Learning Objectives

After studying this unit, you will be able to

- Know what is an Engine
- Know different types of Engines
- Explain the function of IC Engines
- Classify of IC Engines

Introduction

An automobile is a self-propelled vehicle which is used for the transportation of passengers and goods upon the ground. Auto means automatically and mobile or motive means one which can move. Automobile engineering is a branch of mechanical engineering and have practice to propel them. Car, bus, truck, jeep, tractor, scooter, motorcycle are examples of automobiles.

1.1 Engine

It is a machine which converts heat energy into mechanical energy. It should be understandable that the energy supplied to the engine is of the chemical form like diesel or petrol or kerosene. This chemical energy is converted into heat energy by the process of compression or spark ignition inside the engine. The heat energy is then is converted into mechanical energy.
1.2. Types of Engines

Mainly engines are of two types.

**External Combustion Engines.** E.g.: Steam Engines.

**Internal Combustion Engines.** E.g.: All Automobile Engines.

**External Combustion Engines:** The External Combustion Engines are those in which the combustion takes place outside the engine cylinder. E.g.: Steam Engine.

**Internal Combustion Engines:** In the Internal Combustion Engines the combustion of fuel takes place inside the engine cylinder. E.g.: All Automobile Engines.

1.3. Functions of I.C. Engine

Engine is that kind of prime mover which converts chemical energy of fuel into mechanical energy. The fuel on burning changes to gas which impinges upon the piston and pushes it to change into reciprocating motion. The reciprocating motion of piston is then converted to rotary motion of crank shaft with the help of slider mechanism involving connecting rod and crank shaft.

Several types of I.C. Engines are used on various automobiles, i.e. marine, locomotive, air craft and other industrial applications.
1.4. Classifications of I.C. Engines

The I.C. Engine can be classified on the basis of -

1. Working cycle:
   b. Diesel Cycle Engine or Compression Ignition engine.

2. Number of strokes:
   a. Two Stroke engine.
   b. Four Stroke engine.

3. Fuel used:
   a. Liquefied petrol engines
   b. Diesel engines
   c. Gasoline or petrol
   d. Compressed Natural gas engines,
   e. Methane or ethanol engines

4. Fuel supply system:
   a. Fuel supply through carburetor
   b. Fuel injected by Fuel injecting pump

5. Method of ignition system:
   a. Battery or coil ignition
   b. Magneto ignition
   c. Electronic ignition

6. Method of cooling:
   a. Air cooled
   b. Water cooled

7. Cylinder Arrangement:
   a. in line type
   b. V type
c. Opposed cylinder type
d. Radial type

8. Valve operating system:
a. Overhead type
b. Side valve type.

Fig 1.2 Classification of I.C. Engines

Advantages of I.C.E. over E.C.E.

1. More mechanical simplicity and lower weight/power ratio.
2. They do not need auxiliary equipment, such as boiler & condenser.
3. They could be started and stopped in a short time.
4. Their thermal efficiency is higher than other heat engines.
5. Their initial cost is low.

These advantages make I.C.E. more suitable in the transport sector; motor cars, small ships, submarines, and small aircrafts.
Summary

1. Engine is the heart of an automobile.
2. Engines are widely used in the fields of automobiles, agriculture, power generators etc.
3. The identification of the engine can be justified by its physical appearance like spark plug, injector, valves etc.
4. Before the internal combustion engines, there is a wide usage of external combustion engines like steam engines
5. Steam engines are widely used in locomotive trains, sugar industries etc.
6. Radial engines are ancient type of engines.

Short Answer Type Questions

1. What is an engine?
2. How the energy converts in an engine?
3. What are the fuels used in an engine?
4. What is meant by I.C. engine and an E.C. Engine?
5. How do you mean by S.I. Engine?
6. How the petrol engine and diesel engine can be identified?
7. In which type of engine can you find the valves?
8. Name the engine in which ports are used.

Long Answer Type Questions

1. How the engines are classified?
2. Discuss about the classifications of I.C. Engines?
3. Mention the differences of Internal Combustion and External Combustion engines.

Practical Work/OJT work

1. Study different IC & EC engines
2. Identify classification of IC engines
UNIT 2

Petrol Engines

Learning Objectives

After studying this unit, you will be able to

- Know about petrol engine, construction details and material used and functions of petrol engine.
- Explain construction and working of 2 and 4 stroke petrol
- Describe the comparison between 2 and 4 stroke petrol engines
- Know valve timing diagram of 2 and 4 stroke engines

Introduction

A petrol engine is an internal combustion engine with spark-ignition, designed to run on petrol (gasoline). In most petrol engines, the fuel and air are usually pre-mixed before compression (although some modern petrol engines now use cylinder-direct petrol injection). The pre-mixing was formerly done in a carburetor, but now it is done by electronically controlled fuel injection, except in small engines where the cost/complication of electronics does not justify the added engine efficiency. The process differs from a diesel engine in the method of mixing the fuel and air, and in using spark plugs to initiate the combustion process. Because of the difference in burn rates between the two different fuels, petrol engines are mechanically designed with different timing than diesels, so to auto-ignite a petrol engine causes the expansion of gas inside the cylinder to reach its greatest point before the cylinder has reached the "top dead center" (TDC) position. A typical spark ignition occurs just a few degrees of crankshaft
rotation before the piston reaches TDC, which allows time for the gas to begin to expand. Then the bulk of the expansion occurs just after the piston has rotated beyond TDC. Higher octane petrol burns slower, therefore it has a lower propensity to auto-ignite and its rate of expansion is lower. Thus, engines designed to run high-octane fuel exclusively can achieve higher compression ratios.

Petrol engines run at higher speeds than diesels, partially due to their lighter pistons, connecting rods and crankshaft (a design efficiency made possible by lower compression ratios) and due to petrol burning faster than diesel. However the lower compression ratios of a petrol engine give a lower efficiency than a diesel engine. To give an example, a petrol engine is like operating a bicycle in its lowest gear where each push from your feet adds little energy to the system, but you still expend energy to move your legs back to the TDC position.

2.1 Materials used, function and Constructional details of Petrol Engine

Materials used for various components-The cylinder block and cylinder head are made of gray cast iron and sometimes with addition of nickel and chromium. Some cylinder blocks are cast from aluminum, cast iron or steel. The cylinder blocks are made of Casting process. Small engine cylinder blocks walls are plated with chromium to reduce wall wear and to increase their service life.

The cylinder gaskets are made of copper-asbestos, steel asbestos and stainless steel. The upper part of the crankcase is made of ferrous alloy or semi-steel to provide a stronger and harder casing. The cylinder liners are barrels made of special alloy iron containing silicon, manganese, nickel and chromium. The cylinder liners are centrifugal castings. The piston is the most important part in the engine which converts chemical energy into mechanical power. As the piston is to convey the expansion of the gases via connecting rod it is made of aluminum alloy by the process of either cast or forged. As the conductivity of aluminum alloy is more than cast iron, it is made of aluminum alloy.

The piston rings are coated to minimize the wear. The piston rings are coated with chromium plating to decrease the rate of wear. Ring coating absorbs oil thus improving lubrication. The piston rings are castings. The connecting rod is generally I-beam cross-section and is made of forged steel. Aluminum alloy is also used for connecting rods. But they are carefully matched in sets of uniform weight in order to maintain engine balance. The connecting rod is made of forging process. The crankshaft is made of casting or forging of heat treatment alloy steel and is machined and ground to provide suitable journals for the connecting rod and main bearings.
The flywheel is a fairly heavy bulk mass of steel attached to the crankshaft. The size of the flywheel depends upon the number of cylinders and the general construction of the engines. During the power stroke the engine tends to speed up and during the other three strokes it tends to slow down. The inertial of the flywheel tends to keep it running at constant speed. The valves are usually made of austenitic stainless steel which is a corrosion and heat resistant material. Exhaust valve is made of silchrome steel which is an alloy of silicon and chromium with unusual resistance to heat. Inlet valve is usually made of nickel chromium alloy steel.

**Function and constructional details of Petrol Engine:**

**Cylinder Block:** the body of the engine is known as the cylinder block. This is generally cast from iron and typical unit. You can see four cylinders and the long bolts called cylinder head studs, which hold the cylinder head. The cylinder head contains the valve mechanism as well as spark plugs, the connection for the inlet and exhaust. As the left hand end of the cylinder block there is a hole for the end of the crankshaft
**Cylinder Head:** the cylinder head covers the top of the cylinder and forms the top of the combustion chamber. Cylinder heads are made of cast iron or aluminum. Aluminum is a better conductor of heat. Thus there is less trouble with the overheating of parts. But cast iron is stronger than aluminum and is used on most engines. A gasket is used between the mating surfaces of the cylinder block to provide a tight seal between the various openings in both parts.

