I.C. ENGINES & COMPRESSORS(NOTES)

UNIT- I

Engine: An engine is a device which transforms one form of energy into another form. Normally, most of the engines convert thermal energy into mechanical work and therefore they are called 'heat engines'.

Heat Engine: Heat engine is a device which transforms the chemical energy of a fuel into thermal energy and utilizes thermal energy to perform useful work. Thus, thermal energy is converted to mechanical energy in a heat engine.

Heat engines can be broadly classified into two categories:

(a) Internal Combustion Engines (IC Engines): In internal combustion engines combustion of fuel takes place within the engine cylinder.

(b) External Combustion Engines (EC Engines): External combustion engines are those in which combustion of fuel takes place outside the engine cylinder.

Classification and Some Basic Details of Heat Engines:

Engines whether Internal Combustion or External Combustion are of two types, viz.,

(a)Rotary engines

(b)Reciprocating engines

External Combustion and Internal Combustion Engines:

External combustion engines are those in which combustion of fuel takes place outside the cylinder of the engine whereas in internal combustion engines combustion of fuel takes place within the cylinder of engine.

ENGINE COMPONENTS:

A cross section of a single cylinder spark-ignition engine with overhead valves is shown in Fig.1. The major components of the engine and their functions are briefly described below.

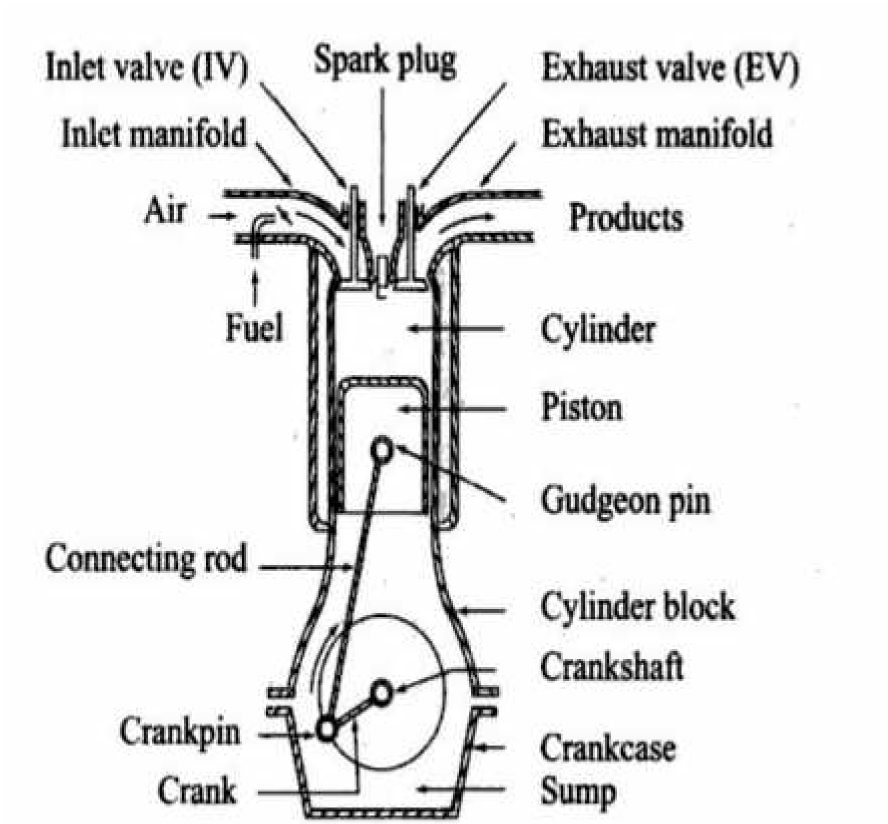


Fig:1

Cylinder: As the name implies it is a cylindrical vessel or space in which the piston makes a reciprocating motion. The varying volume created in the cylinder during the operation of the engine is filled with the working fluid and subjected to different thermodynamic processes. The cylinder is supported in the cylinder block.

Piston: It is a cylindrical component fitted into the cylinder forming the moving boundary of the combustion system. It fits perfectly (snugly) into the cylinder providing a gas-tight space with the piston rings. It forms the first link in transmitting the gas forces to the output shaft.

Combustion Chamber: The space enclosed in the upper part of the cylinder, by the cylinder head and the piston top during the combustion process, is called the combustion chamber. The combustion of fuel and the consequent release of thermal energy results in the building up of pressure in this part of the cylinder.

Inlet Manifold: The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel mixture is drawn into the cylinder is called the inlet manifold.

Exhaust Manifold: The pipe which connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape into the atmosphere is called the exhaust manifold

Cylinder Block: The cylinder block is the main supporting structure for the various components. The cylinders of a multi-cylinder engine are cast as a single unit, called cylinder block. The cylinder head is mounted on the cylinder block. The cylinder head and cylinder block are provided with water jackets in the case of water cooling or with cooling fins in the case of air cooling. Cylinder head gasket is incorporated between the cylinder block and cylinder head. The cylinder head is held tight to the cylinder block by number of bolts or studs. The bottom portion of the cylinder block is called crankcase

Inlet and Exhaust Valves: Valves are commonly mushroom shaped poppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve) from the cylinder.

Spark Plug: It is a component to initiate the combustion process in Spark-Ignition (SI) engines and is usually located on the cylinder head.

Connecting Rod: It interconnects the piston and the crankshaft and transmits the gas forces from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end (Fig. 2). Small end is connected to the piston by gudgeon- pin and the big end is connected to the crankshaft by crank- pin.

Crankshaft: It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there is a pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.

Piston Rings: Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases (Fig.2).

Gudgeon Pin: It forms the link between the small end of the connecting rod and the piston.

Camshaft: The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears.

Cams: These are made as integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

Fly Wheel: The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia mass in the form of a wheel is attached to the output shaft and this wheel is called the flywheel.

NOMENCLATURE

Cylinder Bore (*d*): The inner diameter of the working cylinder is called the cylinder bore and is designated by the letter *d* and is usually expressed in millimeter (mm).
Piston Area (A): The area of a circle of diameter equal to the cylinder bore is called the piston area and is designated by the letter *A* and is usually expressed in square centimeter (cm^2).
Stroke (L): The distance through which a working piston moves between two successive reversals of its direction of motion is called the stroke and is designated by the letter *L* and is expressed usually in millimeter (mm).
Stroke to Bore Ratio: *L/d* ratio is an important parameter in classifying the size of the engine. $d < L$, it is called under-square engine. If $d = L$, it is called square engine. If $d > L$, it is called over-square engine, .An over-square engine can operate at higher speeds because of larger bore and shorter stroke.
Dead Centre: The position of the working piston and the moving parts which are mechanically connected to it, at the moment when the direction of the piston motion is reversed at either end of the stroke is called the dead centre. There are two dead centres in an engine as indicated in Fig.2. They are: (i) Top Dead Centre (ii) Bottom Dead Centre

(i) ***Top Dead Centre (TDC)***: It is the dead centre when the piston is farthest from the crankshaft. It is designated as *TDC* for vertical engines and Inner Dead Centre *(IDC)* for horizontal engines.
(ii) ***Bottom Dead Centre (BDC)***: It is the dead centre when the piston is nearest to the crankshaft. It is designated as *BDC* for vertical engines and Outer Dead Centre (*ODC*) for horizontal engine.

