ABES ENGINEERING COLLEGE, GHAZIABAD

Subject: Fundamentals of Mechanical Engineering (BME101)

Unit 2 (Part 1)
Topic: Introduction to IC Engines
Lecture Notes

INDEX

1. Basic definition of Engine and Components

Heat Engines –

A machine or device which derives heat from the combustion of fuel and converts part of this energy into mechanical work is called a *heat engine*. Heat engines may be classified into two main classes as follows:

1. *External combustion engines*
2. *Internal combustion engines*.

1. **External Combustion Engines** - In this case, combustion of fuel takes place outside the cylinder as in the case of *steam engines* where the heat of combustion is employed to generate steam which is used to move a piston in a cylinder. Other examples of *external combustion engines* are hot air engines, steam turbine and closed cycle gas turbine.

2. Internal Combustion Engines - In this case, combustion of fuel with oxygen of the air occurs within the cylinder of the engine. The *internal combustion engines* group includes engines employing mixtures of combustible gases and air, known as gas engines, those using lighter liquid fuel or spirit known as petrol engines and those using heavier liquid fuels, known as oil, compression ignition or diesel engines.

The important *applications of I.C. engines* are: (i) Road vehicles, locomotives, ships and aircraft, (ii) Portable standby units for power generation in case of scarcity of electric power, (iii) Extensively used in farm tractors, lawn movers, concrete mixing devices and motor boats.

Constructional details or Components of I.C. Engines

A cross-section of an air-cooled I.C. engine with principal parts is shown in Fig. (Air-cooled I.C. engine).

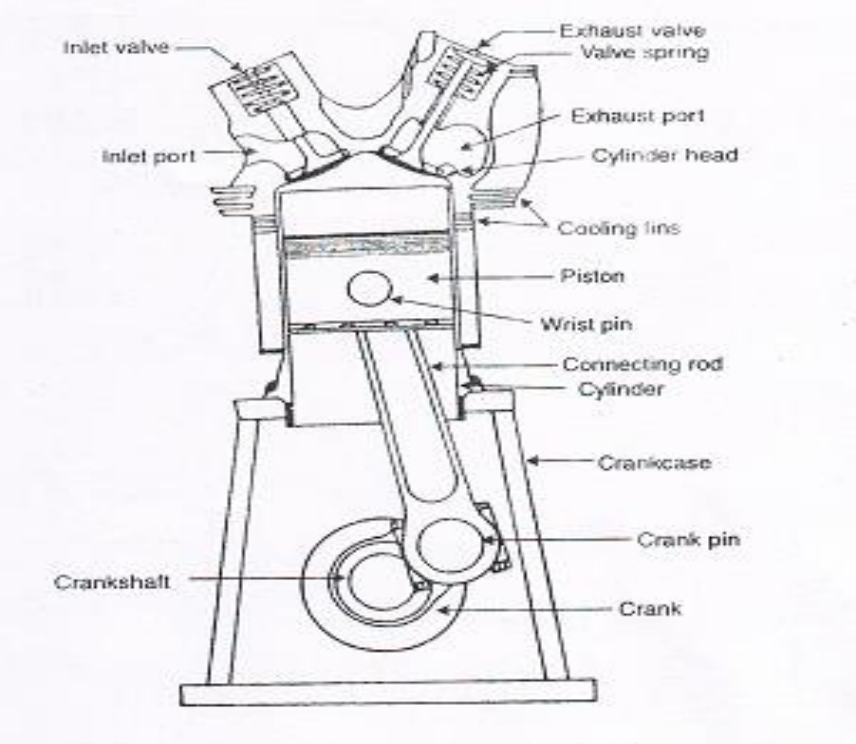

Fig. Air-cooled I.C. engine

A. Parts common to both Petrol and Diesel engine:

1. Cylinder, 2. Cylinder head, 3. Piston,
4. Piston rings, 5. Gudgeon pin, 6. Connecting rod,
7. Crankshaft, 8. Crank, 9. Engine bearing,
10. Crank case. 11. Flywheel, 12. Governor,
13. Valves and valve operating mechanism.

