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IES/GATE

MECHANICAL ENGINEERING

VOLUME - 3

I.C ENGINE, ENGINEERING MECHANICS, FLUID MACHINERY

SIERRA INNOVATIONS

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IC Engine

Engineering Mechanics

Fluid Machinery

I.C. Engine

Chapter :- 1 Basis And Air Standard Cycles

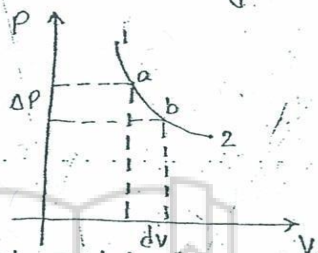
- The only difference in b/w reversible & irreversible process is Friction loss.
- In quasi-static process will not to be taken in irreversible process.
- Degree of randomness means measurment of out of order. (for entropy).

Quasistatic process :-

⇒ Quasi → partly (or) rest
or. differential calculus are same meaning.

$w = \int dw = \int_1^2 P dv$

$w = P(V_2 - V_1)$



Quasi-static process is not used for irreversible process.
- It should be taken when the value is constant & it change the value.

Table showing the various expression For the different thermodynamic process undergone by a system:-

- only For ideal gas reversible process

SL NO	CONTENTS / process	constant Volume Process	constant Pressure Process	constant Temprature Process	The Adiabatic process
1.	P, V & T relations	$\frac{P_2}{P_1} = \frac{T_2}{T_1}$	$\frac{V_2}{V_1} = \frac{T_2}{T_1}$	$P_1V_1 = P_2V_2$	① $P_1V_1^{\gamma} = P_2V_2^{\gamma}$ ② $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ ③ $\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_2}{T_1}$ ④ $\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_2}$
2.	Change in Internal energy (du)	$mc_v(T_2 - T_1)$	$mc_v(T_2 - T_1)$	0	$mc_v(T_1 - T_2)$
3	work done	0	$P(V_2 - V_1)$	$P_1V_1 \log_e \frac{V_2}{V_1}$	$\frac{P_1V_1 - P_2V_2}{\gamma - 1}$
4.	Heat transfer (dQ)	$mc_v(T_2 - T_1)$	$mc_p(T_2 - T_1)$	$P_1V_1 \log_e \frac{V_2}{V_1}$	0
5	change in enthalpy (dH)	$mc_p(T_2 - T_1)$	$mc_p(T_2 - T_1)$	0	$mc_p(T_2 - T_1)$
6	change in entropy (ds)	$mc_v \log_e \frac{T_2}{T_1}$	$mc_p \log_e \frac{T_2}{T_1}$	$mR \log_e \frac{T_2}{T_1}$	$ds = 0$ (or) $(S_2 - S_1) = 0$ (or) $(S_2 = S_1)$

- Heat supplied, work done, heat rejection & compression then the cycle is completed.

The order of cycle is – HA → WD (expansion) → HR → compression
- No heat rejection in case of expanssion process then it should be adiabaticand also it is for compression process.

Cycle :-

- when a system after undergoing a number of process is called or is able to attain its original condition, it is then said to have completed a cycle.
- IF a cycle is not completed, then continous work will not be obtained
- The following are the requirment for completing a cycle. i.e, HA, HR, Expansion (useful WD) & compression.

Ideal cycle :-

An ideal cycle is cycle in which both the expanssion and compression Process must take place reversily & Adiabatically.

I.C. Engines :-

An I.C. engine is the engine in which the combustion takes place inside the engine, besides all the operations required for a complete cycle take places inside the engine. thus the I.C-engine (his by itself a complete plant).

Only costly liquid and gaseous fuel can be used for I.C. engines.

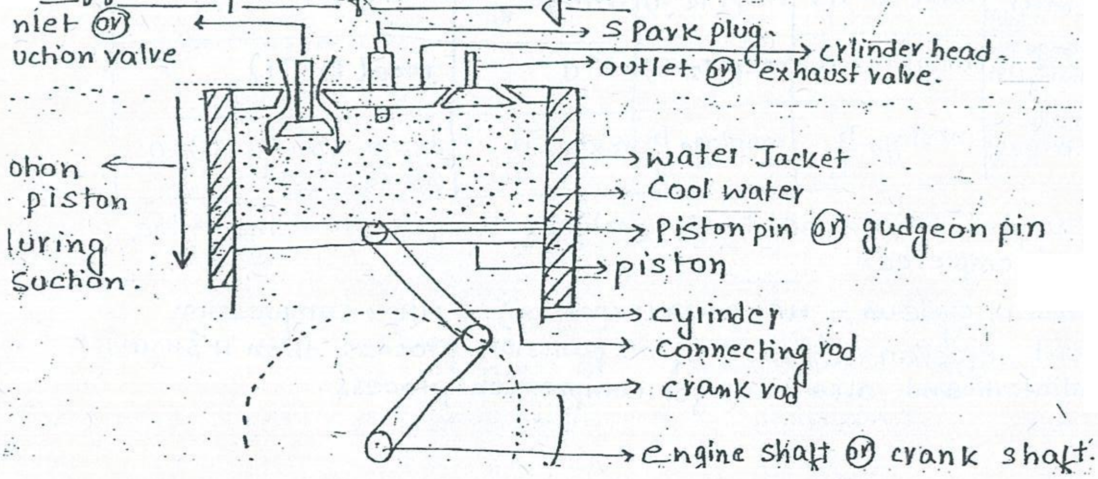
External combustion engine :-

An external combustion engine is the engine in which the combustion take place on the outside of the engine. excepting the expanssion process, the rest of the operation are carried out outside the engine.

cheaper solid fuels can also be used for external combustion engines.

when a cycle is taken into account by considering only the expanssion process, then the efficiency of the external combustion engine is higher than that of the internal combustion engines.

