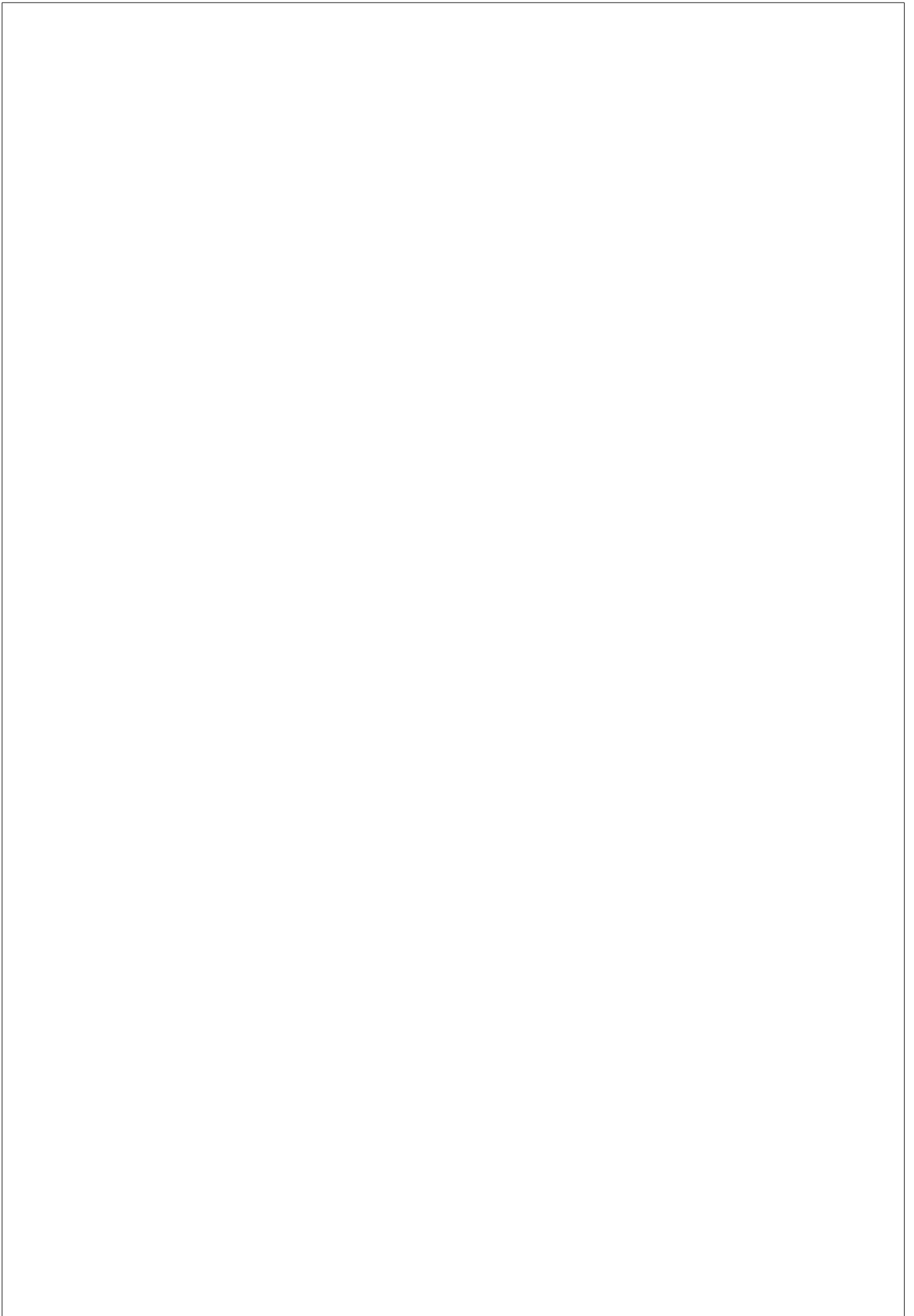




Shaikh Sir's Diploma Classes

Subject: Power Engg

Ch 2. I.C. Engines Testing and Pollution Control



2.1 Basics Terms, Definitions and formulas

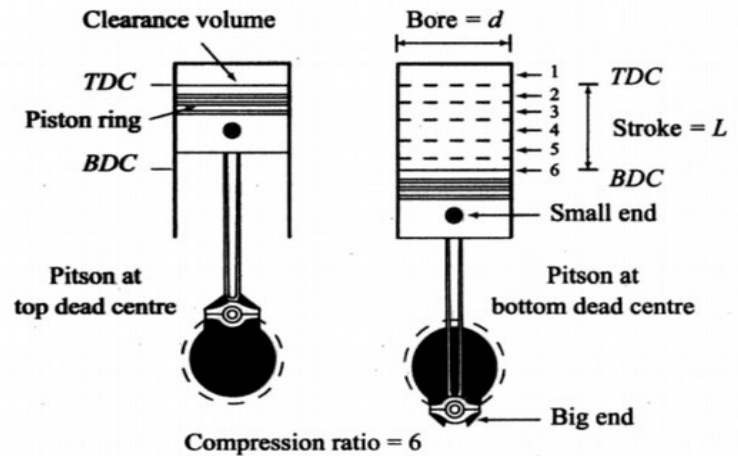
Top Dead Centre (TDC) : It is the dead centre when the piston is farthest from the crankshaft. It is designated as TDC for vertical engines and Inner Dead Centre (IDC) for horizontal engines.

Bottom Dead Centre (BDC) : It is the dead centre when the piston is nearest to the crankshaft. It is designated as BDC for vertical engines and Outer Dead Centre (ODC) for horizontal engines.

Displacement of Swept Volume (Vs) : The nominal volume swept by the working piston when travelling from one dead centre to the other is called displacement volume. It is expressed in terms of cubic centimeter (cc)

Clearance Volume (Vc) : The nominal volume of the combustion chamber above the piston when it is at the top dead centre is clearance volume. It is designated as Vc and expressed in cubic centimeter (cc).

Compression Ratio (r) : It is the ratio of the total cylinder volume when the piston is at the bottom dead centre, to the clearance volume.



Compression ratio = Total volume/Clearance Volume

Indicated power.

Indicated power is the power actually developed by engine cylinder.

It is given by formula,

$$I_p = P_m \cdot L \cdot A \cdot N / 60 \text{ watts. For two stroke and}$$

$$I_p = P_m \cdot L \cdot A \cdot N / 120 \text{ watts. For four stroke.}$$

Where,

P_m = Mean effective pressure

L = Stroke length

A = Area of piston

N = Speed of engine

K = No. of cylinders.

