

Chapter No.1

1.0 Farm power

Various types of agricultural operations performed on a farm can be broadly classified as:

1. Tractive work – such as seed bed preparation, cultivation, harvesting and transportation.
2. Stationary work- such as silage cutting, feed grinding, threshing, winnowing and lifting of irrigation water.

These operations are done by different sources of power, namely human, animal, mechanical power (oil engines and tractors), electrical power and renewable energy (solar energy, biogas, biomass and wind energy).

1.1 Human power

Human beings are the main sources of power for operating small tools and implements at the farm. They are also employed for doing stationary work like threshing, winnowing, chaff cutting and lifting irrigation water. Of the total rural population in India, only 30% is available for doing farm work. The indications are that the decline in number of labourers employed for agriculture. On an average, a man develops nearly 0.1 horse power (hp).

Advantages: Easily available and used for all types of work.

Disadvantages: Costliest power compared to all other farms of power, very low efficiency, requires full maintenance when not in use and affected by weather condition and seasons.

1.2 Animal power

The most important source of power on the farm all over the world and particularly in India is animal. It is estimated that, nearly 80% of the total draft power used in agriculture throughout the World is still provided by animals. India is having 22.68 crore cattle, which is the highest in the World. Mainly, bullocks and buffaloes happen to be the principle sources of animal power on Indian farms. However, camels, horses, donkeys and elephants are also used for the farm work. The average force a bullock can exert is nearly equal to one tenth of its body weight. Power developed by an average pair of bullocks is about 1 hp for usual farm work.

Advantages:

1. Easily available.
2. Used for all types of work.
3. Low initial investment.
4. Supplies manure to the field and fuels to farmers.
5. Live on farm produce.

Disadvantages:

1. Not very efficient.
2. Seasons and weather affect the efficiency.
3. Cannot work at a stretch.
4. Require full maintenance when there is no farm work.
5. Creates unhealthy and dirty atmosphere near the residence.
6. Very slow in doing work.

1.3 Mechanical power

It is available through tractors, power tillers and oil engines. The oil engine is a highly efficient device for converting fuel into useful work. The efficiency of diesel engine varies between 32 and 38%, whereas that of the carburettor engine (Petrol engine) is in the range of 25 and 32%. In recent years, diesel engines, tractors and power tillers have gained considerable popularity in agricultural operations. It is estimated that, about one million tractors of 25 hp range are in use for various agricultural operations in India. Similarly, total number of oil engines of 5 hp for stationery work is 60 lakhs. Normally, stationery diesel engines are used for pumping water, flour mills, oil ghanis, cotton gins, chaff cutter, sugarcane crusher, threshers and winnowers etc.,

Advantages: Efficiency is high; not affected by weather; cannot run at a stretch; requires less space and cheaper form of power.

Disadvantages: Initial capital investment is high; fuel is costly and repairs and maintenance needs technical knowledge.

1.4 Electrical power

Now-a- day's electricity has become a very important source of power on farms in various states of the country. Electrical power is used mostly for running electrical motors for pumping water, dairy industry, cold storage, farm product processing, and cattle feed grinding. It is clean source of power and smooth running. The operating cost remains almost constant throughout its life. Its maintenance and operation need less attention and care. On an average, about 1/10th of the total electrical power generated in India, is consumed for the farm work, approximately it is 4600 megawatt.

Advantages: Very cheap form of power; high efficiency; can work at a stretch; maintenance and operating cost is very low and not affected by weather conditions.

Disadvantages: Initial capital investment is high; require good amount of technical knowledge and it causes great danger, if handled without care.

1.5 Renewable energy

It is the energy mainly obtained from biomass; biogas, solar and wind are mainly used in agriculture for power generation and various agricultural processing operations. It can be used for lighting, power generation, water heating, drying, greenhouse heating, water distillation, refrigeration and diesel engine operation. This type of energy is inexhaustible in nature. The availability of wind energy for farm work is quite limited. Where the wind velocity is more than 32 kmph, wind mills can be used for lifting water. Main limitation for this source is uncertainty. Average capacity of a wind mill would be about 0.5 hp. There are about 2540 windmills in India. It is the cheapest sources of farm power available in India.

Chapter No.2

Heat engine is a machine for converting heat, developed by burning fuel into useful work (or) it is equipment which generates thermal energy and transforms it into mechanical energy. Heat engine is of two types: (i) External combustion engine, and (ii) Internal combustion engine.

2.0 External combustion engine: It is the engine designed to derive its power from the fuel, burnt outside the engine cylinder. Here combustion process uses heat in the form of steam, which is generated in a boiler, placed entirely separate from the working cylinder.

2.1 Internal combustion engine (I. C. Engine): It is the engine designed to derive its power from the fuel, burnt within the engine cylinder. Here combustion of fuel and generation of heat takes place within the cylinder of the engine.

2.2 Principle of I.C. Engine A mixture of fuel with correct amount of air is exploded in an engine cylinder which is closed at one end. As a result of explosion, heat is released and this causes the pressure of the burning gases to increase. This pressure increase, forces a close fitting piston to move down the cylinder. This movement of piston is transmitted to a crankshaft by a connecting rod so that the crankshaft turns a flywheel. To obtain continuous rotation of the crankshaft this explosion has to be repeated. Before this, the burnt gases have to be expelled from the cylinder. At the same time the fresh charge of fuel and air must be admitted and the piston must be returns back to its starting position. This sequence of events is known as working cycle.

2.3 Working of I.C. Engine

I.C. engine converts the reciprocating motion of piston into rotary motion of the crankshaft by means of connecting rod. The piston which reciprocates in the cylinder is very close fit in the cylinder. Rings are inserted in the circumferential grooves of the piston to prevent leakage of gases from sides of the piston. Usually a cylinder is bored in a cylinder block. A gasket, made of copper sheet or asbestos is inserted between the cylinder and the cylinder head. The combustion space is provided at the top of the cylinder head where combustion takes place. There is a rod called connecting rod for connecting the piston and the crankshaft. A pin called gudgeon pin or wristpin is provided for connecting the piston and the connecting rod of the engine. The end of the connecting rod which fits over the gudgeon pin is called small end of the connecting rod. The other end which fits over the crank pin is called big end of the connecting rod. The crankshaft rotates in

main bearings which are fitted in the crankcase. A flywheel is provided at one end of the crankshaft for smoothening the uneven torque, produced by the engine. There is an oil sump at the bottom of the engine which contains lubricating oil for lubricating different parts of the engine (Fig.1).

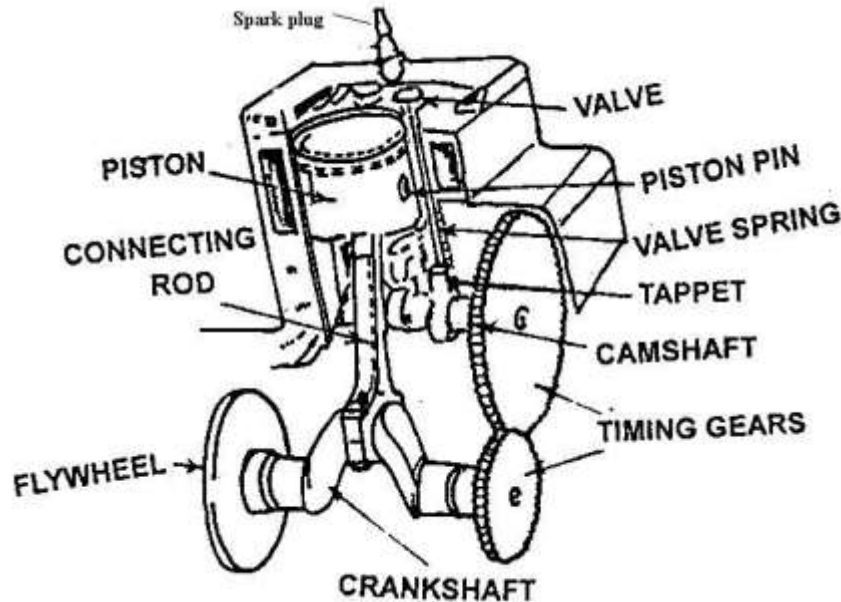


Fig. 1. Working components of I.C.Engine

2.4 Engine components Internal combustion engine consists of the following parts (Fig.2):

- **Cylinder:** It is a part of the engine which confines the expanding gases and forms the combustion space. It is the basic part of the engine. It provides space in which piston operates to suck the air or air-fuel mixture. The piston compresses the charge and the gas is allowed to expand in the cylinder, transmitting power for useful work. Cylinders are usually made of high grade cast iron.
- **Cylinder block:** It is the solid casting which includes the cylinder and water jackets (cooling fins in the air cooled engines).
- **Cylinder head:** It is detachable portion of an engine which covers the cylinder and includes the combustion chamber, spark plugs and valves.
- **Cylinder liner or sleeve:** It is a cylindrical lining either wet or dry which is inserted in the cylinder block in which the piston slides. Cylinder liners are fitted in the cylinder bore and they are easily replaceable. The overhauling and repairing of the engines, fitted with liners is easy and economical. Liners are classified as: dry liner, and wet liner. *Dry liner* makes metal to metal contact with the cylinder block casting. *Wet liners* come in contact with the cooling water, whereas dry liners do not come in contact with cooling water.

