In 1876 German engineer Nikolaus Otto developed four stroke engine based on Otto cycle. It revolutionized the development of internal combustion engines and are even used till date. In 1892 another German engineer Rudolf Diesel developed diesel engine.

ENGINE

Engine is a device which converts one form of Energy into another form.

HEAT ENGINE

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

Heat engine may be classified based on where the combustion of fuel takes place, i.e. whether outside the cylinder or inside the cylinder.

a) External Combustion Engines (E.C. Engines)
b) Internal Combustion Engines (I.C. Engines)

Comparison of I.C. Engines and E.C. Engines

Comparison of IC engine and EC engine is given in table 1.

Table 1 Comparison of IC engine and EC engine

Sr.	I.C. Engine	E.C. Engine
1	Combustion of fuel takes place inside the cylinder	Combustion of fuel takes place outside the cylinder
2	Working fluid may be Petrol, Diesel & Various types of gases	Working fluid is steam
3	Require less space	Require large space
4	Capital cost is relatively low	Capital cost is relatively high
5	Starting of this engine is easy & quick	Starting of this engine requires time
6	Thermal efficiency is high	Thermal Efficiency is low
7	Power developed per unit weight of these engines is high	Power Developed per unit weight of these engines is low
8	Fuel cost is relatively high	Fuel cost is relatively low

IC engine Classification

I.C. Engines may be classified according to,

a) Type of the fuel used as :

(1) Petrol engine (2) Diesel engine

(3) Gas engine (4) Bi-fuel engine (Two fuel engine)

b) Nature of thermodynamic cycle as :

(1) Otto cycle engine (2) Diesel cycle engine

(3) Duel or mixed cycle engine

c) Number of strokes per cycle as :

(1) Four stroke engine (2) Two stroke engine

d) Method of ignition as:

(1) Spark ignition engine (S.I. engine)

Mixture of air and fuel is ignited by electric spark.

(2) Compression ignition engine (C.I. engine)

The fuel is ignited as it comes in contact with hot compressed air.

e) Method of cooling as:

(1) Air cooled engine (2) Water cooled engine

f) Speed of the engine as :

(1) Low speed (2) Medium speed

(3) High speed

Petrol engine are high speed engines and diesel engines are low to medium speed engines

g) Number of cylinder as :

(1) Single cylinder engine (2) Multi cylinder engine

h) Position of the cylinder as :

(1) Inline engines (2) V – engines

(3) Radial engines (4) Opposed cylinder engine

(5) X – Type engine (6) H – Type Engine

(7)U – Type Engine (8) Opposed piston engine

(9) Delta Type Engine

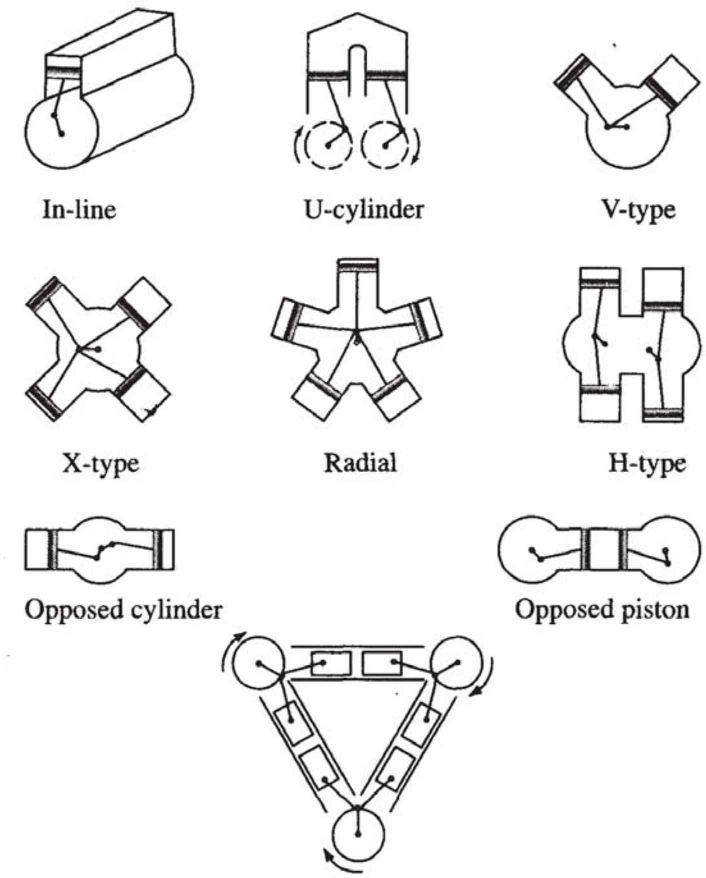

Fig. 7.1 Engine classification by cylinder arrangements

Engine details

The various important parts of an I.C. engine are shown in fig. 7.1.

1. Cylinder

It is the heart of the engine in which the fuel is burnt and the power is produced. Cylinder has to withstand very high pressure and temperature because the combustion of fuel takes place inside the engine cylinder. Therefore cylinder must be cooled. To prevent the wearing of the cylinder block, a sleeve will be fitted tightly in the cylinder.

2. Cylinder head

Cylinder head covers top end of cylinder. It provides space for valve mechanism, spark plug, fuel injector etc.

3. Piston

The piston is a close fitting cylindrical plunger reciprocating inside the cylinder. The power developed by the combustion of the fuel is transmitted by the piston to the crank shaft through connecting rod.

