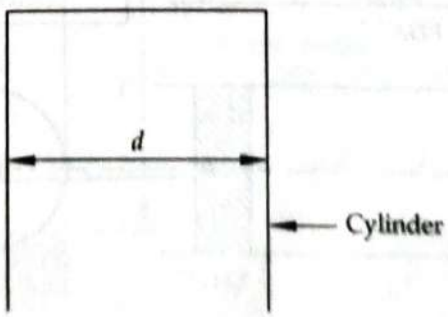
1. *According to the fuel used:*
   (a) Petrol engines. (b) Diesel engines
   (c) Gas engines.
2. *According to the working cycle:*
   (a) Engines based on Otto cycle (b) Engines based on Diesel cycle.
   (c) Engines based on dual combustion cycle
3. *According to the Method of Ignition:*
   (a) Spark ignition engines (S.I. Engines) (b) Compression ignition engines (C.I Engines).
4. *According to the method of fuel Injection:*
   (a) Fuel injection with carburettor. (b) Air injection or air blast injection.
   (c) Airless injection or solid injection.
5. *According to the strokes per cycle:*
   (a) Two stroke engine. (b) Four stroke engines.
6. *According to the cooling system employed:*
   (a) Air cooled engines. (b) Water cooled engines.
7. *According to the number of cylinders:*
   (a) Single cylinder engines. (b) Multi-cylinder engines.
8. *According to the valve mechanism:*
   (a) Engines with overhead valve mechanism. (b) Engines with side valve mechanism.
9. *According to the speed:*
   (a) Low speed engines. (b) Medium speed engines.
   (c) High speed engines.
9. *According to the cylinder arrangement:*
   (a) Horizontal cylinder engines. (b) Vertical cylinder engines.
   (c) V-type multi-cylinder engines. (d) In-line multi-cylinder engines.
   (e) Radial engines. (f) Opposite cylinder engines.
   (g) Opposite piston engines.
11. *According to the field of application:*
   (a) Stationary engines. (b) Automotive engines.
   (c) Aircraft engines. (d) Marine engines (Ship).
   (e) Locomotive engines (Diesel).

9.1.5 Some important terms

1. **Bore:** The internal diameter of the cylinder of the engine is known as *Bore*. (shown in Fig. 1).



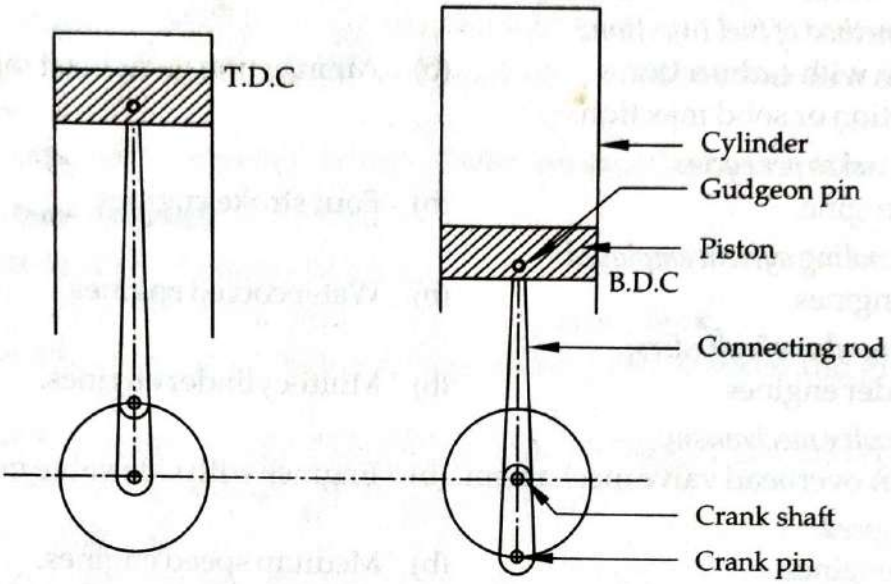
where
d = Internal diameter of the cylinder or Bore

Fig. 1 Bore

2. Dead centres: The piston moves inside the cylinder with reciprocatory (to and tro) motion. The extreme positions of the piston inside the cylinder during its motion are known as dead centre positions. The dead centre positions of the piston are corresponding to the instant, when the centre of the crankshaft, centre of crank pin and centre of gudgeon pin, all lie on the same straight lines.

There are two dead centre positions.