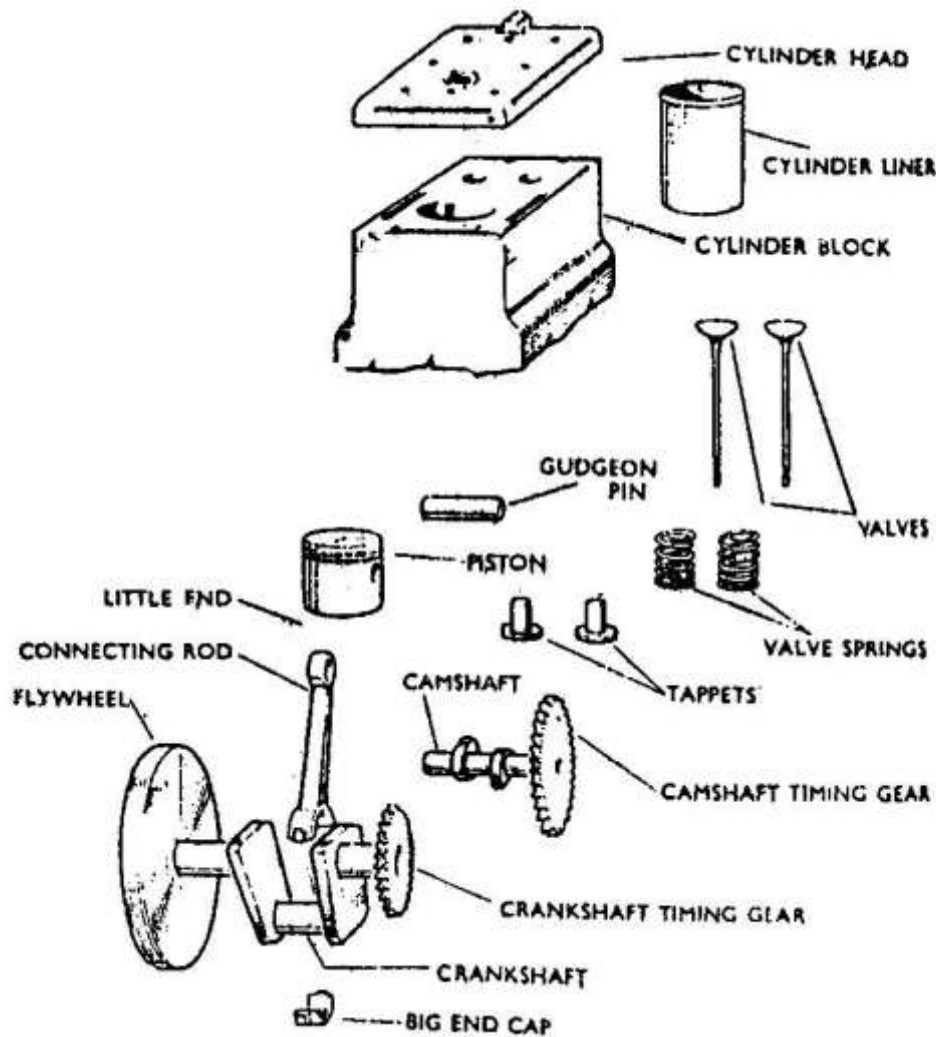


Fig. 2.Components of I.C. Engine.

- **Piston:** It is a cylindrical part closed at one end which maintains a close sliding fit in the engine cylinder. It is connected to the connecting rod by a piston pin. The force of the expanding gases against the closed end of the piston, forces the piston down in the cylinder. This causes the connecting rod to rotate the crankshaft. Cast iron is chosen due to its high compressive strength, low coefficient of expansion, resistance to high temperature, ease of casting and low cost. Aluminum and its alloys are preferred mainly due to its lightness.
- **Head (crown) of piston:** It is top of the piston.
- **Skirt:** It is that portion of the piston below the piston pin which is designed to absorb the side movements of the piston.
- **Piston ring:** It is a split expansion ring, placed in the groove of the piston. Piston rings are fitted in the grooves, made in the piston. They are usually made of cast iron or pressed steel alloy. The functions of the ring are as follows:
 - (a) It forms a gas tight combustion chamber for all positions of piston.

- (b) It reduces contact area between cylinder wall and piston wall for preventing friction losses and excessive wear.
- (c) It controls the cylinder lubrication.
- (d) It transmits the heat away from the piston to the cylinder walls.

Piston rings are of two types: (a) Compression ring and (b) Oil ring.

(a) **Compression ring.** Compression rings are usually plain, single piece and are always placed in the grooves, nearest to the piston head.

(b) **Oil ring.** Oil rings are grooved or slotted and are located either in lowest groove above the piston pin or in a groove above the piston skirt. They control the distribution of lubrication oil in the cylinder and the piston. They prevent excessive oil consumption also. Oil ring is provided with small holes through which excess oil returns back to the crankcase chamber.

- **Piston pin:** It is also called wrist pin or gudgeon pin. Piston pin is used to join the connecting rod to the piston. It provides a flexible or hinge like connection between the piston and the connecting rod. It is usually made of case hardened alloy steel.
- **Connecting rod:** It is a special type of rod, one end of which is attached to the piston and the other end to the crankshaft. It transmits the power of combustion to the crankshaft and makes it rotate continuously. It is usually made of drop forged steel.
- **Crankshaft:** It is the main shaft of an engine which converts the reciprocating motion of the piston into rotary motion of the flywheel. Usually the crankshaft is made of drop forged steel or cast steel. The space that supports the crankshaft in the cylinder block is called main journal, whereas the part to which connecting rod is attached is known as crank journal.
- **Fly wheel:** Fly wheel is made of cast iron. Its main functions are as follows:
 - (a) It stores energy during power stroke and returns back the same energy during the idle strokes, providing a uniform rotary motion by virtue of its inertia.
 - (b) It also carries ring gear that meshes with the pinion of the starting motor.
 - (c) The rear surface of the flywheel serves as one of the pressure surfaces for the clutch plate.
 - (d) Engine timing marks are usually stamped on the flywheel, which helps in adjusting the timing of the engine.
 - (e) Some times the flywheel serves the purpose of a pulley for transmitting power.

- **Crankcase:** The crankcase is that part of the engine which supports and encloses the crankshaft and camshaft. It provides a reservoir for the lubricating oil of the engine.
- **Cam shaft:** It is a shaft which raises and lowers the inlet and exhaust valves at proper time. Camshaft is driven by crankshaft by means of gears, chains or sprockets. The speed of the camshaft is exactly half the speed of the crankshaft in four stroke engine. Camshaft operates the ignition timing mechanism, lubricating oil pump and fuel pump. It is mounted in the crankcase, parallel to the crankshaft.
- **Timing gear:** Timing gear is a combination of gears, one gear of which is mounted at one end of the camshaft and other gear on the end of the crankshaft. Camshaft gear is bigger in size than that of the crankshaft gear and it has twice as many teeth as that of the losing crankshaft gear. For this reason, this gear is commonly called Half time gear. Timing gear controls the timing of ignition, timing of opening and closing of valves as well as fuel injection timing.
- **Inlet manifold:** It is that part of the engine through which air or air-fuel mixture enters into the engine cylinder. It is fitted by the side of the cylinder head.
- **Exhaust manifold:** It is that part of the engine through which exhaust gases go out of the engine cylinder. It is capable of with-standing high temperature of burnt gases. It is fitted by the side of the cylinder head.

2.5 Internal engine classification Internal combustion engines are classified in two types depending on the period required to complete a cycle of operation. They are four stroke and two stroke engines.

1. When the cycle is completed in two revolutions of the crankshaft, it is called *four stroke cycle engines*.
2. When the cycle is completed in one revolution of the crankshaft, it is called *two stroke cycle engines*.

I.C. engines are of two types:

- (i) Petrol engine (carburettor type, spark ignition engine), and
- (ii) Diesel engine (compression ignition engine).

Petrol engine: It is the engine, in which liquid fuel is atomized, vaporized and mixed with air in correct proportion before entering onto the engine cylinder during suction stroke. The fuel is ignited in the cylinder by an electric spark.

Diesel engine: In this engine, during suction stroke, only air is entered into the cylinder and compressed. The fuel is injected through fuel injectors and ignited by heat of compression.

