The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

QUESTION BANK

Chapter 3. I C Engine Testing and Pollution Control

Program Name: Mechanical Engineering
Name of Subject & Code : Power Engineering (315371)
Date -24/07/2026

Program Code: ME5k
Semester : Fifth

Q. NO.	QUESTION	DETAIL	MAPPING
1	State the purpose of Exhaust Gas Recirculation (EGR) system in I.C. engine.	W-25 2 M	TLO-3.4 A
2	List the major pollutants regulated under BS VI norms.	W-25 2 M	TLO- 3.4 R
3	Define the following terms related to I.C. engine :– i) Brake Power ii) Brake Specific Fuel Consumption iii) Indicated Power iv) Mechanical Efficiency.	W-25 4 M	TLO-3.1 R
4	State the function of any four sensors used in Engine Control Unit (ECU).	W-25 4 M	TLO-3.4 R
5	During a Trial on a single-cylinder 4-stroke oil engine, the following observations were made: Bore = 25cm; Stroke = 40 cm, duration of trial = 1 hour; Total fuel consumption = 8.4 kg; Calorific value of fuel = 45,000 kJ/kg, Engine speed = 1500 rpm; Mean effective pressure = 5.8 bar, net brake load = 1.2 kN; Brake drum diameter = 1.5 m, rope diameter = 2.5 cm; mass of jacket water circulated = 600 kg, water enters at 18°C and leaves at 55°C; total air consumption = 360 kg; Room Temperature = 22°C; Exhaust Gas Temperature = 280°C, Specific Heat of Exhaust Gases = 1.2 kJ/kg. K, Specific Heat of Water = 4.186 kJ/kg.K. Solve to determine :– i) Brake specific fuel consumption ii) Indicated thermal efficiency iii) Draw the heat balance sheet on a minute basis.	W-25 6M	TLO-3.2 A
6	A four cylinder, 4-stroke petrol engine 6 cm bore and 9 cm stroke was tested at constant speed. The fuel supply was fixed to 0.0014 kg/sec and calorific value of fuel is 42000 kJ/kg. The plug of 4-cylinders were successively short circuited without change of speed. The power measurement were as follows:– B.P. developed with all cylinders working = 16.25 kW B.P. developed when cylinder No. 1 cut off = 11.55 kW B.P. developed when cylinder No. 2 cut off = 11.65 kW B.P. developed when cylinder No. 3 cut off = 11.70 kW B.P. developed when cylinder No. 4 cut off = 11.50 kW Solve to determine :– i) Indicated power of engine. ii) Mechanical efficiency. and State the purpose of conducting Morse Test.	W-25 6M	TLO- 3.2 A
7	Explain the Morse testing of IC engine	OTHER- 4M	TLO- 3.2 U
8	Explain working of 3 way catalytic converter with neat sketch.	OTHER- 4M	TLO- 3.3 U
9	The following data is collected during a trial of four cylinder petrol engine : B.P. with all cylinder working = 15.8 Kw B.P. with cylinder No. 1 cutoff = 11.14 kW B.P. with cylinder No. 2 cutoff = 11.2 kW B.P. with cylinder No. 3 cutoff = 11.36 kW B.P. with cylinder No. 4 cutoff = 11.3 kW Find mechanical efficiency of engine.	OTHER- 4M	TLO- 3.2A
10	List the various methods to reduce the pollution in diesel engine.	OTHER- 4M	TLO- 3.3 R
11	List diagnostic tools used in fault finding in two wheelers.	OTHER- 4M	TLO- 3.4 R
12	Explain Heat balance sheet of testing IC engine.	OTHER- 6M	TLO- 3.2 U
13	List the polluting emissions in exhaust of I C Engine. Explain their effect on environment.	OTHER- 4M	TLO- 3.3 U
14	List the various performance parameter of IC Engine.	OTHER- 4M	TLO- 3.1 R
15	Define 1.Mean effective pressure. 2.Indicated thermal efficiency 3.Brake thermal efficiency 4.Volumetric efficiency.	OTHER- 6M	TLO- 3.1 R

Mr. B. S. Patil

27/07/20

Chapter No: 3

I.C. Engine testing & pollution control

3.1:→

*Terminology of I.C. Engine:-

In first chapter notes.

* piston speed:-

The average distance travelled by the piston per minute in an engine is known as piston speed.

∴ piston speed $= 2LN$ m/min

where, $L =$ Length of stroke in 'm'.

