HANDWRITTEN NOTES OF

(IC ENGINE)

BY

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Cycle :-

When a System after undergoing a number of Process is ablle to attain its original Conditions, it is then to have Completed a Cycle.

If a Cycle is not Completed, then Continous Work Will not be Obtained.

The Following are the Requirments of a Cycle :-

Heat added, Heat Rejected, Workdone (expansion), 2 Compression.

The order in Which, the different operations, Should takes place are,

Heat Added, ~~W~~

Workdone (expansion)

Heat Rejection

Compression

Ideal Cycle :-

An ideal Cycle is the cycle in Which the expansion and Compression takes place isentropically (Reversibly Adiabatic).

Reversible and Irreversible process :-

When a System undergoes a path in Such a manner, then it is able to attain the original Conditions, When following the same path in the reverse direction, then it is then Said to have undergone a Reversible Process.

On the other hand, When the System is not able to attains its original Conditions, When following the reverse path, then it said to have undergone an irreversible Process.

When the System is able to attain its original Conditions along a different path, then the process is still irreversible.

The Difference between a reversible & an irreversible process is the, Process is process, Without & With friction.

Reversible → Without friction

IRReversible → With friction

A Reversible process is theoritical.

Irreversible process is Actual.

Reversible Cycle :-

1) InTernally Reversible Cycle :-

$du = 0$

$mC_v(T_2 - T_1) = 0$

$(T_2 - T_1) = \frac{0}{mC_v} = 0$

$T_2 = T_1$

→ Expansion and Compression must be an adiabatic process.

→ The Heat addition and Rejection must takes place at Constant Temperature.

Externally Reversible Cycle :-

→ Expansion and Compression must be Reversibly adiabatic.

→ The equation "(HA − HR) = WD" Should be Completly Satisfied.

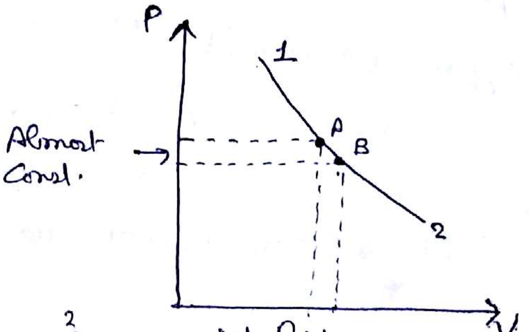
→ Only Carnot Cycle is externally & Internally Reversible.

All other Cycles are only externally Reversible.

Hence, Carnot Cycle alone is Completly Reversible.

Quasi-Static Process :-

When a System undergoes a process in Such a manner then the final Condition is nearest to the original or equilibrium Condition. The process is then Said to be a Quasi Static process.



$\int dW = \int_1^2 P\,dv$

$W = PV$

A Quasi Static process is same as, differentially small change in Calculus.

→ A Quasi Static process is applied, when a Quantity must Remain Constant, but is Varying for any Application.

→ A Quasi Static process can be used for only a Reversible process.

→ Quasi Static process is only theoritical

Enthalpy :

Property :-

Properties of System are those quantities which Belongs to the System and without which System cannot exist.

"Thus, Pressure, volume, Temperature are, the fundamental properties of System."

It is to be noted that, heat transfer and Work done are not the properties of the System.

→ Enthalpy of the System is defined as the total Energy present in a System, due to its properties.

→ In thermodynamics, enthalpy (Also Known as total Heat) is given by,

$$\boxed{H = U + PV}$$ Imp

or

$$H = mC_vT + mRT$$

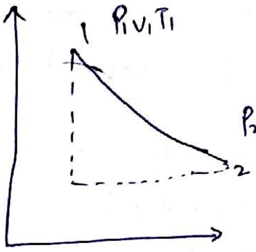
$$H = mC_vT + m(C_p - C_v)T$$

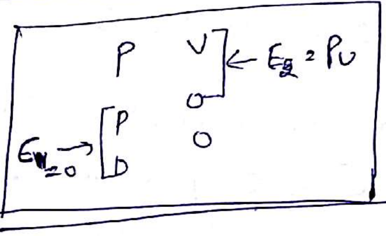
Imp $\boxed{H = mC_pT}$ only for Ideal Gases only

Change in enthalpy $\boxed{dH = mC_p dT}$

$$\boxed{H = U + PV}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$





$$H = U + PV$$
$$= mC_vT + mRT$$
$$= mC_vT + m(C_p - C_v)T$$
$$= \boxed{H = mC_pT}$$
$$\boxed{dH = mC_p dT}$$

Absolute → Something which starts from zero 0.

Mayer's equa^n

$$R = C_p - C_v$$

Ideal Cycles for I.C Engines :-

→ The following are requirements for Ideal Cycles of I.C. Engines.

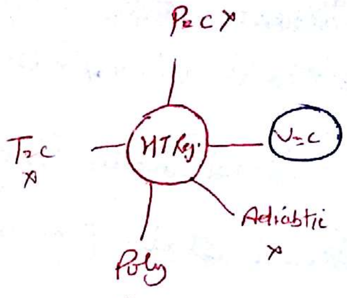
i) Expansion & Compression are Reversibly Adiabatic (Isentropic Process).

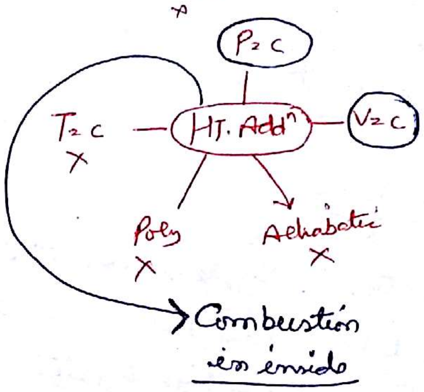
→ Heat Rejection Takes place at Constant volume only.

→ Thus it is the Heat Addition, that will be different for different cycles. either at P=C or V=C

→ When Heat Addition Takes Place at Constant volume, the cycle is called as Otto cycle or Constant volume Cycle.

Heat Rejection at Constant volume





→ When Heat addition takes place at Constant pressure, the cycle is Known as Constant pressure cycle or diesel cycle.

→ In another Cycle, Heat addition takes place, first and at Constant volume and then at Const. Pressure. Such a cycle is called as Dual Combustion Cycle or Semi diesel Cycle.

Heat Rejection → at Constant volume

Heat addition → at either Constant volume / Constant pressure.

Heat Addition at → Constant volume → Otto cycle

Heat Addition at → Constant Pressure → Diesel cycle

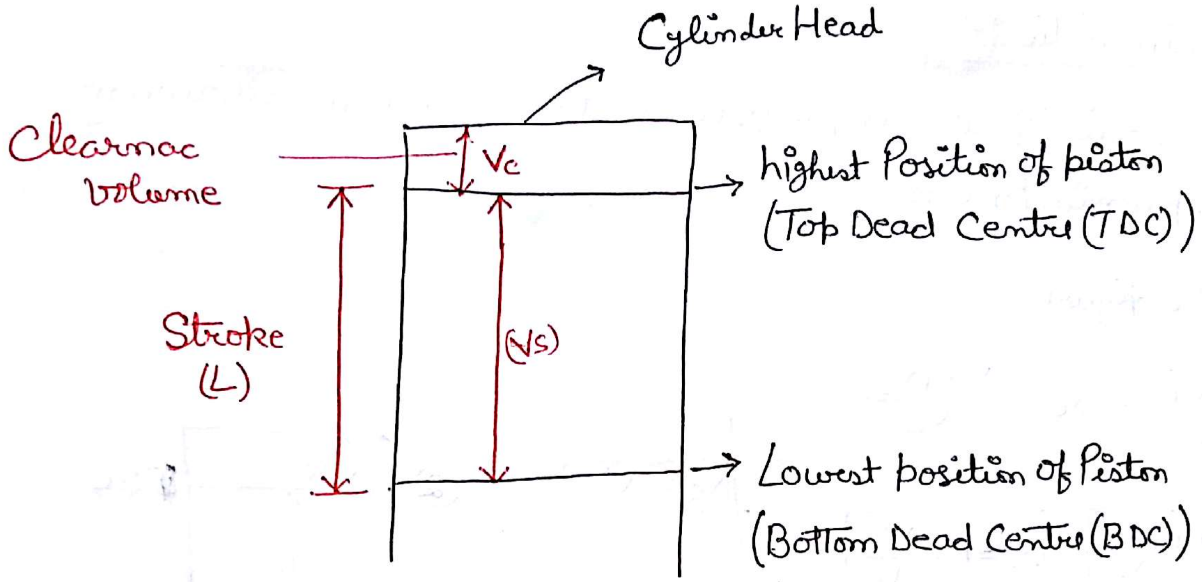
Heat Addition at → first Constant volume then

$\downarrow$

Constant pressure

$\downarrow$

Semi diesel cycle (Dual Combustion)



Clearnac volume :- (Vc)

It is the Space occupied between cylinder head and TDC.

Stroke Volume :- (Vs)

It is the volume Covered by the piston for one stroke.
Stroke volume is also Known as Swept volume.

Clearnac Ratio :- (C)

It is a Ratio of the Clearnac volume to Stroke volume of engine and is given by

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

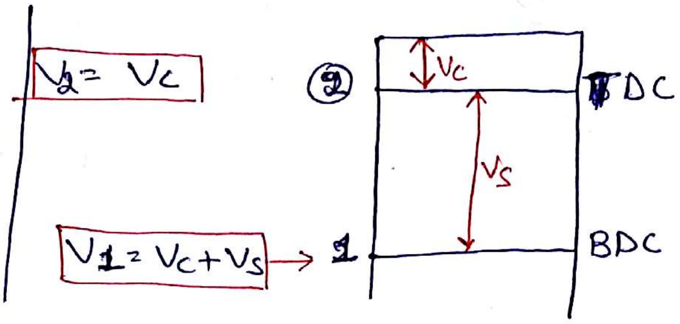
Compression Ratio :-

It is the ratio of a larger volume to Lesser volume during the Compression process.

From the figure

$$r = \frac{V_1}{V_2} \Rightarrow r = \frac{V_c+V_s}{V_c}$$

$$\boxed{r = 1 + \frac{V_s}{V_c}} \quad \boxed{r - 1 = \frac{V_s}{V_c}}$$



Compression Ratio is same for All the I C engines

Expansion Ratio :-

→ It is ratio of larger volume to lesser volume during expansion.

→ Expansion Ratio is different for different Cycle.

→ In general the $\boxed{\text{volume ratio} = \frac{\text{large volume}}{\text{Less volume}}}$

Relation between P&T and V&T for An Adiabatic process:-

For Adiabatic → $\boxed{PV^\gamma = C}$

$$\Rightarrow \quad P_1 V_1^\gamma = P_2 V_2^\gamma \quad — ①$$

or

$$\Rightarrow \quad \left(\frac{P_2}{P_1}\right) = \left(\frac{V_1}{V_2}\right)^\gamma \quad — (1a)$$

$$\Rightarrow \quad \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad — ②$$ from $(PV = mRT)$

$$\Rightarrow \quad \frac{P_2}{P_1} = \frac{T_2}{T_1} \times \left(\frac{V_1}{V_2}\right) \quad — (2a)$$

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

$$\rightarrow \quad \boxed{\left(\frac{V_1}{V_2}\right)^{\gamma-1} = \frac{T_2}{T_1}} \quad — ③$$

from 1a

$$\rightarrow \quad \boxed{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_2}{T_1}} \quad — ④$$

Working of Constant volume Cycle or Otto cycle :-

1) The Adiabatic Compresion (1-2) (volume decreases, Presssure ↑)

(Volume (V) ↓, Presure (P) ↑, entropy (S) = Const)

$\boxed{V\downarrow, P\uparrow, S=C}$

2) The Constant volume Heat Addition Process (2-3)

(V=C, P↑, T↑, S↑)

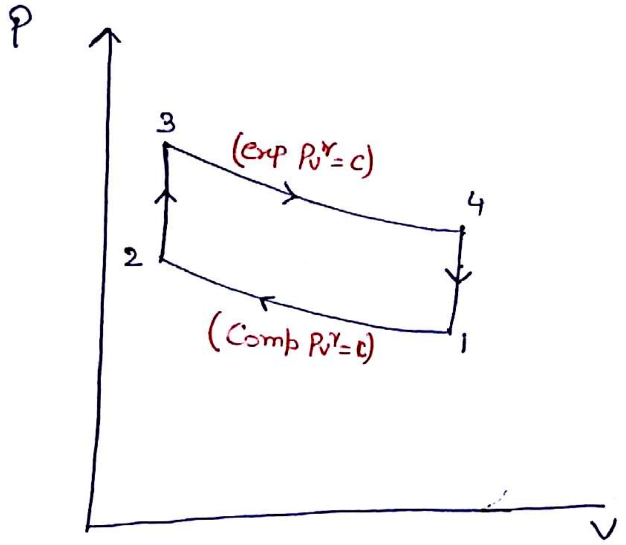
[Volume (V) = Const., Pressure (P) ↑, Temp. (T) ↑, entropy (S) ↑]

3) The Adiabatic Expansion Process (3-4)

(V ↑, P ↓, T ↓, S = Constant)

4) Constant volume Heat Rejection Process :- (4-1)

(V = Constant, P ↓, T ↓, S ↓)



Slope 1-2 ≠ 3-4

bcz, if Slope (1-2) = (3-4)

then HA = HR

& We know that

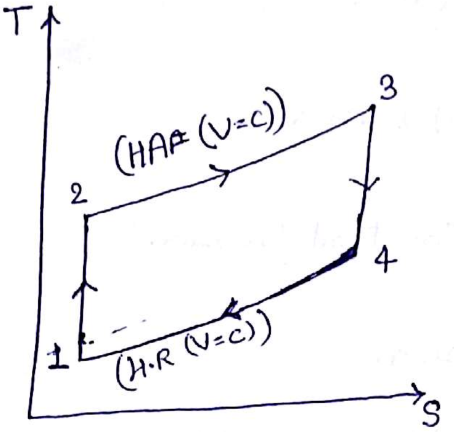
WD = HA − HR

$\boxed{WD = 0}$

Otto Cycle (P-V Dia)

or

Constant volume cycl



T-S Diagram Otto Cycle

Efficiency :-

$$\eta_v = \frac{HA-HR}{HA} \quad \text{i.e} \quad \frac{WD}{HA}$$

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

$$\eta_v = 1 - \frac{\cancel{m}C_v(T_4-T_1)}{\cancel{m}C_v(T_3-T_2)}$$

Efficiency of Otto Cycle, $\boxed{\eta_v = 1 - \left(\frac{1}{r}\right)^{\gamma-1}}$

↳ from eqn D Below

$r = \frac{V_1}{V_2}$, the Compression Ratio, And

Expansion Ratio, is,

$$\frac{V_4}{V_3} = \frac{V_1}{V_2} = r \Rightarrow \frac{V_3}{V_4} = \frac{V_2}{V_1} = \frac{1}{r}$$

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

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

therefore, $\left(\frac{1}{r}\right)^{\gamma-1} = \frac{T_4}{T_3} = \frac{T_1}{T_2}$

(D) ← $\left(\frac{1}{r}\right)^{\gamma-1} = \frac{T_4-T_1}{T_3-T_2}$ (from Algebric)

$$\frac{a}{b} = \frac{c}{d} = \frac{a-c}{b-d}$$

$$\frac{8}{4} = \frac{5}{2.5} = \frac{8-5}{4-2.5}$$

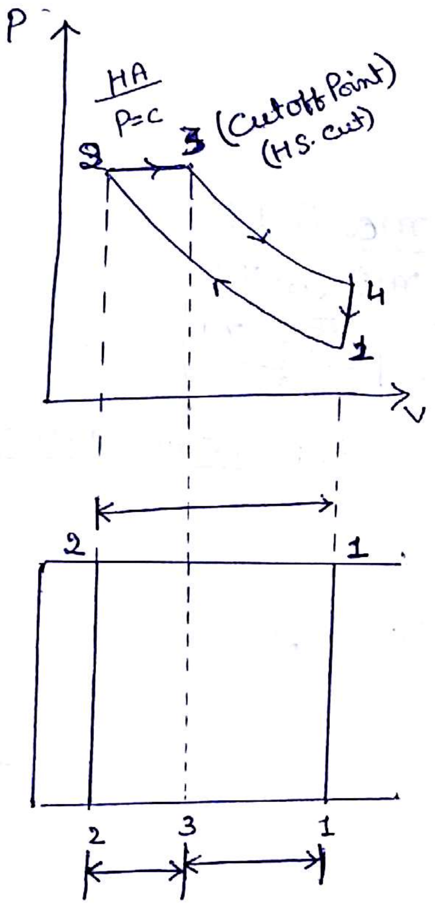
Constant Pressure Cycle or Diesel Cycle :-

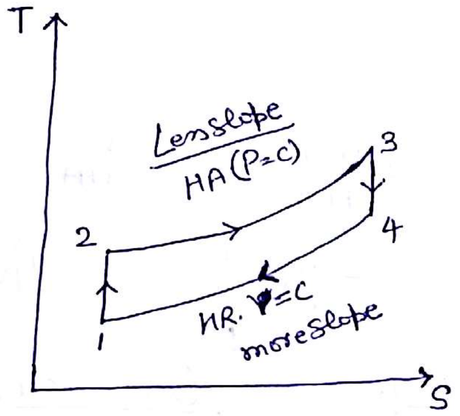
(1) (1-2) Adiabatic Compression.

(2) (2-3) Heat Added at Constant Pressure.

(3) (3-4) Adiabatic Expansion.

(4) (4-1) Constant volume Heat Rejection.





Let, $\frac{V_1}{V_2} = r$, the Compression Ratio.

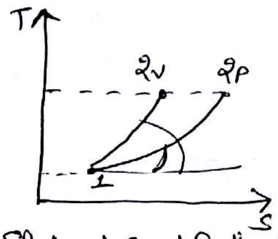
& $\frac{V_3}{V_2} = \rho$, the cut off Ratio

$$\boxed{\text{The Expansion Ratio} = \frac{V_4}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_3} = \frac{r}{\rho}}$$

$ds_p = m\,C_p \log_e \frac{T_2}{T_1}$

$ds_v = m\,C_v \log_e \frac{T_2}{T_1}$

if we take mass & Temp Same for both two, change in entropy at Const Pressure will be high.



Slope at Const P. is low than slope at Const Vol.

Slope at Const V. is high

Slope at Const P is Less.

(1-2) $$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\frac{T_2}{T_1} = (\gamma)^{\gamma-1} \Rightarrow T_2 = T_1 \times (\gamma)^{\gamma-1} \quad \text{—①}$$

(2-3)

$\boxed{\because P=C}$

$$T_3 = T_2 \frac{V_3}{V_2} \Rightarrow T_3 = T_1 (r^{\gamma-1}) \rho$$

$$\frac{T_3}{T_2} = \frac{V_3}{V_2} \Rightarrow T_3 = T_1 \times (r)^{\gamma-1} \times \rho \quad \text{—②}$$

(3-4) $$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = T_4 = T_1 r^{\gamma-1} \rho \times \left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$\downarrow\ T_4 = T_1 \cancel{r^{\gamma-1}} \rho^1 \frac{\rho^{\gamma-1}}{\cancel{r^{\gamma-1}}}$$

$$T_4 = T_1 \rho^{\gamma} \quad \text{—③}$$

Efficiency of the Cycle is,

$$\eta_\rho = 1 - \frac{HR}{HA} \Rightarrow \eta_\rho = 1 - \frac{m c_v (T_4 - T_1)}{m c_p (T_3 - T_2)}$$

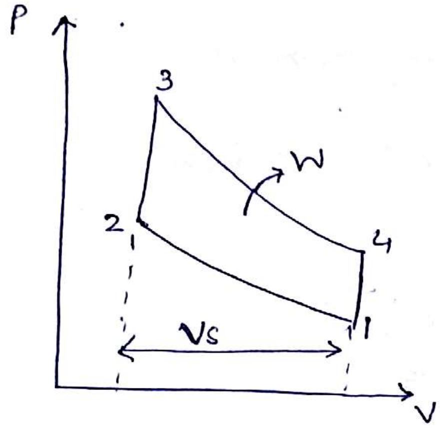
$$\eta_\rho = 1 - \frac{1}{r}\left(\frac{T_1 \rho^{\gamma} - T_1}{T_1 r^{\gamma-1}\rho - T_1 r^{\gamma-1}}\right)$$

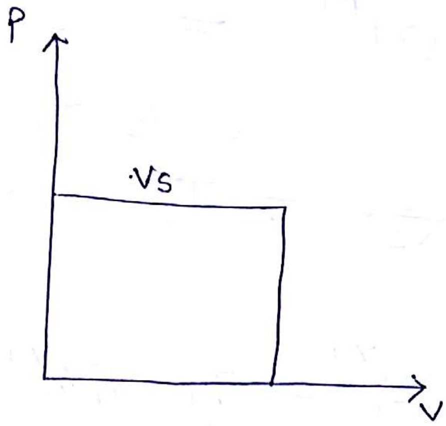
$$\boxed{\eta_\rho = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}}$$

most important

Gate & I.E.S

Mean Effective Pressure (P_m or meP) :-





vol.	Mean P.
Min 65	70
71	70
Max 74	70
210	210

W = 210 P_m = 70

~~VD = Bm~~

210 = 70 × 3

$W_D = P_m \times V_s$

When We Consider an imaginary Pressure, in such a manner then, if it Remains Constant and gives us the Same Workdone for the Same Change in volume, like that of an actual Cycle. Then the imaginary Pressure is Known as the mean effective Pressure of Cycle.

The Workdone by taking the mean effective pressure into account is given by,

$$\boxed{W = P_m \times V_s}$$

Important term

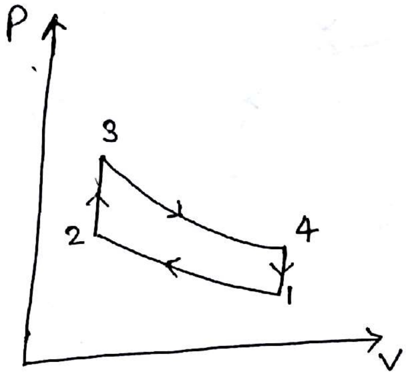
i.e Workdone = meP × Swept volume

Qn) For the Diagram shown,

Prove that the meP is given by

$$\boxed{P_m = \frac{\eta_v}{(\gamma-1)(r-1)} \times \Delta P}$$

where $\Delta P = (P_3 - P_2)$



Soln)

$$\eta_v = \frac{WD}{HA} \Rightarrow \frac{P_m \times V_s}{m C_v (T_3 - T_2)}$$

& $PV = mRT$

$$mT = \frac{PV}{R}$$

$$\boxed{R \rightarrow C_p - C_v}$$

$$mT = \frac{PV}{C_p - C_v}$$

$$\eta_v = \frac{P_m V_s}{C_v\left(\frac{P_3V_3 - P_2V_2}{C_p - C_v}\right)} \leftarrow V_3 = V_2 = V_c$$

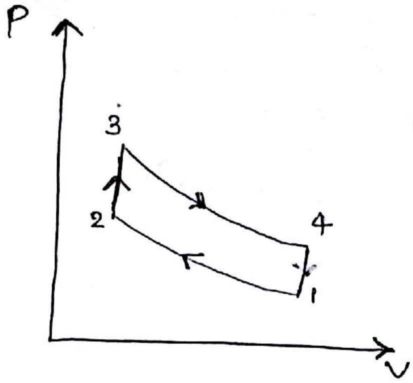
$$= \frac{P_m V_s (C_p - C_v)}{V_c (P_3 - P_2) C_v} = \frac{P_m (r-1)(\gamma-1)}{\Delta P}$$

$\rightarrow \frac{V_s}{V_c} = (r-1)$

$\rightarrow \frac{C_p}{C_v} = \gamma$

$$P_m = \frac{\eta_v}{(\gamma-1)(\gamma-1)} \times \Delta P$$

Qn 12) For the Cycle Shown,



Show that,

$$T_2 = T_4 = \sqrt{T_1 T_3}$$

for Maximum Workdone,

Soln

$$WD = HA - HR$$

$$WD = m C_v \left[(T_3 - T_2) - (T_4 - T_1) \right]$$

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

$$\text{Also} \quad \frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} = \left(\frac{1}{r}\right)^{\gamma-1} = r^{-\gamma+1} \qquad T_4 = T_3 r^{-\gamma+1}$$

$$\therefore WD = m C_v \left[(T_3 - T_1 r^{\gamma-1}) - T_3 \times r^{-\gamma+1} - T_1) \right]$$

$$\therefore \text{For max. Workdone,} \quad \frac{d(WD)}{d(r)} = 0$$

On diffrintiating,

$$\therefore -T_1 (\gamma-1) r^{(\gamma-1)-1} - T_3 (-\gamma+1) r^{(-\gamma+1)-1} = 0$$

$$\text{Or} \quad -T_1 (\gamma-1) r^{\gamma-2} = T_3 (-\gamma+1) r^{-\gamma}$$

~~$-(\gamma-1) r^{\gamma-2} \times r^{\gamma} = -(\gamma-1)\frac{T_3}{T_1}$~~

$$\left(r^{\gamma-1}\right)^2 = \frac{T_3}{T_1} \quad \text{or} \quad \left(\frac{T_2}{T_1}\right)^2 = \frac{T_3}{T_1}$$

from 1

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} = r^{\gamma-1}$$

Therefore,

$$T_2 = \sqrt{T_1 T_3} \leftarrow \left(\frac{T_2}{T_1}\right)^2 = \frac{T_3}{T_1} \Rightarrow T_2^2 = \frac{T_3 \times T_1^{\cancel{2}}}{\cancel{T_1}}$$

$$T_2 = \sqrt{T_3 T_1}$$

Or,

$$\left(\frac{T_3}{T_4}\right)^2 = \frac{T_3}{T_1} \Rightarrow (T_3)^2 = \frac{T_3 \times T_1^{\cancel{2}}}{\cancel{T_1}} \qquad T_4 = T_1$$

$$T_3 = \sqrt{T_3 T_1}$$

$\therefore T_4 = \sqrt{T_1 T_3}$

$\therefore T_4 = T_2 = \sqrt{T_1 T_3}$

Hence proved.

Qn) The Compression Ratio of an Otto cycle is 7. The initial value of ratio of Specific heat is 1.4. Find the Percentage decrease in efficiency of the cycle, when the Specific heat at Constant volume increase by 1%.

Soln) $C_{V2} = 1.01\, C_{V1}$

$$\gamma_1 = \frac{C_{P1}}{C_{V1}} = 1.4 \Rightarrow C_{P1} = 1.4\, C_{V1}$$

$$(C_{P1} - C_{V1}) = R = (C_{P2} - C_{V2})$$

or $(1.4\, C_{V1} - C_{V1}) = C_{P2} - 1.01\, \underline{C_{V1}}$

its Already 100% & then 1% increased so it is 1.01

$$C_{P2} = 1.41\, C_{V1}$$

$$\therefore \gamma_2 = \frac{C_{P2}}{C_{V2}} = \frac{1.41\, C_{V1}}{1.01\, C_{V1}} = 1.396$$

$$\eta_1 = 1 - \left(\frac{1}{r}\right)^{\gamma_1 - 1} = 1 - \left(\frac{1}{7}\right)^{1.4-1} = 0.5407$$

$$\eta_2 = 1 - \left(\frac{1}{r}\right)^{\gamma_2 - 1} = 1 - \left(\frac{1}{7}\right)^{1.396-1} = 0.5372$$

Therfore % decrease in effeciency

$$\% \downarrow \eta = \frac{0.05407 - 0.5372}{0.5407} \times 100\%$$

$$\boxed{\eta = 10.4\%}$$

Qn) If the Workdone of diesel Cycle is increased, its efficiency Will

A) Increase

B) Remain Same

[✓ C) Decrease]

D) Any thing is Possible

Soln)

$$\eta_D = \frac{WD}{HA} = 1-\left(\frac{1}{r}\right)^{\gamma-1} \times \frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

$$\text{or} \downarrow \eta_D = \frac{W.D}{H.A} = \frac{r^{\gamma-1}\times \gamma(\rho-1) - (\rho^{\gamma}-1)\uparrow}{r^{\gamma-1}\times \gamma(\rho-1)\uparrow}$$

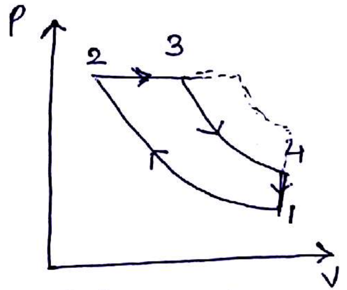
It may be seen from above equation, that, when the Workdone (Numerator) is increased then the (denominator) equal to Heat Added, will ↑ even more, as there is no negative term in the denominator.

