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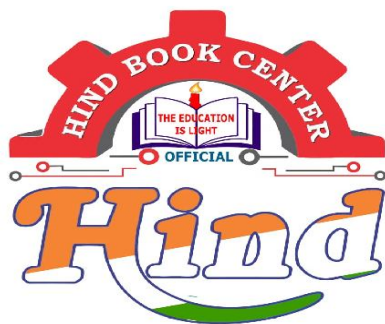
I C Engine

By Aakash sir

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IC Engine

(1) Air standard cycle

(a) otto cycle

(b) Diesel cycle

(c) Dual cycle

(2) Thermochemistry

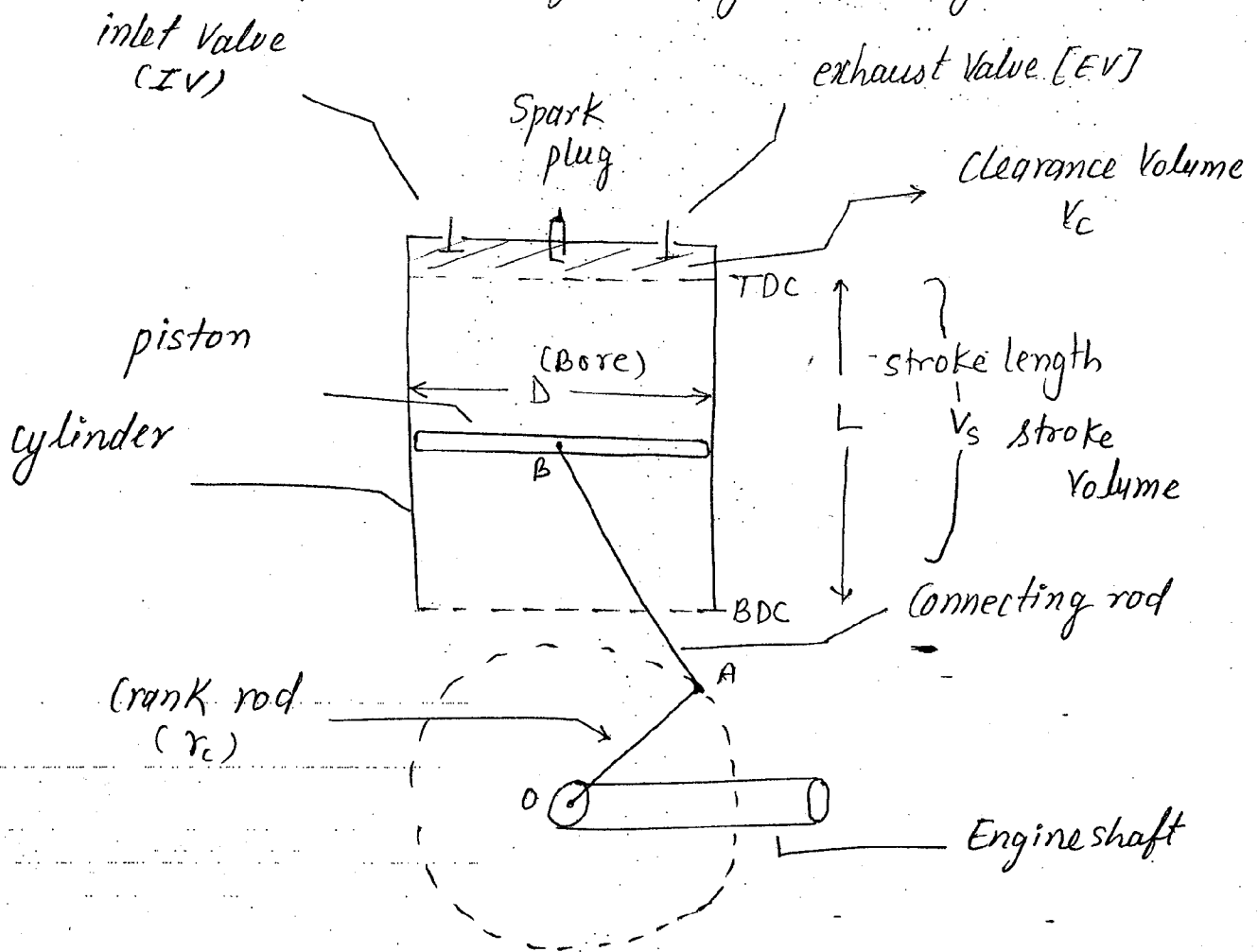
(3) Testing of IC Engine

Reference Book

V. Ganeshan

Made Easy theory book

⇒ Basic Design of Engine Cylinder system



(1) Stroke Volume $V_s = \frac{\pi}{4} D^2 \times L$

(2) Clearance Ratio $C = \frac{V_c}{V_s}$

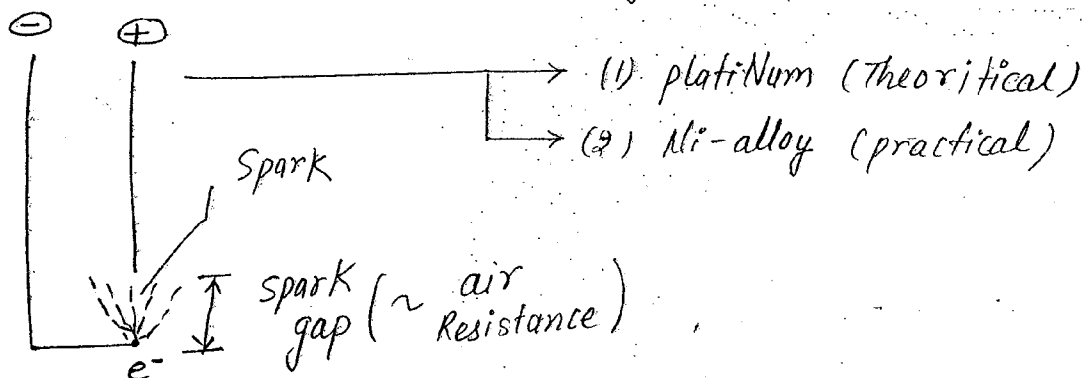
Note * Stroke length = 2 x crank radius

$$L = 2 r_c$$

* piston rings made up of Cast Iron.

#1 Spark plug

* $V_{High} = 10000 \text{ V} +$



* Spark plug should be made up of platinum theoretically but practically it should be made up of Ni alloy to have thermal strength.

* For sparking very high Voltage is required to overcome the resistance present in spark gap.

⇒ piston Displacement.

