The Shirpur Education Society's

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

Department of Mechanical Engineering

NAME OF COURSE: - Thermal Engineering (TEG)

CODE OF COURSE: - 313310

SEMESTER: - SYME-3K

SUBJECT TEACHER: - Mr. Bhushan S. Patil

Chapter-05 - Introduction to IC Engine & power cycles.

Total Marks = 12

Total Hours = 06

Q - Q.1 Q.4 C & D Q.6 C

M - 2M 4 & 4 6M

5.1 Power cycles:-

1] Carnot cycle:-

i] PV & TS diagram:-

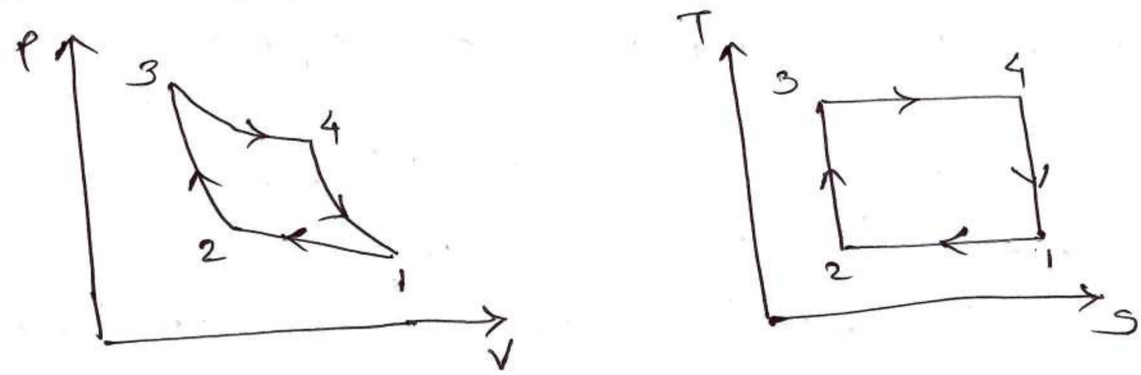


fig. P-V & T-S diagram of Carnot cycle.

ii] Processes:- 4 processes

1] 1→2 process:- Isothermal heat rejection process

2] 2→3 process:- Reversible Adiabatic Compression process

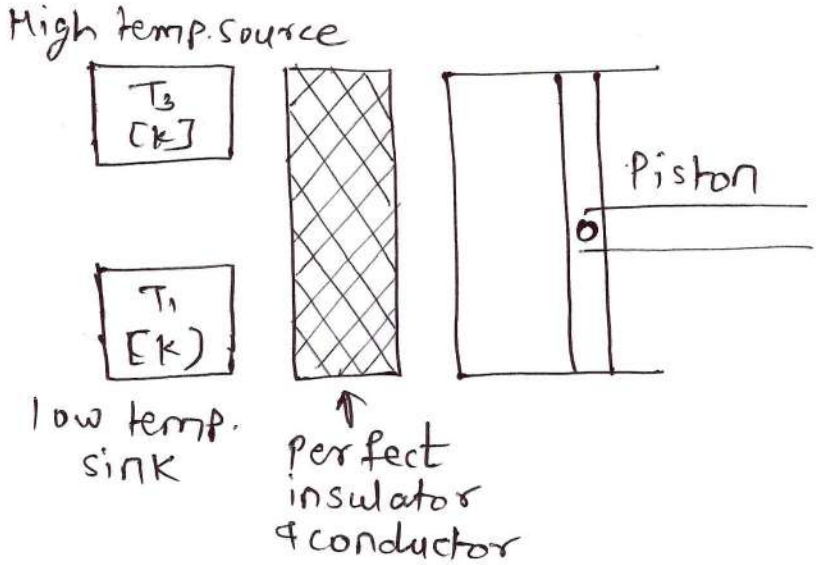
3] 3→4 process:- Isothermal heat addition process

4] 4→1 process:- Reversible adiabatic expansion process

Explaination:-

It is reversible cycle inwhich, the working medium receives heat at a higher temperature & rejects heat at a lower temperature.

It gives the concept of maximizing work output between two temperature limits.



a] first heat is transfered from high temperature source [T_3], to the working medium in the cylinder at constant temperature [$T_3 = T_4$] along a process $3 \to 4$. Head is act as conductor.

b] The working medium expands adiabaticaly along Process [$4 \to 1$]. Head is acts as insulator

c] The system is brought in contact with a constant low temperature sink [T_1] where heat is rejected to the sink represented by process [$1 \to 2$]. Head acts as conductor.

d] Working medium is compressed adiabaticaly along process [4-1].