2.5.1 Working of four stroke cycle engine In four stroke cycle engine, all the events taking place inside the engine cylinder are completed in four strokes of the piston i.e., suction, compression, power and exhaust stroke (Fig.3). This engine has got valves for controlling the inlet of charge and outlet of exhaust gases. In two stroke cycle engine, all the events take place in two strokes of the piston. The four strokes of the piston are as follows:

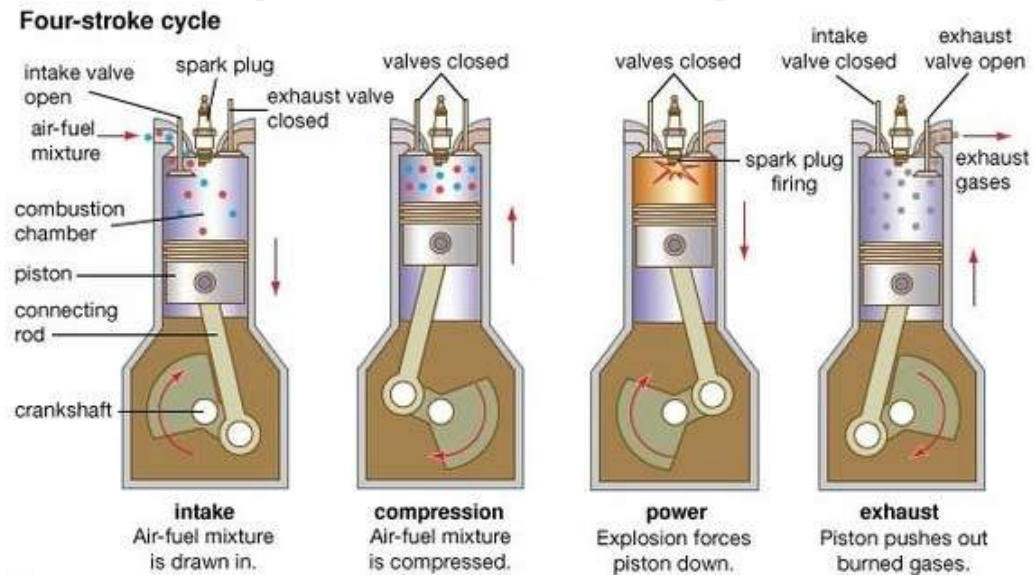


Fig. 3. Working of four stroke cycle engine

1. Suction stroke: During this stroke, only air or mixture of air and fuel are drawn inside the cylinder. The charge enters the engine through inlet valve which remains open during admission of charge. The exhaust valve remains closed during this stroke. The pressure in the engine cylinder is less than atmospheric pressure during this stroke.

2. Compression strike: The charge taken in the cylinder is compressed by the piston during this stroke. The entire charge of the cylinder is compressed to a small volume contained in the clearance volume of the cylinder. If only air is compressed in the cylinder (as in the case of diesel engine), the fuel is injected at the end of the compression stroke. The ignition takes place due to high pressure and temperature. If the mixture of air and fuel is compressed in the cylinder (as in the case of spark ignition engine i.e., petrol engine), the mixture is ignited by spark plug. After ignition, tremendous amount of heat is generated, causing very high pressure in the cylinder which pushes the piston backward for useful work. Both valves are closed during this stroke.

3. Power stroke: During power stroke, the high pressure developed due to combustion of fuel causes the piston to be forced downwards. The connecting rod with the help of crankshaft transmits the power to the transmission system for useful work. Both valves are closed during this stroke.

4. Exhaust stroke: Exhaust gases go out through exhaust valves during this stroke. All the burnt gases go out of the engine and the cylinder becomes ready to receive the fresh charge. The inlet valve is closed and exhaust valve remains open during this stroke. The exhaust valve is closed just after the end of the exhaust stroke, and the inlet valve is opened just before the burning of the suction stroke to repeat the cycle of operation. Thus it is found that out of four strokes, there is only one power stroke and three idle strokes. The power stroke supplies necessary momentum for useful work.

2.5.2 Two stroke cycle engine In such engines, the whole sequence of events i.e. suction, compression, power and exhaust are completed in two strokes of the piston and in one complete revolution of the crankshaft (Fig.4). There is no valve in this type of engine. Gas movement takes place through holes called ports in the cylinder. The crankcase of the engine is gas tight in which the crankshaft rotates.

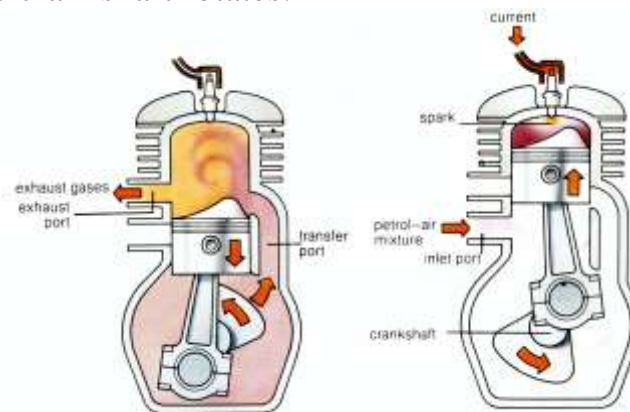


Fig. 4. Working of two stroke cycle engine

First stroke (suction + compression): When the piston moves up the cylinder, it covers two of the ports, the exhaust port and the transfer port, which are normally almost opposite to each other. This traps a charge of fresh mixture in the cylinder and further upward movement of the piston compresses this charge. Further movement of the piston also uncovers a third port in the cylinder suction port. More fresh mixture is drawn through this port into the crankcase. Just before the end of this stroke, the mixture in the cylinder is ignited as in the four stroke cycle.

Second stroke (Power + exhaust): The rise in pressure in the cylinder caused by the burning gases forces the piston to move down the cylinder. When the piston goes down, it covers and closes the suction port, trapping the mixture drawn into the crankcase during the previous stroke then compressing it. Further downward movements of the piston uncover first the exhaust port and then transfer port. This allows the burnt gases to flow out through exhaust port. Also the fresh mixture under pressure in the crankcase is transferred into the cylinder through transfer port during this stroke. Special shaped piston crown deflect the incoming mixture up around the cylinder so that it can help in driving out the exhaust gases.

When the piston is at the top of its stroke, it is said to be at the top dead centre (TDC). When the piston is at the bottom of its stroke, it is said to be at its bottom dead centre (BDC). In two stroke cycle engine, both the sides of the piston are effective, which is not the case in case of four stroke cycle engine.

Scavenging: The process of removal of burnt or exhaust gases from the engine cylinder is known as scavenging. Entire burnt gases do not go out in normal stroke, hence some type of blower or compressor is used to remove the exhaust gases in two stroke cycle engine.

2.6 Comparison between diesel and petrol (carburettor) engines

S.No.	Diesel engine	Petrol engine
1.	Diesel fuels are used.	Vapourizing fuels such as petrol, powerine or kerosene are used.
2.	Air alone is taken in during suction stroke.	Mixture of air and fuel is taken in.
3.	Fuel is injected into super heated air of the combustion space where burning takes place.	Air-fuel is compressed in the combustion chamber where it is ignited by an electric spark.
4.	Air-fuel ratio is not constant as the quantity of air drawn into the cylinder is always the same. To vary the load and speed the quantity of fuel injected is changed.	Air and fuel are almost always in the ratio of 15:1, but to vary the engine power, quantity of mixture is varied.
5.	Compression ratio of the engine varies from 14:1 to 20:1.	Compression ratio of the engine varies from 5:1 to 8:1.
6.	Specific fuel consumption is about 0.2 kg per BHP per hour.	Specific fuel consumption is about 0.29 kg per BHP per hour.
7.	4.5 litres of fuel is sufficient for nearly 20 hp hour.	4.5 litres of fuel will last about 12 hp hour.
8.	Diesel engine develops more torque, when it is heavily loaded.	This characteristic is not present in carburettor engines.
9.	Thermal efficiency varies between 32 and 38%.	Thermal efficiency varies between 25 and 32%.
10.	It runs at a lower temperature on part load.	Combustion gas temperature is slightly higher under part load.
11.	Engine weight per horse power is high.	Engine weight per horse power is comparatively low.
12.	Initial cost is high.	Initial cost is low.
13.	Operating cost is low.	Operating cost is comparatively high.