**Crank Case:** Below the cylinder is the crankcase. It supports the crankshafts and the camshaft and provides arms or brackets for supporting the engine on foundation. The crankcase may be cast integral with the cylinder block or made as a separate casting, which is attached to the block by bolts. Material used for crankcase is grey cast iron or aluminum.

**Fig 2.2 Cylinder Heat and Crankcase**

**Oil Pan:** it is the lower part of the crankcase being a reservoir for lubricating oil. It is made of pressed steel or aluminum and is screwed to the lower end of the main casting.
Automobile Engineering Technician

Cylinder Liners: The cylinder wears due to the movement of the piston against its walls. To prevent the materials used for liners are nitride steel, nitrated cast iron, chromium-coated alloy steel. Liners are harder than the cylinder blocks. Cylinder from wearing, a cylinder liner is used which can be replaced when it is worn-out. The liner is made of cast iron, which is centrifugally cast. It contains chromium for hardness. There are two types of liners:

Dry Liner: it is made in the form of a barrel fitted in the cylinder block. A flange is provided at the top of the dry liner to keep it in position.

Wet Liner: it is so called because it is in direct contact with the coolant on its outside. Aluminum alloy pistons are now commonly used as they are lighter in weight and are good conductors of heat. Burning of air/fuel mixture causes expansion of piston. In order to keep the expansion within limits, two methods are used slots are cut on skirt of the piston. Heat dam is provided in the piston i.e. groove is made on the full periphery of the piston top land.
Piston

The piston reciprocates in the cylinder and causes suction, compression, power, and exhaust in the cylinder as per the operation cycle of the engine. The power developed in the engine cylinder is transmitted by the piston to the crankshaft via the connecting rod. Pistons are made of cast iron, cast steel or aluminum alloy.

![Piston Parts](image)

**Fig 2.5 Piston Parts**

**Piston Heads Shapes:** The flat head piston is the simplest one. Various dome shapes are used to decrease combustion chamber volume and to increase compression ratio such pistons may have notches in the piston head to provide valve clearance. A cup or bowl is provided in some piston heads to improve turbulence.

**Piston Clearance:** Piston is slightly smaller than the cylinder bore. The difference in the two diameters is known as piston clearance. This clearance is provided because of following reasons:

a). There is unequal expansion of piston and cylinder. b). To provide space for lubricating oil film.

![Piston Head Shapes](image)

**Fig 2.6 Piston Head Shapes**
Piston Rings: In order to maintain a gas-tight fit in the cylinder, the piston is fitted with a number of springy iron piston rings, located in grooves cut in the piston. These rings fill the small clearance between the piston and the cylinder wall by springing outwards against the cylinder. The bottom ring usually has slots cut in it, and holes are drilled in its locating grooves, right through to the inside of the piston itself. This is the scraper ring, and the purpose is to remove excess oil sticking to the walls of the cylinder. Without the scraper ring excessive amounts of oil would be burnt in the combustion chamber. A horizontal gudgeon pin is fitted into the piston, to transmit power to the connecting rod.

Piston Pin: A piston pin connects the piston to the connecting rod. It is also known as gudgeon pin or wrist pin. The piston pin is generally made in tubular form to reduce its weight. The piston passes through the piston bosses and the connecting rod small end. There are two types of piston pins: 1. fully floating piston pins 2. semi floating piston pins.

Air Cleaner: The air cleaner is located either on the top of the carburetor or in the air inlet manifold. Its purpose is: 1. to clean the intake air. 2. to reduce the noise of intake air and 3. to arrest the flame if the engine backfires.

There are two types of air cleaners: wet type and dry type. A dry type cleaner consists of specially treated paper element through which the atmospheric air passes before going to the carburetor via the entrance. The air from the atmosphere enters through the side passage and strikes the oil surface. The oil absorbs heavy dust particles. The air then passes through the filter element. Here the filtering element collects fine particles. The air is thus cleaned which moves through the passage to the inlet manifold.
**Intake and Exhaust Manifold**: intake manifold is connected to the side of the cylinder head to carry airfoil mixture from the carburetor to the cylinders. Similarly, an exhaust manifold is provided to carry away burnt gases from the engine cylinders.

![Fig 2.8 Manifold](image)

**Gaskets**: gaskets are used to provide a tight fitting joint between two surfaces: for example the joint between cylinder head and block, between crankcase and oil pan, between the cylinder block and manifold or water pump.

![Fig 2.9 Gaskets](image)

**Connecting Rod**: The connecting rod transmits power from the piston to the crankcase. Its small end is attached to the piston by piston pin and the big end is attached to the crankshaft by crank pin.

The connecting rod is cast or forged from high strength alloy steel. In some engines a hole is drilled in the connecting rod from the big end to the small end. It allows oil to flow from the big end to the small end bush.
Connecting Rod Bearings: the petrol engine used in a car is called upon to work reliably for a considerable time. For most of this time it will be providing considerable power, which is produced in the cylinders and transmitted to the crankshafts through the connecting rods. The bearings at the end of the connecting rods must be very strongly made. The figure shows a typical connecting rod. The upper bearing, pivoting on the gudgeon pin and allowing the connecting rod to move inside the hollow piston, is called the small end. The lower bearing, which rotates on the crankshaft, is called the big end.

Main Bearings: the crankshaft main bearings supports the crankshaft and allow it to rotate. The main bearings are usually similar to the big end bearings in construction, with bearing shells that can be replaced if necessary. Modern four cylinder engine crankshafts usually have three main bearings.

Crank Shaft: the crank shaft converts the reciprocating motion of the piston into rotary motion, and transmits the torque to the flywheel. It is made of forged steel. A flywheel is fitted to the rear end of the crankshaft. A damper, fan pulley and small sprocket are fitted to the front end of the crankshaft. Holes are drilled in the crankshaft from the main bearing journals to the crankpins for the lubricating oil to pass through.
**Fly Wheel:** the fly wheel is attached to a flange on the crankshaft and is usually made from cast iron. Around the outside of the flywheel is the ring gear, which is used by the starting motor to crank the engine. The main purpose of fly wheel is to smoothen the power supplied to the crankshafts by the pistons. There is only one working stroke in four so a flywheel is needed to drive the crankshaft during the time that the engine is performing the non-power strokes. The flywheel 'carries' the engine over the non-working strokes.

**Cams and Camshaft:** A cam changes the rotary motion of the camshaft to the reciprocating motion of the valve lifters. The cams are formed as integral parts of the camshaft. There are two cams for each cylinder, one for intake valve and other for exhaust valve. The surface of cams is hardened for longer life. The camshaft has a series of support bearings along the length. The camshaft is made of forged alloy steel.
The camshaft rotates once for every two revolutions of the crankshaft. Each time a cam rotates, it lifts its pushrod, opening a valve. It is not usual for the pushrod to bear directly on the cam, instead the end of the pushrod rests in a hard steel bucket, called a tappet, which in turn rests on the cam. The pushrod and tappet are free to rotate, so that wear takes place evenly. The cams are continuously lubricated by oil splashing about inside the engine.

**Camshaft Drive Mechanism**: each valve must operate once in every two revolutions of the crankshaft, so camshaft rotates a half crankshaft speed. There are three types of drive mechanism in use: a) gear drive b) chain drive c) belt drive.

Inlet and exhaust valves are fitted to each cylinder of the four stroke engine. The inlet valve admits the petrol/air mixture, and the exhaust valve releases the combustion products, which are vented via the exhaust.

Valve Operating Mechanism: Two types of valve operating mechanisms are used in engines: a) side valve mechanism: a cam mounted on a rotating camshaft operates the tappet, which further actuates the valve against a spring.
The valve moves in a valve stem guide and is seated on valve seats when closed. A valve spring, fitted between a section of block and a valve retainer locked with bottom end of the valve stem, acts to close the valve when the cam moves in the closing position. b) Overhead valve mechanism: it has two additional moving parts, i.e., a push rod and a rocker arm. The cam lifts the valve lifter, which actuates the rod. The pushrod in turn, causes the rocker arm to rotate about a shaft. The other end of the rocker arm pushes down the valve against the pressure of the valve spring.

Muffler: the function of muffler is to reduce the noise that would be produced if the exhaust gases were allowed to pass directly through the pipes to the rear of the vehicle. It contains a series of holes, passages and resonance chambers to absorb high-pressure surges.
1. Inline arrangement – 2 in line, 3 inline, 4 inline, 6 inline and 8 inline.
2. V arrangement – v-4, v-6, v-8 and v-12.
3. Opposed cylinder or flat arrangement – flat 2, flat 4 and flat 6.
4. Radial cylinder arrangement.

![Fig 2.18 Side valve and over head valve operating mechanism, L,L,F, and T type valve arrangements](image)

The valves used in four stroke engines are operated by two mechanisms.