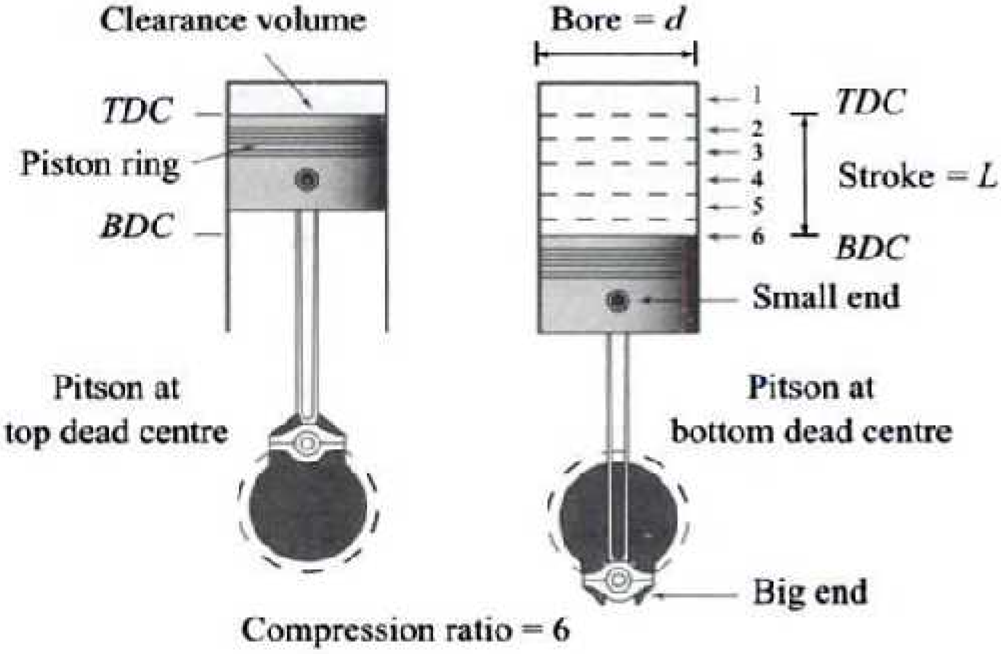


Fig. 2 Top and Bottom Dead Centres

Clearance Volume *(Vc)* : The volume of the combustion chamber above the piston when it is at the top dead centre is the clearance volume. It is designated as *Vc* and expressed in cubic centimeter (cc).
Displacement or Swept Volume (V_s): *The volume* swept by the working piston when travelling from one dead centre to the other is called the displacement or swept volume. It is expressed in terms of cubic centimeter (cc) and given by

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

Cubic Capacity or Engine Capacity: The displacement volume of a cylinder multiplied by number of cylinders in an engine will give the cubic capacity or the engine capacity. For example, if there are *K* cylinders in an engine, then

$$\textbf{Cubic capacity} = V_s \times K$$

Compression Ratio (r): It is the ratio of the total cylinder volume when the piston is at the bottom dead centre, V_T, to the clearance volume; V_C- It is designated by the letter r.

$$r = \frac{V_T}{V_C} = \frac{V_C + V_s}{V_C} = 1 + \frac{V_s}{V_C}$$

THE WORKING PRINCIPLE OF ENGINES

If an engine is to work successfully then it has to follow a cycle of operations in a sequential manner. The sequence is quite rigid and cannot be changed. In the following sections the working principle of both SI and Cl engines is described. Even though both engines have much in common there are certain fundamental differences.

The credit of inventing the spark-ignition engine goes to Nicolaus A. Otto (1876) whereas compression-ignition engine was invented by Rudolf Diesel (1892). Therefore, they are often referred to as Otto engine and Diesel engine.

Four-Stroke Spark-Ignition(Petrol) Engine

In a four-stroke engine, the cycle of operations is completed in four strokes of the piston or two revolutions of the crankshaft. During the four strokes, there are five events to be completed, viz., suction, compression, combustion, expansion and exhaust. Each stroke consists of 180° of crankshaft rotation and hence a four-stroke cycle is completed through 720° of crank rotation. The cycle of operation for an ideal four-stroke SI engine consists of the following four strokes:

(i) Suction or intake stroke; (ii) compression stroke; (iii) expansion or power stroke and (iv) exhaust stroke.

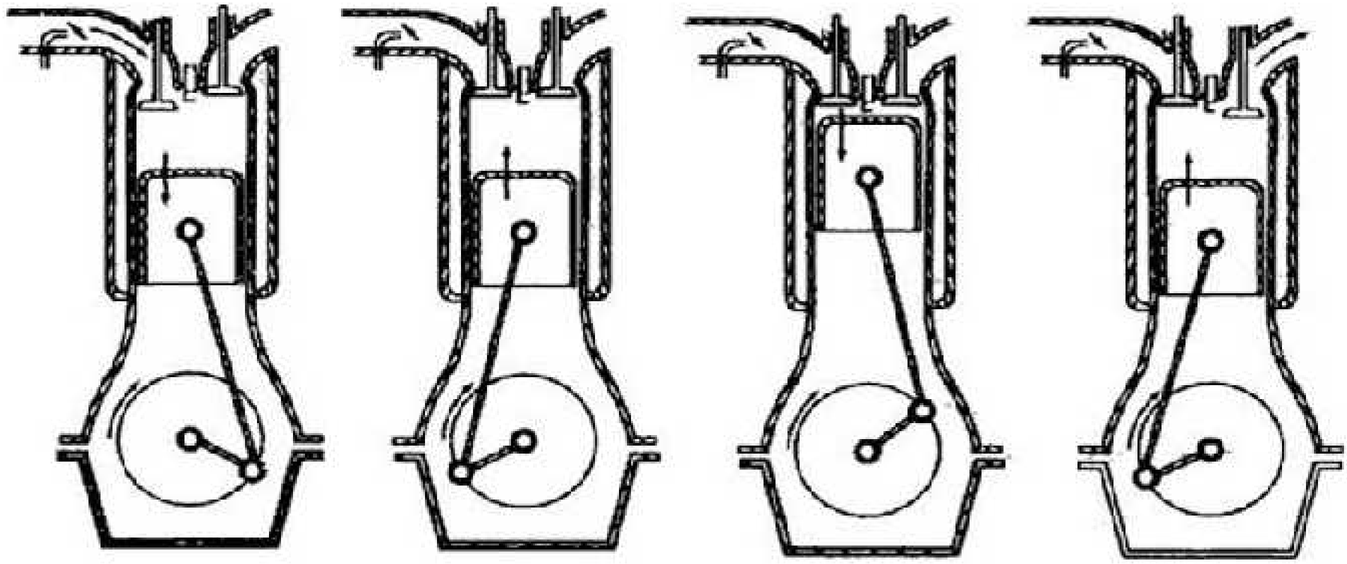
The details of various processes of a four-stroke spark-ignition engine with overhead valves are shown in Fig: 3 (a-d). When the engine completes all the five events under ideal cycle mode, the p-V diagram will be as shown in fig:4

Suction or Intake Stroke: Suction stroke 0—1 (Fig: 4) starts when the piston is at the Top Dead Centre and about to move downwards. The inlet valve is open at this time and the exhaust valve is closed, Fig: 3(a). Due to the suction created by the motion of the piston from Top Dead Centre (T.D.C.) to Bottom Dead Centre (B.D.C.), the charge consisting of fuel-air mixture is drawn into the cylinder. When the piston reaches the bottom dead centre, the suction stroke ends and the inlet valve closes.

Compression Stroke: The charge taken into the cylinder during the suction stroke is compressed by the return stroke of the piston 1—2 (adiabatic compression), (Fig: 4). During this stroke both inlet and exhaust valves are in closed position, Fig: 3(b). The mixture which fills the entire cylinder volume is now compressed into the clearance volume. At the end of the compression stroke the mixture is ignited with the help of a spark plug located on the cylinder head.