Brake power :

Brake power of engine is the actual power available at brake shaft.

Brake power is always less than the indicated power.

Frictional power:

The difference between indicated power and brake power is known as frictional power

Mechanical efficiency :

It is ratio of brake power to indicated power.

$$\eta = \frac{B.P.}{I.P.} \times 100$$

Thermal efficiency :

ANS: It is ratio of power output to the heat supplied to engine.

$$\text{Brake thermal efficiency} = \frac{P_b}{h_f} \times 100$$

Brake thermal efficiency is the ratio of brake power to supplied heat by fuel. Indicated thermal efficiency is the ratio of indicated power to supplied heat by fuel.

Relative efficiency :

It is ratio of indicated thermal efficiency to air standard efficiency.

Volumetric efficiency.

It is ratio of volume of air admitted to cylinder during suction stroke to the swept volume of engine

BSFC (Brake specific fuel consumption)

It is ratio of fuel consumption to brake power developed

$$\text{BSFC} = \frac{\text{fuel consumption in kg/hr}}{\text{brake power in kw}} \quad (\text{kg/kw})$$

2.2 Numerical Problems

[8 marks]

1. Problem on Morse test.
2. Problems on heat balance sheet.
3. Problems on performance of I.C engine.

A) Problems On Morse Test

Q. What is Morse test (Motoring Test)? State the procedure to conduct the Morse test.

Ans :Morse Test – This test carried out for multi cylinder I.C. engine. In this test, first engine is allowed to run (4-cylinder I.C. engine) at constant speed and brake power of engine is measured when all four cylinders are working and developing indicated power.

