2.1. Fuel Injection system for SI engines;

2.1.1. Carburetion

Spark-ignition engines normally use volatile liquid fuels. Preparation of fuel-air mixture is done outside the engine cylinder and formation of a homogeneous mixture is normally not completed in the inlet manifold. Fuel droplets, which remain in suspension, continue to evaporate and mix with air even during suction and compression processes. The process of mixture preparation is extremely important for spark-ignition engines. The purpose of carburetion is to provide a combustible mixture of fuel and air in the required quantity and quality for efficient operation of the engine under all conditions.

Definition of Carburetion;

The process of formation of a combustible fuel-air mixture by mixing the proper amount of fuel with air before admission to engine cylinder is called carburetion and the device which does this job is called a carburetor.

Definition of Carburetor;

The carburetor is a device used for atomizing and vaporizing the fuel and mixing it with the air in varying proportions to suit the changing operating conditions of vehicle engines.

Factors Affecting Carburetion

Of the various factors, the process of carburetion is influenced by
i. The engine speed
ii. The vaporization characteristics of the fuel
iii. The temperature of the incoming air and
iv. The design of the carburetor

Principle of Carburetion

Both air and gasoline are drawn through the carburetor and into the engine cylinders by the suction created by the downward movement of the piston. This suction is due to an increase in the volume of the cylinder and a consequent decrease in the gas pressure in this chamber.

It is the difference in pressure between the atmosphere and cylinder that causes the air to flow into the chamber. In the carburetor, air passing into the combustion chamber picks up discharged from a tube. This tube has a fine orifice called carburetor jet that is exposed to the air path.

The rate at which fuel is discharged into the air depends on the pressure difference or pressure head between the float chamber and the throat of the venturi and on the area of the outlet of the tube. In order that the fuel drawn from the nozzle may be thoroughly atomized, the suction effect must be strong and the nozzle outlet comparatively small. In order to produce a strong suction, the pipe in the carburetor carrying air to the engine is made to have a restriction. At this restriction called throat due to increase in velocity of flow, a suction effect is created. The restriction is made in the form of a venturi to minimize throttling losses.

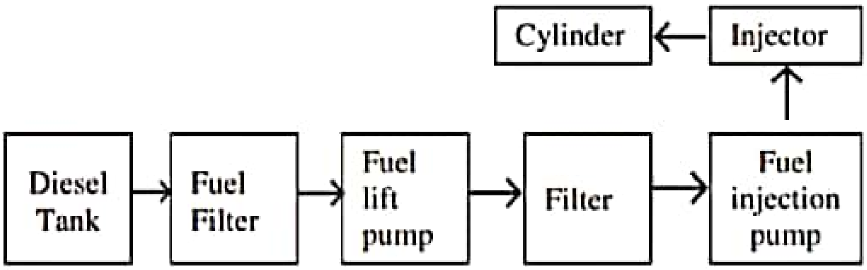
The end of the fuel jet is located at the venturi or throat of the carburetor. The geometry of venturi tube is as shown in Fig.16.6. It has a narrower path at the center so that the flow area through which the air must pass is considerably reduced. As the same amount of air must pass through every point in the tube, its velocity will be greatest at the narrowest point. The smaller the area, the greater will be the velocity of the air, and thereby the suction is proportionately increased

As mentioned earlier, the opening of the fuel discharge jet is usually loped where the suction is maximum. Normally, this is just below the narrowest section of the venturi tube. The spray of gasoline from the nozzle and the air entering through the venturi tube are mixed together in this region and a combustible mixture is formed which passes through the intake manifold into the cylinders. Most of the fuel gets atomized and simultaneously a small part will be vaporized. Increased air velocity at the throat of the venturi helps he rate of evaporation of fuel. The difficulty of obtaining a mixture of sufficiently high fuel vapour-air ratio for efficient starting of the engine and for uniform fuel-air ratio indifferent cylinders (in case of multi cylinder engine) cannot be fully met by the increased air velocity alone at the venturi throat.