1. Valve mechanism for operating the valve in engine block or straight or side valve mechanism.
2. Valve mechanism for operating the valve in cylinder head or over head valve mechanism.

**Side valve operating mechanism**

This mechanism is used in the engine block. It is mostly adopted in L,T and F type engine heads. The valve stem slides up and down in the valve stem guide which acts as a slipper bearing. It also prevents the gases from passing from the valve port to the valve chamber of the engine block.

Valve spring is fitted between the engine block and spring retainer, which keeps the valve closed tightly on the valve seat, until lifted by the valve tappet by the rotation of the cam. The tappet or lifter is held between guide which is generally a part of the engine block.

Adjusting screw is provided on the tappet to adjust the clearance between the upper end of the tappet and the bottom of the valve stem. As the cam rotates, it lifts the tappet which lifts the valve to the open position thus connecting the valve port to the combustion chamber.
Valve seat inserts are fitted on the valve seats. These inserts are in the form of rings tapered grounded to suit the valve faces, and made of special alloy steels. Usually they are used only on exhaust valve seats. They reduce wear and can be replaced when worn out.

**Over head valve mechanism**

It is used in I type and F type engine heads. This type valve operating mechanism requires a push rod and a rocker arm.

As the cam rotates, it lifts the valve tappet or the lifter which actuates the push rod. The push rod rotates the rocker arm about a shaft - the rocker arm shaft, or a ball joint in some designs to cause one end to push down on the valve stem to open the valve, thus connecting the valve port with the combustion chamber.

In this mechanism, the valve tappet clearance is between the rocker arm and valve stem. It is adjusted by means of an adjusting screw on the rocker-arm end that contacts the push rod.
Valve Timing: the opening and closing of the valves in an engine in relation to the movement of the piston and flywheel is called valve timing. Very old, slow speed engines had the following valve timing:

Inlet valve—opens at t.d.c and closes at b.d.c.

Exhaust valve—opens at b.d.c and closes at t.d.c.

Modern engines operate at high speeds, so to allow for this the valve timing is modified to:

Inlet valve—opens just before t.d.c and closes well past b.d.c.

Exhaust valve—opens well before b.d.c and closes just after t.d.c.

Valve Clearance: A slight clearance is kept between the valve tappet and the valve stem in the case of straight poppet valve, and between the rocker arm and valve stem in the case of overhead poppet valve. This is known as valve tappet clearance.

Valve Clearance:

<table>
<thead>
<tr>
<th>Type</th>
<th>Intake Range</th>
<th>Exhaust Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>L-JETRONIC</td>
<td>0.400 - 0.450 mm (0.0157 - 0.0177 in.)</td>
<td>0.450 - 0.500 mm (0.0177 - 0.0197 in.)</td>
</tr>
<tr>
<td>MOTRONIC</td>
<td>0.380 - 0.450 mm (0.015 - 0.018 in.)</td>
<td>0.430 - 0.500 mm (0.017 - 0.020 in.)</td>
</tr>
</tbody>
</table>

Fig 2.21 Valve timing mechanism

Fig 2.22 Valve Clearance
Timing gears: Timing gears are a pair of which one is mounted on the crankshaft and the other on the camshaft. The gear mounted on camshaft is larger in diameter than the other mounted on the crankshaft. The sizes of these gears are such that they maintain a speed ratio of two between them. It means that a camshaft has to rotate at half the speed of crankshaft. It is because a valve has to open and close once in every two revolutions of the crankshaft. The two timing gears are provided with timing marks.

2.3 Construction and working of 2 Stroke and 4 stroke Petrol Engines

Two Stroke petrol engine

The two stroke engine there are two strokes namely upward stroke and downward stroke. In a two stroke engine, the two strokes are completed in two strokes of the piston or one complete revolution of the crankshaft.

Upward stroke: during the upward stroke the piston moves upward from bottom dead centre to top dead centre. The air fuel mixture is compressed in the combustion chamber of the cylinder. Due to upward movement of the piston, a partial vacuum is created in the crankcase, and a new charge is drawn into the crankcase through the uncovered inlet port.

The exhaust port and transfer port are covered when the piston is at top dead centre position. The compressed charge is ignited in the combustion chamber.
**Downward Stroke**: As soon as the charge is ignited, the hot gases compress the piston which moves downward, rotating the crankshaft thus doing the useful work. During this stroke the inlet port is covered by the piston and the new charge is compressed in the crankcase. Further downward movement of the piston uncovers first the exhaust port and then the transfer port, and hence the exhaust starts through the exhaust port. As soon as the transfer port opens, the charge through it is forced into the cylinder. The charge strikes the deflector on the piston crown, rises to the top of the cylinder and pushes out most of the exhaust gases. The piston is now at bottom dead centre position.

The cylinder is completely filled with the fresh charge, although it is then repeated, the piston making two strokes for each revolution of the crankshaft.

**Four Stroke petrol Engine**

The four stroke engine comprises of suction, compression, power or working and exhaust strokes. In a 4 stroke engine, the 4 strokes are completed in four individual strokes of the piston or two revolutions completed of crankshaft.

1. **Suction Stroke**: the inlet valve opens. The piston starts to move downward from top dead center position and reaches to bottom dead center position. Fresh charge of air-fuel mixture enters the cylinder. The exhaust valve remains closed. The crankshaft completes half of the revolution.

2. **Compression Stroke**: both the valves remain closed. The piston starts to move upward from b.d.c, thus compressing the charge till it reaches the t.d.c. The pressure and temperature raises, volume decreases. The crankshaft completes half of the revolution.

3. **Power Stroke**: both the valves remain closed. Sparking takes place from the spark plug which ignites the compressed charge. The piston moves downward from, t.d.c and reaches to b.d.c. The crankshaft completes half of the revolution.
4. **Exhaust Stroke:** the exhaust valve opens. the piston moves from b.d.c. and reaches to t.d.c. thus rushing out the burnt gases from the cylinder. The inlet valve remains closed. the crankshaft completes half of the revolution.

### 2.4 Comparison between 2 Stroke and 4 Stroke Engines

<table>
<thead>
<tr>
<th>Two Stroke Engine</th>
<th>Four stroke engine</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. One working stroke in each revolution of the crankshaft.</td>
<td>One working stroke for every two revolutions of the crankshaft.</td>
</tr>
<tr>
<td>2. Turning moment on the crankshaft is more even due to one working stroke for each revolution of the crankshaft. Hence lighter flywheel is required and engine runs balanced.</td>
<td>Turning moment on the crankshaft is not even due to one working stroke for every two revolution of the crankshaft. Hence heavy flywheel is required and engine runs unbalanced.</td>
</tr>
<tr>
<td>3. Engine is light.</td>
<td>Engine is mostly heavy.</td>
</tr>
<tr>
<td>4. Engine design is simple.</td>
<td>Engine design is complicated.</td>
</tr>
<tr>
<td>5. The engine is less in cost.</td>
<td>The engine is more in cost comparatively.</td>
</tr>
<tr>
<td>6. More Mechanical Efficiency due to less friction on a few parts.</td>
<td>Less mechanical efficiency due to more friction on many parts.</td>
</tr>
<tr>
<td>7. Less output due to mixing of fresh charge with the burnt gases.</td>
<td>More output due to full fresh charge intake and full burnt gases exhaust.</td>
</tr>
<tr>
<td>9. Engine is air cooled.</td>
<td>Engine is mostly water cooled</td>
</tr>
<tr>
<td>11. Fresh charge mixes with the burnt gases.</td>
<td>Full burning of fuel takes place.</td>
</tr>
<tr>
<td>12. Engine requires less space.</td>
<td>Engine requires more space.</td>
</tr>
<tr>
<td>13. Simple lubrication system.</td>
<td>Complicated lubrication system.</td>
</tr>
<tr>
<td>15. Generally used mostly in mopeds, scooters, motor cycles etc.</td>
<td>Used in cars, buses, trucks. Presently using in motor cycles and scooters.</td>
</tr>
<tr>
<td>16. Engine consists of ports.</td>
<td>Engine consists of mostly valves.</td>
</tr>
<tr>
<td>18. It consumes more lubricating oil.</td>
<td>Consumes less lubricating oil.</td>
</tr>
</tbody>
</table>
2.5 Valve Timing Diagram of 2 Stroke and 4 Stroke Petrol Engines

IVO – Inlet valve Opens
IVC – Inlet Valve Closes
IS – Ignition Starts
EVO – Exhaust Valve Opens
EVC – Exhaust Valve Closes
TDC – Top Dead Center
BDC – Bottom Dead Center.
2.6 Firing order of Multi Cylinder Engine

The sequence in which the power impulses occur in an engine is called the firing order.

The firing order for a four cylinder engine is 1-2-4-3 or 1-3-4-2

![Firing order diagram for a four cylinder engine]

The firing order for a six cylinder engine is 1-4-2-6-3-5 or 1-5-3-6-2-4

The firing order for a V-6 engine is 1-6-5-4-3-2.