Limitations :-

a] Heat addition at constant temperature is very slow process & ~~heat~~ adiabatic expansion is very fast process. Both are not possible during a same stroke of piston.

b] No material is ~~pe~~ both perfect insulator & perfect conductor.

* Efficiency of Carnot Cycle:-

$$\eta_{carnot} = \frac{\text{Work done during cycle [W]}}{\text{Heat supplied [Q]}}$$

By I^{st} law of Thermodynamics

Work done [W] = heat supplied [Q_S] - heat rejected [Q_R]

$$\therefore \quad W = Q_S - Q_R$$

for Isothermal process $1 \to 2$ & $3 \to 4$

we get,

$$Q_R = mRT_1 \ln[V_1/V_2]$$

$$Q_S = mRT_4 \ln[V_4/V_3]$$

for adiabatic process,

$$\left(\frac{V_3}{V_2}\right) = \left(\frac{T_2}{T_3}\right)^{\frac{1}{\gamma-1}}$$

$$\left(\frac{V_4}{V_1}\right) = \left[\frac{T_1}{T_4}\right]^{\frac{1}{\gamma-1}}$$

Since, $T_1 = T_2$ & $T_3 = T_4$ we have.

$$\frac{V_4}{V_1} = \frac{V_3}{V_2}$$

OR

$$\frac{V_4}{V_3} = \frac{V_1}{V_2} = r \text{ - [Compression ration]}$$

then,

$$\eta_{carnot} = \frac{mRT_3 \log[r] - mRT_1 \ln(r)}{mRT_3 \ln(r)}$$

$$= \frac{T_3 - T_1}{T_3} = 1 - \frac{T_1}{T_3}$$

$$\therefore \boxed{\eta_{carnot} = 1 - \frac{T_1}{T_3}}$$

The lower temp. [T_1] is normally a atmospheric temperature & fixed.

So, The increase in thermal efficiency can be achieved by increase in Source temperature.

2] Otto cycle OR Petrol cycle OR Spark ignition Engine [S.I] S.I. Engine.

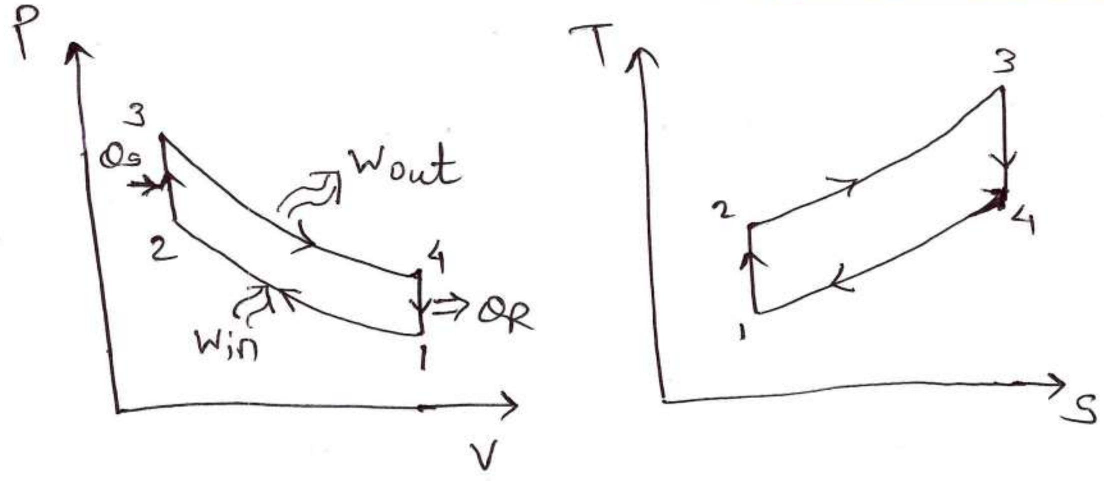


fig. P-V & T-S diagram of otto cycle

Processes :-

$1 \rightarrow 2 \Rightarrow$ Reversible adiabatic or isentropic compression process.

$2 \rightarrow 3 \Rightarrow$ Constant volume heat addition process

$3 \rightarrow 4 \Rightarrow$ Reversible adiabatic or isentropic expansion process