2.7 Comparison between two stroke and four stroke engines

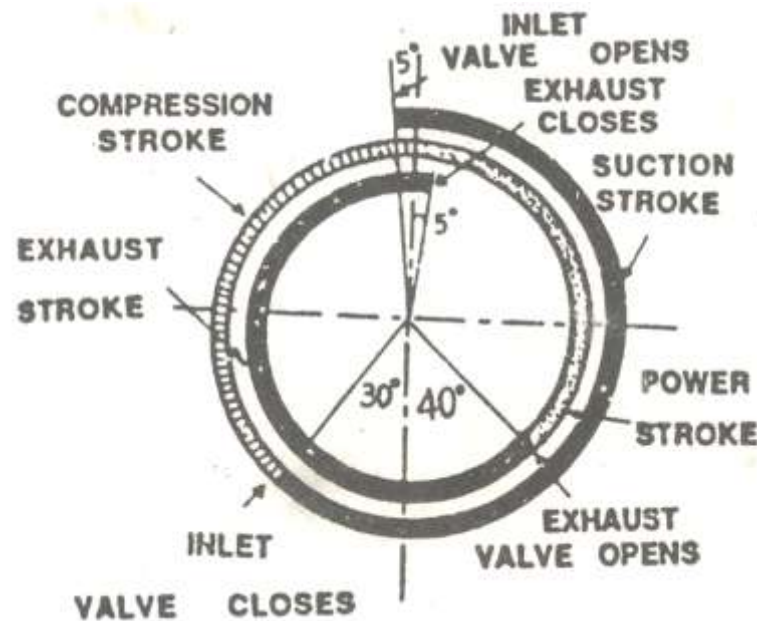
S.No.	Particulars	Four stroke engine	Two stroke engine
1.	No. of power stroke	one power stroke for every two revolutions of the crankshaft	one power stroke for each revolutions of the crankshaft
2.	Power for the same cylinder volume	Small	Large (about 1.5 times of 4 stroke)
3.	Valve mechanism	Present	Ports instead of valves
4.	Construction and cost	Complicated and expensive	Simple, cheap
5.	Fuel consumption	Little	High (about 15% more)
6.	Removal of exhaust gases	Easy	Difficult
7.	Durability	Good	Poor
8.	Stability of operation	High	Low
9.	Lubrication	Equipped with an independent lubricating oil circuit	Using fuel, mixed with lubricating oil
10.	Oil consumption	Little	Much
11.	Carbon deposit inside cylinder	Not so much	Much because of mixed fuel
12.	Noise	Suction & exhaust is noiseless, but other working is noisy	Suction & exhaust is noiseless, but other working is noise less
13.	Air tight of crankcase	Un necessary	Must be sealed
14.	Cooling	Normal	Chances of overheating
15.	Self weight and size	Heavy & large	Light & small

2.8 Valve timing diagram

A valve timing diagram is a diagram of crank rotation on which the time of opening and closing of inlet valve, exhaust valve are shown.

Valve timing mechanism is concerned with relative closing and opening of valves and their duration with respect to the cylinder position and the degree of crankshaft rotation. Top dead centre (TDC) is the instant when a piston is at the top of its stroke i.e. it is on the point of changing from upward to downward motion. Bottom dead centre (BDC) is the instant when a piston is at the bottom of its stroke i.e. it is on the point of changing from

downward to upward motion. Theoretically the intake valve should open on TDC and close at BDC, whereas the exhaust valve should open on BDC and close on TDC, but in actual practice these angles differ. Valve timing is a function of engine speed. The best valve timing for any given engine can be determine only by actual test, as it depends greatly on the design of the intake and exhaust passage. For most of the average tractor engine of four stroke cycle, the inlet valve opens about 5° before TDC and close at about 30° after BDC, the exhaust valve opens about 40° before BDC and closes at about 5° after TDC.



Firing order: The sequence in which the power stroke in each cylinder of an engine occurs is called firing order. The arrangement of the crankpin on the crankshaft and design of the camshaft both determine the firing order. For four cylinder engine the most commonly used firing order is 1-3-4-2 (or 1-2-4-3). For six cylinder engines firing order may be 1-4-2-6-3-5 or 1-5-3-6-2-4.

Firing interval (F. I): The interval between successive power strokes in different cylinders of the engine is called firing interval and is determined as below.

$$\text{F. I.} = \frac{720^\circ}{\text{No. of cylinder}} \quad (\text{for four stroke engine})$$

$$\text{F. I.} = \frac{360^\circ}{\text{No. of cylinder}} \quad (\text{for two stroke engine})$$

During the first 180° rotation of crankshaft, the cylinder No. 1 has got the power stroke, cylinder No. 2 has got the compression stroke, cylinder No. 3 has got the exhaust stroke and cylinder No.4 has got the suction stroke. Similarly during 360° rotation of the crankshaft, the first cylinder has got exhaust stroke, second cylinder power stroke, third Cylinder

intake stroke and fourth cylinder compression stroke. Similar are the cases for 540° rotation of crankshaft and 720° rotation of crankshaft. At one time, each cylinder has got different strokes and after two revolutions of the crankshaft, each cylinder has got only one power stroke for a four stroke four cylinder engine.

CRANK SHAFT ROTATION	CYLINDER 1	CYLINDER 2	CYLINDER 3	CYLINDER 4
180°	Power	Compression	Exhaust	Suction
360°	Exhaust	Power	Suction	Compression
540°	Suction	Exhaust	Compression	Power
720°	Compression	Suction	Power	Exhaust

Chapter No.3

3.0 Engine Terminology

- **Bore:** Bore is the diameter of the engine cylinder (Fig.5).
- **Stroke:** It is the linear distance travelled by the piston from Top dead centre (TDC) to Bottom dead centre (BDC).
- **Stroke-bore ratio:** The ratio of length of stroke (L) and diameter of bore (D) of the Cylinder is called Stroke-bore ratio (L/D). In general, this ratio varies between 1 to 1.45 and for tractor engines, this ratio is about 1.25.

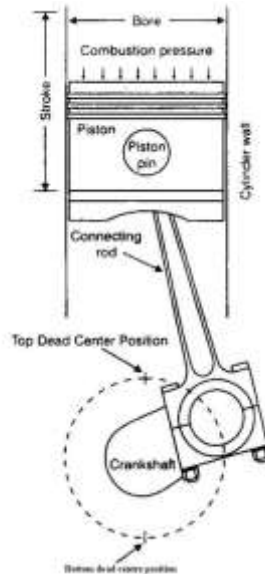


Fig.5. Diagram showing TDC and BDC positions

- **Swept volume (Piston displacement):** It is the volume ($A \times L$) displaced by one stroke of the piston where A is the cross sectional area of piston and L is the length of stroke. **Compression ratio:** It is the ratio of the volume of the charge at the beginning of the compression stroke to that at the end of compression stroke, i.e., ratio of total cylinder volume to clearance volume. Compression ratio of diesel engine varies from 14:1 to 20:1, carburetor engine varies from 4:1 to 8:1.
- **Power :** It is the rate of doing work. Unit of power in SI units - Watt (Joule/sec).
- **Horse power:** It is the rate of doing work. One HP is equivalent to 75 kg-m /sec.
- **Indicated Horse Power (IHP):** it is the total horse power developed by all the cylinders and received by pistons, without friction and losses within the engine.

$$\text{IHP} = \frac{PLAN}{4500} \times \frac{n}{2} \quad (\text{for four stroke engine})$$

$$\text{IHP} = \frac{PLAN}{4500} \times n \quad (\text{for two stroke engine})$$

Where P - Mean effective pressure in Kg/cm²
 L- Length of the piston stroke in meters
 A -Cross sectional area of piston in cm²
 N- rpm of the engine
 n - Number of cylinders in the engine

Brake horse power (B.H.P): It is the horsepower delivered by the engine and is available at the end of the crankshaft and it is measured by suitable dynamometer.

Frictional horse power (F.H.P): It is the power required to run the engine at a given speed with out producing any useful work. It represents the friction and pumping losses of the engine.

$$F.H.P = I.H.P - B.H.P$$

$$I.H.P = B.H.P + F.H.P$$

Drawbar horse power (DBHP): It is the power of a tractor measured at the end of the drawbar. It is the power required to pull the loads.

Brake mean effective pressure (BMEP): It is the average pressure acting throughout the entire power strokes which are necessary to produce BHP of the engine.

$$BMEP = \frac{BHP \times 75 \times 60}{L \times A \times N \times \frac{n}{2}} \quad (\text{for four stroke engine})$$

$$BMEP = \frac{BHP \times 75 \times 60}{L \times A \times N \times n} \quad (\text{for two stroke engine})$$

Thermal efficiency: It is the ratio of the horse power output of the engine to the fuel horse power.

Mechanical efficiency: It is the ratio of the brake horse power to the indicated horse power.

$$\text{Mechanical efficiency} = \frac{BHP}{IHP} \times 100$$

Piston speed (Np) : It is the total length of travel of the piston in a cylinder in one minute. Piston speeds of the high speed tractor engine range between 300 to 500 m/m.

