assuming volumetric efficiency 100%

$$\therefore \quad pV_S = m_a RT$$

$$0.76 \times 13.6 \times 10^3 \times 9.81 \times V_S = \frac{B.P.}{627} \times 287 \times 288$$

$$\text{Brake mean effective pressure} = \frac{B.P.}{V_S}$$

$$= \frac{0.76 \times 13.6 \times 10^3 \times 9.81 \times 627}{287 \times 288} \text{ kPa} = 7.69 \text{ bar or } 5765.1 \text{ mm of Hg}$$

Q.2 A four cylinder 4-stroke diesel engine has a bore of 212 mm and stroke 292 mm. At full load at 720 rpm the Brake mean effective pressure is 5.93 bar and specific fuel consumption is 0.226 kg/kWH. The air fuel ratio as determined by exhaust gas analysis is 25 : 1. Calculate the brake thermal efficiency and volumetric efficiency of the engine. Atmospheric conditions are 1.01 bar and 15°C. The calorific value of fuel may be taken as 44200 kJ/kg.

Solution:

Given data: $n = 4$; $d = 212$ mm; $l = 292$ mm; $N = 720$ rpm; $p_{bm} = 5.93$ bar

SFC = 0.226 kg/kW hr.; $A/F = 12$, C.V = 44.2 MJ/kg; $P = 1.01$ bar, $T_1 = 288$ K

$$bp = \frac{p_{bm}LANK}{60000 \times 2} = \frac{5.93 \times 10^5 \times 0.292 \times \pi/4 \times 0.212^2 \times 4 \times \left(\frac{720}{2}\right)}{60000} = 146.69 \text{ kW}$$

$$\eta_{bth} = \frac{bp}{\dot{m}_f \times CV}$$

$$\dot{m}_f = 0.226 \times 146.69 = 33.15 \text{ kg/h}$$

$$\eta_{bth} = \frac{146.69 \times 3600}{33.15 \times 44200} = 0.36 = 36\%$$

$$\rho = \frac{p}{RT} = \frac{1.01 \times 10^5}{287 \times 288} = 1.2219\,\text{kg/m}^3$$

$$\frac{A}{F} = 25$$

$$\Rightarrow \quad \dot{m}_a = \dot{m}_f \times 25 = 828.75\ \text{kg/h}$$

Volume flow rate at intake condition:

$$\dot{V}_a = \frac{\dot{m}_a RT}{p} = \frac{828.75}{1.2219} \times \frac{1}{60} = 11.300\,\text{m}^3/\text{min}$$

$$\dot{V}_s = \frac{\pi}{4} D^2 \frac{LNK}{2} = \frac{\pi}{4} \times 0.212^2 \times 0.292 \times 360 \times 4 = 14.84\ \text{m}^3/\text{min}$$

$$\eta_v = \frac{\dot{V}_a}{\dot{V}_s} \times 100 = \frac{11.300}{14.84} \times 100 = 76.15\%$$

Q.3 The output of an engine is given as input to an agricultural pump set. The pump is used for lifting water from a depth of 30 m at the rate of 200 litres/minute. The transmission efficiency between the engine and the pump is 100% and the pump is considered to be 100% efficient. The brake thermal efficiency of the engine is 35%, the calorific value of the fuel is 43 MJ/kg, the cost of fuel is ₹ 53.00 per litre and the density of the fuel is 780 kg/m³. Estimate the running cost of the fuel for 1000 m³ of water lifted.

Solution:

$$\text{Power required to lift the water} = \rho g Q H = \frac{1000 \times 9.81 \times 200 \times 10^{-3} \times 30}{1000 \times 60} = 0.981\ \text{kW}$$

$$\text{Brake work done} = \text{Power} \times \text{time} = \frac{(0.981) \times (1000) \times (60)}{200 \times 10^3} = 294.3\,\text{MJ}$$

$$\text{Brake thermal efficiency} = \frac{\text{Brake work done}}{\text{Calorific value} \times \text{Mass of fuel}}$$

$$\Rightarrow \quad 0.35 = \frac{294.3 \times 1}{43 \times \text{Mass of fuel}}$$

$$\Rightarrow \quad \text{Mass of fuel} = 19.55\,\text{kg}$$

$$\text{Volume of fuel} = \frac{\text{Mass of fuel}}{\text{Density of fuel}} = \frac{19.55}{780} = 25.0769\ \text{litre}$$

Running cost of engine $= 25.07 \times 53 =$ **₹ 1328.7 only**

Q.4 A single cylinder 4-stroke SI engine is producing 100 kW power at an overall efficiency of 20%. Engine uses fuel-air ratio of 0.07. Determine how many m³/hr of air is used if air density is 1.2 kg/m³. The fuel vapour density is 4 times that of air. How many m³/hr of mixture is required? Calorific value of fuel is 42000 kJ/kg.