In ideal engines it is assumed that burning takes place instantaneously when the piston is at the Top Dead Centre and hence the burning process can be approximated as heat addition at constant volume (process 2-3) Fig:4. During the burning process the chemical energy of the fuel is converted into heat energy producing a temperature rise of about 2000 °C (process 2—3), Fig: 4. The pressure at the end of the combustion process is considerably increased due to the heat release from the fuel.

Expansion or Power Stroke: The high pressure of the burnt gases forces the piston towards the BDC. Both the valves are in closed position, Fig: 3(c). Of the four- strokes only during this stroke power is produced and pressure and temperature decreases in expansion (process 3—4) Fig:4.



(a) Intake (b) Compression (c) Expansion (d) Exhaust

Fig: 3

Exhaust Stroke: At the end of the expansion stroke the exhaust valve opens and the inlet valve remains closed, Fig. 3(d). The pressure falls to atmospheric level a part of the burnt gases escape. The piston starts moving from the Bottom Dead Centre to Top Dead Centre (stroke 1—0), Fig. 4 and sweeps the burnt gases out from the cylinder almost- at atmospheric pressure. The exhaust valve closes when the piston reaches *TDC.* at the end of the exhaust stroke and some residual gases trapped in the clearance volume remain in the cylinder.

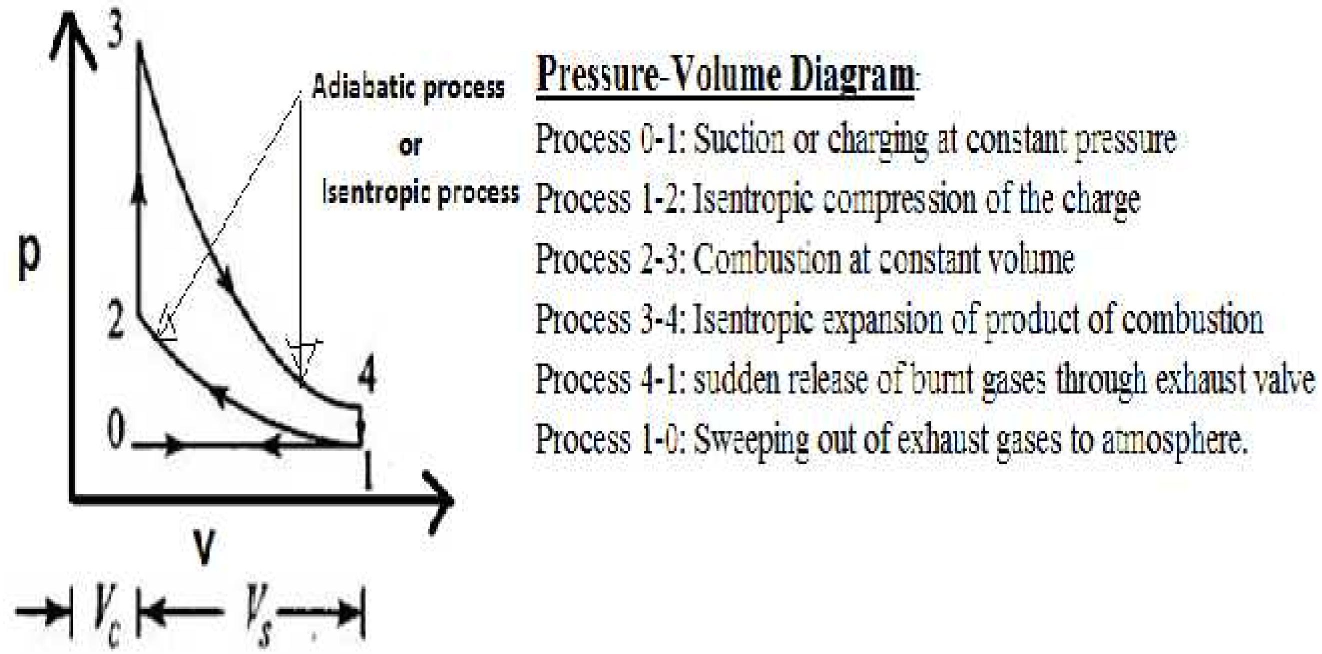
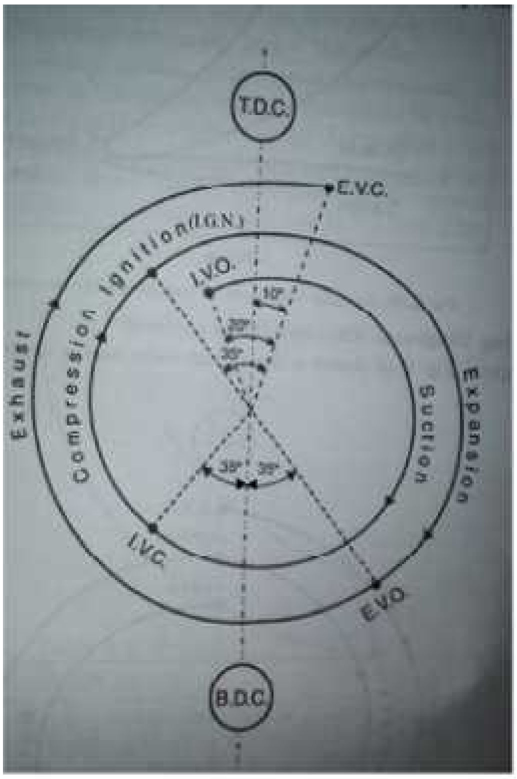


Fig: 4

Pressure Volume Diagram



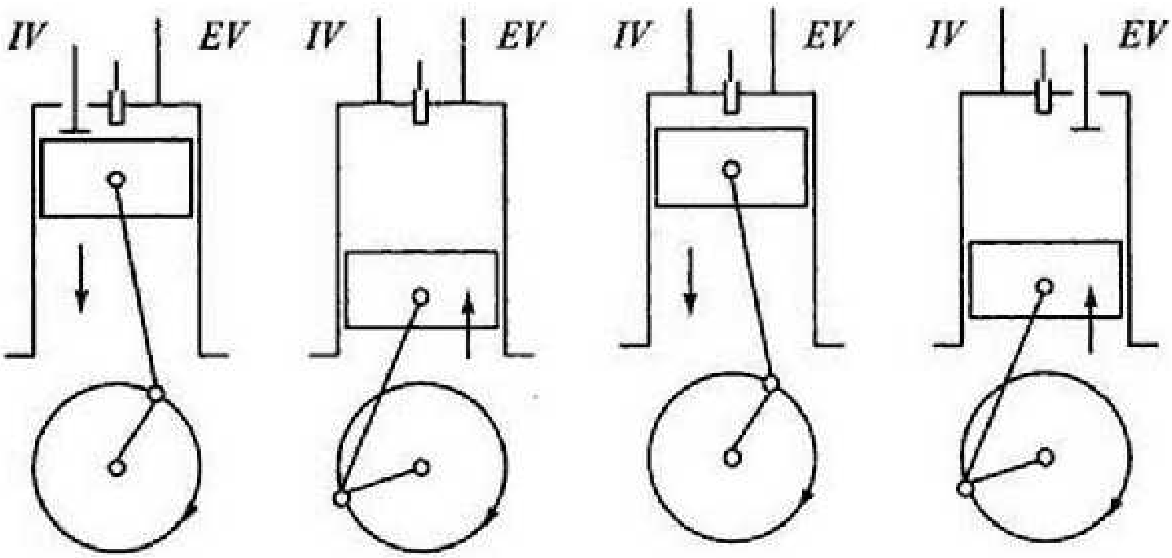
Actual Valve Timing Diagram for Four stroke Otto cycle engines