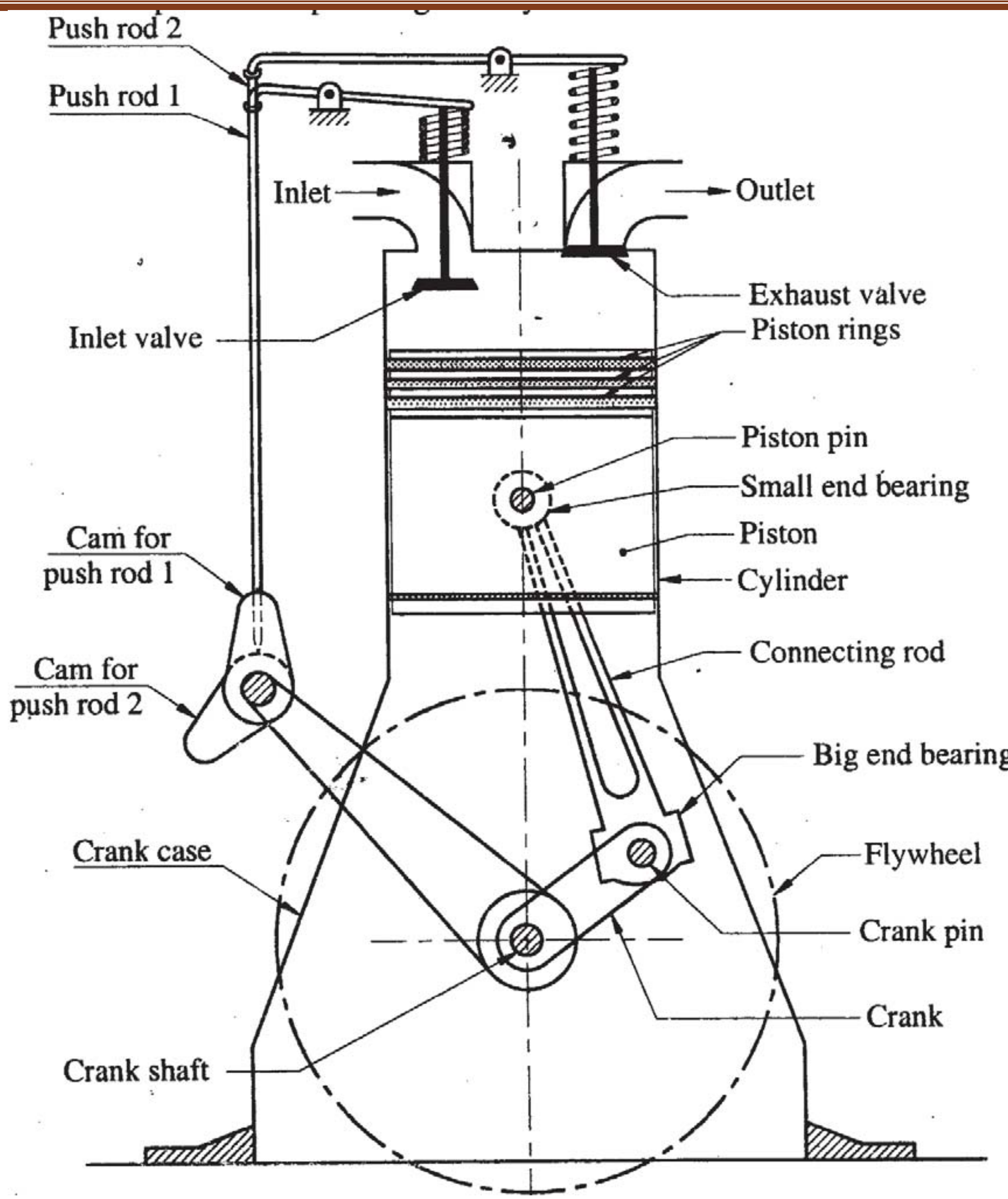

Fig. 7.2 I.C. Engine details

4. Piston Rings

The piston rings are the metallic rings inserted into the circumferential grooves provided at the top end of the piston. These rings maintain a gas-tight joint between the piston and the cylinder while the piston is reciprocating in the cylinder.

5. Piston pin or Gudgeon pin

It is the pin joining small end of the connecting rod and piston. This is made of steel by forging process.

6. Connecting rod

It is the member connecting piston through piston pin and crank shaft through crank pin. It converts the reciprocating motion of the piston into rotary motion of the crankshaft. It is usually made of steel forging.

7. Crank and Crankshaft

The crank is a lever that is connected to the big end of the connecting rod by a pin joint with its other end connected rigidly to a shaft, called crankshaft. It rotates about the axis of the crankshaft and causes the connecting rod to oscillate.

8. Valves

Engine has both intake and exhaust type of valves which are operated by valve operating mechanism (Refer fig. 7.2). The valves are the device which controls the flow of the intake and the exhaust gases to and from the engine cylinder.

9. Flywheel

It is a heavy wheel mounted on the crankshaft of the engine. It minimizes cyclic variation in speed by storing the energy during power stroke, and same is released during other stroke.

10. Crankcase

It is the lower part of the engine, serving as an enclosure of the crankshaft and also as a sump for the lubricating oil.

11. Carburetor

Carburetor is used in petrol engine for proper mixing of air and petrol.

12. Fuel pump

Fuel pump is used in diesel engine for increasing pressure and controlling the quantity of fuel supplied to the injector.

13. Fuel injector

Fuel injector is used to inject diesel fuel in the form of fine atomized spray under pressure at the end of compression stroke.

14. Spark plug

Spark plug is used in petrol engine to produce a high intensity spark for ignition of air fuel mixture in the cylinder.

Terminologies used in IC engine

1. Bore:

The inner diameter of the engine cylinder is called a bore.

2. Stroke:

It is the linear distance traveled by the piston when it moves from one end of the cylinder to the other end. It is equal to twice the radius of the crank.

