ENGINE & WORKING PRINCIPLES

A heat engine is a machine, which converts heat energy into mechanical energy. The combustion of fuel such as coal, petrol, diesel generates heat. This heat is supplied to a working substance at high temperature. By the expansion of this substance in suitable machines, heat energy is converted into useful work. Heat engines can be further divided into two types:

(i) External combustion and
(ii) Internal combustion.

In a steam engine the combustion of fuel takes place outside the engine and the steam thus formed is used to run the engine. Thus, it is known as *external combustion engine*. In the case of *internal combustion engine,* the combustion of fuel takes place inside the engine cylinder itself.

The IC engine can be further classified as: (i) stationary or mobile, (ii) horizontal or vertical and (iii) low, medium or high speed. The two distinct types of IC engines used for either mobile or stationary operations are: (i) diesel and (ii) carburettor.

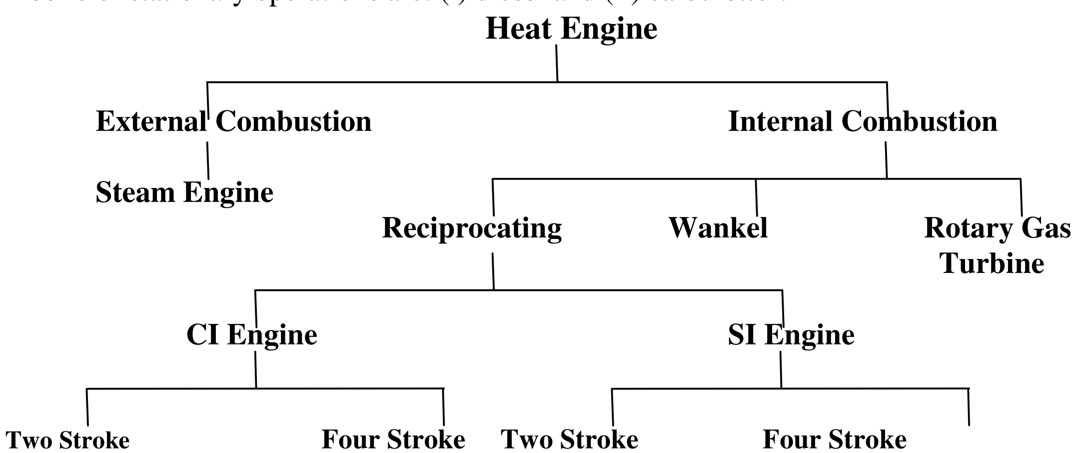

Chart 1. Types of Heat Engines

Spark Ignition (Carburettor Type) IC Engine

In this engine liquid fuel is atomised, vaporized and mixed with air in correct proportion before being taken to the engine cylinder through the intake manifolds. The ignition of the mixture is caused by an electric spark and is known as spark ignition.

Compression Ignition (Diesel Type) IC Engine

In this only the liquid fuel is injected in the cylinder under high pressure.

CONSTRUCTIONAL FEATURES OF IC ENGINE:

The cross section of IC engine is shown in Fig. 1. A brief description of these parts is given below.

Cylinder:

The cylinder of an IC engine constitutes the basic and supporting portion of the engine power unit. Its major function is to provide space in which the piston can operate to draw in the fuel mixture or air (depending upon spark ignition or compression ignition), compress it, allow it to expand and thus generate power. The cylinder is usually made of high-grade cast iron. In some cases, to give greater strength and wear resistance with less weight, chromium, nickel and molybdenum are added to the cast iron.

Piston:

The piston of an engine is the first part to begin movement and to transmit power to the crankshaft as a result of the pressure and energy generated by the combustion of the fuel. The piston is closed at one end and open on the other end to permit direct attachment of the connecting rod and its free action.