Hence efficiency will only decrease.

Qn) A Compression Ratio of diesel Cycle is 14. Cut off changes from 5-15% of the stroke. Determine the Percentage decrease, in the efficiency of the Cycle?

Soln)

$$r = 14 = \frac{V_1}{V_2} = \frac{V_c+V_s}{V_c}$$



Diesel Cycle.

$$\therefore = V_s = 13V_c = 13V_2$$

$$V_3 - V_2 = \frac{5}{100}V_s$$

$$\text{or } V_3 = 0.05\times 13V_2 + V_2 = 1.65V_2$$

$$\rho = \frac{V_3}{V_2} = \frac{1.65V_2}{V_2}$$

$$\boxed{\rho = 1.65}$$

$$\eta_1 = 1-\left(\frac{1}{r}\right)^{\gamma-1}\frac{\rho^{\gamma}-1}{\gamma(\rho-1)} = 1-\left[\left(\frac{1}{14}\right)^{1.4-1}\times\frac{1.65^{1.4}-1}{1.4(1.65-1)}\right] = 0.6115$$

$$\boxed{\eta_1 = 0.6115}$$

When Cut off take place at 15% of the Stroke, then;

$$V_3' - V_2 = \frac{15}{100} V_s$$

$$V_3' = 0.15 \times 13 V_s + V_2 = 2.95 V_2$$

$$\rho' = \frac{V_3'}{V_2} = \frac{2.95 V_2}{V_2} = 2.95$$

~~$\eta_2 = 1 - e$~~ [illegible]

$$\eta_2 = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{(\rho')^{\gamma} - 1}{\gamma(\rho' - 1)}$$

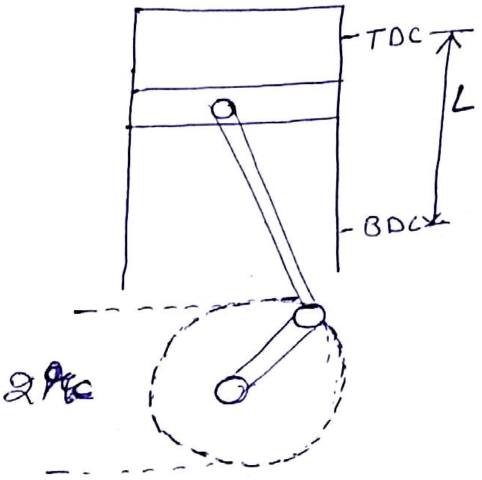
$$= 1 - \left(\frac{1}{14}\right)^{1.4-1} \times \frac{2.95^{1.4} - 1}{1.4(2.95 - 1)} = 0.5478$$

Percentage ↑ in efficiency is,

$$\uparrow \% \eta = \frac{0.6115 - 0.5478}{0.6115} \times 100\% = 10.4\%$$

Pg No 6 Workbook

Q21 The engine of the car has 3 cylinders of 68 mm bore & 37.5 mm Crank radius. The Compression Ratio is 8. The clearnac volume of each cylinder is ______ cm^3.



Soln) bore = d = 68 mm = 6.8 cm

r_c = 37.5 mm = 3.75 cm

r = 8 Vc = ?

$L = 2 r_c$

$= 2 \times 3.75$ cm

$= 7.5$ cm

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

Length of Stroke = $2 r_b$

this is because, for one rotation of Piston from TDC to BDC is Called L i.e Stroke

$L = 2 r_c$

r_c = Crank radius

$\frac{V_c + V_s}{V_c} = r = 8$

$V_s = 7V_c$

$V_c = \frac{V_s}{7}$

or $V_c = \frac{\frac{\pi}{4} d^2 \times L}{7}$

$= \frac{\pi}{4} \times \frac{6.8^2 \times 7.5}{7} cm^3$

therefore $\boxed{V_c = 38.9 cm^3}$ Ans

(Qn) 22) An oil engine Work on Diesel cycle, the Compression Ratio being 15. The temperature at the start of Compression is 17° C & 700 KJ of heat is Supplied at Constant pressure per Kg of air and it attains a temperature of 417°C at the end of adiabatic expansion. Take specific heat at Constant volume, $C_V = 0.717$ KJ/Kg-K and Ratio of Specific heat, $\gamma = 1.4$. The air Standard efficiency of the Cycle is ______ %

Soln)

$r = 15 = \frac{V_1}{V_2}$

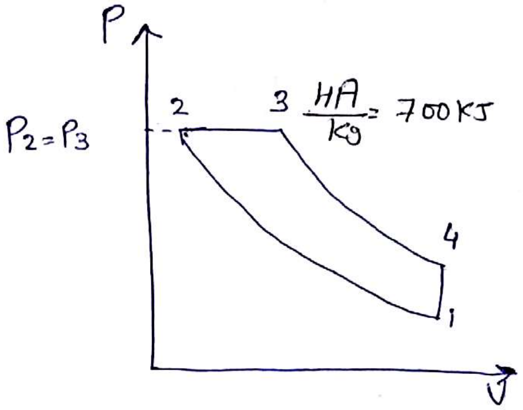
$T_1 = 17°C = 290\,K$

$T_4 = 417°C = 690\,K$

$C_V = 0.717\ KJ/kg\,K$

$\gamma = 1.4$

$\eta_P = ?$



[Without Heat Addition This Problem can be Solve]

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$$

$$\therefore\ T_2 = 290 \times 15^{1.4-1}$$

$$\boxed{T_2 = 856.7\,K.}$$

$$\&\ P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma}$$

$$P_2 = P_1 \times 15^{1.4}\ bar = P_3 \qquad \boxed{(P_2 = P_3)}$$

$$\frac{P_4}{P_1} = \frac{T_4}{T_1} \qquad \boxed{As\ V = C}$$

$$P_4 = P_1\,\frac{690}{290} \qquad P_4 = \frac{69}{29}P_1$$

$$(3\text{-}4)\quad \frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow T_3 = 690\left(\frac{\cancel{P_1} \times 15^{1.4}}{\frac{69}{29}\cancel{P_1}}\right)^{\frac{1.4-1}{1.4}}$$

$$\boxed{T_3 = 1591.1\,K}$$

Cutoff ratio $\rho = \frac{V_3}{V_2} = \frac{T_3}{T_2}$ ⟶ (from charles Law) $\boxed{P=C}$

$$\rho = \frac{V_3}{V_2} = \frac{T_3}{T_2} = \frac{1591.1}{856.7} = 1.85$$

$$\eta_\rho = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \times \frac{\rho^\gamma - 1}{\gamma(\rho-1)}$$

$$= 1 - \left(\frac{1}{15}\right)^{1.4-1} \times \frac{1.85^{1.4} - 1}{1.4(1.85-1)} = 0.607 \text{ or } 60.7\%$$

Qn 23) Air enters a diesel engine with density of 1.0 Kg/m³. The Compression Ratio is 21. At Steady State, the air intake is 30×10^{-3} Kg/s and the net Work output is 15 KW. The mean effective pressure (KPa) is ________.

(GATE 2015)

Soln)

$$d = 1\ \text{Kg/m}^3 = \frac{m_a}{Vol.\,a}$$

$r = 21$

$m_a = 30\times10^{-3}$ Kg/sec

$WD = 15$ KW

$P_m = ?$

Let us imagine that the volume of air entering the cylinder during Suction is equal to stroke volume.

$\boxed{\frac{N}{m} = Pa}$

$\left(\frac{J}{sec} = Watt\right)$

$$\therefore\ V_s = \frac{m_a}{d} = \frac{30\times10^{-3}}{1} = m^3/sec.$$

$$P_m = \frac{WD}{V_s}$$

$$P_m = \frac{15\times1000}{30\times10^{-3}}\ N/m^2 \text{ or Pascal}$$

$$= 500\times1000\ Pa$$

$\boxed{P_m = 500\ KPa}$ — mean effective pressure.

$$\boxed{P_m = 500\ KPa}$$

Qn24) Efficiency of an Otto cycle is 54%. The Compression begins at 1bar and 15°C. The max. Pressure is 75 bar. find heat added, Heat Rejected and workdone per kg. Estimate the Compression Ratio and mep of the Cycle.

($C_v = 0.71$ & $R = 0.29$ kJ/kgK)

Soln

$\eta_v = 0.54$

$P_1 = 1$ bar

$T_1 = 15°C = 288K$

$P_3 = P_{max} = 75$ bare

~~$C_v = 0.71$~~

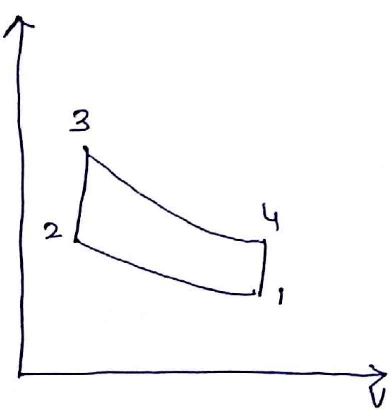
$C_v = 0.71$, $R = 0.29$] kJ/kg

$\frac{HA}{kg} = ?$

$\frac{HR}{kg} = ?$

$\frac{WD}{kg} = ?$

meP = ?



$C_p - C_v = R$ by Mayer's equation

$C_p = R + C_v$

$C_p = (0.29 + 0.71)$ kJ/kg $= 1$ kJ/kgK

$$\gamma = \frac{C_p}{C_v} = \frac{1}{0.71} = 1.408$$

$$\eta_v = 0.54 \quad \text{or} \quad 1 - \left(\frac{1}{r}\right)^{1.408-1} = 0.54$$

$$r = 6.7 = \frac{V_1}{V_2}$$

$$r = \frac{V_c + V_s}{V_c} = 6.7$$

$V_s = 5.7 V_c = 5.72 V_2$

$$V_1 = V_c + V_s = \frac{V_s}{5.7} + V_s$$

$\therefore V_s = 0.81 V_1$

$$\eta_V = \frac{WD}{HA}$$

$$HA - HR = WD$$

$$\boxed{HA = C_V(T_3 - T_2}$$

$$P_1V_1^\gamma = P_2V_2^\gamma$$

$$P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma = 1 \times 1.67^{1.408} \text{ bar}$$

$$\boxed{P_2 = 14.55 \text{ bar}}$$

$$\& \quad \frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1} \quad \therefore T_2 = 288 \times 6.7^{1.408-1}$$

$$\boxed{T_2 = 624.4 \text{ K}}$$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2}$$

$$\therefore T_3 = 624.4 \times \frac{.75}{14.55K} = 3218.5 \text{ K}$$

$$\uparrow$$

$$\boxed{\because (V = C)}$$

$$\therefore HA = C_v(T_3 - T_2) = 0.71(3218.5 - 624.5) \text{ KJ/kg}$$

$$HA = 1841.85 \text{ KJ/Kg}$$

$$\text{and} \quad WD = \eta_v \times HA = 0.54 \times 1841.85 \frac{KJ}{kg} = 994.5 \text{ KJ/kg}$$

$$HR = HA - WD = (1841.85 - 994.5) \text{ KJ/kg} = 847.4 \frac{KJ}{kg}.$$

Also, $P_1V_1 = mRT_1$ (for 1kg of Air)

$$V_1 = \frac{RT_1}{P_1} = \frac{290 \times 288}{1 \times 10^5} m^3 = 0.835 \; m^3/kg$$

$$\therefore V_s = 0.81V_1 \Rightarrow V_s = 0.81 \times 0.835 \; m^3/kg$$

$$V_s = 0.676 \; m^3/kg$$

$$P_m = \frac{WD}{V_s} = \frac{994.5 \times 1000}{0.676} N/m^2$$

Changin KW to Watt by mutliply 1000

$$P_m = 14 \times 10^5 \; N/m^2$$

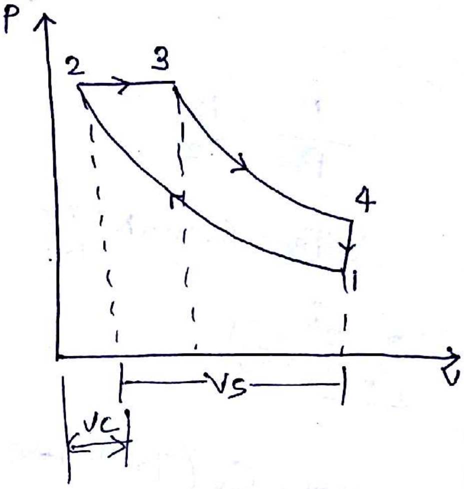
(Qn 25) A diesel engine has Stroke to bore Ratio 1.5:1. Cut off takes place 5% of Stroke. Estimate

i) Stroke and bore of the engine, if WD/cycle is 1500J.

ii) meP, if clearnac ratio is 10%. The pressure at the end of Suction may be taken as 1 bar.

iii) Efficiency of the Cycle.

$\frac{L}{d} = 1.5 \qquad d = ? \qquad L = ?$



$(V_3 - V_2) = \frac{5}{100} V_s$

$\frac{WD}{Cycle} = 1500J$

$(W_1 + W_2 + W_3) = 1500J$

$meP = ?$

$C = \frac{V_c}{V_s} = 0.1$

$\boxed{P_1 = 1 \text{ bar}}$

$V_c = 0.1\, V_s = V_2$

$V_1 = V_c + V_s = 0.1 V_s + V_s = 1.1\, V_s = V_4$

$V_3 = 0.05 V_s + 0.1 V_s = 0.15 V_s$

$r = \frac{V_1}{V_2} = \frac{1.1 V_s}{0.1 V_s} = 11$

$\rho = \frac{V_3}{V_2} = \frac{0.15 V_s}{0.1 V_s} = 1.5$

Imp must Remember.

& $P_1 V_1^\gamma = P_2 V_2^\gamma$ or $P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma$

$\boxed{P_2 = P_3}$

$\boxed{P_2 = 1 \times 11^{1.4} \text{ bar} = 28.7 \text{ bar} = P_3}$

$P_3 V_3^\gamma = P_4 V_4^\gamma$ or $P_4 = P_3 \left(\frac{V_3}{V_1}\right)^\gamma = 28.7 \times \left(\frac{0.15 V_s}{1.1 V_s}\right)^{1.4} \text{bar} = 1.76$

$\boxed{P_4 = 1.76 \text{ bar}}$

(Adiabatic Compression) $W_1 = \frac{P_1V_1 - P_2V_2}{\gamma - 1} = \frac{(1 \times 1.1 V_s - 28.7 \times 0.1 V_s) \times 10^5}{1.4 - 1} = -4.43 \times 10^5 V_s \, J$

(Const V=c) $W_2 = P_2(V_3 - V_2) = 28.7 \times 10^5 (0.15 V_s - 0.1 V_s) J = 1.4325 \times 10^5 V_s \, J$

(Adiabatic Expansion) $W_3 = \frac{P_3V_3 - P_4V_4}{\gamma - 1} = \frac{(28.7 \times 0.15 V_s - 1.76 \times 1.1 V_s) 10^5}{1.4 - 1} = 5.92 \times 10^5 V_s \, J$

& $W_1 + W_2 + W_3 = \frac{WD}{Cycle} = 1500 J$

$-4.43 \times 10^5 + 1.4325 \times 10^5 + 5.92 \times 10^5 \, V_s = P_m \times V_s = 1500 J$

$(-4.43 + 1.4325 + 5.92) 10^5 V_s = P_m \times V_s = 1500 J$

$P_m = 2.92 \times 10^5 N/m^2 = 2.92 \text{ bar}$

$V_s = 5.15 \times 10^{-3} m^3$

$\frac{\pi}{4} d^2 \times L = 5.15 \times 10^{-3} m^3$

$\frac{\pi}{4} d^2 \times 1.5 d = 5.15 \times 10^{-3} m^3$

$\therefore \boxed{d = 0.163 m = 16.3 cm}$

$\boxed{L = 24.45 cm}$

$\eta_p = 1 - \left(\frac{1}{r}\right)^{\gamma - 1} \frac{\rho^{\gamma} - 1}{\gamma(\rho - 1)}$

$\eta_p = 1 - \left(\frac{1}{11}\right)^{1.4 - 1} \frac{1.5^{1.4} - 1}{1.4(1.5 - 1)}$

$\eta_p = 0.5816$

or

$\boxed{\eta_p = 58.16\%}$

(Qn26) The pressure & temperature of a diesel cycle at the start of compression are 1 bar & 30°C respectively. The compression ratio is 15. Pressure at the end of expansion was 3.5 bar find the % of working stroke at which heat is supplied per kg of air. (Take $\gamma = 1.4$, $C_p = 1.008$ KJ/kg K).

Soln) Given Data:-

$P_1 = 1$ bar

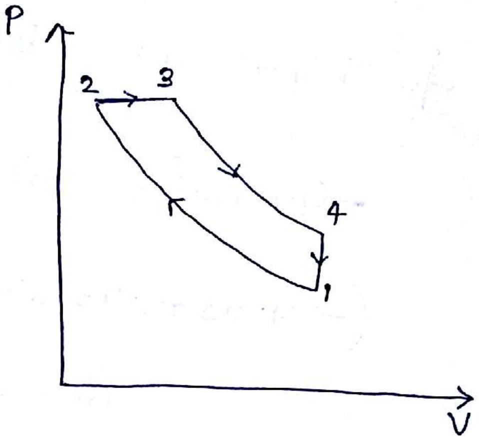
$T_1 = 30^\circ C = 303K$

$r = 15 = \frac{V_1}{V_2}$

$P_4 = 3.5$ bar

$\gamma = 1.4$

$C_p = 1.008$ KJ/kgK.



$$V_3 - V_2 = \frac{x}{100} \times V_s$$

$$\therefore \quad x = \frac{V_3 - V_2}{V_s} \times 100 = ?$$

or

$$x = \frac{\frac{V_3}{V_2} - 1}{\frac{V_s}{V_c}} \times 100 = ?$$

$$\boxed{\frac{V_s}{V_c} = r - 1}$$

or

$$x = \frac{\frac{T_3}{T_2} - 1}{r - 1} \times 100 = ? \quad \text{——} ①$$

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$\text{Or } P_2 = P_1 \cdot \left(\frac{V_1}{V_2}\right)^\gamma$$

$$P_2 = 1 \times 15^{1.4} \text{ bar}$$

$$\boxed{P_2 = 44.3 \text{ bar} = P_3}$$

& $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma-1}$ ∴ $T_2 = \underline{303 \times 15^{1.4-1}}\ K$

$$\boxed{\therefore\ T_2 = 895.1\ K}$$

Process (4-1)

$\frac{T_4}{T_1} = \frac{P_4}{P_1}$ or $T_4 = 303 \times \frac{3.5}{1} = 1060.5\ K$

$$\boxed{T_4 = 1060.5\ K}$$

And (Adiabatic Process)

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}.$$

$$T_3 = 1060.5\left(\frac{44.3}{3.5}\right)^{\frac{1.4-1}{1.4}} K = 2190.66\ K$$

$$\boxed{T_3 = 2190.66\ K}$$

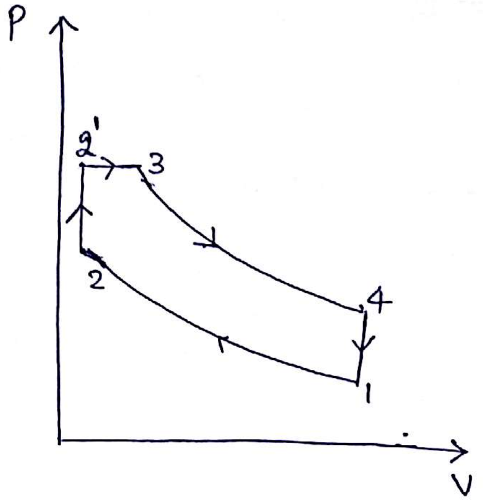
From ①

$$x = \frac{\frac{2190.6}{895.1} - 1}{15-1} \times 100\%$$

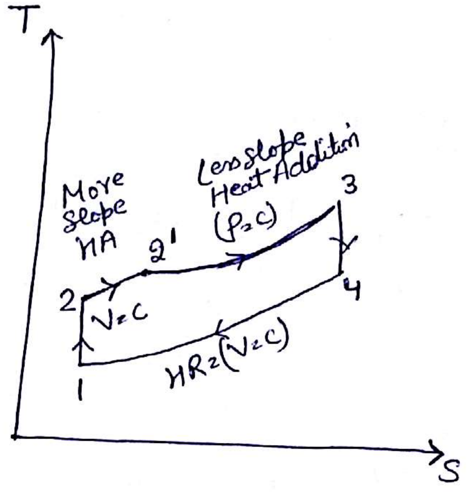
$$x = 10.3\%$$

The Dual Combustion Cycle Or The Semi Diesel Cycle :- T↑

(NO SPARK PLUG)



(P-V)



(T-S)

→ For Dual Cycle, the heat addition takes places, first at Constant volume, then at atmospheric Pressure.

→ If Heat addition takes places, first at Constant pressure & then at Constant Volume, then the efficiency of cycle will be reduced. Besides the Piston will hault in the middle of its motion for the Constant volume heat addition & then Continuing its motion for the Expansion process.

* This is not Possible in Practice.

→ For, Higher Efficiency of dual cycle, the heat addition at Constant volume, will be much as, then the heat addition at Constant Pressure.

→ Heat Addition at Constant Pressure is, 2-3 times more than Heat addition at Constant volume.

→ The Ratio of the Pressures, during the Constant vol. Heat addition is Known as explosion Ratio.

[In the figure explosion Ratio $\alpha = \frac{P_2'}{P_2}$]

→ For the, Same Peak pressure, the efficiency of diesel cycle is higher than that of the dual cycle, as its Compression Ratio (r) is higher.

→ For, diesel Cycles, Compression Ratio $r = 16-20$ ★★★

→ For Dual Cycles, Compression Ratio $r = 12-16$ ★★★

→ Since, the Compression Ratio for Dual Cycle is less, Hence, the stroke length ~~enhances~~ & hence, the Size of dual engine will be smaller then that of the Diesel cycle engine.

→ The Sound Pollution for the Dual Cycle engine is much less than that of the Diesel cycle engine.

→ The maintenance of Dual Cycle engine is easier & so also is the maintenance Cost.

→ Due to Above reasons, the present day diesel engines employ Dual cycles more than the Diesel cycles.

Efficiency Of Dual Cycle:-

Let,

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

& $\frac{P_2'}{P_2} = \alpha$ The explosion Ratio

$\rho = \frac{V_3}{V_2'} = \frac{V_3}{V_2}$ the Cut off Ratio

The Expansion Ratio is

$$\frac{V_4}{V_3} = \frac{V_1}{V_2} \times \frac{V_2}{V_1} = \frac{r}{\rho}$$

Adiabatic Compression → $\boxed{PV^{\gamma}=C}$

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

H.A. at Constant volume $(V=C)$

$$\frac{P_2'}{P_2} = \frac{T_2'}{T_2} . \quad \Rightarrow T_2' = T_1 r^{\gamma-1} \alpha \quad \text{—} ②$$

H.A. at Constant Pressure $(P=C)$

$$\frac{T_3}{T_2'} = \frac{V_3}{V_2'} \Rightarrow T_3 = T_1 r^{\gamma-1} \alpha \rho \quad \text{—} ③$$

Adiabatic expansion

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{\gamma-1} \Rightarrow T_4 = T_1 \times r^{\gamma-1} \alpha \rho' \left(\frac{\rho}{r}\right)^{\gamma-1}$$

$$T_4 = T_1 \alpha \rho^{\gamma} \quad \text{—} ④$$

$$\eta_s = 1 - \frac{HR}{HA}$$

$$= 1 - \frac{mC_v(T_4 - T_1)}{mC_v(T_2' - T_2) + mC_p(T_3 - T_2')}$$

Or

$$\eta_s = 1 - \frac{T_1 \alpha \rho^{\gamma} - T_1}{(T_1 r^{\gamma-1}\alpha - T_1 r^{\gamma-1}) + \gamma(T_1 r^{\gamma-1}\alpha\rho - T_1 r^{\gamma-1}\alpha)}$$

$$\boxed{\therefore \eta_s = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{\alpha\rho^{\gamma} - 1}{(\alpha - 1) + \gamma(\rho - 1)\alpha}}$$

imp objective

Efficiency of Dual Cycle

Qn 27 In an engine working on the dual cycle, the Pressure and temperature at the beginning of Compression are 1·03 bar and 30°C. The temp. at the end of Compression is 400°C. and the max. temp. of the Cycle is 2000°C. The heat added at Constant pressure is 2·5 times that at Constant volume. Determine the max. Pressure & the efficiency of the Cycle?

Soln) $P_{max} = P_3 = ?$ $\eta_s = ?$

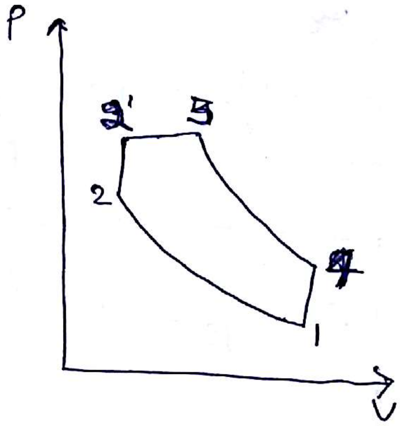
$\boxed{HA_p = 2.5\, HA_v}$

$P_1 = 1.03\,\text{bar}$

$T_1 = 30°C = 303\,K$

$T_2 = 400°C = 673\,K$

$T_{max.} = T_3 = 2000°C = 2273\,K$



$HA_p = 2.5\, HA_v$

$m C_p (T_3 - T_2') = 2.5\, m C_v (T_2' - T_2)$

$\therefore\ 0.56(2273 - T_2') = (T_2' - 673)$

$\boxed{T_2' = 1247.4\,K}$

$$r = \frac{V_1}{V_2} = \left(\frac{T_2}{T_1}\right)^{\frac{1}{\gamma-1}} = \left(\frac{673}{303}\right)^{\frac{1}{1.4-1}} = 7.35$$

$P_1 V_1^\gamma = P_2 V_2^\gamma$

Or $\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^\gamma$

$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^\gamma = 1.03 \times 7.35^{1.4} = 16.8\,\text{bar}.$

Also $\frac{P_2'}{P_2} = \frac{T_2'}{T_2}$ $\therefore \Rightarrow P_2' = 16.8 \times \frac{1247.4}{673} = 31.1\,\text{bar} = P_{max}.$

As $(V = C)$

Cut off Ratio
~~Explosion Ratio~~ $\rho = \frac{V_3}{V_2'} = \frac{T_3}{T_2'} = \frac{2273}{1247.4} = 1.83$ As (V=C)

Explosion Ratio = $\alpha = \frac{P_2'}{P_2} = \frac{31.1}{16.8} = 1.85$

$$\eta_s = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{\alpha(\rho^{\gamma}-1)}{(\alpha-1)+\gamma(\rho-1)\alpha}$$

$$= 1 - \left(\frac{1}{7.35}\right)^{1.4-1} \times \frac{1.85 \times 1.83^{1.4} - 1}{1.4(1.83-1)1.85 + (1.85-1)}$$

$\eta_s = 0.503\%$ or 50.36%

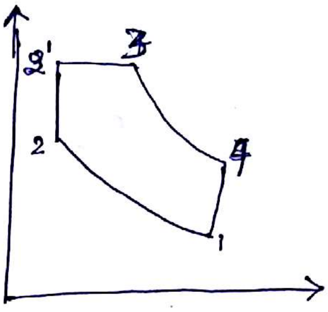
Qn) In a Dual Cycle, Pressure & temperature at the start of Compression are 1 bar at 90°C. The Compression Ratio is 13. The total Heat Added Per kg of Air is 1675 KJ. Half of this Heat added takes place at Constant volume.