3. Dead Centers:

In the vertical engines, top most position of the piston is called Top Dead Centre (TDC). When the piston is at bottom most position, it is called Bottom Dead Centre (BDC).

In horizontal engine, the extreme position of the piston near to cylinder head is called Inner Dead Centre (I.D.C.) and the extreme position of the piston near the crank is called Outer Dead Centre (O.D.C.).

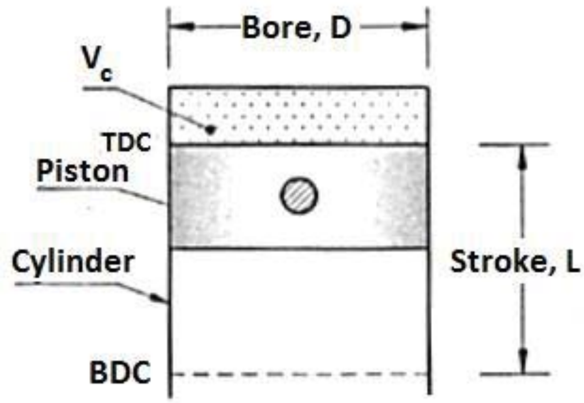

Fig. 7.3 Stroke and bore of piston

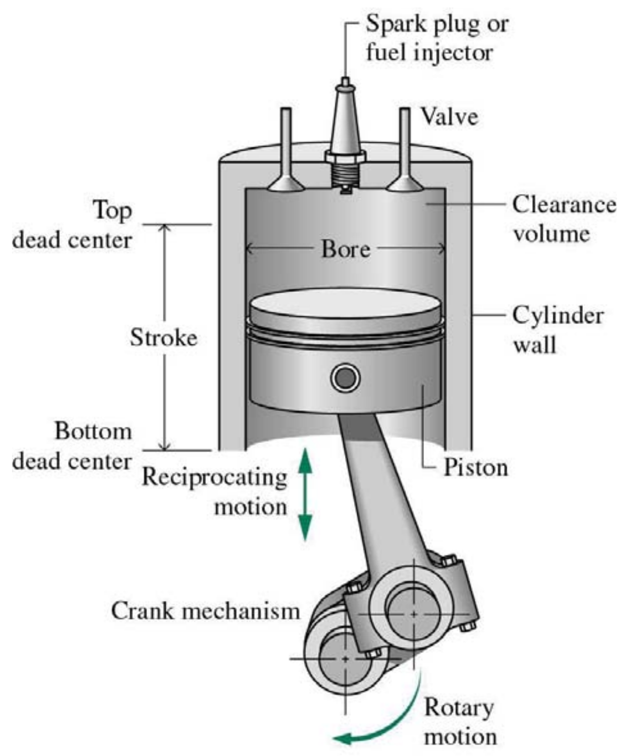

Fig 7.4 I.C engine nomenclature

4. Clearance Volume, (V_c)

It is the volume contained between the piston top and cylinder head when the piston is at top or inner dead centre.

5. Stroke volume (swept volume)

It is volume displaced by the piston in one stroke is known as stroke volume or swept volume.

Let, V_s = stroke volume, L = stroke length, d = Bore

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

6. Compression Ratio

The ratio of total cylinder volume to clearance volume is called the compression ratio (r) of the engine.

Total cylinder volume = $V_c + V_s$

Compression Ratio, $$r = \frac{Total\ cylinder\ volume}{Clearance\ volume}$$

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

For petrol engine r varies from 6 to 10 and for Diesel engine r varies from 14 to 20.

7. Piston speed

It is average speed of piston. It is equal to 2LN, where N is speed of crank shaft in rev/sec.

$$\therefore Piston\,speed, V_p = \frac{2LN}{60}\, m/sec$$

Where,

L = Stroke length, m

N = Speed of crank shaft, RPM

Otto four stroke cycle OR Four stroke petrol engine or Spark Ignition Four stroke engine

This engine works on Otto cycle and uses petrol (or gas) as a fuel. In this engine spark is produced to ignite the charge. This type of engines work on constant volume combustion cycle as combustion takes place nearly at constant volume with increase of pressure.

In a petrol engine, the petrol is evaporated and also it is mixed with correct proportion of air by the device which is known as carburetor.

The whole cycle is completed in four strokes, namely

1. Suction stroke
2. Compression stroke
3. Working or Power stroke
4. Exhaust stroke

All these strokes are represented on P-V diagram in fig. 7.5.

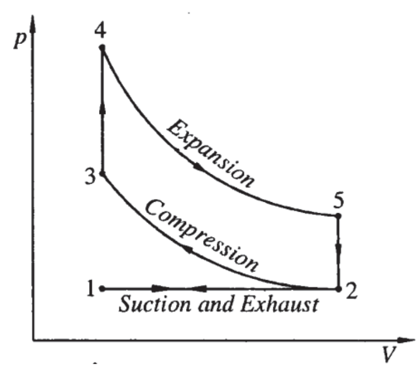

Fig. 7.5 p-V diagram of petrol engine

1. Suction stroke

During this stroke, inlet valve remains open and exhaust valve is closed, the pressure in the cylinder will be atmospheric.

The piston moves from TDC to BDC. So the volume in the cylinder increases, while simultaneously the pressure decreases. This creates a pressure difference between the atmosphere and inside of the cylinder. Due to this pressure difference the petrol and air mixture will enter into the cylinder through carburetor. This stroke is represented by the horizontal line 1-2 on the p-v diagram in fig. 7.5.

At the end of this stroke piston reaches at BDC, the cylinder will be filled completely with petrol and air mixture called charge and inlet valve is closed.