The firing order for an opposed six cylinder engine is 1-4-5-2-3-6

The firing order for an V-8 engine is 1-8-4-3-6-5-7-2.
Summary

• An engine is a device that converts chemical energy into mechanical energy.

• The valve timing diagram shows the position of valve operation in the four strokes the engine.

• Port timing diagram is applicable for Two stroke engines.

• Gaskets are provided between the cylinder and cylinder head to prevent escape of gases.

• Cylinder liners are used for heavy duty engines.

• Piston clearance prevents piston seizure. It is helpful for film of lubrication.

• Combustion chamber is the space enclosed between the cylinder head and piston head, when the piston is at top dead centre position.

Model Questions

1. What is a petrol engine? Name the types of engines.

2. List out the materials used for the construction of various engine parts.

3. Mention the constructional details of various engine parts.

4. What are the types of valve operating mechanisms used in automobiles?

5. What type of valve operating mechanism is used in L type engine?

6. In which type of engine the side valve operating mechanism is used?

7. List out the various types of cylinder arrangements used in automobiles.

8. Write the construction and working of a two stroke engine.

9. With the help of a neat sketch explain a four stroke engine.

10. Explain about the valve timing diagram of a petrol engine.

11. Give the firing order of a 4 cylinder engine.

12. What do you mean by firing order?

13. Write a short note on vibration damper.
Practical Work/O.J.T

1. Identify different components of petrol 2 stroke and 4 stroke engines.

2. Identify valve, valve operating mechanism of 2 stroke and 4 stroke engines.

3. Observe the valve timing & firing orders of different engines.

4. Study construction and working of 2 stroke petrol engines

5. Study construction and working of 4 stroke engines
UNIT 3

Petrol Engine Fuel System

Learning Objectives

After studying this unit, you will be able to

Know about construction and working of petrol engine fuel system.

Know about construction and working of fuel pump and carburetor.

Know about petrol injection system in modern vehicles.

Know about superchargers.

3.0. Introduction

Petrol engines fuel is used petrol or gasoline. petrol is composition of different hydrocarbons. the approximate proportions of hydrocarbons, of different families, present in gasoline are 10 to 80% parafins, 15 to 85% napthenes and 4 to 40% aromatics. the molecular weight and hydrogen content of gasoline are 113 and 15.5 respectively. the specific gravity varies from 0.70 to 0.78.

Gasoline is produced by any of the following methods-distillation from crude petroleum. Cracking the residual oil. polymerization of the gases evolved during the cracking process. extraction from natural gas evolved during the cracking process. Extraction from natural gas coming out of the bore wells by compression and cooling. gasoline is sold in 3 grades, premium, unleaded and regular.
3.1. Line Diagram of Petrol Engine Fuel System

3.2 Constructional Details of Fuel Feed System

The fuel feed system of a petrol engine are having the following components.

1. Fuel Tank
2. Fuel Pump
3. Fuel Filter
4. Carburetor
5. Intake manifold
6. Fuel lines

**Fuel Tank**

The fuel tank is made of sheet metal. It is usually attached to the frame at a rear of vehicle. Its capacity ranges from 70 to 120 liters. The filler neck of the
tank is closed by a cap. In some other tanks, there is a filtering element at the fuel line connection to convert dirt and prevent it from reaching to the pump and carburetor. A drain plug is provided at the bottom for emptying the tank. The tank also contains the float unit of the fuel gauge. It may also have a vent pipe which allows air to escape when the tank is being filled. In the cars, that are equipped with vapor recovering system, the vent pipe is connected to condenser which contains the vaporized gasoline in the tank and prevents its escape into the air.

**Fuel Line**

The copper or steel tubes and hoses are used for connecting fuel tank with pump with carburetor. The tube connecting the fuel tank and pump is fastened rigidly to the frame or body. The first and last portion generally consists of a flexible tube that joins the rigid line to the fuel tank or to the pump. This allows the fuel tank to oscillate with the body and the pump with the engine without breaking or loosening the line.

**Fuel Filters**

The fuel is filtered at different stages in a fuel supply system. Therefore, many fuel filters are used in the fuel circuit. The fuel filter serves the purpose of filtration in the fuel delivery system by preventing foreign particles from entering into the fuel pump and the carburetor. The modern filtration practice employs a combination of coarse and fine filters. Course filters are incorporated within the fuel tank. Medium coarse filter are outside the fuel tank and on the inlet side of the pump. Fine filters of built in surface type at inlet of fuel pumps pumping chamber. Fine filter in pipe line is between fuel pump and the carburetor.

**3.3 Construction and Working of Fuel Pumps**

A fuel pump is used to deliver fuel from the fuel tank to the float chamber of carburetor. Main types of fuel pumps commonly used on auto vehicles.

1. A.C. Mechanical pump
2. S.U. Electrical pump
3. Electromagnet pump
4. Combined pump (fuel pump with a vacuum pump)

**Mechanical Pump**

The mechanically operated diaphragm type fuel pump is operated by an eccentric mounted on the camshaft of the engine. The pump consists of a spring loaded flexible diaphragm actuated by a rocker arm. The rocker arm is actuated
by the eccentric. Spring loaded valves are there in the inlet and outlet of the pump. These valves ensure flow of fuel in the proper direction. As the rocker arm is moved by the eccentric, the diaphragm is pulled down against the spring force. This movement causes a partial vacuum in the pump chamber.

![Fig 3.3 Mechanical Fuel Pump](image)

Now the delivery valve remains closed and the suction valve opens. This admits fuel into the pump chamber. At the maximum position of the eccentric, the diaphragm is flexed to the maximum extent after this further rotation of the eccentric will release the rocker arm. Now the rocker arm will simply follow eccentric by the action of the return spring. The diaphragm spring will now push the diaphragm upwards and the force the fuel to flow out, opening the delivery valve, into the delivery tube. Now the suction valve remains closed.

In this pump, the downward movement is caused by the rocker arm, while the delivery stroke is achieved by the force of the diaphragm spring. The diaphragm spring is so designed that the fuel pressure is suitable balanced by the buoyancy of the float system of the carburetor. As such, when deliver fuel to the carburetor. In this case, the rocker arm simply continues to rock while the diaphragm remains at or near its lowest travel. However, as the carburetor uses fuel, the needle valve opens to admit fuel into the float bowl. Now the diaphragm moves downward by the rocker action and sucks the fuel to deliver back the same when required. This self regulating feature helps the pump to deliver the correct quantity of fuel at all operating conditions.

**Electrical Fuel Pump**

The electrical fuel pump is mounted in the engine compartment. A pump with electrically operated diaphragm is the SU Horizontal pump. The pump contains a flexible diaphragm that is operated by an electromagnet instead of the mechanical system. The diaphragm consists of a number of layers of impregnated fine gut fabric. The middle of the diaphragm is clamped to an armature. A rod attached to the middle of the diaphragm passes through the center hole in the...
electromagnet. All the other end of the rod electrical contact points are there. There is a return spring which keeps the diaphragm in position.

![Fig 3.4 Electrical Fuel Pump](image)

When the electromagnet is connected to the battery, it produces the armature compressing the return spring and there by flexes the diaphragm. This produces vacuum in the fuel chamber. Fuel from the fuel tank enters the fuel chamber through the inlet valve. Then, as the rod attached to the diaphragm reaches its limit of travel it opens the set of electrical contact points. This disconnects the electromagnet from the battery. The compressed return spring therefore pushes the armature and the diaphragm. This forces the fuel from the fuel chamber through the outlet valve to the carburetor. As the diaphragm flexes back to its original position and the rod attached to its reaches the limit of its travel, it closes the electrical contacts. Now the electromagnet is again energized and tries to pull the armature and diaphragm. This series of actions is repeated as long as the ignition switch is turned on.

If the float chamber is so full as to close the needle valve, the pump diaphragm will remain at rest in the flexed position with the electrical circuit broken, until further delivery is required. The float mechanism of the carburetor must be method with the return spring of the pump so that flooding of the carburetor cannot occur.

### 3.4 Requirements of an Automobile Carburetor

The carburetor is a device for atomizing and vaporizing the fuel and mixing it with the air in varying proportions to suit the changing conditions of spark ignition engines. The air fuel mixture so obtained from the carburetor is called the combustible mixture. The process of mixing the gasoline fuel with air to obtain the combustible mixture is called carburetion. Vaporization is the change
of state of the fuel from liquid to vapor. Atomization is the mechanical breaking up of the liquid fuel into small particles, so that every particle of the fuel is surrounded by air. In order to produce very quick vaporization of the liquid fuel, it is sprayed into the air passing through the carburetor. Spraying of the liquid turns it into many fine particles, so that the vaporization occurs almost instantly.

