Module - 3

Performance parameters of IC Engines

Syllabus

1. Performance parameter - Indicated power, Break power, frictional power, Indicated thermal efficiency, Break thermal efficiency, volumetric efficiency, Mechanical efficiency, Mean effective pressure and specific fuel Consumption. 2. Simple problems to find out various efficiency. 3. Morse test and preparation of heat balance sheet, and simple problems

Indicated power (IP)

It is the power that is actually produced inside the engine cylinder which acts on the piston. It includes breakpower + frictional power

$$IP = \frac{P_m L A n k}{60} \quad \text{unit (W)}$$

P_m - mean effective pressure in pa

L - stoke length in m

A - Cross sectional areas of cylinder in m^2

$= \frac{\pi}{4} D^2$

D - Diameter of cylinder in m

n - No of power stroke per minute $= N$ for 2 stroke

$\frac{N}{2}$ for 4 stroke

N = Speed of engine in rpm

k = no. of cylinders.

Mean effective pressure is the average pressure acting on the piston during power stroke

Break power (BP)

It is the power available at the crankshaft of the engine. It is the actual output of the engine.

$$BP = \frac{2\pi NT}{60} \text{ (W)}$$

N - Speed of the engine in rpm

T - Torque of the engine in Nm.

Thermal efficiency

It is the percentage of heat converted into useful work. There ~~is~~ are mainly two types

1) Brake thermal efficiency
2) Indicated thermal efficiency.

Brake thermal efficiency

It is defined as the percentage of heat converted into brake power.

$$\eta_{bth} = \frac{\text{Brake power}}{\text{Heat supplied}} = \frac{BP}{F_C \times CV}$$

where,

F_C - fuel consumed per sec ~~in~~ in kg/sec

CV - Calorific value in KJ/kg.

Indicated thermal efficiency

It is defined as the percentage of heat converted into indicated power.

$$\eta_{ith} = \frac{\text{Indicated power}}{\text{Heat supplied}} = \frac{IP}{F_C \times CV}$$

F_C - fuel consumed per sec in kg/sec

CV - Calorific value in KJ/kg

volumetric efficiency

volumetric efficiency of an engine is an indication of the measure of the degree to which the engine fills its swept volume.

$$\eta_{vol} = \frac{\text{Actual volume of air inhaled by engine per sec}}{\text{Theoretical volume per sec}}$$

$$\text{Theoretical volume/sec} = \text{Swept volume} \times \frac{\text{no of suctions}}{\text{sec}} \times \text{no of cylinders}$$

$$= \frac{\pi}{4} D^2 L \times \frac{n}{60} \times k$$

Relative efficiency

$$\text{Relative efficiency} = \frac{\text{Actual efficiency}}{\text{Air standard efficiency}}$$

Specific fuel consumption (SFC)

$$SFC = \frac{TFC}{BP}$$

SFC is defined as the mass of required for unit power production.

Q A four cylinder 4 stroke petrol engine is to be designed to develope and indicated power of 41 kW at a speed of 3000 rpm. The bore and stroke are identical. The indicated mean effective pressure is estimated to be 7.97 bar. determine the bore of the engine.

An: Given data

4 stroke 4 cylinder

$I_P = 41\,kW = 41 \times 10^3\,W$

$N = 3000\,rpm$

$P_m = 7.97\,bar = 7.97 \times 10^5\,pa$

bore and stroke identical, $D = L$

no of power stroke, $n = \frac{N}{2}$ (4 stroke)

~~no of~~ no of cylinder, $k = 4$

Area of the cylinder, $A = \frac{\pi}{4} D^2$

$$IP = \frac{P_m L A n k}{60}$$

$$IP = \frac{P_m L \frac{\pi}{4} D^2 n k}{60}$$

$$= \frac{P_m L \pi D^2 n k}{60 \times 4}$$

$$41 \times 10^3 = \frac{7.97 \times 10^5 \times D \times \pi D^2 \times 1500 \times 4}{4 \times 60}$$

$$41 \times 10^3 = \frac{150154.8 \times 10^5 \times D^3}{4 \times 60}$$

$$41 \times 10^3 = 62564500 \times D^3$$

$$D^3 = \cancel{\frac{62564500}{41 \times 10^3}} \quad \frac{41 \times 10^3}{62564500}$$

$$= \cancel{1525.96} \; \cancel{655}$$

$$D = 0.086$$

Mechanical Efficiency :

$$\eta_{mech} = \frac{BP}{IP}$$

Q A 4 cylinder 2 stroke engine developes 23.5 kW BP at 2500 rpm the mean effective pressure on each piston is 8.5 bar. The mechanical efficiency is 85%. Calculate the diameter and stroke of each cylinder assuming the length of stroke equal to 1.5 times the diameter of the cylinder.