Valve Timing Diagram:

T.D.C. : Top Dead Centre
B.D.C. : Bottom Dead Centre
I.V.O. : Inlet valve opens (10° -20° before TDC)
I.G.N . : Ignition (20°-30° before TDC)
E.V.O. : Exhaust valve opens (30° - 50° before BDC)
I.V.C . ; Inlet valve closes (30°-40° after BDC)
E.V.C. : Exhaust valve closes (10°-15° after TDC)

FOUR-STROKE COMPRESSION-IGNITION (DIESEL) ENGINE

The four-stroke Cl engine is similar to the four-stroke SI engine but it operates at a much higher compression ratio. The compression ratio of an SI engine is between 6 and 10 while for a Cl engine it is from 12 to 24. In the Cl engine during suction stroke, air, instead of a fuel-air mixture, is inducted. Due to the high compression ratio employed, the temperature at the end of the compression stroke is sufficiently high to self-ignite the fuel which is injected into the combustion chamber. In Cl engines, a high pressure fuel pump and an injector are provided to inject the fuel into the combustion chamber. The carburettor and ignition system necessary in the SI engine are not required in the Cl engine. The ideal sequence of operations for the four-stroke Cl engine is as follows:



(a) Suction (b) Compression (c) Expansion (d) Exhaust

Fig: 5 Cycle of Operation of a CI Engine

(i) **Suction Stroke*:*** *Air* alone is inducted during the suction stroke. During this stroke intake valve is open and exhaust valve is closed, Fig: 5(a). Process (0-1) in p-V diagram Fig:6 shows the suction process at constant pressure.The piston moves from Top Dead Centre (TDC) to Bottom Dead Centre (BDC).

(ii) **Compression Stroke***:* Air inducted during the suction stroke is compressed into the clearance volume. Both valves remain closed during this stroke, Fig: 5(b). Process (1-2) in p-V diagram Fig:6 shows the adiabatic compression of air. The piston moves from B.D.C. to T.D.C. and air is compressed.

(iii) **Expansion Stroke***:* Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that combustion maintains the pressure constant in spite of the piston movement. After the injection of fuel is completed (i.e. after cut-off)(process2-3), the products added of combustion expand adiabatically as shown by process 3-4 on p-V diagram in Fig;6. Both the valves remain closed during the expansion stroke, Fig. 5(c).The piston moves from T.D.C. to B.D.C.

(iv) **Exhaust Stroke*:*** *The* piston travelling from *BDC* to *TDC* pushes out the products of combustion. The exhaust valve is open and intake valve is closed during this stroke, Fig. 5(d). The ideal *p-V* diagram is shown in Fig: 6

Due to higher pressures in the cycle of operations the Cl engine has to be more sturdy than a SI engine for the same output. This results in a Cl engine being heavier than the SI engine. However, it has a higher thermal efficiency on account of the high compression ratio (of about 18 as against about 8 in SI engines) used.

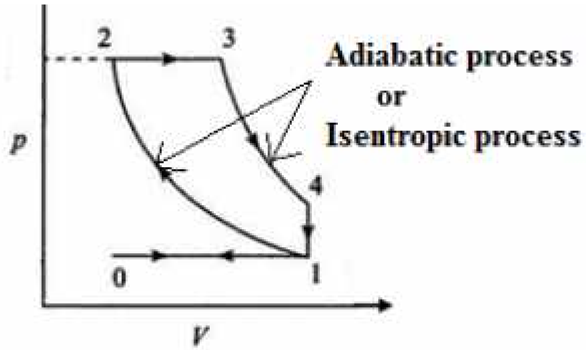


Fig: 6

Pressure-Volume Diagram:

Process 0-1: Suction of air at constant pressure

Process 1-2: Isentropic compression of the air

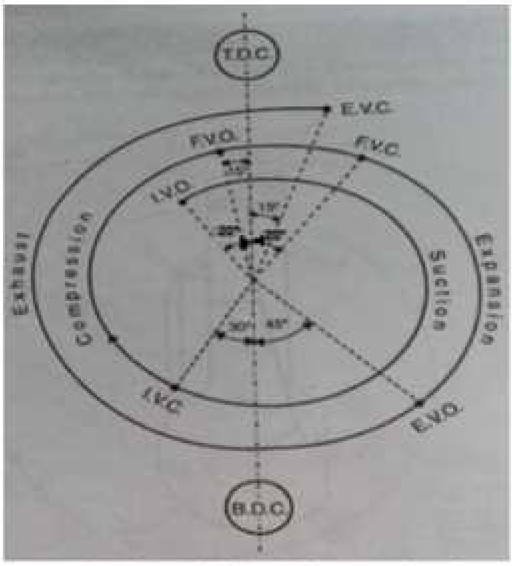
Process 2-3: Combustion of fuel at constant pressure

Process 3-4: Isentropic expansion of product of combustion

Process 4-1: sudden release of burnt gases through exhaust valve

Process 1-0: Sweeping out of exhaust gases to atmosphere.

Pressure-Volume Diagram:



Actual Valve Timing Diagram for Four stroke Diesel cycle engine

Valve Timing Diagram:

TDC. : Top Dead Centre

BDC. : Bottom Dead Centre

IVO : Inlet valve opens (10° -20° before TDC)

IVC : Inlet valve closes (25°-40° after BDC)

FVO : Fuel valve opens (10°-15° before TDC)

FVC : Fuel valve closes (15°-20° after TDC)

EVO : Exhaust valve opens (30° - 50° before BDC)

EVC : Exhaust valve closes (10°-15° after TDC)

Comparison between a Petrol Engine and Diesel Engin

S..No.	Petrol Engine	Diesel Engine
1.	Air-Petrol mixture is sucked in the engine cylinder during suction stroke.	Only air is sucked during suction stroke.
2.	Spark plug is used to ignite the charge.	The fuel is ignited when sprayed into air at high temperature after compression stroke.
3.	Power is produced by spark ignition.	Power is produced by compression ignition.
4.	Thermal efficiency up to 25%	Thermal efficiency up to 40%.
5.	Occupies less space.	Occupies more space.
6.	More running cost.	Less running cost
7.	Light in weight.	Heavy in weight.
8.	Fuel used ‘Petrol’ is costlier.	Fuel used ‘Diesel’ is cheaper.
9.	Petrol being volatile is dangerous.	Diesel being not volatile is not dangerous.
10.	Pre-ignition possible.	Pre-ignition not possible.
11.	Works on Otto Cycle.	Works on Diesel Cycle.
12.	Used in cars & motorcycles.	Used in heavy duty vehicles like bus and trucks.
13.	Petrol engines are high speed engines.	Diesel engines are low speed engines.
14.	Combustion takes place at constant volume.	Combustion takes place at constant pressure.
15.	Compression ratio is about 6 to 10.	Compression ratio is about 15 to 25.
16.	The maximum pressure after the compression stroke is about 10 bar.	The maximum pressure after the compression stroke is about 35 bar.
17.	Low compression ratio helps in easy starting.	High compression ratio causes difficult starting.
18	Carburettor is normally used.	Fuel injector is used.

TWO-STROKE ENGINE

If the two unproductive strokes, viz., the suction and exhaust could be served by an alternative arrangement, especially without the movement of the piston then there will be a power stroke for each revolution of the crankshaft. Dugald Clark (1878) invented the two-stroke engine.