$4 \rightarrow 1 \Rightarrow$ Constant volume heat rejection process

Thermal Efficiency :-

$$\eta_{otto} = \frac{Q_S - Q_R}{Q_S} \Rightarrow \frac{W.D.}{Q_S} \Rightarrow \frac{\text{Work done}}{\text{heat supplied}}$$

where, $Q_S = mc_v[T_3 - T_2]$ & $Q_R = mc_v[T_4 - T_1]$

$$\therefore \eta_{otto} = \frac{m[T_3 - T_2] - m[T_4 - T_1]}{mc_v[T_3 - T_2]} \Rightarrow 1 - \frac{T_4 - T_1}{T_3 - T_2}$$

for isentropic process $1 \rightarrow 2$ & $3 \rightarrow 4$

$$\frac{T_2}{T_1} = \left[\frac{V_1}{V_2}\right]^{\gamma-1}, \quad \frac{T_3}{T_4} = \left[\frac{V_4}{V_3}\right]^{\gamma-1}$$

but $\frac{v_1}{v_2} = \frac{V_4}{V_3} = r_c$ = Compression ratio

$$\therefore \quad \frac{T_2}{T_1} = \frac{T_3}{T_4}$$

now, $\frac{T_4}{T_3} = \frac{T_1}{T_2} = \frac{T_4 - T_1}{T_3 - T_2}$

$$\therefore \quad \eta_{otto} = 1 - \frac{T_1}{T_2} \Rightarrow 1 - \frac{1}{\left[\frac{v_1}{v_2}\right]^{\gamma-1}}$$

$$\boxed{\eta_{otto} = 1 - \frac{1}{r_c^{\gamma-1}}}$$

The thermal efficiency of otto cycle is a function of compression ratio & ratio of sp. heats [γ]

efficiency can be increased by increasing compression ratio. but, its upper limit is limited by the self ignition temperature of the fuel.

3] Diesel Engine or Combustion Ignition [C.I. Engine] or Constant pressure Engine.

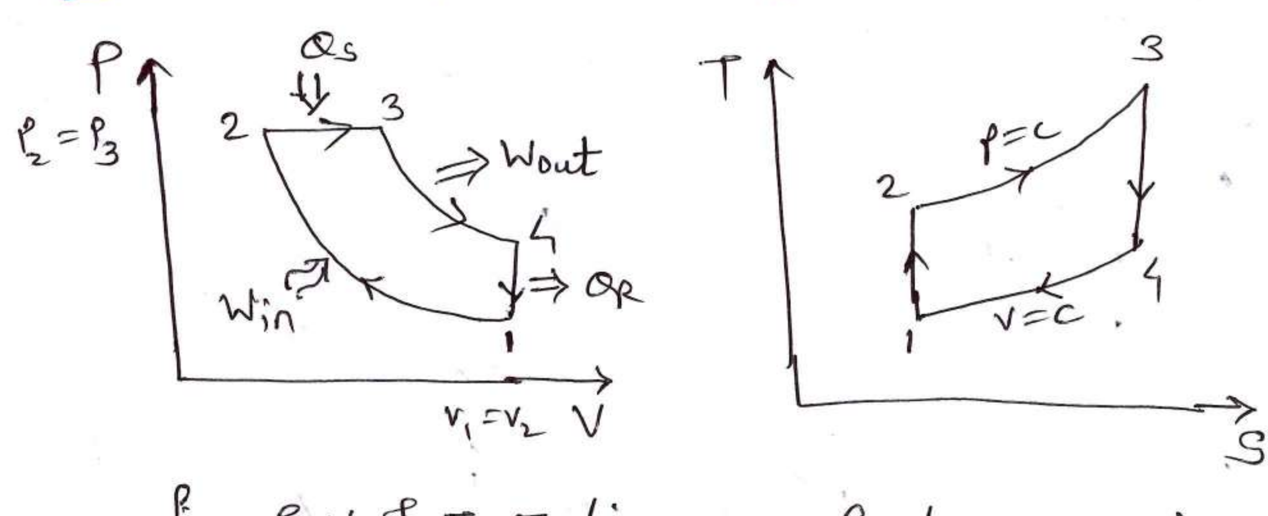


fig. P-V & T-S diagram of diesel Engine.

Processes :- 4 - processes.

1) Process $(1 \rightarrow 2)$ ⇒ isentropic Compression process
2] Process $[2 \rightarrow 3]$ ⇒ isobaric heat addition process
3] Process $[3 \rightarrow 4]$ ⇒ Isentropic expansion process

Process $[4 \rightarrow 1]$ ⇒ Isobaric heat rejection Process

Efficiency of diesel Engine:-

$$\eta_{diesel} = 1 - \frac{1}{r_c^{\gamma-1}}\left[\frac{r_k^{\gamma}-1}{\gamma[r_k-1]}\right]$$

The efficiency of diesel Engine/cycle is different from that of the otto cycle only in the bracketed factor, This factor is always greater than unity. Hence for a given compression ratio. The otto cycle is more efficient.

However, compression ratio used for diesel cycle is 16 to 20 & that of petrol engine is 6 to 10. therefore the efficiency of diesel Engine is more than petrol Engine.

4] Dual Engine/cycle:-

It is a mixed cycle or limited pressure cycle & compromise between otto cycle & diesel cycle.