Different parts of an I.C. engine :-

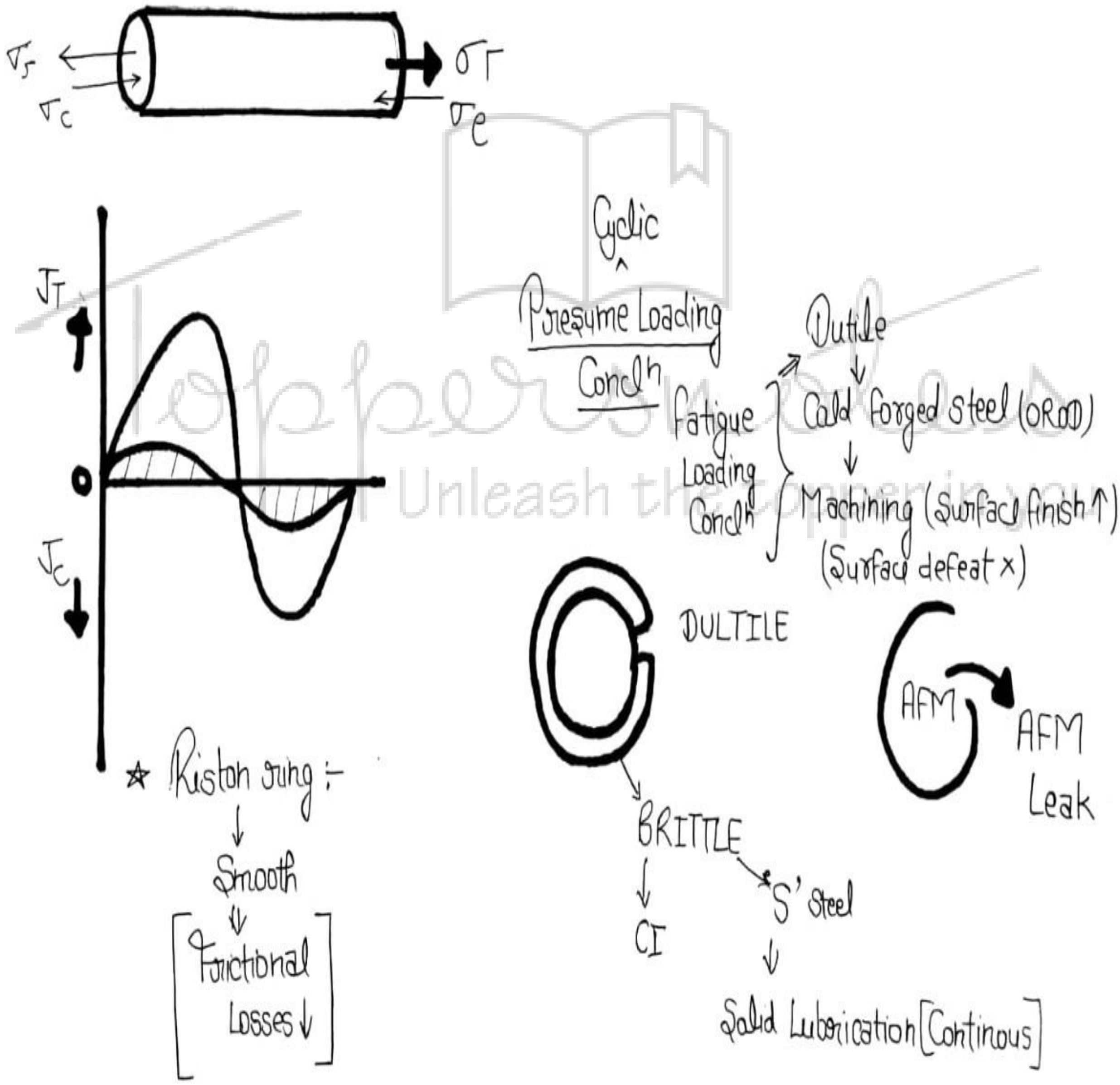


Piston pin/ Gudgeon kin (G) :-

- It is subjected to pressure loading condition (Completely reversed coding cycle), Hence it should be made up of forged steel
- In clear to remove surface defects it is undergone machining

Note: - connecting rod and crank rod is also made up of forged steel but specially by drop forging (cold)