In two-stroke engines the cycle is completed in one revolution of the crankshaft. The main difference between two-stroke and four- stroke engines is in the method of filling the fresh charge and removing the burnt gases from the cylinder. In the four-stroke engine these operations are performed by the engine piston during the suction and exhaust strokes respectively. In a two-stroke engine, the filling process is accomplished by the charge compressed in crankcase or by a blower. The induction of the compressed charge moves out the product of combustion through exhaust ports. Therefore, no piston strokes are required for these two operations. Two strokes are sufficient to complete the cycle, one for compressing the fresh charge and the other for expansion or power stroke.

Figure:7 shows one of the simplest two-stroke engines, viz., the crankcase scavenged engine. Figure:8 shows the ideal indicator diagram of such an engine. The air or charge is inducted into the crankcase through the spring loaded inlet valve when the pressure in the crankcase is reduced due to upward motion of the piston during compression stroke. After the compression and ignition, expansion takes place in the usual way.

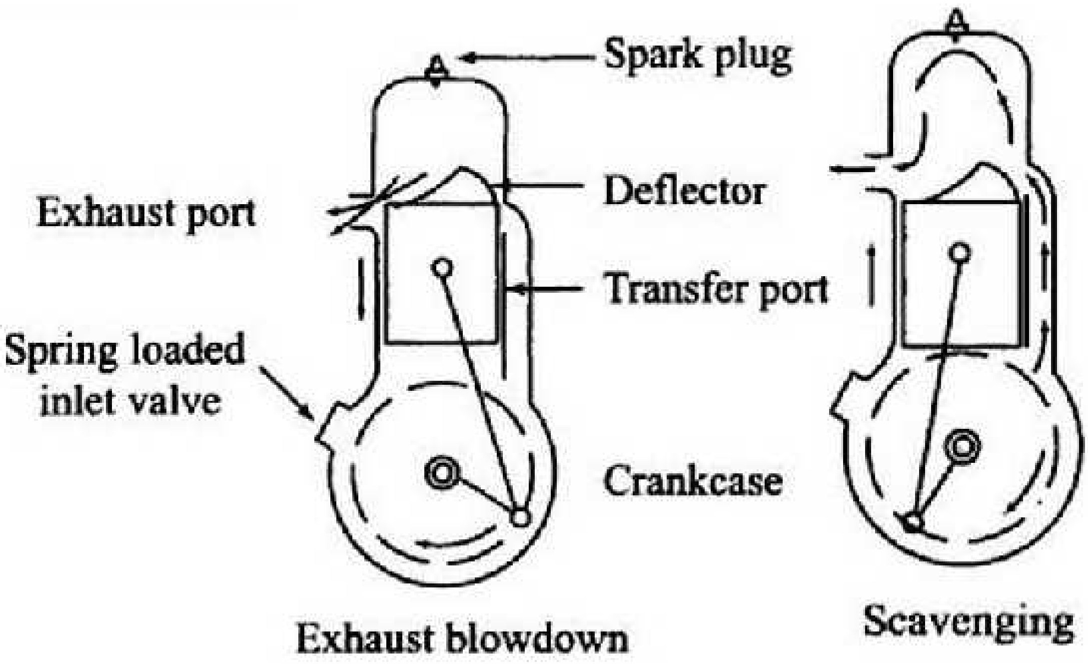


Fig.7 Crankcase Scavenged Two-Stroke Engine

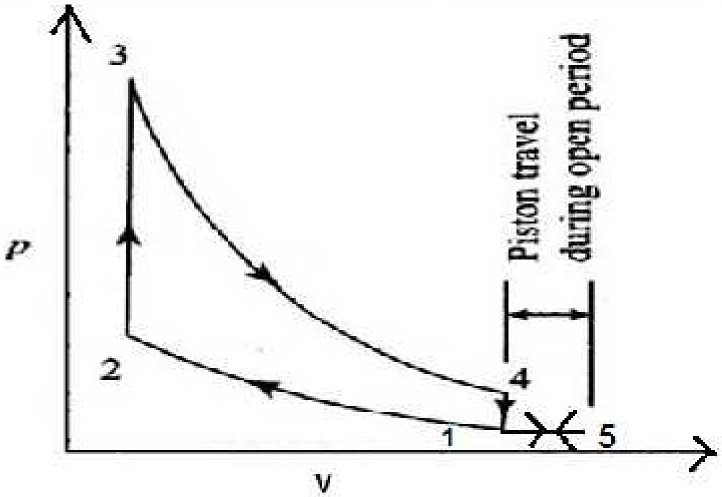


Fig: 8

During the expansion stroke the charge in the crankcase is compressed. Near the end of the expansion stroke, the piston uncovers the exhaust ports and the cylinder pressure drops to atmospheric pressure as the combustion products leave the cylinder. Further movement of the piston uncovers the transfer ports, permitting the slightly compressed charge in the crankcase to enter the engine cylinder. The top of the piston has usually a projection to deflect the fresh charge towards the top of the cylinder before flowing to the exhaust ports. This serves the double purpose of scavenging the combustion products from the upper part of the cylinder and preventing the fresh charge from flowing directly to the exhaust ports.

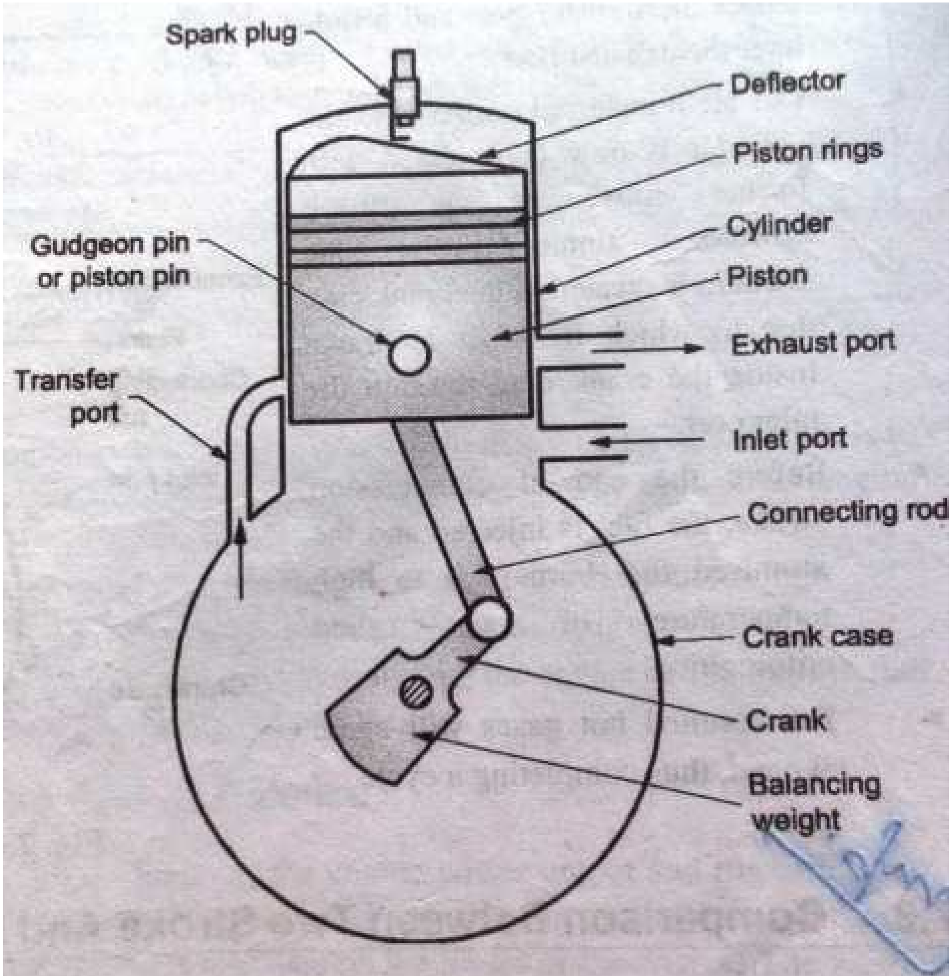
During the upward motion of the piston from *BDC* the transfer ports close first and then the exhaust ports close when compression of the charge begins and the cycle is repeated.