Take $\gamma = 1.4$ for Compression. only for Compression only.

$R = 0.287$ KJ/kgK

$C_v = [0.71 + 20 \times 10^{-5} T \text{(kelvin)}]$ KJ/kg K

for Product of Combustion.



Determine,

→ Percentage of Working Stroke during Heat addition.

Soln

$$x = \frac{\frac{T_3}{T_{2'}} - 1}{r - 1} \times 100\% \quad \text{——} \; ①$$

$$HA_v = \frac{1675}{2} \text{ KJ/kg.}$$

$P_1 = 1$ bar

$T_1 = 90°C = 363$ K

$P_2 V_2^{\gamma} = P_1 V_1^{\gamma}$

$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{\gamma}$

~~$P_2 = 1 \times 13$~~

$P_2 = 1 \times 13^{1.4} = 36.26$ bar

Process (1-2) $PV^{\gamma} = C$ As adiabatic

~~$P_2 = P_1 V$~~

$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{\gamma - 1} = \quad T_2 = T_1 \left(\frac{V_1}{V_2}\right)^{\gamma - 1}$

$T_2 = 363 \times 13^{1.4 - 1}$ K $= 1012.7$ K

$\boxed{T_2 = 1012.7 \text{K}}$

$C_v(T_2'-T_2) = HA_v$ taking Quasi static Process Here.

$$\Rightarrow \int_2^{2'} C_v\,dT = \int dHA_v$$

$$\Rightarrow \text{or} \int_2^{2'} (0.71+20\times10^{-5}T)\,dT = \frac{1675}{2}$$

$$\Rightarrow \int_2^{2'} 0.71\,dT + \int_2^{2'} 20\times10^{-5}T\,dT = \frac{1675}{2}$$

$$\Rightarrow 0.71\int_2^{2'} dT + 20\times10^{-5}\int_2^{2'} dT = \frac{1675}{2}$$

$$\Rightarrow 0.71(T_2'-T_2) + 10^{-4}\left((T_2')^2-(T_2)^2\right) = \frac{1675}{2}$$

$$\Rightarrow 0.71(T_2'-1012.7) + 10^{-4}(T_2')^2 - 1012.7^2 = \frac{1675}{2}$$

$$\boxed{T_2' = 1853.1\ K}$$

$$\Rightarrow C_p - C_v = R \qquad \text{or} \qquad C_p = R + C_v$$

$$\Rightarrow C_p = 0.287 + (0.71 + 20\times10^{-5}T)$$

$$\Rightarrow C_p = 0.997 + 20\times10^{-5}T$$ Specific Heat changes Here

$$\Rightarrow 0.997[T_3 - T_2'] + 10^{-4}\ T_3^2 - T_2'^2 = \frac{1675}{2}$$

$$0.997(T_3-1853.1) + 10^{-4}(T_3^2 - 1853.1) = \frac{1675}{2}$$

$$\boxed{T_3 = 2440.17\,K}$$

$$\boxed{x = \frac{\frac{2440.17}{1853.1}}{13-1}\times 100\,\% = 2.64\,\%}$$

Working Of A Four Stroke Petrol Engine :-

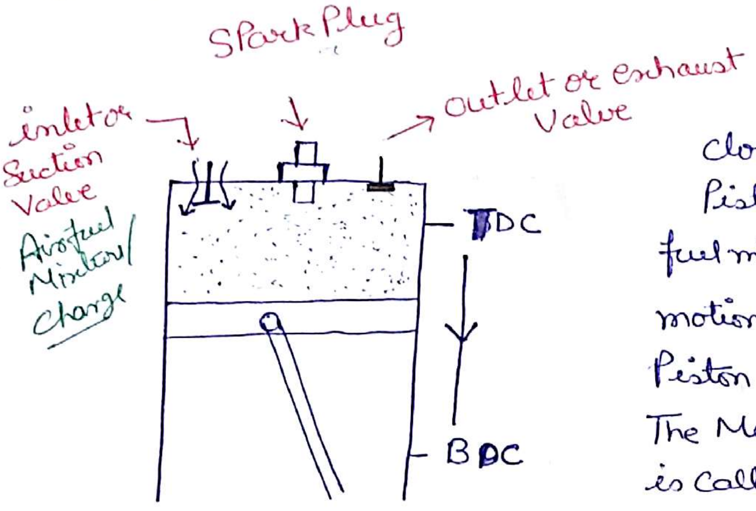


figure 1 :- Suction Stroke

Piston is at TDC. Inlet Valve (IV) is fully opened and the outlet Valve is closed. Energy is supplying from the Shaft to the Piston and piston goes downwards. Fresh air fuel mixture (AFM) is taken in during the downward motion of the Piston. At the end of Suction Process, the Piston is at BDC & cylinder is filled with fresh (AFM). The Motion of the piston during Suction (TDC to BDC) is called the Suction Stroke

→ At the end of Suction Stroke, inlet Valve closes and the piston begins to move up (due to Continuous rotation of the Shaft) Compression takes place, for the air fuel Mixture inside the Cylinder untill the piston Reaches TDC this motion of Piston is known as the Compression Stroke

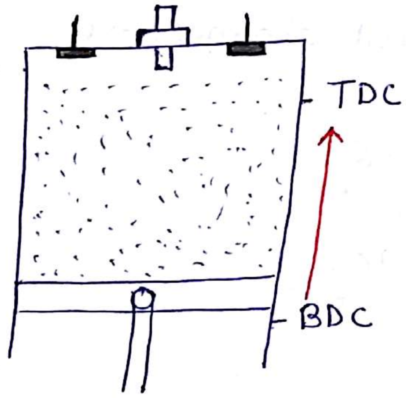


figure 2 :- Compression Stroke

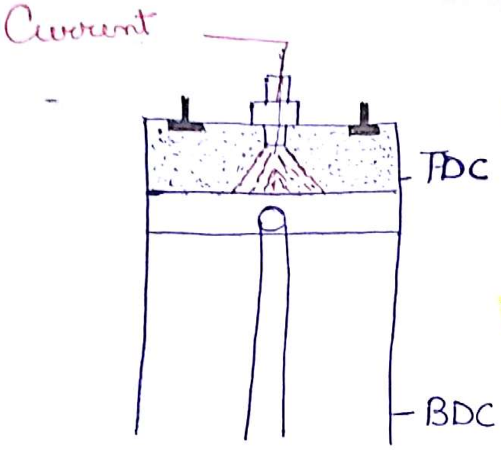


figure 3:- Heat Added at Constant volume

At the end of the Compression Stroke i.e, When the Piston is at TDC, Current is Supplying to the Spark plug & Sparking takes Place. The fuel Particles in the AFM inside the cylinder gets ignited and Comb^n takesplace at Constant volume. In actual Practice, piston undergoes change in direction at TDC during heat addition. Both Valves Remain Closed at this instant. The voltage available during Heat Addition is about 1000 V.

insulated When Comes in Contact then Spark generated

After, Heat Addition the Hot gases expand and pushes the piston down from TDC to BDC. This motion of the Piston is known as the expansion/Power Stroke. Both valves remains closed. The Pressure of the Charge, inside the cylinder at the end of expansion Stroke is above the atmospheric pressure.

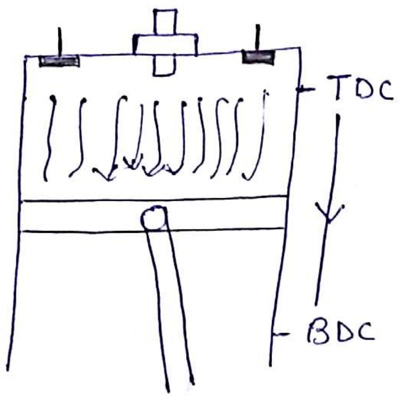
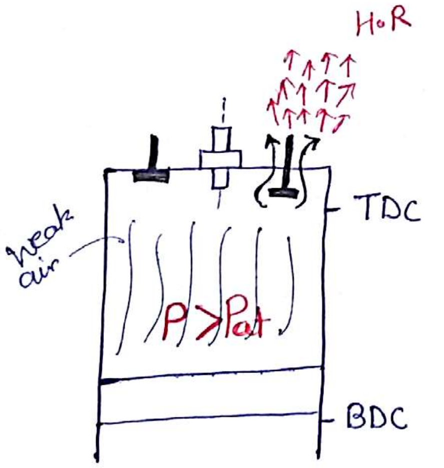


figure 4:- Expansion or Power Stroke



At the end of expansion Stroke (Piston is at BDC) outlet valve opens. (It is open by another CAM). The expanded gases leaves the cylinder through the exhaust valve and heat rejection takes place at Constant volume. In actual Practice piston undergoes change in direction at BDC during Heat Rejection.

figure 5:- Heat Rejection at Constant volume.

(Via) (CAM)

(Here gas have flow energy)

At this time when changing dir^n 95% HR

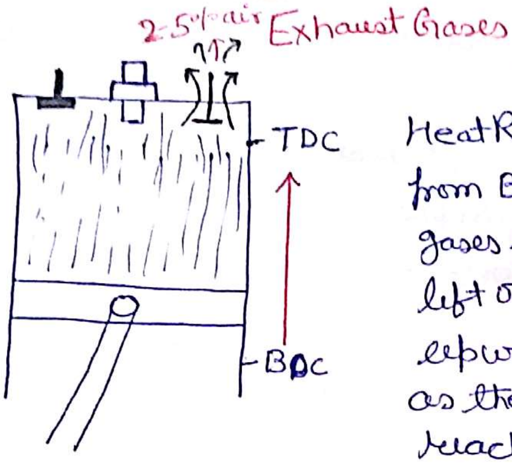


figure 6: Exhaust stroke

The inlet valve remains closed throughout the Heat Rejection. After HR, Piston Begins to move up from BDC. The left over gases (about 95% of the expanded gases leaves the cylinder during Heat Rejection), so left over gases put out off the exhaust valve by the upward motion of the piston. This motion is known as the exhaust stroke & it continues untill the Piston reaches TDC. At the end of Stroke (exhaust), the cylinder will be filled with exhaust gases in the Clearnac volume.

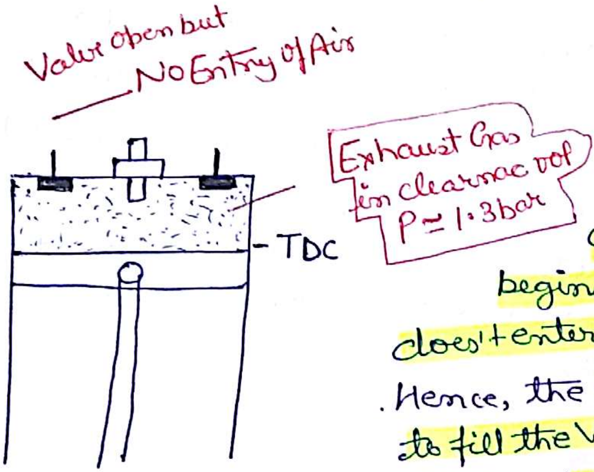


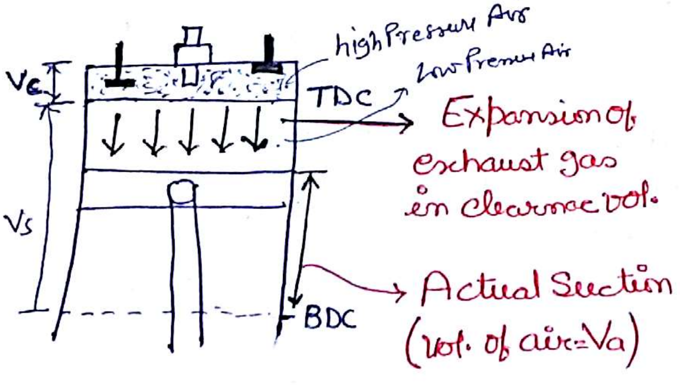
figure 7:-

The Pressure of the exhaust gas in clearnac volume is about 1.2 – 1.3 bar. The outlet valve closes and the inlet valve opens. Suction Stroke begins for the next cycle. but, fresh air fuel mixture does't enter in at the start of this Suction stroke. Hence, the exhaust gas in the clearnac volume expands to fill the Vaccume, created by the downward motion of Piston. When the Pressure inside cylinder is become equal to atmospheric pressure then the Fresh AFM begins to enter in. For the remaining of the Suction stroke.

It may be Seen from the figure that, actual volume of air enters in cylinder during the Suction stroke is less than the Stroke volume (Actual volume = Va).

The Ratio of the actual volume to the Stroke volume is defined as volumetric efficiency η_v of engine. and is given by.

$$\eta_v = \frac{Va}{Vs}$$



$$\boxed{\eta_v = \frac{Va}{Vs}}$$

figure. 8:-

When Pressure of clearnace vol $P_c = 1.03$ is goes down & become equal to Patm then Pressure at inlet will be ↑ than ↓ then Charge is in.

Two Stroke Engine :-

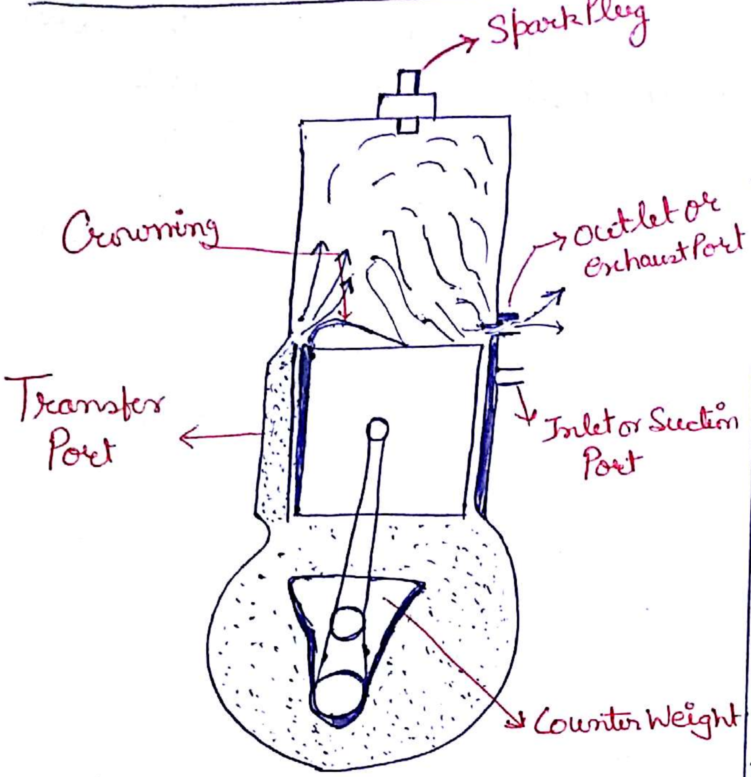
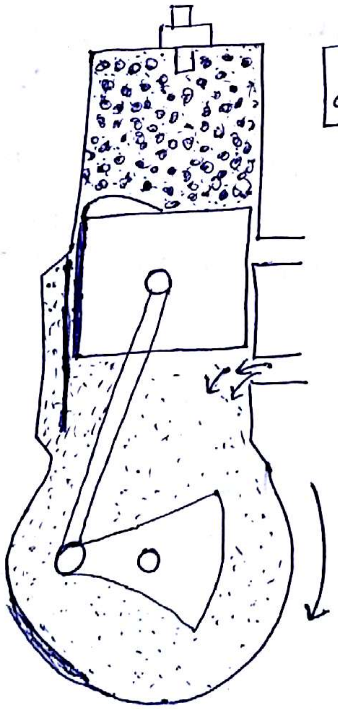


figure 1

The Piston is at BDC. The Transfer Port is open on Both Sides of the Piston. The Partly compressed fresh AFM below the Piston flows through the Transfer Port and Occupies the Space above the piston.

It may be seen that both the transfer and exhaust port are open at the Same time. hence Some fresh AFF flowing out of a transfer Port will also leave the exhaust Port. To Prevent this loss a crown is introduced at the top of the piston. The fresh AFF entering the space above the piston & flowing in the direction of transfer Port will collide with the crown & rise to the top. In the mean time, the fresh AFF, above the Piston pushes out the left over expanded gases of the Previous cycle through the exhaust Port. This process of the fresh AFF Pushing out the expanded gases is Known as Scavanging.

When the Piston is at the end of moving up; the space inside the cylinder above the Piston is filled with the charge of fresh AFF.



When the piston Complete about 30% of upward motion (Compression stroke). The inlet port open to the Space Below the piston. Further upward motion of the Piston, fresh AFF of the next cycle is Sucked into the engine's cylinder in the Space below the piston. From the Carburettor, through the inlet port. This Suction Continuses until the piston Reaches (TDC) (end of Compression).

figure 2

After Compression, Heat addition takes place, at Constant volume (Piston is at TDC). hence, current is supplied to the spark plug at this Stage. The voltage available for the Spark plug is about 10000 volts.

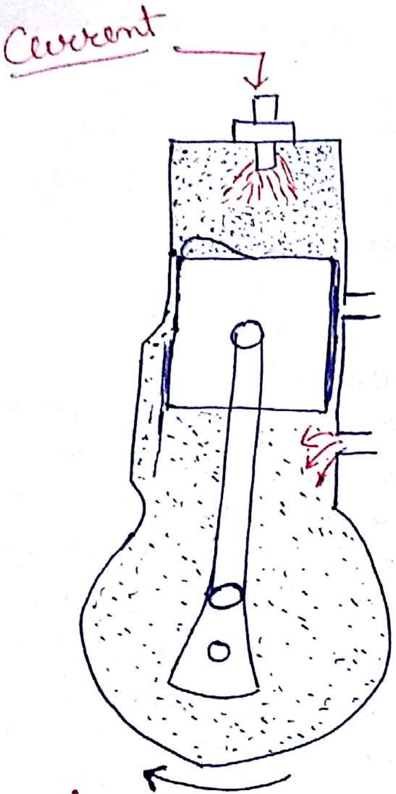


figure 3

After Heat Addition the hot gases pushes the piston down from TDC & useful power is obtained. When the Piston Completes about 70% of the Power Stroke, the inlet port Closes, further Downward motion of Piston will Partly Compressed the fresh AFF of the next cycle, in the space below the piston

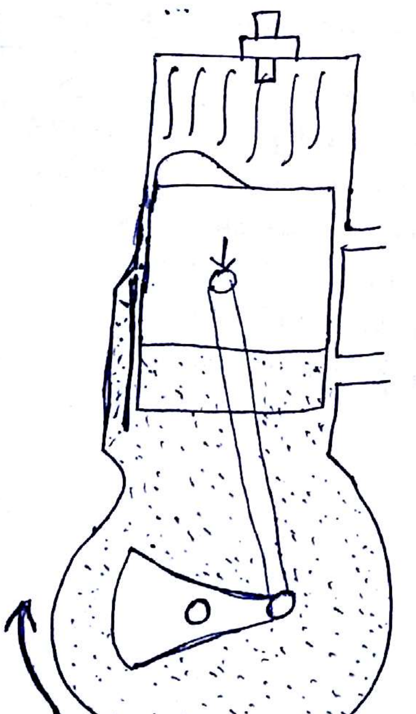


figure 4

When the Piston Completes about 90% of the Power flow, the outlet Port is open to the space above the piston & major portion of the expanded gases leaves the Cylinder out of the exhaust Port during the remaining downward stroke of the Piston.

When the piston Reaches BDC, the Operations are repeated in the Same manner as expands.

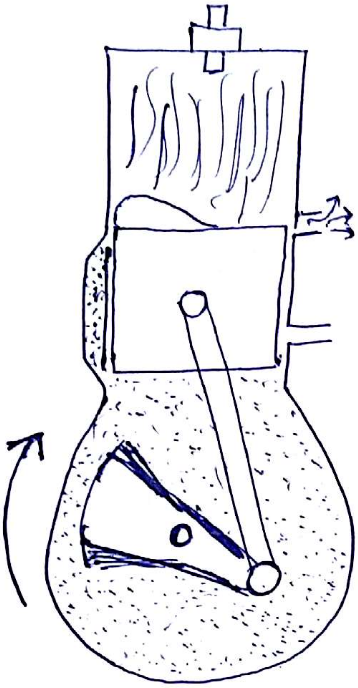


figure 5

I.C. Engine Calculations:-

1) Calculations for volume:-

a) Two Stroke Engine:- One Cycle — Two Stroke — One Suction

One Cycle — Two Stroke — One Suction — vol. of air = Vol s. — One Rotation

∴ for N rotations, $\boxed{\text{volume of air taken in} = \boxed{V_s \times N}}$ ** imp

b) Four Stroke Engine:

One Cycle — Four stroke — 2 rotation are over — One Suction Completed Vol of air = Vs

(volume of air = Vs)

∴ Average volume of Air per rotation = $\frac{V_s}{2}$

for N rotations. $\boxed{\text{volume of Air} = \frac{V_s}{2} \times N = \boxed{V_s \times \frac{N}{2}}}$

2) Mechanical Efficiency :- η_M (Piston efficiency)

$$\frac{\text{Piston input} \rightarrow \text{integrated Workdone}}{\text{Piston output} \rightarrow \text{Brake Workdone}}$$

The Energy input to the Piston is due to the expansion of air. (Pressure & Volume changes). Hence, the Work input to the piston is determined from the pressure volume diagram. The P-V diagram is also known as the indicator diagram. Hence the Work input to the piston is Called the indicated Workdone [IWD]

The Workoutput of the piston, is the energy available at the Shaft of the engine and is determined by applying a brake mechanism (Dynamometer) to the Shaft. Hence, the Work output of the piston is Known as the Brake Workdone (BWD).

The Ratio of the Brake Workdone to indicated Workdone is defined as the Mechanical efficiency of engine and is given by;

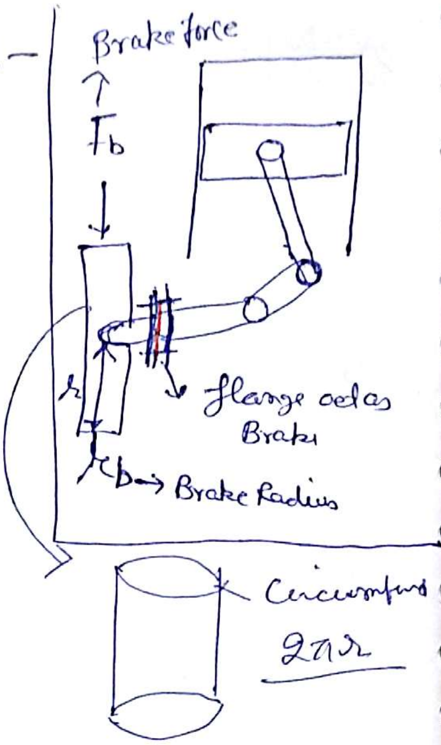
$$\boxed{\eta_m = \frac{BWD}{IWD} = \frac{\text{Brake Workdone}}{\text{Indicated Workdone}}}$$

Or

$$\boxed{\eta_m = \frac{bmep \times V_s}{imep \times V_s}}$$

$$\boxed{\therefore \quad \eta_m = \frac{bmep}{imep}}$$

3) Calculations For Brake Work Done :-



For N Rotations;

$$\boxed{BWD = F_b \times 2\pi r_b \times N}$$

F_b → Brake force

r_b → Radius of drum

N → No. of Rotation

4) Power :- (P)

$$\boxed{P = \frac{W.D}{time}}$$

Or

$$\boxed{P = \frac{W.D}{Sec}}$$

Power in Watts

$$\boxed{1\,Watt = \frac{Joule}{Sec}}$$

$$\boxed{\text{Indicated Power} = \frac{\text{Indicated Workdone}}{Sec}}$$

$$\boxed{B.P = \frac{BWD}{Sec}}$$

5) Heat Added and Thermal Efficiency :-

$$\boxed{\frac{\text{Heat Added}}{\text{Kg}_{\text{fuel}}} = \text{Calorific Value}}$$

$$\boxed{\text{Heat Added/sec} = \text{Calorific value} \times m_{f/\text{sec}}}$$

Or

$$\boxed{\frac{HA}{\text{Sec}} = \frac{HA}{\text{Kg}_{\text{fuel}}} \times m_f/\text{Sec}}$$

$\boxed{m_f \rightarrow \text{mass of fuel}}$

$$\boxed{\eta_{Th} = \frac{W.D}{H.A}}$$

$$\boxed{\eta_{I.T} = \frac{IWD}{HA}}$$

$$\boxed{\eta_{B.T} = \frac{BWD}{HA}}$$

6) Specific fuel Consumption (Sfc) :-

$$\boxed{Sfc = \frac{m_f\ (\text{Kg/hr})}{\text{Power (KW)}}}$$

When Power → Brake Power

$$\boxed{bsfc = \frac{m_f\ (\text{Kg/hr})}{\text{B. Power KW}}}$$

When Power → Indicated Power

$$\boxed{Isfc = \frac{m_f\ (\text{Kg/hr})}{\text{I. Power}}}$$

Imp

$$\boxed{\text{Average Piston Speed} \simeq 2LN}$$

Qn14 Fuel Consumption of a Diesel engine is 10gm/sec, when the power output is 160KW. If the mechanical efficiency is 75%, then the indicated Specific fuel consumption is ______ Kg/KWh.

Soln $m_f/_{sec} = 10gm$

Brake Power = 160KW

$\eta_m = 0.75$ or 75%

isfc = ?

$$bsfc = \frac{m_f/hr}{B.Power} = \frac{\frac{10}{1000} \times 3600}{160} = \frac{9}{40} \, Kg/_{kWhr}$$

$$\eta_m = \frac{Brake\ Power}{I.\ Power} = \frac{B.Power/_{m_f/hr}}{I.Power/_{m_f/hr}} = \frac{\frac{1}{bsfc}}{\frac{1}{isfc}} = \frac{isfc}{bsfc}$$

$$isfc = \frac{9}{40} \times 0.75 \frac{Kg}{Kw/hr} = 0.1675 \, Kg/Kw/hr$$

$$\boxed{isfc = 0.1675 \, Kg/_{Kw/hr}}$$

Qn) 15) A Car engine operates at a fuel-air ratio of 0.05, volumetric efficiency of 90% & indicated mean effective pressure is 6 bar. If the calorific value of fuel is 45000 KJ/Kg & density of air at intake is 1 Kg/m³, then the indicated thermal efficiency of the cycle is ______ %.

Soln) $\frac{m_f}{m_a} = 0.05$ $\eta_{vol} = 0.9$ $imep = 6\ bar$

$HA/kg\ fuel = 45000\ KJ$ $\rho_a = 1\ kg/m^3$ $\eta_{It} = ?$

for 1 kg of fuel ⇒ $m_a = \frac{1}{0.05}\ kg = 20\ kg$

$\therefore \frac{m_a}{V_a} = \rho_a \Rightarrow V_a = \frac{m_a}{\rho_a} = \frac{20}{1}\ m^3/kg\ fuel$

$\eta_{vol} = \frac{V_a}{V_s} \Rightarrow V_s = \frac{V_a}{\eta_{vol}} = \frac{20}{0.9}\ m^3/kg\ fuel$

$IWD/kg\ fuel = imep \times Vs/kg\ fuel = (6\times10^5)\ \frac{20}{0.9} \cdot J \Rightarrow \frac{12000}{0.9}\ KJ$

$\eta_{IT} = \frac{IWD/kg\ fuel}{HA/kg\ fuel} = \frac{12000}{0.9\times45000} = 0.292$ i.e equal to ~~29.2~~ 29.2%

Qn16) 4 cylinder two stroke Petrol engine has a mean effective fuel Pressure of 10 bar & the mechanical efficiency of 75%. The size of cylinder is 10cm in diameter and 15 cm Stroke. The speed is 2500 rpm. Determine the Brake Power of the engine & its Brake specific fuel Consumption $\eta_{BT} = 30\%$, CV = 42000 KJ/Kg.

Soln) 4 cylinder, 2 Stroke

mep = 10 bar

$\eta_m = 0.75$

$d = 10.0\ cm = 0.1\ m$

$L = 15.0\ cm = 0.15\ m$

$N = 2500\ rpm$

B. Power = ?

bsfc = ?