As: Given data.

$BP = 23.5\,kW = 23.5\times10^3$

$rpm = 2500$

$P_m = 8.5\,bar = 8.5\times10^5$

$\eta_{mech} = 85\% = 0.85$

$n = N$ (2 stroke)

$L = 1.5D$

$\cancel{\eta_{mech} = \frac{BP}{IP}} = \frac{23.5\times10^3}{\cancel{BP}} = \cancel{0.85}$

$\cancel{IP = \frac{P_m L A n k}{60}}$

$$IP = \frac{BP}{\eta_{mech}} = \frac{23.5\times10^3}{0.85} = 27.65\times10^3\,kW$$

$$IP = \frac{P_m L A n k}{60}$$

$$27.65\times10^3 = \frac{8.5\times10^5\times1.50\times\frac{\pi}{4}D^2\times2500\times4}{60}$$

$$27.65\times10^3 = \frac{8.5\times10^5\times1.50\times\pi D^2\times2500\times4}{60\times4}$$

$$27.65\times10^3 = \frac{400350\times10^5\times D^3}{240}$$

$$27.65\times10^3 = 16681.2500\times D^3$$

$$D^3 = \frac{27.65\times10^3}{166812500}$$

$$D = 0.055\,m$$

Q A rope brake was used to measure the brake power of a single cylinder 4 stroke petrol engine. It was found that the torque due to brake load is 1.75 Nm and the engine makes 500 rpm. Determine the brake power developed by the engine Also find the indicated power if the mechanical efficiency of the engine is 80%

Given data

$T = 175\ Nm$

$N = 500\ rpm$

$\eta_{mech} = 80\% = 0.8$

Single cylinder 4 stroke

$$BP = \frac{2\pi N T}{60} = \frac{2 \times 3.14 \times 500 \times 175}{60} = \underline{9158.3}$$

$$\eta_{mech} = \frac{BP}{IP}$$

$$0.8 = \frac{9158.3}{IP}$$

$$IP = \frac{9158.3}{0.8} = 11447.9\ W$$

$$= \underline{11.4\ kW}$$

$$FP = IP - BP = 11447.9 - 9158.3 = \underline{2289.9\ W}$$

Morse test

constant speed + varying load

all cylinder working $\rightarrow$ $BP = (IP_1 + IP_2 + IP_3 + IP_4) - FP$ — ①

I^{st} cylinder cut off $\rightarrow BP_1 = (IP_2 + IP_3 + IP_4) - FP$ — ②

II^{nd} cylinder cut off $\rightarrow BP_2 = (IP_1 + IP_3 + IP_4) - FP$ — ③

III^{rd} cylinder cut off $\rightarrow BP_3 = (IP_1 + IP_2 + IP_4) - FP$ — ④

4^{th} cylinder cut off $\rightarrow BP_4 = (IP_1 + IP_2 + IP_3) - FP$ — ⑤

$BP = IP - FP$

① − ② $\rightarrow BP - BP_1 = IP_1$

① − ③ $\rightarrow BP - BP_2 = IP_2$

① − ④ $\rightarrow BP - BP_3 = IP_3$

① − ⑤ $\rightarrow BP - BP_4 = IP_4$

$IP = IP_1 + IP_2 + IP_3 + IP_4$

$FP = IP - BP$

Q A 4 stroke petrol engine 80 mm bore and 100 mm stroke is tested at constant speed. The fuel supply is fixed at 0.068 kg/min and the plugs of 4 cylinders are successievly short circuited without change of speed. The brake power measurements are the following. with all cylinders firing equal to 12.4 kW, with no.1 cut off = 9 kW, no. 2 cut off = 9.15 kW, no.3 cut off = 9.2 kW & with no.4 cut off = 9.1 kW. Determine the Indicated power of the engine. Also determine indicated thermal efficiency, calorific value of fuel is 44100 kJ/kg. Determine the relative efficiency if the air standard efficiency is 56.85.