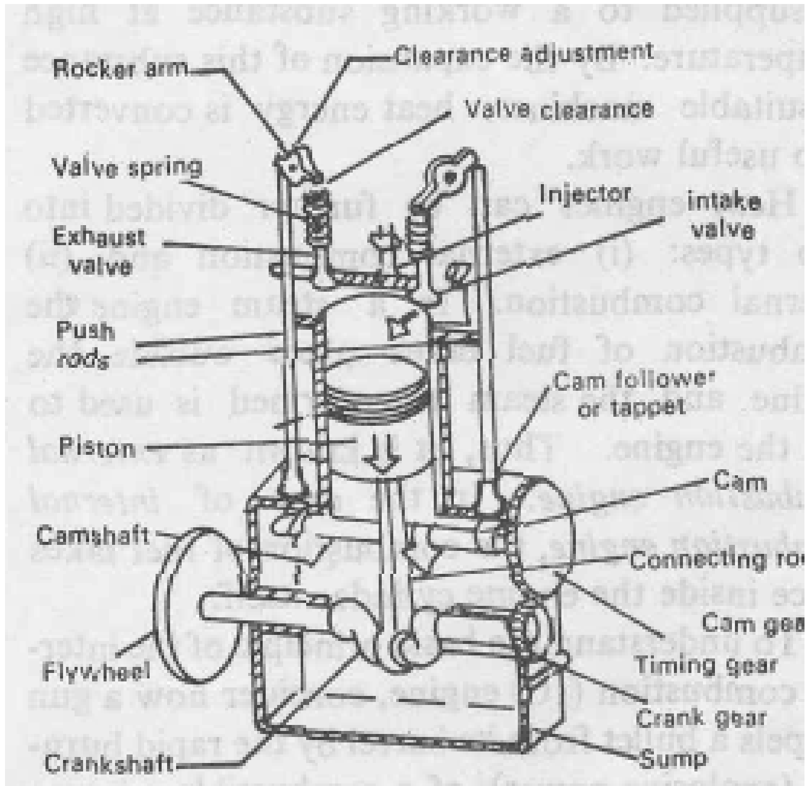

Fig. 1 Cross-section of a diesel engine

The materials used for pistons are grey cast iron, cast steel and aluminium alloy. However, the modern trend is to use only aluminium alloy pistons in the tractor engine.

Piston Rings:

These are made of cast iron on account of their ability to retain bearing qualities and elasticity indefinitely. The primary function of the piston rings is to retain compression and at the same time reduce the cylinder wall and piston wall contact area to a minimum, thus reducing friction losses and excessive wear. The other important functions of piston rings are the control of the lubricating oil, cylinder lubrication, and transmission of heat away from the piston and from the cylinder walls. Piston rings are classed as compression rings and oil rings depending on their function and location on the piston.

Compression rings are usually plain one-piece rings and are always placed in the grooves nearest the piston head. Oil rings are grooved or slotted and are located either in the lowest groove above the piston pin or in a groove near the piston skirt. Their function is to control the distribution of the lubricating oil to the cylinder and piston surface in order to prevent unnecessary or excessive oil consumption ion.