$N =$ speed of crank shaft in rpm

* Engine testing:-

Purpuse:-

1] to get information, that is not possible to be determined by calculations.

2] To confirm the validity of data used while designing the engine

3] To satisfy the costomers as to the rated power with guaranteed fuel consumption

Two types of tests

A] commercial tests   B] Thermodynamics tests.

A] Commercial tests:-

Purpose:- to check

(1) Rated power with a guaranteed fuel consumption in kg/kw-hr.

(2) The quantity of lubricating oil consumed on brake power basis per kwh.

(3) The overload carrying capacity of engine

(4) The quantity of cooling water circulated on brake power basis in kg/kw-hr.

Thermodynamic test :-

Purpose :-

(1) To compare actual results with theoretical or ideal performance.

The measurements necessary to determine the mechanical & thermal efficiency of engine & to draw the Heat balance account are.

(1) Indicated power [IP] (2) Brake power [BP]
(3) friction power [FP] (3) Heat carried by exhaust gases.
(5) Rate of fuel consumption & its calorific values.
(6) Rate of flow of cooling water & rise in temp. for calculating the heat carried by cooling water.

Imp

* Indicated power [IP]

"The power developed inside the engine cylinder is known as Indicated power [IP]".

$I.P = P_m L A N^*$

P_m = mean effective pressure, avg. pressure in working cycle.

where, L = length of stroke
A = c/s area of cylinder
N^* = No. of power strokes.
= N - for two stroke Engine
= $\frac{N}{2}$ for four stroke Engine.

$$\boxed{I.P = P_m \times L \times \frac{\pi}{4} d^2 \times N^*}$$

* mean effective pressure [P_m] :-

The avarage Hypothetical pressure that, if it is acting on piston during the entire explosion or power stroke, would have to produce the same amount of work as that produced during the actual cycle.

∴ Net work produced = $P_m \times$ swept vol^m
$= P_m \times V_s$

Indicated Mean effective pressure [imep]:-
"mean effective pressure based on indicated Power" is called indicated mean effective Pressure.

$$\boxed{I.P = P_{im} \times V_s} \text{ or } \boxed{I.P = imep \times V_s}$$

Brake Mean effective Pressure [bmep]:-
"mean effective pressure based on B.P."

$$\boxed{B.P = b.m.e.p \times V_s}$$

* MEASUREMENT OF I.P:-

I.P. of engine at perticular speed can be calulated with the help of indicator which is fitted with cylinder head & variation of pressure inside the cylinder is obtained with a diagram called as "Indicator diagram".

The typical indicator diagram obtained as follow,

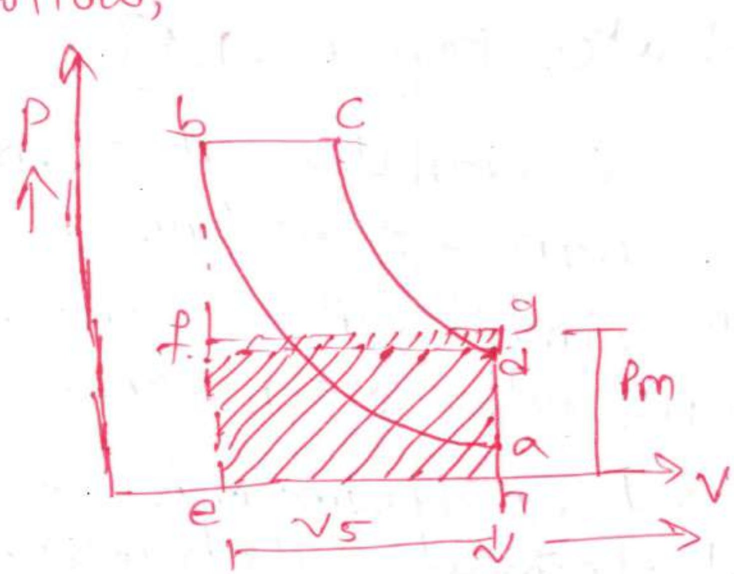


fig. indicator diagram.

The diagram obtained is a curve a-b-c-d.