FUEL SYSTEM OF DIESEL ENGINE

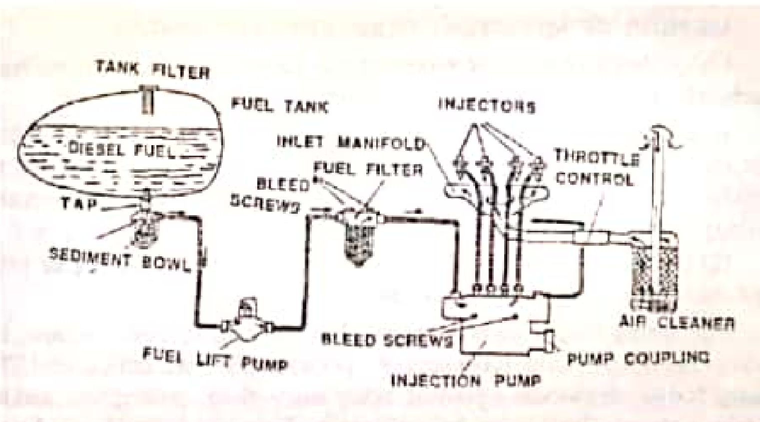
During engine operation, the fuel is supplied by gravity from fuel tank to the primary filter where coarse impurities are removed. From the primary filter, the fuel is drawn by fuel transfer pump and is delivered to fuel injection pump through second fuel filter. The fuel injection pump supplies fuel under high pressure to the injectors through high pressure pipes. The injectors atomise the fuel and inject it into the combustion chamber of the engine. The fuel injection pump is fed with fuel in abundance. The excess fuel is by-passed to the intake side of the fuel transfer pump through a relief valve.

The main components of the fuel system in diesel engine are: (1) fuel filter (2) fuel lift pump (3) fuel injection pump (4) atomisers and (5) high pressure pipe.



Flow diagram of fuel in diesel tractor

Two conditions are essential for efficient operation of fuel system: (i) The fuel oil should be clean, free from water, suspended dirt, sand or other foreign matter, (ii) The fuel injection pump should create proper pressure, so that diesel fuel may be perfectly atomised by injectors and be injected in proper time and in proper quantity in the engine cylinder. Fuel should be filtered before filling the tank also. If these precautions are followed, ninety per cent of diesel engine troubles are eliminated.



Layout of fuel supply in diesel engine

FUEL LIFT PUMP (FEED PUMP OR TRANSFER PUMP)

It is a pump, which transfers fuel from the fuel line to the fuel injection pump. It is mounted on the body of fuel injection pump. It delivers adequate amount of fuel to the injection pump. The pump consists of: (I) body (2) piston (3) inlet valve and (4) pressure valve. The valves are tightly pressed against their seats by springs. The piston is free to slide in the bore. The fuel contained in the space below the piston is forced to flow through secondary fuel filter to the injection pump. At the same time downward movement of the piston creates a depression in the space above the piston which, causes the fuel to be drawn in the transfer pump from the fuel tank through the inlet valve and the primary filter.

FUEL INJECTING PUMP

It is a pump, which delivers metered quantity of fuel to each cylinder at appropriate time under high pressure. Tractor engines may use two types of fuel injection pump:

(i) Multi-element pump and (ii) Distributor (Rotary) type pump.

Fuel Injector: It is the component, which delivers finely atomised fuel under high pressure to the combustion chamber of the engine. Modern tractor engines use fuel injectors, which have multiple holes. Main parts of injector are: nozzle body and needle valve. The nozzle body and needle valve are fabricated from alloy steel. The needle valve is pressed against a conical seat in the nozzle body by a spring. The injection pressure is adjusted by adjusting the screw.

FUEL INJECTION SYSTEM

Diesel fuel is injected in diesel engine through injectors with the help of fuel injection pump. The system using injectors, fuel injection pump, fuel filter, and fuel lines is called fuel injection system. The main functions of fuel injection system are:

(i) To measure the correct amount of fuel required by engine speed and load,
(ii) To maintain correct timing for beginning and end of injection,
(iii) To inject the fuel into the combustion space against high compression pressure.
(iv) To atomise the fuel for quick ignition.

Process of fuel injection in diesel engine is of two types: (i) Air injection (ii) Solid injection.

Air injection: In this process, the engine uses compressed air to force the fuel into the cylinder. It is a bulky system and hence it is not considered very suitable for vehicles and tractors. It is mostly used on heavy-duty stationary engines.

Solid injection: A high-pressure pump is used for forcing the fuel into the combustion chamber.

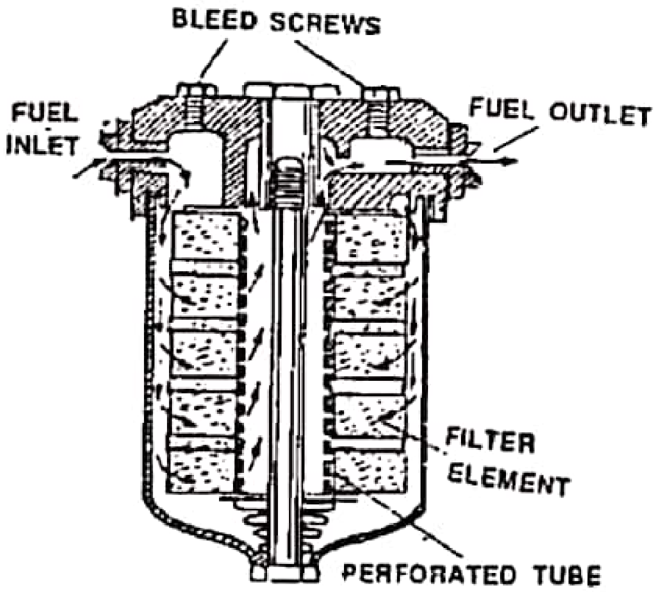
FUEL FILTER

It is a device to remove dirt from fuel oil. 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. A filter is used to remove the dirt and solid particles from the fuel to ensure trouble free fuel supply. 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 gauge in conjunction with various media such as packed fibres, woven cloth, felt, paper etc. These filters are replaced at certain intervals, specified by the manufacturer.