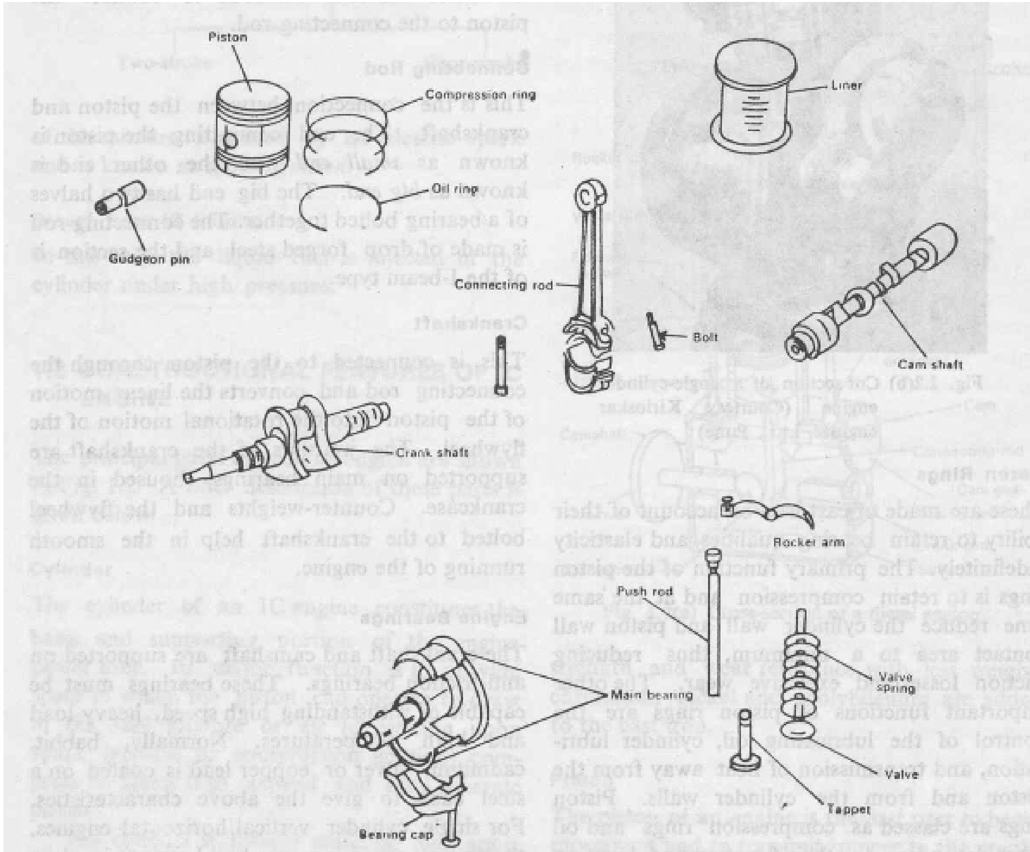

Figure 2. Components of the diesel engine

Piston Pin:
The connecting rod is connected to the piston through the piston pin. It is made of case hardened alloy steel with precision finish. There are three different methods to connect the piston to the connecting rod.

Connecting Rod:
This is the connection between the piston and crankshaft. The end connecting the piston is known as *small end* and the other end is known as big *end.* The big end has two halves of a bearing bolted together. The connecting rod is made of drop forged steel and the section is of the I-beam type.

Crankshaft:
This is connected to the piston through the connecting rod and converts the linear motion of the piston into the rotational motion of the flywheel. The journals of the crankshaft are supported on main bearings, housed in the crankcase. Counter-weights and the flywheel bolted to the crankshaft help in the smooth running of the engine.

Engine Bearings:
The crankshaft and camshaft are supported on anti-friction bearings. These bearings must be capable of with standing high speed, heavy load and high temperatures. Normally, cadmium, silver or copper lead is coated on a steel back to give the above characteristics. For single cylinder vertical/horizontal engines, the present trend is to use ball bearings in place of main bearings of the thin shell type.

Valves:
To allow the air to *enter into* the cylinder or the exhaust, gases to escape from the cylinder, valves are provided, known as *inlet* and *exhaust* valves respectively. The valves are mounted *either on* the cylinder head or on the cylinder block.

Camshaft:
The valves are operated by the action of the camshaft, which has separate cams for the inlet, and exhaust valves. The cam lifts the valve against the pressure of the spring and as soon as it changes position the spring closes the valve. The cam gets drive through *either the* gear or sprocket and chain system from the crankshaft. It rotates at half the speed of the camshaft.

Flywheel
This is usually made of cast iron and its primary function is to maintain uniform engine speed by carrying the crankshaft through the intervals when it is not receiving power from a piston. The size of the *flywheel varies* with the number of cylinders and the type and size of the engine. It also helps in balancing rotating masses.

Materials used for engine parts:

S. No.	Name of the Parts	Materials of Construction
1.	Cylinder head	Cast iron, Cast Aluminium
2.	Cylinder liner	Cast steel, Cast iron
3.	Engine block	Cast iron, Cast aluminum, Welded steel
4.	Piston	Cast iron, Aluminium alloy
5.	Piston pin	Forged steel, Casehardened steel.
6.	Connecting rod	Forged steel. Aluminium alloy.
7.	Piston rings	Cast iron, Pressed steel alloy.
8.	Connecting rod bearings	Bronze, White metal.
9.	Main bearings	White metal, Steel backed Babbitt base.
10.	Crankshaft	Forged steel, Cast steel
11.	Camshaft	Forged steel, Cast iron, cast steel,
12.	Timing gears	Cast iron, Fiber, Steel forging.
13.	Push rods	Forged steel.
14.	Engine valves	Forged steel, Steel, alloy.
15.	Valve springs	Carbon spring steel.
16.	Manifolds	Cast iron, Cast aluminium.
17.	Crankcase	Cast iron, Welded steel
18.	Flywheel	Cast iron.
19.	Studs and bolts	Carbon steel.
20.	Gaskets	Cork, Copper, Asbestos.