B. Parts for Petrol engines only:

1. Spark plug, 2. Carburettor, 3. Fuel pump.

C. Parts for Diesel engine only :

1. Fuel pump, 2. Injector

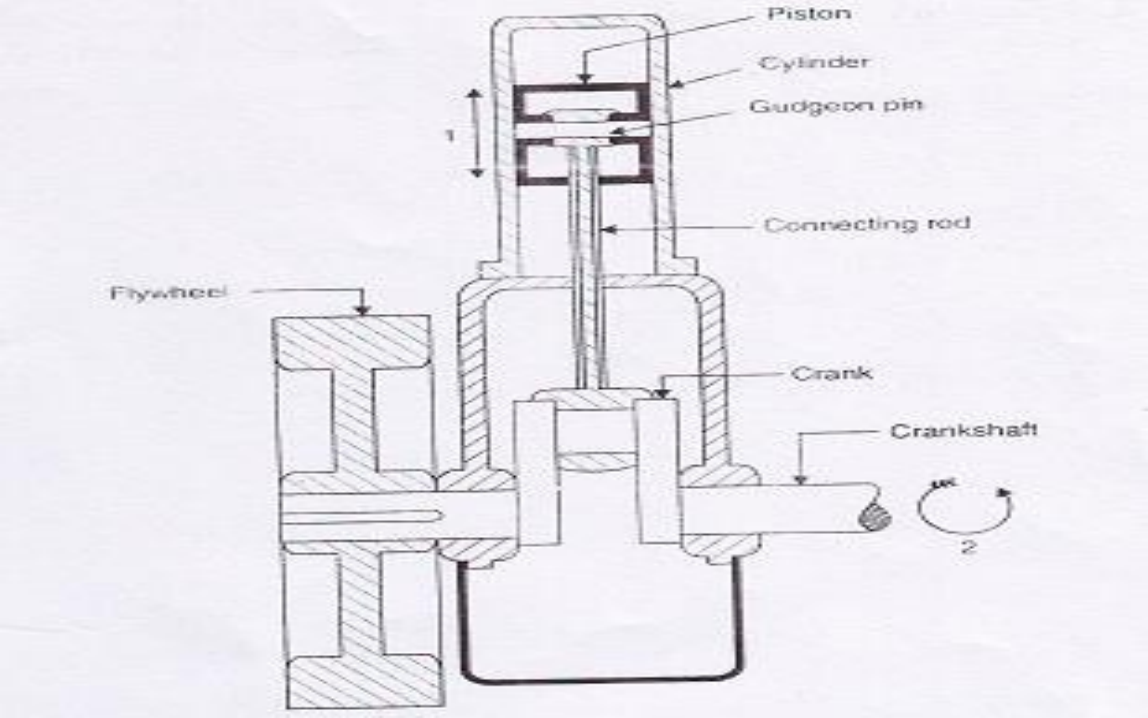

Fig. Basic idea of I.C. engine

The details of the I.C. Engine parts are:

1. **Cylinder -** It is one of the most important part of the engine, in which the piston moves to and fro in order to develop power. The engine cylinder has to withstand a high pressure (more than 50 bar) and temperature (more than 2000 deg C). Thus the material for the engine cylinder should be such that it can retain sufficient strength at such a high pressure and temperature. For ordinary engines, the cylinder is made of ordinary cast iron. But for heavy duty engines, it is made of steel alloys or aluminum alloys.

Sometimes, a liner or sleeve is inserted into the cylinder, which can be replaced when worn out. As the material required for liner is comparatively small, it cab be made of alloy cast iron having long life and sufficient resistance to rapid wear and tear to the fast moving reciprocating parts.

2. Cylinder head - It is fitted on one end of the cylinder, and act as a cover to close the cylinder bore. Generally, the cylinder head contains inlet and exit valves for admitting fresh charge and exhausting the burnt gases. In petrol engines, the cylinder head also contains a spark plug for igniting the fuel-air mixture, towards the end of compression stroke. But in diesel engines, the cylinder head contain nozzles, (i.e. fuel valve) for injecting the fuel into the cylinder.

The cylinder head is cast as one piece and bolted to one end of the cylinder. The cylinder block and cylinder head are made from the same material. A copper or asbestos gasket is provided between the engine cylinder and cylinder head to make an air-tight joint.

3. Piston – It is considered as the heart of an I.C. engine, whose main function is to transmit the force exerted by the burning of charge to the connecting rod. The piston are generally made of aluminium alloys which are light in weight. They have good heat conducting property and also greater strength at higher temperature.

4. **Piston rings** – These are circular rings and made of special steel alloys which retain elastic properties even at high temperatures. The piston rings are housed in the circumferential grooves provided on the outer surface of the piston. Generally, there are two sets of rings mounted for the piston. The function of the upper rings is to provide air tight seal to prevent leakage of the burnt gases into the lower portion. Similarly, the function of the lower rings is to provide effective seal to prevent leakage of the oil into the engine cylinder.

5. **Connecting rod** – It is a link between the piston and crankshaft, whose main function is to transmit force from the piston to the crankshaft. Moreover, it converts reciprocating motion of the piston into circular motion of the crankshaft, in the working stroke. The upper (i.e. smaller) end of the connecting rod is fitted to the piston and the lower (i.e. bigger) end of the crank.

The special steel alloys or aluminium alloys are used for the manufacture of connecting rods. A special care is required for the design and manufacture of connecting rod, as it is subjected to alternatively compressive and tensile stresses as well as bending stresses.

6. **Crankshaft** – It is considered as the backbone of an I.C. engine whose function is to covert the reciprocating motion of the piston into the rotary motion with the help of connecting rod. This shaft contains one or more eccentric portions called cranks. This part of the crank, to which bigger end of the connecting rod is fitted, is called crank pin. Special steel alloys are used for the manufacture of crankshaft. A special care is required for the design and manufacture of crankshaft

7. **Crank case** – It is a cast iron case, which holds the cylinder and crankshaft of an I.C. engine. It also serves as a sump for the lubricating oil. The lower portion of the crank case is known as bed plate, which is fixed with the help of bolts.
8. **Flywheel** – It is a big wheel, mounted on the crankshaft, whose function is to maintain its speed constant. It is done by storing excess energy during power stroke, which, is returned during other stroke.

Terms relating to I.C. Engines:

The various terms relating to I.C. engines are elaborated in Fig.