∴ work obtained = Area [abcd]

By rearranging this area "abcd" into a rectangle of length to stroke vol^{M} as shown in fig.

$$A[a-b-c-d] = A[a-e-f-g]$$

∴ we get the height of ~~triangle~~ rectangle as m.e.p.

$$\therefore I.P = [\text{work/cycle}] \times N$$
$$= P_m \times V_s \times N = \underline{P_m \times A \times L \times N}.$$

mean effective pressure can be calculated as,

$$P_m = \frac{\text{Area of indicator card (diagram)} \times \text{spring index}}{\text{Length of indicator card/diagram}}$$

$$= \frac{a \times s}{l} \; N/m^2$$

a = area of indicator in m^2
l = length of diagram in m
s = spring index [N/m^2 per meter]

Brake Power [BP]

"Useful power available at crankshaft".

BP is less than IP because.

1] friction betn cylinder s/f & piston rings, bearings, gears, valve mechs. etc.

B.P. is measured by dynamometer may be Mechanical, electrical & Hydraulic.

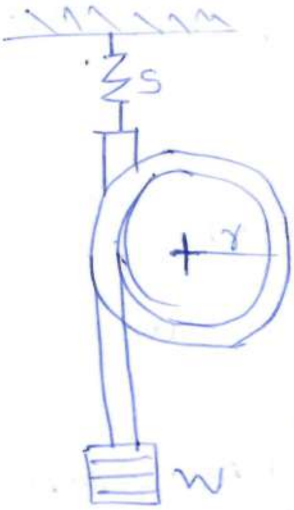
$$\therefore B.P = [W-S] r_e \times 2\pi N$$

W = dead weight, S = spring balance reading

R = Brake drum radius , N = rpm

Net Brake load = [W-S] &

Brake torque = [W-S] $\times r_{eff}$



$r_{eff} = r + \frac{D_R}{2}$

r = radius of drum

r_R = radius of rope

fig. rope brake dynamometer.

Friction power : [F.P]

difference between I.P & B.P

$$\boxed{F.P = I.P - B.P}$$

friction power is measured by Motoring test, William's Straight line, Morse test

Measurement of F.P

By putting ignition off for petrol Engine or by removing the fuel injector for diesel engine, engine is driven to rated speed by some external motor.

The Power given by external motor to drive engine at rated speed is the F.P.

[Motoring test)

IMP

Morse test

To conduct the morse test, first Engine is allowed to run at constant speed & brake power is measured when all four cylinders are working & developing Indicated power.

$$\therefore I_1 + I_2 + I_3 + I_4 = [BP]_{Engine} + [F_1 + F_2 + F_3 + F_4] \quad \text{— (1)}$$

Where, I_1, I_2, I_3 & I_4 are indicated powers developed by cylinders 1, 2, 3, 4 respectively.

$[BP]_{Engine}$ = Brake power of Engine when all four cylinders are developing power.

& F_1, F_2, F_3, F_4 = frictional powers of cylinders 1, 2, 3, 4 resp.

Case I :- short circuiting cylinder (1).

$$\therefore (I_4 + I_2 + I_3) = (BP)_{2,3,4} + [F_1 + F_2 + F_3 + F_4] \quad \text{— (II)}$$

Similiarly cylinders, 2, 3 & 4 are cut-off.

when cylinder 2 is cut-off,

$$[I_1 + I_4 + I_3] = (BP)_{1,3,4} + [F_1 + F_2 + F_3 + F_4] \quad \text{— (3)}$$

when cylinder 3 is cut-off

$$[I_1, I_2 + I_4) = [BP]_{124} + [F_1 + F_2 + F_3 + F_4] \quad \text{— (4)}$$

When cylinder 4 is cut-off,

$$[I_1 + I_2 + I_3] = [BP]_{123} + [F_1 + F_2 + F_3 + F_4] \quad \text{— (5)}$$

$\therefore$ Indicated power of cylinder 1 can be calculated by substracting eqn (2) from eqn (1) we get

$$I_1 = [BP]_{Engine} - [BP]_{2,3,4}.$$

Similliarly
$$I_2 = [BP]_{Engine} - [BP]_{134}$$
$$I_3 = [BP]_{Engine} - [BP]_{124}$$
$$I_4 = [BP]_{Engine} - [BP]_{123}.$$

$\therefore$ total $[I.P]_{Engine} = I_1 + I_2 + I_3 + I_4$

$\therefore$ frictional power $= [I.P]_{Engine} - [BP]_{Engine}$

$$\therefore \quad \eta_{mech} = \frac{B.P}{I.P}$$

Efficiencies

1] Mechanical Efficiency (η_{mech}):-

It is a ratio of B.P to I.P

$$\eta_{mech} = \frac{B.P}{I.P} = \frac{B.P}{BP + I.F.}$$

2] Thermal efficiency:-

ratio of power developed to the Heat energy of fuel supplied.