PRINCIPLES OF OPERATION OF IC ENGINES:
FOUR-STROKE CYCLE DIESEL ENGINE

In four-stroke cycle engines there are four strokes completing two revolutions of the crankshaft. These are respectively, the suction, compression, power and exhaust strokes. In Fig. 3, the piston is shown descending on its suction stroke. Only pure air is drawn into the cylinder during this stroke through the inlet valve, whereas, the exhaust valve is closed. These valves can be operated by the cam, push rod and rocker arm. The next stroke is the compression stroke in which the piston moves up with both the valves remaining closed. The air, which has been drawn into the cylinder during the suction stroke, is progressively compressed as the piston ascends. The compression ratio usually varies from 14:1 to 22:1. The pressure at the end of the compression stroke ranges from 30 to 45 kg/cm^2. As the air is progressively compressed in the cylinder, its temperature increases, until when near the end of the compression stroke, it becomes sufficiently high (650-80O ^oC) to instantly ignite any fuel that is injected into the cylinder. When the piston is near the top of its compression stroke, a liquid hydrocarbon fuel, such as diesel oil, is sprayed into the combustion chamber **under high pressure (140-160 kg/cm^2)**, higher than that existing in the cylinder itself. This fuel then ignites, being burnt with the oxygen of the highly compressed air.

During the fuel injection period, the piston reaches the end of its compression stroke and commences to return on its third consecutive stroke, viz., **power stroke**. During this stroke the hot products of combustion consisting chiefly of carbon dioxide, together with the nitrogen left from the compressed air expand, thus forcing the piston downward. This is only the working stroke of the cylinder.

During the power stroke the pressure falls from its maximum combustion value **(47-55 kg/cm^2),** which is usually higher than the greater value of the compression pressure (45 kg/cm^2), to about **3.5-5 kg/cm^2** near the end of the stroke. The exhaust valve then opens, usually a little earlier than when the piston reaches its lowest point of travel. The exhaust gases are swept out on the following upward stroke of the piston. The exhaust valve remains open throughout the whole stroke and closes at the top of the stroke.

The reciprocating motion of the piston is converted into the rotary motion of the crankshaft by means of a connecting rod and crankshaft. The crankshaft rotates in the main bearings, which are set in the crankcase. The flywheel is fitted on the crankshaft in order to smoothen out the uneven torque that is generated in the reciprocating engine.

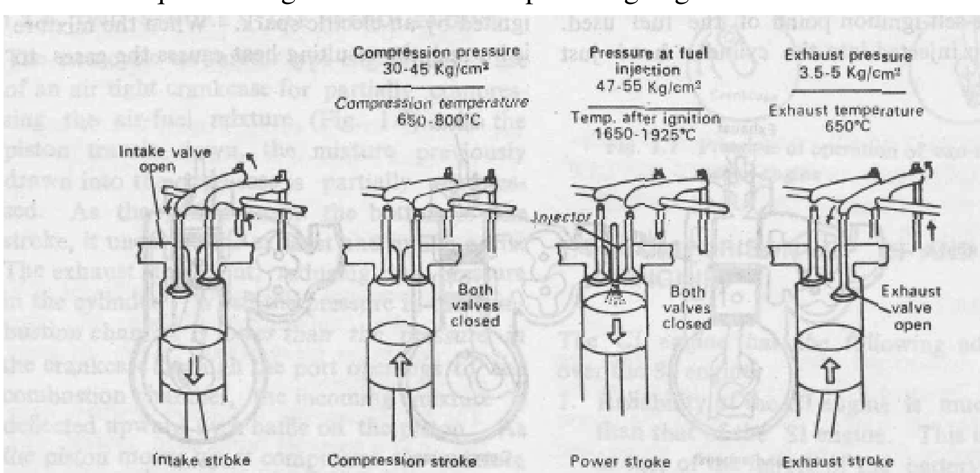

Fig. 3. Principle of four-stroke engine

TWO-STROKE CYCLE DIESEL ENGINE:

The cycle of the four-stroke of the piston (the suction, compression, power and exhaust strokes) is completed only in two strokes in the case of a two-stroke engine. The air is drawn into the crankcase due to the suction created by the upward stroke of the piston. On the down stroke of the piston it is compressed in the crankcase, The compression pressure is usually very low, being just sufficient to enable the air to flow into the cylinder through the transfer port when the piston reaches near the bottom of its down stroke.

The air thus flows into the cylinder, where the piston compresses it as it ascends, till the piston is nearly at the top of its stroke. The compression pressure is increased sufficiently high to raise the temperature of the air above the self-ignition point of the fuel used. The fuel is injected into the cylinder head just before the completion of the compression stroke and only for a short period. The burnt gases expand during the next downward stroke of the piston. These gases escape into the exhaust pipe to the atmosphere through the piston uncovering the exhaust port.