Displacement volume (Vd) : It is the total swept volume of all the pistons during power strokes occurring in a period of one minute.

$$Vd = ALX$$

$$Vd = ALN (n/2)$$

$$Vd = ALN (n)$$

Where, A – Piston area, L – piston stroke

X – Number of power strokes per minute for all cylinders.

N – Crankshaft speed (RPM), n – no of cylinder in engine

Example 1: Calculate the BHP of a 4 stroke, 4 cylinder I.C. Engine which has cylinder bore of 14 cm, stroke length of 16 cm, crankshaft speed of 1100 rpm, frictional horse power of 30, and mean effective pressure is 8 kg/cm².

Solution:

Data given: D = 14 cm ; L = 16 cm; N = 1100 rpm; FHP =30 and P=8 kg/cm²

$$\text{IHP} = \frac{PLAN}{4500} \times \frac{n}{2} \quad (\text{for four stroke engine})$$

$$\text{IHP} = \frac{8 \times 0.16 \times \frac{\pi}{4} \times (14)^2 \times 1100}{4500} \times \frac{4}{2} = 96.4$$

$$\text{I.H.P} = \text{B.H.P} + \text{F.H.P}$$

$$\text{BHP} = \text{IHP} - \text{FHP} = 96.4 - 30 = 66.4$$

Example 2: The horse power developed at the end of crankshaft of a 4 stroke, 4 cylinder I C engines was found to be 30 HP at a speed of 1500 RPM. The mean effective pressure is 6 kg/cm². The stroke-bore ratio is 1.3. Find the length of stroke and diameter of bore if the mechanical efficiency is 80%.

Solution:

Data given: BHP =30; N = 1500; P=6 kg/cm²; η =80%, Mechanical

$$\text{efficiency} = \frac{\text{BHP}}{\text{IHP}} \times 100$$

$$\text{IHP} = \frac{\text{BHP}}{\eta} \times 100 = \frac{30 \times 100}{80} = 37.5$$

$$\text{Stroke-bore ratio} = \frac{L}{D} = 1.3$$

$$L = 1.3 D$$

$$\text{IHP} = \frac{6 \times 1.3 D \times \frac{\pi}{4} \times (D)^2 \times 1500}{4500} \times \frac{4}{2} = 4.08 D^3$$

$$37.5 = 4.08 D^3$$

$$D = 2.1 \text{ cm}$$

$$L = 1.3 \times 2.1 = 2.7 \text{ cm}$$

Example 3: A Four cylinder four stroke diesel engine has a cylinder diameter of 20 cm, stroke-bore ratio is 1.45, clearance volume 4508 cm³, engine speed 250 rpm, mean effective pressure 6.8 kg/cm² and mechanical efficiency is 75%. Calculate (i) IHP, (II) BHP (iii) Compression ratio and (iv) Swept volume.

Solution:

Data given: $D = 20 \text{ cm}$; $N = 250$; $P = 6.8 \text{ kg/cm}^2$; $\eta = 75\%$
 clearance volume = 4508 cm^3

$$\text{Stroke-bore ratio} = \frac{L}{D} = 1.45$$

Where $D = 20 \text{ cm}$

$$L = 1.45 \times 20 = 29 \text{ cm}$$

$$(i) \quad \text{IHP} = \frac{PLAN}{4500} \times \frac{n}{2} \quad (\text{for four stroke engine})$$

$$\text{IHP} = \frac{6.8 \times 0.29 \times \frac{\pi}{4} \times (20)^2 \times 250}{4500} \times \frac{4}{2} = 68.9$$

$$(ii) \text{ Mechanical efficiency} = \frac{\text{BHP}}{\text{IHP}} \times 100$$

$$\text{BHP} = \frac{\text{IHP}}{100} \times \eta = \frac{68.9 \times 75}{100} = 51.7$$

$$(iii) \text{ and } (iv) \text{ Compression ratio: } \frac{\text{Swept volume} + \text{Clearance volume}}{\text{Clearance volume}}$$

$$\begin{aligned} \text{Swept volume} &= A \times L \\ &= \frac{\pi}{4} \times (20)^2 \times 29 = 9114.3 \text{ cm}^3 \end{aligned}$$

$$\text{Compression ratio} = \frac{9114.3 + 4508}{4508} = 3.02$$

Example 4: Calculate (i) IHP (ii) BHP (iii) Stroke bore ratio (iv) Compression ratio (v) Swept volume of a four stroke four cylinder I.C. engine with the following data:

Cylinder size : $12.5 \times 15 \text{ cm}$

Fly wheel speed : 1200 rpm

Mean effective pressure : 7 kg/cm^2

Mechanical efficiency : 70%

Clearance volume : 150 CC

Solution:

Data given: $L = 15 \text{ cm}$; $D = 12.5 \text{ cm}$; $N = 1200$; $P = 7 \text{ kg/cm}^2$; $\eta = 70\%$

$$(i) \quad \text{IHP} = \frac{PLAN}{4500} \times \frac{n}{2} \quad (\text{for four stroke engine})$$

$$\text{IHP} = \frac{7.0 \times 0.15 \times \frac{\pi}{4} \times (12.5)^2 \times 1200}{4500} \times \frac{4}{2} = 68.7$$

$$(ii) \text{ Mechanical efficiency} = \frac{BHP}{IHP} \times 100$$

$$BHP = \frac{IHP}{100} \times \eta = \frac{68.7 \times 70}{100} = 48.1$$

$$(ii) \text{ Stroke- bore ratio} = \frac{L}{D} = \frac{15}{12.5} = 1.2$$

$$(iv) \text{ and (v) Compression ratio: } \frac{\text{Swept volume} + \text{Clearence volume}}{\text{Clearence volume}}$$

$$\begin{aligned} \text{Swept volume} &= A \times L \\ &= \frac{\pi}{4} \times (12.5)^2 \times 15 = 1841.5 \text{ cm}^3 \end{aligned}$$

$$\text{Compression ratio} = \frac{1841.5 + 150}{150} = 13.3$$

Example 5: If the speed of an 4 stroke engine is 130 rev/min, mean effective pressure is 7.5 kg/cm^2 , area of piston is 800 cm^2 , stroke length 45cm, torque due to brake load is 120 kg.m and fuel consumed 4.5 lit/hr compute (1) IHP (2) BHP (3) Mechanical efficiency (4) Fuel consumed per bhp per hour.

Solution:

$$(i) \text{ IHP} = \frac{PLAN}{4500} \times \frac{n}{2} = \frac{7.5 \times 0.45 \times 800 \times 130}{4500} \times \frac{1}{2} = 39$$

$$(ii) \text{ BHP} = \frac{2\pi NT}{60} \text{ watt (T in Newton)}$$

$$\text{torque due to brake load is } 120 \text{ kg.m} = 120 \times 9.8 = 1176 \text{ N}$$

$$\text{BHP} = \frac{2 \times 3.14 \times 130 \times 1176}{60} = 16001.44 \text{ w} = (16001.44/746) = 21.45 \text{ hp}$$

$$(iii) \text{ Mechanical efficiency} = \frac{BHP}{IHP} \times 100 = \frac{21.45}{39.00} \times 100 = 55.00$$

(iv) Fuel consumed per bhp per hour (or Specific Fuel Consumption)

$$= \frac{\text{Total fuel consumed in } \frac{\text{lit}}{\text{hr}} \text{ or } \frac{\text{kg}}{\text{hr}}}{BHP} = \frac{4.5}{21.45} = 0.209 \text{ lit per bhp per hr}$$

Example 6: How many times power of an engine increase or decrease if (1) the diameter of the piston is increased by 20% and stroke length is reduced by 20%, (2) the diameter of the piston is reduced by 20% and stroke length is Increased by 20%, all factor remaining same.

Chapter No.4

4.0 Fuel and fuel supply system

Fuel is a substance consumed by the engine to produce energy. The common fuels for IC engines are: (i) petrol, (ii) power kerosene, (iii) high speed diesel oil (H.S.D oil) and (iv) light diesel oil (L.D.O)

4.1 Quality of fuel

The quality of fuel mainly depends upon the following properties:

(i) volatility, (ii) calorific value and (iii) ignition quality of fuel. A good fuel contains a combination of qualities such as good volatility, high antiknock value, chemical purity, and freedom from gum.

4.1.1 Volatility

It is the vapourizing ability of a fuel at a given temperature. It indicates the operating characteristics of the fuel inside the engine. It is measured by means of distillation tests on the fuel.

In IC engine, all the liquid fuel must be converted into vapour fuel before burning. Petrol which shows lower initial and final boiling points, compared to other fuels, vapourizes at a lower temperature. HSD oil is most difficult to vapourize. Its vapourizing temperature is higher than that of the petrol, hence the petrol vapourizes quicker than diesel oil in the engine cylinder. This helps in easy starting of petrol engines. The oil that vapourizes quickly can be distributed well in different cylinders of the engine, hence distribution of fuel in different cylinders is better in petrol engine than that of diesel engine.