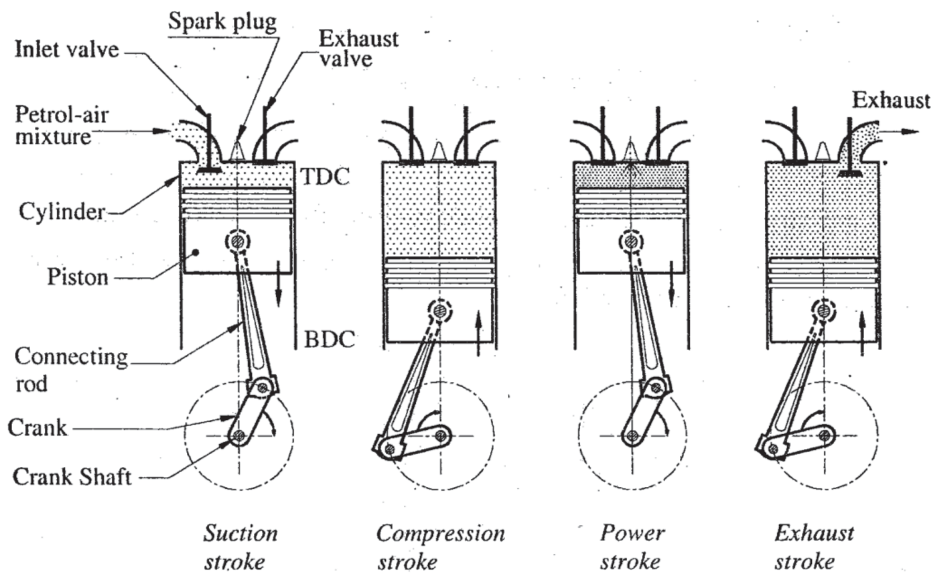

Fig. 7.6 Four stroke petrol engine

2. Compression stroke

As shown in fig., during this stroke both the inlet valve and exhaust valve remains closed. Piston moves from BDC to TDC. As this stroke is being performed, the petrol and air mixture contained in the cylinder will be compressed, so pressure and temperature of mixture increases. The process of compression is shown in fig. 7.5 by the curve 2-3.

Near the end of this stroke, the petrol and air mixture is ignited by electric spark given out by the spark plug. The combustion of the petrol releases the hot gases which will increase the pressure at constant volume. This constant volume combustion process is represented by the vertical line 3-4 on the p-V diagram.

3. Power or Expansion stroke

During this stroke both the inlet valve and exhaust valve remain closed, the piston moves from TDC to BDC. The high pressure and high temperature burnt gases force the piston to perform this stroke, called **power stroke.** This stroke is also known as **expansion or working stroke**. *The engine produces mechanical work or power during this stroke.*

As the piston moves from TDC to BDC, the pressure of hot gases gradually decreases and volume increases. This is represented by curve 4-5 on the p-V diagram.

Near the end of this stroke, the exhaust valve opens which will release the burnt gases to the atmosphere. This will suddenly bring the cylinder pressure to the atmospheric pressure. This drop of pressure at constant volume is represented by vertical line 5-2 on the p-V diagram.

4. Exhaust Stroke

During this stroke, the exhaust valve opens and the inlet valve remains closed. The piston moves from BDC to TDC and during this motion piston pushes the exhaust gases (combustion product) out of the cylinder at constant pressure. This process is shown on p-V diagram by horizontal line 2-1 in fig. 7.5.

At the end of the exhaust stroke, the exhaust valve is closed and inlet valve will open. Then there will be again a suction stroke and the same cycle will be repeated.

Diesel four stroke cycle OR Four stroke Diesel engine OR Four stroke compression ignition (C.I) engine.

The diesel engines work on the principle of Diesel cycle, also called constant pressure heat addition cycle shown in fig. 7.7. The four stroke diesel engine cycle also consists of suction, compression, power, and exhaust strokes. Fig. 7.8 shows the working and construction of a four stroke diesel engine.

The basic construction of a four stroke diesel engine is same as that of four stroke petrol engine, except instead of spark plug, a fuel injector is mounted in its place as shown in fig. 7.8. A fuel pump supplies the fuel oil to the injector at higher pressure.

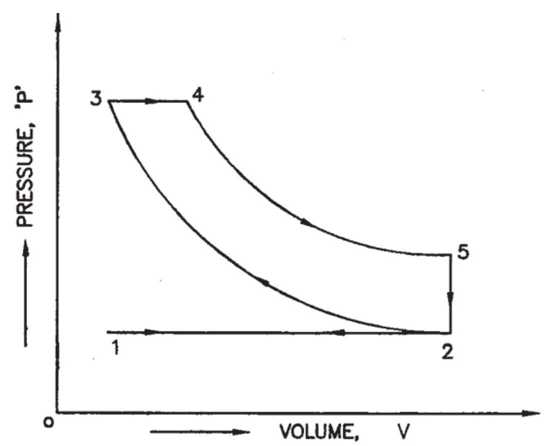

Fig. 7.7 p-V diagram of diesel engine

1. Suction Stroke

During this stroke, inlet valve remains open and exhaust valve remains closed, the pressure in the cylinder will be atmospheric. The piston moves from TDC to BDC position. Air from the atmosphere is drawn into the cylinder as the piston moves. This stroke is represented by horizontal line 1-2 on p- V diagram shown in Fig. 7.7.

At the end of this stroke, the cylinder will be filled completely with air and inlet valve will be closed.

2. Compression stroke

As shown in fig. 7.8 during this stroke, both inlet valve and exhaust valve remain closed. The piston moves from BDC to TDC. As this stroke is being performed, the air in the cylinder will be compressed, so pressure and temperature of air increases.