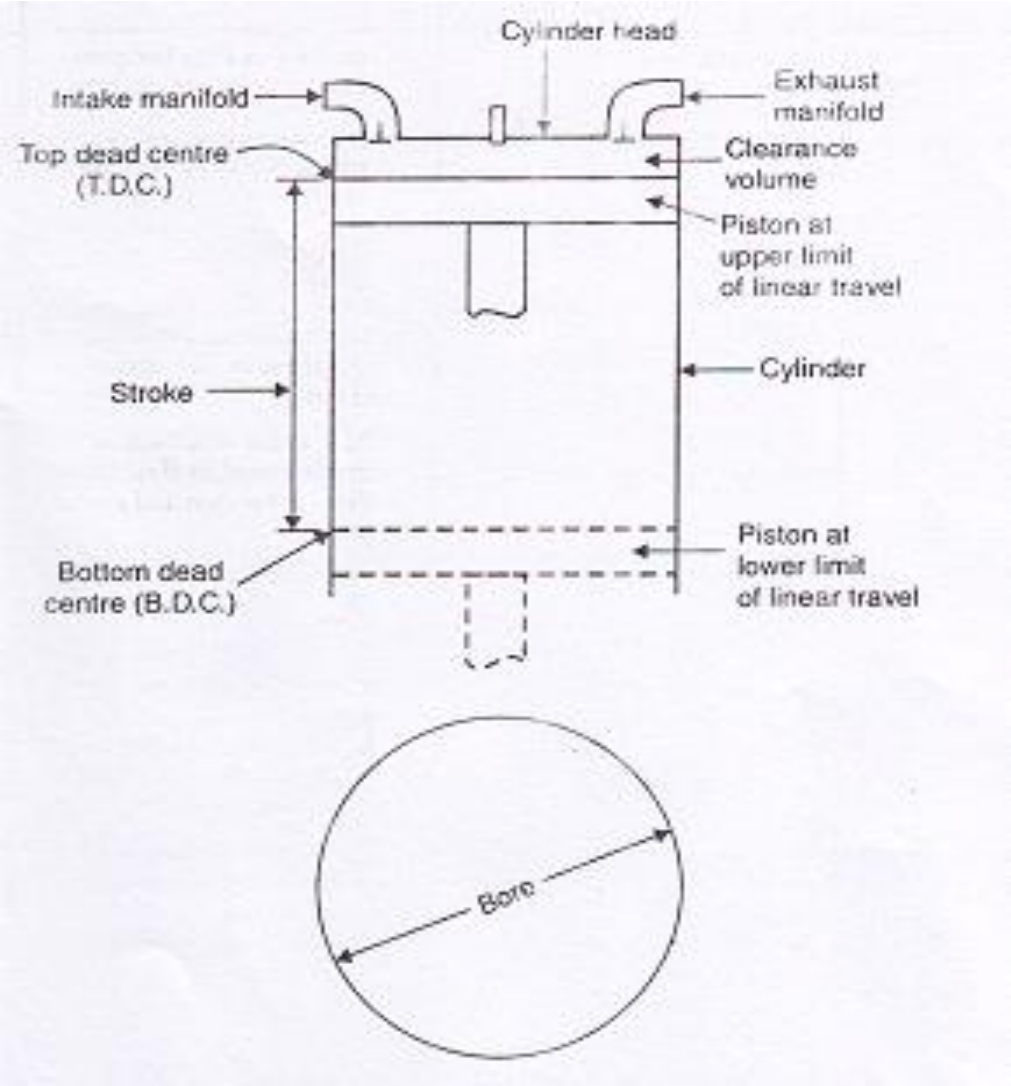

Fig. Terms relating I.C. engines

1. **Bore** – The inside diameter of the cylinder is called *bore*.
2. **Stroke** – As the piston reciprocates inside the engine cylinder, it has got limiting upper and lower positions beyond which it cannot move and reversal of motion takes place at these limiting positions. The linear distance along the cylinder axis between two limiting positions, is called *stroke*.

3. **Top Dead Centre (T.D.C.)** – The top most position towards cover end side of the cylinder is called *"top dead centre"*. In case of horizontal engines, this is known as inner dead centre.
4. **Bottom Dead Centre** – The lowest position of the piston towards the crank end side of the cylinder is called "bottom dead centre". In case of horizontal engines it is called outer dead centre.

Classification of I.C. Engines:

The internal combustion engines may be classified in the following ways:

1. According to the *type of fuel* used
   a) Petrol engines, b) Diesel engines, and c) Gas engines.
2. According to the *method of igniting* the fuel
   a) Spark ignition engines, and b) Compression ignition engines.
3. According to the *number of strokes* per cycle
   a) Four stroke cycle engines, and b) Two stroke cycle engines.
4. According to the *cycle of operation*
   a) Otto cycle engines, b) Diesel cycle engines, and c) Dual cycle engines.
5. According to the *speed of the engine*
   a) Slow speed engines, b) Medium speed engines, and
   c) High speed engines.
6. According to the *cooling system*
   a) Air-cooled engines, and b) Water-cooled engines.
7. According to the *method of fuel injection*
   a) Carburettor engines, and b) Air injection engines.
8. According to the *number of cylinders*
   a) Single cylinder engines, and b) Multi-cylinder engines.
9. According to the *arrangement of cylinders*
   a) Vertical engines, b) Horizontal engines, c) Radial engines,
   d) In-line multi-cylinder engines, e) V-type multi-cylinder engines,
   f) Opposite-cylinder engines, and g) Opposite-piston engines.
10. According to the *valve mechanism*
    a) Overhead valve engines, and b) Side valve engines.
11. According to the *method of governing*
    a) Hit and miss governed engines, b) Quantitatively

governed engines, and Qualitatively governed engines.

Sequence of Operation in IC Engine:

The *sequence of operation* in a cycle are as follows:

1. **Suction stroke** – In this stroke, the fuel vapour in correct proportion, is applied to the engine cylinder.
2. **Compression stroke** –. In this stroke, the fuel vapour is compressed in the engine cylinder.
3. **Expansion stroke** – In this stroke, the fuel vapour is fired just before the compression is complete. It results in the sudden rise of pressure, due to expansion of the combustion products in the engine cylinder. This sudden rise of pressure pushes the piston with a great force, and rotates the crankshaft. The crankshaft, in turn, drives the machine connected to it.
4. **Exhaust stroke** – In this stroke, the burnt gases (or combustion products) are exhausted from the engine cylinder, so as to make space available for the fresh fuel vapour.

2. Construction and Working of Two stroke and four stroke SI & CI engine

Two-stroke Cycle Petrol Engine:

In this cycle, the *suction, compression, expansion* and *exhaust* takes place during two strokes of the piston. There is one working stroke after every revolution of the crankshaft. A two stroke engine has *ports instead of valves*. All the four stages of a two stroke petrol engine are described below:

1. **Suction stroke** – In this stroke, the piston, while going down towards bottom dead centre (*BDC*), uncovers both the transfer port and the exhaust port. The fresh fuel-air mixture flows into the engine cylinder from the crank case, as shown in Fig.

2. **Compression stroke** – In this stroke, the piston, while moving up, first covers the transfer port and then exhaust port. After that the fuel is compressed as the piston moves upwards as shown in Fig. In this stage, the inlet port opens and fresh fuel-air mixture enters into the crank case.

3. **Expansion stroke** – Shortly before this piston reaches the top dead centre (*TDC*) during compression stroke, the charge is ignited with the help of a spark plug. It suddenly increases the pressure and temperature of the products of combustion but the volume remains constant. Due to rise in the pressure, the piston is pushed downwards with a great force as shown in Fig. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy produced is transformed into mechanical work.