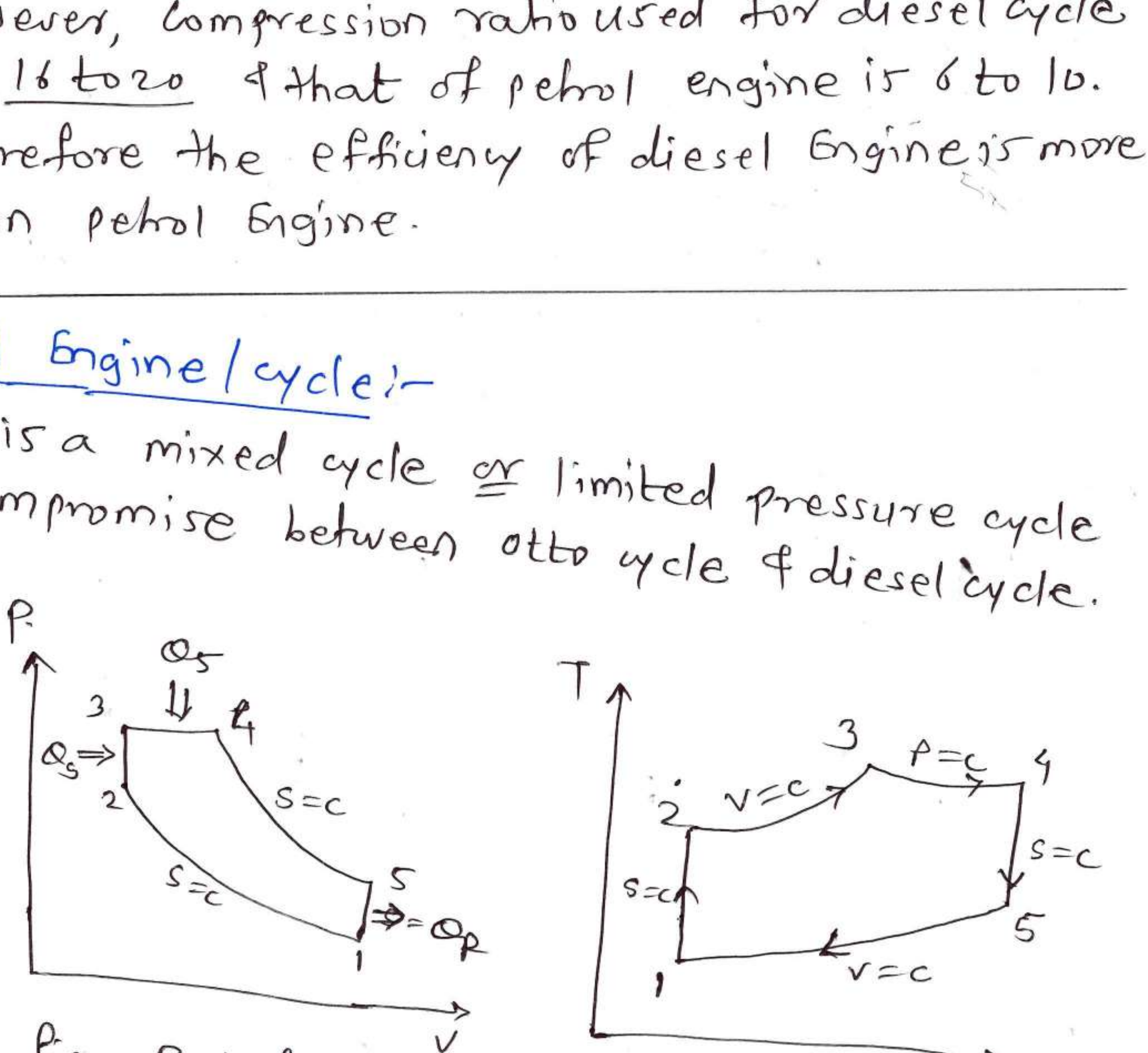


fig. P-V & T-S diagram for dual cycle.