$\eta_{BT} = 0.3$

$HA/kg\ fuel = 42000\ KJ/$

$$\frac{bmep}{imep} = \eta_m$$

$$\Rightarrow \quad bmep = \eta_m \times imep$$

$$bmep = 0.75 \times 10 \text{ bar}$$

$$\boxed{bmep = 7.5 \text{ bar}}$$

$$V_s = \left(\frac{\pi}{4} d^2 \times L\right) 4 \times \frac{N}{60}$$

(As air Comes in 4 Cylinder at Same time)

$$V_s = 4 \times \frac{\pi}{4} 0.1^2 \times 0.15 \times \frac{2500}{60} \, m^3/sec = 0.196 \, m^3/sec \quad \boxed{V_s = 0.196 \, m^3/s}$$

$$\text{Brake Power} = \underline{BWD/sec} = bmep \times \underline{V_s/sec} = (7.5 \times 10^5) \times \frac{0.196}{1000} = 147.26 \, KW$$

$$\boxed{\text{Brake power} = 147.26 \, KW}$$

$$\eta_{BT} = \frac{BWD/sec}{HA/sec} \text{ or } HA/sec = \frac{147.26}{0.3} \, KJ \text{ or } HA/kg \, fuel \times m_f/sec = HA/sec$$

$$= \frac{147.16}{0.3} \, KJ$$

$$bsfc = \frac{m_f/hr}{B.Power} = \frac{147.26 \times 3600}{0.3 \times 42000 \times 147.26} \, kg/kwhr$$

$$\boxed{bsfc = 0.2857 \, kg/kwhr}$$

~~(Qn17~~)

Difference between Two Stroke & Four Stroke Petrol Engine :-

Two Stroke engine	Four stroke Engine
↓	↓
1) One Cycle – One Rotation	One Cycle – Two Rotation

2) The Valves of 4 stroke engine are replaced by 3 different ports of a
2 stroke engine

3) In two Stroke engine, the lubricating oil is mixed with the fuel.
In four stroke engine, the lubricating oil is taken in seprate

4) The flywheel of a four stroke engine is bigger in size, than a two
stroke engine for single cylinder engines.

5) The Size of a two stroke engine is bigger than that of a four stroke
engine. Hence, the Radiation losses are more in two Stroke engines.
The thermal efficiency of two stroke engine is thus lesser.

6) In two stroke engines the lubricating oil with flow along with
the fuel, hence, Small Quantity of lubricating oil undergoes combustion.
and thus, gets burnt. Hence, for the piston motion After heat
addition, the heat losses are more due to friction. Hence, the
Work output of two Stroke engine is less than that of four stroke
engine.

7) The Size of the fly wheel is much bigger for a four stroke engine
than that of two stroke engine.

8) In two Stroke engines, the transfer port and exhaust port
are open at the same time. hence, Some fresh AFM escapes
Out of the exhaust port without undergoing any Combustion.
Due to this reason, the mileage of two Stroke engine is much
less than that of a four stroke engine

9) The Actual Power output of a two stroke engine is about 70% of the Ideal Power, whereas, for four stroke engines, it is arround 90%.

10) Due to the above reasons the overall efficiency of the two stroke engine is much less than that of four stroke engine.
Due to this reason the two stroke engines are been replaced by four stroke engines.

Difference between a petrol engine & Diesel Engine :-

1) In a Diesel Engine, the Air and the fuel do not mix before to the entry in engine cylinder. Thees deisel engines do not have a Carburettor.

2) For diesel engines, self ignition temperature is reached at the end of Compression, which is good enough for igniting the fuel. hence, diesel engine do not have a spark plug.

3) For the Seprate enerty of fuel, After the Compression stroke, a Nozzle is provided for diesel engines (Nozzles are also known as ejectors).
Petrol engines donot have the nozzoles.

4) For the Same Compression Ratio, the efficiency of Petrol engine is higher than that of a diesel engine. But this is theoritical.

5) In Practice, the Compression Ratio of a diesel engine is 1.5 - 3 times more than that of a Petrol engine. hence, efficiency of a diesel engine is only higher.

6) For diesel Engines, Compression ratio → 14 - 16
for Petrol engines Compression ratio → 6 - 10

7) In the Case of Petrol Engine, HA takes place at Constant vol.
and at Constant pressure for diesel engines.

8) At cruising (economy) speed (30 - 60) AFR for petrol engine is 16.
& for diesel engine is b/w 25 - 35.

Q) The following Data refers to Single Cylinder 4 stroke diesel Engine.

Brakepower = 73.5 KW, the Speed is 4000 rpm.

Brake mean effective pressure is 8.5 bar.

Mechanical efficiency is 80%.

Brake Specific fuel Consumption is 0.36 Kg/KW hr

Calarofic value of fuel is 42260 KJ

Determine the ~~stroke~~ bore of the engine.

When it is equal to the Stroke.

Also find the Brake thermal efficiency & Indicated mean effective Pressure.

Sol:)

$BP = 73.5\ KW$

$N = 400\ r/m$

$B_{mep} = 8.5\ bar$

$\eta_m = 0.8$

$B_{sfc} = 0.36\ Kg/kw\ hr$

$\frac{HA}{Kg\ fuel}$ $CV = 42260\ KJ$

$L = d = ?$

$\eta_{BT} = imep = ?$

$$BWD/_{sec} = bmep \times V_s/_{sec}$$

$$V_s = \frac{73.5 \times 1000}{8.5 \times 10^5}\ m^3/sec = 0.0864\ m^3/sec.$$

Or $$\frac{\pi}{4} d^2 \times L \times \frac{N}{60 \times 2} = 0.0864\ m^3/sec.$$

$$\Rightarrow \frac{\pi}{4} d^2 \times d \times 400 = 0.0864\ m^3/sec$$

$\boxed{d = 0.321 m = 32.1 cm = 4}$

$HA/_{sec} = HA/_{kg fuel} \times M_f/_{sec} = 43260 \times M_f/_{sec}$ — ⓐ

$bsfc = \frac{M_f/\cancel{hr}}{B.P}$

$M_f = 0.36 \times 73.5$ kg/hr

$\boxed{M_f = 26.46 \text{ kg/hr}}$

$HA/sec = 43260 \times \frac{26.46}{3600} = 317.9$ KJ $\boxed{HA/sec = 317.9 KJ}$

$\eta_{BT} = \frac{BWD/sec}{HA/sec} = \frac{73.5}{317.9} = 0.2311$ or $\boxed{\eta_{BT} = 23.11\%}$

$\frac{bmep}{imep} = \eta_m$ or $imep = \frac{8.5}{0.8}$ bar $= 10.625$ bar

$\boxed{imep = 10.625 \text{ bar}}$

(Qn) The following Data are Known for 4 cylinder 4 stroke Petrol engine. Cylinder dimensions are; 11 cm bore, 13 cm stroke. The engine speed is 2250 rpm. The brake power is 50 KW. The mass of fuel consumed is 10.5 kg/hr. frictional Power is 15 KW. The calorific value of the fuel is 50000 KJ/kg. Air Inhalation is 300 Kg/hr. Ambient Conditions are ~~50°C~~ 15°C and 1.03 bar.

Determine bmep, $\eta_{vol.}$, B Thermal efficiency & η_m of the engine?

Soln

4 cylinder

4 stroke

$d = 11\text{cm} = 0.11\text{m}$

$L = 13\text{cm} = 0.13\text{m}$

$N = 2250\ \text{r/m}$

$B.P = 50\text{KW} = \text{BWD/sec}$

$F.P = 15\text{KW}$

$m_f = 10.5\ \text{Kg/hr}$

$\text{HA/Kg fuel} = 50000\ \text{KJ}$

$m_a = 300\ \text{Kg/hr}$

bmep = ?

$\eta_{vol} = ?$

$\eta_{BT} = ?$

$\eta_m = ?$

(inhalation provided above in Question to find Actual volume)

ambient temp = $T_1 = 15°C = 288\text{K}$

$P_1 = 1.03\ \text{bar}$

$$V_s = \frac{\pi}{4} d^2 \times L \times \frac{N}{2\times 60} \times 4$$

$$= 4 \times \frac{\pi}{4} \times 0.11^2 \times 0.13 \times \frac{2250}{2\times 60}\ \text{m}^3/\text{sec} = 0.0927\ \text{m}^3/\text{sec}$$

$$\boxed{V_s = 0.0927\ \text{m}^3/\text{sec}}$$

$$\text{bmep} = \frac{\text{BWD/sec}}{\text{Vs/sec}} = \frac{50\times 1000}{0.0927}\ \text{N/m}^2 = \frac{50\times 1000}{0.0927\times 10^5}\ \text{bar} = 5.4\ \text{bar}$$

$$\boxed{\text{bmep} = 5.4\ \text{bar}}$$

$$P_1 V_a = m_a R_a T$$

$$V_a = \frac{m_a \times R_a \times T}{P_1} = \frac{300}{3600} \times \frac{287 \times 288}{1.03 \times 10^5} \ m^3/sec$$

$$\boxed{V_a = 0.66 \ m^3/sec}$$

$$\eta_{vol} = \frac{V_a}{V_s} = \frac{0.66}{0.0927} = 0.723 \text{ or } 72.3\%$$

$$\boxed{\eta_{vol} = 0.723 \text{ or } 72.3\%}$$

$$I.Power = B.Power + F.Power = (50+15)\,KW = 65\,KW$$

B.P & F.P are both Kind of Loss

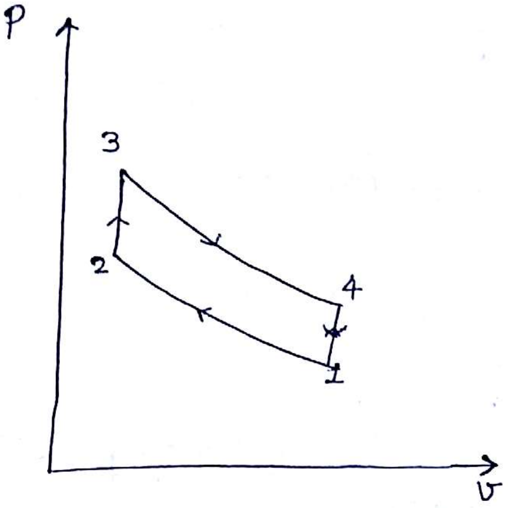
$$\boxed{I.Power = 65\,KW}$$

$$\eta_m = \frac{B.Power}{I.Power} = \frac{50}{65} = 0.7692 \text{ or } 76.92\%$$

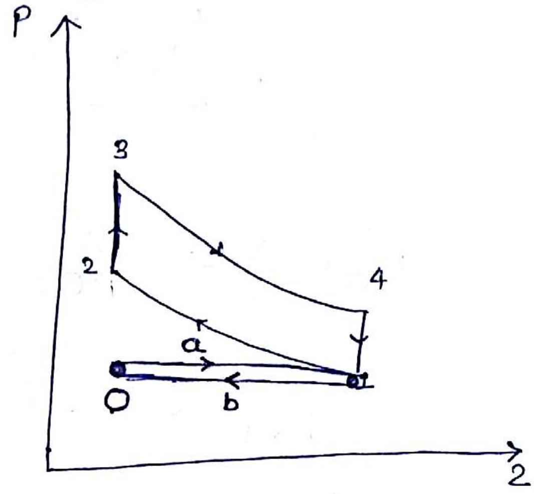
$$\boxed{\eta_m = 0.7692 \text{ or } 76.92\%}$$

Imp topic

Difference between the Theoritical and Actual Four stroke Petrol Engine :-



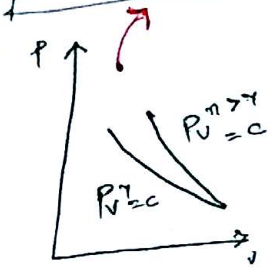
Otto Cycle



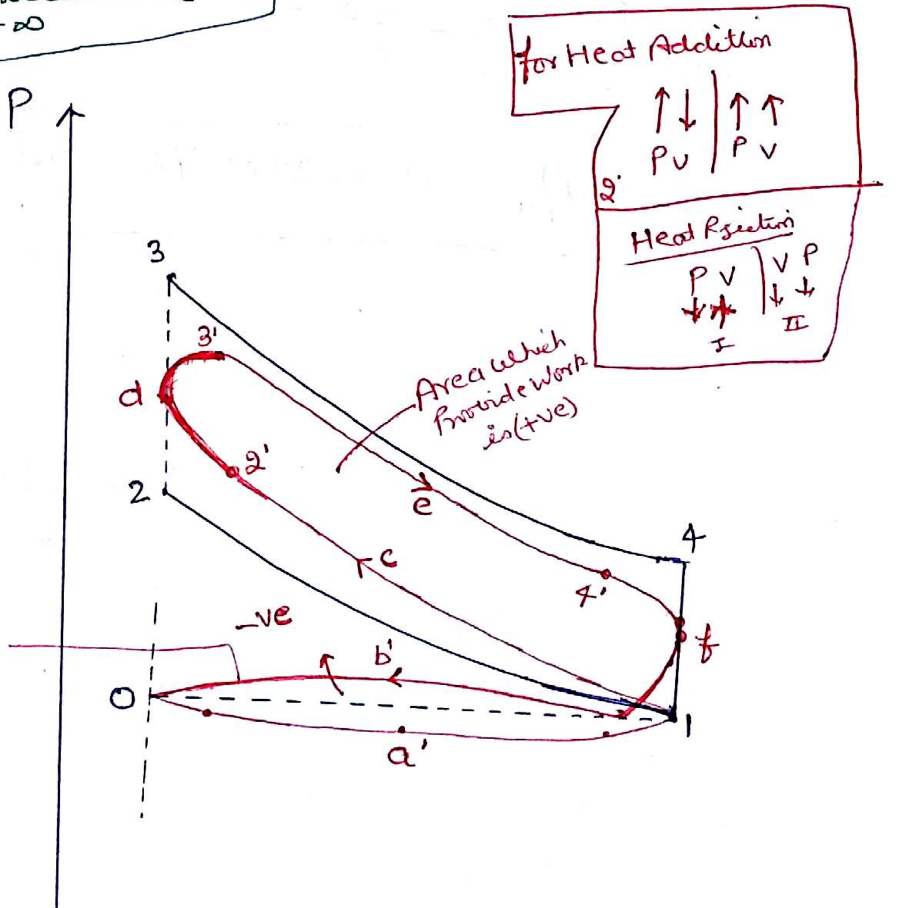
0 - a - 1 :- Suction
1 - b - 0 :- Exhaust
] At Const. atmosphere Pressure

Theoritical P-V diagram

Important
When Pressure & volume ↑ both
Value of Polytropic Index can be (-ve)
and it can be $-\infty$ to $+\infty$



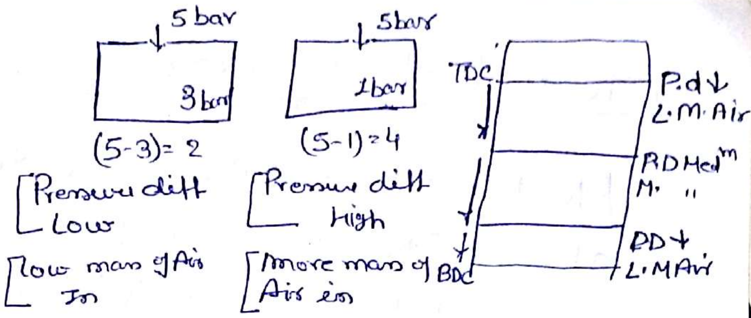
$$\text{diagonal factor} = \frac{A_{net}}{\text{Ideal Area}}$$



Pumping Loss

Actual diagram

Actual dia is not Perfect
So we have Average) mean
Area
$(A = h_m \cdot l)$
$\rightarrow h_m = \frac{A}{l}$
Mean height



Actual Suction:-

Air at atmospheric pressure, flow from the Carburettor to engine Cylinder (high Pressure → low pressure). Hence Suction Pressure Will be below atmospheric pressure. The piston speed is less at the Start of Suction Stroke. Hence, this less air Will be Sucked in at the begining. Thus, the difference b/w Atmospheric pressure & Suction pressure Will also be less. Later, as the piston picks up speed (during the middle of Suction Stroke). more mass of air Will entering. The pressure difference Will also be Known. Finally the speed decreases and the piston Comes to rest at BDC.

Hence, less air Will entering & Pressure difference Will also be less.

The actual suction process is therefore given by, 0 — a' — 1.

Actual Compression:

Due to heat Carried away by Cool Water, the actual Compression Process is polytropic & Work of Compression is higher (Area is more). It means that the slope of the actual Compression process will be more than that of adiabatic Compression. Hence, The index of Compression $(n > \gamma)$.

Actual Compression process is given by 1 — C — 2'.

Actual Heat Addition :-

Heat Addition takes place during a changing dirⁿ of of Piston at TDC. The volume of Charge first ↓ then ↑. The pressure ↑ throughout the Heat addition. The Heat addition process is given by 2'-3-d'.

Actual Expansion :-

Due to Heat Carried away by Cool Water, the actual Polytropic expansion process will have lesser work output (Area is less). The expansion process is shown by 3'-e-4'.

Actual Heat Rejection :-

During Heat Rejection, the piston undergoes change in dirⁿ at BDC. The volume of gases first ↑ and then ↓. The pressure ↓ throughout the heat Rejection. The Heat Rejection process is given by the curve 4'-f-1'.

Actual Exhaust :-

The Left over Gases after Heat Rejection is pushed by the next upward motion of the Piston out of the Cylinder through the exhaust valve (high pressure to lesser pressure) Thus, the exhaust pressure will be above atmospheric pressure. Depending on the piston speed, the exhaust process is given by 1'-b'-0.

It may be seen that the ~~area~~ in actual diagram area is of diagram by Combined Suction & exhaust process (0 - a' - 1 - 1' - b' - 0) and is Known as Pumping loss of the engine

This area is treated as (-ve). The area formed by the other operations is taken +ve and the net area is determined.

→ The Ratio of the net area to the area of a Ideal diagram is known as diagram factor of the engine. and is given by

Diagram factor;

$$df = \frac{\text{Actual Indicated Work done}}{\text{Ideal Indicated Work done}}$$

The mean height of the diagram is given by

mean height;—

$$\boxed{h_m = \frac{\text{Area of the Diagram}}{\text{Length of diagram}}}$$

& $\boxed{I_{mep} = h_m \times (\text{Spring Scale})}$

Q.17) Following observation were taken during trial of single cylinder 4-T oil engine running at full load positive area is 6.5 cm², the area of negative diagram is 0.5 cm². Length of diagram is 4 cm. The spring stiffness is 10 bar/cm speed is 400 RPM. The net break load is 35 kg. Diameter of brake drum is 120 cm. The mass of fuel per hour is 3 kg. The calorific value of fuel is 42000 KJ. The bore of the engine is 16 cm and stroke is 20 cm. Calculate IP, BP, η_m & η_{bth}.

$L = 20\ cm = 0.2\ m$

$d = 16\ cm = 0.16\ m$

$I.P = ?$ $\quad \eta_m = ?$

$B.P = ?$ $\quad \eta_{bth} = ?$

Soln)

$$h_m = \frac{6.5 - 0.5}{4}\ cm = 1.5\ cm$$

$$imep = h_m \times (\text{Spring Stiffness})$$
$$= 1.5 \times 10\ bar = 15\ bar$$

$N = 400\ rpm$

$F_b = 35\ kg \quad = 35 \times 9.8\ N$

$D_b = 120\ cm = 1.2\ m$

$r_b = 0.6\ m$

$m_f = 3\ kg/hr \quad HA/kg\ fuel = 42000\ KJ$

$$V_s = \frac{\pi}{4} d^2 L \times \frac{N}{2\times 60}$$

$$V_s = \frac{\pi}{4} \times 0.16^2 \times 0.2 \times \frac{400}{2\times 60}\ m^3/sec$$

$$\boxed{V_s = 0.0134\ m^3/sec}$$

$$I.P = IWD/sec = imep \times V_s$$
$$= \frac{(15\times 10^5) \times 0.0134}{1000}\ kW$$

$$\boxed{I.P = 20.1\ kW}$$

$$B.P = BWD/sec = F_b \times \frac{2\pi r_b}{1000} \times \frac{N}{60} = \frac{35\times 9.8\,(2\pi \times 0.16) \times 400}{60 \times 1000}\ kW$$

$$\boxed{BP = 8.6\ kW}$$

$$\eta_m = \frac{B.P}{I.P} = \frac{8.6}{20.1} = 0.49 \text{ or } 49.9\%$$

$$\boxed{\eta_m = 0.49 \text{ or } 49.9\%}$$

$$HA/sec = HA/kg\,fuel \times m_f/sec = 42000 \times \frac{3}{3600}\ kJ = 35\,kJ$$

$$\boxed{HA = 35\ kJ}$$

$$\eta_{BT} = \frac{BWD/sec}{HA/sec} = \frac{8.6}{35} = 0.246 \text{ or } 24.6\%$$

$$\boxed{\eta_{BT} = 0.246 \text{ or } 24.9}$$

Qn) A 6 Cylinder 4-T SI engine of 10×12 cm (bore/Stroke) is tested at 4800 rpm on a dynamometer arm (Brake Radius) of 55 cm. During a 10 minute test, the dynamometer reaches 45 kg & engine Consumed 5 kg of Petrol. The Calorific value is 45 MJ. The Carburettor recives the air at 29°c & at one bar (1 bar) at 10 kg/min then, Calculate;

1) BP
2) BmeP
3) Bsfc
4) BSAC → Brake Specific Air Consumption
5) ~~Bth~~ η_{bth}
6) Air fuel Ratio
7) volumetric efficiency

Soln) 10×12 (bore/stroke)

$N = 4800 \text{ rpm}$

$r_b = 55 \text{ cm} = 0.55 \text{ m}$

$F_b = 45 \text{ kg} = (45 \times 9.8) \text{ N}$

$m_f = \frac{.5}{10} \text{ kg/min}$

$HA/\text{kg fuel} = 45 \text{ MJ} = 45000 \text{ KJ}$

$T_1 = 29°C = 302 K$

$P_1 = 1 \text{ bar} \qquad M_a = 10 \text{ kg/min}$

$B.P = ? \qquad bmeP = ? \qquad Bsfc = ? \qquad BSAC = ? \qquad \eta_{bth} = ? \qquad AFR = ? \qquad \eta_v = ?$

$$B.P = F_b \times \frac{2\pi r_b}{1000} \times \frac{N}{60} = \frac{(45 \times 2\pi \times 0.55)}{1000 \times 6} \times 4800 \text{ Kw} = 121.9 \text{ Kw}$$

$$\boxed{B.P = 121.9 \text{ KW}}$$

$$V_s = 6\left(\frac{\pi}{4} d^2 \times L \times \frac{N}{2 \times 60}\right) = 6 \times \frac{\pi}{4} \times 0.1^2 \times 0.12 \times \frac{48000}{2 \times 60} \text{ m}^3/\text{sec} = 0.226 \text{ m}^3/\text{sec}$$

$$\boxed{V_s = 0.226 \text{ m}^3/\text{sec}}$$

$$bmep = \frac{BWD/\text{sec}}{V_s/\text{sec}} = \frac{121.9 \times 1000}{0.226 \times 10^5} = 5.4 \text{ bar}$$

$$\boxed{bmeP = 5.4 \text{ bar}}$$

$$bsfc = \frac{m_f/hr}{B.P} = \frac{5/10 \times 60}{121.9} = 0.246\ Kg/kw\,hr$$

$$\boxed{Bsfc = 0.246\ Kg/Kw/hr}$$

$$bsac = \frac{m_a/hr}{B.P} = \frac{10 \times 60}{121.9} \frac{Kg}{Kwhr} = 4.92\ Kg/kw\,hr$$

$$\boxed{bsac = 4.92\ Kg/kwhr}$$

$$HA/sec = HA/_{Kg\,fuel} \times m_f/sec = 45000 \times \frac{5}{60 \times 10}\ KJ = 375\ KJ$$

$$\boxed{HA/sec = 375\ KJ}$$

$$\eta_{BT} = \frac{BWD/sec}{HA/sec} = \frac{121.9}{375} = 0.325 \text{ or } 32.5\%$$

$$\boxed{\eta_{BT} = 0.325 \text{ or } 32.5\%}$$

$$AFR = \frac{m_a}{m_f} = \frac{10}{5/10} = 20$$

$$\boxed{AFR = 20}$$

$$P_1V_1 = m_a R_a T_1 \text{ or } V_a = \frac{m_a R_a T_1}{P_1} = \frac{10}{60} \times \frac{287 \times 302}{1 \times 10^5}\ m^3/sec$$

$$= 0.144\ m^3/sec$$

$$\eta_{vol} = \frac{V_a}{V_s} = \frac{0.144}{0.226} = 0.637 \text{ or } 63.7\%$$

$$\boxed{\eta_{vol} = 0.637 \text{ or } 63.7\%}$$

Very important

Difference b/w Theoritical and Actual valve timinigs of Four stroke Petrol Engine :-

→ At (A), end of exhaust stroke and beginning of Suction stroke, Piston is at TDC.. Inlet valve is fully open.

→ (A-B) rotation of Shaft during Suction stroke Inlet valve Remains fully open.

→ At, B, end of Suction stroke, piston is at BDC, Compression stroke begins, inlet valve fully closed.

→ (B-C), Rotation of Shaft during Compression stroke, both Valves remains closed.

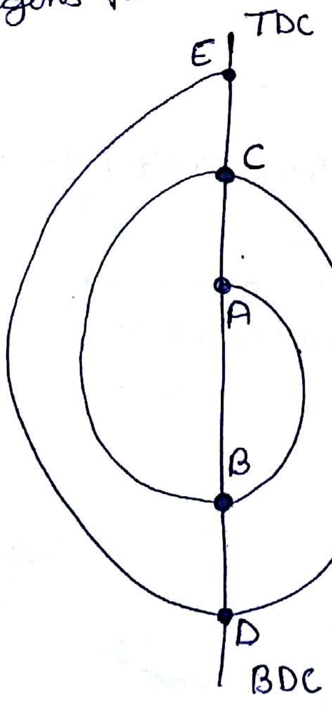
→ At, C, End of Compression stroke, piston is at TDC. Heat Addition begins and also gets over.

→ (C-D), rotation of Shaft during expansion stroke both Valve remain closed.

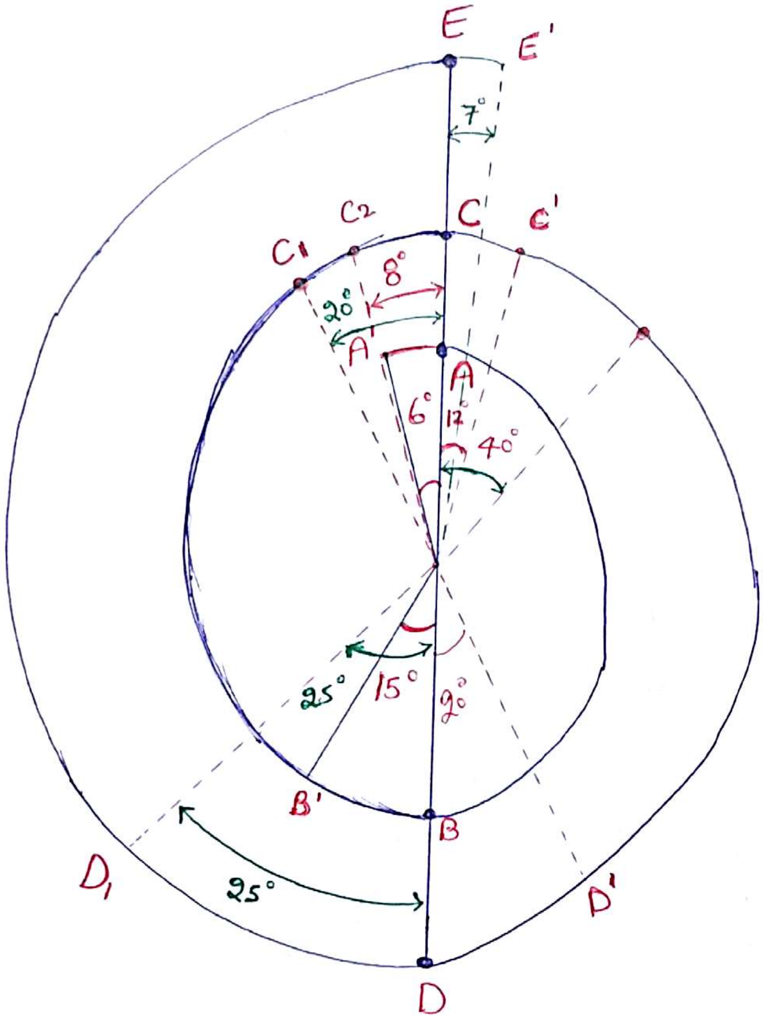
→ At. D, end of of expansion stroke, Piston is at BDC, exhaust valve is fully opened. Heat Rejection begins & also gets over.