4. **Exhaust stroke** - In this stroke, the exhaust port is opened as the piston moves downwards. The products of combustion, from the engine cylinder are exhausted through the exhaust port into the atmosphere, as shown in Fig. This completes the cycle and the engine cylinder is ready to suck the charge again

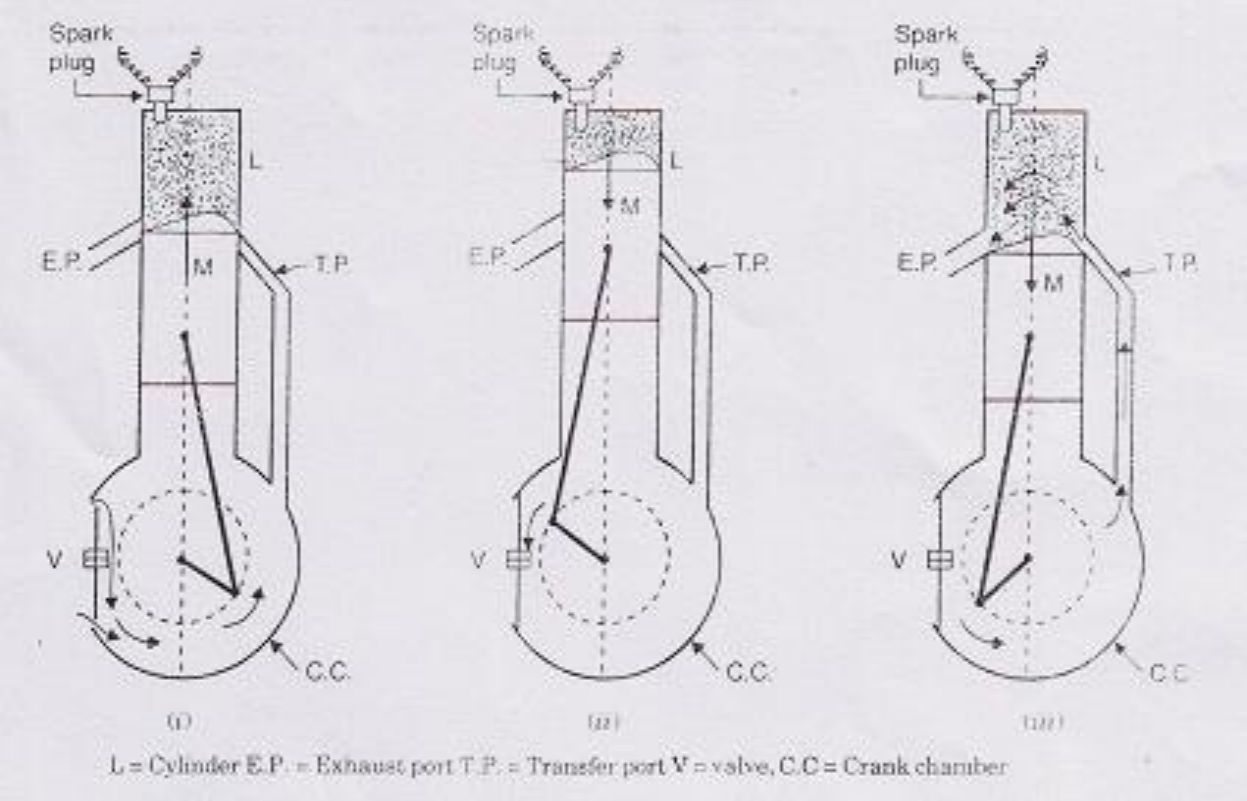

Fig. Two-stroke cycle petrol engine

Two-stroke Cycle Diesel Engine:

In a *two-stroke Diesel cycle* engine all the operations are the same as in the spark ignition (*Otto cycle*) engine with the differences; firstly in this case, only air is admitted into cylinder instead of air-fuel mixture and secondly *fuel injector* is fitted to supply the fuel instead of a *sparking plug*. All the *four stages of a two-stroke cycle diesel engine* are described below:

1. **Suction stroke** – In this stroke, the piston while going down towards Bottom Dead Centre (*BDC*) uncovers the transfer port and the exhaust port. The fresh air flows into the engine cylinder from the crank case.
2. **Compression stroke** – In this stroke, the piston while moving up, first covers the transfer port and then exhaust port. After that the air is compressed as the piston moves upwards. In this stage, the inlet port opens and the fresh air enters into the crank case.
3. **Expansion stroke** – Shortly before the piston reaches the Top Dead Centre (TDC) during compression stroke, the fuel oil is injected in the form of very fine spray into the engine cylinder through fuel injection valve. At this moment, temperature of the compressed air is sufficiently high to ignite the fuel. It suddenly increases the pressure and temperature of the products of combustion. The fuel oil is assumed to be burnt at constant pressure. Due to increased pressure, the piston is pushed with a great force. The burnt gases expand due to high speed of the piston. During the expansion, some of the heat energy produced is transformed into mechanical work.
4. **Exhaust stroke** – In this stroke, the exhaust port is opened and the piston moves downwards. The products of combustion from the engine cylinder are exhausted through

the exhaust port into the atmosphere. This completes the cycle, and the engine cylinder is ready to suck the air again.