![Fig 3.5 Simple Carburettor](image)

The carburetor supplies the air-fuel mixture of varying proportions to suit the changing conditions of the engine. The mixture must be rich for starting, accelerating and high speed operation. The mixture should be lean for operation at intermediate speed with a warm engine. The theoretically perfect mixture of air and gasoline contains 15 parts of air and 1 part of gasoline by weight.

### 3.5 Air-Fuel Ratio

The carburetor must supply the air-fuel mixture of varying proportions to suit the different operating requirements. The mixture must be rich for starting and must be relatively lean for idling and intermediate speeds. The air-fuel ratio for different speeds of a car can be as follows. For starting of the car, the air-fuel ratio is 9:1. It is called rich mixture. For idling condition, the air-fuel ratio lies about 12:1. It is called lean mixture.

For intermediate speeds between 35 to 105 km/hour, the air-fuel ratio varies further leans out to 15:1.

But at higher speeds from 120 to 150 km/hour, with a wide open throttle, the mixture is again enriched to about 13:1.

For acceleration at any speed the throttle is suddenly opened which causes a momentary enrichment of the mixture.

Two examples of acceleration are shown by dotted lines, on at 25 km/hour and the other at 45 km/hour.
### 3.6. Types of Carburetors and their Arrangements

Carburetors used in S.I. Engines may be up draught, down draught and side draught. This classification is based on the direction of air flow into the carburetor and air fuel mixture flow at the carburetor outlet to the inlet manifold.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Ppm by volume</th>
<th>Molecular weight</th>
<th>Mole fraction</th>
<th>Molar ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_2$</td>
<td>209,500</td>
<td>31,998</td>
<td>0.2095</td>
<td>1</td>
</tr>
<tr>
<td>$N_2$</td>
<td>780,900</td>
<td>28,012</td>
<td>0.7905</td>
<td>3.773</td>
</tr>
<tr>
<td>Ar</td>
<td>9,300</td>
<td>39,948</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$CO_2$</td>
<td>300</td>
<td>44,009</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air</td>
<td><strong>1,000,000</strong></td>
<td><strong>28,962</strong></td>
<td><strong>1.000</strong></td>
<td><strong>4.773</strong></td>
</tr>
</tbody>
</table>

![Fig 3.6](image1)

**Air fuel ratio for different speeds of a car**

![Fig 3.7](image2)

![Fig 3.8](image3)
In down draught carburetor, the air enters top of the carburetor and leaves at the bottom. In side draught carburetor, the air enters the top of the carburetor and leaves at the side. In up draught carburetor the air enters the bottom or side of the carburetor and leaves at the top. In semi down draught carburetor the direction of air flow is from top to bottom. Side drought carburetors are used on Hero Honda, Kawasaki Bajaj and Sunny.

Most passenger cars are used down draught carburetors.

Carter Carburetor

It is a down draught type carburetor. It is typical in construction like Zenith Carburetor.

It consists of the following circuit.

1. Float circuit
2. Starting circuit
3. Idle and low speed circuit
4. Port throttle circuit
5. Full throttle circuit
6. Acceleration pump circuit.

The float circuit controls the supply of the fuel from the fuel filter into the float chamber. The float is pivoted at a side of the chamber and operates a needle valve to close and open the passage through which the fuel enters the chamber.
At the time of starting the cold engine, the choke valve is operated to close the air supply. The choke valve is mounted eccentrically, due to which it opens automatically after the engine has started. The whole suction is applied on the main nozzle which delivers fuel. The air supply being quite small, the air fuel mixture becomes rich for starting. A rich mixture is required in small quantity for idling. The throttle valve is almost closed during the idling. Thus the engine suction is applied at the idle port which supplied the required air fuel mixture. For low speed the throttle valve is little opened. The main nozzle also begins to supply the fuel. The throttle valve is further opened for increasing the speed. At this stage, the throttle valve is partly opened and the fuel is supplied by the main nozzle only.

When the throttle valve is fully opened the maximum amount of air passes through the venture and a higher rate of fuel supply is required. This is achieved by means of the metering rod. When the acceleration pedal is depressed, the throttle valve is fully opened and simultaneously the metering rod is lifted up in the jet providing larger area for fuel supply. This amount of air fuel mixture is supplied for high speed.

**Zenith Carburetor**

The zenith carburetor is one of the most popular carburetors. It is found in many models as

1. Zenith negative
2. Stormberg
3. DBV
4. New Zenith
5. NV type  
6. W type  
7. WIA type  
8. Case emission type.

The current model of zenith carburetor contains economy device and accelerating pump. The old type of float chamber the fuel enters from the bottom and the float is controlled by toggle lever. This system is entirely eliminated in recent years. There are 3 jets – main jet, compensating jet and idling jet in the carburetor. This compensating jet is around the main jet. The choke valve is used for starting. For idling and slow speed running, the air enters through the holes A and B, mixes with the fuel in idling passage and the mixture passes to the idling jet. A separate knob is provided for idle adjustment, which controls the opening B to supply the mixture. When the throttle valve is opened, the main jet comes into action, along with the idling jet. On further opening the throttle valve, the whole suction is applied on the main and compensating jet, the idling jet is cut off. The compensating jet takes care to maintain correct air fuel ratio at different speeds.

![Fig 3.13 Solex Carburetor](image)

**Solex Carburetor**

The solex carburetor is a down draught type carburetor. It consists of a device for starting, idling, normal running and acceleration. It consists of starter valve in the form of flat disc having holes of different sizes. These holes connect the petrol jet and starter jet sides to the passage, which opens into the air horn just below the throttle valve. The starter lever is operated by the driver from the dash board, which adjusts the position of the starter valve, so that either bigger or smaller hole comes opposite the passage. At the time of starting, bigger holes
connect the passage so that more fuel may go to the engine. The throttle valve being closed, the whole of engine suction is applied to the starting passage 1, so that the petrol from the float chamber passage through the starter petrol jet and rises into passage 2. Some of it comes out, and mixes with the air entering through the air jet. This air fuel mixture is rich enough for starting for engine.

Fig 3.14

Fig 3.15

After the engine has started, the starter lever is brought to the second position, so that smaller holes connect the passage reducing the amount of petrol. In this position the throttle valve is also partly opened, so that the petrol is also coming from the main jet. The reduced mixture supply from the starter system in this situation is, however, sufficient to keep the engine running. When the engine reaches the normal running temperature, the starter is brought to “OFF” position.

**S.U. Carburetor**

The SU carburetor is an example of constant vacuum type of carburetor. It consists of a single jet in which a tapered needle operates. The area of the throat is varied by means of a piston which slides up and down. The tapered needle is connected to the accelerator.

Fig 3.16

Fig 3.17 Section View of Carburetor
When the accelerator is operated the piston move up and down in the throat, controlling the supply of air. And the needle moves up and down to the jet controlling the supply of fuel. When the piston moves down, throat area decreases the annular area in the jet to pass less fuel. The piston and tapered needle are so designed that they maintain correct air fuel mixture at different operating conditions of the engine.

The upper side of the piston is connected to the throttle passage through a slot cut in the piston. The lower side is covered to the atmospheric pressure. Thus, the piston at any instant depends upon the balance of its own weight against the vacuum force. As the weight of the piston is constant the vacuum also remains constant. The jet can move broadly up and down with respect to the tapered needle by an adjusting screw fitted at the bottom of the screw. This is done for adjusting the mixture strength. There is no separate idling or slow speed system and no accelerating pump. This type of carburetor is the rapid response during accelerating and hence it is fitted with racing cars and in most of the scooters and motorcycles.

### 3.7 Petrol Injection System in Modern Vehicles

Petrol injection system is used in modern cars where a single carburetor is used to deliver air fuel mixture into multi cylinder engine. It is likely that some of the cylinders may not get regular supply of the mixture. The use of petrol injection system overcomes these difficulties. It ensures unrestricted fuel supply and controls it at all times of the engine operation. Petrol injection gives both higher power and low specific fuel consumption. But it has some disadvantage also like higher initial cost and maintenance cost, complicated design and difficult in operation.

**Construction layout of petrol injection system**

The petrol injection fuel supply requires following main parts.

1. Petrol injection pump
2. Acceleration pump
3. Metering distributor
4. Injection nozzle.

It uses an injection pump to each cylinder, the pump being actuated through rockers by a camshaft rotating at half the engine speed. The accelerator pedal controls a butterfly throttle which regulates the air supply to the inlet manifold and at the same time varies the return stop of each pump plunger to control its stroke and thus the rate of fuel delivery. This is alone through an ingenious “3 dimensional cam” which adjusts the pivot points of the pump rockers. The same cam is also the influenced by a governor device in accordance with engine speed to maintain correct mixture over the entire petrol directly into the inlet manifold for starting purposes, operating only whilst the starter motor is energized.