$$I_2 + I_3 + I_4 = (BP)_{\text{engine}} + (F_1 + F_2 + F_3 + F_4)$$

Where I_1, I_2, I_3 and I_4 – Indicated power of four cylinders

$(BP)_{\text{engine}}$ – Brake power of engine when all cylinders are working

F_1, F_2, F_3, F_4 – Frictional power of all four cylinders

The first cylinder is cut off by short circuiting in case S.I. engine or cutting fuel supply in case C.I. engine. This causes the speed to drop due to non working of first cylinder and consumption of frictional power. This speed is once again maintained to its original value by reducing load on the engine

$$I_2 + I_2 + I_3 + I_4 = (BP)_{2,3,4} + (F_1 + F_2 + F_3 + F_4)$$

Where $(BP)_{2,3,4}$ – Brake power of 2,3 & 4 cylinders only.

Repeat the above procedure for remaining cylinders and calculate I.P. of the engine.

$$\text{Cylinder 2 is cut off} - I_1 + I_3 + I_4 = (BP)_{1,3,4} + (F_1 + F_2 + F_3 + F_4)$$

$$\text{Cylinder 3 is cut off} - I_1 + I_2 + I_4 = (BP)_{1,2,4} + (F_1 + F_2 + F_3 + F_4)$$

$$\text{Cylinder 4 is cut off} - I_1 + I_2 + I_3 = (BP)_{1,2,3} + (F_1 + F_2 + F_3 + F_4)$$

I.P. of cylinder 1 is calculated as Eq. 1 – Eq.2

$$I_1 = (BP)_{\text{engine}} - (BP)_{2,3,4}$$

Similarly I_2, I_3 and I_4 is calculated as follows

$$I_2 = (BP)_{\text{engine}} - (BP)_{1,3,4}$$

$$I_3 = (BP)_{\text{engine}} - (BP)_{1,2,4}$$

$$I_4 = (BP)_{\text{engine}} - (BP)_{1,2,3}$$

Indicated power of engine = I.P.

$$IP = I_1 + I_2 + I_3 + I_4$$

Frictional power of engine

$$FP = IP - (BP)_{\text{engine}}$$

and mechanical efficiency

$$\eta = \frac{B.P. \text{ all}}{I.P} \times 100$$

$$\text{mech} = (B.P)_{\text{all}} / (I.P) \times 100$$

Thus Morse test is used to calculate IP, FP and mech by assuming FP of each cylinder remains constant.

1. Following results are obtained doing morse test

Brake power when all cylinders firing 16.2kw

Brake power when cyl.1 cut off 11.5 kw .

Brake power when cyl. 2 cut off 11.6 kw.

Brake power when cyl.3 cut off 11.68 kw.

Brake power when cyl.4 cut off 11.57 kw.

Calculate mechanical efficiency.

(Ans: 87.80%)

2. Following observation were recorded on four stroke four cylinder engine .

Brake power with all cylinders working 14.7 kw.

Brake power with all 1 cut off 10.14 kw .

Brake power with all 2 cut off 10.3 kw.

Brake power with all 3 cut off 10.36 kw .

Brake power with all 4 cut off 10.21 kw. Calculate mechanical efficiency.

(Ans: 82.63%)

3. During a trial on 4 cylinders four stroke engine coupled to hydraulic dynamo-meter, the following readings were recorded.

Brake power with all cylinder working = 14.7kw

Brake power with cylinder 1 cut off = 10.14kw

Brake power with cylinder 2 cut off = 10.3kw

Brake power with cylinder 3 cut off = 10.36 kw

Brake power with cylinder 4 cut off = 10.21kw

Petrol consumption 5.5 kg/hr.

calorific value of CV petrol = 42000 kJ/kg.

Dia of cylinder = 8 cm, stroke of piston = 10 cm.

clearance volume = 0.1 liter

Calculate 1] Mech efficiency 2] Air std efficiency 3] Indicated thermal efficiency 4] Brake thermal efficiency 5] relative efficiency

(Ans: 82.63%, 52.15%, 27.8%, 23.02%, 53.30%)

4. Following data relates to 4 cylinder, 4 stroke petrol engine.

Dia of piston = 80mm

stroke length = 120mm

clearance volume 0.1 litre

fuel supply = 4.8 kg/hr

CV = 44100 kJ/kg

Brake power all cylinder working 14.5 kw

Brake power 1 cut off 9.8kw

Brake power 2 cut off 10.3kw

Brake power 3 cut off 10.14kw

Brake power 4 cut off 10kw

Calculate 1] Mech efficiency 2] air std. efficiency

3] Indicated thermal efficiency

4] Brake thermal efficiency

5] relative efficiency

(Ans = 81.64%, 54.18%, 30.207%, 24.65%, 55.26%.)