a] Brake thermal efficiency [η_{Bth}]:-

$$\eta_{Bth} = \frac{B.P \text{ in KW}}{\text{mass of fuel in kg/sec} \times \text{C.V. in KJ/Kg}}$$

b] Indicated thermal efficiency [η_{ith}]:-

$$\eta_{ith} = \frac{I.P \text{ in KW}}{\text{mass of fuel in kg/sec} \times \text{C.V. in KJ/Kg}}$$

3] Relative efficiency [η_r]:-

"ratio of Brake thermal efficiency to the corrosponding air standard efficiency."

$$\eta_r = \frac{\eta_{Bth}}{\eta_{air\,std.}}$$

for diesel Engine $\eta_{air\,std} = 1 - \frac{1}{(r_c)^{\gamma-1}}\left[\frac{\alpha_k^{\gamma}-1}{\gamma(\alpha_k-1)}\right]$

for petrol Engine $\eta_{air\,std} = 1 - \frac{1}{(r_c)^{\gamma-1}}$.

5] Volumetric efficiency [η_v]:-

ratio of volume of air admitted or charge admitted to the engine cylinder (V_a) during suction stroke at N.T.P to the swept vol^m

$$\boxed{\eta_v = \frac{V_a}{V_s}}$$

NTP = Normal temp. & pressure.

* Brake specific fuel consumption (B.S.F.C):-

it is a mass of fuel required to develop 1KW of Brake power for a period of 1 Hr & it is inversely proportional to Brake thermal efficiency

$$b.s.f.c = \frac{\text{fuel consumption in Kg/Hr}}{\text{Brake power in KW.}}$$

$$\boxed{\text{Unit} = \text{Kg/Kwh}}$$

Problems

Q.1] Engine has piston diameter of 15cm, length of stroke 40 cm & mean effective pressure 5 bar. The Engine makes 120 explosions/min. Determine η_{mech} if B.P. = 5KW.

→ $d = 15 = 0.15\,m$, $L = 40\,cm = 0.4\,m$, $P_m = 5\text{ bar} = 5\times10^5 \frac{N}{m^2}$

B.P = 5 KW, 120 explosions/min.

$$I.P = P_m L A N^* = P_m \times L \times \frac{\pi}{4} d^2 \times N^*$$

$$= 5\times10^5 \times 0.4 \times \frac{\pi}{4} \times (0.15)^2 \times \frac{120}{60}$$

$$= 7068.58 \text{ Nm/s or W}$$

$$\boxed{I.P = 7.068 \text{ KW}}$$

$$\eta_{mech} = \frac{B.P}{I.P} = \frac{5}{7.068} \times 100\,\%$$

$$\boxed{\eta_{mech} = 70.74\%}$$

2] Test on single cylinder 4-stroke Engine fitted with indicator gave following results.

Area of indicator diagram = 840 mm^2
length of — " — = 50 mm
spring stiffness = 50 kN/m^2/m elongation
cylinder diameter = 10 cm
Piston stroke = 15 cm
Engine speed = 600 rpm
Brake wheel diameter = 62.5 cm
load on Brake wheel = 170 N
spring scale reading = 18 N
Calculate I.P.:

$\Longrightarrow$

$$P_m = \frac{\text{Area of indicated diagram}}{\text{length of indicated diagram}} \times \text{spring Index}$$

$$= \frac{0.840 \times 10^{-3}}{0.050} \times 50 = 840 \ N/m^2$$

I.P. of 4-S Engine,

$$I.P. = P_m L A N^* \quad \& \quad N^* = N/2$$

$$I.P = P_m L A \frac{N}{2} = P_m L \frac{\pi}{4} d^2 \frac{N}{2}$$

$$= 840 \times 0.15 \times \frac{\pi}{4} (0.1)^2 \times \frac{600}{2 \times 60}$$

$$= 4.978 \text{ Watt.}$$

3] The following observations were made while taking trial on a single cylinder IC Engine

$B.P = 45 KW$, $\eta_{mech} = 80\%$, $\eta_{bth} = 35\%$ $C.V = 42000$ KJ/Kg

determine, I.P & fuel consumption.