4.1.2 Calorific value

The heat liberated by combustion of a fuel is known as calorific value or heat value of the fuel. It is expressed in kcal/kg of the fuel. Calorific values (kcal/kg) of different fuels are as follows:

- 1) Petrol – 11,100 (highest)
- 2) Power kerosene – 10,850
- 3) High speed diesel oil (HSD oil)- 10,550
- 4) Light diesel oil (LDO oil) – 10,300

4.1.3 Ignition quality

It refers to ease of burning the oil in the combustion chamber. Octane number and cetane number are the measures of ignition quality of the fuel. Octane number is standard yardstick for measuring knock characteristics of fuels.

Cetane number is the relative measure of the interval between the beginning of injection and auto-ignition of the fuel. The higher the cetane number, the shorter the delay interval and the greater its combustibility.

Fuels with low cetane Numbers will result in difficult starting, noise and exhaust smoke.

4.2 Detonation

Detonation or engine knocking refers to violent noises heard in an engine during the process of combustion after the piston has passed over the TDC. It is an undesirable combustion and results in sudden rise in pressure, a loss of power and overheating of the engine. This may cause damage to pistons, valves, gasket and other parts. Detonation is caused by improper combustion chamber, high compression pressure, early ignition timing, improper fuel and inadequate cooling arrangement.

4.3 Pre-ignition

Burning of air-fuel mixture in the combustion chamber before the piston has reached the TDC is called pre-ignition. This may be due to excessive heat in the cylinder.

4.4 Fuel supply system in compression ignition engine or diesel engine

The main components of the fuel supply system in diesel engine are: (i) fuel tank, (ii) primary fuel filter, (iii) fuel transfer pump or fuel lift pump, (iv) secondary fuel filter, (v) fuel injection pump, (vi) high pressure pipes, (vii) fuel injection nozzles or fuel injectors and over flow pipe (Fig.6).

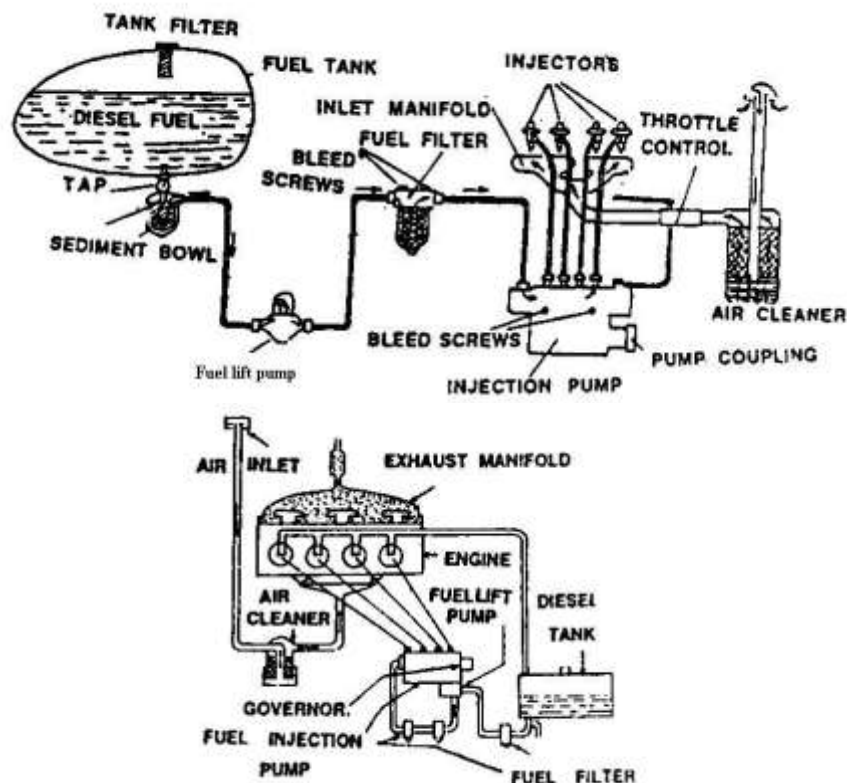


Fig. 6. Fuel supply system in diesel engine

During engine operation, the fuel is supplied by gravity from fuel tank to the primary filter where coarse impurities are removed. From the primary filter, the fuel is drawn by fuel transfer pump. This pump is also known as fuel lift pump, is activated by a cam on the engine camshaft. The fuel lift pump forces fuel under low pressure (2.5 kg/cm^2) through the secondary fuel filter to the injection pump, which is generally driven by the camshaft. The purpose of fuel injection pump is to deliver a metered quantity of fuel at a predetermined time under pressure (120 to 175 kg/cm^2 or more) through the high pressure tubes to the injection nozzles or injectors. The fuel that leaks out from the injection nozzles passes out through leakage pipe and returns to the fuel tank through the over flow pipe. In some tractors and industrial engines, the fuel supply is by gravity and hence no fuel lift pump is provided.

Two conditions are essential for efficient operation of the system:

- (a) The fuel should be clean, free from water, suspended dirt, sand or other foreign matter.
- (b) The fuel injection pump should create proper pressure, so that diesel fuel may be perfectly atomized by injectors at proper time and quantity.

4.4.1 Components of fuel supply system

Fuel tank

It is a storage tank of suitable size and shape, usually made of mild steel sheet. Atmospheric pressure is maintained in the tank with the help of a pin hole on the cap. Usually a wire gauge strainer is provided under the cap to prevent foreign particles. Usually a drain plug is provided at the bottom for flow of fuel.

Fuel lift pump

It transfers adequate amount of fuel from the fuel tank to the inlet gallery of the injection pump through fuel filter. The fuel pressure at the fuel lift pump in the range of 1.5 to 2.5 kg/cm^2 . It is mounted on the body of fuel injection pump. Fuel lift pump may be (i) plunger type, (ii) diaphragm type.

Fuel filter

It is a device to remove dirt and solid particles from the fuel to ensure trouble free fuel supply (Fig.7). Solid particles and dust in diesel fuel are very harmful for giving a fine degree of filtration. Fuel injection equipment in diesel engines is extremely sensitive to dirt and solid particles present in fuel. It consists of a hollow cylindrical element contained in a shell, an annular space being left between the shell and the element. The filtering element consists of metal gauze in conjunction with various media such as

packed fibers, woven cloth, felt, paper etc. These filters are replaced at certain intervals, specified by the manufacturer.

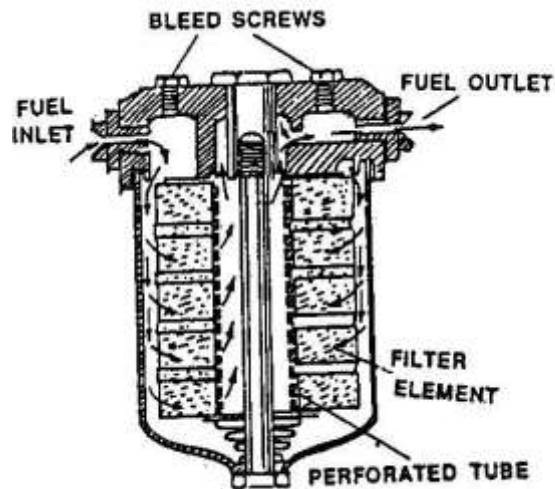


Fig. 7. Fuel filter

Usually there are two filters in diesel engine: (1) Primary filter and (2) secondary filter. The primary filter removes water and coarse particle of dirt from the fuel. The secondary filter removes fine sediments from the fuel. Usually the primary filter is placed between the tank and the fuel lift pump.

Fuel injection pump

It is a high pressure pump, which delivers metered quantity of fuel to each cylinder at appropriate time under pressure according to the firing order of the engine. It is used to create pressure varying from 120 to 175 kg/cm². Fuel injection pumps are mostly constant stroke type and in most of the tractors there is an individual pump for each cylinder. The pumps used in tractor are of two types: (i) multi element pump and (ii) Distributor (Rotor) type pump.

Multi element injection pump

The plunger (Fig.8) reciprocates in close fitting barrel with the help of tappet and spring. The upper part of the plunger has got helix, which makes it possible to vary the delivery of the fuel. An annular groove in the central part of the plunger facilitates the distribution of fuel over the barrel. As the plunger moves down, the fuel enters the barrel from inlet side. As plunger moves up, it closes the inlet part of the barrel and pressurizes the fuel in the barrel. This causes delivery valve to lift off its seat and allows the fuel to enter into the injection line, leading to the fuel injector. As soon as the edge of the helix uncovers the split part of the barrel, the fuel pressure quickly drops. The cam shaft of the fuel injection pump is driven directly from the engine timing gear.