Type 2:- Problem on heat balance sheet:-

A heat balance sheet provides details of heat generated

and expenditure.

Heat supplied			Expenditure		
Item	KJ	%	Item	KJ	%
Heat supplied by fuel			Heat to brake power		
			Heat to cooling water		
			Heat to exhaust		
			Unaccounted		

Calculation:-

1. Heat supplied:-

$$\text{Heat supplied} = m_f \times \text{C.V}$$

where, m_f = mass of fuel per minute

C.V = Calorific value (KJ/KG)

2. Heat equivalent to brake power:-

a) When power is given in kw

$$\text{Heat eq. of } P_b = \text{kw} \times 60 = \text{KJ/min.}$$

b) When rope brake is used,

$$P_B = (w-s) \times r \times \frac{2\pi N}{60} \text{ watt}$$

and heat equation to $P_B = (P_B) \times 60 \text{ KJ/min.}$

W= Load on drum, S= Spring reading, r= effective radius of drum, N= rpm.

3. Heat carried away by water:-

$$\text{Heat to cooling water} = m_w \text{ cp}_w \Delta \text{ tw}$$

Where m_w = mass of water per minute

cp_w = Specific heat of water at const. pressure (4.184 KJ/Kg⁰k)

$\Delta \text{ tw}$ = Change in temp of water ($tw_e - tw_i$)

4. Heat carried away by exhaust gases:-

$$m_e \times \text{cp}_e \times (T_e - T_{\text{ambient}})$$

M_e = mass of exhaust gases

$$= m_a + m_f$$

$(\text{cp})_e$ = specific heat of exhaust gases

ambient = Room temperature.

5. Unaccounted losses

$$\text{unaccounted} = \text{Heat}_{\text{sup}} - [P_b + H_W + H_e]$$

Problems:

1. Following observations are recorded during trial of four stroke, diesel engine.

1. fuel supplied 0.1kg/min
2. C.V of fuel 45000 KJ/kg
3. Speed 400 rpm
4. Effective brake drum dia = 1m
5. Mass of cooling water 10 Kg/min
6. Rise in temp. of water = 30^oc
7. Air supplied = 5kg/min
8. Room temp = Ambient = 30^oc
9. Temp of exhaust gas = 200^oc
10. Sp. heat of air = 1 KJ/Kg/K
11. Sp. heat of water = 4.2 KJ/Kg k

Draw heat balance sheet on minute bases.

2. An I.C engine uses 6kg fuel having calorific value 44000 KJ/Kg in 1hr. The power developed is 18kw. The temp. of 11.5 kg of cooling water was found to rise through 25^o c per minute. The temp. of 4.2 kg/min of exhaust gas with sp. heat 1 KJ/kg was found to rise through 220^o c. Draw heat balance sheet on per minute basis. Sp. heat of water = 4.2 KJ/Kg k

3. Following observation were recorded on and stroke diesel engine duration of trial is 1 min.

Draw heat balance sheet on percentage base.

Fuel supplied $m_f=0.1$ kg/min

CV of fuel = 41840 KJ/Kg

speed $N=400$ rpm.

Net load on drum $w=1000$ N

Effective dia. of brake drum = 1m

Mass of cooling water $m_w=10$ kg/min

Rise in temp. of water = 25^oc

Mass of air supplied = 6 kg/min

Temperature of exhaust gas = 200^oc

Ambient temp = 30^oc

Sp. heat of exhaust gas $c_{p_e}=1$ kg/kg k

Sp. heat of water $c_{p_w} = 4.184$ KJ/Kg k.