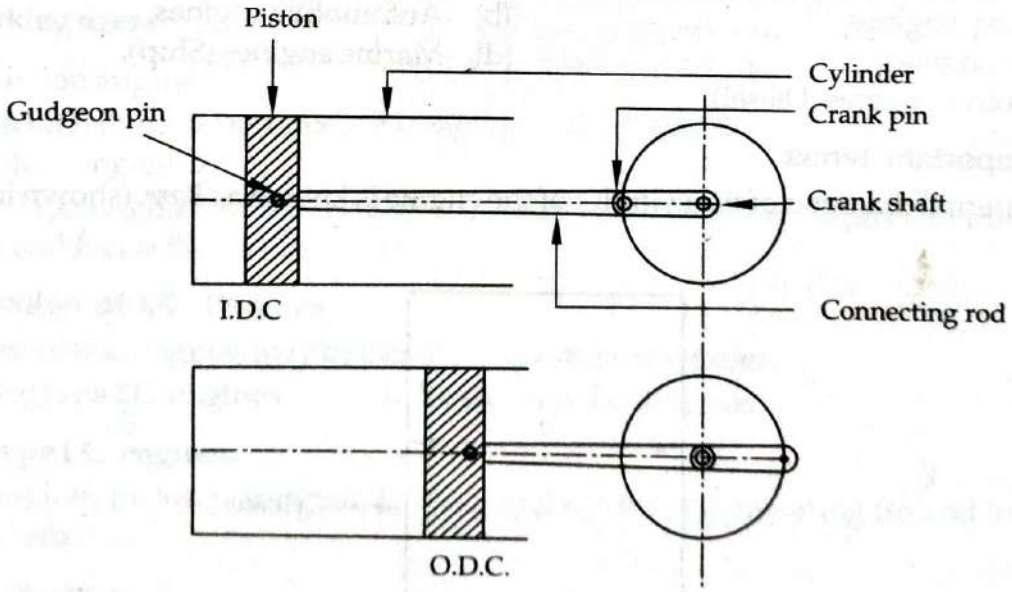
In vertical engines, these positions are known as Top Dead Centre position (T.D.C) and bottom dead centre position (B.D.C). As shown in Fig. 2.



T. D. C → Top Dead Centre
B. D. C → Bottom Dead Centre

Fig. 2 Vertical Cylinder Engines showing, T.D.C & B.D.C positions

In horizontal I.C. engines, these positions are known as inner dead centre position (I.D.C) and outer dead position (O.D.C). Hence, they may be defined as follows (As shown in Fig. 3):



I. D. C → Inner Dead Centre
O. D. C → Outer Dead Centre

Fig. 3 Horizontal Cylinder Engine showing, I.D.C & O.D.C positions

Top Dead Centre position (T.D.C): In vertical engines, the top most position of the piston (towards the cylinder cover side), when the centres of the crankshaft, crank pin and the gudgeon pin lie on the same straight line is known as T.D.C.

Bottom Dead Centre position (B.D.C): In vertical engines, the bottom most position of the piston (towards the crank side), when the centres of the crankshaft, crank pin and gudgeon pin lie on the same straight line, is known as bottom dead centre position.

Inner Dead Centre position (I.D.C): In horizontal engine the inner most position of the piston (towards the cylinder cover side) when the centres of crankshaft, crank pin and gudgeon pin, lie on the same straight line is called Inner dead centre position.

Outer Dead Centre position (O.D.C): In horizontal engines the outer most position of the piston (towards crank side), when the centres of the crankshaft, crank pin and gudgeon pin lie on the same straight line, is called outer dead centre position.

3. Stroke: The distance travelled by the piston from one of the dead centres to the other dead centre, is called stroke.

It is also equal of two times the crank radius, (shown in Fig. 4).

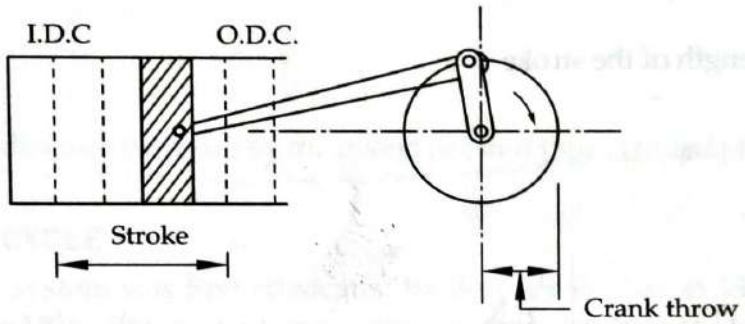


Fig. 4

4. Crank throw: The distance between the centres of the crankshaft and crank pin is known as crank throw. It is equal to half of the stroke length. It is also called crank radius, (shown in Fig. 4).

5. Clearance volume: The volume of space included in between the under cover and piston, when the piston is at its I.D.C position or T.D.C. position, is known as clearance volume, (shown in Fig. 5).