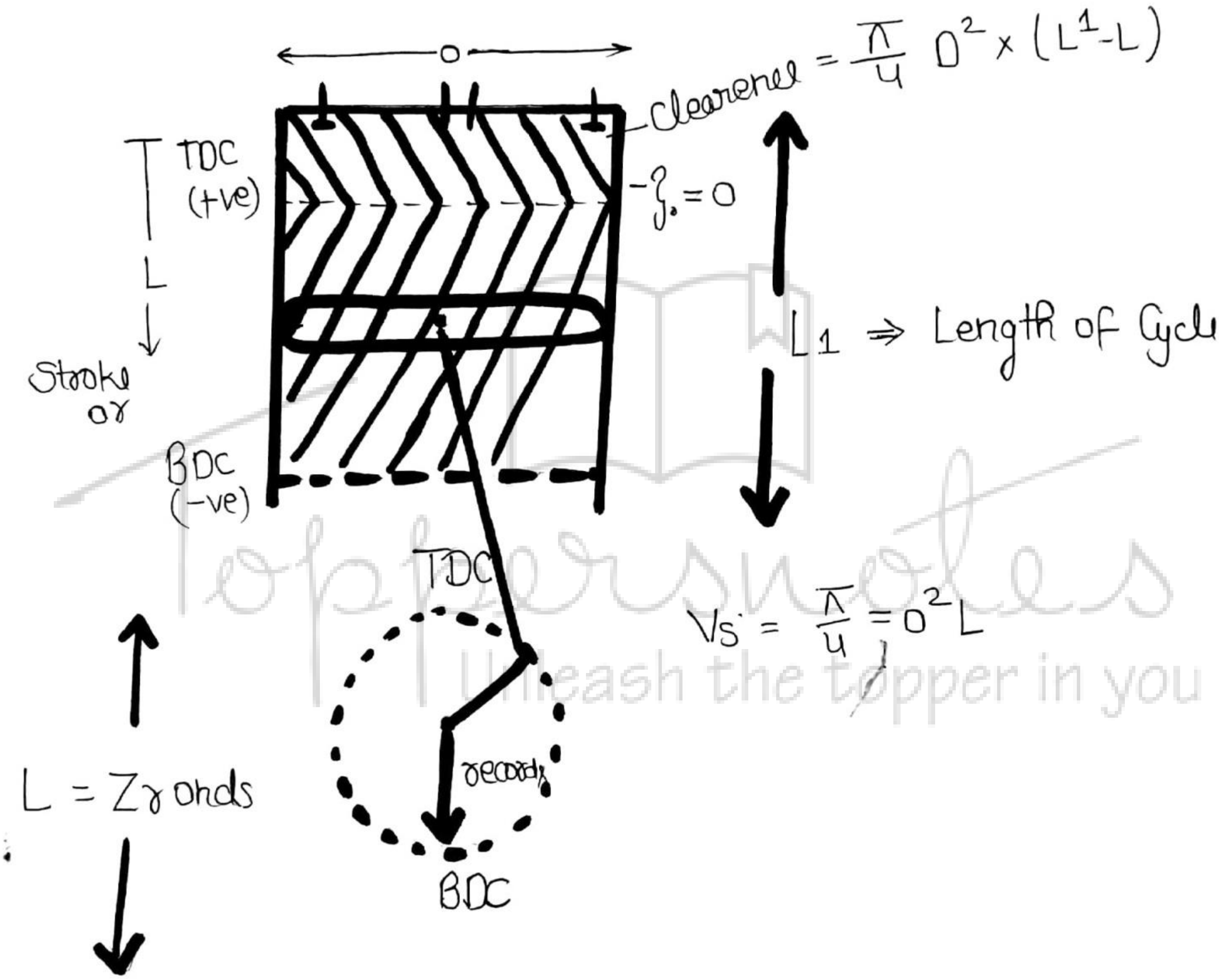
To remove internal defects



It should be smooth and brittle

Brittle because if it is ductile after some usage line it will deform and create a space from where AFM may leaks out

This is called as blow by defeat

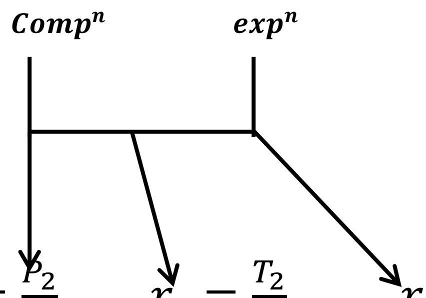


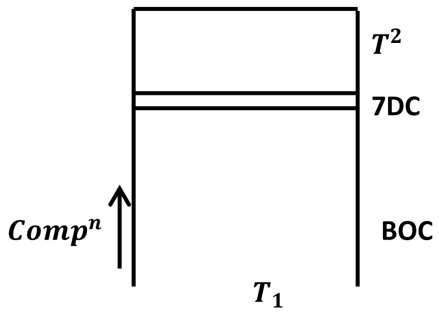
$\rightarrow$ $Clearance\ ratio = c = \frac{Vc}{Vs} < 1$ → Deb^n

It is the ratio of the volume which is not Covered by piston to the volume which Is covered by the piston and It is Generally Len than 1

$\therefore [C < 1]$

$\rightarrow \quad r > 1 = \frac{More}{Less}$

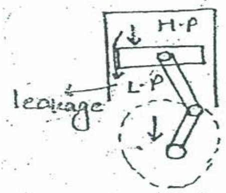


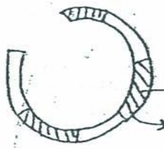


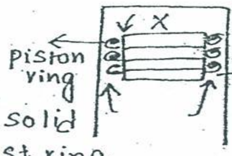
$Comp^r.r_p = \frac{P_2}{P_1} \qquad r_p = \frac{T_2}{T_1} \qquad r_p = \frac{v_1}{v_2}$

$exp^n r_{pe} = \frac{P_3}{P_4} \qquad r_e = \frac{T_3}{T_4} \qquad r_e = \frac{V_4}{V_3}$

Leakage is more → engine starting create problem.