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.

4



Fuel filter for diesel engine

4.2 IGNITION SYSTEM TYPES

Basically Convectional Ignition systems are of 2 types :

(a) Battery or Coil Ignition System, and

(b) Magneto Ignition System.

Both these conventional, ignition systems work on mutual electromagnetic induction principle.

Battery ignition system was generally used in 4-wheelers, but now-a-days it is more commonly used in 2-wheelers also (i.e. Button start, 2-wheelers like Pulsar, Kinetic Honda; Honda-Activa, Scooty, Fiero, etc.). In this case 6 V or 12 V batteries will supply necessary current in the primary winding.

Magneto ignition system is mainly used in 2-wheelers, kick start engines. (Example, Bajaj Scooters, Boxer, Victor, Splendor, Passion, etc.).

In this case magneto will produce and supply current to the primary winding. So in magneto ignition system magneto replaces the battery.

Battery or Coil Ignition System

Figure 4.2 shows line diagram of battery ignition system for a 4-cylinder petrol engine. It mainly consists of a 6 or 12 volt battery, ammeter, ignition switch, auto-transformer (step up transformer), contact breaker, capacitor, distributor rotor, distributor contact points, spark plugs, etc.

Note that the Figure 4.1 shows the ignition system for 4-cylinder petrol engine, here there are 4-spark plugs and contact breaker cam has 4-corners. (If it is for 6-cylinder engine it will have 6-spark plugs and contact breaker cam will be a perfect hexagon).

The ignition system is divided into 2-circuits :

(i) **Primary Circuit :** It consists of 6 or 12 V battery, ammeter, ignition switch, primary winding it has 200-300 turns of 20 SWG (Sharps Wire Gauge) gauge wire, contact breaker, capacitor.

(ii) **Secondary Circuit :** It consists of secondary winding. Secondary winding consists of about 21000 turns of 40 (S WG) gauge wire. Bottom end of which is connected to bottom end of primary and top end of secondary winding is connected to centre of distributor rotor. Distributor rotors rotate and make contacts with contact points and are connected to spark plugs which are fitted in cylinder heads (engine earth).

(iii) **Working :** When the ignition switch is closed and engine in cranked, as soon as the contact breaker closes, a low voltage current will flow through the primary winding. It is also to be noted that the contact beaker cam opens and closes the circuit 4-times (for 4 cylinders) in one revolution. When the contact breaker opens the contact, the magnetic field begins to collapse. Because of this collapsing magnetic field, current will be induced in the secondary winding. And because of more turns (@ 21000 turns) of secondary, voltage goes unto 28000-30000 volts.

