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IC Engine

(1) Air Standard Cycle

(a) otto cycle

(b) Diesel cycle

(c) Dual cycle

(2) Thermochemistry

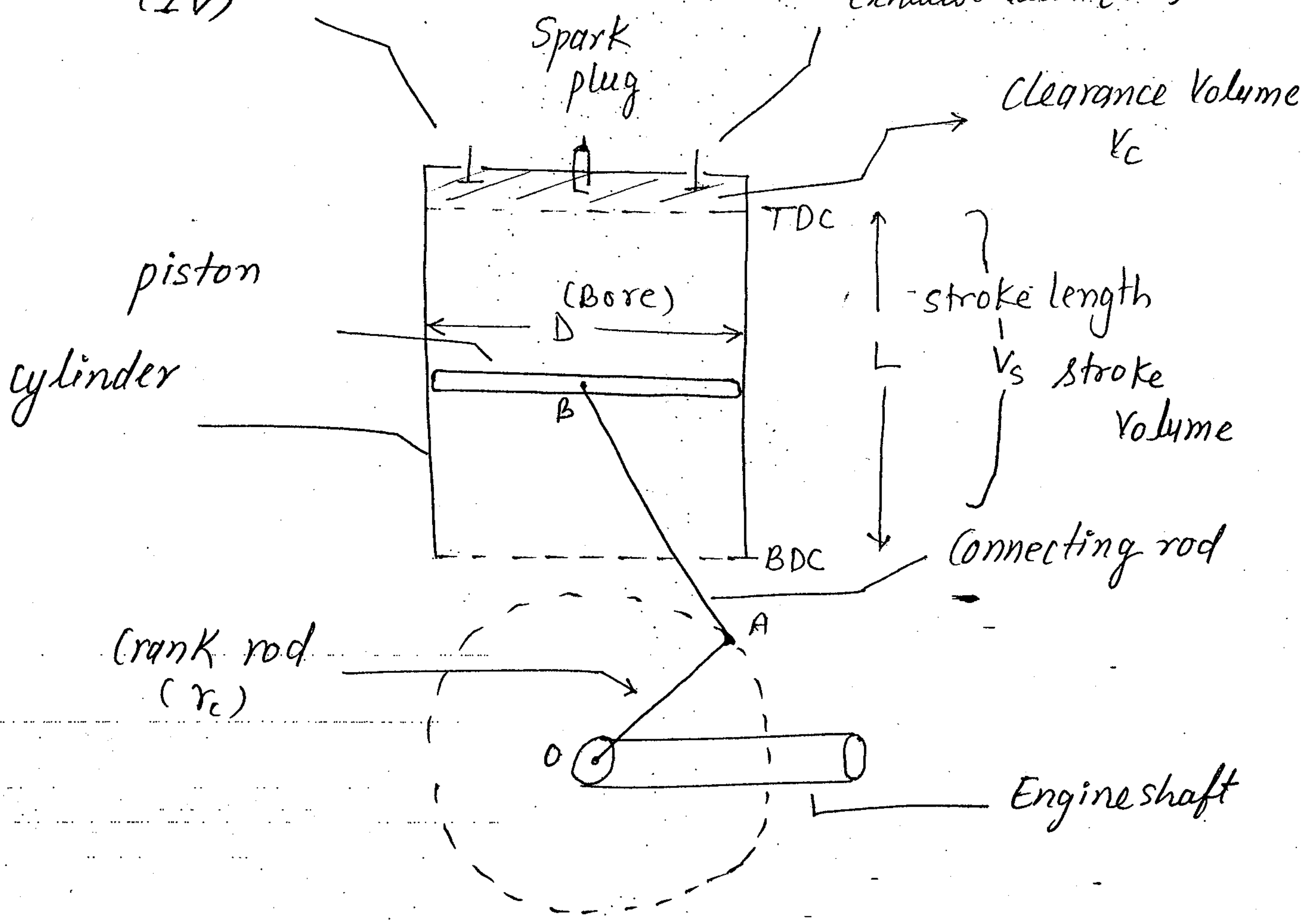
(3) Testing of IC Engine

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

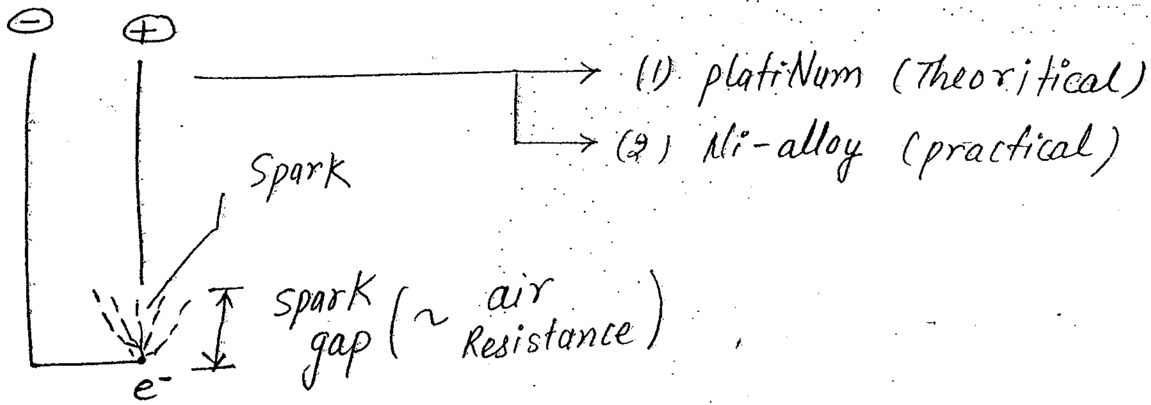
Note * Stroke length = 2 x crank radius