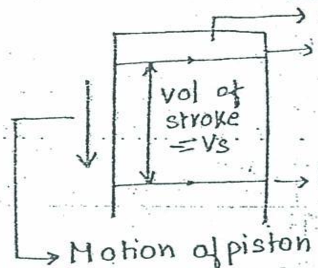






· compression ratio is same for all cycle.

→ Thermodynamics of I-c-engine :-



$$C = \frac{V_c}{V_s}$$ *

→ Vc is not in motion piston is not move on the top.

· clearance is provide in the cylinder because the pressure is still inside the cylinder.

· In case of heat addition the diesel engine, the volume will change.

clearance ratio :-

The ratio of the clearance volume to stroke volume is defined as the clearance ratio of the engine.

It is given by,

$$C = \frac{V_c}{V_s}$$ *

Volume ratio :-

The ratio of longer volume to lesser volume during any process inside an I-c engine is defined as the volume ratio of that Process. the volume ratio during compression is known as compression ratio. compression ratio remains same for all the cycles of I-c engines.

The volume ratio during the expanssion Process is known as expanssion ratio & is different for different cycle of I-c engine.

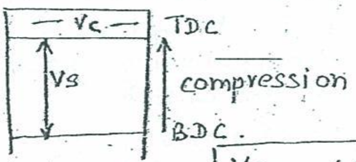
⇒ The compression ratio is :-

$$r = \frac{V_1}{V_2}$$

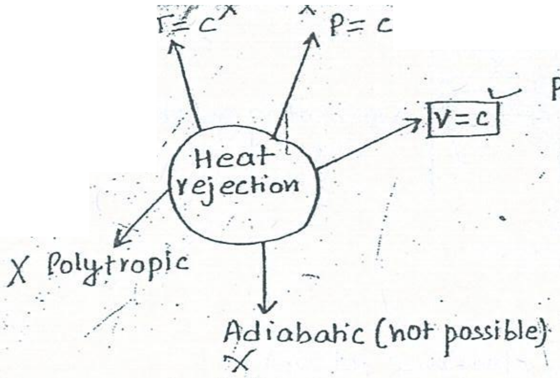
$V_2 = V_c$ — 2.

$$r = \frac{V_c + V_s}{V_c}$$

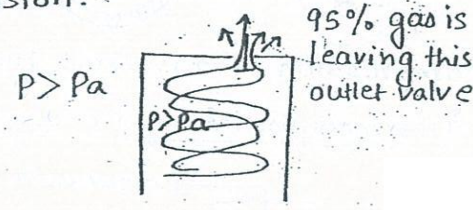
$V_1 = (V_c + V_s)$ — 1.

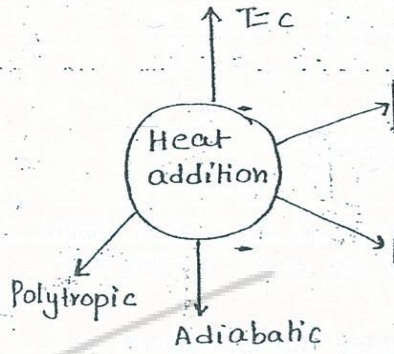


or, $r = 1 + \frac{V_s}{V_c} \Rightarrow \frac{V_s}{V_c} = (r - 1)$ **

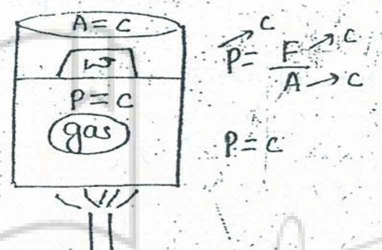


Piston is change its direction inside the cylinder during expanssion is over, then piston is at BDC piston.

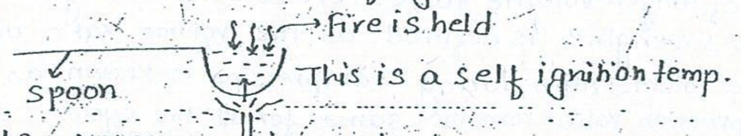




Same as for heat rejection.



- For any fuel is to be burn then it is should be at Flash point temp.
- Fire point temp – minimum temp so fuel to be burn at the burner.
- spark plug is behaves like a burner.
- Fire point temp to Flash point temp then spark plug is takes place continously.
- compression ratio in petrol engine is less (6 to 8). in comparision to that of diesel engine (and it is 15 to 16).
- No need of Burner in diesel engine so it is not have any spark plug required.
- Temp is very high in diesel engine so that the fuel is automatically burned & this process is called a self ignition temp.



— Diesel cycle → pressure is constant
— Nicolus August otto → Gives at a constant volume

Due to engine limitations, heat rejection will take place at constant volume only for all the cycle of I-C engine.

Hence, the following operation are the same for all the ideal cycle of I-C engine.

— Isentropic exapansion.
— Isentropic compression.
— Heat rejection at const volume.

~~It is thus clear that different cycle~~ exist for I-C engines only due to different type of heat addition.

When heat addition takes place at const volume, the cycle is known as the constant volume cycle or the otto cycle.

When heat addition takes place at const pr. the cycle is known as the const pr cycle (or) the "diesel cycle"

In other cycle the heat addition takes place first at const volume & then at const pressure, such a cycle is known as Dual combustion cycle (or) semi-diesel cycle.

For IC engines heat rejection can take place at constant volume only for all the cycle.

Hence, the following operations are common for all the ideal cycles for IC engines:-

I. Isentropic expansion
II. Heat rejection at const volume.
III. Isentropic compression

It is thus clear that it is only the heat addition that will be different for different ideal cycle for IC engines.