Solution:

$$\text{Overall efficiency, } \eta_o = \frac{BP}{\dot{m}_f \times CV}$$

$$\dot{m}_f = \frac{BP}{\eta_o \times CV} = \frac{100}{0.2 \times 42000} = 0.012\ \text{kg/s}$$

$$\text{Air density, } \rho_a = 1.2 \text{ kg/m}^3$$

$$\text{Fuel vapour density, } \rho_f = 4 \times 1.2 = 4.8 \text{ kg/m}^3$$

$$\text{Fuel mass flow rate, } \dot{m}_f = 0.012 \times 3600 = 43.2 \text{ kg/h}$$

$$\text{F/A ratio} = 0.07$$

$$\dot{m}_a \text{ (Air flow rate)} = \frac{\dot{m}_f}{0.07} = 617.143 \text{ kg/h}$$

$$\text{Volumetric flow rate of air} = \frac{\text{Mass flow rate}}{\text{Density}} = \frac{617.43}{1.2} = 514.525 \text{ m}^3\text{/hr}$$

$$\text{Volumetric flow rate of fuel} = \frac{\dot{m}_f}{\rho_f} = \frac{43.2}{4.8} = 9 \text{ m}^3\text{/hr}$$

$$\text{Volumetric flow of fuel mixture} = \dot{V}_a + \dot{V}_f = 514.525 + 9 = 523.525 \text{ m}^3\text{/hr}$$

Practice Questions : Level-II

Q.5 A six cylinder 4-stroke diesel engine has a bore of 60 mm and a crank radius of 32 mm. The compression ratio is 9 : 1 and engine volumetric efficiency is 90%. Determine: (i) Stroke length, (ii) Mean volume per cylinder, (iii) Swept volume per cylinder, (iv) Clearance volume per cylinder, (v) Cubic capacity of the engine, (vi) Actual volume of air aspirated per stroke in each cylinder.

Solution:

$$\text{Stroke length, } L = 2 \times \text{crank radius} = 2 \times 32 = 64 \text{ mm} \qquad \text{Ans.(i)}$$

$$\text{Mean piston speed, } \bar{V}_p = \frac{2LN}{60} = 2 \times 64 \times 10^{-3} \times \frac{1000}{60} = \frac{128}{60} = 2.13 \text{ m/s} \qquad \text{Ans.(ii)}$$

$$\text{Swept volume per cylinder, } V_s = \frac{\pi}{4} D^2 L = \frac{\pi}{4} \times 6^2 \times 6.4 = 180.956 \text{ (cm)}^3 \approx 181 \text{ cc} \qquad \text{Ans.(iii)}$$

$$\text{Compression ratio, } r = \frac{V_s + V_c}{V_c} = \frac{V_s}{V_c} + 1$$

$$\text{Clearance volume, } V_c = \frac{V_s}{r-1} = \frac{181}{9-1} = 22.625 \text{ cc} \qquad \text{Ans.(iv)}$$

$$\text{Cubic capacity of the engine} = \text{Number of cylinder} \times \text{Swept volume}$$

$$= 6 \times 181 = 1086 \text{ cc} \qquad \text{Ans.(v)}$$

$$\text{Volumetric efficiency} = \frac{\text{Actual volume flow rate of air}}{\text{Volume flow rate of air corresponding to displacement volume}}$$

$$\dot{V}_a = \eta_v \times \frac{\pi}{4} D^2 L \times \frac{N}{2 \times 60}$$

$$= 0.9 \times \frac{\pi}{4} \times (0.06)^2 \times 0.064 \times \frac{1000}{2 \times 60}$$

$$= 1.357 \times 10^{-3} \text{ m}^3\text{/s} = 4.8858 \text{ m}^3\text{/hr} \qquad \text{Ans.(vi)}$$

Q.6 A six-cylinder, 4-stroke petrol engine has a swept volume of 3 litres with a compression ratio of 9.5. Brake output torque is 205 N-m at 3600 r.p.m. Air enters at 85 kN/m^2 and 60°C. The mechanical efficiency of the engine is 85% and air-fuel ratio is 15 : 1. The heating value of fuel is 44,000 kJ/kg and the combustion efficiency is 97%. Calculate:

(i) Rate of fuel flow
(ii) Brake thermal efficiency
(iii) Indicated thermal efficiency
(iv) Volumetric efficiency
(v) Brake specific fuel consumption