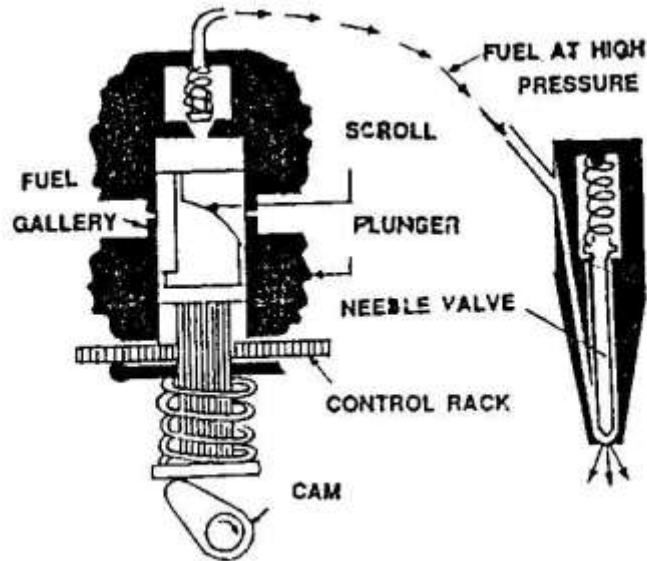


Fig. 8. Multi element fuel injection pump

Distributor (rotor) type pump: In this type of pump, one plunger and one barrel assembly deliver fuel not to one cylinder but to several cylinders. The plunger not only reciprocates, but rotates in a close fitting barrel. This helps in distributing fuel to a number of cylinders at a time.

Fuel injector It is the component which delivers finely atomized fuel under high pressure to the combustion chamber of the engine. Modern tractor engines use fuel injectors which have multiple holes.

Air cleaner

It is a device, which filters and removes dust, moisture and other foreign matter from the air before it reaches the engine cylinder. Air cleaner is usually of two types: (1) Dry type air cleaner and (2) Oil bath type air cleaner.

- **Dry type air cleaner** The filtering element in this case is a type of felt. The felt has got larger surface area, reduces the air speed while passing through and consequently particle or dirt in the air is deposited on or stopped by its surface.
- **Oil bath type air cleaner** In this type of air cleaner, the incoming air impinges upon the surface of the oil, kept in a container in the lower part of the casing. The foreign particles of the air are trapped in the oil and then the air passes through a wire element before reaching the inlet manifold of the engine. The wire element also arrests the remaining dirt particles of the air.

Governor

Governor is a mechanical device designed to control the speed of an engine within specified limit used on tractor or stationary engine for: (i) maintaining a nearly constant speed of engine under different load conditions (ii) protecting the engine and the attached equipments against high speeds, when the load is reduced or removed. Tractor engines are always fitted with governor. There is an important difference in principle between the controls of a tractor engine and that of a motor car. In case of motor car, the fuel supply is under direct control of the accelerator pedal, but in tractor engine, the fuel supply is controlled by the governor. The operator changes the engine speed by moving the governor control lever.

A governor is essential on a tractor engine for the reason that load on the tractor engine is subjected to rapid variation in the field and the operator cannot control the rapid change of the engine speed without any automatic device. For example, if the load on the tractor is reduced, the engine would tend to race suddenly. If the load is increased, the engine would tend to slow down abruptly. Under these circumstances, it becomes difficult for the operator to regulate always the throttle lever to meet the temporary changes in the engine load. A governor automatically regulates the engine speed on varying load condition and thus the operator is relieved of the duty of constant regulating the throttle lever to suit different load conditions.

Principle of governor

Engine Governor is used for automatically controlling the speed of an engine regulating the intake of fuel or injection fuel, so that engine speed is maintained at the desired level under all conditions of loading. Governor used on tractor engine is called *variable* speed governor and the one used on stationary engine is called constant speed governor. Governing system is classified as: (i) hit and miss system, (ii) throttle system

4.5 Cooling System

Fuel is burnt inside the cylinder of an internal combustion engine to produce power. The temperature produced on the power stroke of an engine can be as high as 1600°C and this is greater than melting point of engine parts.

The cylinder and cylinder head are usually made of cast iron and pistons in most cases are made of aluminum alloy. It is estimated that about 40 % of total heat produced is passed to the atmosphere via the exhaust, 30 % is removed by cooling system and only about 30% is used to produce useful power.

4.5.1 Bad effect of high temperature in the engine

- (i) Cylinder and piston may expand to such an extent that the piston would seize in the cylinder and stop the engine.
- (ii) Lubricating quality of the oil inside the cylinder would be destroyed due to high temperature and there may not be sucking of air in the cylinder.
- (iii) Pre-ignition of fuel mixture would take place and would cause engine knocking as well as loss of power.

For satisfactory performance of the engine, neither overheating nor over-cooling is desirable. Experiments have shown that best operating temperature of I.C engine lies between 140°F to 200 °F, depending upon types of engines and load conditions.

4.5.2 Purpose of cooling

- (i) To maintain optimum temperature of engine for efficient operation under all conditions.
- (ii) To dissipate surplus heat for protection of engine components like cylinder, cylinder head, piston, piston rings and valves.
- (iii) To maintain the lubricating property of the oil inside the engine cylinder for normal functioning of the engine.

There are two different methods of cooling: (i) air cooling and (ii) water cooling.

4.5.3 Air cooling

Air cooled engines are those engines, in which heat is conducted from the working components of the engine to the atmosphere directly. In such engines, cylinders are generally not grouped in a block.

Principle of air cooling

The cylinder of an air cooled engine has fins to increase the area of contact of air for speedy cooling. The cylinder is normally enclosed in a sheet metal casing called *Cowling*. The flywheel has blades projecting from its face, so that it acts like a fan drawing air through a hole in the cowling and directing it around the finned cylinder. For maintenance of air cooling system, passage of air is kept clean by removing grasses etc. This is done by removing the cowling and cleaning out the dirt etc. by a stiff brush or compressed air. When separate fan is provided, the belt tension is to be checked and adjusted if necessary.

Advantages of air cooling It is simpler in design and construction. Water jackets, radiators, water pump, thermostat, pipes, hoses etc. are not needed. It is more compact. It is comparatively lighter in weight.

Disadvantages There is uneven cooling of the engine parts. Engine temperature is generally high during working period.

4.5.4 Water cooling

Engines, using water as cooling medium is called “water cooled engines”. The liquid is circulated round the cylinders to absorb heat from the cylinder walls. In general, water is used as cooling liquid. The heated water is conducted through a radiator which helps in cooling the water.

There are three common methods of water cooling: (i) Open jacket or hopper method, (ii) Thermo siphon method, and (iii) Forced circulation method.

Forced circulation method In this method, a water pump is used to force water from the radiator to the water jacket of the engine. After circulating the entire run of water jacket, hot water goes to the radiator, where it passes through tubes surrounded by air. A fan is driven with the help of a V-belt to suck air through tubes of the radiator unit, cooling radiator water. To maintain the correct engine temperature, a thermostat valve is placed at the outer end of cylinder head. Cooling liquid is by-passed through the water jacket of the engine until engine attains the desired temperature. Then thermostat valve opens and the by-pass is closed, allowing the water to go to the radiator. The system consists of water pump, radiator, fan, fan-belt, water jacket, thermostat valve, temperature gauge and hose pipe (Fig.9).

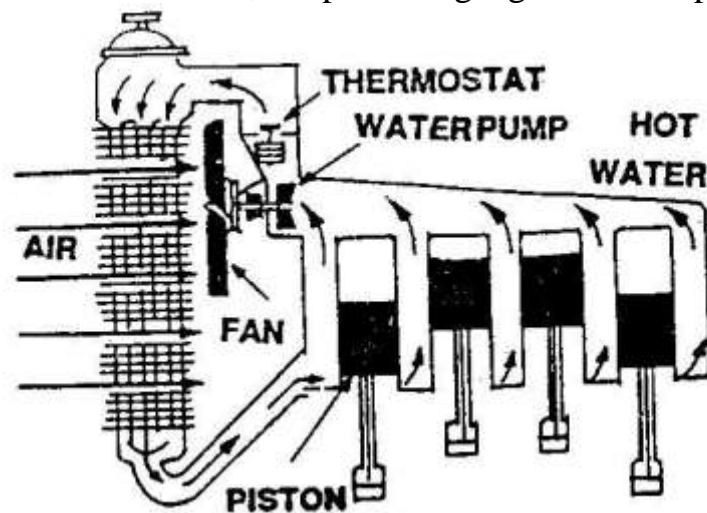


Fig. 9. Working of forced circulation cooling system

Water pump

It is a centrifugal type pump. It has a casing and an impeller, mounted on a shaft. The casing is usually made of cast iron. Pump shaft is made of some non-corrosive material. At the end of the shaft, a small pulley is fitted which is driven by a V-belt. Water pump is mounted at the front end of the cylinder

block between the block and the radiator. When the impeller rotates, the water between the impeller blades is thrown outward by centrifugal force and thus water goes to the cylinder under pressure. The pump outlet is connected by a hose pipe to the bottom of the radiator. The impeller shaft is supported on one or more bearings. There is a seal which prevents leakage of water.