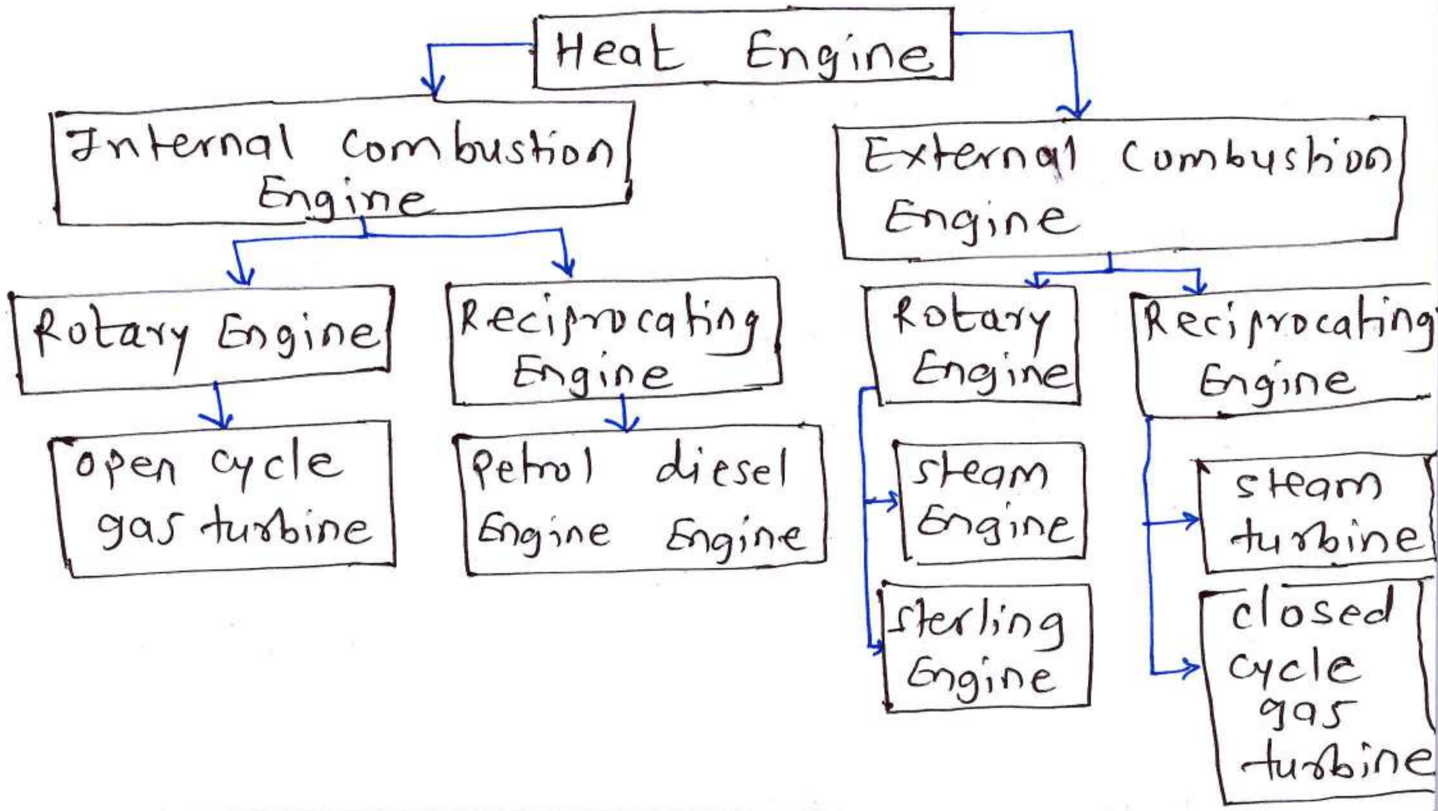
Here, heat addition partly taken place at constant volume process & partly at constant pressure process.

5.2] Internal Combustion Engine [I.C. Engine]

Engine :- A device which transforms one form of Energy into another form.

Heat Engine :- A device which transforms the chemical Energy of a fuel into thermal Energy & utilises this thermal energy to perform useful work.

* Classification of heat Engine.



Internal Combustion Engine :-

The Engine inwhich Combustion of fuel takes place inside of an Engine.

External Combustion Engine :-

The Engine inwhich combustion of fuel takes place outside of an Engine.

Classification of I-C. Engine :-

A] According to nature of cycle :-

a] Constant volume or otto cycle.
b] Constant pressure or diesel cycle.
c] Duel cycle or constant vol^m & constant Pr cycle

B] According to Number of stroke :-

a] 4-stroke Engine
b] 2-stroke Engine

C] According to method of Ignition.

a] Spark Ignition [SI Engine]
b] Compression Ignition [CI Engine]

D] According to Number of cylinders.

a] Single cylinder Engine.
b] multi cylinder Engine

E] According to arrangement of cylinder

a] Vertical Engine
b] Horizontal Engine
c] Radial Engine

Application of IC Engine :-

1] Propulsion of road vehicles, eg. bus, cars, etc
2] Power generation eg. petrol or diesel Engine generator
3] Aircraft propulsion
4] Marine & agricultural application.