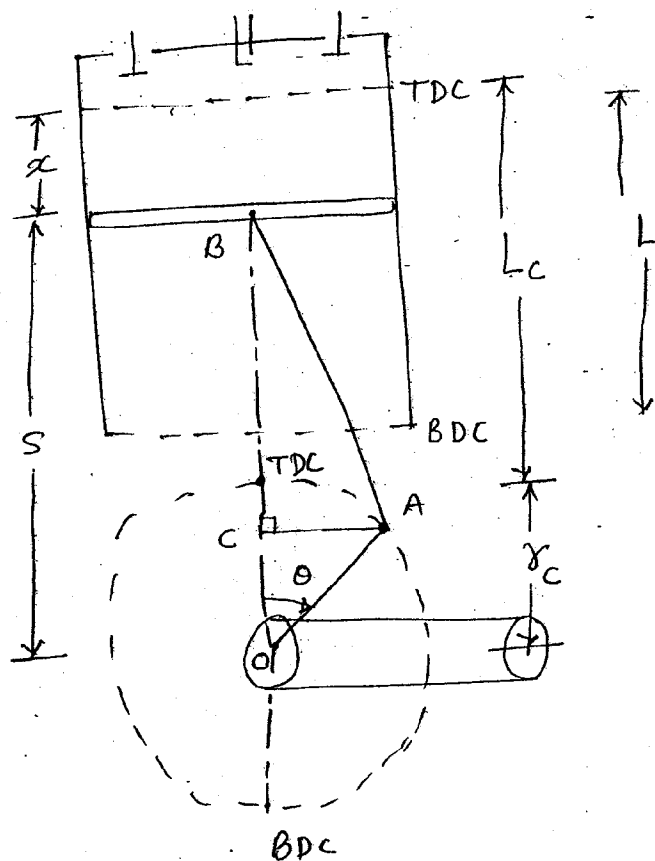
θ = Crank angle

$$S = OC + CB$$

$$= r_c \cos \theta + \sqrt{L_c^2 - CA^2}$$

$$S(\theta) = r_c \cos \theta + \sqrt{L_c^2 - r_c^2 \sin^2 \theta}$$

$$\therefore x = L_c + r_c - s(\theta)$$