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

* piston rings made up of Cast Iron.

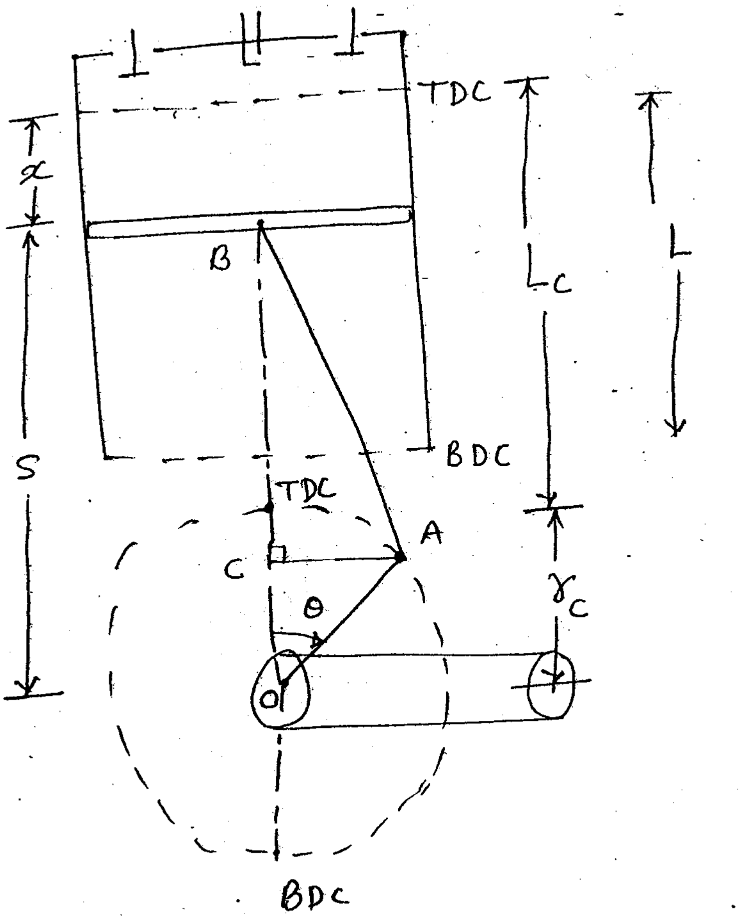
#1 Spark plug

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



* Spark plug should be made up of platinum theoritically 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 $\theta = 0°$