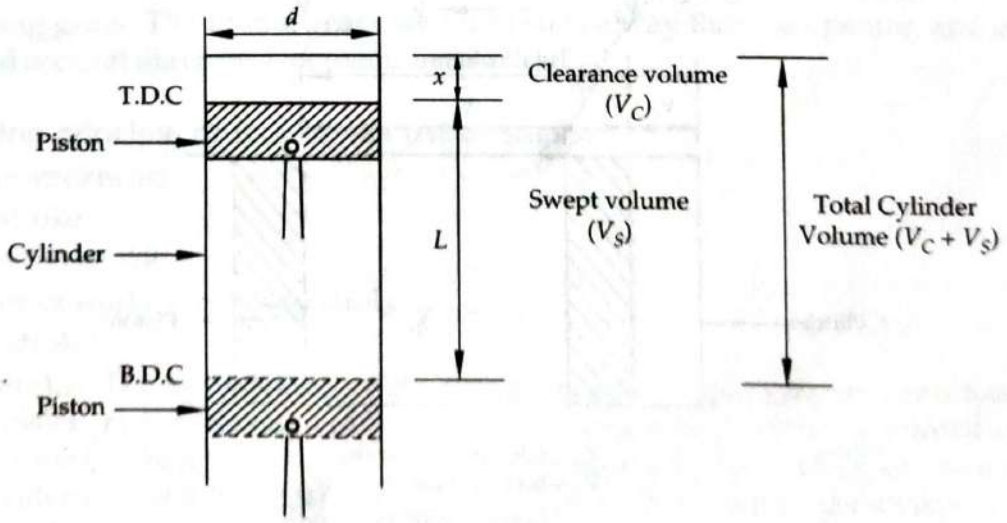


Fig. 5 Swept & Clearance Volume

When the piston reaches its T.D.C. position (in vertical engines) or I.D.C position (in horizontal engines), it is not allowed to touch the under head. That is, some clearance is provided in between the piston and cylinder head. The volume of this space is known as clearance volume. It is generally represented by V_C

Mathematically:

$$\text{Volume } V_C = \frac{\pi}{4} d^2 \times x$$

Where d = internal diameter of cylinder

x = distance between under cover and piston.

The clearance volume is generally expressed in terms of the percentage of the swept volume.

6. Swept volume: The volume swept by the piston when its moves from one of its dead centre position, to the other, is called swept volume (shown in Fig. 5).

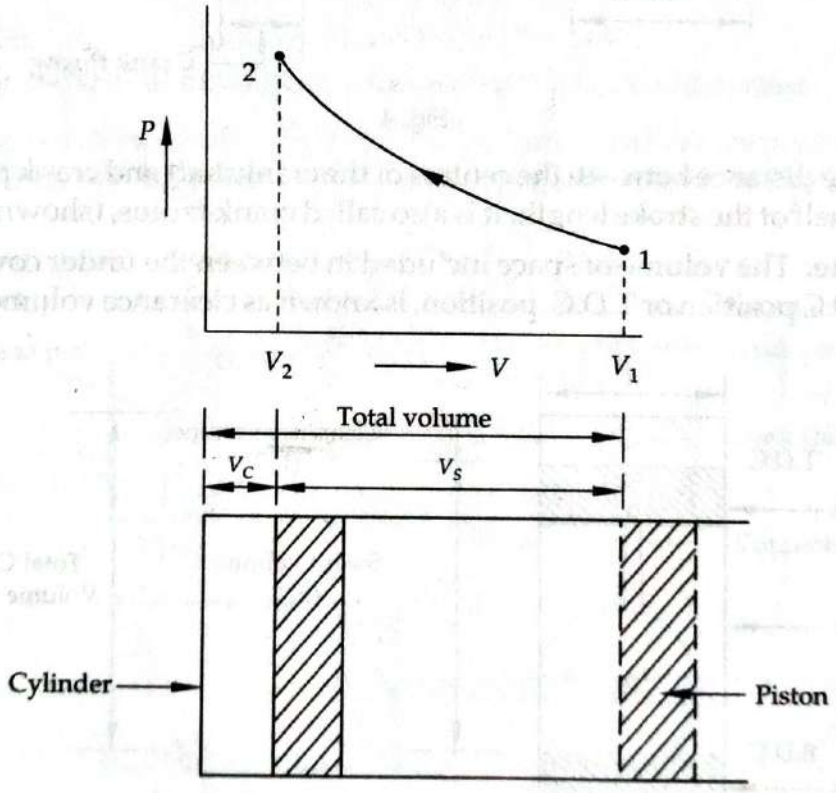
It is also known as piston displacement. It is generally expressed by V_S.

Mathematically:

Swept volume or piston displacement

$$= \frac{\pi}{4} d^2 \times \text{Length of the stroke}$$

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



where

V_C = Clearance volume

V_S = Swept volume

r = Compression ratio = $\frac{V_1}{V_2}$

$V_1 = V_C + V_S$

$V_2 = V_C$

Fig. 6

where d = Internal dia of the cylinder

L = Length of the stroke

7. Total cylinder volume: The sum of the clearance volume and swept volume (piston displacement) is called total cylinder volume, (shown in Fig. 5).