Modern Two-Stroke Cycle Diesel Engine

The crankcase method of air compression is unsatisfactory, as the exhaust gases do not escape the cylinder during port opening. Also there is a loss of air through the exhaust ports during the cylinder charging process. To overcome these disadvantages blowers are used to pre-compress the air. This pre-compressed air enters the cylinder through the port. An exhaust valve is also provided which opens mechanically just before the opening of the inlet ports (Fig. 4).

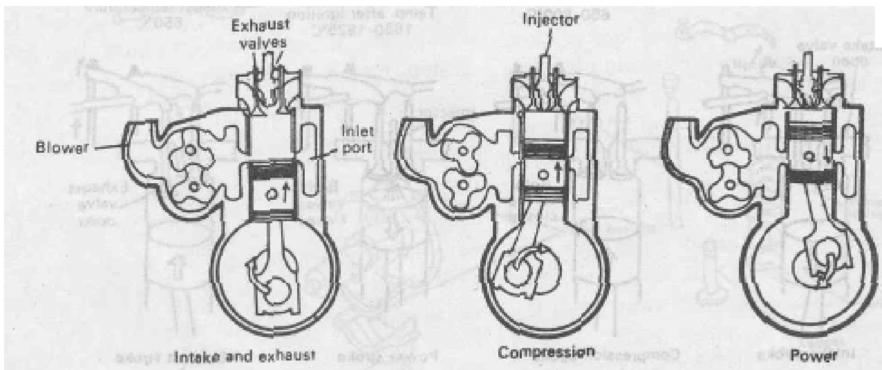

Fig. 4 Principle of two-stroke cycle diesel engine

FOUR-STROKE SPARK IGNITION ENGINE

In this gasoline is mixed with air, broken up into a mist and partially vaporized in a carburettor (Fig. 5). The mixture is then sucked into the cylinder. There it is compressed by the upward movement of the piston and is ignited by an electric spark. When the mixture is burned, the resulting heat causes the gases to expand. The expanding gases exert a pressure on the piston (power stroke). The exhaust gases escape in the next upward movement of the piston. The strokes are similar to those discussed under four-stroke diesel engines. The various temperatures and pressures are shown in Fig. 6. The compression ratio varies from 4:1 to 8:1 and the air-fuel mixture from 10:1 to 20:1.

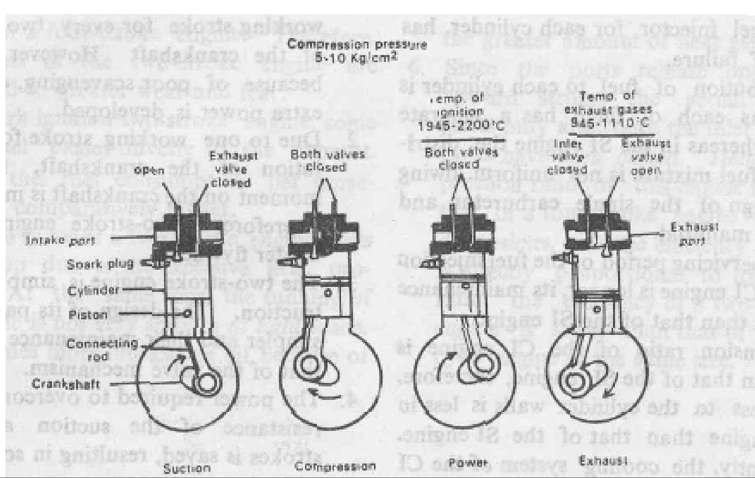

Fig. 5. Principle of operation of four-stroke petrol engine

TWO-STROKE CYCLE PETROL ENGINE

The two-cycle carburettor type engine makes use of an airtight crankcase for partially compressing the air-fuel mixture (Fig. 6). As the piston travels down, the mixture previously drawn into the crankcase is partially compressed. As the piston nears the bottom of the stroke, it uncovers the exhaust and intake ports. The exhaust flows out, reducing the pressure in the cylinder. When the pressure in the combustion chamber is lower than the pressure in the crankcase through the port openings to the combustion chamber, the incoming mixture is deflected upward by a baffle on the piston. As the piston moves up, it compresses the mixture above and draws into the crankcase below a new air-fuel mixture.