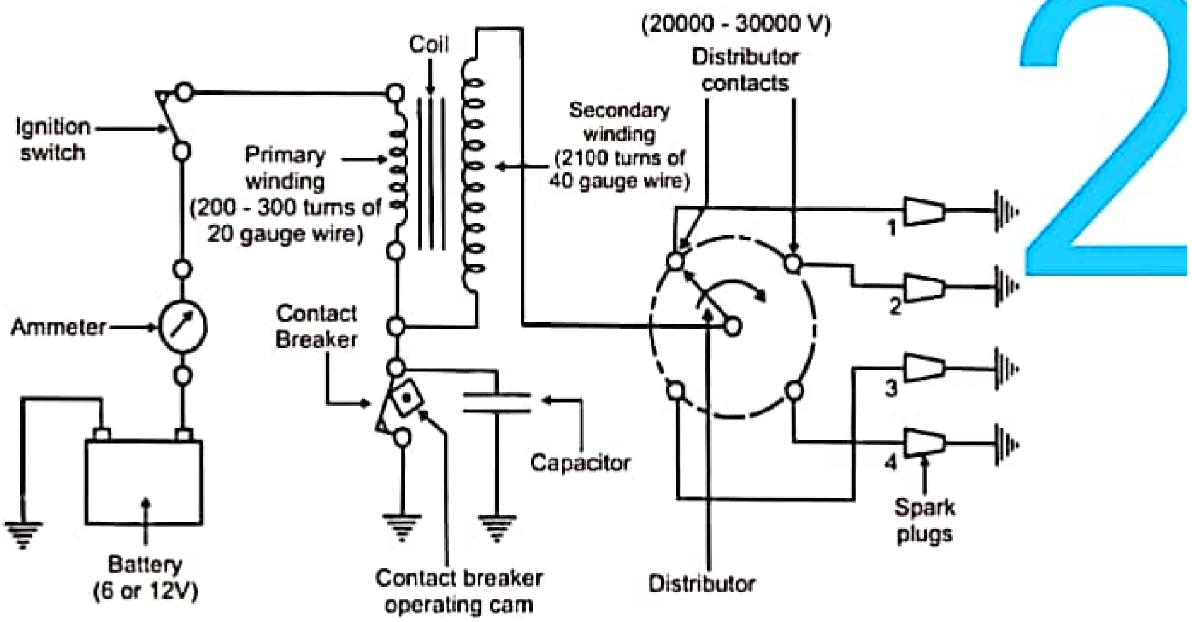


Figure 4.2 : Schematic Diagram of Coil/Battery Ignition System

This high voltage current is brought to centre of the distributor rotor. Distributor rotor rotates and supplies this high voltage current to proper stark plug depending upon the engine firing order. When the high voltage current jumps the spark plug gap, it produces the spark and the charge is ignited-combustion starts-products of combustion expand and produce power.

Note :

(a) The Function of the capacitor is to reduce arcing at the contact breaker (CB) points. Also when the CB opens the magnetic field in the primary winding begins to collapse. When the magnetic field is collapsing capacitor gets fully charged and then it starts discharging and helps in building up of voltage in secondary winding.

(b) Contact breaker cam and distributor rotor are mounted on the same shaft.

In 2-stroke cycle engines these are motored at the same engine speed. And in 4-stroke cycle engines they are motored at half the engine speed.

3

Advantages

(a) Low initial cost.

(b) Better spark at low speeds and better starting than magneto system.

(c) Reliable system.

(d) No problems due to adjustment of spark timings.

(e) Simpler than magneto system.

Disadvantages

(a) Battery requires periodical maintenance.

(b) In case of battery malfunction, engine cannot be started.

3.4.2 Magneto-ignition System

This system consists of a magneto in place of a battery. So, the magneto produces and supplies current in primary winding. Rest of the system is same as that in battery ignition system. A magneto ignition system for a four cylinder SI engine has been shown in Figure 3.2.

The magneto consists of a fixed armature having primary and secondary windings and a rotating magnetic assembly. This rotating assembly is driven by the engine.

Rotation of magneto generates current in primary winding having small number of turns. Secondary winding having large number of turns generates high voltage current which is supplied to distributor. The distributor sends this current to respective spark plugs. The magneto may be of rotating armature type or rotating magnet type. In rotating armature type magneto, the armature having primary and secondary windings and the condenser rotates between the poles of a stationary horse shoe magnet. In magneto, the magnetic field is produced by permanent magnets.

Advantages

(a) Better reliability due to absence of battery and low maintenance.

(b) Better suited for medium and high speed engines.

(c) Modern magneto systems are more compact, therefore require less space.

Disadvantages

(a) Adjustment of spark timings adversely affects the voltage.

(b) Burning of electrodes is possible at high engine speeds due to high voltage.

(c) Cost is more than that of magneto ignition systems.

Magneto Ignition System

In this case magneto will produce and supply the required current to the primary winding. In this case as shown, we can have rotating magneto with fixed coil or rotating coil with fixed magneto for producing and supplying current to primary, remaining arrangement is same as that of a battery ignition system.