Total cylinder volume $V = V_S + V_C$

where V_S = Swept volume

V_C = Clearance volume

8. Compression ratio: The ratio of the total cylinder volume to the clearance volume known is compression ratio, (shown in Fig. 6).

It is generally represented by r.

$$\text{i.e. compression ratio} = \frac{\text{Total cylinder volume}}{\text{Clearance volume}}$$

$$r = \frac{V_C + V_S}{V_C}$$

$$r = \frac{V_1}{V_2} \qquad \left[\because \begin{matrix} V_1 = V_C + V_S \\ V_2 = V_C \end{matrix}\right]$$

9. Piston speed: The distance travelled by the piston per unit time is called piston speed.

9.2 FOUR STROKE CYCLE

The four stroke cycle system was first advocated by Beau de Rochas in 1862 and later on it was introduced by Otto in 1876. The cycle of operation is completed in four strokes of the piston. An engine operating on this cycle is said to work on a four stroke cycle.

The engine which requires four strokes of piston or two revolutions of the crankshaft to complete the cycle, is known as four stroke engine.

There are two, mechanically operated valves in a engine working on four stroke cycle. These valves are generally referred as inlet and exhaust valves. The opening and closing of these valves are controlled by means of cams mounted on the shaft. The camshaft gets its drive from the crankshaft through timing gears. The timing gears are set in such a way that the opening and closing of the valves should occur at the correct moments in the cycle.

9.2.1 Working principle of four stroke petrol engine

There are four strokes as:

1. Suction stroke
2. Compression stroke
3. Expansion or working or power stroke
4. Exhaust stroke

1. **Suction stroke:** The suction stroke starts with the piston at top dead centre position. During this stroke, the piston moves downwards by means of crankshaft which is rotated either by the momentum of the flywheel or with the help of starter motor or by hand. The inlet valve is opened and the exhaust valve is closed. The partial vacuum created by the downward movement of the piston, sucks in the fresh charge (mixture of air and petrol) from the carburettor through the inlet valve. The stroke is completed during the half revolution (180°) of the crankshaft, which means at the end of the suction stroke, piston reaches the bottom dead centre position. (Shown in Fig. 7(a)).