Terminology of IC Engine :-

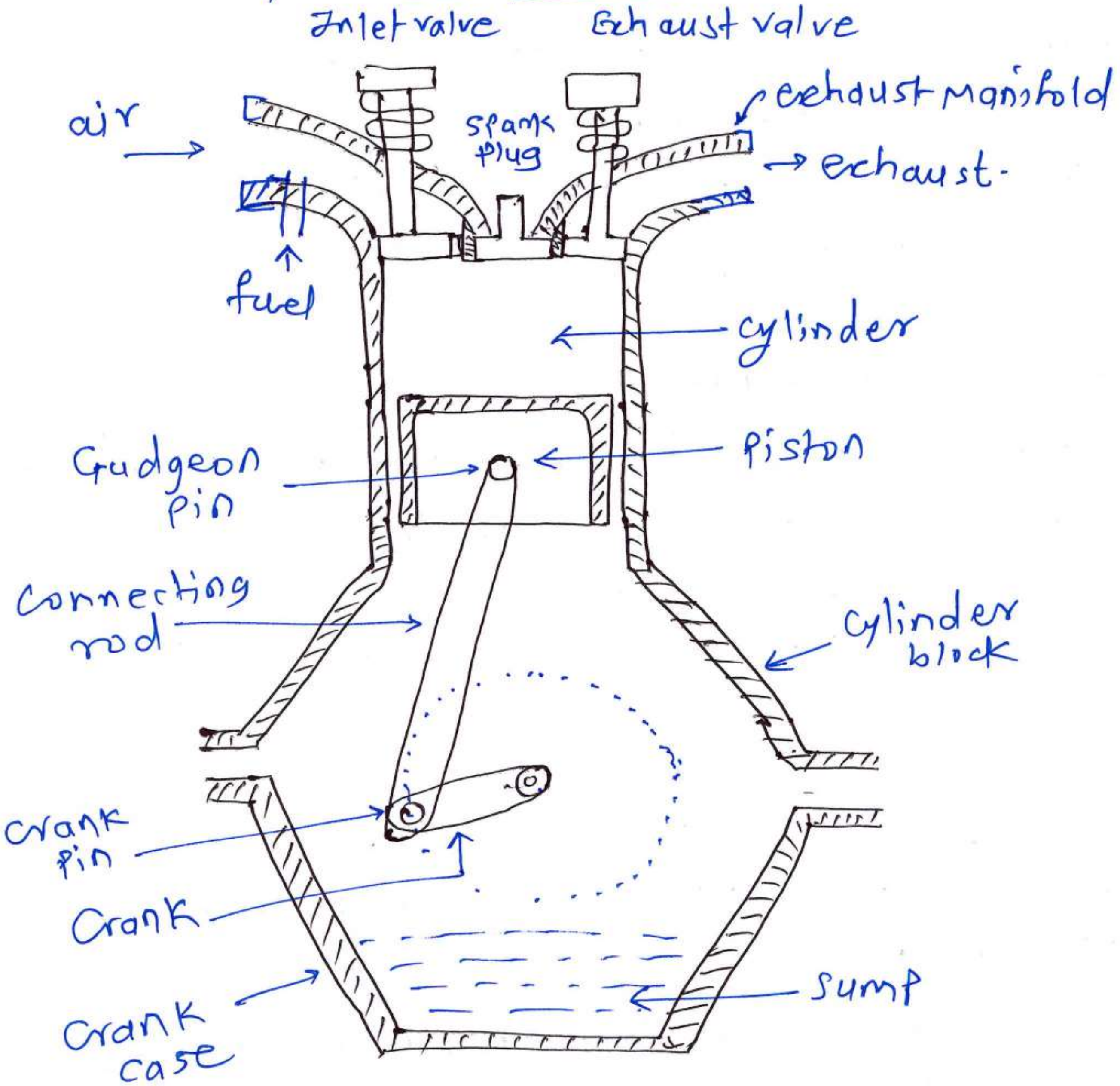


fig. I.C. Engine

1] **Cylinder Bore** :- The Nominal inner diameter of the cylinder is called as cylinder Bore.
unit :- mm, cm.

2] **Piston area [A]** :- The area of circle of diameter equal to the cylinder bore is known as Piston area.

$$\boxed{A = \frac{\pi}{4} d^2}$$ unit $\Rightarrow$ mm^2, cm^2 etc.

3] stroke [L]:-

Nominal distance through which a working Piston moves through two successive reversals of its direction of motion is called the stroke. measured in mm or cm.

4] Stroke to bore Ratio:-

Ratio of stroke to diameter of piston [$\frac{L}{d}$].

if, $L = d \Rightarrow$ square Engine

$L > d \Rightarrow$ under square Engine

$d > L \Rightarrow$ over square Engine.

5] dead centre:-

The position of piston at which it reverse its direction.

a] Inner dead center [IDC] → For Horizontal Engine
Bottom dead center [BDC]:- For vertical Engine.

It is a dead center when the piston is nearest from the crankshaft.

b] outer dead center [ODC] → For Horizontal
TOP dead center [TDC] → for vertical.