Figure 4.3 given on next page shows the line diagram of magneto ignition syste

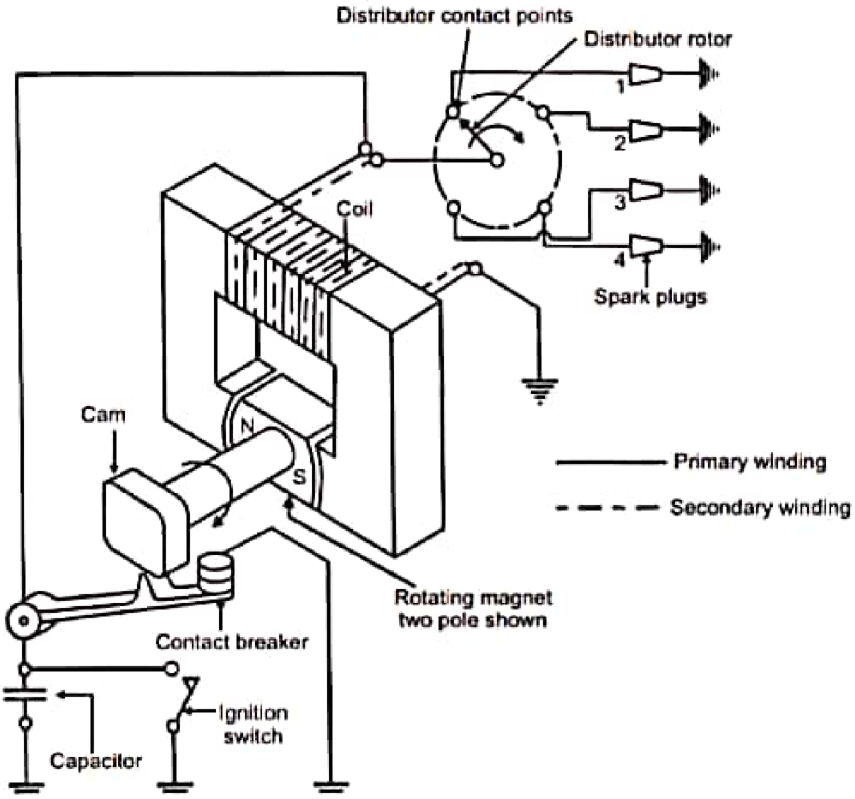


Figure 4.3 : Schematic Diagram of Magneto Ignition System

4.3 COMPARISON BETWEEN BATTERY AND MAGNETO IGNITION SYSTEM

Battery Ignition	Magneto Ignition
Battery is a must.	No battery needed.
Battery supplies current in primary circuit.	Magneto produces the required current for primary circuit.
A good spark is available at low speed also.	During starting the quality of spark is poor due to slow speed.
Occupies more space.	Very much compact.
Recharging is a must in case battery gets discharged.	No such arrangement required.
Mostly employed in car and bus for which it is required to crank the engine.	Used on motorcycles, scooters, etc.
Battery maintenance is required.	No battery maintenance problems.

5

4.4 DRAWBACKS (DISADVANTAGES) OF CONVENTIONAL IGNITION SYSTEMS

Following are the drawbacks of conventional ignition systems :

(a) Because of arcing, pitting of contact breaker point and which will lead to regular maintenance problems.

(b) Poor starting : After few thousands of kilometers of running, the timing becomes inaccurate, which results into poor starting (Starting trouble).

(c) At very high engine speed, performance is poor because of inertia effects of the moving parts in the system.

(d) Some times it is not possible to produce spark properly in fouled spark plugs.

In order to overcome these drawbacks Electronic Ignition system is used.

4.5 ADVANTAGES OF ELECTRONIC IGNITION SYSTEM

Following are the advantages of electronic ignition system :

(a) Moving parts are absent-so no maintenance.

(b) Contact breaker points are absent-so no arcing.

(c) Spark plug life increases by 50% and they can be used for about 60000 km without any problem.

(d) Better combustion in combustion chamber, about 90-95% of air fuel mixture is burnt compared with 70-75% with conventional ignition system.

(e) More power output.

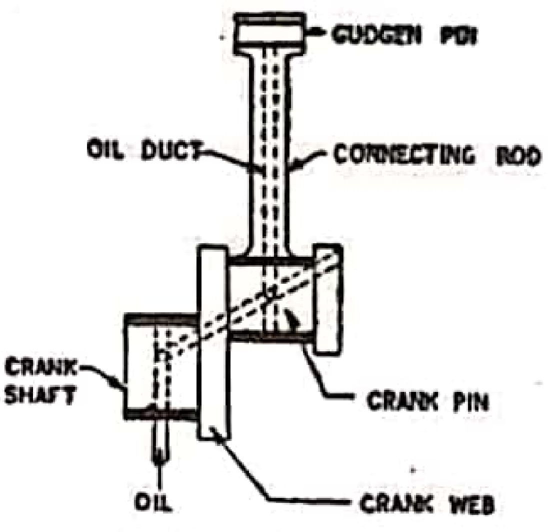
(f) More fuel efficiency.

3. Pressure System: (W - 11)

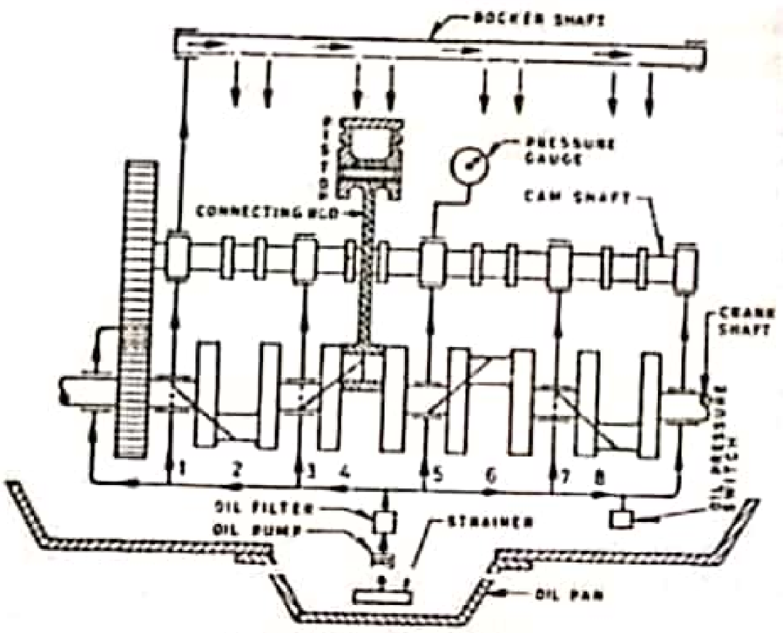
The features of this Pressure system are as follows;