4. In a trial of oil engine. Following data were recorded

1. Duration of trial: 30min
2. Speed 1750 rpm.
3. Brake torque 330 N-m
4. Fuel consumption 9.35 kg/30min
5. Heat value of fuel 42300 KJ/kg
6. Mass of cooling water = (60)k
7. Rise in cooling water temp. 60k
8. Air consumption 182 kg
9. Exhaust gas temp. 486^oc
10. Atm. temp. 17^oc
11. $c_{p_e}= 1.25$ KJ/kg k
12. $c_{p_w}= 4.3$ KJ/kg k

Type III:- Problems on performance of ic engine

1. Indicated power:-

$$P_i = \frac{P_M \cdot L \cdot A \cdot N}{60} \times k \text{ watt - two stroke}$$

$$= \frac{P_m L \cdot A \cdot N k}{120} \text{ watt - four stroke.}$$

Where,

P_M = Mean effective pressure (N/m^2)

L = Stroke length (m)

A = area of piston ($\frac{\pi}{4} \times d^2$)

K = No. of cylinders

2. Mean effective pressure from indicator dia.:-

$$P_M = \frac{\text{Area of indicator diagram}}{\text{length of indicator diagram}} \times \text{spring stiffness}$$

3. Mechanical efficiency $\eta_{mech.}$:-

$$\eta_{mech.} = \frac{P_B}{P_i} \times 100$$

4. Brake power:-

$$P_B = \frac{2\pi NT}{60} - \text{watt}$$

$$= \frac{2\pi NT[(w-s)r]}{60} - \text{watt}$$

5. Brake thermal efficiency:-

$$\eta_{Bth.} = \frac{P_B}{h \cdot f} \times 100$$

6. Brake specific fuel consumption (BSFC):-

$$\text{BSFC} = \frac{M_F}{P_B}$$

7. Relative η :-

$$\eta_r = \frac{\eta_{Bth}}{\eta_{airstd.}} \times 100$$

Problems:-

1. Test on single cylinder 4-stroke engine indicates following results:-

Area of indicator diagram (a) = 840 mm^2

Spring stiffness $s = 50 \text{ KN/m}^2$. length of indicator dia = 50 mm

Cylinder diameter (d) = $10 \text{ cm} = 0.1 \text{ m}$.

Piston stroke (L) = 15 cm .

Engine speed (N) = 600 rpm .

Brake wheel dia. (D) = 62.5 cm

Load on brake drum (w) = 170 N

Spring scale reading (S) = 18 N

Calculate I.P, B.P and $\eta_{mech.}$

2. Test is conducted on single cylinder four stroke diesel engine. Following results were recorded:-

1. Mean effective pressure $P_m = 900 \text{ kpa}$.

2. Cylinder diameter = $100 \text{ mm} = 0.1$

3. Piston stroke (L) = 150 mm

4. Engine speed (N) = 500 rpm

5. Brake wheel dia. (D) = 650mm = 0.65m
6. Load on brake drum (w) = 250N
7. Spring load (S) = 60N
8. Calculate P_I, P_B and $\eta_{mech.}$

3. Following are observations on 4-stroke gas engine

- Stroke (L) = 40 cm = 0.4m
 Net brake load (W) = 850N
 Brake drum radius = 75 cm
 Bore = 24 cm
 Fuel supplied = 0.21 m³
 C.V of fuel = 18632 KJ/m³
 Explosions = 115 per min.
 IMEP = 6.65 bar

Find:-

- 1) BP
- 2) IP
- 3) $\eta_{mech.}$
- 4) $\eta_{Bth.}$

4. A 4 cylinder, 4-stroke engine develops 175 kw. at 2500 rpm. The stroke to bore ratio 1.5. If $\eta_{mech.} = 70\%$ and IMEP = 8 bar

Determine bore and stroke length of cylinder.

$$(d=147.12\text{mm}, L=220.68)$$

5. Four cylinder, two stroke, petrol engine develops 23.5 kw at 2500 rpm. mean effective pressure is 8.5 bar. If mechanical efficiency is 85%. Calculate stroke and bore of engine. Take length 1.5 times of bore.

6. An engine uses 6.5 kg of cycle per hour of C.V 30000 KJ/kg B.P of engine is 22 kw and $\eta_{mech.} = 85\%$ calculate,

- 1) Indicated power
- 2) Indicated thermal efficiency .
- 3) Brake thermal efficiency

7. A petrol engine uses 3.6 kg petrol. Per hour. If C.V is 44100 KJ/kg and mechanical efficiency is 78% and compression ratio 5.6. it develops 12 kw of brake power.