Two Stroke Petrol Engine(S.I. Engine)

It requires two stroke of piston to complete one cycle. The suction and compression processes are completed during upper movement of piston and expansion and exhaust processes are completed during downward movement of piston. There are no valves. Engines has transfer port, inlet port and exhaust port.

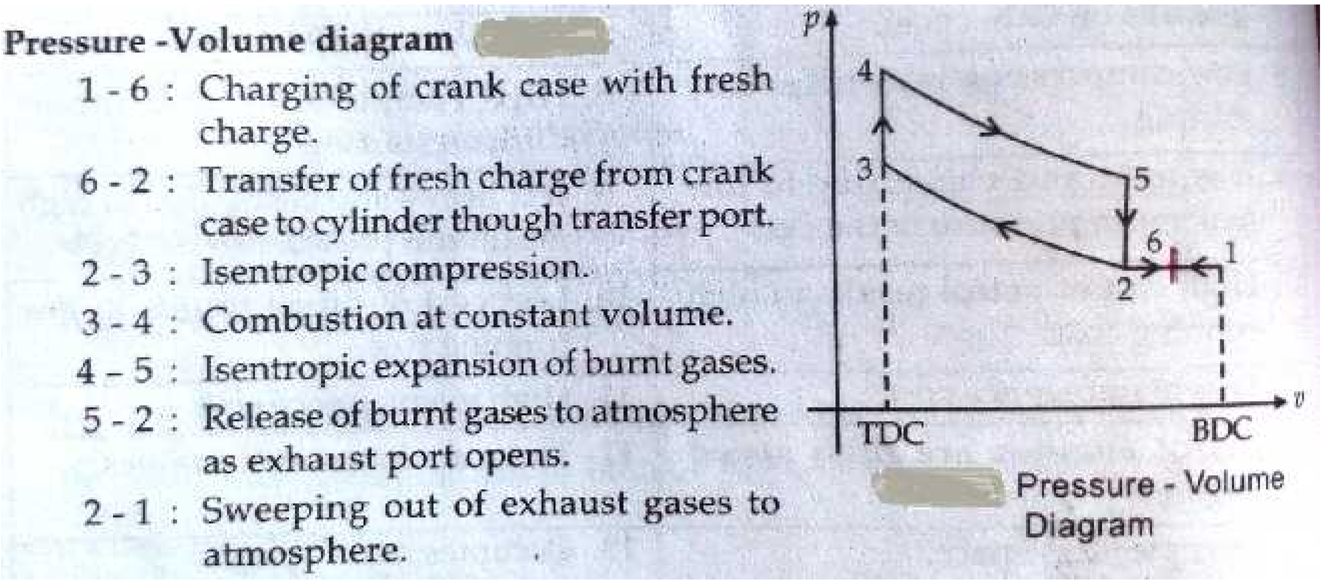
Working of Two Stroke S.I. Engine (Petrol Engine):

- Fig: 9 given below shows the schematic diagram of two stroke petrol engine. In this type of engine, considering that the piston is at T.D.C. which has the high pressure and high temperature gases of the previous stroke and the fresh charge in the crank-case.
- When the piston moves from T.D.C. to B.D.C. the burnt gases expands and develop the motive power.
- When the piston moves downwards during its expansion stroke, the piston first covers the inlet port and compresses the fresh charge held in the crank-case.
- After completion of about 80% of expansion stroke, the piston uncovers the exhaust port and some of the products of combustion escape to atmosphere.
- On further motion of the piston, the piston uncovers the transfer port and allows the slightly compressed charge from the crank-case to be admitted into the cylinder via the transfer port.
- The top of the piston usually has a deflector. The fresh charge sweeps out the remainder of the burnt gases while passing over the deflector. This process of sweeping out the burnt gases from the cylinder by the fresh charge is called scavenging.
- During the upward motion of the piston from B.D.C. to T.D.C., the piston first uncovers the inlet port allowing the fresh charge to be admitted into the crank-case due to the partial vacuum created in the crank-case and then it uncovers the transfer and exhaust ports.
- The fresh charge admitted into the cylinder in its previous stroke is now compressed. Before the end of compression stroke, a spark is supplied which burns the fuel-air mixture.
- Cycle is now again repeated.



: Two Stroke S.I. Engine

Fig:9



Pressure -Volume diagram

1 - 6 : Charging of crank case with fresh charge.

6 - 2 : Transfer of fresh charge from crank case to cylinder though transfer port.

2 - 3 : Isentropic compression.

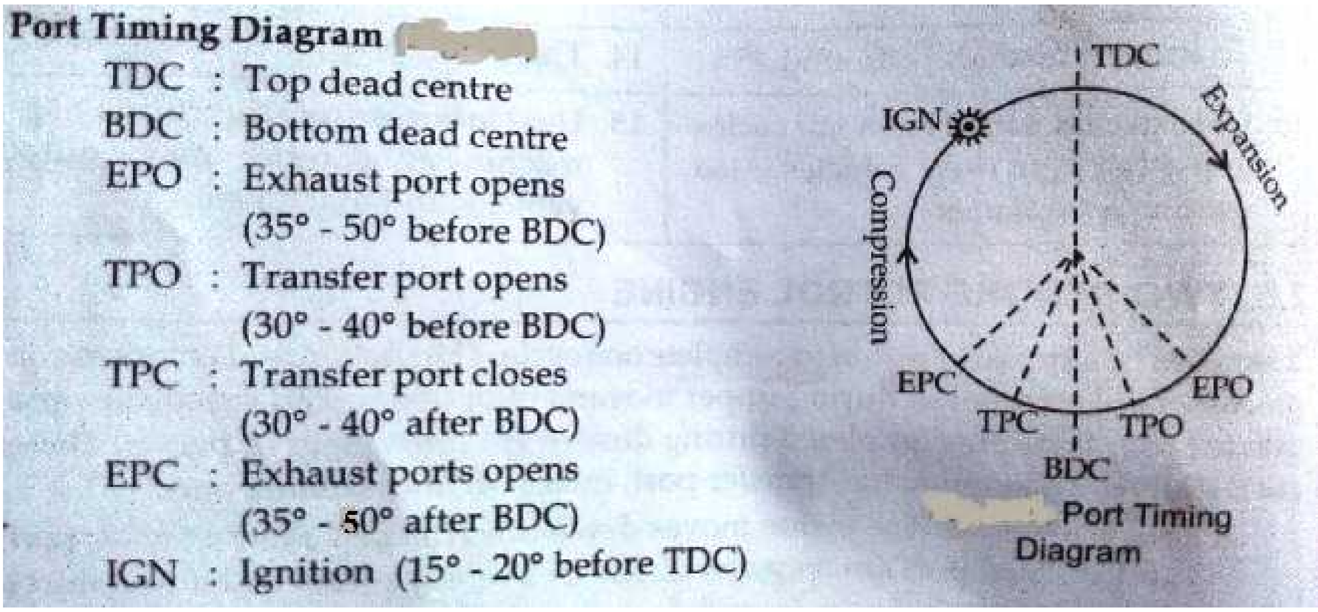
3 - 4 : Combustion at constant volume.