The compression ratio of this engine is higher than petrol engine. Due to higher compression ratio, air will have attained a higher temperature than self-ignition temperature of the diesel fuel.

Near the end of this stroke, the diesel fuel is injected into the cylinder. As the diesel fuel particles come in contact with high temperature air, it will ignite automatically. This is called auto-ignition or self-ignition. In this engine compressed air ignites the diesel fuel; this type of engine is also called as compression Ignition engine or C.I. engine.

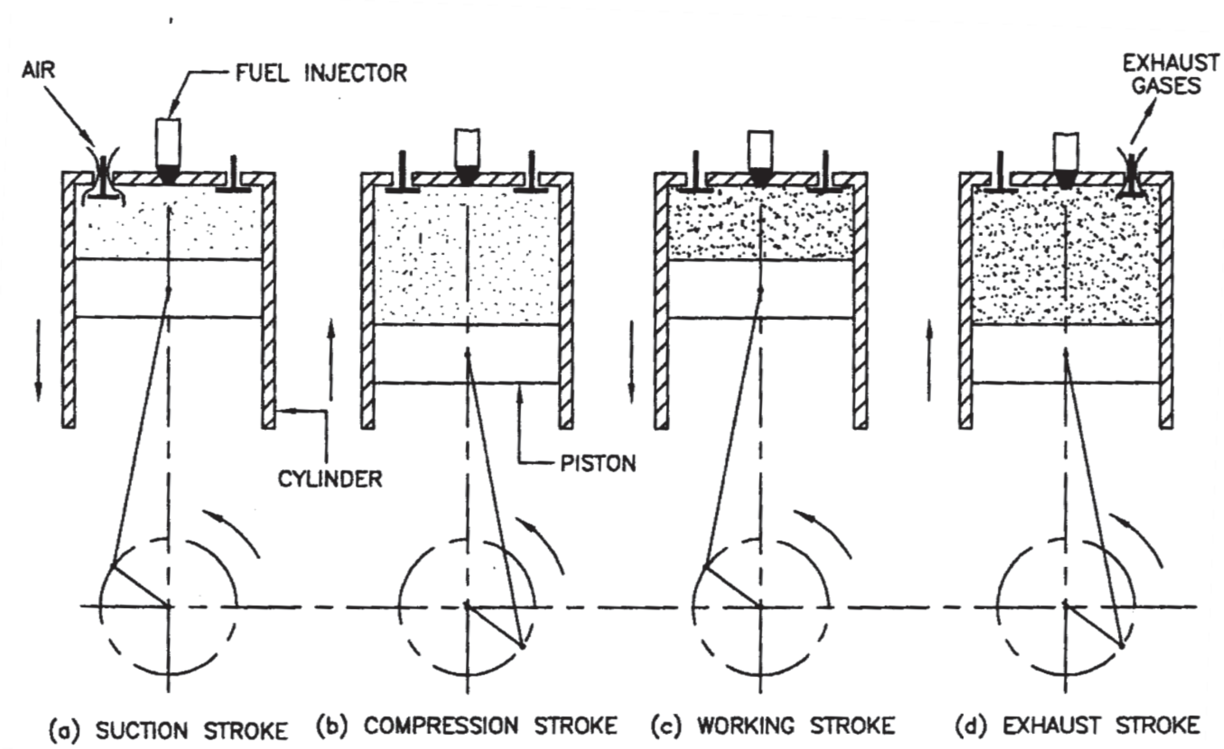

Fig. 7.8 Four stroke diesel engine

3. Power or Expansion stroke

During this stroke, both the inlet and exhaust valve remain closed. The piston moves from TDC to BDC. The fuel injection starts nearly at the end of compression stroke, but the rate of fuel injection is such that combustion maintains constant pressure. It is shown on P-V diagram by horizontal line (3-4).

The high temperature and high pressure gases expand and push the piston downward. Thus useful work is done during this stroke. As the piston moves from TDC to BDC, the pressure of hot gases gradually decreases and volume increases. This is represented by curve (4-5) on the P-V diagram shown in fig. 7.7.

As the piston reaches BDC position, the exhaust valve opens and the pressure suddenly falls nearly to atmospheric pressure at a constant volume. It is shown by line 5-2 on P-V diagram.

4. Exhaust stroke

During this stroke, the exhaust valve remains opened and inlet valve is closed. The piston moves from BDC to TDC. During this motion, piston pushes the exhaust gases (combustion product) out of cylinder at constant pressure. This process is shown on p- V diagram by horizontal line 2-1 in fig. 7.7. Again inlet valve opens and a new cycle starts.

Difference between Petrol (S.I.) engine and Diesel (C.I.) engine

Sr.	Principle	Petrol engine	Diesel engine
1	Thermodynamic cycle	Works on Otto cycle (Constant volume cycle)	Works on Diesel cycle (Constant pressure cycle)
2	Fuel used	Petrol (Gasoline)	Diesel
3	Supply of fuel	In carburetor, fuel gets mixed with air and then mixture enters the cylinder during suction stroke	Diesel is pressurized with the help of fuel pump and then injected into the engine cylinder by the fuel injector at the end of compression stroke
4	Compression ratio (r)	Low (6 to 10)	High (14 to 20)
5	Charge drawn during the suction stroke	Mixture of air and petrol	Only air
6	Fuel ignition	Compressed charge is ignited by spark plug	Fuel is ignited by the heat of compressed air no any external source is required
7	Engine speed	High (3000 RPM)	Low to medium (500 to 1500 RPM)
8	Thermal efficiency	Lower due to lower compression ratio	Higher due to higher compression ratio
9	Weight of the engine	Lighter	Heavier
10	Initial cost	Less	More
11	Maintenance cost	Less	Slightly higher
12	Running cost	Higher because petrol is costlier	Less because diesel is cheaper
13	Starting of engine	Easier starting even in cold weather	Difficult to start in cold weather

Two stroke cycle engine

As the name itself implies, all the processes in the two stroke cycle engine are completed in two strokes. In four stroke engine two complete revolutions of crank shaft is required for completing one cycle.