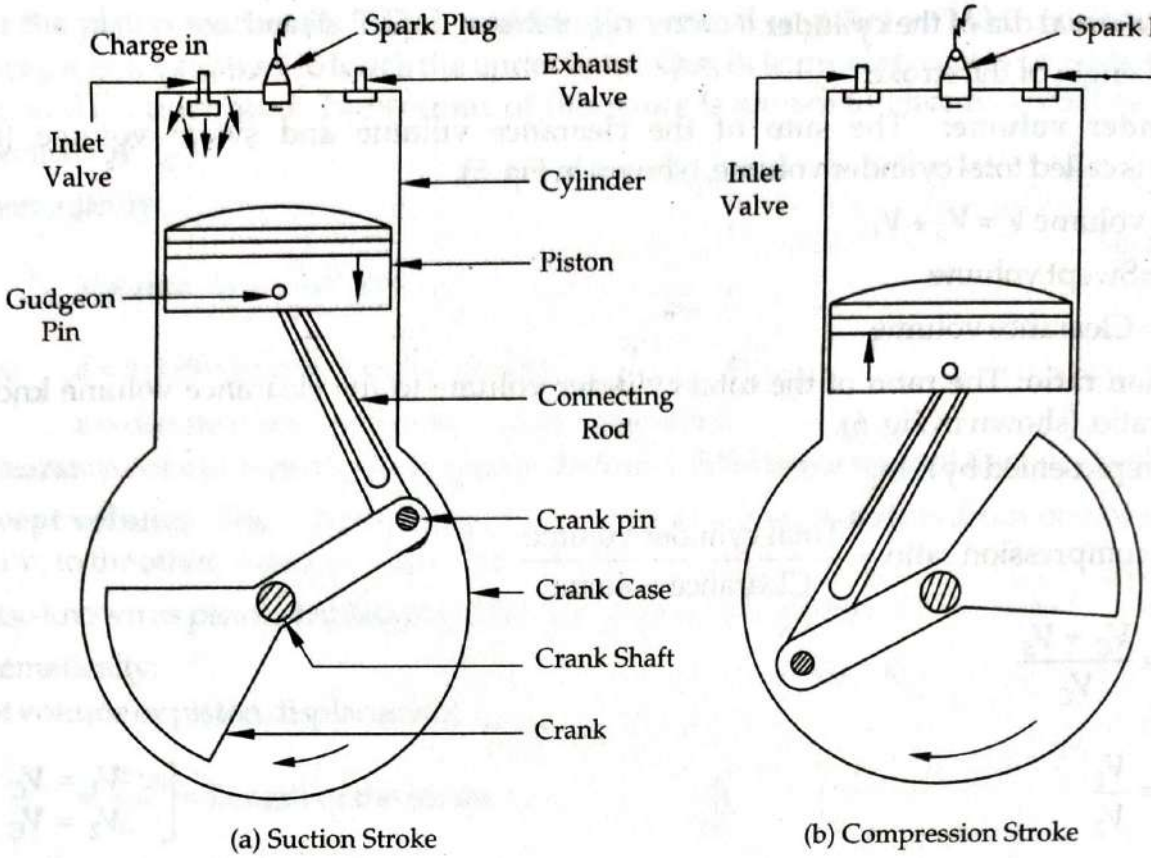


Fig. 7 Working Principle of a four stoke petrol engine

2. **Compression stroke:** During this stroke the inlet and exhaust valves are closed and the piston returns from bottom dead centre position. The piston is still driven by the momentum of the flywheel. As the piston moves up, the charge is compressed. During compression the pressure and temperature rises. This rise in temperature and pressure depends upon the compression ratio. (in petrol engines the compression ratio generally varies between 6 : 1 and 9 : 1). Just before the completion of the compression stroke, the charge is ignited by means of an electric spark, produced at the spark plug, (shown in Fig. 7(b)).

3. **Working or Expansion stroke:** The ignition of the compressed charge, just before the completion of compression stroke, causes a rapid rise of temperature and pressure in the cylinder. The explosion of the charge is completed by the time, the piston reached its top dead centre position.

During this stroke the inlet and exhaust valves remain closed. The expansion of gases due to the heat of combustion, exerts pressure on the piston due to which the piston moves downward, doing some useful work.

This is the stroke, during which power is produced by the expansion of the gases. This is why this stroke is also known as power stroke. The energy produced during this stroke may be stored in the flywheel, (shown in Fig. 7(c).

4. **Exhaust stroke:** The exhaust valve is opened and the inlet valve remain closed. The piston moves upward (from its B.D.C. position) with the help of energy stored in the flywheel during the working stroke. The upward movement of the piston discharges the burnt gases through the exhaust valve. The pressure, at which the burnt gases are exhausted out, is slightly above the atmospheric pressure due to the resistance offered by the exhaust valve.

At the end of exhaust stroke, piston reaches its T.D.C position and the next cycle starts (shown in Fig. 7(d)).