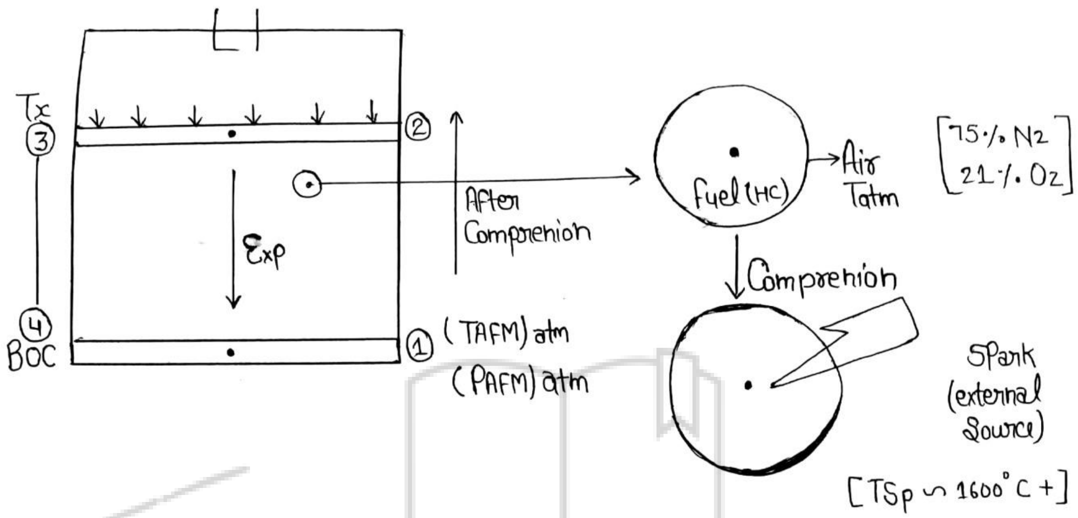
- When heat addition takes place at constant volume the cycle is known as the constant volume cycle (or) otto cycle.
- When heat addition takes place at constant pressure the cycle is known as a constant pressure cycle (or) Diesel cycle.
- In another cycle heat addition takes place 1st at const volume & then at constant pressure such a cycle is known as the dual combustion cycle or the semi diesel cycle.

CI
↓
Strong
↓
Heavy
↓
Mass ↑
↓
Inertia ↑
↓
(Milleage ↓)$_{least}$

SI
↓
Heavy ↓
↓
Milleage ↑

Al- Alloy
↓
(Milleage)$_{max}$

Otto Cycle: [constant volume heat addition cycle air standard cycle for petrol engine]

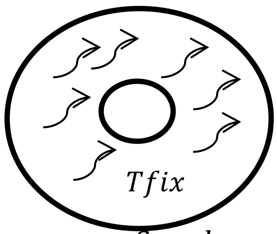


(1) Air is working fluid

(2) Air is perfect gas treated as ideal gas $[Pv = RT]$ $TAFM >> Tatm$

$C_p > C_v \& r = constant$

$Tflash$



$$CH_4 + 2\left[O_2 + \frac{79}{21}N_2\right] \xrightarrow{Spank} CO_2 + 2H_2O + 2 \times \frac{79}{21}N_2 + \Delta H + \Delta C$$

The const volume cycle or the otto cycle :-

1. The adiabatic compression process (1-2) →
   - volume ↓, Pressure ↑, S = const, Tempt ↑
2. The constant volume heat addition (2-3) →
   - volume = const, Pressure ↑, temp ↑, s ↑

charles law,

$$\frac{P_2}{P_1} = \frac{T_2}{T_1} \quad \left\{ \text{when volume is const} \right.$$

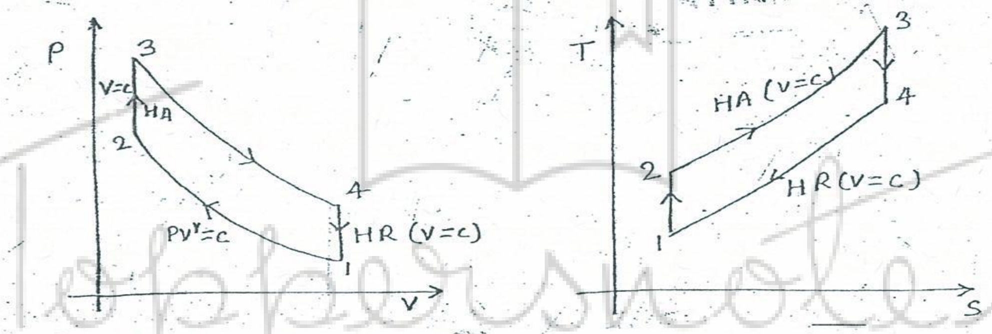
entropy :-

$$ds = c_v m dT$$

$$ds = mc_v \log_e \frac{T_2}{T_1}$$

$$+(S_2 - S_1) = mc_v \log_e \frac{T_2}{T_1}$$

3. The adiabatic expansion process (3-4) →
   - volume ↑, Pressure ↓, Tempt ↓, S = const
4. The heat rejection at constant volume (4-1) →
   - Volume = const, Pressure ↓, Temp ↓, S ↓



Efficiency of the cycle :-

$$\eta_v = \frac{WD}{HA} = \frac{HA - HR}{HA} = 1 - \frac{HR}{HA}$$

$$\eta_v = 1 - \frac{mc_v(T_4 - T_1)}{mc_v(T_3 - T_2)}$$

$$HR = -dQ = -(T_1 - T_4) = (T_4 - T_1)$$

$\frac{V_1}{V_2} = r$, the compression ratio.