Note $x(\theta) = L_c + r_c - \left[r_c \cos \theta + \sqrt{L_c^2 - r_c^2 \sin^2 \theta} \right] = f(\theta)$

(a) at TDC $\theta = 0^\circ$

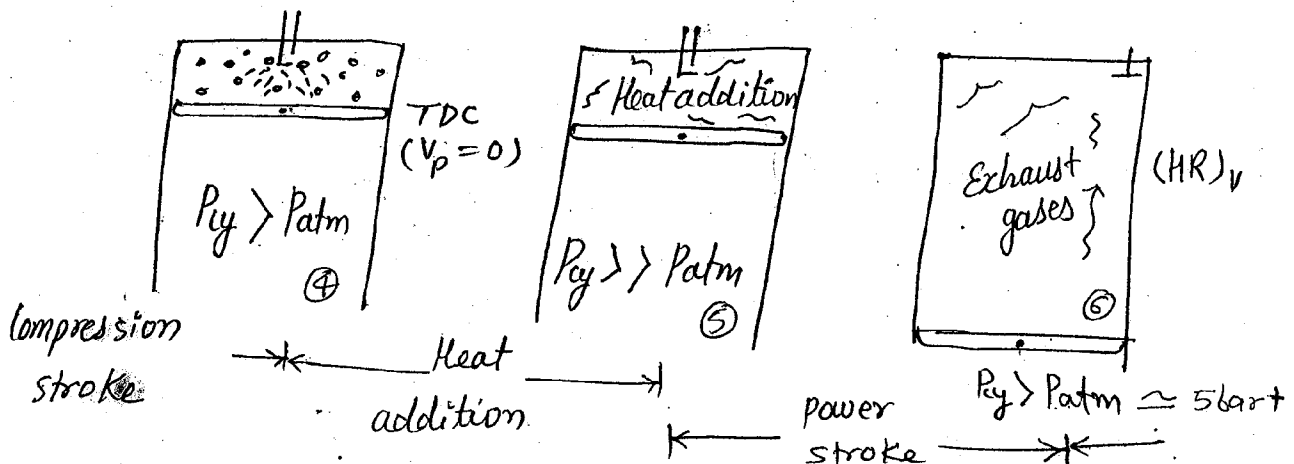
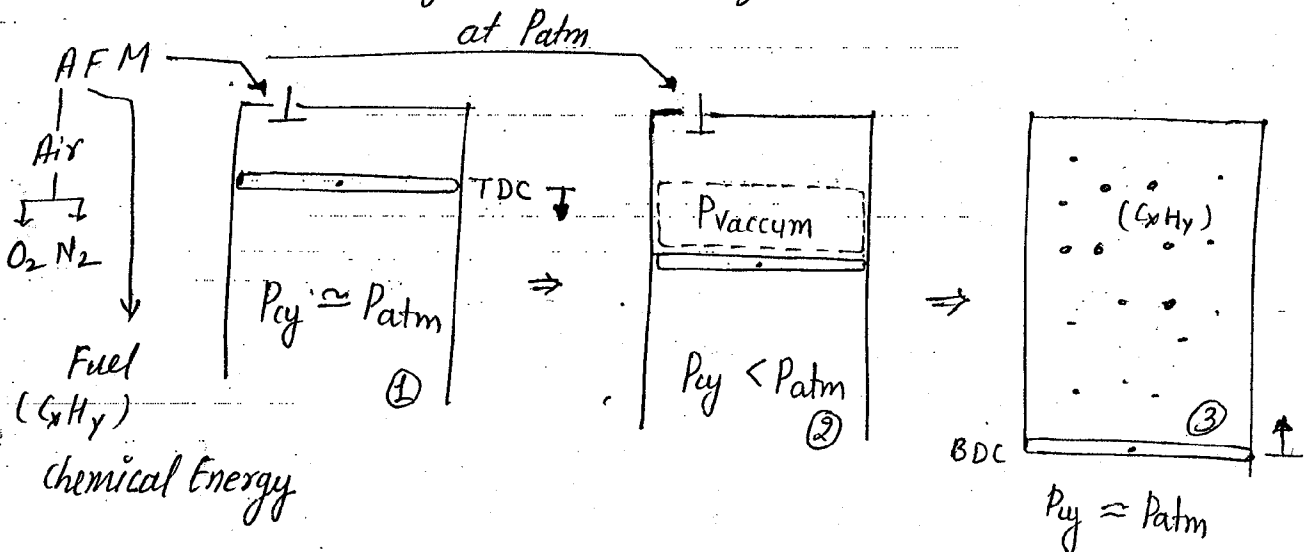
$$x = L_c + r_c - [r_c + L_c] = 0 \Rightarrow \boxed{x = 0}$$