→ (D-E), rotation of shaft during exhaust stroke. exhaust valve remains fully opened. ~~AFE~~

→ At E, end of exhaust stroke, exhaust valve fully closed. Suction stroke begins for the next cycle.



Theoritical Diagram



At A' – 6° Remains for end of the exhaust stroke of the Previous Cycle. Inlet Valve begins to open.

→ At A – End of exhaust stroke, then begining of Suction stroke inlet Valve is fully opened.

→ At-B — End of Suction stroke, piston is at BDC, begining of Compression Stroke, inlet valve begins to close.

→ At B' – 15° of rotation is Completed, from the start of Compression stroke. Suction valve is fully closed.

→ At C_1 → 20° remain for end of Compression stroke, Sparking begins.

→ At C_2 – 8° Remain for end of Compression stroke. Ignition begins.

→ **At C** – end of Compression stroke, beginning of expansion stroke piston is at TDC.

→ **At C'** – 12° of rotation is over from the start of the expansion stroke. Sparking stops. Both sparking & ignition takes place from C_2 to C'.

Only ignition exists beyond this point.

→ **At C''** – Ignition stops for 40° of rotation is completed from the start of the expansion stroke. Only expansion takes place beyond this point.

→ **At D'** – 20° Remains for end of expansion stroke. ~~Ex~~ Exhaust valve begins to open. Both valves remains closed from B'–D'. Heat Rejection Begins at D'.

→ **At D** – End of expansion stroke, Piston is at BDC. Exhaust valve is fully opened. Heat Rejection Continues.

→ **At D_1** – 25° of Rotation is Completed After the end of expansion Stroke. Heat Rejection gets over. Exhaust process begins. Exhaust Continues beyond this point.

→ **At E** – End of exhaust stroke. Rotation begins for the suction stroke of next cycle. Exhaust valve begins to close.

→ **At E'** – 7° of Rotation is Completed for the next Cycle. Exhaust valve is fully closed.

Imp

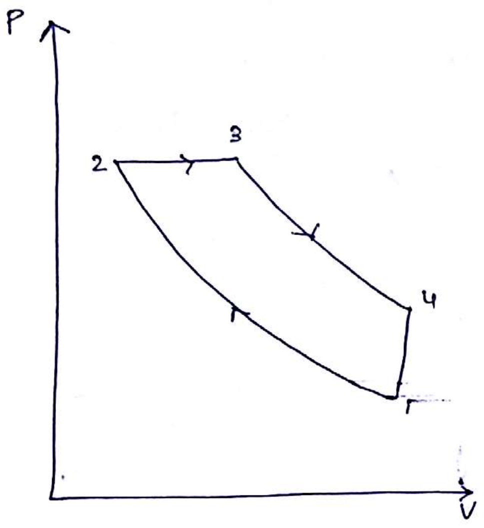
It may be seen, from the end of exhaust stroke to the begining of the Suction stroke, both valves (either partly or fully) remain open at the same time and is known as "valve operlap of the engine".

This Valve overlap, should be for as small an angle, as Possible.

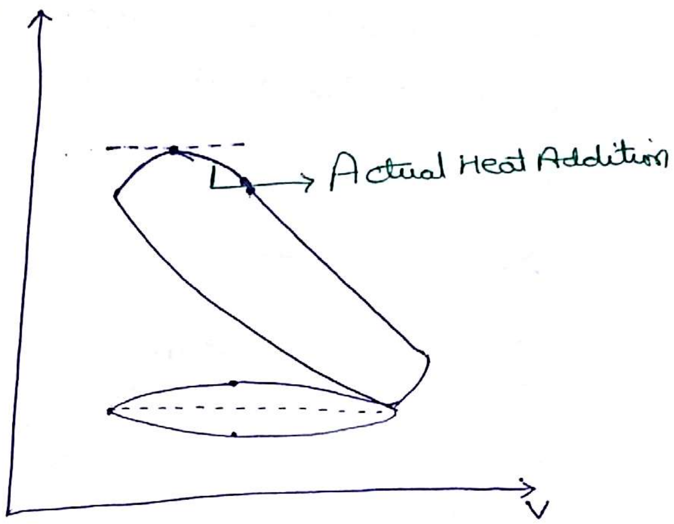
↗ Reason

Otherwise more Amount Of fuel in the fresh Air fuel Mixtures, Entering in through inlet valve will esccape out the exhaust Value.

→ Actual P-V Diagram for Diesel Engine :-



Theoritical P-V
Diesel

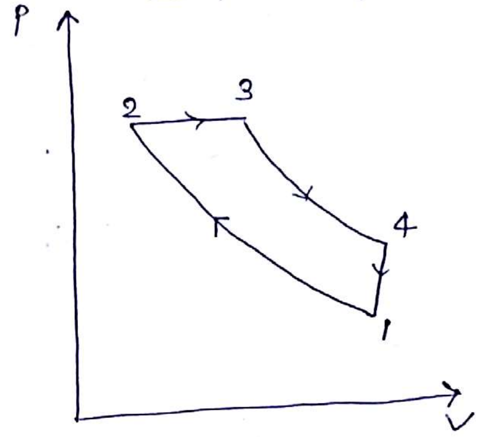


Actual P-V
Diesel

Qn) Volume Ratio for expansion & Compression for a diesel engine 15.3 & 7.5 Respectively. The pressure and temp. at the beginning of Comp^{n} 1 bar and 21°C. Determine the mep, then ratio of maximum pressure to mean effective pressure & cycle efficiency. Also find fuel consumption per kw/hr if the Indicated thermal efficiency is 50% of Air Standard efficiency. η_m of the engine is 80%. Calorific of the fuel is 42000 KJ/Kg

~~Data~~

Diesel Cycle



Soln)

$r = 15.3 = \frac{V_1}{V_2}$

$\frac{r}{\rho} = 7.5 = \frac{V_4}{V_3}$ Expansion Ratio

bcz $\frac{V_3}{V_2} = \rho$

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

$\rho = \frac{r}{7.5} = \frac{15.3}{7.5} = 2.04$

$P_1 = 1$ bar

$T_1 = 27°C = 300K$

$\boxed{\text{Standard} \rightarrow \text{Ideal}}$

mep = ?

$\frac{P_{max}}{P_{mean}} = ?$

$\eta_p = ?$

bsfc = ?

$\eta_{IT} = 0.5\,\eta_p$

$\eta_m = 0.8$

HA/kg fuel = 42000 KJ

$\frac{V_1}{V_2} = \frac{15.3}{\cancel{7.5}} = \frac{V_c + V_s}{V_c}$

$\therefore \boxed{V_s = 14.3 V_c}$

$\Rightarrow V_c = \frac{V_s}{14.3} = 0.07 V_s = V_2$

$\boxed{V_c = 0.07 V_s = V_2}$

$V_1 = V_c + V_s\,(0.07 V_s + V_s) = 1.07 V_s = V_4$

$\boxed{V_1 = 1.07 V_s = V_4}$

$V_3 = \frac{V_4}{7.5} = \frac{1.07 V_s}{7.5} = 0.14 V_s$

$\boxed{V_3 = 0.14 V_s}$

$$P_2V_2^\gamma = P_1V_1^\gamma$$

$$\therefore P_2 = P_1\left(\frac{V_1}{V_2}\right)^\gamma \Rightarrow P_2 = 1\times 15.3^{1.4}\ \text{bar}$$

$$\boxed{P_2 = 45.55\ \text{bar} = P_3}$$

$$P_4V_4^\gamma = P_3V_3^\gamma$$

$$P_4 = P_3\left(\frac{V_3}{V_4}\right)^\gamma$$

$$P_4 = 45.55\left(\frac{1}{7.5}\right)^{1.4}\ \text{bar} = 2.71\ \text{bar}$$

$$\boxed{P_4 = 2.71\ \text{bar}}$$

$$W_1 = \frac{P_1V_1 - P_2V_2}{\cancel{\gamma}-1} = \frac{(1\times 1.07V_s - 45.55\times 0.07V_s)}{1.4-1} = -5.29\times 10^5\ V_s\ J$$

$$\boxed{W_1 = -5.29\times 10^5\ \cancel{V_s}\ \text{Joules}}$$

$$W_2 = P_2(V_3 - V_2) = (45.55\times 10^5)\cdot(0.14V_s - 0.07V_s)J = 3.18\times 10^5\ V_s\ J$$

$$\boxed{W_2 = 3.18\times 10^5\ V_s\ J}$$

work for closed cycle

$$W_3 = \frac{P_3V_3 - P_4V_4}{\gamma-1} = \frac{(45.55\times 0.14V_s - 2.71\times 1.07V_s)10^5}{1.4-1}\ J = 8.69\times 10^5\ J$$

$$\boxed{W_3 = 8.69\times 10^5\ J}$$

So total Work done per cycle,

$$W_1 + W_2 + W_3 = \text{WD Per cycle}$$

$$(-5.29 + 3.18 + 8.69)10^5\ V_s = P_m\times V_s$$

$$P_m = 6.6\times 10^5\ N/m^2 = 6.6\ \text{bar}$$

$$\boxed{P_m = 6.6\ \text{bar}}$$

$$\eta_D = 1 - \left(\frac{1}{r}\right)^{\gamma-1} \frac{\rho^{\gamma}-1}{\gamma(\rho-1)}$$

$$\eta_D = 1 - \left(\frac{1}{15.3}\right)^{1.4-1} \frac{(2.04)^{1.4}-1}{1.4(2.04-1)}$$

$$\boxed{\eta_D = 0.6 \text{ or } 60\%}$$

$$\eta_{IT} = 0.50\,\eta_P = 0.5 \times 0.6 = 0.3$$

$$\eta_m = \frac{\eta_{BT}}{\eta_{IT}} \Rightarrow \eta_{BT} = \underline{\eta_m} \times \eta_{IT} \Rightarrow \eta_{BT} = 0.8 \times 0.3 = 0.24$$

$$\boxed{\eta_{BT} = 0.24 \text{ or } 24\%}$$

Ans

or

$$\frac{BWD/sec}{HA/sec} = 0.24 \xrightarrow{\hspace{3em}} \text{Assuming BWD/sec as } x$$

$$HA/sec = \frac{x}{0.24}$$

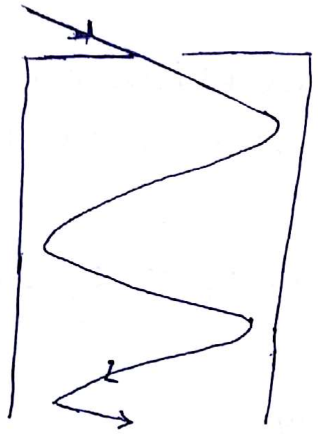
$$HA/\text{kg fuel} \times m_{f/sec} = \frac{x}{0.24}$$

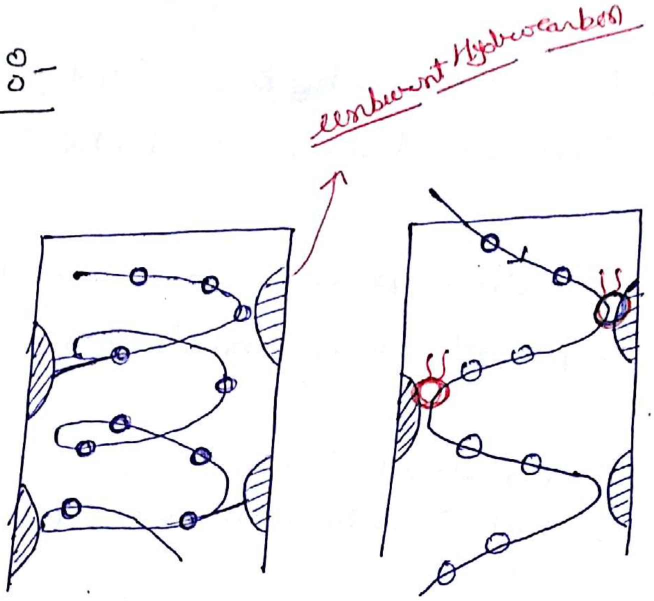
therefore, $m_f = \dfrac{x}{0.24 \times 42000}$ kg/sec

$$bsfc = \frac{m_f/hr}{B.P} = \frac{x \times 3600}{(0.24 + 42000) \times x} \ \text{kg/kwhr}$$

$$\boxed{bsfc = 0.357 \text{ kg/kwhr}}$$

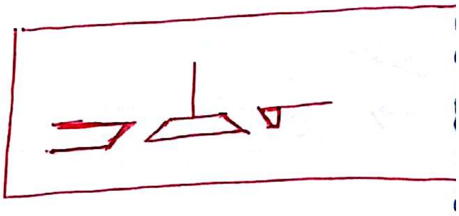
→ Preignition Or Misfiring :-





When unburnt Hydrocarbon Heated

Air get ignited by this heat, and causing Preignition, and Result in seizing



Misfiring is only for Petrol engine & it is not Applicable for Diesel.

The following are to be noted :-

→ During Suction, Air fuel Mixture enters the engine Cylinder With the vortex flow. This Vortex flow Continues untill exhaust.

→ During heat addition a few of the fuel Particles remains unburnt (unburnt Hydrocarbon) (UBHC). This UBHC Willbe in circulation along with the Hot gases.

→ Some of the UBHC Particles stick to the inner Walls of the Cylinder during the circulation.

→ During the next Cycle, Some fuel Particles in the fresh AFM Contact the UBHC. Some of them get ignited after a Chemical Rxn. on Receiving the heat from the UBHC. This ignition is Known as Preignition or Misfiring.

→ Heat From the preignited fuel Particles flows through the Surrounding air and the Particles expands in all dir^n.

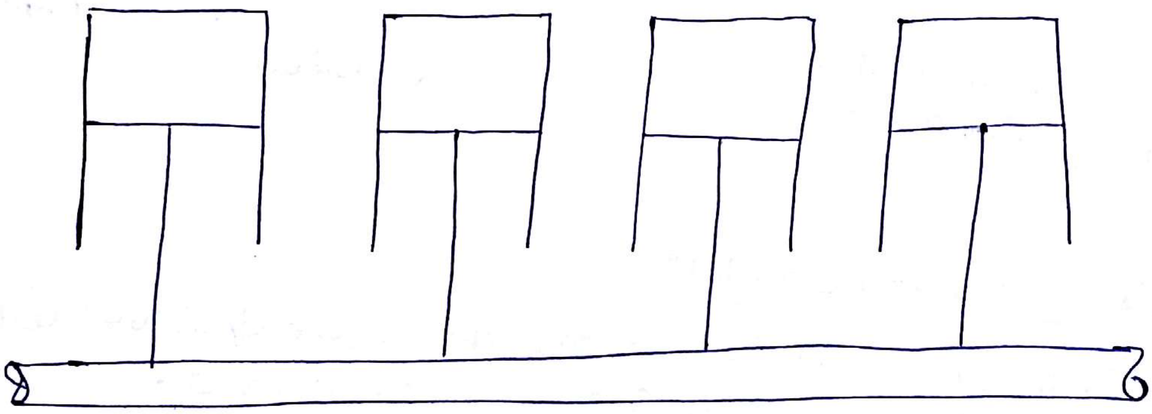
The air expanding downwards Collides with piston moving upwards during the Compression Stroke. Thus, there is loss of Work.

→ Under worst Condition the entire Work output of the cycle is will be lost Completely, due to misfiring.

→ Misfiring will takes place in SI engine only.

Imp.

→ Testing of I.C Engines :- (Morse Key Test) :-



$$4I = 4B - 4F \quad - ①$$

$$3I = 3B - 4F \quad - 2$$

$$\underline{- \qquad - \qquad +}$$

$$I = (4B - 3B)$$

$$4I' = 4(4B - 3B)$$

(Bcz Average e.g)

$$\begin{array}{cc} 65 & 70 \\ 71 & 70 \\ 74 & 70 \\ \hline 210 & 210 \end{array}$$

$$\boxed{\underset{\text{Averag}}{\underset{\downarrow}{70}} \times 3 = 210}$$

Let us Consider a four cylinder engine.

Let Brake power per cylinder = B

Indicated Power Per cylinder = I

Friction Power Per cylinder = F

(friction loss Per cylinder)

Initially, the engine is tested (with a dynamometer) for all the four Working cylinders and the BP is noted. We have for four Working cylinder,

$$4I = 4B + 4F \quad — ①$$

Later, one of the cylinder is cut off (fuel supply is stopped for Diesel engines or spark plug is short circuited in the case of Petrol / SI engines). The Brake Power is then noted for the remaining three cylinders.

In this manner, different single cylinder is cut off at a time and the brake power is noted. Four different readings for the BP of three Working cylinders Will be obtained.

if this readings are $3B_1$, $3B_2$, $3B_3$, $3B_4$ then, average of these readings Will be;

$$3B = \frac{3B_1 + 3B_2 + 3B_3 + 3B_4}{4} \quad — (A)$$

We have for three Working cylinders;

$$3I = 3B + 4F \quad — ②$$

equⁿ ① & equⁿ ② Gives

$$\begin{array}{l} 4I = 4B + 4F \\ \underline{\underset{-}{3I} \underset{-}{=} 3B \underset{-}{+} 4F} \\ \underline{I = (4B - 3B)} \quad — ③ \end{array}$$

Total IP of engine will be;

$$4I = 4(4B - 3B) \text{ — } ④$$

Depending up on other giving data, any other unknown value can be determined from this test.

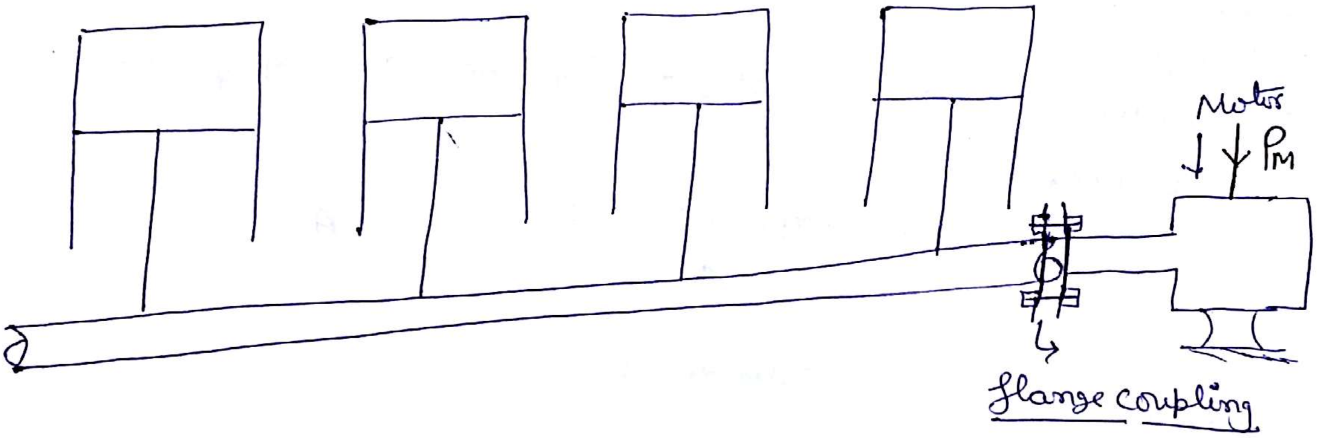
The following Points are to be noted :-

$$(4B - 3B) \neq B \text{ — (i)}$$

$$\& \quad (4B - 3B) \neq (3B - 2B) \text{ — (ii)}$$

$$\text{Also} \quad 4B \neq 4B \text{ — (iii)}$$

→ Motoring Test :-



The following Points are to be noted :-

1) During The Morse Key Test, Speed of engine must be noted

→ The engine must be stopped before Starting the motoring test.

→ The engine is then Coupled to motor attached to the dynamometer.

→ On Starting the motor, the Speed of the motor, must be equally to Speed of the engine during the morse test.

Imp.

→ The Power input to the motor will be equal to the frictional Power of the engine.

→ If the efficiency of the motor is given, then:

$$\text{frictional Power} = (\text{Power input to motor}) \times (\eta_{motor})$$

→

Qn) The following Readings were taken during the Morse Test of the 4-T Petrol engine.

Cylinder	B. Power (KW)
All cylinders firing	12.5
Cylinder no. 1 cut off	9.5
Cylinder no. 2 cut off	9.2
Cylinder no. 3 cut off	9.0
Cylinder no. 4 cut off	8.8

Determine Mechanical efficiency of the engine? Wht would be cylinder dimensions if stroke is 1.25 times the bore. The calorific value of the fuel is 42000 KJ. mass of fuel circulated is 0.07 kg/min. the clearance volume is 75 cm³. and the indicated thermal efficiency is 50% of Air standard efficiency?

Soln) $\eta_m = ?$ $d = ?$ $L = ?$ $L = 1.25d$

$HA/kg\,fuel = 42000\,KJ$ $m_f = 0.07\,kg/min$

$V_c = 75\,cm^3$ $\eta_{IT} = 0.5\,\eta_o$

$$4I = 4B + 4F$$

$$4I = 12.5 + 4F \quad — ①$$

for three cylinder any working one neglected so their average

$$3B = \frac{9.5 + 9.2 + 9.0 + 8.8}{4}$$

$$(3B = 9.125\,KW)$$

$$3I = 3B + 4F \quad \text{—} ②$$

Substracting eqⁿ ② by ①

$$\begin{array}{r}
4I = 4B + 4F \\
3I = 3B + 4F \\
- \quad - \quad - \\
\hline
I = (4B - 3B)
\end{array}$$

$$\boxed{I = 3.375 \text{ KW}}$$

So the Indicated Power of engine is;

$$4I = 4 \times 3.375 = 13.5 \text{ KW}$$

$$\eta_m = \frac{4B}{4I} = \frac{12.5}{13.5} = 0.9259 \text{ or } 92.59\%$$

$$\boxed{\eta_m = 0.09259 \text{ or } 92.59\%}$$

$$HA/sec = HA/kg\,fuel \times m_f/sec =$$

$$HA/sec = 42000 \times \frac{0.07}{60}$$

$$\boxed{HA/sec = 49 \text{ KJ}}$$

$$\Rightarrow \quad \eta_{IT} = \frac{IWD/sec}{HA/sec} = \frac{13.5}{49}$$

$$\Rightarrow \quad \eta_V = \frac{\eta_{IT}}{0.5} = \frac{13.5}{0.5 \times 49}$$

$$\text{or} \quad 1 - \left(\frac{1}{r}\right)^{1.4-1} = \frac{27}{49} \qquad \Rightarrow \boxed{\eta_V = 1 - \left(\frac{1}{r}\right)^{\gamma-1}}$$

$$r = 7.4$$

$$\frac{V_c+V_s}{V_c} = 7.4$$

$$V_s = 6.4\,V_c$$

$$V_s = 6.4 \times 75\,\text{cm}^3 = 480\,\text{cm}^3$$

$$\boxed{V_s = 480\,\text{cm}^3}$$

$$\frac{\pi}{4} d^2 \times L = 480$$

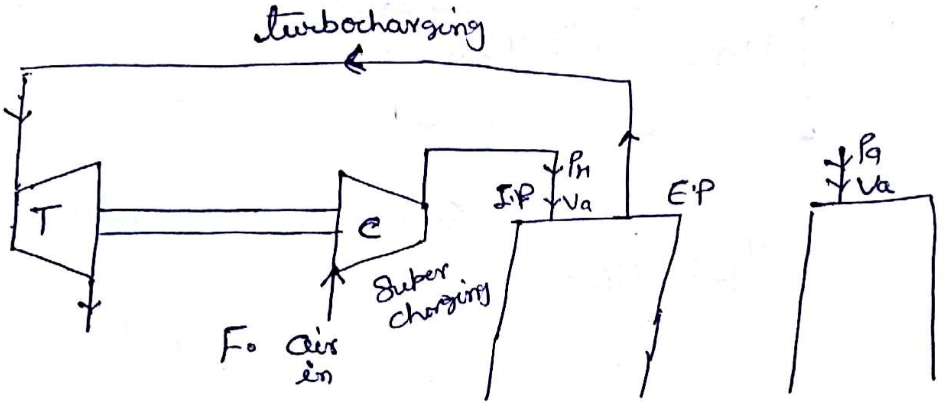
$$\frac{\pi}{4} d^2 \times 1.25\,d = 480\,\text{cm}^3$$

$$\boxed{d = 7.8\,\text{cm}}$$

$$\boxed{L = 1.25\,d = 9.84\,\text{cm}}$$

→ Supercharging :-

Supercharger (Compressor) :-
Rotary Type



$P_a \leftarrow P_H$

$V_a > V_a \leftarrow V_a$

→ Supercharger is A Rotary Compressor.

→ Super charger is attached to I.C Engines, Just before the engine's cylinder (in the Case of Petrol engines, it is attached before the Carburettor).

→ The mass of Air circulated is ↑ due to Supercharging.

→ For I.C Engines The pressure After supercharging is 1.5 times to 2 times the entry pressure.

→ Superchargers for I.C Engines are of two types;

- → In one type of Supercharger, it is driven by engine shaft
- → In another Type of Supercharger, the exhaust from the engine is used to drive a turbine and the turbine runs the super charger.

Such a Supercharger is Known as Turbocharger.

Following are the Advantage of Supercharging ;

1) Higher Work output & hence higher thermal efficiency of the engine.

2) At higher Altitudes (flight of Aircrafts), Supercharging of Air helps in reducing the consumption of fuel.

3) There is an ↑ in the volumetric efficiency of the engine i.e (η_v)

4) There is relaxtion in Specific fuel Consumption of the engine.

* 5) The energy in the exhaust gas is utilized to turn the turbocharger.

** 6) Scvanging is better in a Super charge engine.

Disadvantages

1) Higher thermal stresses in the different moving Parts of the engine, including the bearing of the shaft. This neccessiates the Replacement of the moving Part earlier.

2) There is more leakage of air passed the piston.

*** 3) Supercharging ↑ the temperature of Air. This increases Knocking in Petrol engines.

④ Using Supercharger for petrol engines, an intercooler must be used. this increases the Cost of & ~~at~~ overall size of the engine.

Carburettors

→ Working of a Simple Plain tube Carburettor :-

A Simple Plain tube Carburettor Consist of two different Sections of Chamber.

One Section is Known as main unit (MU) & the other section is called the float Chamber (FC).

A pipe extends from the main unit to the inlet valve of the engine Cylinder. This pipe is Known as the intake manifold. During Suction inside the engine cylinder, the Vaccume extends to the main unit, through the intake manifold.

This Vaccume in the main unit sucks the air from the atmosphere (After filtering). The Area of Cross section of the main unit, Keeps on decreasing in the direction of the Air flow and at a particular Point on main unit, the area of cross section is a minimum and is Known as throat or Venturie. The velocity of Air as flowing the throat will be a maximum. It is at the throat that the fuel, from the float chamber is pulled by the air flow into the main unit. The flow of fuel from the flow chamber to main unit, takes place through a pipe Known as the metering Jet.

The tip of the metering jet at the throat is Known as the discharge jet or the Orifice. The other end of the metering jet, is attached is too. This Screw is Known as metering Screw. The flow of the fuel through the metering jet is Controlled by the Operation of the metering Screw. The air and fuel are present in the main unit below the Venturie. Hence mixing takes place between them, In this space. Thus, this regin is Known as the mixing chamber.

The following event takes place during mixing in the mixing Chamber :-

1) Atomization :-

Fuel, flowing out of the discharge Jet, gets divided into Very fine & Small masses, known as atomizatation. Due to this reason, fuel Spreads over the entire mixing chamber and thus, Very good mixing takes place b/w the air and the fuel.

2) Vapourization :-

Vapourization is atomization and then change in state of a fuel from liquid to Vapour. Vapourization is done to have an efficient Combustion of the Air fuel Mixture, during heat addition in the Clearnac volume (Combustion chamber) of the engine Cylinder.