Calculate:-

- 1) Bth. efficiency
- 2) Indicated thermal efficiency
- 3) Ideal air standard efficiency

(Ans 27.21%, 34.88%, 0.4979)

2.3 Pollution Control:-

Q.1 What are various pollutants in petrol engine and diesel engine.

ANS:

Pollutants	Petrol engine		Diesel engine	
	Part	Fuel load	Part load	Fuel load
1) Carbon monoxide (%)	0.2 to 1	2 to 5	0.01 to 0.06	0.35 to 0.20
2) Hydrocarbons (HC)	0.01 to 0.02	0.01 to 0.03	0.01 to 0.03	0.02 to 0.06

%				
3) Oxide of nitrogen (vol%) (NOX)	0.005 to 0.03	0.25 to 0.35	0.25 to 0.08	0.06 to 0.015
4) Carbon dioxide (vol%)	13 to 14	11 to 13	6.5	12.6
5) Hydrogen	0.5	0.1 - 0.5	6.50	12
6) water vapour	9.0 to 11.0	10.0 to 11.0	4.0	11.0
7) lead compound	40.800	50.00	x	x

Q.2 State harmful effects of various pollutants emitted from automobile

ANS: 1) CO:-

Partial combustion of fuel produces carbon monoxide. Although, it is colorless, odorless it is toxic and poisoning. carbon monoxide combine with hemoglobin forming carboxyhemoglobin which reduces oxygen carrying capacity of blood. This leads laziness and exhaustion of body and headache. prolong exposure can even leads to death. It also affects cardiovascular system thereby causing heart problems.

2) CO_2 :-

It is released in atmosphere in the form of smoke which is produced by burning of petroleum fuels. Causes respiratory disorder and suffocation. It is also toxic in large qty.

3) NO_2 :-

Higher flame temp. and rapid cooling of the combustion products favors the formation of NO. Average resistance time of NO and NO_2 in the atmosphere are 4 days and 3 days respectively. It causes respiratory irritation, headache, bronchitis, pulmonary, emphysema, impairment of lung ,loss of appetite and corrosion of teeth etc.

4) HC:-

Hydrocarbon plays role in formation of photochemical smog with NOX and sunlight which has effects like reduced visibility eye irritation , peculiar odours and damage to vegetation and accelerates the cracking of rubber products.

Q.3) Write note on Bharat stage 1,2,3 norms.

ANS:- In central motor vehicle act section 115 deals with various norms related to pollution. From automobile this norms are divided in 3-classes as bharat stage 1,2,3. The norms deal with following a

1) Emission of smoke, vapour etc. from motor vehicle.

a) Every motor vehicle shall be manufactured, maintain and driven in such manner that is should not emit smoke, sparks, ashes or oily substances.

b) Idling carbon monoxide Emission shall not exceed 3% by volume for 4-wheelers and shall not exceed 4.5% by volume for 2 and 3 wheeler

2) Design and manufacturing:-

The vehicle shall be so manufacture that they comply with following there annexure.

Annexure 1:- Ignition standard

Annexure 2:- Breakdown of operating side

Annexure 3:- Fuel for tests.

3) PUC certificate:-

After the period of registration every vehicle shall carry a valid pollution under control certificate issued by authorized agency.

Q. List various fuel in I.C engine.

ANS: Following are commonly used fuels:

1. Petrol or gasoline
2. Diesel
3. Benzol
4. Propene
5. Ethenol
6. Methanol
7. Bio-diesel
8. Natural gas CNG/LPG

Q What are various lubricants additives and their functions.?

ANS:

No.	Additives	Functions
1	Detergent	It controls high temperature deposits.
2.	Dispersant	Control of low temperature sludge and deposits.
3.	Anti-wear	To reduce friction
4.	Antirust	To prevent corrosion
5.	Viscosity index improver	To increase viscosity index.
6.	Anti foam	To prevent forming of foam
7.	Anti oxidant	To prevent bearing foam oxidation

Q. What is a catalytic converter? What is its function? What are its types

A **catalytic converter** is an emissions control device that converts toxic gases and pollutants in exhaust gas to less toxic pollutants by catalyzing a redox reaction (an oxidation and a reduction reaction).