→

$\eta_m = \frac{B.P}{I.P} \Rightarrow I.P = \frac{45}{0.8} = 56.25 KW$

$\eta_{bth} = \frac{B.P.}{\text{Heat supplied}} \Rightarrow \text{heat supplied} = \frac{45}{0.35} = 128.57$ kW

Now, heat supplied $= \dot{m}_f \times C.V \Rightarrow \dot{m}_f = \frac{128.57}{42000}$

$\therefore \dot{m}_f = 3.0611 \times 10^{-3}$ kg/sec

* Heat balance sheet

* It is used to trace the Energy distribution
* It is prepared in KJ/sec, KJ/min & percentage

Sample of heat balance sheet.

Heat supplied	KJ/min	%	Heat distribution	KJ/min	%
$\dot{m}_f \times CV$	KJ/min	100%	1] Heat equivalent to B.P	Q_{BP}	$\frac{Q_{BP}}{Q_s} \times 100\%$ =
			2] Heat loss in Cooling Water	Q_W	$\frac{Q_W}{Q_s} \times 100\%$
			3] Heat loss in Exhaust gas	Q_{eg}	$\frac{Q_{eg}}{Q_s} \times 100\%$
			4] Unaccounted heat	Q_{acc}	$Q_s - [Q_{BP} + Q_W + Q_{eg}]$
Total	Q_s	100	Total	Q_s	100%

*Heat supplied = mass of fuel × Calorific value

$$= \dot{m}_f \times C.V. \quad \left[\frac{Kg}{min} \times \frac{KJ}{Kg} = \frac{KJ}{min} = KW\right]$$

*Heat equivalent to B.P. = B.P in KJ/min

$$= [W-S] \cdot r \cdot \frac{2\pi N}{60}$$

* Heat lost in cooling water $= m_w \times C_{p_w} \times \Delta t$

where, m_w = mass of cooling water circulated in kg/min

C_{p_w} = sp. heat of water, 4.18 KJ/kg K

$\Delta t = (T_2 - T_1)$ - temperature rise

* Heat carried out by Exhaust gas $= m_{eg} \times C_{p_{eg}} \times [T_{eg} - T_{room}]$

where, $m_{eg} = m_a + m_f \Rightarrow m_f\left(1 + \frac{m_a}{m_f}\right)$

$= m_f\left[1 + \frac{A}{F}\right]$ ---in kg/min

C_{eg} = Sp. heat of exhaust gas = 1.005 KJ/kg K

T_{eg} = Temp. of Exhaust gas.

* unaccounted heat loss := [Heat supplied]

minus

[Heat equivalent to B.P, cooling water & Exhaust gas]

Example:-

following observations were recorded during a trial on 4-S oil Engine

speed of Engine = 290 rpm, oil consumption = 3.5 kg/hr

water flow = 270 kg/hr, cooling water temp. rise = 36°C

A:F = 25:1 room temp = 294 K Exhaust gas temp = 688 K

sp. heat of Exhaust gas = 1.005 KJ/kgK

Calorific value of gas = 45200 KJ/kg

B.P = 11.9 KW

Calculate heat balance sheet in KJ/min.

→ Heat equivalent to B.P ⇒ $11.9 \times 60 = 714$ KJ/min

1] heat supplied $= m_f \times C.V \Rightarrow \frac{3.5}{60} \times 45200$

$Q_s = 2636.66$ KJ/min.

2] Heat carried out by cooling water $= m_w C_{pw} \Delta T$

$= \frac{270}{60} \times 4.18 \times 36$

$= 677.6$ KJ/min

3] mass flow rate of Exhaust gas $[m_{eg}]$ $= m_f [1 + \frac{A}{F}]$

$= \frac{3.5}{60} [1+25]$

$= 1.51666$ kg/min

4] heat carried out by Exhaust gas $= m_{eg} \times C_{Peg} \times [T_{eg} - T_{room}]$

$= 1.51666 \times 1.005 \times [688 - 294]$

$= 600.52$ kJ/min

∴ Unaccounted heat $= \begin{bmatrix} \text{heat} \\ \text{supplied} \end{bmatrix} - \begin{bmatrix} \text{Heat equivalent to BP, cooling water} \\ \text{Exhaust gas} \end{bmatrix}$

$= 2636.66 - [714 + 677.16 + 600.50]$

$= 644.98$ kJ/min

Heat balance sheet

Heat supplied	kJ/min	%	Heat distribution	kJ/min	%
Qs	2636.66	100	1] B.P	714	27.07
			2] Heat in cooling water	677.14	25.68
			3] heat in Exhaust gas	600.52	22.77
			4] Unaccounted heat loss	644.98	24.48
total	2636.66	100	Total	2636.66	100

3.2 Pollution control

Pollution two category.