3) Uniform Distribution Of Air and fuel :-

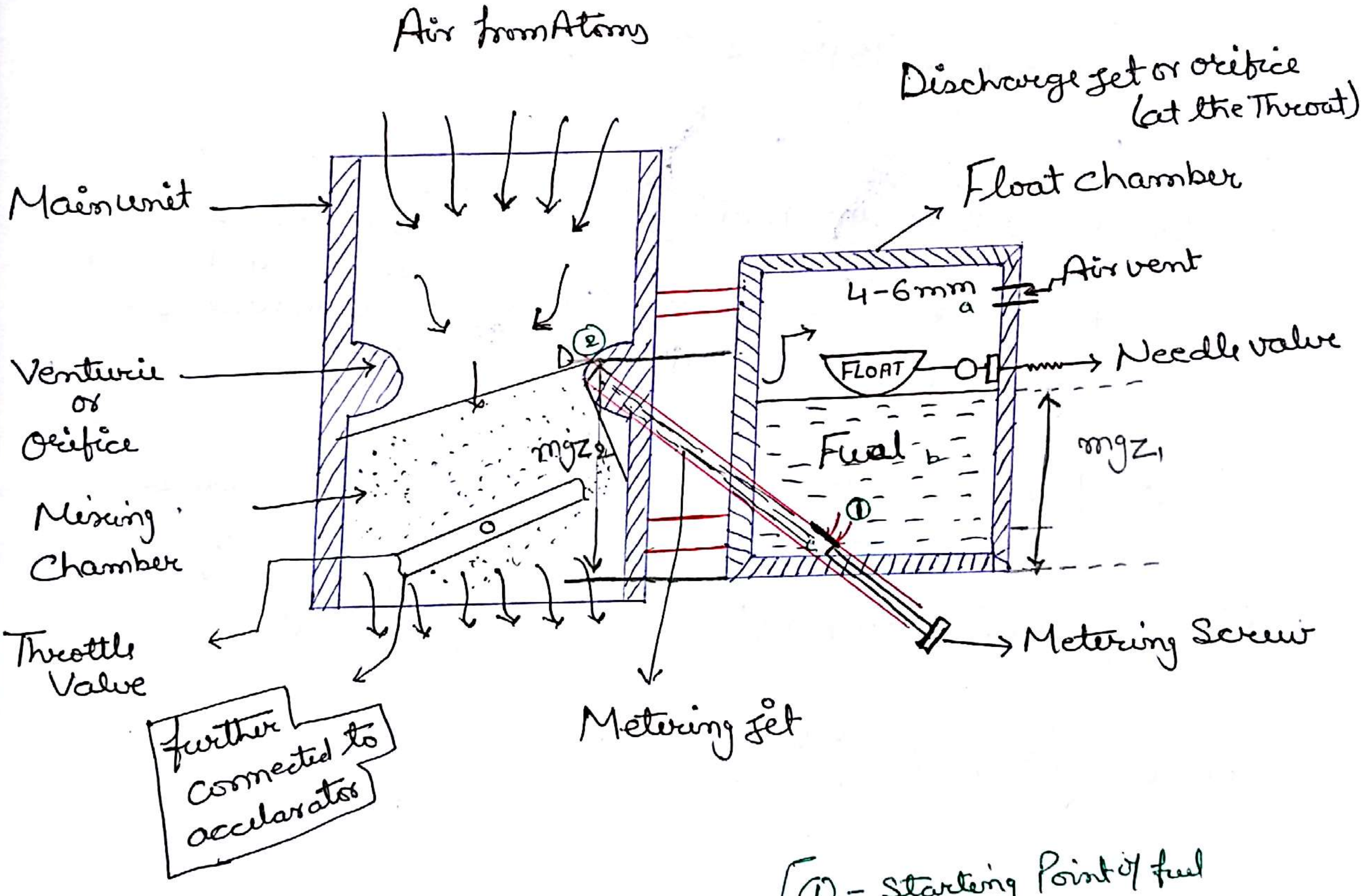
The Air fuel Ratio will be the Same at all the points in the mixing chamber.

There is a valve in the main unit, below the mixing Chamber, i.e. Operator to Control the Quantity of the air fuel mixture, into the engine cylinder, through the intake manifold. There is a hollow vessel that always floats on the Surface of the fuel in the float chamber. A valve is attached to this hollow vessel. A Hollow vessel is known as float & the Valve is known as the needle Valve.

When the level of fuel ↓ in the float chamber, the float lowest down and the needle Valve opens, fuel from the fuel tank floats into the float chamber, through the needle Valve.

As, the level rises in the float chamber, the float moves up and the needle valve closes. Thus, the level of the fuel is maintaining in the float chamber. This level is 4-6 mm below the discharge jet in the main unit.

There is a gap in the float chamber, i.e left open to the atmosphere and is known as the air vent. ~~Air vent~~ This gap is to ensure that atmospheric pressure will act on the surface the fuel, at all time in the float chamber for the different height of the fuel. So that, there will be good flow of fuel always through the metering jet.



① - Starting Point of fuel
② Exit of fuel.

Pressure at a, b, c is almost same

Air Fuel Ratio :-

Case 1) When the flow of air is adiabatic.
(from entry ① to throat ②)

$$\text{Density};\ \rho = \frac{\text{mass}}{\text{volume}} = \frac{P \times V}{(RT)\times V} \quad \text{or} \quad \boxed{\rho = \frac{P}{R \times T}}$$

And,
$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma} \quad \text{or} \quad P_1\left(\frac{m}{\rho_1}\right)^{\gamma} = P_2\left(\frac{m}{\rho_2}\right)^{\gamma}$$

$$\therefore \boxed{\rho_2 = \rho_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}}}$$

Imp

Considering the energy equation :-

b/w Pt 1 & 2
very small change in
Potential energy so we
neglect it

$$H_1 + \underset{\text{(negligible)}}{\frac{1}{2} m C_1^2} = H_2 + \frac{1}{2} m C_2^2$$

$$\therefore \frac{1}{2} m C_2^2 = (H_1 - H_2)$$

As it is Adiabatic Process

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\text{or} \quad \frac{1}{2} m C_2^2 = m C_p T_1 \left(1 - \frac{T_2}{T_1}\right)$$

$$\therefore C_2 = \sqrt{2 C_p T_1 \left(1 - \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right)} \quad \text{——} \quad ①$$

Q. Why Cd is used in Carburettor
bcz due to throat b/w main unit flow of air is reduce from
top to mid Part

Mass flow (at the throat)

Actual mass/sec = C_d × ideal mass = $C_2 (P_2 \times V_2/\text{sec})$

$V_2 \rightarrow$ volume$_2$

Or

$$\boxed{\dot{m}/\text{sec} = C_d \times \rho_1 \left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}} \times A_2 \times C_2}$$

$C_d \rightarrow$ Cofficient of discharge

$$\boxed{C_d = \frac{m_a}{m_i}}$$

Case 2 :- When the flow of air is incompressible.

Assumptions :-

(i) $\rho_2 = \rho_1 = \rho$

(ii) $T_2 = T_1$

(iii) $P_2V_2 \neq P_1V_1$

Considering the energy equation :-

$$H_1 + \frac{1}{2} m C_1^2 = H_2 + \frac{1}{2} m C_2^2 \longrightarrow \text{or } (\cancel{U_1} + P_1V_1) = (\cancel{U_2} + P_2V_2) + \frac{1}{2} m C_2^2$$

(negligible)

As $(T_2 = T_1)$

$$\therefore \frac{1}{2} \cancel{m} C_2^2 = P_1V_1 - P_2V_2 = P_1\left(\frac{\cancel{m}}{\rho}\right) - P_2\left(\frac{\cancel{m}}{\rho}\right)$$

$$\therefore C_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}} \qquad \text{———} \quad ②$$

Mass Flow :- (for Air)

$$\text{Actual mass/sec} = C_d \times \text{ideal Mass/sec}$$

$$= C_d \times (\rho \times \text{vol}_2/\text{sec})$$

Or

$$m/\text{sec} = C_d \times \rho \times (A_2 \times C_2)$$

$$= C_d \times \rho \times A_2 \sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

$$\boxed{\text{mass per sec}; \quad m/\text{sec} = C_d A_2 \sqrt{2(P_1 - P_2)\rho}}$$

Important

Fuel Flow :-

The fuel flow takes place from the entry to the metering jet to the discharge jet. Since, the fuel is a liquid, the fuel flow will be only incompressible.

Considering the energy equation & we get;

$$H_1 + \underbrace{\frac{1}{2} m C_1^2}_{\text{(negligible)}} + mgZ_1 = H_2 + \frac{1}{2} m C_2^2 + mgZ_1$$

mgZ₁ & mgZ₂ are height as we considering Potential energy

$$\text{Or } H_1 - H_2 = \frac{1}{2} m C_2^2 + mg(Z_2 - Z_1)$$

Or

$$(\cancel{U_1} + P_1V_1) - (\cancel{U_2} + P_2V_2) = \frac{1}{2} m C_2^2 + mgZ$$

as ($T_1 = T_2$)

$$(P_1V_1 - P_2V_2) - mgZ = \frac{1}{2} m C_2^2$$

Or

$$P_1\left(\frac{m}{\rho}\right) - P_2\left(\frac{m}{\rho}\right) - mgZ = \frac{1}{2} m C_2^2$$

$$C_2 = \sqrt{2\left(\frac{P_1 - P_2}{\rho} - gZ\right.} \quad \text{——} \quad ①$$

Mass flow :- For fuel

$$\text{Actual mass/sec} = C_d \times \text{Ideal mass/sec}$$

$$= C_d \times \rho \times \text{vol}_2/\text{sec} = C_d\, \rho\,(A_2 \times C_2)$$

$$\therefore\ m/\text{sec} = C_d \cdot \rho A_2 \sqrt{2\left[\frac{P_1 - P_2}{\rho} - gz\right]}$$

$$m/\text{sec} = C_d A_2 \sqrt{2\rho(P_1 - P_2) - \rho g z}$$

$\boxed{Z \rightarrow \text{height} = H}$

Air Fuel Ratio for Incompressible Flow of Air :-

$$\text{Air fuel Ratio} = \frac{\text{Mass of air}}{\text{Mass of fuel}}$$

$$AFR = \frac{m_a}{m_f} = \frac{Cd_{(a)} \times A_{2(a)} \sqrt{2(P_1 - P_2)\rho_a}}{Cd_{(f)} \times A_{2(f)} \sqrt{2(P_1-P_2) - \underset{\text{(negligible)}}{\rho_f g Z}}}$$

$$AFR = \frac{m_a}{m_f} = \frac{Cda}{Cd_f} \times \frac{A_{2(a)}}{A_{2(f)}} \sqrt{\frac{\rho_a}{\rho_f}}$$

Or

$$\boxed{\frac{m_a}{m_f} = AFR \propto \sqrt{\rho_a}}$$

At, higher Altitudes (flight of Air crafts), where the density of air is less. They Air fuel ratio from the above equation will be a rich mixture. To Overcome this drawback, an angular Space (Jacket) is introduced around the main unit.

The Vaccume in the main unit, extends to the jacket. Hence, Some amount of atmospheric air, also enters into the jacket. This air ~~tothen~~ then mixed with air fuel mixture in the main unit below the throttle valve, Hence, the rich air fuel mixture is transformed into the normal air fuel mixture.

Qn) 13 A Simple Carburettor has to supply 5 Kg air per minute, the atmospheric ~~pr~~ air is at 1.013 bar & 27°c. Calculate the diameter at the throat if the flow velocity is 90 m/sec. The C_v (coefficient of velocity) = 0.8 Assume isentropic flow?

Soln)

mass/min(a) = 5 Kg

$$\boxed{\rho_1 = \frac{P_1}{RT_1}}$$

$P_1 = 1.013$ ~~Kg~~ bar

$T_1 = 27°C = 300K$

$d_2 = ?$ $C_2 = 90 m/s$

$C_v = 0.8$

Isentropic flow

$$mass/sec = C_d \times \rho_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}} \times A_2 \times C_2 \quad — ①$$

$$C_2 = C_v\sqrt{2C_pT_1\left(1-\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}\right]} \quad — ②$$

Or $$90 = 0.8\sqrt{2\times1000\times300\left(1-\left(\frac{P_2}{P_1}\right)^{\frac{1.4-1}{1.4}}\right)}$$

So, $\frac{P_2}{P_1} = 0.928$

$$\rho_1 = \frac{P_1}{RT_1}$$

$$= \frac{1.013\times10^5}{287\times300} \text{ Kg/m}^3$$

$$\rho_1 = 1.176 \text{ Kg/m}^3$$

from eqn ①

$$mass/sec = C_d \times \rho_1 \times \left(\frac{P_2}{P_1}\right)^{\frac{1}{\gamma}} \times A_2 \times C_2$$

~~$\frac{5}{60} = 1 \times 1.176$~~ $$\frac{5}{60} = 1 \times 1.176 \times (0.928)^{\frac{1}{1.4}} \times \frac{\pi}{4} d_2^2 \times 90$$

$$\boxed{d_2 = 0.0318 m \text{ or } 31.8 mm}$$

Qn 14 Very important

↳ A Venturie of Simple Carburettor has a throat diameter of 20mm and fuel orifice diameter is 1·120mm. The level of petrol surface in the float chamber is 6mm below the throat. Assume ~~the~~ in Compressible flow.

$C_{do} = 0.85$ $C_{df} = 0.78$ $\rho_1 = 750\ \text{Kg/m}^3$

Calculate;

1) AFR (Pressure drop is 0·08 bar)
2) Petrol Consumption in Kg/hr
3) Critical air velocity.

(Take $P_1 = 1\text{bar}$ & $T_1 = 29°C$)

Soln) $d_{2(a)} = 20\text{mm}$

$d_{2(f)} = 1{\cdot}12\text{mm}$

$Z = 6\text{mm} = \frac{6}{1000}\text{m}$

flow is incompressible

$C_{d(a)} = 0.85$

$C_{d(f)} = 0.78$

$\rho_{(f)} = 750\ \text{Kg/m}^3$

$\Delta P = (P_1 - P_2) = 0{\cdot}08\text{bar}$

$P_1 = 1\text{bar}$, $T_1 = 29°C = 302K$

As flow is incompressible, Considering eqn;

(i) $$AFR = \frac{C_{d(a)}}{C_{d(f)}} \times \frac{A_{2(a)}}{A_{2(f)}} \sqrt{\frac{2(P_1 - P_2)\rho_a}{2\rho_{(f)}(P_1 - P_2) - \rho_f gz}}$$

$$AFR = \frac{0.85}{0.78} \times \frac{20^2}{1{\cdot}12^2} \sqrt{\frac{2 \times 0{\cdot}08 \times 10^5 \times 1{\cdot}15}{2 \times 750 [0{\cdot}08 \times 10^5 - 750 \times 9{\cdot}8 \times \frac{6}{1000}}} = 13{\cdot}6$$

$$\boxed{AFR = 13{\cdot}6}$$

(ii) $$m_f = C_{d(f)} \times A_{2(f)} \sqrt{2\rho_{(f)}(P_1 - P_2) - \rho_{(f)} g Z}$$

Or

$$m_{(f)} = 0.78 \times \frac{\pi}{4} \times \left(\frac{1.12}{1000}\right)^2 \sqrt{2\times750\left[0.08\times10^5 - 750\times9.8\times\frac{6}{1000}\times 3600\right.}$$

$$\boxed{m_{(f)} = 9.56\ \text{Kg/hr}}$$

iii) Critical Air velocity:

Critical velocity of Air is that velocity, when the fuel is at the verge of flowing (about to flow) into metering jet. hence in this Case, the mass of fuel flow is just zero.

We thus, have mass of fuel flow = 0

$$m_f = 0$$

Or

$$C_{d(f)} \times A_{2(f)} \sqrt{2\rho_{(f)}\left[(P_1 - P_2)_{crit} - \rho_f g Z\right]} = 0$$

$$\therefore (P_1 - P_2)_{Critical} - \rho_{(f)} g Z = 0$$

$$(P_1 - P_2)_{crit} = \rho_{(f)} g Z = 750 \times 9.8 \times \frac{6}{1000}$$

$$(P_1 - P_2)_{crit} = 44.1\ \text{N/m}^2$$

$$(C_2)_{crit} = \sqrt{\frac{2(P_1 - P_2)_{crit}}{\rho_a}} = \sqrt{\frac{2\times44.1}{1.15}}\ \text{m/s} = 8.7\ \text{m/s}$$

$$\boxed{(C_2)_{crit} = 8.7\ \text{m/s}}$$ Ans

Qn T [redacted]

Qn) Determine the AFR at 6000m altitude in a Carburettor adjusted to give an AFR of 15 at Sea level, where the air temp is 27°C and Pressure is 1.013bar. The temp. of air at any altitude is given by the equation $t_h {}^\circ C = t_s ({}^\circ C) = -0.0065h$. The pressure at any height is given by the equation,

$$h = 19220 \log_e \frac{1.013}{P(\text{bar})}$$

Soln $AFR \propto \sqrt{\rho_a}$

impt link $AFR \propto \sqrt{\rho_a}$

$$AFR = K\sqrt{\rho_a}$$

$$(AFR)_h = K\sqrt{\rho_h}$$

$$(AFR)_s = K\sqrt{\rho_s}$$

$$\frac{(AFR)_h}{(AFR)_s} = \sqrt{\frac{\rho_h}{\rho_s}} \quad \text{— ①}$$

$$\boxed{\begin{array}{l} PV = mRT \\ \frac{m}{V} = \rho = \frac{P}{RT} \end{array}}$$

$$\rho_s = \frac{P_1}{RT_1} = \frac{1.03 \times 10^5}{287 \times 300} = 1.76 \ \text{kg/m}^3$$

$$\boxed{\rho_s = 1.176 \ \text{kg/m}^3}$$

or

$$t_h = (27 - 0.0065) \times 6000)^\circ C = -12^\circ C = 261 K$$

$$\boxed{t_h = -12^\circ C \text{ or } 261 K}$$

Also,

$$\log_e \frac{1.013}{P_h} = \frac{6000}{19220} \text{ or } \frac{1.013}{P_h} = e^{\frac{6000}{19220}}$$

$\therefore P_h = 0.74$ bar.

$$\rho_h = \frac{P_h}{RT_h} = \frac{0.74\times10^5}{287\times261} \text{ kg/m}^3 = 0.989 \text{ kg/m}^3$$

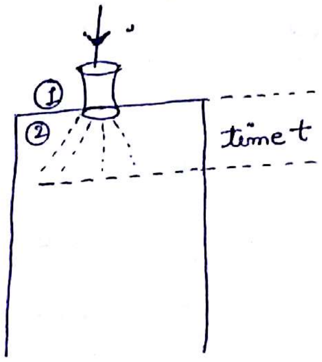
$$\boxed{\rho_h = 0.989 \text{ kg/m}^3}$$

from ①

$$(AFR)_h = 15 \times \sqrt{\frac{0.989}{1.15}} = 13.76$$

$$\boxed{(AFR)_h = 13.76}$$ Ans

Diesel Fuel Injection :-



$$t = \frac{\theta}{60} \quad — ①$$

$$\rho = \frac{m/sec}{vol/sec} \quad — ②$$

$$C_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}} \quad — ③$$

$$Vol/sec = Vol/cycle \times No.\ of\ cycles/sec \quad — ④$$

movement of Shaft

Speed of Shaft is const.
i.e = N rpm
Oscillation → Cycles

$$\boxed{\frac{1}{t} = f = \frac{No.\ of\ Cycles}{sec}}$$

$$Vol/sec = Vol/cyc \times No.\ of\ Cycles/sec$$

or

$$\boxed{Vol/sec = Vol/cycle \times f = Vol/cycle \times \frac{1}{t}}$$

$$\therefore\ vol/cyl = Vol/sec \times t$$ that for ideal Cycle.

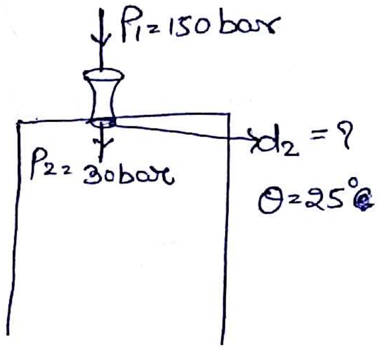
$$vol/cycle = Cd \times vol/sec \times t$$ for Actual Cycle.

$$\boxed{Vol/cycle = Cd \times A_2 \times C_2 \times t} \quad ——— ⑤$$

Qn

Qn) A Single Cylinder 4T diesel engine running at 1500rpm. uses 2.5 Kg of fuel Per hour. The specified gravity of fuel is 0.88. The injection pressure is 150 bar & the cylinder pressure is 30bar find the diameter of fuel orifice. The injection Period is 25° = C.

$C_d = 0.88$ for fuel orifice.



Soln) 4 stroke Diesel engine

$N = 1500$ rpm

$m_f = 2.5$ Kg/hr → m/sec (divide by 3600)

$\rho = 880$ kg/m^3

$C_d = 0.88$

$$t = \frac{\theta}{6N} = \frac{25}{6\times1500}\text{ sec} = \frac{1}{360}\text{ sec} \qquad \boxed{t = \frac{1}{360}\text{ sec}}$$

$$\text{vol/sec} = \frac{\text{m/sec}}{\rho} = \frac{2.5}{3600\times880}\text{ m}^3 = 7.89\times10^{-7}\text{ m}^3$$

$$\boxed{\text{vol/sec} = 7.89\times10^{-7}\text{ m}^3}$$

$$C_2 = \sqrt{\frac{2(P_1-P_2)}{\rho}} \Rightarrow C_2 = \sqrt{\frac{2(150-30)10^5}{880}}\text{ m/s}$$

$$\boxed{C_2 = 165.14\text{ m/s}}$$

$$\text{vol/sec} = \text{vol/cycle} \times \frac{N}{2\times60} \quad \text{(As it is 4T)}$$

$$\text{vol/cycle} = \frac{7.89\times10^{-7}(2\times60)}{1500}\text{ m}^3$$

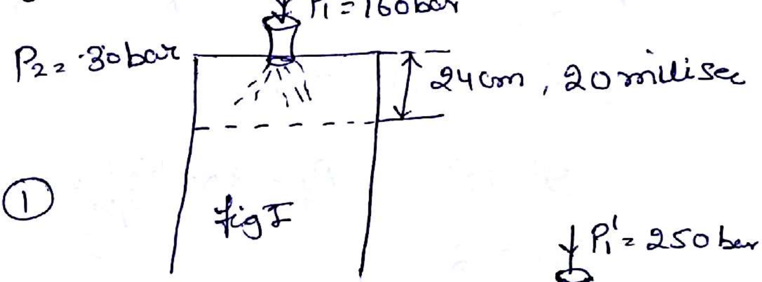
$$\boxed{\text{vol/cycle} = 6.31\times10^{-8}\text{ m}^3}$$

$$C_d \times \frac{\pi}{4} d_2^2 \times C_2 \times t = 6.31 \times 10^{-8}$$

$$0.88 \times \frac{\pi}{4} d_2^2 \times 165.14 \times \frac{1}{360} = 6.31 \times 10^{-8}$$

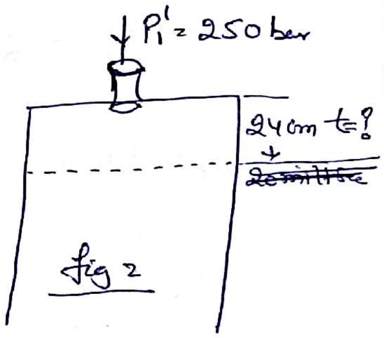
$$\therefore d_2 = 0.446 \times 10^{-3}\ m = 0.446\ mm$$

Qn When the Pressure inside the Combⁿ. Chamber is 30 bar. Injection Pressure is 160 bar, the fuel Penetrates 24 cm in 20ms find the time taken for the fuel to penetreate the same distance when the injection pressure is changed to 250 bar?



for fig 1

$$\frac{24}{20} = C_2 = \sqrt{\frac{2(P_1-P_2)}{\rho}} \quad —①$$



for fig 2

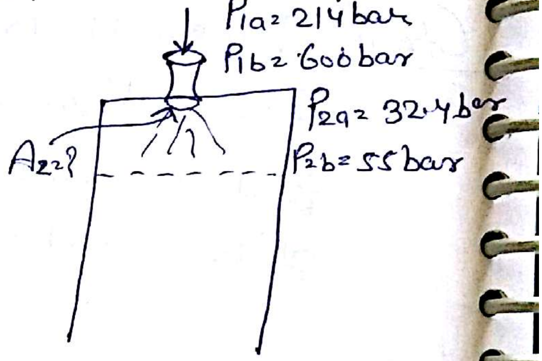
$$\frac{24}{t} = C_2' = \sqrt{\frac{2(P_1'-P_2)}{\rho}} \quad —②$$

divide equⁿ ① by equⁿ ②

$$t = 20\sqrt{\frac{160-30}{250-30}}\ ms$$

$$t = 15.34 \text{ milisec.}$$

Qn16 A 16 cylinder diesel engine has a Power out of 800 kW at 900 rpm. The engine works on the 4T cycle & has fuel Consumption of 0.238 kg/kWhr. The pressure in the cylinder at the begiging of injection is 32.4 bar & the max. cylinder pressure is 55 bar. The injector is set at 214 bar & has a max. of 600 bar. $C_d = 0.6$, $\rho_f = 860\ kg/m^3$ find the orifice area if injection takes place over 10° of the crank angle.