The cycle of operations, i.e. suction, compression, expansion and exhaust are completed in one complete revolution of the crank shaft in two stroke engines. These engines have one power stroke per revolution of the crank shaft.

In two stroke engines, there are two openings called *ports* are provided in place of valve of four stroke engines. These ports are opened and closed by reciprocating motion of the piston in the cylinder. One port is known as inlet port and another port is known as exhaust port.

Two stroke engines consist of a cylinder with one end fitted with a cylinder head and other end fitted with a hermetically sealed crankcase which enables it to function as a pump in conjunction with the piston.

Working of two stroke petrol engine

In this type of engine, since suction of petrol and air mixture into the cylinder will not take place in a separate stroke, the technique involved in the intake or suction of petrol and air mixture must be well understood before knowing the actual working of a two stroke petrol engine.

Intake of petrol and air mixture:

When the piston moves upward, as shown in fig. 7.9. Partial vacuum is created in the crankcase until its lower edge uncovers the inlet port completely as shown in fig. 7.9(A).

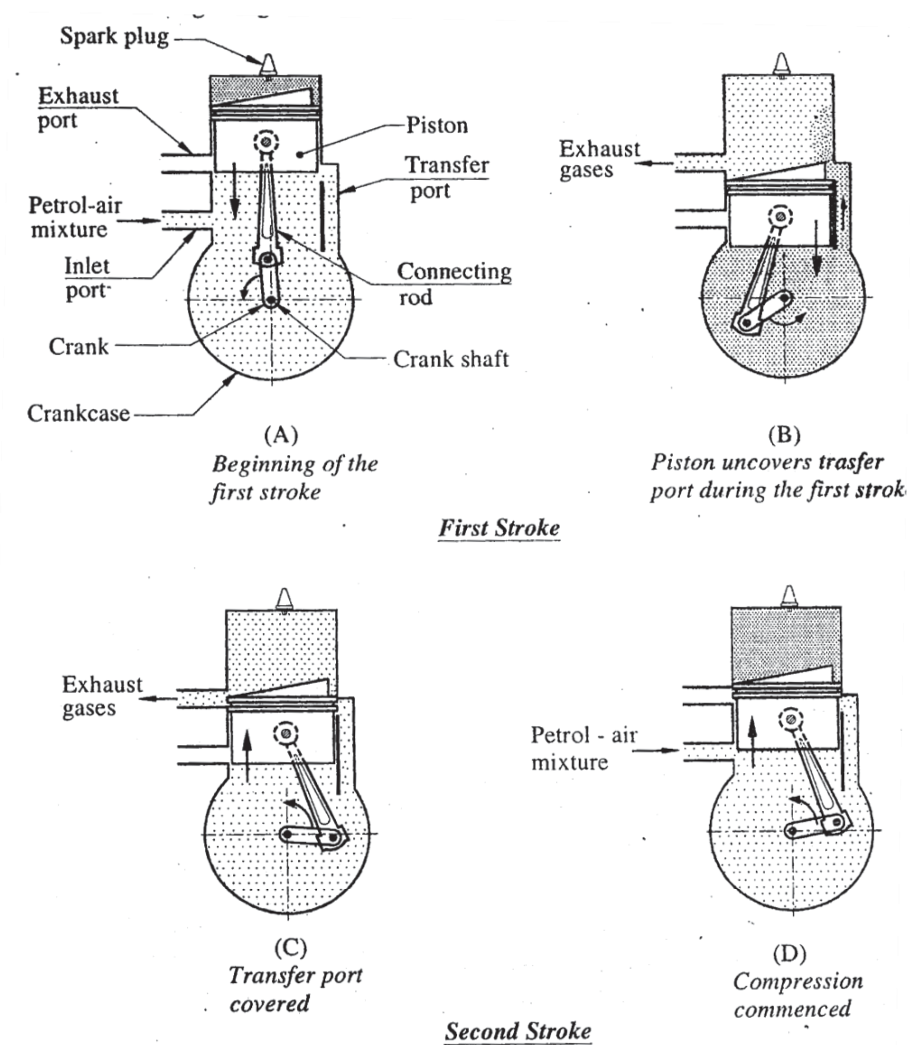

Fig. 7.9 Two stroke petrol engine

The pressure difference set up between the atmosphere and crankcase will suck the petrol and air mixture through the carburetor fitted (not shown in fig. 7.9) to inlet port, into the crankcase as shown in fig. 7.9. The suction will be continued till the inlet port is covered by the piston during its next downward stroke.

After the inlet port is covered by the piston as shown in fig. 7.9 its further downward motion will compress the charge in the crankcase up to top edge of the piston uncovers the transfer port as shown in Fig. The compressed charge flows from the crankcase to cylinder through transfer port. This will continue till the piston covers the transfer port during its next upward stroke as shown in fig. 7.9.

First stroke

At the beginning of the first stroke the piston is at TDC as shown in fig. 7.9. Piston moves from TDC to BDC. The electric spark ignites the compressed charge. The combustion of the charge will release the hot gases which will increase the pressure and temperature in the cylinder. The high pressure combustion gases force the piston downwards. The piston performs the power stroke till it uncovers the exhaust port as shown in fig. 7.10.

The combustion gases which are at a pressure slightly higher than the atmospheric pressure escape through the exhaust port. The piston uncovers the transfer port as shown in fig. 7.9. The fresh charge flows from the crankcase into the cylinder through transfer port.