It is a dead center when the piston is farthest from the crankshaft.

6] sweft volume or displacement volume:→

The Nominal volume sweft by working piston when traveling from a one dead center to another dead center.

swept volume $[V_s] = \frac{\pi}{4} d^2 \times L$

7] clearance volume [Vs] :-

The Nominal volume of a Combustion chamber above the piston when it is at the top dead center. denoted by V_c.

8] Compression ratio [r_c] :-

It is a ratio of total cylinder volume to the clearance volume.

$$\therefore \; r_c = \frac{V_T}{V_c} = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c}$$

$$\therefore \; \boxed{r_c = 1 + \frac{V_s}{V_c}}$$, it is always greater than one.

9] Piston Speed :- [N]

The linear distance travelled by piston in Minute

$$\therefore \; \text{piston speed} = 2LN$$

where L = stroke in meter
N = rpm.

10] cut-off ratio :-

Ratio of volume at the end of fuel injection to the volume before fuel injection.

11] Indicated power [IP] :-

The power developed inside of an Engine cylinder by combustion of fuel is known as indicated power. denoted by I.P.

12] Brake power [BP] :-

The useful power available at the crankshaft of Engine is known as Brake power.

13] Frictional Power: [FP] :-

It is a difference between indicated power & Brake power.

It is a measure of powerloss due to friction

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

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* Four Stroke Engine :- [observe IC Engine diagram]

Engine cycle is completed in 4-stroke of piston or two revolution of crankshaft.

Two Types of 4- stroke Engine.

a] 4 - stroke petrol Engine or S.I. Engine :→
It is spark ignition, spark plug used.

b] 4- stroke diesel Engine or C.I. Engine:→
It is a combustion ignition, fuel injector is used.

strokes :-

1] Suction stroke [TDC to BDC]
2] Compression stroke [BDC to TDC]
3] Expansion stroke [TDC to BDC]
4] Exhaust stroke [BDC to TDC]

1] Suction stroke :-

During suction stroke, piston moves from TDC to BDC, which creates vaccum in the cylinder head. As a result of which air in case of C.I Engine or charge [air fuel mixture] from carburator in case of S-I Engine is taken into a cylinder until it is completely filled. Inlet valve is open & Exhaust valve is closed during this stroke.

2] Compression stroke:-

During compression stroke piston travels from BDC to TDC as a result of which trapped charge or air in cylinder is compressed, which results in high pressure or temperature in cylinder which is sufficient to ignite the fuel.

Inlet valve closes & also Exhaust valve closes.

* fuel Injection or spark:-

At the end of Compression stroke, fuel is injected in case of C.I. Engine or spark is produced incase of S.I. Engine, which ignites the fuel.

3] Expansion stroke:-

The Bursting of fuel creates a tremendous pressure inside the cylinder & exerted high pressure or Force on the piston head & pushes it towards BDC, which creates a mechanical power

Both inlet valve & Exhaust valve are closed during the stroke.

4] Exhaust stroke:→ At the end of expansion stroke the exhaust valve opens simultaneously & inlet valve remains closed. Piston travels from BDC to TDC & sweeps burnt gases out from the cylinder almost.

* 2-stroke Engine:-

* All four processes of 2-stroke Engine cycle is completed in 2-stroke of piston or one revolution of crank.
* one power stroke in one revolution of crank
* Inlet & Exhaust valves are replaced by inlet & exhaust port.