Sol^n) 16 cylinder, 4 stroke

Power = 800 kW   N = 900 rpm

Sfc = 0.238 kg/kW hr

$\theta = 10°$ $\rho_f = 860\ kg/m^3$

$C_d = 0.6$

1-Cylinder — 1 injector

$P_1 = \frac{214+600}{2}$ bar $= 407$ bar

$P_2 = \frac{32.4+55}{2} = 43.7$ bar

from specific fuel Consumption for ① cylinder

$$\frac{m_f/hr}{Power\ (for\ 1\ cyl)} = Sfc$$

$$m_f = 0.238 \times \frac{800}{16}\ kg/hr = 11.9\ kg/hr$$

$$t = \frac{\theta}{6N} = \frac{10}{6 \times 900}\ sec = \frac{1}{540}\ sec.$$

$$Vol/sec = \frac{m/sec}{\rho} = \frac{11.9}{3600 \times 860}\ m^3 = 3.84 \times 10^{-6}\ m^3$$

or

↳ $$Vol/cycle \times \frac{N}{2 \times 60} = 3.84 \times 10^{-6}$$

$$\therefore\ Vol/cycle = \frac{3.84 \times 10^{-6}\,(2 \times 60)}{900}\ m^3 \simeq 5.12 \times 10^{-7}\ m^3$$

$$C_2 = \sqrt{\frac{2(P_1-P_2)}{\rho}} = \sqrt{\frac{2\times 407 - 43.7\times 10^5}{860}}\ m/sec = 290.66\ m/sec$$

and,

$$Vol/cyc = C_d \times A_2 \times C_2 \times t$$

$$5.12\times10^{-7} = 0.2\times A_2 \times 290.66 \times \frac{1}{150}$$

$$\therefore \boxed{A_2 = 1.58\times10^{-6}\ m^2}$$

$$\boxed{A_2 = 1.58\ mm^2}$$ Ans

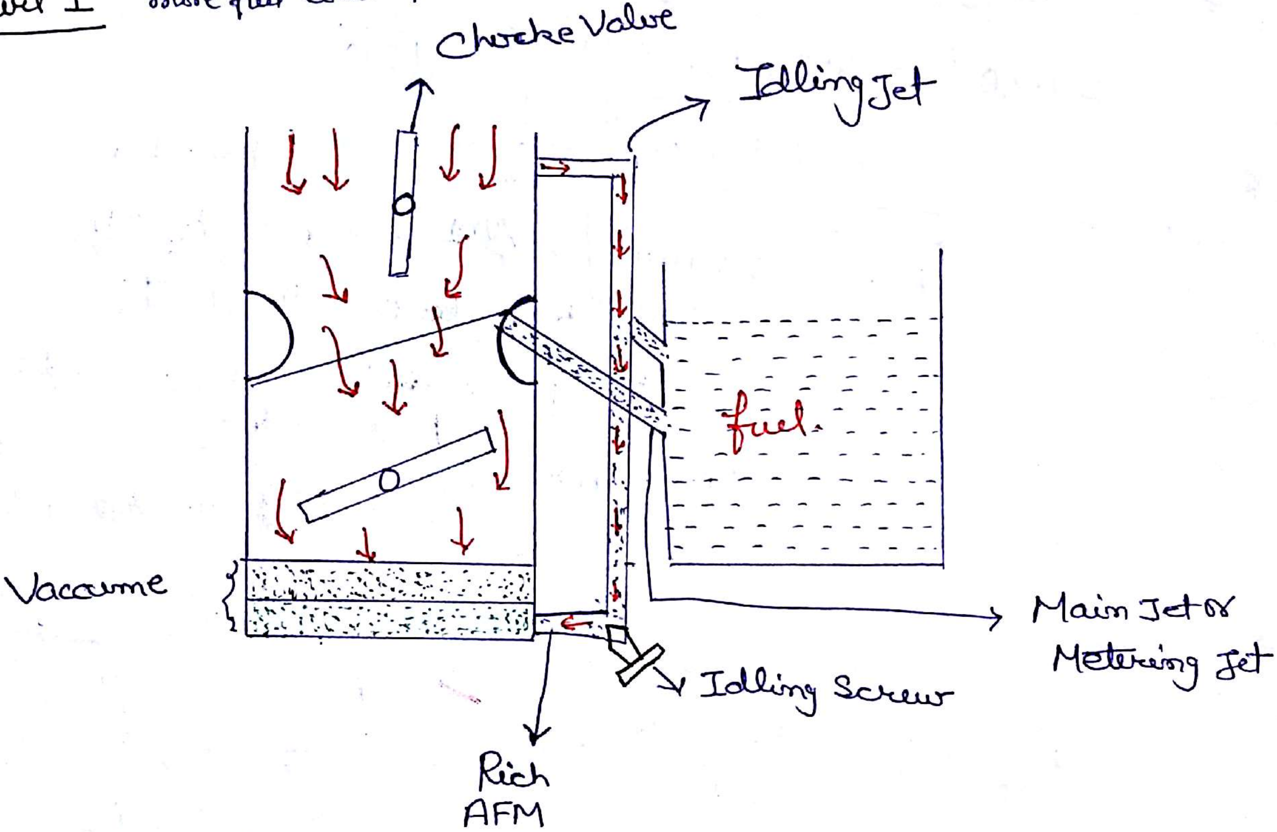
Advanced Carburettor System :-

The Idling System :-

Downflow Carburettor

Speed (0-15)

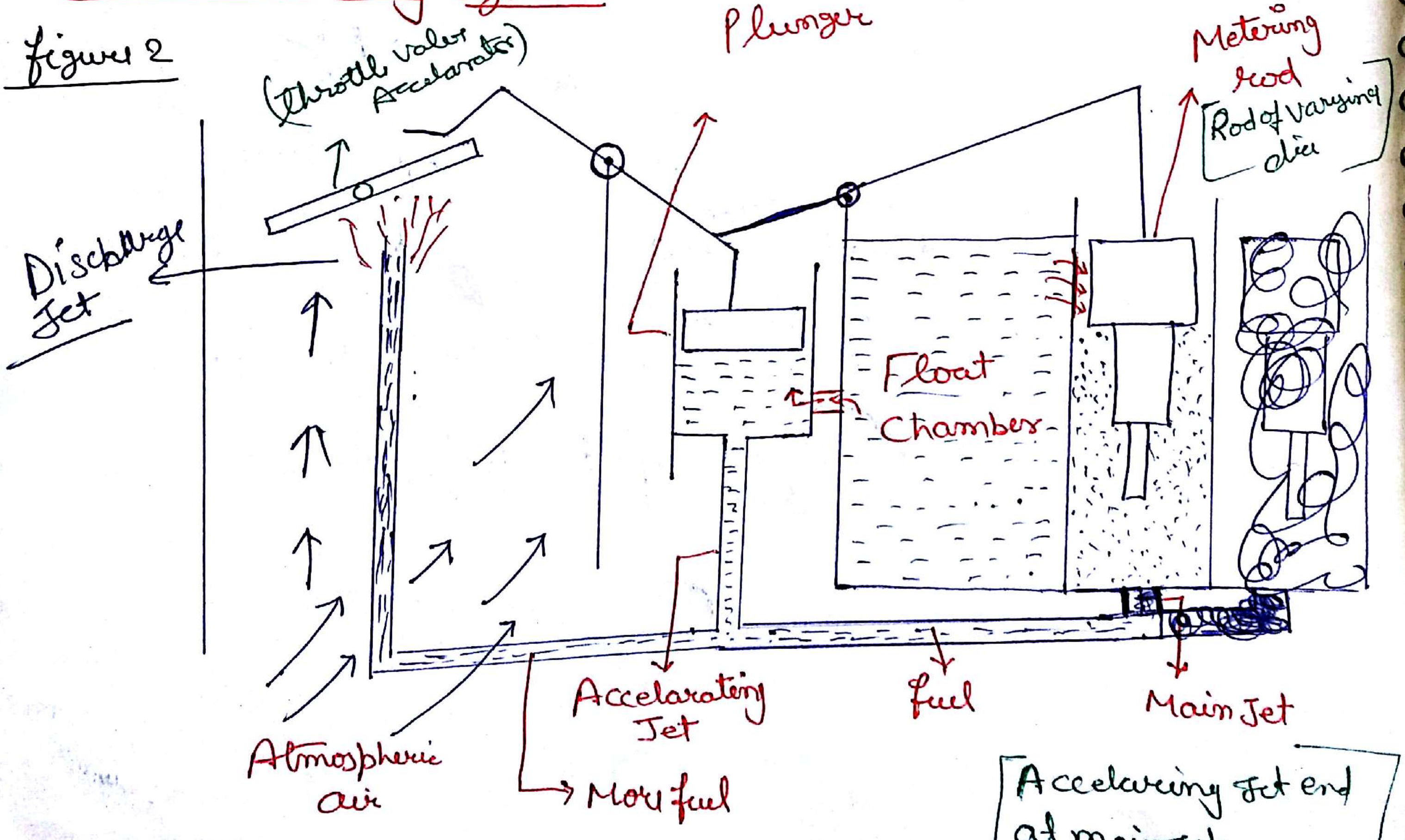
figure 1 more fuel Consumpn?



The Accelarating System

UP flow Carburettor

figure 2



[Accelaring Jet end at main Jet]

Side Flow Carburettor

figure 3 a

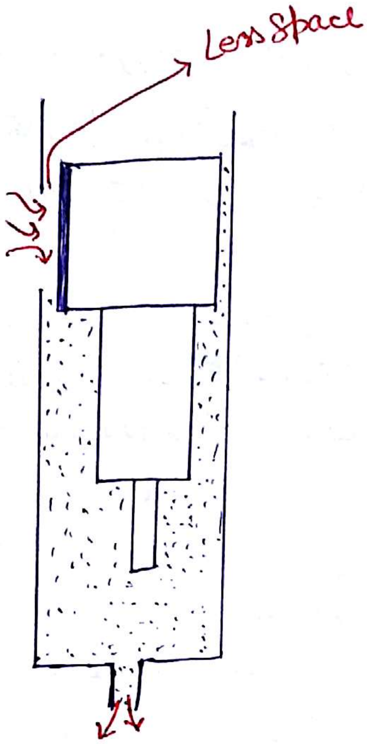
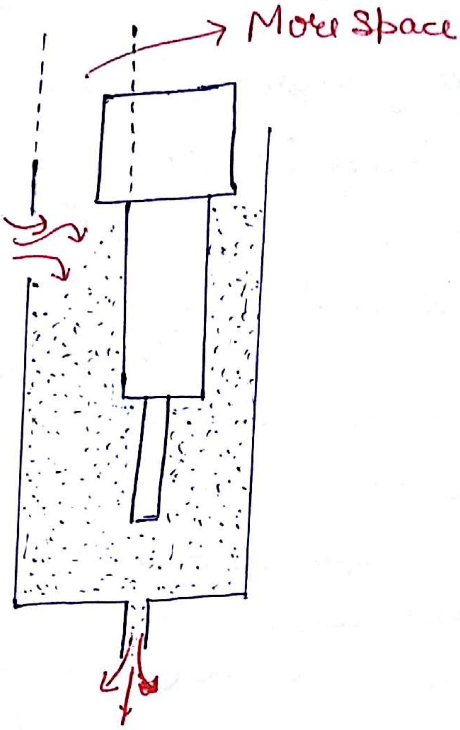


figure 3b



The Economiser
Or
The Metering Rod System

Idling System :-

Idleing System Consist of a jet Known as idling Jet. The idling jet Start from a Point near the choke valve (entry to the main unit) and ends up at a Point below the throttle Valve of the main unit.

The Design of idling jet is the Same as that of the main jet; But is much Smaller in Size. Thus, less Air flows through the idling jet ~~&~~ the AFM will be a rich mixture.

For Slow Speeds, the throttle opening is less. Thus, less air Fuel mixture flows from the metering jet and crosses the throttle Valve to fill the Vaccume (The metering jet is also Known as main jet). The remaining vaccume ~~which~~ will act on the idling jet & hence, Some air enters into the idling jet for the flow of the rich Air fuel mixture. This rich Air fuel mixture fills the remaining Vaccume in the main unit. hence more amount of fuel enters in Combustion chamber and more heat will be liberated during heat addition, due to which the engine Continuses to run Without Stopping.

On opening the throttle Valve further Additional Air fuel mixture will flow from the main jet, to fill the Vaccume. At one Stage the throttle opening will be Such that the entire Vaccume will be Completely filled by the Air fuel mixture from the main jet. The throttle opening at this instant is about 10-12% and the engine Speed is nearly 15 Km/h.

The Air fuel ratio for idling Conditions is between 5-9.

The Accelarating System :-

The Accelarating System Consist of Piston-cylinder arrangement Known as the Plunger. The plunger is placed in the float Chamber. There is a jet leaving the Plunger and joing the metering jet. This jet is Known as the Accelarating jet. There is an orifice through which the fuel from float chamber flows into the plunger.

When, the throttle valve is open by above 60%, it operates a lever and the lever moves the piston down the Plunger. The fuel inside the plunger is pushed into the Accelarating jet and thus, the more fuel will flow through the main jet and then out of the discharge jet. There is rapid increase in the speed of the engine (Accelaration).

On reversing the throttle value, the lever Pushes the Piston up the plunger, creating a partial vaccume inside. Fluid from the float chamber, rushes into the plunger through the Orifice to fill the vaccume.

The air fuel ratio for the accelarating system, is between 12-13.

The Economiser Or Metering Rod System :-

This arrangement Consist of rod of Varying diameters and is Placed in front of the entrance to the main jet.
The piston inside the plunger, at the metering rod are linked in Such a manner that it allways moves in opposite dir^{ny}.
When accelarator is Stop in new position. the piston inside the Plunger Will also stop. in a new downward position.
The flow of fuel through the accelarating jet is Stopped.
At this instant, the metering rod Will Stop in a new higher position.
Thus Smaller diameter Will face the fuel flow, at entrance to the main jet. Hence, additional fuel, Will flow out of metering jet, that Will Compensate for the stoppage of the fuel flow in the accelarating jet. Hence, high Speed of the engine Will be maintained.

On Reversing the throttle Valve, the piston inside the plunger moves up & the metering rod Will moves down. The bigger diameter Will face the fuel flow. Hence, less amount of fuel Will flow through the main jet. Besides, a Part of this fuel flow is directed into the accelarating jet in the Opposite direction, to fill the Vaccume. Thus, Very less fuel Will flow out of the discharge jet and the Speed decreases rapidly (Declaration)

It may be noted that UBHC Will be a max. When the engine is undergoing Declaration.

Choke Valve :-

Choke Valve is placed under the main unit at entrance to air. Normally, the choke Valve remains in an open position. On closing the choke Valve, very little or low air will enter the main unit. Hence the Vaccume will be filled by only large Quantity of the fuel.

The Choke Valve is operated when the engine is Very old or under old ~~Wether~~ Weather Condition. On closing the Choke Valve, large amount of fuel enters the Combustion chamber and plenty of energy is liberated. Partl of this heat is taken by the different Parts of the engine, and the remaining is transferred to air and thus the engine gets Started easily.

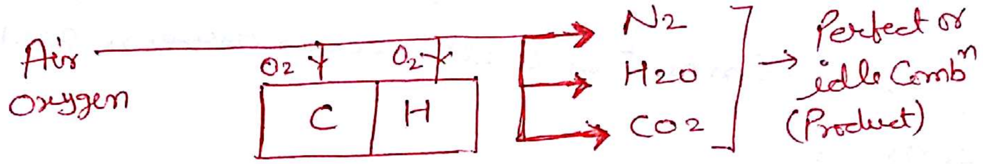
Once, the engine get Started, Care must be taken to open the thrott valve immediately. Otherwise it will result in the early damage of the engine.

The air fuel Ratio, for Cold Weather Conditions is b/w 2-3.

O – 1-2
C – 2010 – Now

Analysis Of fuel and Exhaust Gas :-

When Combustion of air takes place in Such a manner that there is no fuel remaining in any form After Combustion, nor is any free oxygen left. Then Combustion Known as idle or perfect Combustion and the air fuel Ratio for such a Combustion is Known as Stichiometric Air fuel ratio.



Lower Calorific Value :-

When the Steam in the exhaust gas is allowed to escape, then, the total heat available due to the Combustion Of 1Kg Of fuel is Known as the Lower Calorific Value of fuel (LCV).

The Calorific value of fuel, from I.C engine is Lower Calorific Value.

Higher Calorific Value :-

When the Steam in exhaust gas (Flue gas) is recirculated for useful Heating (In this Case the Steam is Condensed to Water) Then, ~~additional heat~~ Heat available due to the Combustion of the fuel for one 1Kg is Known as Higher Calorific Value of the fuel.

Higher Calorific Value is available for Stationary & Large Power Plant.

Products Of Combustion :-

In the analysis of exhaust gas, when steam is also taken into account, then the exhaust gases are known as the total products of combustion or wet product of Combustion. When steam is not taken into account for analysis, then the exhaust gases are Called dry product of combustion.

Any fuel on Combustion will receive oxygen and give out CO_2 & H_2O.

Therefore;

$$\text{Fuel} + O_2 \longrightarrow CO_2 + H_2O$$ — universal for All fuel /any type

Avagandro's Law

Equal volume of All gases Contain equal number of molecule.

Vol	Molecule
Gas 1 x	y
Vol 1 x	y

This find avagandro's Sir

In air	by mass	mass vol.
N_2	77%	79%
O_2	23%	21%

Oxygen is heavier than nitrogen.

Imp

Qn) Methane burns with stiochiomitric quantity of air. The air fuel ratio by weight

(a) 4,	(b) 14.7
(c) 15	[✓ (d) 17.16.]

Methane → CH_4.

$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

by means of molecular weight | 16 kg + 64 kg — 44 kg + 36 kg.

on divide entire eqn by 16.

1 + 4 — $\frac{44}{16}$ kg + $\frac{36}{64}$

in 100 kg air there is 23% of oxygen

23 — 100

4 — $\frac{100}{23} \times 4$ kg/kg fuel

$\boxed{d = 17.16\ \text{Kg/kg fuel}}$

Qn) If methane undergoes Combustion with stiochiometric quantity of air, the air fuel Ratio on the basis of molar ~~Ratio~~ basis,

(a) 15.22

(b) 12.3

(c) 14.56

[✓ (d) 9.52]

No of mole

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

1 vol + 2 vol → 1 vol + 2 vol

$AFR = \frac{100}{21} \times 2$ (by volume / molar bases)

$\boxed{A\cdot FR = 9.52}$

Qn) dry flue gas with Composition of CO_2 = 10.4%, O_2 = 9.6%
N_2 = 80%. Indicate that,

a) ✓ Excess air is used
b) Air is insufficient
c) H_2 is not present in the fuel
d) N_2 is 80%

dry → Hydrogen is Present but not taking into account

for d) choice d is incorrect as 80% of Nitrogen in the exhaust gas analysis doesn't mean that the Percentage of N_2 in air will also be 80%

for c) Choice c is incorrect as, Hydrogen is present but will not be included for dry gas analysis.

for B) choice B is wrong as for insufficient air carbon will not completely burnt the CO_2 & not will there be any free oxygen left in the exhaust gas.

~~for A~~) only A is Correct.

Qn) The Stichiometric Air fuel Ratio by volume for Comb^n for CO in air,

(A) 1.19
(b) ✓ 2.38
(c) 2.45
(d) 4.76

$$2CO + O_2 \longrightarrow 2CO_2$$

$$2\text{vol} + 1\text{vol} \longrightarrow 2\text{vol.}$$

$$1\text{vol} + \frac{1}{2}\text{vol} \rightarrow 1\text{vol.}$$

AFR (by vol) $\frac{100}{21} \times \frac{1}{2} = 2.38$ Ans

Qn) A liquid fuel C_7H_{16} is burn with 10% more air. Assume Complete Combustion. Calculate

1) The mass of air Per kg of fuel
2) volumetric Analysis of dry product of combustion
3)

$$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$$

$$84+16$$

$$100\,kg + 352\,kg \rightarrow 308\,kg + 144\,kg$$

$$1\,kg + 3.52\,kg \rightarrow 3.08\,kg + 1.44\,kg$$

Theoritical Air = $\frac{100}{23} \times 3.52\,kg$ = 15.3 kg.

For 10% ~~excess~~ excess air Supply

$\boxed{100+10=110}$ 1.1

$m_a = 1.1 \times 15.3$ kg. $m_a = 16.8$ kg

~~$m_a = 16.8$ kg~~

$$M_{N_2} = 0.77 \times M_a = 0.77 \times 16.8\,kg = 12.9\,kg.$$

$$\boxed{M_{O_2} = 16.8 - 12.9}$$

$(0.23 \times M_a = 0.23 \times 16.8\,kg = 3.9\,kg$

$$M_{O_2} = 3.9\,kg$$

∴ Excess air is O_2 (excess) in exhaust Gas,

= total Supply of oxygen − 3.52 kg

= 0.38 kg

Analysis of dry exhaust gas

SNo	Constituent	Analysis by wt. Mass	mol.w	Analysis by vol	
1	CO_2	3.08	44	3.08/44 = 0.070	0.07/0.544×100 = 12.9
2	Excess oxygen	0.38	32	0.38/22 = 0.012	0.012× 0.0542×100 = 02.2
3	N_2	12.90	28	12.9/28 = 0.460	By diff = 84.9
				Σvol = 0.542	

Q.n T1 | Lignite — Peat — Bitum — Anthracite

Q.n T1)

$C - 0.819 = 81.9\%$
$H_2 = 0.049 = 4.9\%$
$O_2 = 0.06 = 6\%$
$N_2 = 0.023 = 2.3$
Ash = 0.049 = 4.9

their sum must be equal to 1. if not then Question is not solved.

(i) The stoichiometric air Fuel Ratio for complete comb^n

(ii) The volumetric Analysis of wet & dry Products of comb^n when the air supplied is 25% in excess of that required for complete Combustion

S.NO	Analysis by wt.	O_2 Required/kg fuel	Mass of CO_2	Mass of H_2O
C	0.819	$\frac{32}{12} \times 0.819 = 2.184$	3 kg.	—
H_2	0.049	$0.049 \times 8 = 0.392$	0.44	0.44
O_2	0.06	~~[illegible]~~ −0.06		
N_2	0.023	—		

total O_2 = 2.516 kg

∴ stoichiometric ratio $= \frac{100}{23} \times M_{O_2}$

$= \frac{100}{23} \times 2.516$ kg

$= 10.94$ kg

$2H_2 + O_2 \rightarrow 2H_2O$
$4 + 32 \rightarrow 36$
$1\text{ kg} + \frac{32}{4} \rightarrow \frac{36}{4}$
$1 + 8 \rightarrow 9$

$C + O_2 \rightarrow CO_2$
12 32 44
$0.819 + \frac{32}{12} \times 0.819 \rightarrow \frac{44}{12} \times 0.819$

or .819 kg + 2.184 kg → 3.0 kg

$\frac{\cancel{32}\,16}{\cancel{12}\,6}$

for 25% excess air supplied

$$M_{air} = 1.25 \times 10.94\,kg = 13.67\,kg$$

$$M_{N_2} = 0.77 \times M_a = 10.52\,kg$$

$$\text{Excess } O_2 = (0.23 \times M_a - O_2 \text{ for fuel}) =$$

$$= 0.23 \times 13.67 - 2.516\,kg$$

$$= 0.63\,kg$$

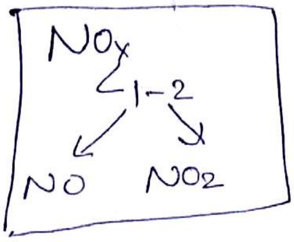
Analysis of Exhaust Gas

S.No	Constituents	Analysis by Wt%	Mol. Wt	Analysis by Wt
1	CO_2	3	44	$3/44 = 0.068$
2	N_2	10.52	28	$10.52/28 = 0.376$
3	O_2	0.63	32	$0.63/32 = 0.019$ $\Sigma dry = 0.488$
4	H_2O	0.44	18	$0.44/18 = 0.024$ $\Sigma wet = 0.487$

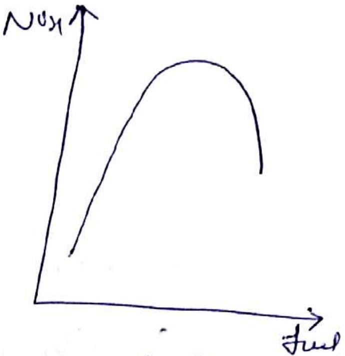
	Analysis of dry gas	Analysis ~~by~~ wet gas
CO_2	$\frac{0.068}{0.463} \times 100 = 14.68$	$\frac{0.068}{0.487} \times 100 =$
N_2	$\frac{0.376}{0.463} \times 100 = 81.2$	$\frac{0.376}{0.487} \times 100 =$
O_2	$\frac{0.019}{0.463} \times 100 = 4.12$	$\frac{0.019}{0.487} \times 100 =$
H_2O		$\frac{0.024}{0.487} \times 100 =$

Pollution In Exhaust Gases :-

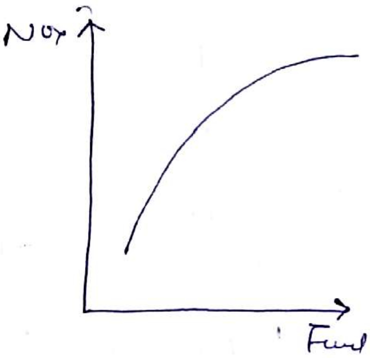
↑temp ↑ fuel Supply ↑ NO_x Production



Exhaust Gas Recirculation



Petrol engine



Diesel engine

Pollution In exhaust Gases :-

1) Co :-

→ It is Poisoness, will cause giddiness; when taken in Small quantities can also prove (fatal).

2) HC :

→ Causes Skin Cancer. & affects the lungs, when exposed to atmosphere. Also Affects plants and animals.

3) NOx :-

When NOx is exposed, ~~to~~ it form Photochemical Smoke (Smog) Affects is same as HC. Also affects under water creatures.

NOx is form when,

i) Temp. of Combⁿ chamer is very high.
ii) Acces air is supplied
iii) In complete Combⁿ of the fuel.

One of the Method of Reducing NOx is By exhaust gas Recirculation (EGR)

in India – 70-80 octane no. of Petrol

Octane No. of Petrol 77.

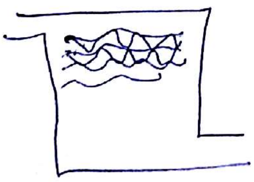
Catalyst

Costly fuel
unburnt fuel
↓

Oxidation Rxn [Costly → Platinum — HC → H_2O, CO_2

Palladium — CO → CO_2

Rhodium — NOx



Catalytic convert in vehicles

Imp

Catalyst in fuel
TEL
TML
but due to Lead it effect Catalytic chamber

Rhodium first bcz it break Nitrogen & oxygen so that Oxygen from outside is less used and Some ~~Rhodium~~ Oxygen produced by Rhodium is used for this process.

ethylene di Bromide is used as catalyst in fuel / Petrol

Methods Of Preventing Pollution in Exhaust Gas:

→ A Slightly Leaner mixture (more than 10% excess air).

→ Slightly Lesser Compression Ratio.

→ Use of thermal Converter.

Thermal Converter is use for oxidising HC to H_2O & CO_2, and for Converting CO to CO_2.
Thus, thermal Converter are also Known as two Way Converters.

→ Use of Catalytic Convertors.

1) Passage of Stainless Steel Box, has,
2) Has Alumina (Al_2O_3) inside in the form of Honey foam.
3) Has three different Catalyst to accelarate Reactions. for removing the Pollutants.
4) The different Catalyst are;

Platinum — for oxidation of HC.

Palladium — for Oxidation of CO

Rhodium — for Reducing NOx into ~~Hydrogen &~~ oxygen & Nitrogen

Unleaded Petrol :

To improve the Quality of Petrol, Chemicals like TEL (Tetra ethyle lead) and TML (Tetra methyl lead) are used.

During Combustion lead from the above chemical gets sepreated. and is in circulation, As lead itself in the exhaust gas. This lead Corrodes the different Catalyst in the Catalytic Convertor. Hence, ethylene di bromide is used. instead of the lead Compound for improving the anti Knock quality of Petrol. Such a fuel is Known as unleaded Petrol.

Rating Of Fuel :

In order to determine the anti Knock Quality of fuels, the fuel is Compared With the standard fuel. The standard fuel is a mixture Of two ~~off~~ other fuels.

"For Petrol, the Standard fuel is a mixture of isooctane (Zero Knock) and normal Heptane Readily Knock."

The % of isooctane in Standard fuel is a measure of anti Knock Quality of Petrol. If the % of Octane in the standard fuel is 70% (Heptane is 30%) then, matches with the Quality of Petrol, then Petrol ~~Octane~~ is Said to have an octane number of 70. Higher the Octane number, better Will be the Quality of fuel.

In india, Octane number of Petrol is b/w 70-80.

For special Quality fuels like Speed, extrapremium etc the Octane number is b/w 90-94.

For the Diesel fuel, the Standard fuel is a, mixture of Normal Cetane (Zero Knock) and alpha methyle Nepthlene (readily Knocks). Higher the Cetane No. of the fuels better Will be its Anti Knock Quality.

In India cetane no. of Diesel fuel is b/w 40-50.

Equivalence Ratio (ϕ) :- $\phi = \frac{Act.FAR}{I.FAR} = \frac{Act.m_f / m_a}{Ideal\, m_f / m_a} = \frac{Act.m_f}{Ideal\, m_f}$

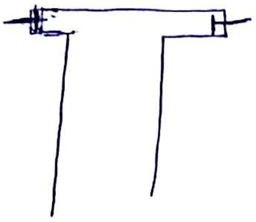
FAR – Fuel Air Ratio

Equivalence Ratio is the Ratio of FAR under actual Conditions (When the engine is running) to the FAR under Stiochromitic Condⁿˢ.

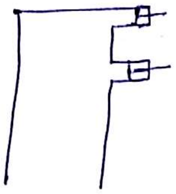
Ideal↑

Side Valve engine

overhead engine

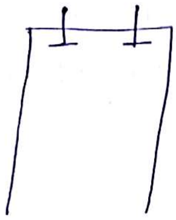


T Shaped engine



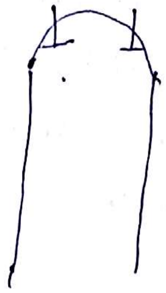
F Shaped engine

Knocking is ↑



flat Shaped engine

Knocking is Present



Hemi Spherical Shaped engine

Interview :

When Equivalence ratio is less than 1, It means that there will be Shortage of fuel Supply & Power output will also be less. The Temperature of the charge will also be the less. In Petrol engines, Knocking will be reduced.

When equivalence Ratio is b/w 1.1 & 1.3, Then good amount of energy will be liberated from the fuel. The Power output & the Temp. of the charge will be high ∴ tendency to Knock will be more for Petrol engines.