Four-stroke Cycle Petrol Engine:

It requires four strokes of the piston to complete one cycle of operation in the engine cylinder. The four strokes of a petrol engine sucking fuel-air mixture (petrol mixed with proportionate quantity of air in the carburettor known as charge) are described below:

1. **Suction stroke** – In this stroke, the inlet valve opens and charge is sucked into the cylinder as the piston moves downward from *TDC*. It continues till the piston reaches its *BDC* as shown in Fig.
2. **Compression stroke** – In this stroke, both the inlet and exhaust valves are closed and the charge is compressed as the piston moves upwards from *BDC* to *TDC*. As a result of compression, the pressure and temperature of the charge increases considerably. This completes one revolution of the crank shaft. The compression stroke is shown in Fig

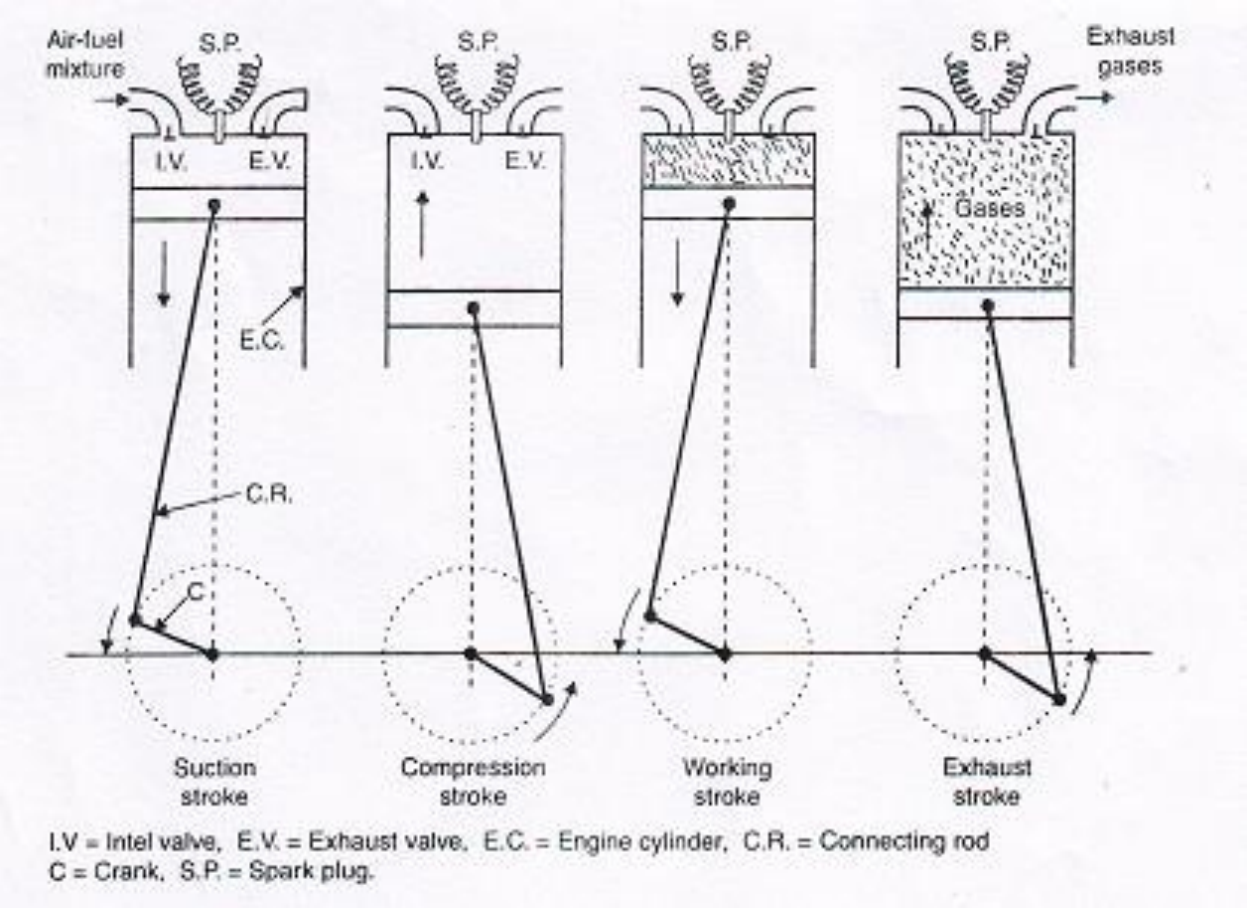

Fig. Four-stroke Cycle Petrol engine

3. **Expansion stroke** – Shortly before the piston reaches *TDC*, the charge is ignited with the help of a spark plug. It suddenly increases the pressure and temperature of the products of combustion but the volume, practically remains constant. Due to the rise in pressure, the piston is pushed down with a great force. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy produced is transformed into mechanical work. During this working stroke, as shown in Fig., both the valves are closed and piston moves from *TDC* to *BDC*.

4. **Exhaust stroke** – In this stroke, the exhaust valve is open as piston moves from *BDC* to *TDC*. This movement of the piston pushes out the product of combustion, from the engine cylinder and exhausted through the exhaust valve into the atmosphere, as shown in Fig. This completes the cycle, and the engine cylinder is ready to suck the charge again.