The expansion ratio $\frac{V_4}{V_3} = \frac{V_1}{V_2} = r$, only for this cycle.

$$\Rightarrow \frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \quad \text{— (b)}$$

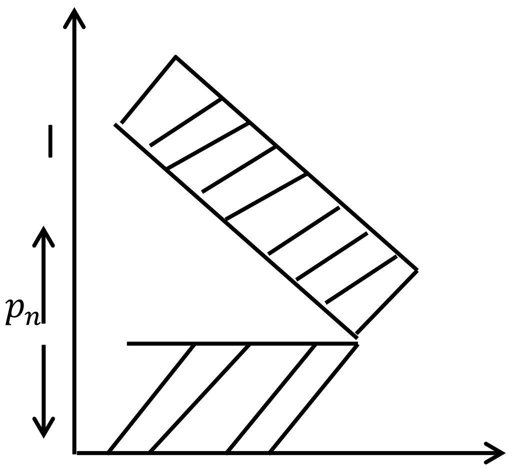
$$\Rightarrow \frac{T_1}{T_2} = \left(\frac{V_2}{V_1}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} \quad \text{— (c)}$$

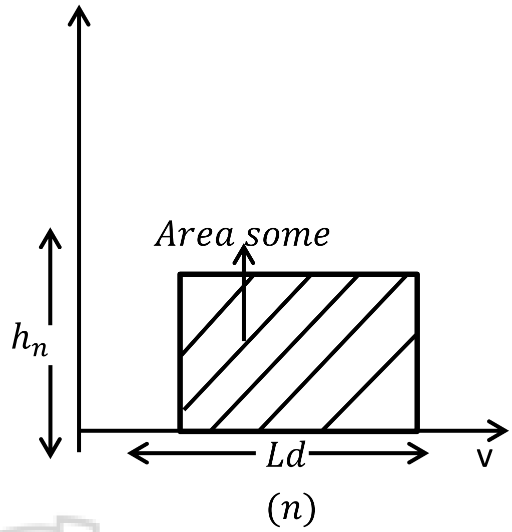
$$\boxed{\left(\frac{1}{r}\right)^{\gamma-1} = \frac{T_4}{T_3} = \frac{T_4}{T_3}}$$

$$\left(\frac{1}{r}\right)^{\gamma-1} = \frac{T_4}{T_3} = \frac{T_1}{T_2} = \frac{T_4 - T_1}{T_3 - T_2} \quad \text{— (d)}$$

$$\therefore \eta_v = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \quad \text{— *}$$

Mean effective Pressure :-





Mean Effective pressure :- It is a mathematical to determine an imaginary pressure which will gives us the mean work done like the work done of the actual cycle for the same change in volume (Swept volume)

GATE 2004:-

Sq. Engine ⇒ $\frac{L}{D} = 1:1$

Ques. Sq. engine ⇒ $\frac{L}{D} = 1.5$

An engine working on Otto cycle and bore 10cm and stroke is of 15m with the clearance volume of 196.3cm and the adiabatic index of the air is 1.4. The heat added is 1800KJ/Kg

(i) Find the work done per kg

(ii) Determine the mean effective pressure of the cycle 0.001 kg of the working fuel

Solution:-

$D = 10cm$

$L = 15cm$

$Vc = 196.3cm^3$

$r = 1.4$

$Q = \frac{1800KJ}{Kg}$

$W = ?$

$Pn = ?$

$Vs = \frac{\Delta}{u} l^2 L = 1178.09 cm^3$

$C = \frac{Vc}{Vs} = 0.167$

$\pi = 7602$

$\int = 1 - \left(\frac{1}{1\pi}\right)^{r-1} = \frac{(W)^{-?9z6.5kg.}}{\underset{1800}{HA}} = 59.09\%$