When equivalence Ratio is greater than 1.4, then the fuel Supply will be so much in access that the air supplied will be not enough for complete Combustion. Hence less fuel will undergoes Combustion & the effect will be the Same as well the equivalence Ratio is less than 1.

Combustion In I.C Engine :-

Combustion in S I Engine :-

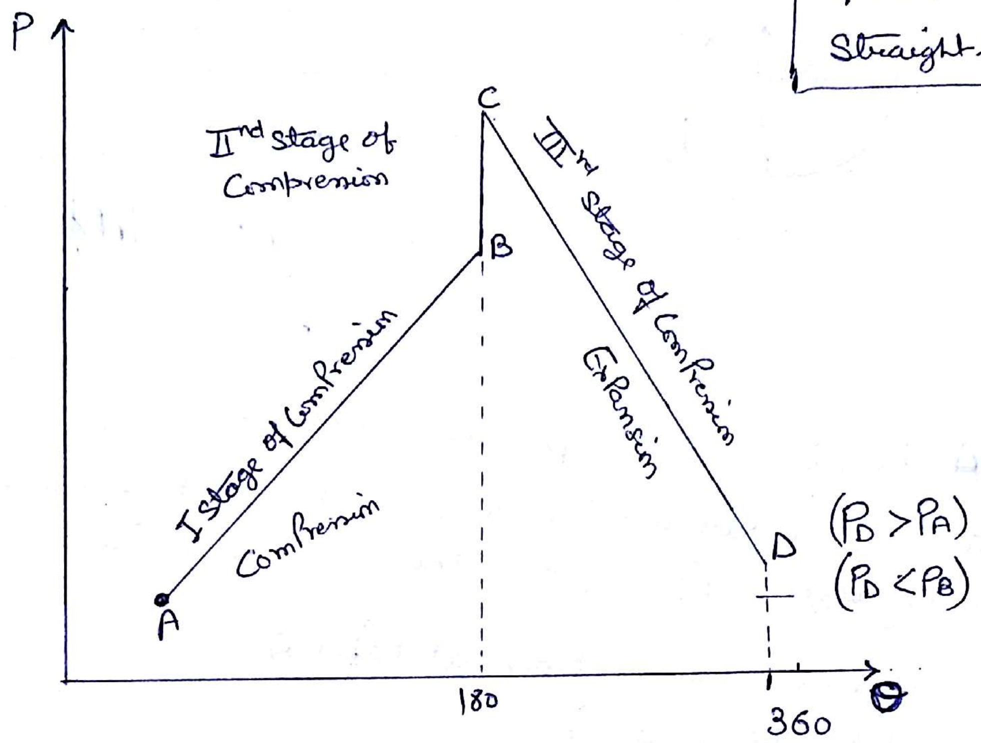
$\Delta P \propto \theta$

$\Delta P = m\theta$

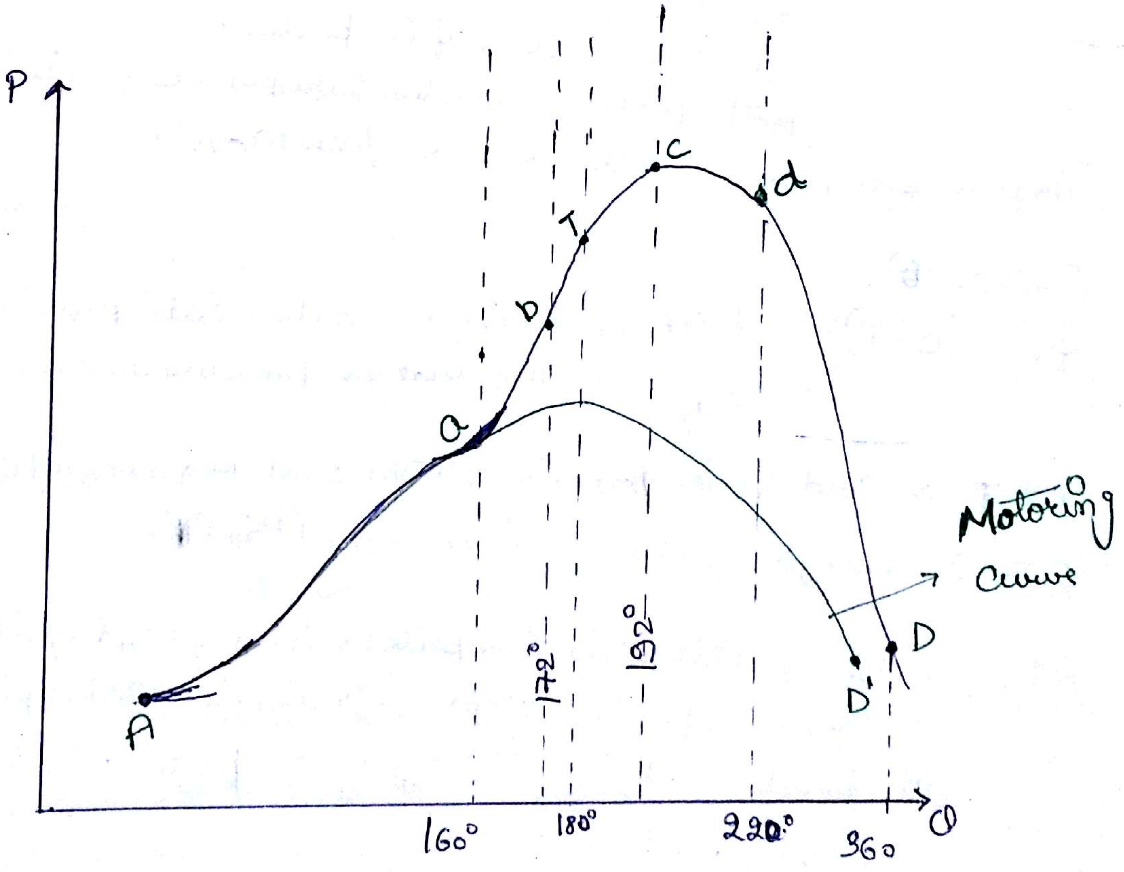
$y = mx$

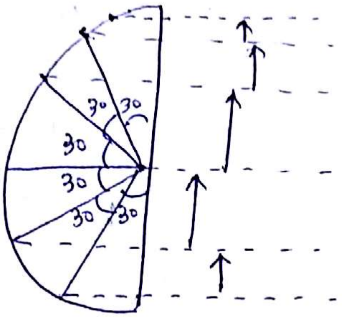
Straight line

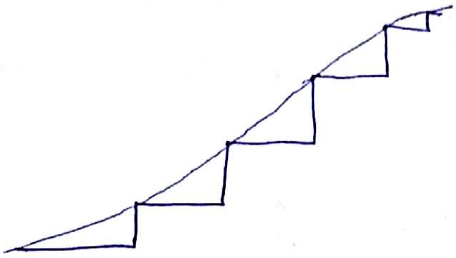
Theoritical Diagram

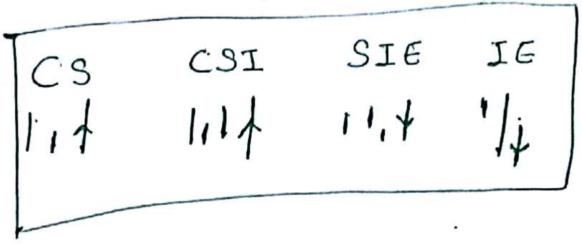


Actual Diagram :-









→ At A, beggining of Compression stroke.

→ At a, 160° of rotation is over from the start of the Compression. Sparking begins. From A-a, there is normal rise in Pressure.

First stage of Combustion begins at Point A.

Chemical Rxn begins at a.

from (a-b) → 12° of Rotation is Completed After the begining of Sparking.

[Ignition begins at point b.

End of first stage of Compustion.

Both sparking & ignition takesplace beyond point b.

There is sharp rise in the pressure from (a-b).

~~From (b-B)~~

from (b-T) → Both sparking & ignition takes place alongwith Compression. The rise in pressure is very sharp.

At T → end of Compression stroke and begining of expansion stroke.

Both sparking & ignition Continues beyond Point T.

At C → 12° of rotation is Completed, from start of the expansion stroke. Sparking stops. only ignition takes place beyond this point. end of IInd stage of Compustion. Third stage begins at point C.

At d:- 40° of rotation is Completed from the Start of the expansion stroke. Ignition stops. End of third stage of Combustion. There is a drop in pressure during IIIrd stage of Combustion.

There is a little rise in Pressure during, the 12° of rotation after expansion has started.

Motoring Curve:

It is the curve traced by a Similar engine in which, there is no Combustion taking place (only Compression & expansion will exist).

It may be seen from the motoring curve that the rise in pressure is mainly due to combustion. Thus, the engine in which the Combustion takes place will only have a higher efficiency.

First Stage of Combustion:-

When the Spark plug Contact the fuel in a particular area, ~~then~~ then, Chemical Action begins for the fuel in this region. Heat is generated, that spreads to the other areas of fluid/fuel. Chemical Action begins also in these areas. There is a rise in the Temp. of the fuel. There is a propogation of the Neucleus of the area in which chemical action taking place. During the chemical action, different amount of Heat get stored in different areas of the fuel.

At the end of the chemical action, if the temp. of the fuel is below the self ignition temp, then, the fuel Particle remains as UBHC. And ~~is~~ is in circulation with the hot gases untill exhaust.

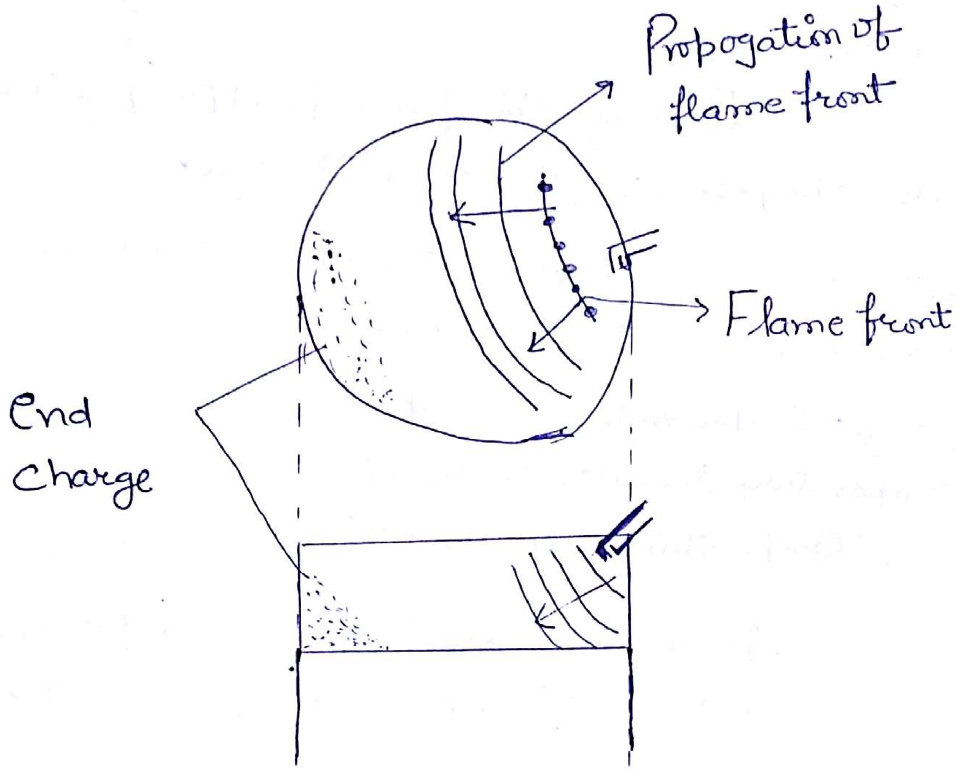
When the temp. of the fuel Particle is equal to or above the Self ignition temperature at the end of the chemical action, then there is distribution of Heat in the different areas of the fuel. The temp. remains same, during this heat distribution. The equal amount of heat stored in the equal different area of the fuel, then ignition begins for the fuel Particles.

The time taken, from begining of ~~chem ignition~~ Chemical action to begining of ignition is known as the chemical lag / Ignition Lag.

For Petrol engines Chemical Lag is also known as ignition Lag.

Chemical Lag is also the duration for I^st Stage of Combustion, which is even known as the Preparatory Phase.

Abnormal Combustion In S I Engines



Flame front :-

During Sparking, the fuel particles near the Spark plug gets ignited. The line joining the ignited fuel particles is Known as the flamefront.

Propogation Of flame front :-

After the formation of first flamefronts, Heat from this flame front is recieved by the nearby fuel particles & another flamefront is formed. At the same instant the fuel particles in the first flame front gets Completely burnt. It will thus appear that the first flame front has only reached the new position. This immagenary movement of the flame front is Known as the Propogation of the flame front.

End Charge:

The AFM and the other end of flamefront propogation is Known as the end charge.

During, the flamefront propogation, the following events takesplaces for the end charge:-

1) The Air particles near the flamefront gets heated and expands. This expanding air, Compresses the end charge.

2) As the end charge get compressed, the temperature of end charge ↑. this increasing temperature results in chemical action being set up in the end charge. Temperature of the end charge increases further.

3) During the flame front progation, there is heat transfer, from the flamefront to the end charge. Temperature of the end charge continues to increase.

If the temperature of the end charge becomes equal to the self ignition of end charge or above, a seprate flame front is formed & the charge. The two flame fronts move in opposite directions & collides with another one. This collision is known as Detonation.

If the flame front from the Spark plug reaches the end charge, before the formation of the flamefront at the end charge, then Knocking will not Occure.

Interview

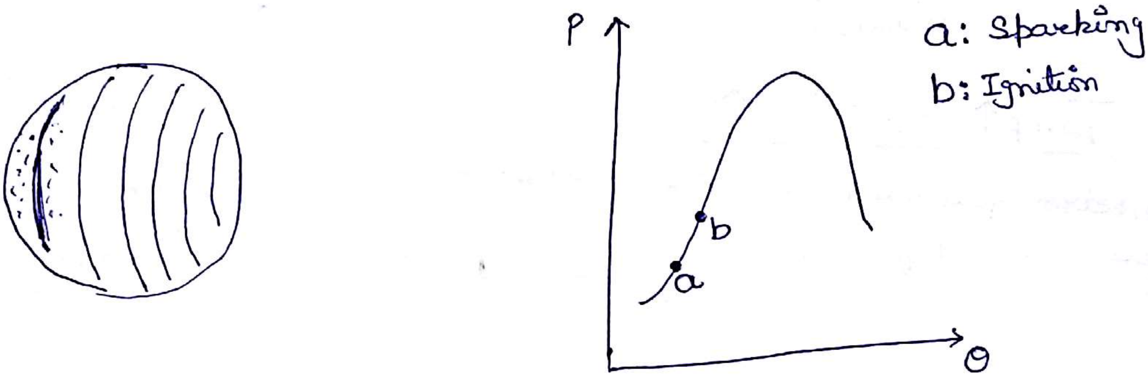
Following are disadvantages of detonation:-

1) When the two flame front collide, a high energy wave is set up at the point of collision, that can travel in any direction at a speed of about 2500 - 5000 Cycles/sec. This wave start pushing the piston sidewaves & ~~ad~~ the piston Knock against at a cylinder. Hence detonation is known as Knocking. Due to Knocking a crack can be develop in the piston or in the cylinder.

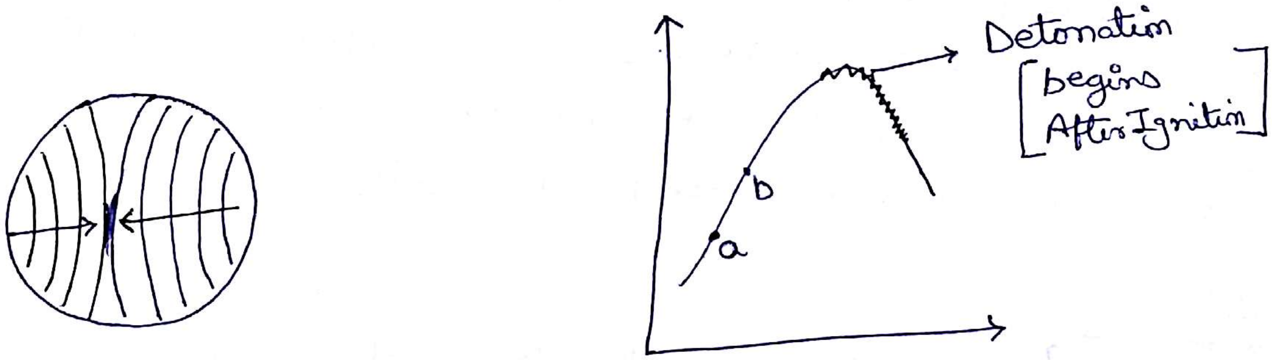
2) Due to Knocking, a high metallic sound is ~~Heated~~ Heard, known as pinging. Hence, detonation or knocking is also known as Pinging.

3) Vibrations are set up in the engine.

4) There is loss of work.



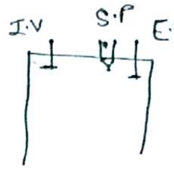
Normal Combustion



Abnormal Combustion

3) Advancing the Spark :-

Advancing the spark will results in more duration of Sparking. The pressure and temperature of Charge. will have a higher increase. Tendency to Knock will be more. Hence, Sparking Should not be in advanced. Instead Sparking Should be retarded for minimum detonation.



Interview

4) Distance Of Flame Travel :-

Distance travel by the flame must be Such that, the time taken by it Should be less than the chemical log of the end Charge. for this purpose, the diameter of the Cylinder is limited to 15 Cm.

Interview (By maintaining the dia of cylinder and ↑ the Power, Such that no. of extra cylinder used in Petrol) In diesel dia. of cylinder must be high to avoid Knock)

5) Location Of Spark plug :-

The Spark plug must be Kept nearest to the Centre of cylinder Head & away from the inlet Valve. closer to exhaust Valve.

Imp Turbulence) Interview)

6) Engine Speed :-

Increasing the Speed will result in turbulence being Set up. The flame front will travel faster in all directions. Detonation will be minimum.

7) Air Fuel Ratio :

A See equivalence Ratio for Details....

8) Rating of fuel :-

See Octane number.

Qn) A Conventional SI engine, What is the Value of fuel air Ratio in the normal operating range?
$\longrightarrow$ Economic Speed

a) 0.056 to 0.083 (C) 0.0056 to 0.83

b) 0.083 to 0.96 (D) 0.056 to 0.83

Normal FAR = $\frac{16}{1} = \frac{1}{16}$

Choice d Matches with the the normal Operating Range fuel air Ratio.

Ⓐ $\frac{0.056}{0.083} = 0.675$

B) $\frac{0.0056}{0.08} = 0.00675$

Ⓑ $\frac{0.083}{0.76} = 0.148$

D) $\frac{0.056}{0.83} = 0.0675$

Very imp

Qn) In SI Engine, Combustion in stage 1 takes 1 milisecond and stage 2 takes 1.5 milli seconds. When the engines runs at 1000 rpm. If the Stage 1, time is independent of the Speed, What will be the additional spark advance, When the engine speed is doubles.

Sol. $1000\,rpm = \frac{1000}{60} = \left(\frac{1000 \times 360}{60 \times 1000}\right)$ degree / milli sec

$= 6°$ in 1 milli sec.

1s — 1000 milisec.

1 rotation — 3600

1000 rotation = 360×1000

Speed	Stage 1	Stage 2
1000	1 msec	1.5 msec
2000	1 msec	?

A) 0° (B) 6°

(C) 12° (D) 24°

When speed is 2000 rpm, Angle turns is 2×6° = 12° in 1 mi/sec

therefore Spark Advance is 12 − 6° = 6°.

Qn) To Prevent detonation in SI engines, the end charge Should have

a) Low temp

b) Low density

c) Long ignition delay

All choices are Correct

$$\boxed{\rho = \frac{m}{V}}$$

$$PV = mRT$$

$$\boxed{\frac{P}{RT} = \rho}$$

Explanation of b — low density

for less density, the mass of a fuel in end charge will be less. Hence the heat liberated during the chemical action of the fuel Particles in the end charge will also be less.

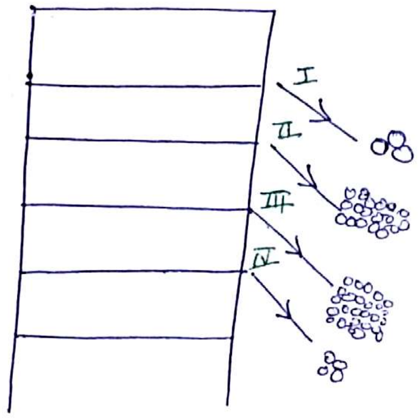
Temperature of the end charge will also be the less.

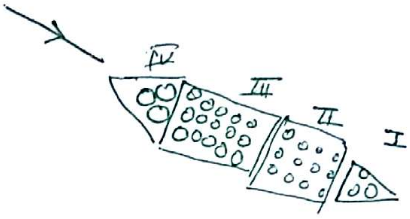
Chemical charge of the end Charge will be longer. Hence, detonation will not occurs.

Combustion in C.I Engines :- Vortex flow

~~Different Stedges of Suction~~

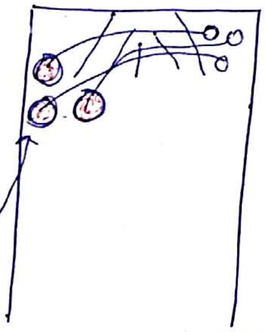
Different Stages of Suction :





Ist Stage Of Combustion :-

After Compression



→ Less air is Circulated. Hence, the many fuel spread is also less. As the air crosses the fuel Spray, it will be in Contact with fuel for Some times. The time for which air & the fuel are physical in Contact with one another is Known as the Physical delay.

→ For Dieselengines, Physical delay + chemical deay = Ignition delay.

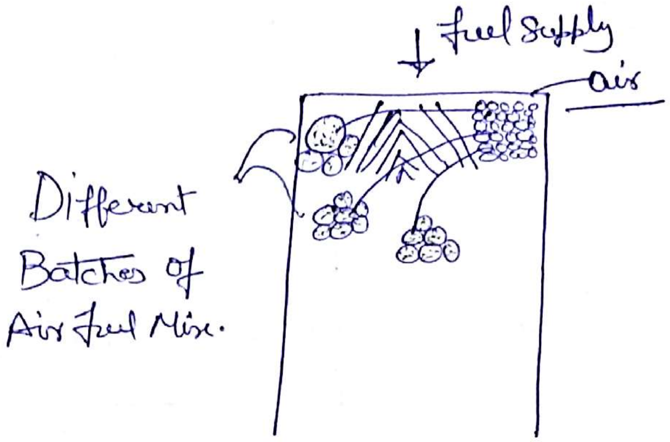
Physical lag + ~~Ignition~~ Chemical lg = Ignition Lag

→ The temperature Of the Combustion chamber, at the Start Of the first Stage of combustion (end of Compression) is Slightly above the Self ignition temperature.

→ The chemical delay during the first stage of Combustion is longer. The first stage of Combustion is Known as the delay Period.

→ The Temperature, at the end of first Stage of Compression is much above the Self ignition temperature.

IInd Stage of Combustion :-



→ Large mass of air is circulated, Hence, the mass of fuel spray is also larged.

→ The temp. of the Combustion chamber at the start of the second stage of combustion is much above the self ignition temperature. Hence, Combustion is faster, during the second stage.

→ Due to large Quantity of Passing through the fuel spray, it crosses the fuel in different batches.

→ If, the Combustion takes place for the different batches of air fuel mixture. one after another untill the Last batch, then Combustion is said to be normal or smooth.

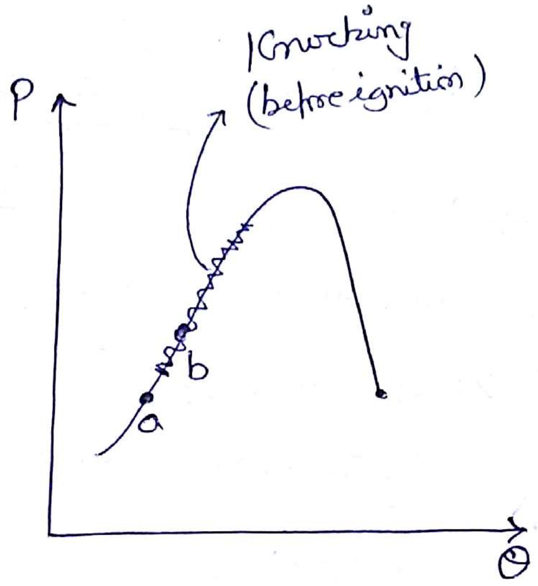
→ On the other hand, if for some reason or other, the air Particles in a particular batch carries less amount of fuel With it, then less heat Will be developed during chemical action. due to Which the temp. of this charge is Less. Hence, the chemical delay for this batch ~~of~~ air fuel mixture Will be longer. In the mean time, more batches of air fuel mixture Will get ~~connected~~ Collected Along With this batch and Combustion Will ~~takes~~ place for all these batches at the Same time.

due to which, enormous amount of heat is liberated. that the piston is not able to handles and Knocking Occures.

Abnormal Combustion :-

a :- Injection of fuel (20° before TDC during compression)

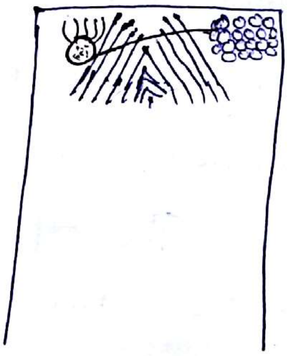
b :- Ignition



→ The Second Stage of Combustion is Known is uncontrolled Combⁿ.

→ The temp. of the Combustion chamber is ~~much~~ Very much above the Self ignition temperature.

→ 3rd Stage of Combustion :- (Knocking Less Stage) No Knock



→ Large Quantity of Air is Circulated. Hence, the fuel's spray will also be large.

→ The air Crosses the fuel spray in different batches.

→ Since, the temp. of the Combustion Chamber is much above the Self ignition temp, Chemical lag is Very short.

→ Combustion takes place for the Air fuel mixture. immediately After Crossing the fuel spray.

→ Knocking Does't take place, during the third stage of Combustion.

→ The Third Stage of Combustion is Known as Controlled Comb^n.

4th Stage of Combustion :-

→ Very Less Quantity of Air remains during IV stage of Combustion. hence, Very less fuel will remains.

→ 4th Stage of Combustion takes place After burning of major Quantity of fuel during the earlier stages.

→ The 4th Stage of Combustion is Known as After burning.

Factors Affecting Knocking in CI engines :-

1) Compression Ratio :-

– ↑ Compression Ratio will results in ↑ temp of the Charge. The Tendency to Knock will decrease. For this reason, the Compression Ratio in diesel engines is Kept as ↑ as b/w 16-20.

The Affect will be the same, when inlet Valve temp is higher or a supercharger is used. ~~then increasing the Work~~

2) Increasing Work output :-

increasing the load, that is Work output on Power will result in the more supply of fuel. Temp. of the charge will be higher. Tendency to Knock will decrease.

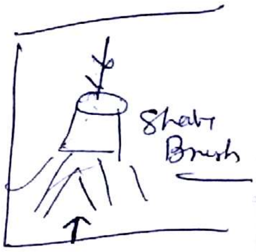
3) Increasing the Speed :-

Increasing the speed will results in more supply of fuel during the first stage of combustion (delay Period Ist stage). Hence, less fuel will be available for the second stage. Temperature of the charge in the second stage will be lesser. Tendency to Knock will ↑.

Hence, The ideal combination for min Knocking in diesel engines will be low speed & high load.

Imp

4) Atomization :-



for better Atomization, the fuel will spread to more space. The physical lag will be more. The air will be in contact with fuel for longer time. Hence, more fuel will be carried by air. more heat will be developed during second stage of combustion.

Tendency to Knock will decrease.

It is noted that, for good atomization, the injection pressure should be as high as possible. and the ~~cyb~~ Cylinder Pressure (After Compression should be near ~~of~~ to the Compression Ratio 16 in the range of

60- 20.

5) Advancing the Injection of fuel:-

Advancing the fuel injection, will result in lesser Compression. Temperature of the Charge will be less. Tendency to Knock will be higher.