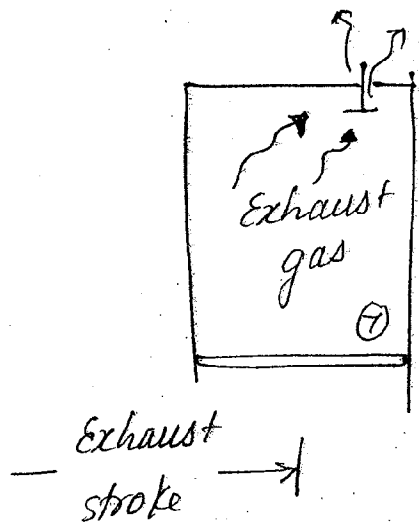
(b) at BTC $\theta = \pi$

$$x = L_c + r_c - [-r_c + \sqrt{L_c^2 + 0}]$$

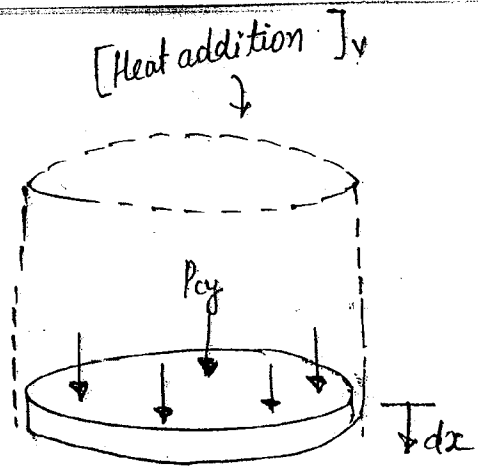
$$\boxed{x = 2r_c = L}$$

\Rightarrow Basic Working of IC Engine [4-STROKE]





Note



$$WD = \int_i^f P_{cy} (A_p dx)$$

$$WD = \int_i^f P_{cy} dv$$

Cycle
↓

Suction → Compression → power → Exhaust

* After power stroke, as exhaust valve is open major exhaust gases will escape out of the cylinder at BDC only and it is termed as heat rejection at constant volume.