4 – 5 : Isentropic expansion of burnt gases.

5 - 2 : Release of burnt gases to atmosphere as exhaust port opens.

2 - 1 : Sweeping out of exhaust gases to atmosphere.

p-V Diagram for two stroke petrol (S.I.) Engine



Port Timing Diagram

TDC : Top dead centre

BDC : Bottom dead centre

EPO : Exhaust port opens (35° - 50° before BDC)

TPO : Transfer port opens (30° - 40° before BDC)

TPC : Transfer port closes (30° - 40° after BDC)

EPC : Exhaust ports opens (35° - 50° after BDC)

IGN : Ignition (15° - 20° before TDC)

Actual Port timing diagram for two stroke petrol (S.I.) Engine

<u>Two Stroke C.I. Engine (Diesel Engine)</u>

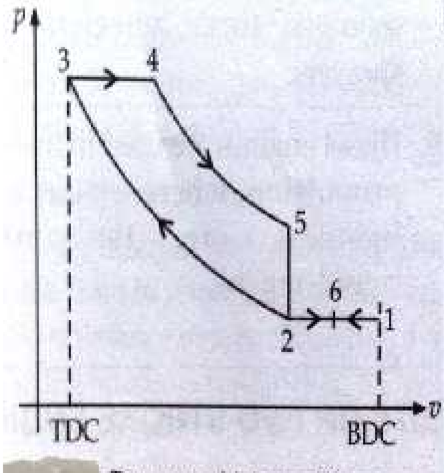
- The fuel is supplied with the help of fuel injection pump and the injector to the cylinder.
- The working of diesel engine is similar two stroke S.I. Engine, except that only air is inducted into the crank-case in case of C.I. Engine in place of mixture of fuel and air. There is no spark plug for combustion.

<u>Working of Two Stroke C.I. Engine (Diesel Engine):</u>

Working of the engine is as follows:

- Consider the piston at T.D.C., when piston moves down, the hot gases expands. During its downward motion, the piston firstly uncovers the exhaust port and a little later it uncovers the transfer port.
- The air compressed during the previous stroke in the crank-case is transferred into the cylinder via the transfer port. This incoming air pushes out the burnt gases while passing over the deflector. This process of sweeping out the burnt gases is called scavenging.

- The piston moves upwards i.e. from B.D.C. to T.D.C. It first closes the transfer port and a little later the exhaust port.
- The air transferred earlier into the cylinder is now compressed with further movement of piston upwards. Simultaneously, the vacuum is created in the crank-case due to which fresh air is drawn inside the crank-case through the inlet port.
- Before the end of compression stroke, the fuel is injected and the atomized fuel burns due to high temperature of air called auto-ignition.
- The resulted hot gases will again expand, thus completing a cycle.



Pressure-Volume Diagram

Pressure-Volume Diagram

1-6 : Charging of crank case with fresh air.
6-2 : Transfer of fresh air from crank case to cylinder through transfer port.
2-3 : Isentropic compression of air.
3-4 : Injection of fuel and combustion of mixture at constant pressure.
4-5 : Isentropic expansion of burnt gases.
5-2 : Release of burnt gases to atmosphere as exhaust port opens.
2-1 : Sweeping out of exhaust gases to atmosphere.

P-v Diagram for two stroke Diesel (C.I.) Engine

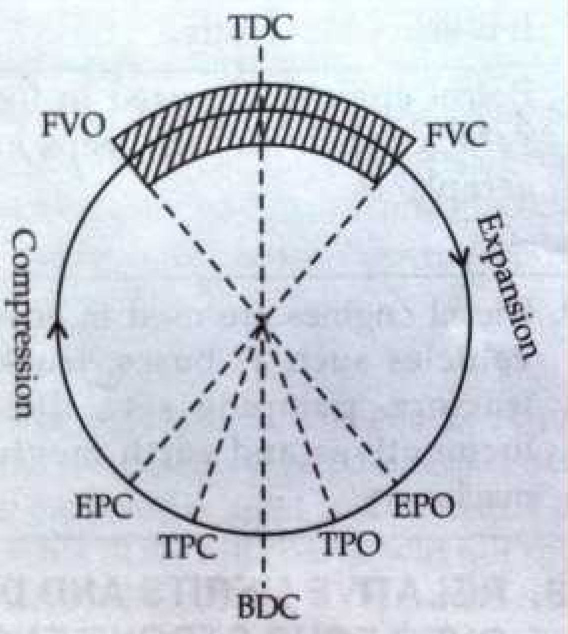


Fig. 2.10. Port Timing Diagram

Port Timing Diagram

TDC : Top dead centre.
BDC : Bottom dead centre.
FVO : Fuel valve opens (10°-15° before TDC).
FVC : Fuel valve closes (15°-20° after TDC).
EPO : Exhaust port opens (35°-50° before BDC).
TPO : Transfer port opens (30°-40° before BDC).
TPC : Transfer port closes (30°-40° after BDC).
EPC : Exhaust port closes (35°-50° after BDC).

Actual Port timing diagram for two stroke Diesel (C.I.) Engine

Comparison between Four stroke & Two stroke cycle engines

S.No.	Aspects	Four Stroke Cycle Engines	Two Stroke Cycle Engines
1.	Completion of cycle	The cycle is completed in four strokes of the piston or in two revolutions of the crank-shaft. Thus one power stroke is obtained in every two revolutions of the crank-shaft.	The cycle is completed in two strokes of the piston or in one revolution of the crank-shaft. Thus one power stroke is obtained in each revolution of the crank-shaft.
2.	Flywheel required	Because of the above turning moment is not so uniform and hence heavier flywheel is needed.	More uniform turning moment and hence lighter flywheel is needed.
3.	Power produced for same size of Engine.	Again because of one power stroke for two revolutions, power produced for same size of engine is small or for the same power the engine is heavy and bulky.	Because of one power stroke in one revolution, power produced for same size of engine is more or for the same power the engine is light and compact.
4.	Cooling and lubrication requirements	Because of one power stroke in two revolutions, Lesser cooling and lubrication requirements. Lesser rate of wear and tear.	Because of one power stroke in one revolution, greater cooling and lubrication requirement. Great rate of wear and tear.
5.	Valve and valve mechanism	Four stroke engine contains valve and valve mechanism.	Two stroke engines have no valves. It contains only ports.
6.	Initial cost	Higher is the initial cost.	Cheaper is the initial cost.
7.	Volumetric efficiency	Volumetric efficiency is more due to more time of induction.	Volumetric efficiency is less due to lesser time of induction.
8.	Thermal and part load efficiency	Thermal efficiency is higher and part load efficiency is better than two stroke cycle engine.	Thermal efficiency is lower and part load efficiency is lesser than four stroke cycle engine
9.	Applications	Used where efficiency is important; in cars, jeeps, buses, trucks, tractors, aeroplanes etc.	Used where low cost, compactness and light weight is important. Two stroke (air cooled) petrol used in very small size only, lawn movers, scooters, motorcycles (Lubricating oil mixed with petrol). Two stroke diesel engines are used in very large size more than 60 cm bore, for ship propulsion because of low weight and compactness.