- This system is most widely used system in modern cars.
- In this system, the engine parts are lubricated under pressure feed. The oil pump takes the oil from the wet sump through a filter to main oil gallery at a pressure of 200 – 400 kPa.
- The oil from main gallery goes to the main bearing, some lubricant fall backs to the sump & some is splashed to lubricate cylinder walls.
- From crank pin it goes to the piston pin through a hole in the connecting rod.

- Lubrication of camshaft and timing gear is gone through separate oil lines from the oil gallery.
- Sometimes rocker arms are mounted on the hollow shaft, which carry oil under pressure. The hollow shaft feeds oil for the lubrication of the rocker arm.
- During oils circulation, the oil gains heat from various engine parts, which is given out to the sump wall. In some heavy duty engines separate oil cooler is also employed.

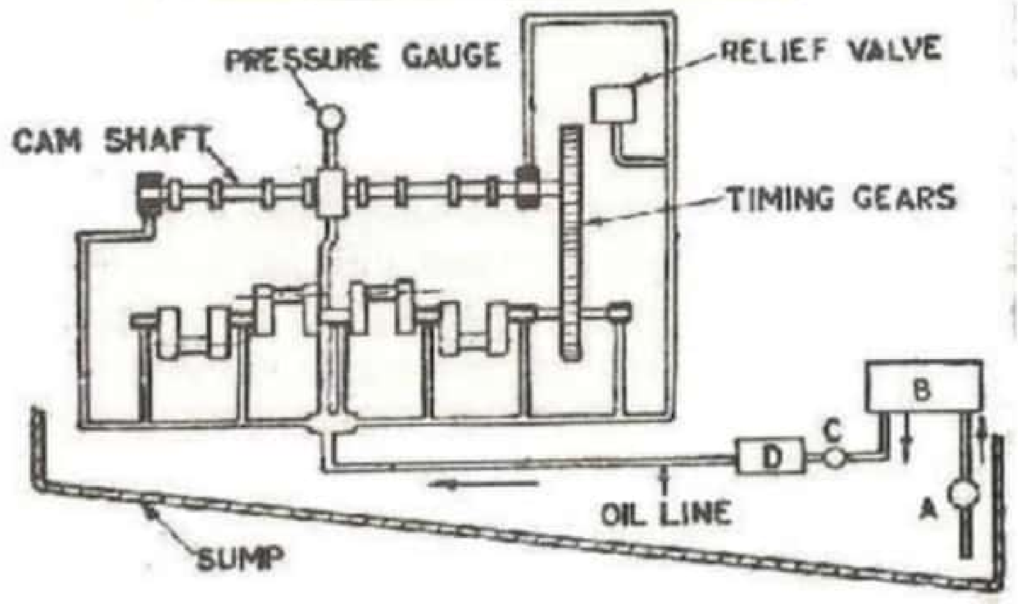


Small end lubrication.



Pressure system of lubrication.

4. Dry Sump System: (W - 11)



Dry sump system.

The features of this Dry Sump system are as follows;

- In this system the lubricating oil is not stored in the oil sump.
- This system is employed in some racing car engines for situations where the vehicle has to be operated at very steep angles.
- If ordinary pressure system of lubrication is used in such a case, the situation may arise when there is no oil at the place where oil pump is installed. To avoid such situation dry sump system is used.
- Two pumps are used instead of single oil pump
- The scavenge pump A is installed in the crankcase portion which is the lowest.
- It pumps oil to a separate reservoir B, from where the pressure pump C pimps the oil through filter D, to the cylinder bearings.
- The oil pressure is maintained at 400 – 500 kPa for main & big end bearings.

5.3 INTRODUCTION TO LUBRICATION SYSTEM

- **NEED/PURPOSE OF LUBRICATION:** (W-12/S-12)

The purpose of the lubrication is as follows:

1) To reduce friction between the moving parts.
2) To reduce wear of the mating parts.
3) To act as a cooling medium for removing heat.
4) To keep the engine parts clean, especially piston ring & ring grooves, oil ways and filter. During the circulation, lubricant dissolves many impurities.
5) It provides cushioning effect by absorbing shocks between bearing and the other engine parts thus reducing engine noise and extending engine life.
6) To form a good seal between piston ring and cylinder wall.
7) To prevent deposition of carbon.
8) It prevents corrosion of the metallic components.