The fresh charge which enters the cylinder pushes the burnt gases, so more amount of exhaust gases come out through exhaust port as shown in fig. 7.9. This sweeping out of exhaust gases by the incoming fresh charge is called ***scavenging*.** This will continue till the piston covers both the transfer and exhaust ports during next upward stroke.

Second stroke

In this stroke the piston moves from TDC to BDC. When it covers the transfer port as shown in Fig. the supply of charge stops and then when it moves further up it covers the exhaust port completely as shown in Fig. 7.9(D) stops the scavenging. Further upward motion of the piston will compress the charge in the cylinder. After the piston reaches TDC the first stroke repeats again.

Working of Two stroke diesel engine

Fig. 11 shows the construction and working of a two stroke diesel engine. The construction of diesel engine is similar to two stroke petrol engine except the fuel pump and fuel injector are there instead of carburetor and spark plug as in petrol engine. The working of diesel engine is similar to two stroke petrol engine except that only air is supplied into crank case in case of diesel engine and diesel fuel is injected at the end of compression of air.

First stroke

At the beginning of the first stroke, the piston is at TDC as shown in Fig. 7.10 Piston moves from TDC to BDC.

At TDC piston is at the end of compression, so the compressed air will attain a temperature higher than the self-ignition temperature of the diesel. The injector injects a metered quantity of the diesel into the cylinder as a fine spray. As diesel is injected, it auto ignites.

The combustion of the diesel will release the hot gases which increases the pressure and temperature in the cylinder. The piston performs the power stroke till it uncovers the exhaust port as shown in Fig.11. The hot gases have slightly higher pressure than the atmosphere. Due to this pressure difference burnt gases come out from the exhaust port.

The top edge of the piston uncovers the transfer port as shown in Fig. 7.10 the air flows from the crank case into the cylinder through transfer port. The fresh air entering the cylinder, it pushes the burnt gases, so burnt gases come out from exhaust port as shown in Fig. 7.10. This pushing out of the exhaust gases is called ***scavenging***. This will continue till the piston covers both the exhaust and the transfer ports during next upward stroke.

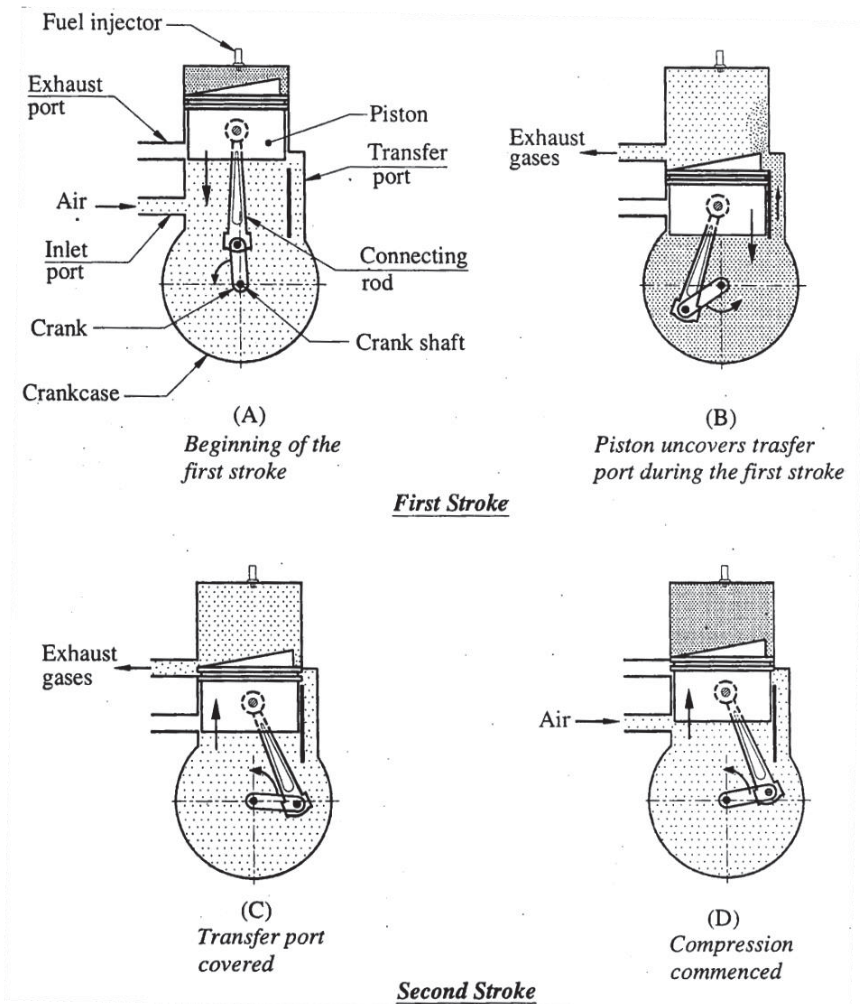

Fig. 7.10 Two stroke diesel engine

Second stroke

In this stroke the piston moves from BDC to TDC. When it covers the transfer port as shown in Fig. 7.10 the supply of air is stop and then when it moves further up it covers the exhaust port completely as shown in Fig. stops the scavenging. Further upward motion of the piston will compress the air in the cylinder. After the piston reaches TDC the first stroke repeats again.