Ans: Given data

$D = 80mm$

$L = 100mm$

$FC = 0.068 \, kg/min = \frac{0.068}{60} = 1.13 \times 10^{-3} \, kg/s$

$BP = 12.4 \, KW = \cancel{12.4 \times 10^3 \, W}$

$BP_1 = 9 \, KW = \cancel{9 \times 10^3 \, W}$

$BP_2 = 9.15 \, KW = \cancel{9.15 \times 10^3 \, W}$

$BP_3 = 9.2 \, KW = \cancel{9.2 \times 10^3 \, W}$

$BP_4 = 9.1 \, KW = \cancel{9.1 \times 10^3 \, W}$

$CV = 44100 \, kJ/kg = \cancel{44100 \times 10^3 \, J/kg}$

$\eta_{air} = 56.85$

Indicated power (IP)

$IP_1 = BP - BP_1 = 12.4 - 9 = 3.4 \, KW$

$IP_2 = BP - BP_2 = 12.4 - 9.15 = 3.25 \, KW$

$IP_3 = BP - BP_3 = 12.4 - 9.2 = 3.2 \, KW$

$IP_4 = BP - BP_4 = 12.4 - 9.1 = 3.3 \, KW$

$IP = 3.4 + 3.25 + 3.2 + 3.3 = 13.15 \, KW$

Indicated thermal efficiency

$$\eta_{ith} = \frac{IP}{FC \times C_V}$$

$$= \frac{13.15}{1.13 \times 10^{-3} \times 44100} = 0.263 = 26.3\%$$

Relative efficiency

$\eta_{rel} = \dfrac{\text{Actual efficiency}}{\text{air standard efficiency}}$

$= \dfrac{\eta_{ith}}{\eta_{air}} = \dfrac{26.3}{56.85}$

$= 0.462 = 46.2\%$

Heat balance test

Heat input → BP
→ Cooling water
→ Exhaust
→ Unaccounted

Heat input, Q_i = Fuel consumption × Calorific value

Brakepower = BP → load test

Heat carried by Cooling water, Q_w $= m_w C_{P_w} \Delta T$

Heat carried by exhaust, $Q_e = m_e C_{P_e} \Delta T$.

Unaccounted loss $= Q_i - (BP + Q_w + Q_e)$

Q A gas engine working on stroke constant volume cycle gave the following results during a test of an hours duration. Heat supplied = ~~1028~~ 10280 kJ/min. Indicated power = 20.8 kW. BP = 18.40 m mass of cooling water circulated 660 kg/hr cooling temperature rise = 34.2°C. Heat loss to the exhaust gas = 8%. prepare a heat balance sheet ~~for~~ the ~~eg~~ engine.

Heat supplied, $Q_s = 10280 \text{ KJ/min} = \frac{10280}{60} = 171.33 \text{ KJ/s}$

$I_P = 20.8 \text{ KW}$

$BP = 18400 \text{ W} = 18.4 \text{ KW}$

$m_w = 660 \text{ kg/hr} = \frac{660}{60 \times 60} = 0.18 \text{ kg/s}$

mass flow rate of cooling water

Temperature rise of cooling water $\Delta T_w = 34.2°C$

Heat loss at exhaust $Q_e = 8\%$ of heat supplied

$= \frac{8}{100} \times \frac{10280}{60}$ KJ/sec

$= 13.7$ KJ/sec

Heat carried away by cooling water

$Q_w = m_w C_{pw} \Delta T_w$

$C_{pw} \rightarrow$ specific heat of water $= 4.18$ KJ/kgK

$Q_w = 0.183 \times 4.18 \times 34.2$

$= 26.16$ KJ/kg8K

Unaccouted losses, $Q_a = Q_s - (BP + Q_w + Q_e)$

$= 171.33 - (18.4 + 26.16 + 13.70)$

$= 113.06$ KJ/sec

% of heat converted + BP $= \frac{BP}{Q_s} \times 100 = \frac{18.4}{171.33} \times 100$

$= 10.73\%$

% ~~he~~ of heat carried ~~b~~ away by cooling water

$= \frac{Q_w}{Q_s} \times 100 = \frac{26.16}{171.33} \times 100 = 15.26$

% of heat carried away by exhaust gas $= \frac{Q_e}{Q_s} \times 100$

$= \frac{13.706}{171.33} = 8\%$

% of heat in unaccounted loss $= \frac{Q_a}{Q_s} \times 100 = \frac{113.07}{171.33} \times 100$

$= 65.9\%$

Heat balance sheet

SL No	Details	Heat	
		KJ/s	%
1	Heat supply	171.33	100%
2	Brake power	18.4	10.73
3	Heat carried away by cooling water	26.16	15.26
4	Heat carried away by exhaust	13.7	8
5	Unaccounted loss	13.06	65.9