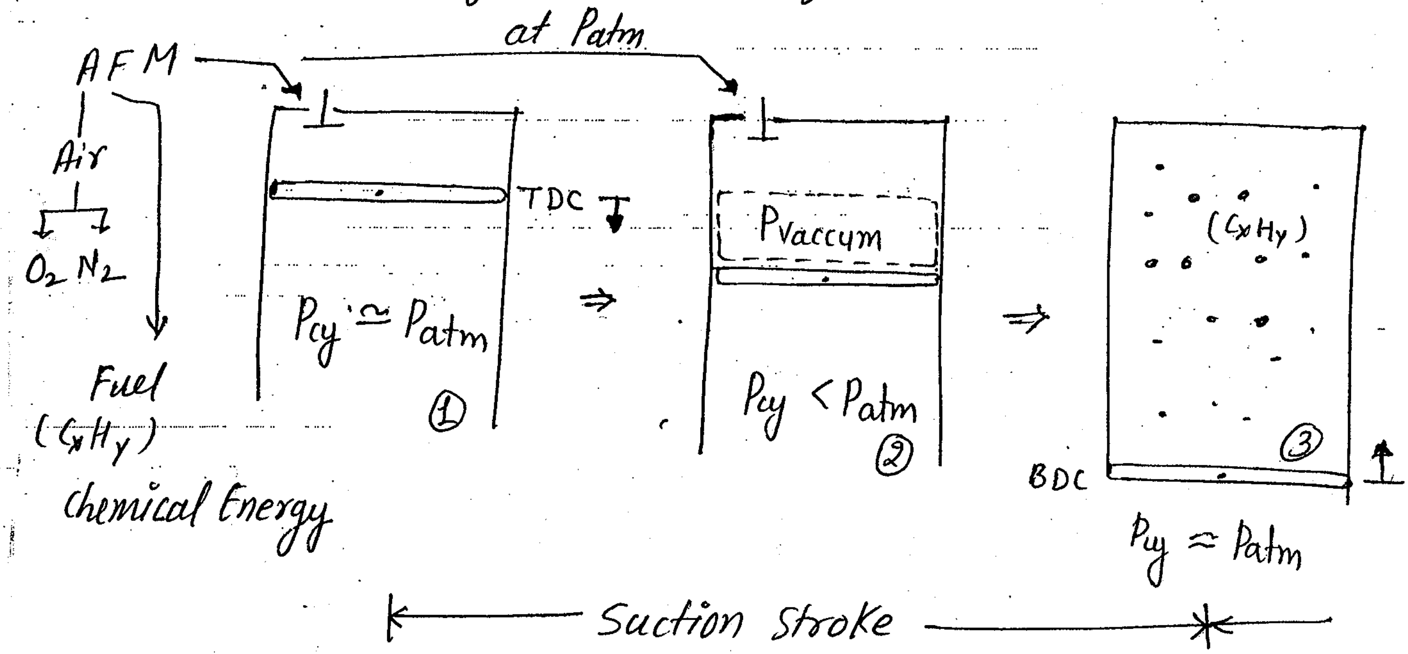
$$x = L_c + r_c - \{ r_c + L_c] = 0 \Rightarrow \boxed{x = 0}$$