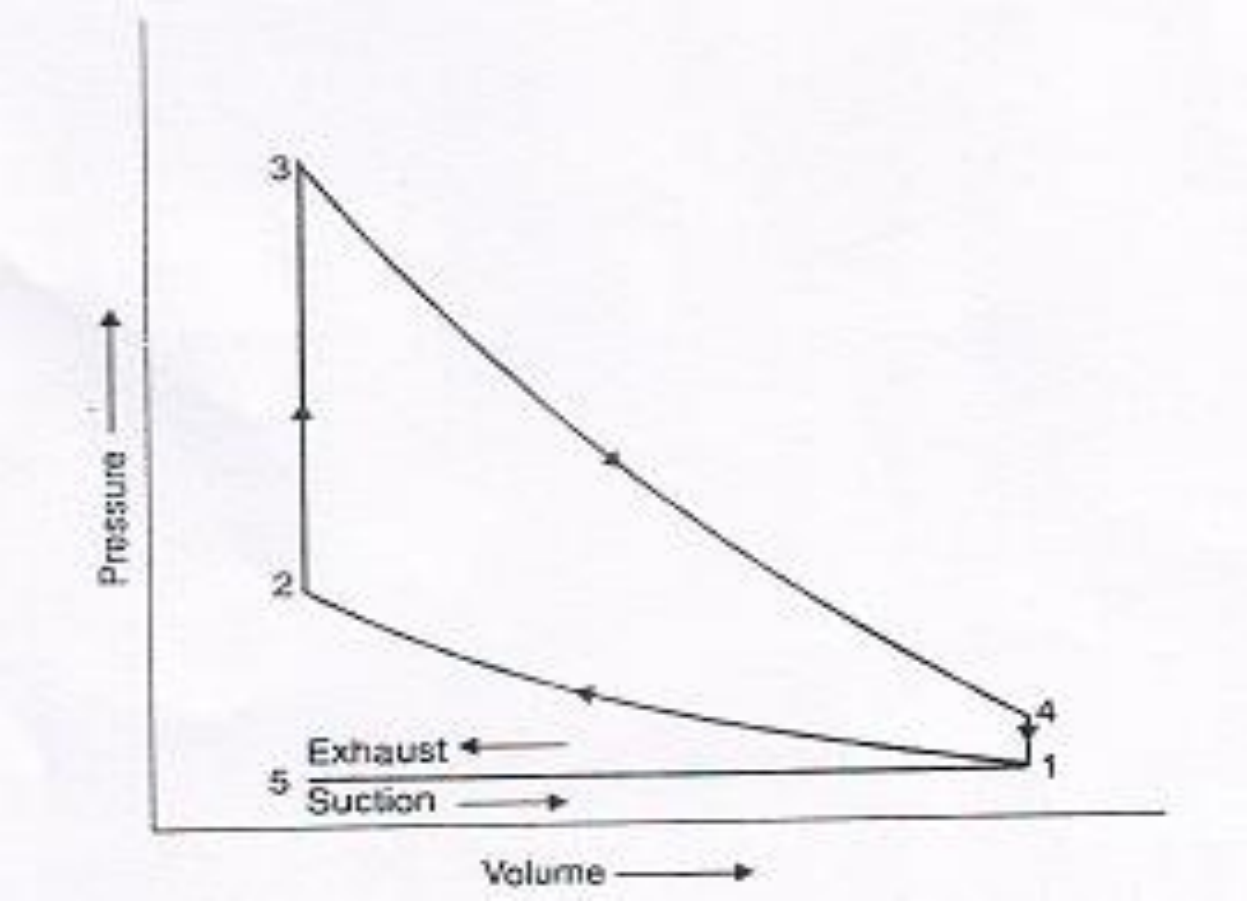

Fig. Theoretical p-V diagram of a four-stroke Otto cycle engine

Four-stroke Cycle Diesel Engine:

It is also known as *compression ignition engine* because the ignition takes place due to the heat produced in the engine cylinder at the end of compression stroke. The four strokes of a diesel engine sucking pure air are described below:

1. **Suction stroke** – In this stroke, the inlet valve opens and pure air is sucked into the cylinder as the piston moves downwards from the *TDC*. It continues till the piston reaches its *BDC* as shown in Fig.
2. **Compression stroke** – In this stroke, both the valves are closed and the air is compressed as the piston move upwards from *BDC* to *TDC*. As a result of compression, pressure and temperature of the air increases considerably. This completes one revolution of the crank shaft. The compression stroke is shown in Fig.