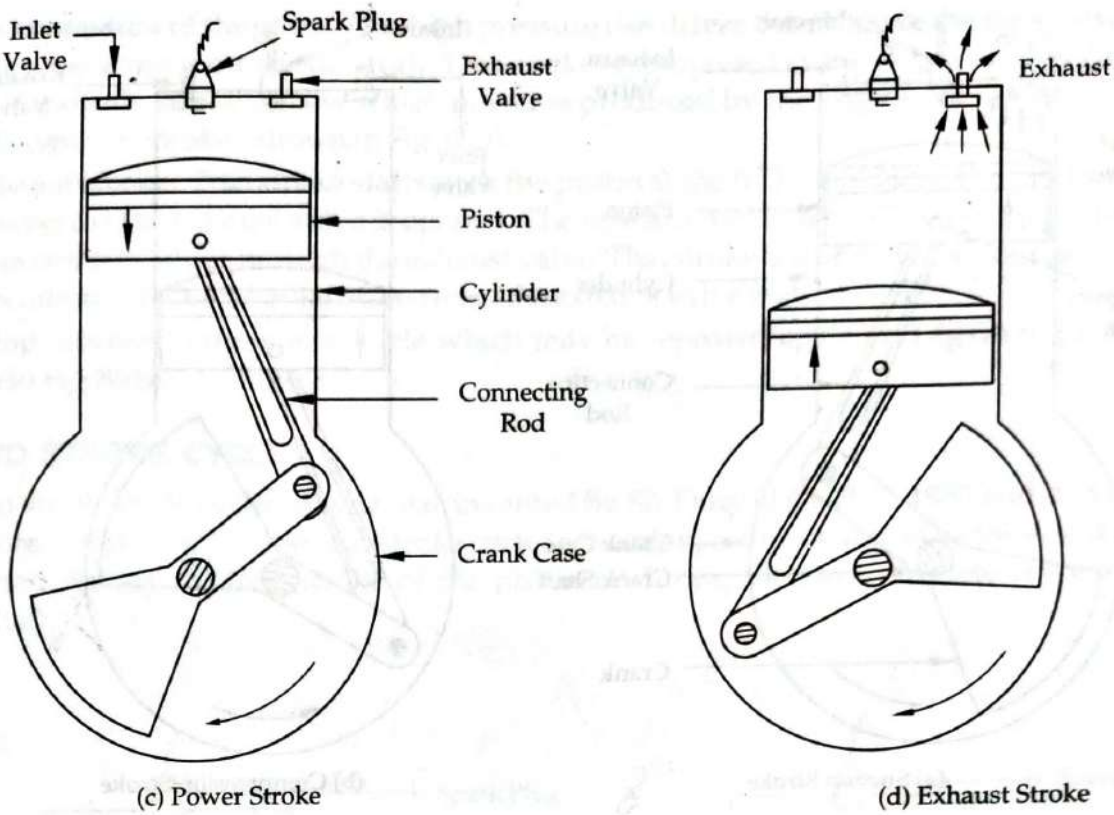


Fig. 7 Working Principle of a four stoke petrol engine

9.2.2 Working principle of 4-stroke diesel engine

The basic difference between the working principle of 4-stroke diesel engine and 4-stroke petrol engine is that in the case of diesel engine, air alone is drawn into the engine cylinder during suction stroke and it is compressed to a very high temperature during the compression stroke. The fuel (diesel) is sprayed into the cylinder, when the compression stroke is about to complete. The injected fuel is ignited due to the heat of compression. This is why the diesel engines are also known as compression ignition engines. The combustion of the fuel takes place at constant pressure.

There are four strokes as:

1. Suction stroke
2. Compression stroke
3. Expansion or working or power stroke
4. Exhaust stroke

1. **Suction stroke:** This stroke starts with the piston at top dead centre position. The inlet valve is opened and the exhaust valve is closed. The downward movement of the piston creates vacuum in the cylinder due to which air is drawn into the cylinder. The movement of the piston is obtained either by the starter motor or by the movement of the flywheel. At the end of this stroke the piston reaches its B.D.C position i.e. crankshaft is rotated through 180° (shown in Fig. 8(a)).

2. **Compression stroke:** This stroke starts with the piston at B.D.C position. Both the inlet and exhaust valves are closed. The air sucked during the suction stroke is compressed as the piston moves in the upward direction. During this stroke the upward movement of the piston is also achieved by the starter motor or momentum of the flywheel. The rise in temperature and pressure of the air at the end of compression depends on the compression ratio. The compression ratio in diesel engine is higher than that of petrol engines.

A few degree before the completion of compression stroke, a very fine spray of diesel is injected into the compressed air (which is at a very high temperature). The fuel ignites spontaneously. The injection of the fuel is assumed to occur at constant pressure.