### 3.8 Working Principle of Supercharger

The process of supplying to the engine the air fuel mixture above the atmospheric pressure is called super charging. A super charger increases the pressure of the air fuel mixture from the carburetor before it enters the engine.

![Supercharger Diagram](image)

**Fig 3.19**

**Superchargers**

A supercharger is a device which increases the pressure of the air fuel mixture from the carburetor before it enters the engine. It is connected between the carburetor and the cylinder in the way of intake manifold. It is usually driven by the engine through suitable gears and shafts. There are 3 types of superchargers.

1. Centrifugal type
2. Vane type
3. Roots air blower type.
Centrifugal Type Supercharger

It consists of an impeller which rotates at a very high speed, about 10000 RPM. The air fuel mixture enters the impeller at the centre and after passing through the impeller and diffuser vanes goes out of the casing to the engine cylinder. Duct to high speed of the impeller is forced into the cylinder at a higher pressure.

Scavenging

The process of driving exhaust gases out of the cylinder, and replacing it with fresh air is called scavenging. In two-stroke diesel engines, the cycle is completed in one revolution of the crankshaft or two strokes of the piston. A series of ports or openings are arranged around the cylinder in such a position that the ports are opened when the piston is at bottom of the stroke. A blower forces air into the cylinder through the opened ports, expelling all the remaining exhaust gases through the open exhaust valve thereby filling the cylinder with fresh air. There are two methods of scavenging:
Loop scavenging: in this type, inlet and exhaust ports are provided on opposite sides of the cylinder. The air entering the cylinder drives out the burnt gases in the form of a loop.

Uniflow scavenging: An exhaust valve is provided on the top of the cylinder. Air entering the cylinder through the inlet port drives out burnt gases flowing in the same direction.

Summary

- A petrol engine uses petrol as the fuel.
- The capacity of the engine does not imply the volume of the fuel tank but the volume of the cylinder.
- The supply of rich or lean air fuel mixture is done by the carburetor.
- Idle air fuel mixture gives the engine to run idle when the vehicle stops for a less time.
- Idle condition is maintained at the position when the runs in neutral gear position.
- Rich air fuel ratio is required when the vehicle is overcoming an up road or carrying heavy loads.

Model Question

1. Draw a neat line diagram of petrol engine fuel system.
2. Explain the constructional details of fuel tank, fuel lines.
3. Explain the construction and working of fuel pump used in a petrol engine.
4. What are the requirements of an automobile carburetor
5. Draw the graph between the speed and air fuel ratio for a petrol engine.

6. Explain the air fuel ratio for different conditions.

7. Explain the types of carburetor according to direction of air flow.

8. With the help of a neat sketch explain the construction and working of a Carter Carburetor.

9. Write the constructional details of a Zenith Carburetor.

10. How a Solex carburetor work?

11. Explain the constructional details of a S.U, Carburetor.

12. Discuss about the petrol injection system in a Modern Vehicles.

13. Explain the working principle of a) a Super charger and b) A Scavenger.

**Practical Work/O.J.T**

1. Observe fuel feed system in 2&4 wheeler petrol engines

2. To know how the service carburetor

3. Observe about scavenging

4. Study construction and working of different carburetors

5. Study construction and working of fuel pump.

6. To observe supercharger and its working.
UNIT 4

Diesel Engine

Learning Objectives

After studying this unit, you will be able to

• Know about construction and working of 2 and 4 stroke diesel engines.
• Know about different combustion chambers used in diesel engines
• Know about Valve timing diagram of 2 stroke and 4 stroke diesel engines

Introduction

In two stroke diesel engines, all the work i.e. intake, compression, power and exhaust are completed in two strokes of the piston or one complete revolution of the crankshaft. In two stroke cycle engines there is one working stroke in two revolutions of the crankshaft or in a cycle of two strokes of the piston and these are usually called the upward and downward strokes.

4.1 Working Principle of 2 Stroke Diesel Engines

In two stroke diesel engine both the ports i.e. intake and exhaust are made in the cylinder and the piston used is also dome type. When the piston travels down, the exhaust port gets uncovered by the piston. As such the burnt gases escape through this port. When the piston travel a little more down, the inlet port also gets uncovered by piston from where the fresh air finds its way in the cylinder.
Upward stroke

When the piston starts traveling up from BDC to TDC, it closes the inlet and exhaust ports and the air which is trapped in the cylinder starts getting compressed. Due to high compression ratio the temperature and pressure of air rises very high. As soon as the piston reaches near TDC, diesel fuel is sprayed in fine atomized form to the highly compressed gases.

Downward stroke

As stated above due to spraying of atomized diesel on highly compressed air, there in spontaneous combustion gases expand rapidly causing piston to travel from TDC to BDC giving us power stroke.

As soon as the piston reaches near BDC the exhaust gases escape out through exhaust port uncovered by the piston thereby relieving piston top of thrust caused by expanded gases. In the mean time, the inlet port also opens causing air to come in the cylinder. This air also helps in sweeping out exhaust gases and thus the cycle continuous.

Working Principle of Four Stroke Diesel Engine

The working of a 4 stroke compression ignition engine consists of the following processes

1. Suction Stroke
2. Compression stroke
3. Power or working stroke
4. Exhaust stroke
1. **Suction Stroke**

When the piston moves from TDC to BDC the inlet valve opens and due to the downward movement of piston a partial vacuum is created in the cylinder above the piston. Due to this partial vacuum air is sucked in at the end of stroke the inlet valve closes.

2. **Compression Stroke**

When the piston starts moving from BDC to TDC the air which has been trapped in the cylinder starts getting compressed, when the piston reaches near TDC, the trapped air gets so compressed that its temperature reaches between 5000°C to 6500°C. This higher increase in temperature is because of higher compression ratio, in this stroke both valves remain closed.

3. **Power Stroke**

At the end of compression stroke diesel oil is sprayed in fine atomized form to the burning hot air which has attained temperature of approximately 5000 to 6500°C here we would like to mention that self-ignition temperature of diesel fuel at atmospheric pressure is 3500°C to 4500°C as such atomized fuel in hot air gets ignited in more or less rapid explosion making gases to expand. We have earlier studied that piston is the only moving part in the cylinder.

4. **Exhaust Stroke**

In this stroke, the exhaust valve opens and due to moving of piston from BDC to TDC, the burnt gases are pushed out.

The inlet valve opens in suction stroke but as a matter of fact it opens 100 to 220 before TDC in exhaust stroke. So that valve is fully open when piston
starts moving down and enough time is given for air to get it. The inlet valve remains open in compression stroke 200 to 300 after BDC. This once again is to allow air which was coming to cylinder to cylinder with great velocity to fill cylinder completely.

### 4.2 Valve Timing Diagram of 2 Stroke and 4 Stroke Diesel Engines

![Valve Timing Diagram](image)

### 4.3 Types of Diesel Engine Combustion Chambers

The Various types of diesel engine combustion chambers are

1. Direct injection combustion chamber
2. Pre combustion chamber
3. Turbulence combustion chamber
1. Direct Injection Combustion Chamber

It is used in medium and high speed engines. The combustion chamber is made like a groove inside the top of the piston. The injection is filled at the centre of the cylinder head so that it injects the fuel in the combustion chamber. Leyland buses are used this type of chambers.

2. Pre combustion Chamber: It is usually used in high speed engines. There are two combustion chambers – one is auxiliary combustion chamber and other is main combustion chamber. This auxiliary chamber is smaller in size than the main combustion chamber and is called pre combustion chamber where it partly burns. This partly burnt fuel goes through a small orifice in the main combustion chamber, where the complete combustion takes place. The turbulence created in combustion chamber helps to ignite the fuel completely.
3. **Swirl combustion or Turbulence combustion chamber**: It is of circular motion which is given to the incoming air during the suction stroke. In the swirl combustion the air is given a swirl while coming in the cylinder. The fuel is injected in this swirled air so that mixing and burning of fuel takes place completely.

![Fig 4.6 Turbulence Combustion Chamber](image)

**Summary**

- There are upward stroke and downward stroke in two stroke engines
- Two stroke engines are very light and are less duty.
- Maintenance of two stroke engines is very easy compared to four stroke engines.
- Only ports are used in two stroke engines.
- Four stroke engines comprises of suction, compression, power or expansion and exhaust strokes.
- Four stroke engines contain valves.
- The valves of a four stroke engine are operated by valve operating mechanism.
- Overhead mechanism, side valve mechanism are most commonly used valve mechanisms in four stroke engines.
- The four stroke engines are lubricated by splash or pressure lubrication system.
• The power developed by a four stroke engine is more compared to a two stroke engine.
• A diesel engine produces more power output than a petrol engine of same capacity.
• The diagram which shows the valve opening and closing time of an engine is called the valve timing diagram.