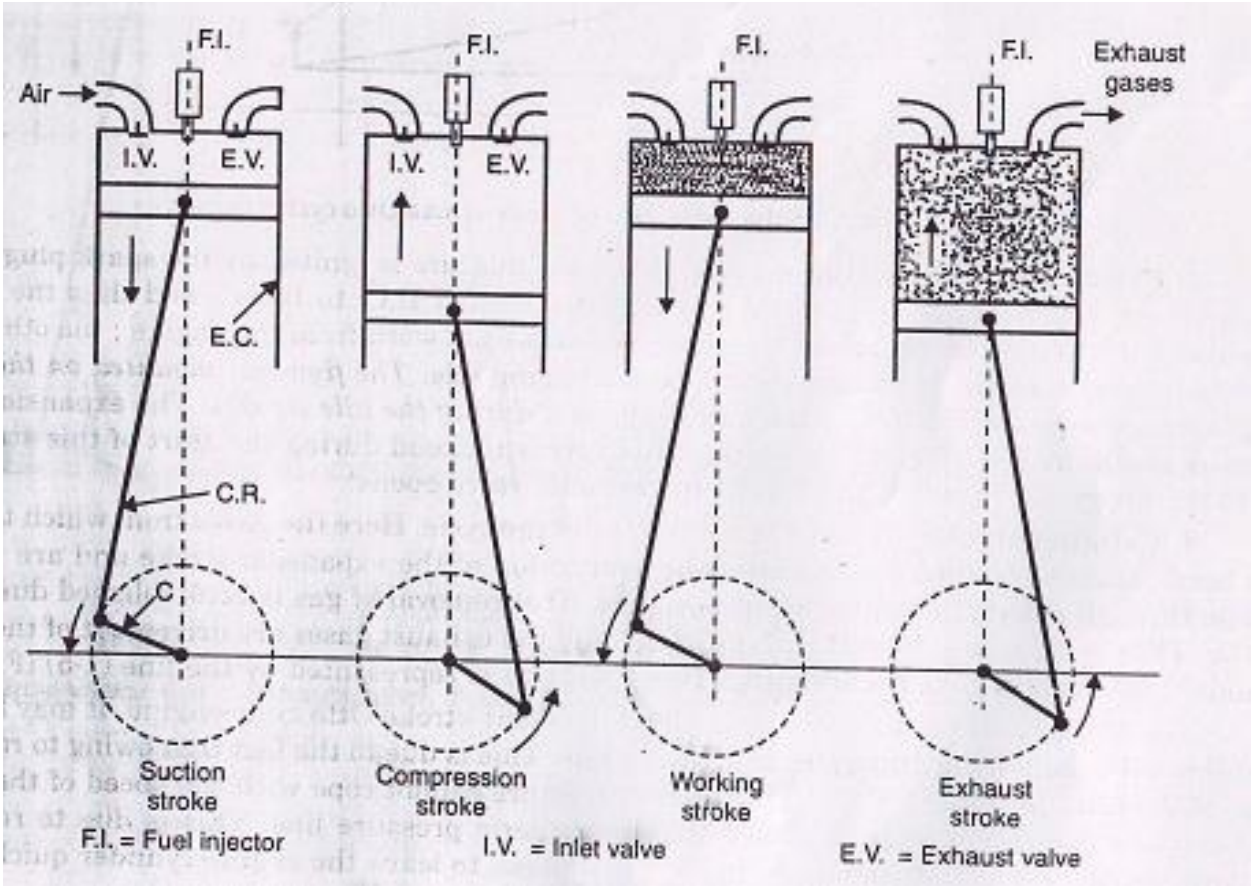

Fig. Four-stroke Diesel cycle engine

3. **Expansion stroke** – Shortly before the piston reaches the *TDC*, the fuel oil is injected in the form of very fine spray into the engine cylinder, through fuel injection valve. At this moment, temperature of the compressed air is sufficiently high to ignite the fuel. It suddenly increases the pressure and temperature of the products of combustion. The fuel oil is assumed to be burnt at constant pressure. Due to increased pressure, the piston is pushed down with a great force. The hot burnt gases expand due to high speed of the piston. During this expansion, some of the heat energy is transformed into mechanical work. During this working stroke, both the valves are closed and the piston moves from *TDC* to *BDC*.
4. **Exhaust stroke** – In this stroke, the exhaust valve is open as the piston moves from *BDC* to *TDC*. The movement of the piston pushes out the products of combustion from the engine cylinder through the exhaust valve into the atmosphere. This completes the cycle and the engine cylinder is ready to suck the fresh air again.

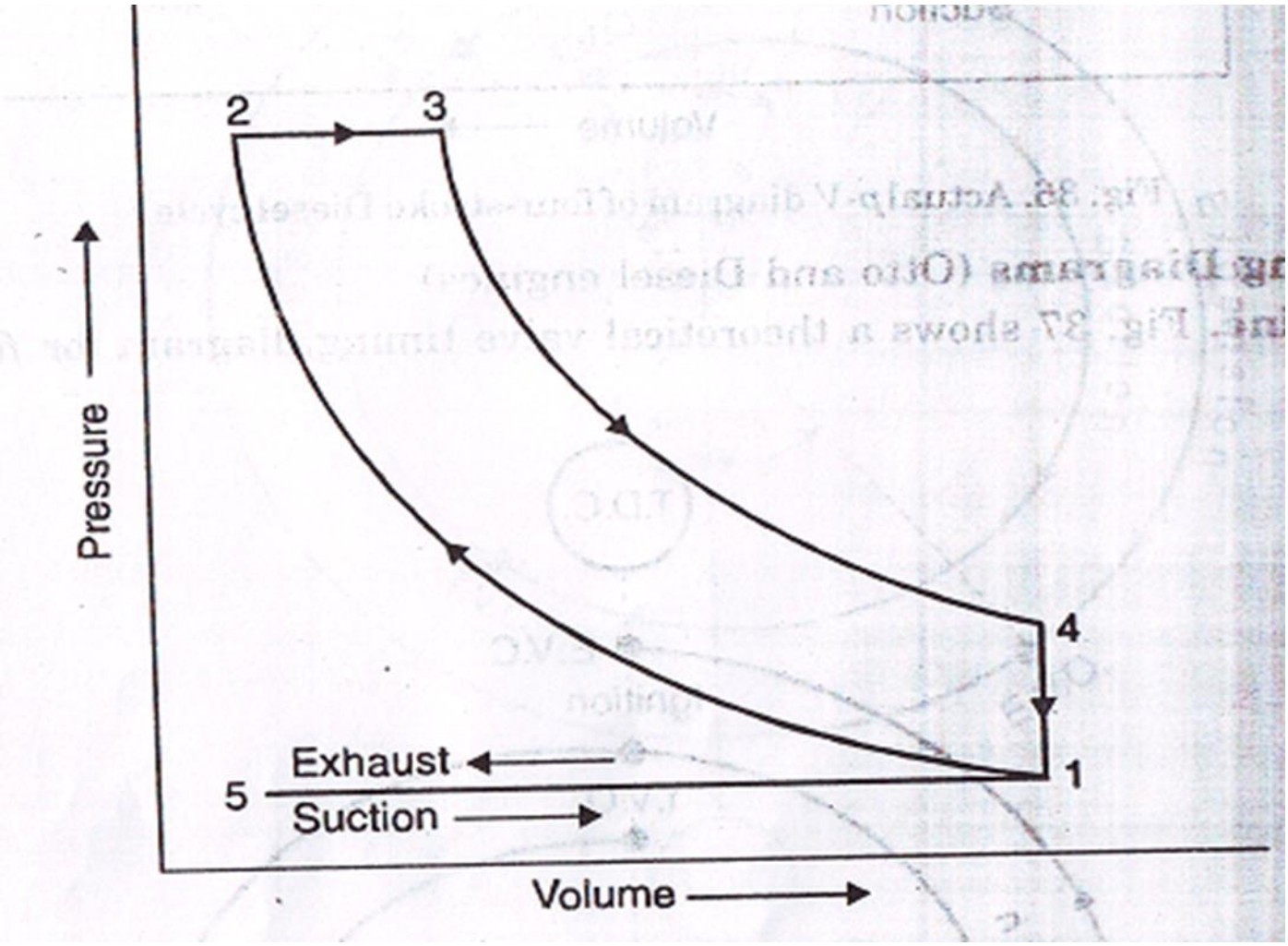

Fig. Theoretical p-V diagram of a four-stroke Diesel cycle

3. Merits and demerits of IC Engines

Merits and demerits of Two-stroke and Four-stroke Cycle Engine:

Following are the *Merits and Demerits* of two-stroke cycle engines over four-stroke cycle engines:

Merits

1. A two stroke cycle engine gives twice the number of power strokes than the four stroke cycle engine at the same engine speed.
2. For the same power developed, a two-stroke cycle engine is lighter, less bulky and occupies less floor area.
3. As the number of working strokes in a two-stroke cycle engine are twice than the four-stroke cycle engine, so the turning moment of a two-stroke cycle engine is more uniform. Thus it makes a two-stroke cycle engine to have a lighter flywheel and foundations. This also leads to a higher mechanical efficiency of a two-stroke cycle engine.
4. The initial cost of a two-stroke cycle engine is considerably less than a four-stroke cycle engine.