Radiator

Radiator is a device for cooling the circulating water in the engine. It holds a large volume of water in close contact with a large volume of air so that heat is transferred from the water to the air easily.

Hot water flows into the radiator at the top and cold water flows out from the bottom. Tubes or passages carry the water from the top of the radiator to the bottom, passing it over a large metal surface. Air flows between the tubes or through the cells at right angles to the downward flowing water. This helps in transferring the heat from the water to the atmosphere. On the basis of fabrication, the radiator is of two types: tubular type and cellular type.

Tubular type radiator: It has round or flat water tubes, leading from the top to the bottom of the radiator. They may be soldered, brazed or welded in place or fastened by means of a stuffing box at each end. Fins or folded strips of light sheet metal, placed between the tubes, increase the radiating surface and improve the heat transfer.

Cellular type radiator: It has a core made of short air tubes which are laid horizontally and soldered together at the ends with space between them to allow water to flow. It is also called *Honey comb type* radiator.

Thermostat valve It is a control valve, used in the cooling system to control the flow of water when activated by a temperature signal.

It is a special type of valve, which closes the inlet passage of the water connected to the radiator. The thermostat is placed in the water passage between the cylinder head and the top of radiator. Its purpose is to close this passage when the engine is cold, so that water circulation is restricted, causing the engine to reach operating temperature more quickly. Thermostats are designed to start opening at 70°C to 75°C and then fully open at 82°C for petrol engine and 88-90°C for diesel engine. The thermostat valves are of two types:

- (a) Bellows and
- (b) Bimetallic.

(a) Bellows type: Bellows type thermostats have got bellows, which contain a liquid like alcohol or ether. The liquid expands with the increase of temperature and raises the valve off its seat. This permits the water to circulate between the engine and the radiator.

(b) Bimetallic type: It consists of a bimetallic strip. Unequal expansion of two metallic strips causes the valve to open and allows the water to flow to the radiator.

Water jackets:

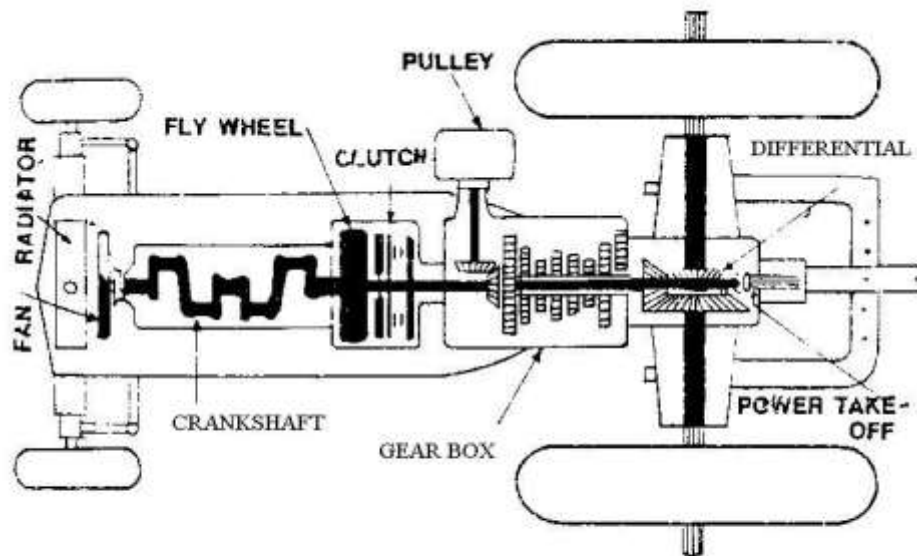
Water jackets are cored out around the engine cylinder so that water can circulate freely around the cylinder as well as around the valve opening.

Fan:

The fan is usually mounted on the water pump shaft. It is driven by the same belt that drives the pump and the dynamo. The purpose of the fan is to provide strong draft of air through the radiator to improve engine cooling.

Chapter No.5

5.1 Power transmission system Transmission is a speed reducing mechanism, equipped with several gears (Fig.11). It may be called a sequence of gears and shafts, through which the engine power is transmitted to the tractor wheels. The system consists of various devices that cause forward and backward movement of tractor to suit different field condition. The complete path of power from the engine to the wheels is called *power train*.



TRACTOR POWER TRANSMISSION SYSTEM

Fig. 11. Power transmission system of tractor

5.1.1 Function of power transmission system

- (i) to transmit power from the engine to the rear wheels of the tractor.
- (ii) to make reduced speed available, to rear wheels of the tractor.
- (iii) to alter the ratio of wheel speed and engine speed in order to suit the field conditions.
- (iv) to transmit power through right angle drive, because the crankshaft and rear axle are normally at right angles to each other.

The power transmission system consists of: (a) clutch, (b) transmission gears (c) differential, (d) final drive, (e) rear axle, (f) rear wheels. Combination of all these components is responsible for transmission of power.

5.1.2 Clutch Clutch is a device, used to connect and disconnect the tractor engine from the transmission gears and drive wheels. Clutch transmits power by means of friction between driving members and driven members.

Necessity of clutch in a tractor

Clutch in a tractor is essential for the following reasons:

- (i) Engine needs cranking by any suitable device. For easy cranking, the engine is disconnected from the rest of the transmission unit by a suitable clutch. After starting the engine, the clutch is engaged to transmit power from the engine to the gear box.
- (ii) In order to change the gears, the gear box must be kept free from the engine power, otherwise the gear teeth will be damaged and engagement of gear will not be perfect. This work is done by a clutch.
- (iii) When the belt pulley of the tractor works in the field it needs to be stopped without stopping the engine. This is done by a clutch.

Essential features of a good clutch

- (i) It should have good ability of taking load without dragging and chattering.
- (ii) It should have higher capacity to transmit maximum power without slipping.
- (iii) Friction surface should be highly resistant to heat effect.
- (iv) The control by hand lever or pedal lever should be easy.

Types of clutch

Clutches are mainly of three types:

- (1) Friction clutch (2) Dog clutch (3) Fluid coupling.

Friction clutch (Fig.12) is most popular in four wheel tractors. Fluid clutch is also used in some tractors these days. Dog clutch is mostly used in power tillers. Friction clutch may be subdivided into three classes: (a) Single plate clutch or single disc clutch (b) Multiple plate clutch or multiple disc clutch (c) Cone clutch.

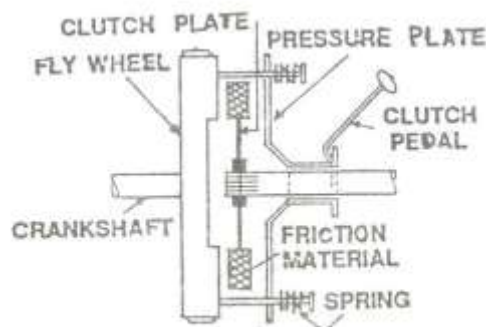


Fig. 12. Single plate clutch

5.1.3 Gears Speed varies according to the field requirements and so a number of gear ratios are provided to suit the varying conditions. Gears are usually made of alloy steels. As the tractor has to transmit heavy torque all the time, best quality lubricants free from sediments, grit, alkali and moisture, is used for lubrication purpose. SAE 90 oil is generally recommended for gear box.

5.1.4 Differential Differential unit (Fig.13) is a special arrangement of gears to permit one of the rear wheels of the tractor to rotate slower or faster than other. While turning the tractor on a curve path, the inner wheel has to travel lesser distance than the outer wheel. The inner wheel requires lesser power than the outer wheel, this condition is fulfilled by differential unit, which permits one of the rear wheels of the tractor to move faster than the other at the turning point.

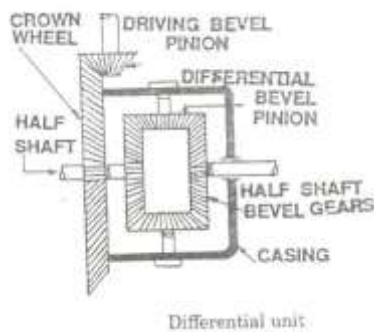


Fig.13. Tractor differential unit

5.1.5 Differential lock Differential lock is a device to join both half axles of the tractor so that even if one wheel is under less resistance, the tractor comes out from the mud etc as both wheels move with the same speed and apply equal traction.

5.1.6 Final drive Final drive is a rear reduction unit in the *power trains* between the *differential* and *drive wheels*.