1] Non- exhaust pollution :- evaporation of fuel Hydrocarbons through fuel tank & carburator.

2] Exhaust pollution :-

1] Nox - such as NO & NO_2
2] CO 3] unburnt HC. 4] soot particles forming smoke.
5] oxides of lead. 6] SO_2.

combustion efficiency in petrol Engine is 95 to 98%
— " ——— in diesel Engine is 98% & above

* Pollutants in exhaust gas of petrol Engine :-

main pollutants.

1] Carbon monoxide :- 3] Hydrocarbon
2] carbon dioxide :- 4] Nox 5] SO_2, smok & lead vapours.

main effects :-

CO :- Carbon monoxide combines with ~~Haemo~~ Haemoglobin in blood forming carboxy Hemoglobin which reduces the oxygen carrying capacity of blood.

① This leads to laziness, exhaustion of body & Headache
② Prolong exposure can even leads to death
③ causes Heart problem.

CO_2 :- Causes respiratory disorder & suffocation (गुदमरणे)

HC :- ① It has effect like reduced visibility, eye irritation & damage to vegetation
② It ~~reduces~~ induces cancer, affect DNA &

cell growth.

SO_2:- it is toxic & corrossive gas, causes Human respiratory track of animals. plants & crops.

* Effects of pollutions on Environment/Biosphere

1] CO:- Same as above [effects of CO]

2] CO_2:- Temperature of earth is increases by 0.05°C as conc. of CO_2 is increases at a rate of 0.75 ppm per year. This warming of atmosphere by trapping of infrared rays is called "Greenhouse effect" & CO_2 plays important role in it.

3] NO_x :-

The avg. residence of NO & NO_2 in the atm. are 4 days & 3 days respectively. They undergo various photochemical & chemical reaction in the atmosphere. leading to formation of HNO_3 which gets precipitated as nitrates during rainfall.

It causes, respiratory irritation, headache, impairement of lungs, corrossion of teeth to human body.

4] HC:→ same as above

5] SO_2:→ toxic & corrossive gas. oxides to SO_3 which combines with water to form H_2SO_4. which is corrossive & can harm respiratory track of Human beings, animals & crops.

Lubricant additives

- desirable properties:-

1] proper viscosity 2] Anti-corrossion property.
3] Anti-oxidation property. 4] Good cleaning ability
5] ability to withstand high pressure
6] Resistance to carbon formation.
7] Ability to not change viscosity with temp.

Imp main additives are:-

1] Detergents:-
To keep Engine parts, such as piston & piston rings, clean & free from deposits.
eg. organic acids.

2] Dispersants:-
शकते
To suspend & disperse materials that could form varnishes, sludge etc. that clog the engine.
गाळ - Clay or slush (अडकणे) गाळाने बंद होणे
eg.

3] Anti-wear:-
To give strength & prevent wear of heavily loaded surfaces such as crankshaft rods & main bearings.
eg. fatty acids.

4] corrossion inhibitors:-
To fight the rust & wear caused by acids & moisture as well as protect vital steel or iron parts from rust & corrosion
eg. Zinc ditinophosphate.

5] oxidation inhibitors:-

oxygen combines with even the best of oils that have high Engine temperature to form materials that damage the Engine. oxidation inhibitors reduce thickening of the oil & prevent sludge formation.

6] Foam inhibitors:-

The crank shaft when spun (loose, lax.) introduces great air turbulence in the crank case, causing oil to bubble & foam. These inhibitors limits bubble growth, break them up quickly to prevent frothing & allow oil pump to circulate oil evenly. eg. silicon polymers.

7] viscosity index improvers:-

It is added to improove viscosity of oil.
eg. Butylene polymers.

8] Pour point depressant:-

This additives improves an oils ability to flow at very low temperature.
eg. Ester

V. IMP

* Catalytic converter:-

It is a device which converts Harmful pollutants to harmless gases. Catalytic converter is used in exhaust emission in control system to convert CO, NO_x, HC & other Harmful gases to harmless gases.

A catalytic converter consists of a cylindrical unit of small size like a small silencer & is installed into the exhaust system of a vehicle. it is placed between the exhaust manifold & the silencer.