**Model Question**

1. Enumerate the working of a two stroke diesel engine with the help of neat sketches.

2. Discuss the advantages and limitations of a diesel engine over a petrol engine.

3. A diesel engine requires more compression ratio. Explain

4. The power output of a diesel engine is more than that of a petrol engine. Explain

5. Briefly explain the valve timing diagram of a diesel engine with the help of a neat sketch.

6. Discuss the various types of combustion chambers

**Practical Work/O.J.T**

1. study comparison between construction and mechanism of diesel & petrol engines

2. observe types of diesel engine combustion chambers used in different vehicles

3. study c&w of 2 stroke diesel engines

4. study c&w of 4 stroke diesel engines

5. observe valve timing diagram of diesel engines
Learning Objectives

After studying this unit, you will be able to

• Know about Fuel Feed system in Diesel engines
• Know about construction and working of Fuel Injection Pump
• Know about construction and working of nozzles and governors

Introduction

Diesel engines use fuel oil. the fuel is sprayed into the compressed air in the combustion chamber at the end of the compression process. heat of compression ignites the fuel oil, and combustion process follows.

The diesel fuel is a mixture of different hydrocarbons which have boiling points in the range of 180-360 degrees centigrade. fuel for C I engines are classified into light, medium and heavy diesel fuels. large slow engines can handle variety of fuels than small high speed engines.

To run an engine, the fuel from the tank must reach by some means to the engine cylinder. In diesel engine, the fuel is injected into the engine cylinder by an injector.
5.1. Line Diagram of Diesel Engine Fuel System

![Fuel System Diagram]

5.2. Types of Fuel Feed Pump—Construction and Working

A fuel feed pump is used to supply the fuel to the fuel injection pump after lifting the fuel from the fuel tank. This is a plunger type pump driven by an eccentric provide on the camshaft of the fuel injection pump, through the roller tappet and the spindle. It consists of the following main parts: 1) body with a barrel, 2) plunger, 3) plunger spindle, 4) plunger return spring, 5) roller tappet, 6) delivery valves, and 7) hand primer.

When the plunger is pushed inwards under the action of return spring pressure, a suction is created inside the barrel. This lifts the suction valve from its seat and the fuel is sucked from the fuel tank. In due course when the camshaft rotates and the eccentric reaches at its maximum throw, the plunger forces the fuel against the spring pressure and delivers it through delivery valve. The suction valve remains closed at this juncture.

![Fuel Feed Line Diagram]

A hand operated priming pump is incorporated in its construction for the purpose of bleeding the fuel, as and when required. Sometimes the plunger
becomes inoperative when back pressure of delivered fuel is build-up on it, and later becomes operative on release of this pressure.

**Requirement of Fuel Injection System**

In the engine to develop full power and operate efficiently its fuel system must do the following:-

**Meter (measure)**

The fuel injection system must measure the fuel supplied to the engine very accurately. Since fuel requirements vary greatly from low to high engine speed. Fuel is measured within the injection pump or injector by measuring it as it fills the pumping chamber or as it leaves the pumping element.

**Time**

The timing of fuel injected into the cylinder is very important during engine starting, full load and high speed operation. Diesel engines start best when fuel is injected at or very close to Top Dead Center, since it is at this point that air in the chamber is the hottest. After the engine is started and running at high speed, the injection timing may have to be advanced to compensate for injection lag, ignition lag, and other factors that influence combustion within the engine cylinder.

**Pressure**

The fuel system must pressurize the fuel to open the injection nozzle or the pressure required to open the nozzle. Some pressure is required to inject the fuel into the combustion chamber to offset the pressure of compression, which may be 350 to 450 psi (25 to 32 kg/cm²).

**Atomize**

The fuel must be atomized when it is injected into the combustion chamber. Since in atomized fuel will not burn easily. The degree of atomization required will vary from engine to engine depending on the combustion chamber design.

**Distributor**

Closely related to timing the distribution of fuel must be accurate and according to the engines firing order distribution pumps deliver fuel to each pump outlet in succession and the lines are hooked to the cylinder in the correct firing order, much like a distributor used on a gas engine.

**Control, start and stop injection**

Injection of fuel must start quickly and end quickly. Any delay in beginning will alter the pump to engine timing, causing hard starting and poor running engines.
5.3 Types of Fuel Injection Systems

There are two methods of fuel injection in compression ignition engines

1. Air blast injection 2. Airless or solid injection.

Air Blast Injection

This method was originally used in large stationary and marine engines. But it is now obsolete. In this method the air is first compressed to a very high pressure. A blast of this air is then injected carrying the fuel along with it into the cylinder. The rate of fuel injection is controlled by varying the pressure of the air. The high pressure air requires multistage compressor so as to keep the air bottles charged. The fuel ignition by the high temperature of the air caused by the high compression.

Airless or Solid Injection

In this method the fuel under high pressure is directly injected into the combustion chamber. It burns due to the heat of compression of the air. This method requires a fuel pump to deliver the fuel at the high pressure. This method is used for all types of small and big diesel engines.

It can be divided into two systems.


a. Individual Pump System: In this system, each cylinder has it individual high pressure pump and a metering unit. It is quite compact method and involves higher cost.

b. Common Rail System: In this system, the fuel is pumped by a multi cylinder pump into a common rail, the pressure in this rail is controlled by relief valve. A metered quantity of fuel is supplied to each cylinder from the common rail. The airless injection in comparison to air blast injection, is simple in construction, light in weight and cheap. The fuel is atomized properly. It is quite suitable for engine of higher output. But it receives higher accuracy in manufacturing the pump barrel and fuel injection plunger.

Diesel Fuel Feed System

The fuel system of a diesel engine consists of the following:-

1. Air cleaner
2. Fuel tank
3. Fuel filter
4. Injection pump
5. Injector
6. Fuel lines
7. Fuel gauge

![Diagram of Diesel Fuel Feed System](image)

**Fig 5.3 Diesel Fuel Feed System**

**5.4 Fuel Injection Pump Construction and Working**

The single plunger diesel fuel injection pump is distinguished from the conventional in line pumps of the PE and PF series by having only one plunger and barrel assembly, common to all fuel outlets of the pump where as each fuel outlet of an inline pump is served by its individual plunger and barrel assembly. The single plunger injection pump described here in features a unique hydraulic governing system which has no rotating mechanical parts and which provides extremely accurate fuel quality control and fast response to variations in fuel demand resulting in very close regulation.

A single plunger by reciprocating action pressurizes the fuel and feeds it into two distinctly separated circuits, primarily at high pressure to the nozzle and holds assemblies and secondly into an auxiliary circuit for the function of governing the fuel quantity delivered to the engine. By simultaneous rotation of the plunger, the pressurized fuel quantity delivered to the engine from the primary circuit is distributed to the individual high pressure outlets. All accessory units such as governor, fuel supply pump and the automatic timing device, normally attached
to the outside of an inline pump are wholly integrated into the single plunger pump to reduce bulk and weight.

The single plunger injection pump can be mounted in any position. In operation, its interior is completely filled with diesel fuel under slight pressure in order to prevent intrusion of air and dust and also to prevent rust formation caused by condensation. Excess fuel is re-circulated within the pump to provide adequate cooling and lubrication.

**Fuel Injector (Atomizer)**

The purpose of the fuel injector is to inject a small volume of fuel in a fine spray and to assist in bringing each droplet into contact with sufficient oxygen to give quick and complete combustion. C.A.V. fuel injector consists of a needle valve which is pressed on its seating in the nozzle by a plunger or spindle. A compression spring controls the pressure upon the plunger by which the needle valve opens. A nozzle is attached to the body of the injector by a cap nut. The fuel enters the nozzle through drillings in the injector body. The fuel may pass from a gallery down the sides of the lower parts of the needle valve. The body or the nozzle holder provides access for the fuel and an outlet for the fuel that leaves into the area occupied by the spring.

**5.5 Fuel Injection Nozzle**

The performance of a modern high speed oil engine depends largely upon the proper functioning of its fuel injection system. The engine be not only provide with fuel in quantities exactly timed and proportional to the amount of work it is received to do.

The fraction of the nozzle, which is held in position in the cylinder head by the nozzle holder. The nozzle may have to deal with many hundreds of fuel charges per minute, with widely varying conditions of pressure and temperature, the uneven precision necessary in the production of these parts will be appreciated.