$(WO)_{net} = 973.5\ 1g./1g.$

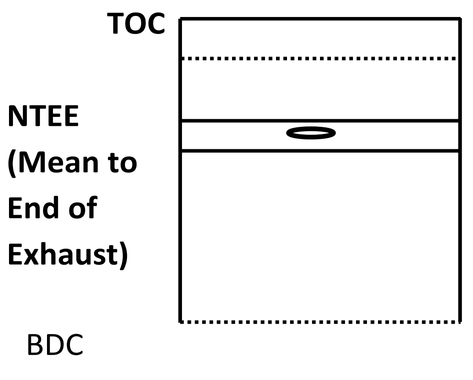
$(WO)_{net} = P_m \times V_s$

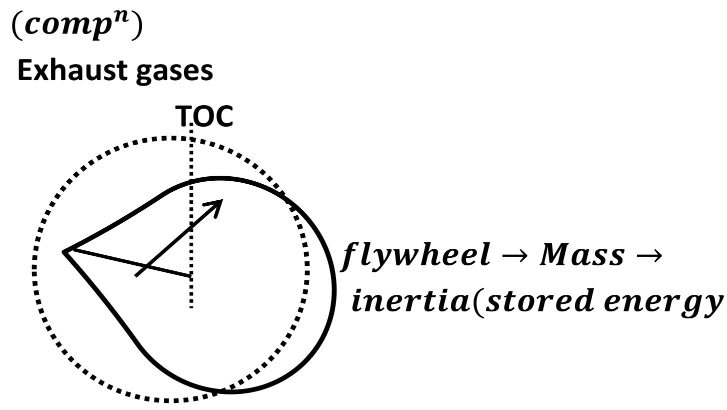
$973.5 = P_m \times 1178.09.$

$P_n = 0.826\ KPa$

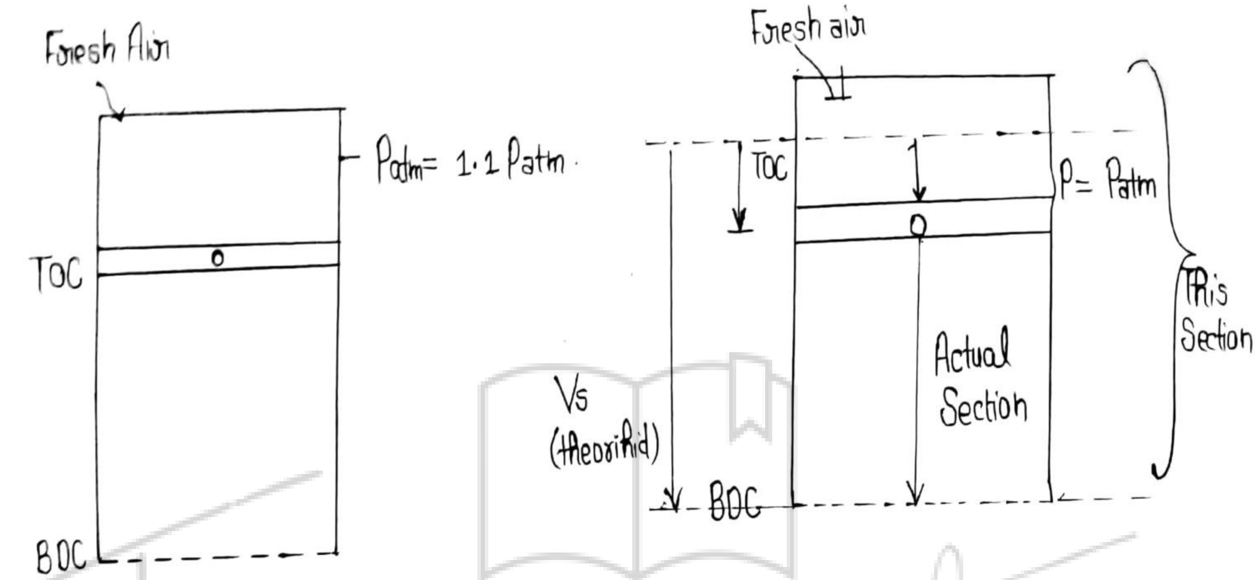
$\boxed{P_n = 0.08\ bar}$

<u>End of Exhaust and beginning of section</u> :-





→ Due to the piston movement during the exhaust stroke (at the very near of exhaust) The exhaust value is closed then due to the compression of exhaust gas, the pressure inside the cylinder will increased



$$\eta_{II} = \frac{A}{T} = \frac{V_a}{V_s} = \eta_{Vol.}$$

$$V_s = \frac{\pi}{4} O^2 L$$

$$P_1 V_a = m_a R T_1$$

→ Hence at the beginning of the section stroke as the inlet value is open but still No entry of the fresh air AFM into the cylinder (From inside the cylinder is above ATM) $[P_m > P_{atm}]$ @ $[TDC\ to\ a]$

→ Due to the expansion of compression exhaust gas its pressure lowers down and reaches to Patm.

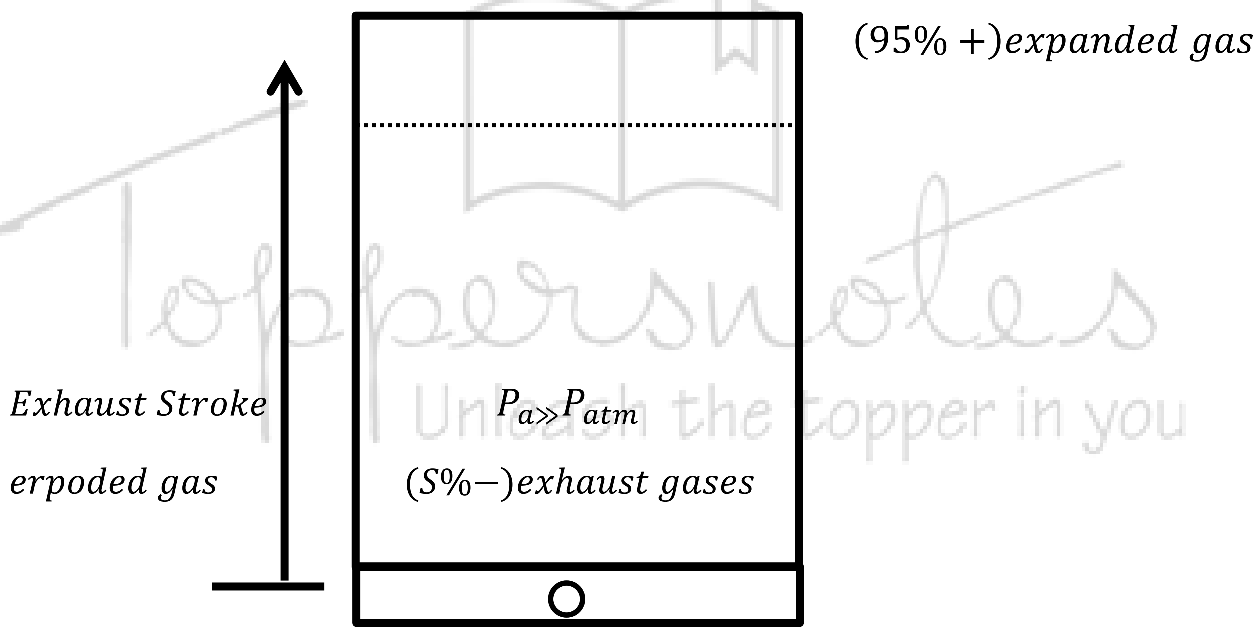
[Then after fresh AFM start entering]