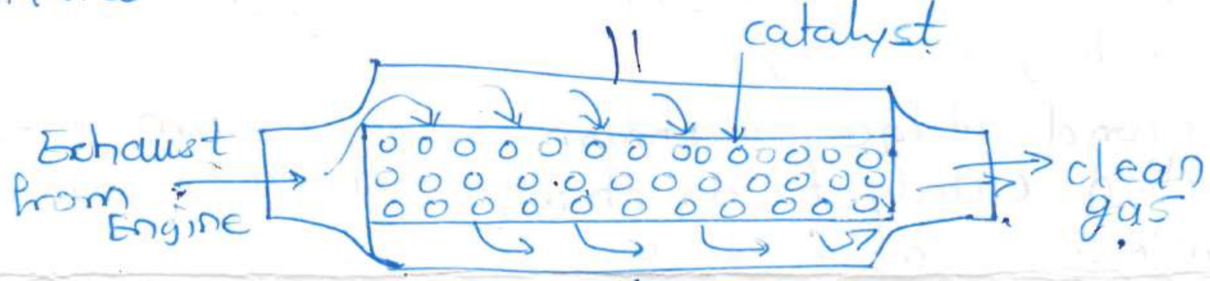


fig. two way catalyst converter

Inside the cylindrical tube ie. converter there is a Honey comb Structure of a ceramic or metal which is coated with allumina based material & thereafter a second coating of precious metal platinum, paladium or rhodium or combination of same. This second coating serves as a catalyst when the exhaust gases pass over the converter substance, the toxic gases as CO, HC & NO_x are converted into harmless gases as CO_2, H_2 & N_2.

1] Two way catalytic converter:-

Through catalytic action, a chemical change converts CO & HC into carbon dioxide & water. such converter is called "two way catalytic converter

2] Three way catalytic converter:-

Three way catalytic converter converts all 3 Harmfull. pollutants such as CO, HC & NO_x ~~into~~ into CO_2, water & free H_2 & N_2 respectively.

It operates in two stages.

In first stage rhodium reduces NO_x in the exhaust into nitrogen & oxygen.

In second stage, platinum or palladium acts as oxidation catalyst to change HC & CO into Har- Harmless water & CO_2.

atmospheric air is fed into the exhaust after the first stage as oxygen is required in 2nd stage.

catalytic converter is made of stainless steel to safeguard from high temperature from heat generated during oxidation reaction.

Advantages:- ① No regular maintenance ✓

② can be used at about 80,000 km or more ✓

③ HC, CO & ~~CO_2~~ NO_x are removed from exhaust gas by oxidation ✓

Limitations:-

① No leaded petrol can be used only ✓

② emissions of SO_2 can be increased if fuel contains sulphur. ✓

③ added cost to engine. ✓

④

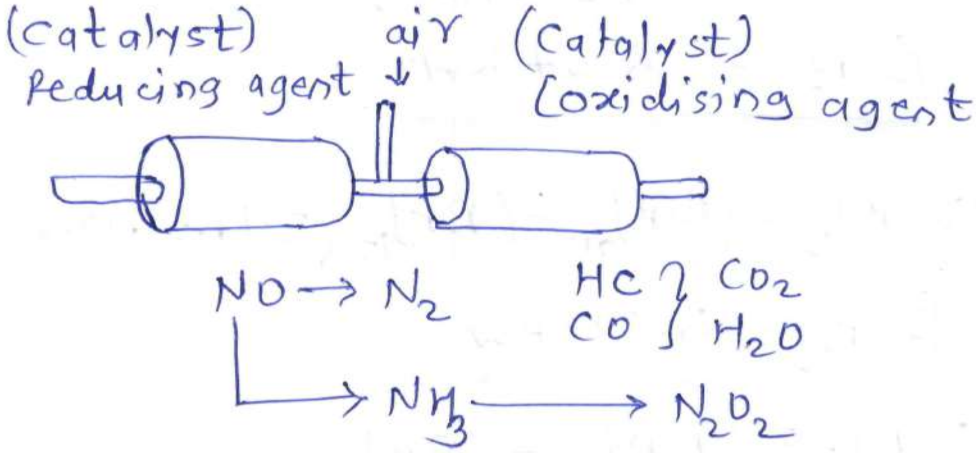


fig. 3-way Catalytic Converter

Numerical on Morse test:-

following results were obtained during morse test on 4-stroke Engine.