* After heat rejection the remaining exhaust gases will be thrown out of the cylinder as piston displaces from BDC to TDC And this process is termed as exhaust stroke.

Air Standard Cycles

→ Air Standard Assumptions:-

- (1) Air is only working fluid. (5) all the processes are internally reversible.
- ↓
- (2) perfect gas
- (3) Ideal gas equation $pV = mRT$
- (4) C_p , C_v and γ should be constant.

$$C_p - C_v = R \quad \frac{C_p}{C_v} = \gamma$$

#1 process 1-2 [Adiabatic Compression] $pV^\gamma = c$

↓

Isentropic Compression

↓

Adiabatic process ($pV^\gamma = c$) + Rev. process ($pV = mRT$)

$$*** \frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2} \right)^{\gamma-1}$$

#2 process 2-3 [Heat Addition $V = \text{Const}$]

$$dq = du + dw \rightarrow 0$$

$$\Rightarrow dq = du = +ve$$

$$u = f(T)$$

$$V = \text{Const}$$

$$\uparrow p \propto T \uparrow$$

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

#3 process 3-4 [Expansion]

Isentropic Expansion ($pV^\gamma = c$)

$$W_E = \frac{P_3 V_3 - P_4 V_4}{\gamma - 1}$$

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4} \right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_4}{V_3} \right)^{\gamma-1}$$

process ratio:- for any process it is defined as the higher value to the lower value for pressure, volume and temp.

Compression

$$r_p = \frac{P_2}{P_1}$$

$$\left[r = \frac{V_1}{V_2} \right]$$

$$r_T = \frac{T_2}{T_1}$$

Expansion

$$r_p = \frac{P_3}{P_4} \rightarrow \max$$

$$r_v = \frac{V_4}{V_3}$$

$$r_{e,T} = \frac{T_3}{T_4} \rightarrow \max$$

$$* \quad \gamma = \frac{V_1}{V_2} = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c} = 1 + \frac{1}{(V_c/V_s)}$$

$$\Rightarrow \boxed{\gamma = 1 + \frac{1}{c}}^{**}$$

* process 1-2

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{V_1}{V_2} \right)^{\gamma-1} = (\gamma)^{\gamma-1}$$

$$\Rightarrow \boxed{T_2 = T_1 (\gamma)^{\gamma-1}}^*$$

$$\Rightarrow \boxed{P_2 = P_1 (\gamma)^\gamma}^*$$

⇒ Derivation of otto cycle Efficiency.

$$\eta = \frac{(WD)_{net}}{(HA)_V} = \frac{(HA)_V - (HR)_V}{(HA)_V} = 1 - \frac{(F/A)_V}{(HA)_V}$$

$$\Rightarrow \eta_o = 1 - \frac{\int_1^4 C_v dT}{\int_2^3 C_v dT} = 1 - \frac{C_v (T_4 - T_1)}{C_v (T_3 - T_2)}$$

const (air stand. assumption)

$$\eta_o = 1 - \frac{T_1}{T_2} \left(\frac{T_4/T_1 - 1}{T_3/T_2 - 1} \right)$$

Note

$$\left. \begin{aligned} \frac{T_2}{T_1} &= r^{\gamma-1} \\ \frac{T_3}{T_4} &= \left(\frac{V_4}{V_3} \right)^{\gamma-1} = (r_e)^{\gamma-1} \end{aligned} \right\} \Rightarrow r = r_e$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{T_3}{T_4} \Rightarrow \boxed{\frac{T_4}{T_1} = \frac{T_3}{T_2}} \Rightarrow T_2 T_4 = T_1 T_3$$

Now $\eta_o = 1 - \frac{T_1}{T_2} = 1 - \frac{1}{(T_2/T_1)}$

$$\boxed{\eta_o = 1 - \frac{1}{(r)^{\gamma-1}} = \frac{(WD)_{net}}{(HA)_V}}$$

Air standard efficiency for otto cycle