- **FUNCTION OF ENGINE LUBRICATION OIL:** (W-12)

The functions of the lubricating oil in an engine are as follows;

1) To minimise friction and wear between mating parts.
2) To cool the engine by carry the heat away.
3) To seal the gap between piston ring and cylinder liner walls & thus prevent escape of gases from cylinder (i.e.: Minimise blow-by).
4) To cushion the parts against vibration and impact.
5) To clean the parts along with lubrication. Thus carry away the impurities.

5.1 ENGINE COOLING SYSTEM

- **NEED/PURPOSE OF COOLING:** (S12/ W11)

The purpose of the cooling system is to keep the engine at most efficient working temperature at all the engine speeds and in all driving condition.

I. All the heat generated by the combustion of fuel in engine cylinder is not converted into useful power at crankshaft.

A typical distribution of the fuel energy is as given below;

a) Useful work at crankshaft --- 25 %
b) Loss to cylinder walls --- 30 %
c) Loss in exhaust gas --- 35 %
d) Loss of friction --- 10 %

II. If the quantity of heat given to engine cylinder is considerable & if this heat is not removed from the cylinder, it will result in;

a) Preignition of the charge.
b) The lubricant would also burn away, thereby causing seizing of the piston.

c) Excess heating will damage the cylinder material.

Thus it is desired to maintain the engine temperature at desired level.

III. However, cooling beyond optimum limit is not desirable, because it decreases the overall efficiency due to following reasons: (S 12)

a) Thermal efficiency is decreased due to more loss of heat at the cylinder walls.
b) The vaporization of the fuel is less; this results in fall of the combustion efficiency.
c) Low temperature increases lubricant viscosity & hence more piston friction is encountered, thus decreased mechanical efficiency.

Although more cooling improves volumetric efficiency, yet above factors result in decreased overall efficiency.

IV. Thus optimum temperature should be maintained & any deviation in this temperature will result in deterioration of the engine performance.

180°F to 185°F, the full-open temperature is 200°F to 202°F. If the test is satisfactory, the thermostat can be reinstalled.

You can also use a digital thermometer to check the operating temperature of an engine and thermostat. Simply touch the tester probe on the engine next to the thermostat housing and note its reading. If the thermostat does not open at the correct temperature, it is defective and should be replaced.

The use of a temperature stick is another way to test a thermostat quickly. The temperature stick is a pencil-like device that contains a wax material containing certain chemicals that melt at a given temperature. Using two sticks (one for opening temperature and the other for full-open temperature), rub the sticks on the thermostat housing. As the coolant warms to operating temperature, the wax-like marks will melt. If the marks do not melt, the thermostat is defective and needs to be replaced.

1.4.4 Engine Fan Test

A faulty engine fan can cause overheating, overcooling, vibration, and water pump wear or damage. Testing the fan ensures that it is operating properly.

To test a thermostatic fan clutch, start the engine. The fan should slip when cold; as the engine warms up, the clutch should engage. Air should begin to flow through the radiator and over the engine. You will be able to hear and feel the air when the fan clutch locks up.

If the fan clutch is locked all the time (cold or hot), it is defective and must be replaced. Excessive play or oil leakage also indicates fan clutch failure.

When testing an electric cooling fan, observe whether the fan turns ON when the engine is warm. Make sure the fan motor is spinning at normal speed and forcing enough air through the radiator.

If the fan does not function, check the fuse, electrical connections, and supply voltage to the motor. If the fan motor fails to operate with voltage applied, replace it.

If the engine is warm and no voltage is supplied to the fan motor, check the action of the fan switch. Use either a voltmeter or test light. The switch should have almost zero resistance (pass current and voltage) when the engine is warm. Resistance should be infinite (stop current and voltage) when the engine is cold.

If these tests do not locate the trouble with the electric cooling fan, refer to the manufacturer's service manual for instructions. There may be a defective relay, connection, or other problem.

1.4.0 Cooling System Tests

It is often necessary to check the cooling system for cooling system problems, which can be grouped into three general categories:

- Coolant leaks—crack or rupture, allowing pressure cap action to push coolant out of the system.
- Overheating—engine operating temperature too high, warning light on, temperature gauge shows hot, or coolant and steam are blowing out the overflow.
- Overcooling—engine fails to reach full operating temperature, engine performance poor or sluggish.

To diagnose and repair cooling system problems, perform several tests. These tests include the cooling system pressure test, combustion leak test, thermostat test, engine fan test, and fan belt test.