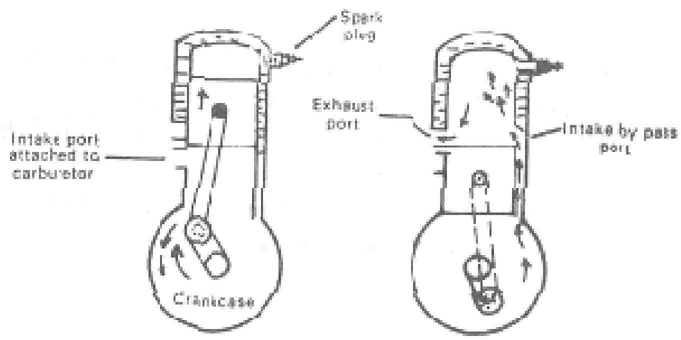

Fig. 6 Principle of operation of two stroke petrol enine

The, two-stroke cycle engine can be easily identified by the air-fuel mixture valve attached to the crankcase and the exhaust Port located at the bottom *of* the cylinder.

COMPARISON OF CI AND SI ENGINES

The CI engine has the following advantages over the SI engine.

1. Reliability of the CI engine is much higher than that of the SI engine. This is because in case of the failure of the battery, ignition or carburettor system, the SI engine cannot operate, whereas the CI engine, with a separate fuel injector for each cylinder, has less risk of failure.
2. The distribution of fuel to each cylinder is uniform as each of them has a separate injector, whereas in the SI engine the distribution of fuel mixture is not uniform, owing to the design of the single carburettor and the intake manifold.
3. Since the servicing period of the fuel injection system of CI engine is longer, its maintenance cost is less than that of the SI engine.
4. The expansion ratio of the CI engine is higher than that of the SI engine; therefore, the heat loss to the cylinder walls is less in the CI engine than that of the SI engine. Consequently, the cooling system of the CI engine can be of smaller dimensions.
5. The torque characteristics of the CI engine are more uniform which results in better top gear performance.
6. The CI engine can be switched over from part load to full load soon after starting from cold, whereas the SI engine requires warming up.
7. The fuel (diesel) for the CI engine is cheaper than the fuel (petrol) for SI engine.
8. The fire risk in the CI engine is minimised due to the absence of the ignition system.
9. On part load, the specific fuel consumption of the CI engine is low.

ADVANTAGES AND DISADVANTAGES OF TWO-STROKE CYCLE OVER FOUR-STROKE CYCLE ENGINES

Advantages:

1) The two-stroke cycle engine gives one working stroke for each revolution of the crankshaft. Hence theoretically the power developed for the same engine speed and cylinder volume is twice that of the four-stroke cycle engine, which gives only one working stroke for every two revolutions of the crankshaft. However, in practice, because of poor scavenging, only 50-60% extra power is developed.
2) Due to one working stroke for each revolution of the crankshaft, the turning moment on the crankshaft is more uniform. Therefore, a two-stroke engine requires a lighter flywheel.
3) The two-stroke engine is simpler in construction. The design of its ports is much simpler and their maintenance easier than that of the valve mechanism.
4) The power required to overcome frictional resistance of the suction and exhaust strokes is saved, resulting in some economy of fuel.
5) Owing to the absence of the cam, camshaft, rockers, etc. of the valve mechanism, the mechanical efficiency is higher.
6) The two-stroke engine gives fewer oscillations.
7) For the same power, a two-stroke engine is more compact and requires less space than a four-stroke cycle engine. This makes it more suitable for use in small machines and motorcycles.
8) A two-stroke engine is lighter in weight for the same power and speed especially when the crankcase compression is used.
9) Due to its simpler design, it requires fewer spare parts.
10) A two-stroke cycle engine can be easily reversed if it is of the valve less type.

Disadvantages:

1. The scavenging being not very efficient in a two-stroke engine, the dilution of the charges takes place which results in poor thermal efficiency.
2. The two-stroke spark ignition engines do not have a separate lubrication system and normally, lubricating oil is mixed with the fuel. This is not as efrective as the lubrication of a four-stroke engine. Therefore, the parts of the two-stroke engine are subjected to greater wear and tear.
3. In a spark ignition two-stroke engine, some of the fuel passes directly to the exhaust. Hence, the fuel consumption per horsepower is comparatively higher.
4. With heavy loads a two-stroke engine gets heated up due to the excessive heat produced. At the same time the running of the engine is riot very smooth at light loads.
5. It consumes more lubricating oil because of the greater amount of heat generated.
6. Since the ports remain open during the upward stroke, the actual compression starts only after both the inlet and exhaust ports have been closed. Hence, the compression ratio of this engine is lower than that of a four-stroke engine of the same dimensions. As the efficiency of an engine is directly proportional to its compression ratio, the efficiency of a two-stroke cycle engine is lower than that of a four-stroke cycle engine of the same size.