<u>Classification of I.C.Engines</u>; Internal combustion engines may be classified as given below;

- **<u>According to cycle of operation</u>**:
  - (i) Two Stroke Cycle Engines
  - (ii) Four Stroke Cycle Engines
- **<u>According to cycle of combustion</u>**:
  - (i) Otto Cycle Engine (combustion at constant volume)
  - (ii) Diesel Cycle Engine (combustion at constant pressure)
  - (iii) Dual Combustion or Semi-Diesel Cycle Engine (combustion partly at constant volume and partly at constant pressure)
- **<u>According to Speed of the Engine</u>**:
  - (i) Low Speed Engine
  - (ii) Medium Speed Engine
  - (iii) High Speed Engine
- **<u>According to method of ignition</u>**:
  - (i) Spark –ignition Engine
  - (ii) Compression-ignition Engine
- **<u>According to method of cooling the cylinder</u>**:
  - (i) Air-cooled Engine
  - (ii) Water-cooled Engine
- **<u>According to method of Governing;</u>**
  - (i) Hit and Miss governed Engine
  - (ii) Quality governed Engine
  - (iii) Quantity governed Engine
- **<u>According to valve arrangement</u>**:
  - (i) Overhead Valve Engine
  - (ii) L-head type Engine
  - (iii) T-head type Engine
  - (iv) F-head type Engine
- **<u>According to number of cylinders</u>**:
  - (i) Single Cylinder Engine
  - (ii) Multi-cylinder Engine
- **<u>According to air intake process</u>**:
  - (i) Naturally aspirated Engine. (No intake air pressure boost system)
  - (ii) Super charged Engine. (Intake air pressure increased with the compressor driven off the engine crank-shaft)
  - (iii) Turbo-charged Engine. (Intake air pressure increased with the turbine-compressor driven by the engine exhaust gases).
  - (iv) Crank-case compresses Engine.

- ## According to fuel employed

  (i) Oil Engine
  (ii) Petrol Engine
  (iii) Gas Engine
  (iv) Kerosene Engine
  (v) L,P,G, Engine
  (vi) Alcohol-Ethyl, methyl Engine
  (vii) Duel fuel Engine
  (viii) Gasohol (90% Gasoline and 10% alcohol)

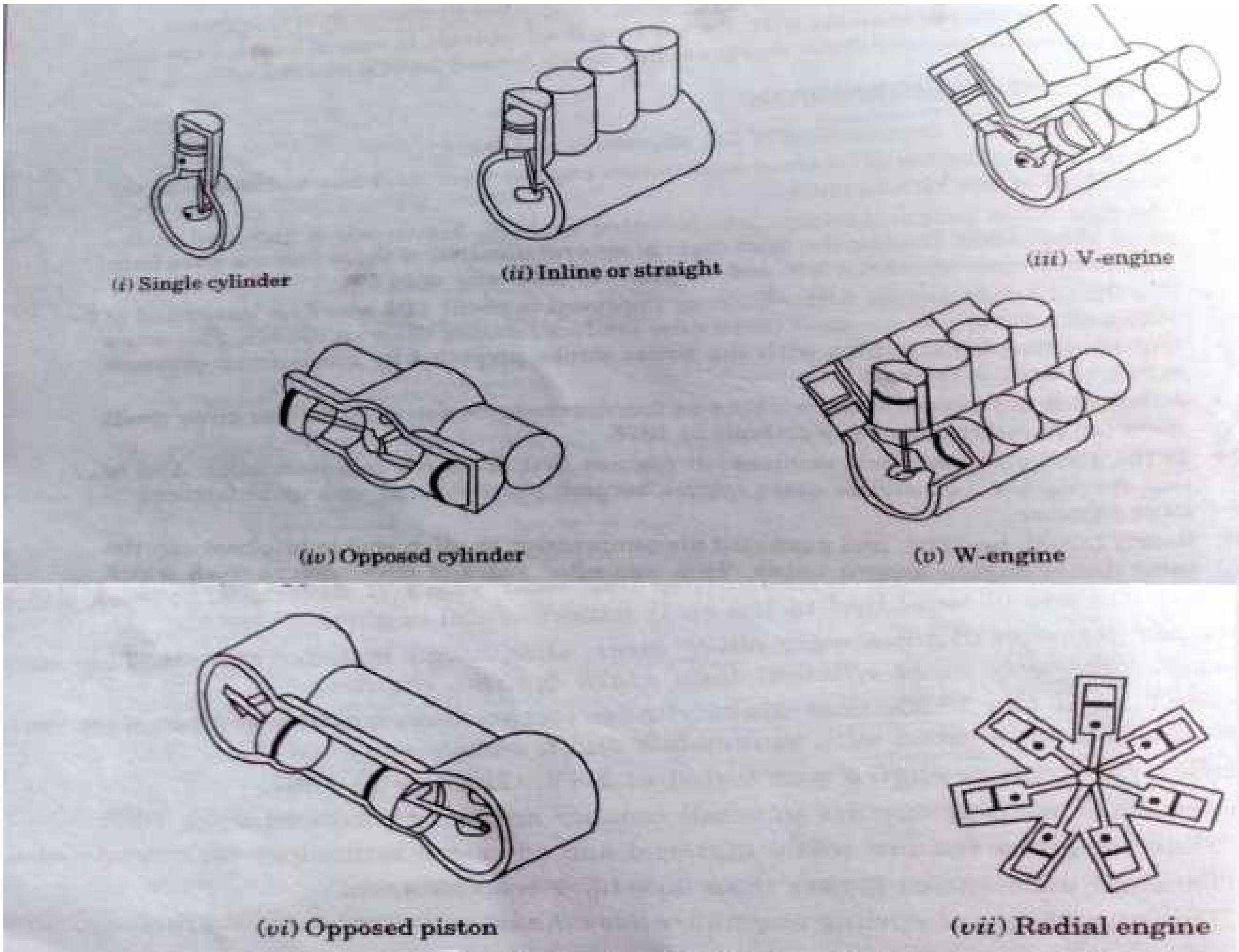
- ## According to method of fuel input for S.I Engines:

  (i) Carburetted
  (ii) Multi-point port fuel injection. One or more injection at each cylinder intake.
  (iii) Throttle body fuel injection. Injectors upstream in intake manifold.

- ## According to their uses:

  (i) Stationary Engine
  (ii) Portable Engine
  (iii) Marine Engine
  (iv) Automobile Engine
  (v) Aero Engine etc.

- ## According to arrangement of cylinder:



. Engine classification by cylinder arrangement.

(i) **Single Cylinder Engine**: Engine has one cylinder and piston connected to the crank-shaft.

(ii) **In-Line or Straight Engines:** Cylinders are positioned in a straight line one behind the other along the length of the crank-shaft.

(iii) **V-Engine**:

(a) An engine with two cylinder banks (i.e. two In-Line Engines) inclined at an angle to each other and with one crank-shaft.

(b) Most of the bigger automobiles use the 8- cylinder V- Engine (4- Cylinder In-Line on each side of V).

(iv) **Opposed Cylinder Engine**:

(a) Two banks of cylinders opposite each other on a single crank-shaft (a V-Engine with 180° V)

(b) These are common on small air craft and some automobile with even number of cylinders from two to eight or more.

(v) **W-Engine**:

(a) Same as V-Engine except with three banks of cylinders on same crank-shaft.

(b) Not common, but some have been developed for racing automobiles.

(vi) **Opposed Piston Engine**:

(a) In this type of engine there are two pistons in each cylinder with the combustion chamber in the centre between the pistons.

(b) A single combustion process causes two power strokes, at the same time, with each piston being pushed away from the centre and delivering power to a separate crank-shaft at each end of the cylinder.

(vii) **Radial Engine**: It is an engine with pistons positioned in a circular plane around the central crank-shaft.. The connecting rods of the pistons are connected to a master rod which in turn is connected to the crank-shaft.