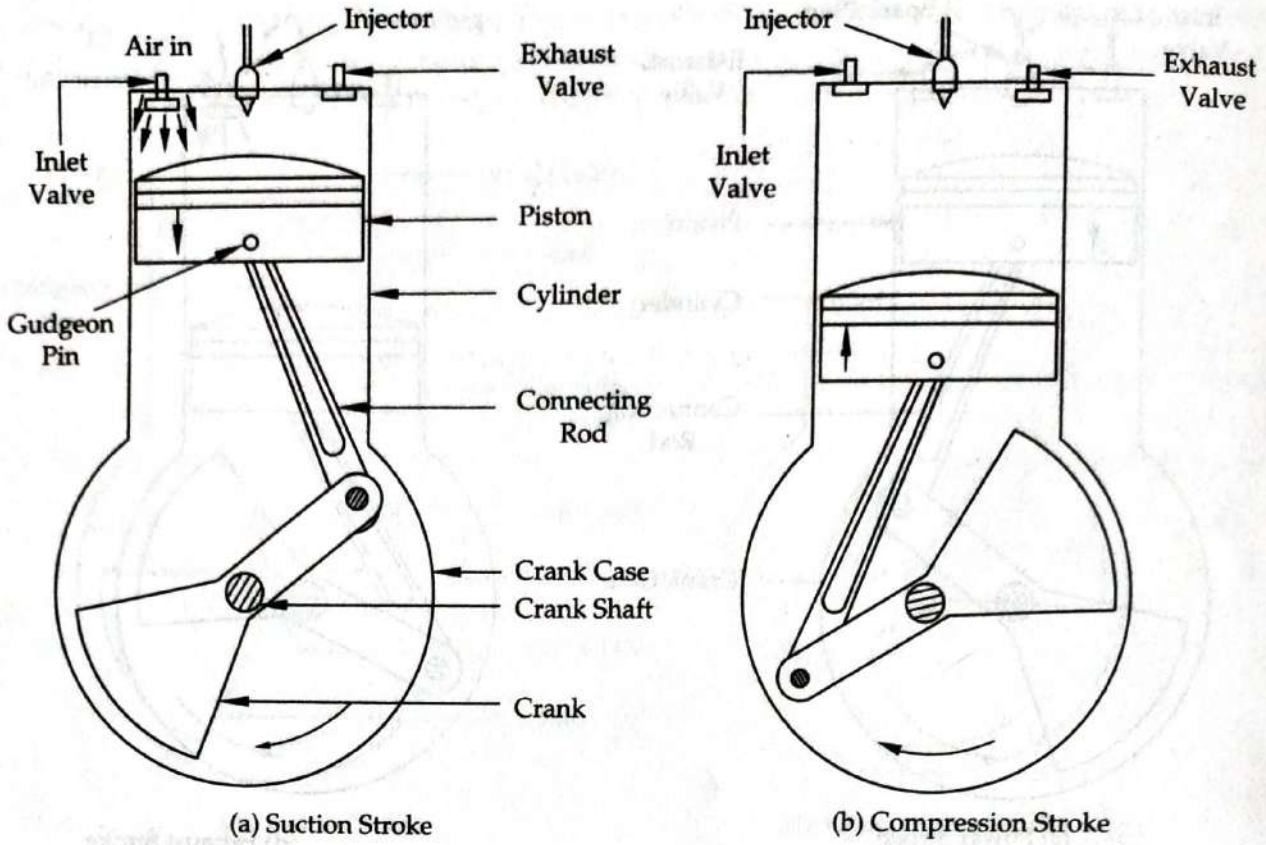


Fig. 8 Working Principle of four stroke diesel engine

At the end of compression stroke the piston reaches its T.D.C position, that is, the crankshaft has further rotated through 180°. (shown in Fig. 8(b)).

3. **Expansion of working stroke:** This stroke starts with the piston at T.D.C position. Both the inlet and exhaust valves remain closed. The heat energy released by the combustion of the fuel, results in

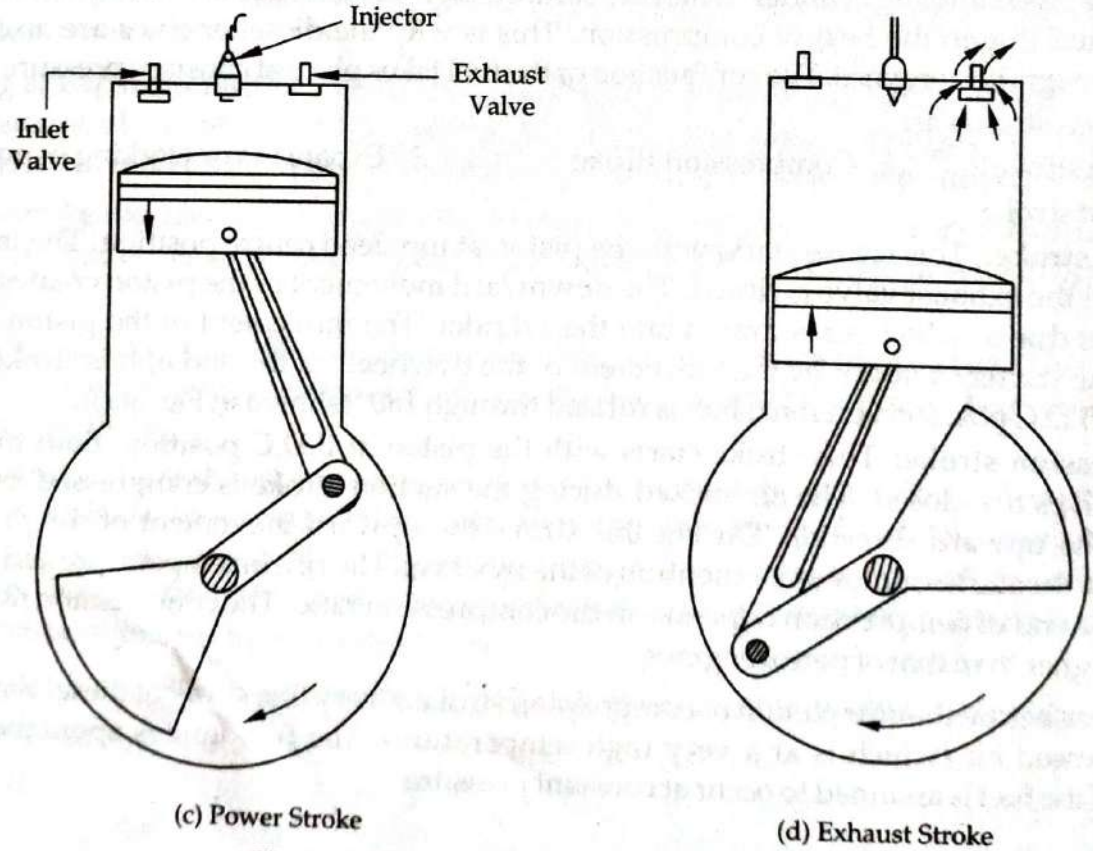


Fig. 8 Working Principle of a four stroke Diesel engine

the rise in pressure of the gases. This high pressure rise drives the piston in the downward direction, there by producing some useful work. This stroke is completed as the piston reaches its B.D.C position. It is the only stroke during which power is produced by the engine. This is why this stroke is also called power stroke. (shown in Fig. 8(c)).