BP when all cylinders are working = 16.2 KW
BP when cylinder 1 cut-off = 11.55 KW
— " — 2 — " — = 11.83 KW
— " — 3 — " — = 11.687 KW
— " — 4 — " — = 11.51 KW

calculate mechanical efficiency, total friction Power & total indicated power.

→

Indicated power of cylinder 1 $[I.P]_1 = [BP]_{All} - [BP]_{234}$

$[I.P]_1 = 16.2 - 11.55 = \underline{4.65 KW}$

similarly, $[I.P]_2 = [B.P]_{all} - [B.P]_{134}$

$= 16.2 - 11.63$

$\underline{[I.P]_2 = 4.57\ kW}$

also, $[I.P]_3 = [B.P]_{all} - [BP]_{124} \Rightarrow 16.2 - 11.687$

$\underline{[I.P]_3 = 4.513\ kW}$

$[I\ P]_4 = [B\ P]_{all} - [BP]_{123}$

$= 16.2 - 11.51$

$\underline{[I.P]_4 = 4.69\ kW}$

Now, $[I.P]_{total} = I.P_1 + IP_2 + IP_3 + IP_4$

$= 4.65 + 4.57 + 4.513 + 4.69$

$\boxed{[IP]_{total} = 18.423\ kW}$

$\therefore$ $[F.P]_{total} = [IP]_{total} - [B.P]_{all}$

$= 18.423 - 16.2$

$\boxed{[FP]_{total} = 2.223\ kW}$

Mechanical efficiency $\eta_m = \frac{B.P}{I.P} \times 100\%$

$= \frac{16.2}{18.423} \times 100\%$

$\boxed{\eta_m = 87.93\%}$

xhaust gas Recirculation [EGR]:-

It is a Engine emission control technique that reduces harmful nitrogen oxide [NO_x] gases by routing a portion of exhaust gas back into the Combustion chambers.

Key Components:-

EGR valve, EGR Cooler & connecting metal Plumbing.

Working:-

- The System takes a small portion of Exhaust gas from the Exhaust manifold before it leaves the tailpipe.
- The gas passes through a heat Exchanger called an EGR cooler to lower its temperature.
- The Engine control module [ECM] opens a regulated valve to mix the cooled Exhaust gas with fresh air entering the intake manifold.
- The inert Exhaust gas [CO_2] displaces O_2 & absorbs Combustion heat, lowering peak cylinder temperatures below the thresold where NO_x forms.

Benefits:-

1] cuts toxic NOx [Nitrogen oxides] pollution by up to 70% in many internal combustion Engine.

2] Reduces fuel Consumption & Throttling losses. Results in Improved efficiency.

3] limitations:-

Soot & Carbon from the Exhaust can clog the Value over time, requiring routine cleaning & replacement.

* Standard pollution Norms:-

Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment.

Bharat stage norms have been styled to suit specific needs & demands of Indian conditions.

commensed in 1989, as std. Emission norms (Ideal) replaced by mass emission for both gasoline (1991) & diesel (1992) vehicles.

India starded adopting European emission from the year 2000 & fuel regulations for four whelled light duty & heavy duty.

Standard

India 2000 - Euro I - Nationwide

2001 - NCR - Mumbai, kolkata, chennai

B.S. II - Euro II - 2003-04 - NCR [10]

BS III - Euro III - 2010 - Nationwide

BS IV - Euro IV - 2010 - NCR

BS VI - Euro VI - 1 April - 2020

BS-VI :- Gross Vehicle wt = Not more than 3500 kg
Manufactured on or after 1st April 2020 for all models as per GSR 889 dt: 16 sept 2016

limit value

CO - 1500 - 4000 mg/kwh

Nox -

Engine type	mass of exhaust gas.	BS4	BS6	Remark
Petrol	CO (mg/Km)	1000	1000	NIL
	HC	100	100	NIL
	NOx	80	60	25% decrease
	PM	—	4.5	
Diesel	CO	500	500	NIL
	HC+NOx	300	170	43% Reduced
	NOx	250	80	68% —
	PM	25	4.5	82% —

ECU:- Electronic Control unit is a generic term for any embedded system that controls one or more of the electrical system ~~that controls on~~ or subsystems in an automobiles.

Signals types:- 1] Input - 2] output

Dignosis process:- 1] visual inspection 2] A simple swap 3] Using a tool such as Scanner 4] process of elimination.