Two-way

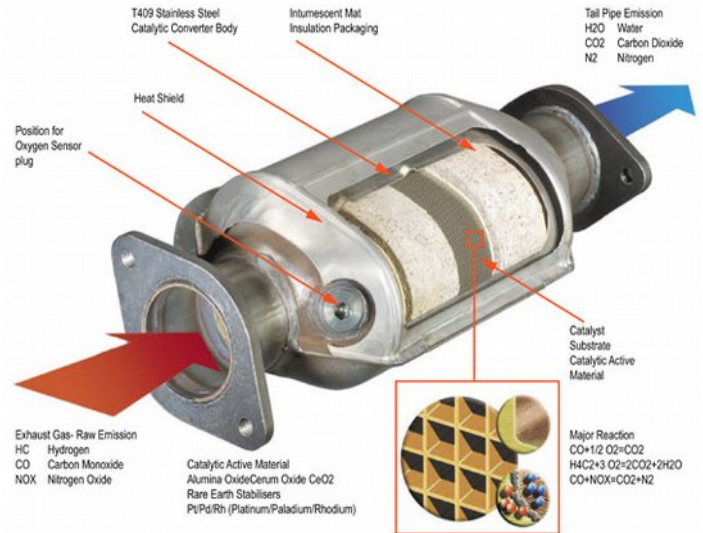
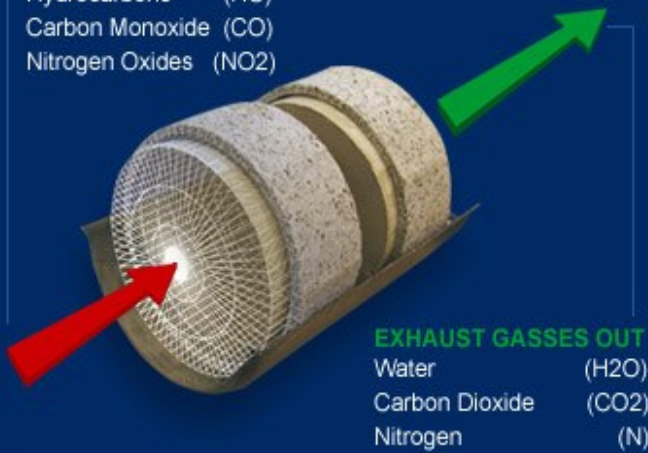
A 2-way catalytic converter has two simultaneous tasks:

1. Oxidation of carbon monoxide to carbon dioxide: $2CO + O_2 \rightarrow 2CO_2$
2. Oxidation of hydrocarbons (unburned and partially burned fuel) to carbon dioxide and water: $C_xH_{2x+2} + [(3x+1)/2] O_2 \rightarrow xCO_2 + (x+1) H_2O$ (a combustion reaction)

This type of catalytic converter is widely used on diesel engines to reduce hydrocarbon and carbon monoxide emissions. They were also used on gasoline engines in American- and Canadian-market automobiles until 1981. Because of their inability to control oxides of nitrogen, they were superseded by three-way converters.

How A Catalytic Converter Works

EXHAUST GASSES IN
 Hydrocarbons (HC)
 Carbon Monoxide (CO)
 Nitrogen Oxides (NO₂)



Three-way

Three-way catalytic converters (TWC) have the additional advantage of controlling the emission of [nitric oxide](#) and [nitrogen dioxide](#), which are causes [acid rain](#) and [smog](#).

A three-way catalytic converter has three simultaneous tasks:

1. [Reduction](#) of nitrogen oxides to [nitrogen](#) and [oxygen](#): $2\text{NO}_x \rightarrow x\text{O}_2 + \text{N}_2$
2. [Oxidation](#) of carbon monoxide to carbon dioxide: $2\text{CO} + \text{O}_2 \rightarrow 2\text{CO}_2$
3. Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and [water](#): $\text{C}_x\text{H}_{2x+2} + [(3x+1)/2]\text{O}_2 \rightarrow x\text{CO}_2 + (x+1)\text{H}_2\text{O}$.