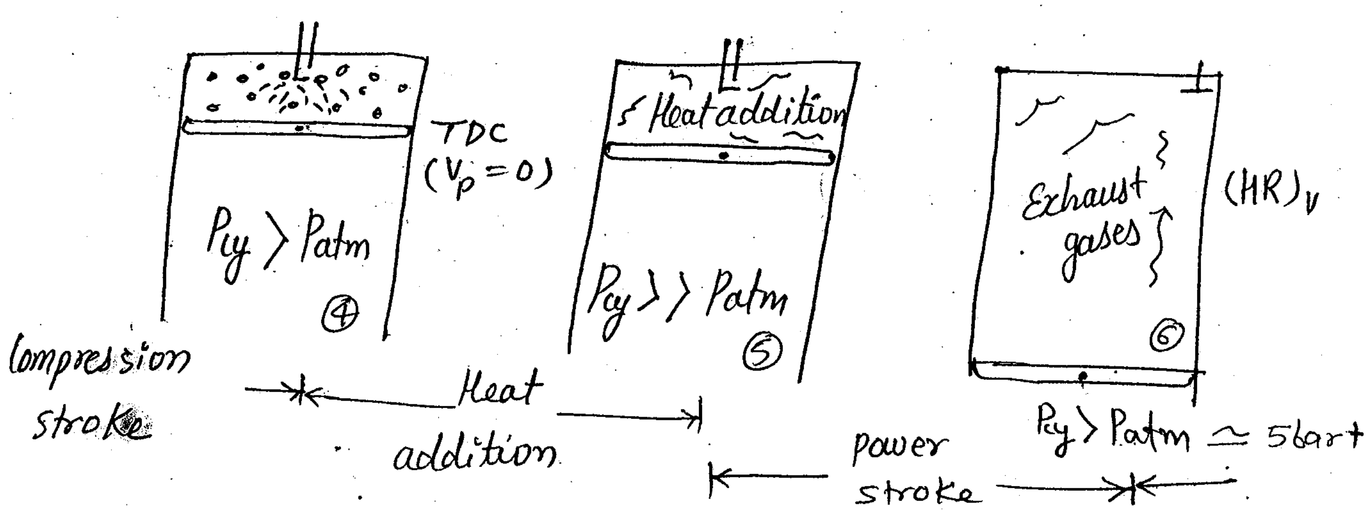
(b) at BTC $\theta = \pi$

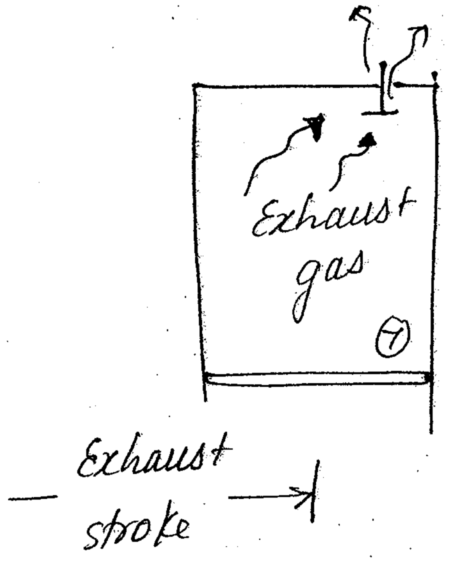
$$x = L_c + r_c - \{ -r_c + \sqrt{L_c^2 + 0}]$$

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

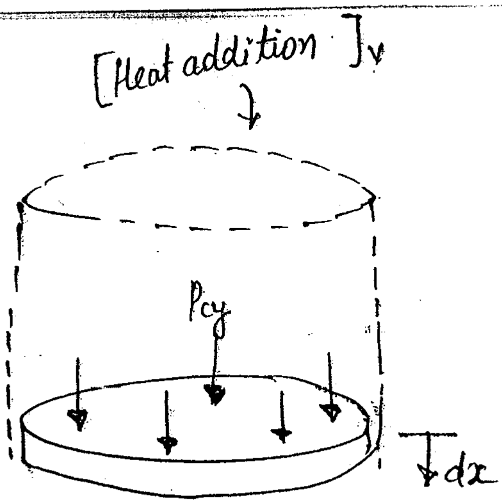
⇒ Basic Working of IC Engine [4 - STROKE]







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 value is open major exhaust gases will escape out of the cylinder at B.D.C only and it is termed at 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.
↓
(2) perfect gas

(3) Ideal gas equation $PV = mRT$

(4) C_p, C_v and γ should be constant.

(5) all the processes are internally reversible.

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

#1 process 1-2 [Adiabatic Compression] $PV^{\gamma} = C$
↓
Isentropic Compression
↓
Adiabatic process ($PV^{\gamma} = C$) + Rev. process ($PV = mRT$)

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

#2 process 2-3 [Heat Addition $V = $ Const]

$$dQ = du + \cancel{dw}^{\,0}$$

$$\Rightarrow dQ = du = +ve$$

$$U = f(T)$$

$V = $ 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 Ration:- 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

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

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

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

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

$$\Rightarrow \boxed{r = 1 + \frac{1}{c}} \quad **$$

* process 1-2

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

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

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

⇒ Derivation of otto cycle Efficiency

$$\eta = \frac{(WD)_{net}}{(HA)_v} = \frac{(HA)_v - (HR)_v}{(HA)_v} = 1 - \frac{(HR)_v}{(HA)_v}$$

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

C_v ↓ 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

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

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

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