Difference between two stroke and four stroke cycle engines

Sr.	Principle	Four stroke engine	Two stroke engine
1	No of piston strokes per cycle	4 piston strokes require to complete one cycle	Only 2 piston strokes require to complete one cycle
2	No of crank rotation per cycle	Two complete revolutions of crank shaft is required to complete one cycle	Only one complete revolutions of crank shaft is required to complete one cycle
3	No of power stroke per min	Equal to half of the speed of engine crank shaft (n = N/2)	Equal to the speed of engine crank shaft (n = N)
4	Power	Power is developed in every alternate revolution of crank shaft	Power is developed in every revolution of crank shaft
5	Flywheel	The power is developed in every alternate revolution, hence heavy flywheel is required	The power is developed in every revolution, hence lighter flywheel is required
6	Size for same power output	These engines are heavier, larger and require more space	These engines are lighter, more compact and require less space
7	Admission of charge	The charge is directly admitted into the engine cylinder during suction stroke	The charge is first admitted into the crankcase and then transferred to the engine cylinder
8	Valves	The inlet and exhaust valves are required and they are operated by valve operating mechanism	In place of valves, ports are there which opens and closes by motion of piston itself
9	Crankcase	Crankcase is not hermetically sealed	Crankcase is hermetically sealed because charge is admitted into it
10	Direction of rotation of crank shaft	The crank shaft rotates only in one direction	The crank shaft can rotates in both directions
11	Lubricating oil consumption	Less	More
12	Thermal efficiency	Higher, because there is no mixing of fresh charge with exhaust gases	Less, because there is mixing of fresh charge with exhaust gas, hence loss of fresh charge
13	Mechanical efficiency	Less, because of more no of moving parts	Higher, because of less no of moving parts
14	Uses	These engines are used in high power applications where more space is available like cars, trucks, tractors, buses, stationary uses etc.	These engines are used for low power applications where less space is available like mopeds, scooters, motor cycles, etc.

Engine performance parameters

Indicated power

The power produced inside the engine cylinder by burning of fuel is known as Indicated power (I.P.) of engine. It is calculated by finding the actual mean effective pressure.

$$Actual\ mean\ effective\ pressure,\ P_m = \frac{sa}{l}\ N/m^2$$

Where,

a = Area of the actual indicator diagram, cm^2

l = Base width of the indicator diagram, cm

s = Spring value of the spring used in the indicator, $N/m^2/cm$

For four stroke engine

P_m = Mean effective pressure, N/m^2

L = Length of stroke, m

A = Area of cross section of the cylinder, m^2

N = RPM of the engine crank shaft

n = Number of power strokes per minute

$$I.P. = \frac{P_m LAn}{60000}\ \text{kW} \qquad where\ \ n = \frac{N}{2}$$

For two stroke engine

$$I.P. = \frac{P_m LAn}{60000}\ \text{kW} \qquad where\ \ n = N$$

Brake Power (B.P.)

It is the power available at engine crank shaft for doing useful work. It is also known as ***engine output power.*** It is measured by dynamometer.

It can be calculated as follows:

Let,

W = Net load acting on the brake drum, N

R = Effective radius of the brake drum, m

N = RPM of the crank shaft

T = Resisting torque, Nm

P_{mb} = Brake mean effective pressure

$$\therefore T = W \times R \quad Nm$$

$$B.P. = \frac{2\pi NT}{60000} = \frac{P_{mb} LAn}{60000} \quad \text{k}W$$

Measurement of Brake Power (B.P.)

The power output (B.P.) of the engine is measured by coupling a dynamometer to engine crank shaft. Various dynamometers are listed below:

1. Rope brake dynamometer
2. Prony brake dynamometer
3. Hydraulic dynamometer
4. Eddy current dynamometer

Friction Power

The piston connecting rod and crank are mechanical parts, moving relative to each other. They offer resistance due to friction. Therefore a certain fraction of power is lost due to friction of the moving parts.

*The amount of the power lost in friction is called **friction power***. The friction power is the difference between the I.P. and B.P.

$$Friction\ power = I.P. - B.P.$$

Efficiencies

Mechanical efficiency:

It is defined as the ratio of the brake power to the indicated power. Mechanical efficiency is indicator of losses due to friction.

$$\eta_{mech} = \frac{B.P.}{I.P.}$$

Thermal efficiency:

It is the efficiency of conversion of the heat energy produced by the actual combustion of the fuel into the power output of the engine. It is the ratio of work done to heat supplied by fuel.

Indicated thermal efficiency = Indicated Power/ Heat supplied by fuel

$$\eta_{it} = \frac{I.P.}{m_f \times CV}$$

Where, m_f = mass of fuel supplied, Kg/sec and CV = calorific value of fuel, J/kg

Brake thermal efficiency = Brake Power/ Heat supplied by fuel

$$\eta_{bt} = \frac{B.P.}{m_f \times CV}$$

Air standard efficiency:

It is the efficiency of the thermodynamic cycle of the engine.

For petrol engine,

$$\eta_{air} = 1 - \frac{1}{(r)^{\gamma-1}}$$

For diesel engine,

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

Relative efficiency:

It is the ratio of indicated thermal efficiency of an engine to air standard cycle efficiency.

$$\eta_{rel} = \frac{\eta_{it}}{\eta_{air}}$$

Volumetric efficiency:

It is the ratio of the volume of charge/air actually sucked at atmospheric condition to swept volume of engine. It indicates breathing capacity of the engine.

$$\eta_{vol} = \frac{\text{Actual volume of charge or air sucked at atm. condition}}{\text{Swept volume}}$$

Specific power output:

The specific output of the engine is defined as the power output per unit area.

$$Specific\,output = \frac{B.P.}{A}$$

Specific fuel consumption:

Specific fuel consumption (SFC) is defined as the amount of fuel consumed by an engine for one unit of power production. SFC is used to express the fuel efficiency of an I.C. engine.

$$SFC = \frac{m_f}{B.P.} Kg / \text{k}Wh$$

Where,

m_f = Mass of fuel consumed in kg/hr and B.P. = Power produced in kW