1.4.1 Cooling System Pressure Test

A cooling system pressure test is used to locate leaks quickly. Low air pressure is forced into the system, causing coolant to pour or drip from any leak in the system.

A pressure tester is a hand-operated air pump used to pressurize the system for leak detection. Install the pressure tester on the radiator filler neck. Then pump the tester until the pressure gauge reads radiator cap pressure.

WARNING

Do not pump too much pressure into the cooling system or damage may result.

With pressure in the system, inspect all parts for coolant leakage. Check at all fittings, at gaskets, under the water pump, around the radiator, and at engine freeze (core) plugs. Once the leak is located, tighten, repair, or replace parts as needed.

A pressure test can also be applied to the radiator cap. The radiator pressure test measures cap-opening pressure and checks the condition of the sealing washer. The cap is installed on the cooling system pressure tester.

Pump the tester to pressurize the cap. Watch the pressure gauge. The cap should release pressure at its rated pressure (pressure stamped on cap). It should also hold that pressure for at least 1 minute. If not, install a new cap.

1.4.2 Combustion Leak Test

A combustion leak test is designed to check for the presence of combustion gases in the engine coolant. It should be performed when signs (overheating, bubbles in the coolant, or a rise in coolant level upon starting) point to a blown head gasket, cracked block, or cracked cylinder head.

A block tester, often called a combustion leak tester, is placed in the radiator filler neck. The engine is started and the test bulb is squeezed and then released. This will pull air from the radiator through the test fluid.

The fluid in the block tester is normally blue. The chemicals in the exhaust gases cause a reaction in the test fluid, changing its color. A combustion leak will turn the fluid yellow. If the fluid remains blue, there is no combustion leak.

Combustion leakage into the cooling system is very damaging. Exhaust gases mix with the coolant and form corrosive acids. The acids can cause holes in the radiator and corrode other components.

An exhaust gas analyzer will also detect combustion pressure leakage into the coolant. Place the analyzer probe over the filler neck and accelerate the engine. The probe will pick up any hydrocarbons (HC) leaking from the system, which indicates combustion leakage.

1.4.3 Thermostat Test

To check thermostat action, watch the coolant through the radiator neck. When the engine is cold, coolant should not flow through the radiator. When the engine warms, the thermostat should open. Coolant should begin to circulate through the radiator. If this action does not occur, the thermostat may be defective.

There are several ways to test a thermostat. The most common is to suspend the thermostat in a container of water together with a high-temperature thermometer. Then by heating the container on a stove or hot plate, you can determine the temperature at which the thermostat begins to open, as well as when it is full open. If the thermostat fails to respond at specified temperatures, it should be discarded. Specifications vary on different thermostats. For example, for a thermostat with an opening temperature of

SPARK PLUGS

The simple requirement of a spark plug is that it must allow a spark to form within the combustion chamber, to initiate burning. In order to do this the plug has to withstand a number of severe conditions. Consider, as an example, a four-cylinder four-stroke engine with a compression ratio of 9:1, running at speeds up to 5000 rev/min. The following conditions are typical. At this speed the four-stroke cycle will repeat every 24 ms.

_ End of induction stroke –0.9 bar at 65 ° C.

_ Ignition firing point –9 bar at 350 ° C.

_ Highest value during power stroke –45 bar at 3000 ° C.

_ Power stroke completed –4 bar at 1100 ° C.

Besides the above conditions, the spark plug must withstand severe vibration and a harsh chemical environment. Finally, but perhaps most important, the insulation properties must withstand voltage pressures up to 40kV.

Construction

The centre electrode is connected to the top terminal by a stud. The electrode is constructed of a nickel-based alloy. Silver and platinum are also used for some applications. If a copper core is used in the electrode this improves the thermal conduction properties.

The insulating material is ceramic-based and of a very high grade. Aluminium oxide, Al_2O_3 (95% pure), is a popular choice, it is bonded into the metal parts and glazed on the outside surface. The properties of this material, which make it most suitable, are as follows:

_ Young's modulus: 340kN/mm2.

_ Coefficient of thermal expansion: 7.8 x10K^{-1}.

_ Thermal conductivity: 15–5W/mK (Range 200–900 ° C).

_ Electrical resistance: $10^{13}\Omega$/m.

The above list is intended as a guide only, as actual values can vary widely with slight manufacturing changes. The electrically conductive glass seal between the electrode and terminal stud is also used as a resistor. This resistor has two functions. First, to prevent burn-off of the centre electrode, and secondly to reduce radio interference. In both cases the desired effect is achieved because the resistor damps the current at the instant of ignition.

Flash-over, or tracking down the outside of the plug insulation, is prevented by ribs that effectively increase the surface distance from the terminal to the metal fixing bolt, which is of course earthed to the engine.