4. **Exhaust stroke:** This stroke starts with the piston at the B.D.C position. The inlet valve remains closed whereas the exhaust valve is opened. The upward movement of the piston pushes the burnt gases out of the cylinder through the exhaust valve. This stroke is completed as the piston reaches the T.D.C position. At the end of exhaust stroke, the exhaust valve is also closed.

These four strokes complete on cycle which may be repeated again and again to produce power (shown in Fig. 8(d)).

9.3 TWO STROKE CYCLE

The two stroke cycle petrol engine was invented by Sir Dugald Clerk in 1880 and diesel engine by Sulzer Brothers in 1907. In the four stroke cycle the suction, compression, expansion and exhaust are completed during the four stroke of the piston or during the two complete revolutions of the crankshaft.

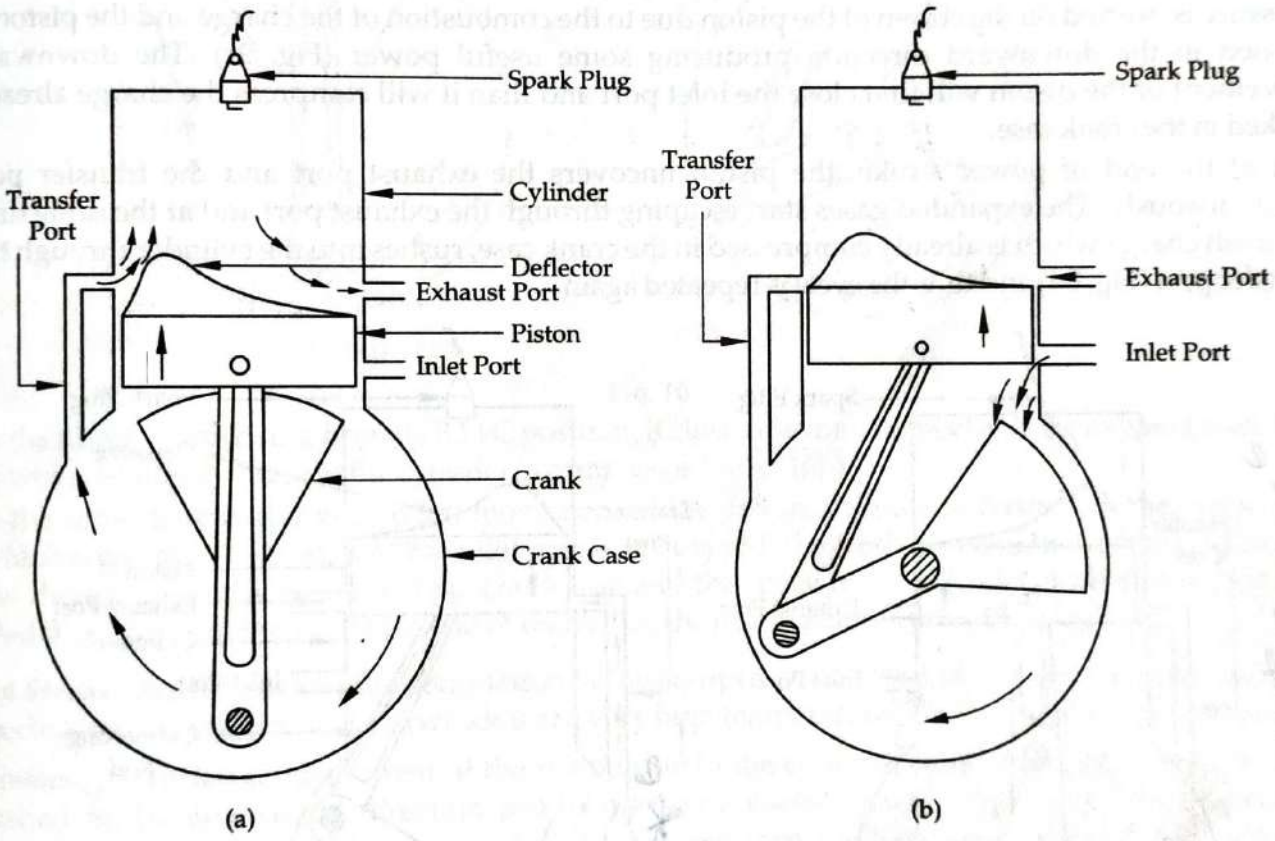


Fig. 9 Working principle of 2 stroke Petrol Engine

Whereas in the case of two stroke cycle, these operation are completed during the two strokes of the piston or during one complete revolution of the crankshaft.

In other words in the two stroke cycle, one working stroke is completed per revolution of the crankshaft. Thus theoretically, the two stroke engine should produce double the power as produced by the four stroke engine of the same size, but actually it is not possible due to number of losses which are difficult to eliminate in practice.