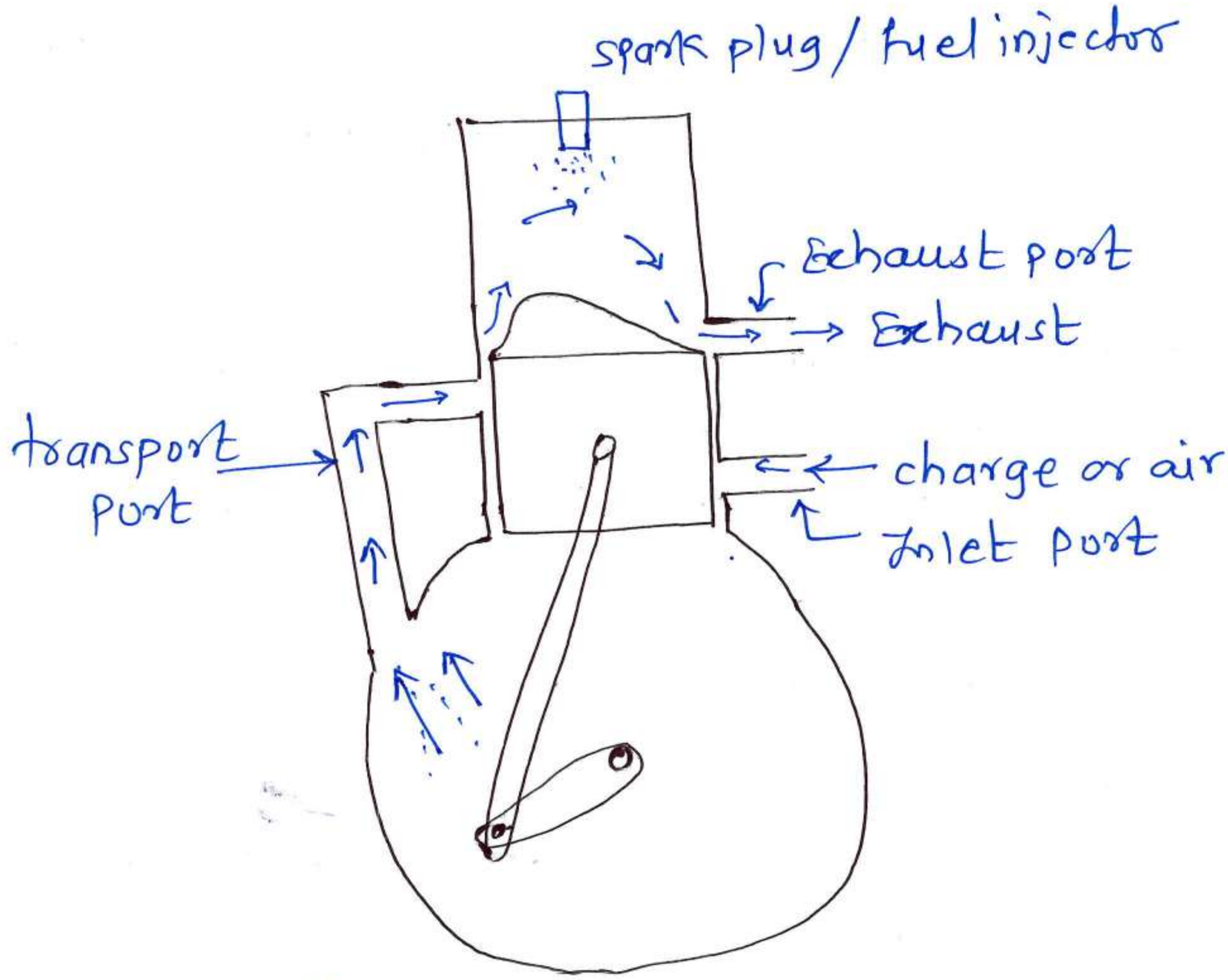

fig. 2-stroke Engine.

2-types:-

a] 2-stroke petrol Engine

b] 2-stroke diesel Engine.

Ist stroke:-

Piston travels from BDC to TDC, during this stroke 2-processes such as suction & compression is taken place simultaneously.

Suction:- With upward motion of piston, vaccum is created inside of the crankcase. As soon as piston uncovered inlet port, the fresh charge is sucked into a crankcase.

Compression:-

At the same time, the charge which is already in the cylinder is compressed.

IInd stroke:-

During second stroke, piston movement is from TDC to BDC.

Slightly before the completion of compression stroke, the compressed charge is ignited by means of spark produced by spark plug.

Expansion stroke:-

Expansion is starts as explosion of charge gives thrust to piston.

The downward movement of the piston will first close the inlet port & then it will compress the charge already sucked in the crank case & this fresh charge is transfered on top side of piston through transfer port.

at the same time exhaust port opens & burnt gases escape through exhaust port.

* Difference between 4-stroke & 2-stroke Engine

4-stroke Engine	2-stroke Engine
1] cycle is completed in two revolution of crank shaft	1] cycle is completed in one revolution of crank shaft.
2] one power stroke in every 2-revolution of crank shaft	2] one power stroke in every ~~r~~ revolution of crank shaft.
3] More thermal efficiency	3] Less thermal efficiency
4] Appl^n:- trucks, buses etc	4] Appl^n:- scooters, lawn cutters.
5] Bulky size for same power generation	5] lighter size for same power generation
6] High Cost	6] less cost.

* difference between petrol cycle & diesel cycle.

Petrol cycle/Engine	diesel Engine.
1] Heat addition takes place at constant volume.	1] Heat addition takes place at constant pressure.
2] Compression ratio $[r_c]$ = 6 to 10	2] Compression ration = 16 to 20
3] for same compression ratio, it is more efficient	3] for same compression ratio, it is less efficient
4] Used in lighter vehicle eg. Car, jeep, motorcycle	4] used in heavy vehicles eg. trucks, tractors etc.
5] high volatility fuel is used.	5] Low volatility fuel is used.

27/06/26