<u>Volumetric efficiency: -</u> (Explained Above)

It is the ratio of actual section volume of air that actually entering into the cylinder during section strike to the theoretical section volume

$$\eta_{II} = \frac{A}{T} = \frac{V_a}{V_s} = \eta_{vol.}$$

<u>NOTE</u>: - {exhaust stroke} "Scavenging"



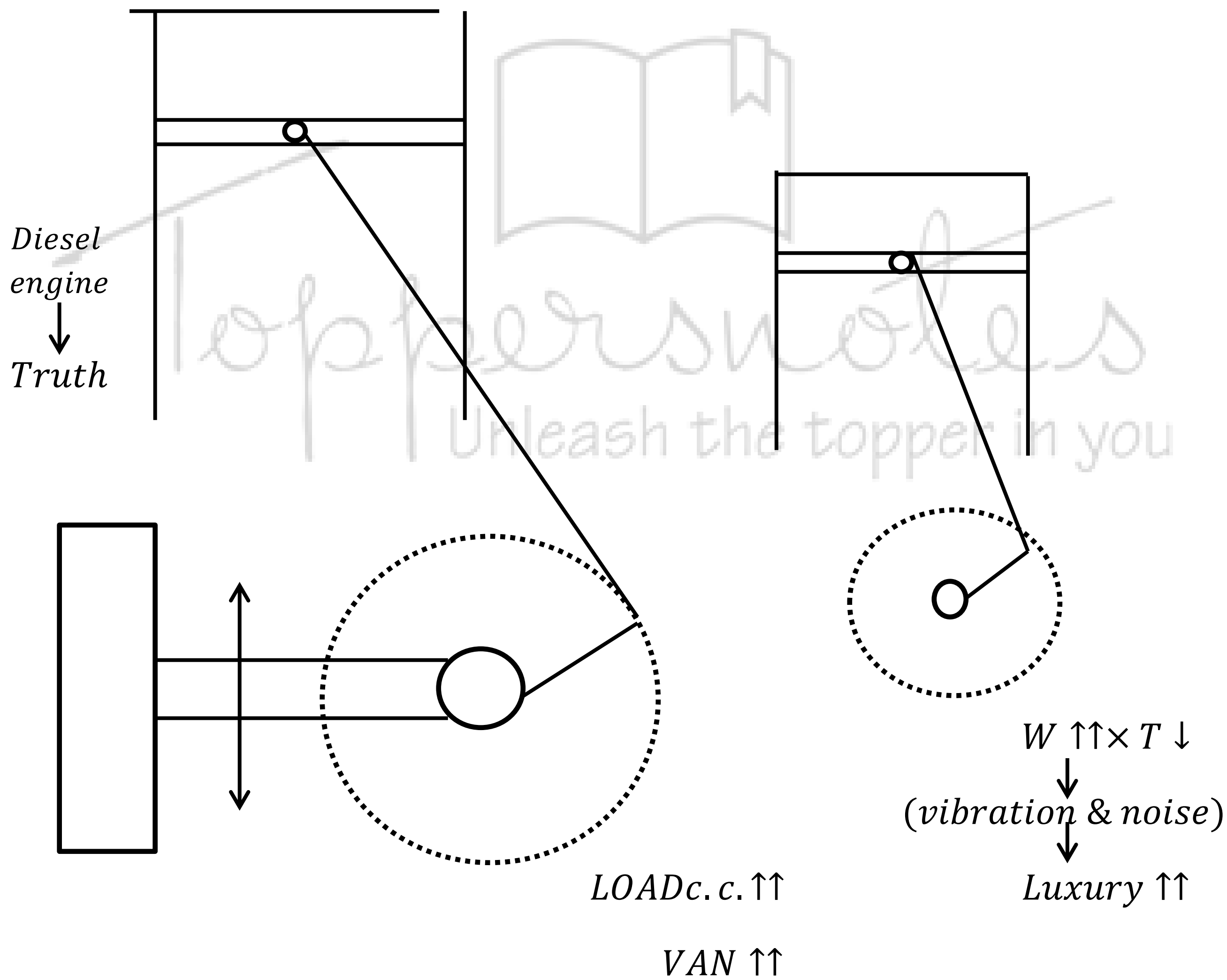
(2) # **"Diesel cycle"** or Cost perm Heat addition cycle:-

$T_{20} = 619k$ (Spark plug)

$\pi_o \rightarrow \overset{6}{\leftarrow} \; to \; 12$

$\pi_d \rightarrow 16 \; to \; \overset{22}{\rightarrow}$

$T_{20} = 1033k \; (> T_{scy19.})$



NOTE: $\boldsymbol{IES \; (Tself \; ign.) diesel < (Tself \; ign.)_{petrol}}$