5. The mechanism of a two-stroke cycle engine is much simpler than a four-stroke cycle engine.
6. The two-stroke cycle engines are much easier to start.

Demerits

1. Thermal efficiency of a two-stroke cycle engine is less than that a four-stroke cycle engine.
2. Overall efficiency of a two-stroke cycle engine is also less than that of a four-stroke cycle engine because in a two-stroke cycle, inlet and exhaust ports remain open simultaneously for some time. A small quantity of charge is lost from the engine cylinder.
3. In case of a two-stroke cycle engine, the number of power strokes is twice as those of a four-stroke cycle engine. Thus the capacity of the cooling system must be higher. There is a greater wear and tear in a two-stroke cycle engine.
4. The consumption of lubricating oil is large in a two-stroke cycle engine because of high operating temperature.
5. The exhaust gas in a two-stroke cycle engine creates noise, because of short time available for their exhaust.

4. Scavenging process of IC Engine

In an internal combustion engine, **scavenging** is the process of replacing the exhaust gas in a cylinder with the fresh air/fuel mixture (or fresh air, in the case of direct-injection engines) for the next cycle. If scavenging is incomplete, the remaining exhaust gases can cause improper combustion for the next cycle, leading to reduced power output. Scavenging is equally important for both two-stroke and four-stroke engines. Most modern four-stroke engines use cross flow cylinder heads and valve timing overlap to scavenge the cylinders. Modern two-stroke engines use either Schnuerle scavenging (also known as "loop scavenging") or uni flow scavenging.

5. Difference between two-stroke and four strokes IC engines

In a *two-stroke engine*, the working cycle is completed in two strokes of the piston or one revolution of the crankshaft. This is achieved by carrying out the suction and compression processes in one stroke (or in inward stroke), expansion and exhaust process in thr second stroke (or in outward stroke).

In a *four-stroke engine*, the working cycle is completed in four strokes of the piston or two revolutions of the crankshaft. This is achieved by carrying out suction, compression, expansion and exhaust processes in each stroke.

Two-stroke IC engines	Four strokes IC engines
1.It has one power stroke for each revolution of the crankshaft	1.It has one power stroke for every two revolutions of the crankshaft
2. A lighter flywheel is required and the engine runs balanced because turning moment is more even due to one power stroke for each revolution of the crankshaft.	2. A heavy flywheel is required and the engine runs unbalanced because turning moment on the crankshaft is not even due to one power stroke for every two revolutions of the crankshaft.
3. The engine consists of inlet Port, Transfer port and exhaust ports.	3. The engine consists of an inlet and exhaust valve.
4.Engine design is simple due to port mechanism	4. Engine design is complicated due to the valve mechanism.
5. Engine is lighter in weight.	5. Engine is heavy in Weight.
6. More wear and tear of moving parts.	6. Less wear and tear of moving parts.
7. More fuel consumption and a small amount of fresh charge are mixed with exhaust gases.	7. Less fuel consumption and complete burning of fuel.
8.Less thermal efficiency	8. More thermal efficiency.
9. In two stroke engine the mechanical efficiency is more because of less friction in the parts.	9.There is more friction in the parts therefore the mechanical efficiency is less
10. Less Power output due to mixing of fresh charge with the hot burnt gases.	10. More Power output due to full fresh charge intake and full burnt gas exhaust.
11. Air-cooled engine which means when the engine gets heated it is cooled by air.	11. The water or air is used for cooling an engine.
12. More noise is created by the engine.	12. Less noise is created by the engine.
13. The two-stroke engine used in motorcycles, scooters, and many more.	13. Four-Stroke engine used in a bus, truck, car, and many more.

6. Difference between SI and CI Engines.

SI (Spark Ignition)Engines	CI (Compression Ignition) Engines.
1. A petrol engine draws a mixture of petrol and air during suction stroke.	1. A diesel engine draws only air during suction stroke.
2. The Carburettor is employed to mix air and petrol in the required proportion and to supply it to the engine during suction stroke.	2. The injector or atomiser is employed to inject the fuel at the end of combustion stroke.
3. Pressure at the end of compression Process is about 10 bars.	3. Pressure at the end of compression process is about 35 bars.
4. The charge (i.e. petrol and air mixture) is ignited with the help of spark plug.	4. The fuel is injected in the form of fine spray. The temperature of the compressed air is sufficiently high to ignite the fuel.
5. The combustion of the fuel takes place at constant volume. It works on Otto cycle.	5. The combustion of the fuel takes place at constant pressure. It works on Diesel cycle.
6. A petrol engine has compression ratio from 6 to 10.	6. A diesel engine has compression ratio from 14 to 20.
7. The starting is easy due to low compression ratio.	7. The starting is difficult due to high compression ratio.
8. As the compression ratio is low, the petrol engines are lighter and cheaper.	8. As the compression ratio is high, the diesel engines are heavier and costlier.
9. The running cost of a petrol engine is high because of the higher cost of petrol.	9. The running cost of diesel engine is low because of the lower cost of diesel.
10. The maintenance cost is less.	10. The maintenance cost is more.
11. The thermal efficiency is about 26%.	11. The thermal efficiency is about 40%.
12. Overheating trouble is more due to low thermal efficiency.	12. Overheating trouble is less due to high thermal efficiency.
13. These are high speed engines.	13. These are relatively low speed engines.
14. The petrol engines are generally	14. The diesel engines are generally

	employed in light duty vehicle such as scooters, motorcycles and cars. These are also used in aero planes.	employed in heavy duty vehicles like buses, trucks, and earth moving machines.