**Types of nozzles**

a. Single hole nozzle
b. Multi hole nozzle
c. Long stem nozzle
d. Pintle nozzle
e. Delay nozzle
f. Pintaux nozzle
a. Single Hole Nozzle

The single hole nozzle has one hole drilled centrally through its body which is closed by the nozzle valve. The hole can be of any diameter from 0.2 mm upwards. The single hole is bored at an angle to the vertical center line of the valve as required.

b. Multi Hole Nozzle

This nozzle can have a varying number of holes drilled in the bulbous end under the valve seating. Their actual number, size and disposition being dependent upon the requirements of the engine concerned.

c. Long Stem Nozzle

For direct injection engines where, owing to a limited space between the valves in the cylinder head it is not possible to provide adequate cooling for the standard short stem nozzle, an alternative form of nozzle with a small diameter extension has been developed.

d. Pintle Nozzle

The pintle nozzle is designed for use in the engine combustion chambers of the air cell, swirl chamber or pre-combustion type, the valve stem is extended to form a pin or pintle which produces through the mouth of the nozzle body.

![Types of nozzles](image-url)
e. Delay Nozzle

The Delay nozzle is a development of pintle type, having an auxiliary spray hole to assist easy starting under cold conditions. At engine starting speeds the nozzle valve is not lifted sufficiently to clear the pin hole and the fuel is discharged through auxiliary hole. At normal running speeds, however when pressures in the fuel system is higher, the nozzle valve is withdrawn from the pintle hole allowing the bulk of the fuel to be discharged through it.

Phasing of Injection Pump

The setting of the fuel injection pump of the diesel engine, which keeps an equal interval between the starting and ending of the diesel injection, is known as phasing.

Calibration of Injection Pump

In a multi-cylinder engine it is necessary that equal and specified quantity of fuel is supplied to each cylinder by the fuel injection pump at a specified time. The measurement of fuel delivered by each plunger with the control rod in a fixed position and its comparison is called calibration of FIP.

5.6 Governors

All the diesel engines are equipped with governors to ensure that engine does not pick up speed when there is no load on it as the speed of the engine is dependent on the quantity of fuel injected. The governor has also to supply enough fuel when engine is loaded so that the vehicle speed does not drop down.

Types of Governors

1. Mechanical Governor
2. Pneumatic Governor
3. Combined (Mechanical and Pneumatic) governor

Construction and working of Mechanical and Pneumatic Governors

Mechanical governors are fitted to large engines on our extension of the pump camshaft and works on centrifugal force principle. In this case 2 weights are hinged to the camshaft pump. Both weights are hinged with lever which in turn is connected to lever with the help of coupling pin, when we increase the speed of engine through an accelerator, the camshaft revolves at high speed, the
weights fly out due to centrifugal force taking along with it the control rod, to stop position due to linkages.

![Fig 5.5 Mechanical Governor](image)

These weights are fixed to the cam shaft with the help of spring placed in them. These springs do not allow the weights to fly out uncontrolled. As such the control rod does not come to stop position, but maintained at intermediate balanced position. As a matter of fact, the springs fitted in the weight counter balance the centrifugal force produced by fast moving camshaft.

![Fig 5.6 Pneumatic Governor](image)
Pneumatic Governor

The pneumatic governor covers the complete range of engine speed i.e. from idling speed to maximum speed. The complete governor consists of 1. Venturi air flow control unit 2. Diaphragm unit. Venturi air flow control unit is fixed in inlet manifold under the air cleaner. In this unit a small venture is fixed by the side of butterfly valve, so that quantity of air can be increased or decreased as delivered. The butterfly valve is linked to the accelerator pedal with suitable linkage. A maximum and idle stop adjustment provided on the venture unit. Diaphragm unit is fitted at the end of injection pump over the opening of control rod. This consists of 2 chambers separated from each other by leather or rubberized diaphragm. The outer chamber is called vacuum chamber and is connected to venturi unit while other unit is open to atmospheric pressure. At the end corner of vacuum chamber is fitted a spring which keeps the diaphragm and control rod towards full load position. The diaphragm is linked to the control rod with the help of a pin and is kept in fuel load position with the help of diaphragm spring. But as soon as the engine starts, vacuum produced in the venturi acts on diaphragm thus pulling it outward, taking control rod along with it. As the speed of engine increases or decreases as such the diaphragm is pulled out and pushed in and speed is kept under control. To stop the engine a stop lever is also placed in the atmospheric chamber which when pulled pushes the diaphragm along with control rod to stop position.

Fig 5.7 Hydraulic Governor

Summary

- Diesel is extracted from its ore called petroleum.
- The self ignition temperature of Diesel fuel is less than that of the petrol. That is the reason why diesel is ignited by the heat of compression.
- The charge is supplied into the cylinder combustion chamber through the opening of the accelerator.
• When the engine is in idle condition, a small quantity of charge enters the combustion chamber.

• The fuels used in the engines should be volatile. Volatility is the property of tendency of it to pass from the liquid into the vapor state at any given temperature.

• For easy starting, the fuel should be highly volatile.

• For smooth acceleration, a sufficient proportion of the gasoline must be sufficiently volatile.

• Pressure feed system and pump system of fuel injection are adopted in four wheelers.

• The filler neck is closed by a cap, which is having a small hole for vent.

• The fuel pump works with the rotation of the crank shaft.

• With increase in speed of the crank shaft the pump supplies more quantity of fuel.

• The opening of the plunger supplies the quantity of fuel to the injector.

• The fuel injector is also called atomizer.

• There should not be any air bubble in the injection system pipe line.

• Removing the air bubble in the pipe line, filters and injection pump is called bleeding.

• Bleeding is done by opening the bleeding screws. Whenever the filter or pipe is replaced, bleeding should be done.

Model Question

1. Draw a neat diagram of diesel engine fuel system.

2. Mention the requirements of diesel engine fuel feed system.

3. What are the types fuel injection systems?

4. Briefly explain the construction of Fuel Injection Pump with the help of a neat sketch.

5. Describe about the Phasing and Calibration of a Fuel Injection Pump.
6. How do you mean the importance of a governor?

7. Mention the types of governors.

8. Explain the types of Governors with neat sketches.

9. Draw and explain with the help of a neat sketch the working of a fuel injector.

10. Mention the types of fuel injectors.

**Practical Work/O.J.T**

1. Identify different vehicle fuel feed systems

2. Study c&w of fuel pumps

3. Study c&w of governors

4. Know how the phasing & calibration of fuel injection pump

5. Know how the injector testing on test bench


Learning Objectives

After studying this unit, you will be able to

• Know about objectives of lubricants and types of lubricants
• Know about properties and requirement of lubricants
• Know about lubricating system

Introduction

Lubrication is very important for reciprocating parts of an engine. Lubrication helps to provide cushioning to the reciprocating parts as well as it cleans the parts from dust. Lubrication helps to prevent the parts from corrosion and wear and tear.

6.1 Types of Lubricants

The various lubricants used in automobiles are discussed below

1. Motor Oil: Diesel engine oil and Spark Ignition engine oil differ primarily in detergency properties. Naphthalene bake oils of low viscosity index may be used as diesel oils.

2. Lubricants: These are used to prevent friction between the parts of any machine lubricants may be liquid like gear oil, semi solid like grease.
3. **Cylinder Oil**: It is unfinished oil stock used directly as lubricant for steam engine cylinders or manufacture of bright stock. It is usually filtered but not dewaxed.

4. **Neutral oil**: It is light or low viscosity lubricating oil stock used for compounding of motor oils and light machine oils.

5. **Bright stock**: It is heavy or high viscosity lubricating oil stock for compounding of motor oils. Lubricating is essentially required in motor vehicle maintenance. To supply lubricating oil between the moving parts is simply termed as lubrication. Lubrication of all moving parts is essential to reduce friction wear and to prevent seizure.

**Objects of Lubrication**

1. To reduce friction between the moving parts.
2. To reduce wear of the moving parts.
3. To act as cooling medium for removing heat.
4. To keep the engine parts clean, especially piston rings and ring grooves, Oil ways and filters.
5. To absorb shock between bearings and other engine parts thus reducing engine noises and extending engine life.
6. To form a good seal between piston rings and cylinder walls.

### 6.2 Properties of Lubricants

An engine lubricating oil must have certain properties or characteristics for it satisfactory function as follows.

1. Viscosity
2. Flash point
3. Fire point
4. Cloud point
5. Pour Point
6. Oiliness
7. Corrosion
8. Color
9. Dilution
10. Emulsification
11. Physical stability
12. Chemical stability
13. Sulphur content
14. Specific gravity
15. Neutralisation
16. Adhesiveness
17. Film strength
18. Cleanliness

**Viscosity:** It is a measure of the resistance to flow or the internal friction of an oil. Viscosity is one of the most important properties of engine lubricating oil. It is used universally to grade lubricants and it is measured by viscosimeter.

**Flash Point:** The flash point is defined as the lowest temperature at which the lubricating oil will flash when a small flame is passed across its surface.

**Fire Point:** If the oil is heated further after the flash point has been reached, the lowest temperature at which the oil will burn continuously is called the fire point.

**Cloud Point:** The oil changes from liquid state to a plastic or solid state when subjected to low temperatures. In some cases the oil starts solidifying which makes it to appear cloudy. The temperature at which this takes place is called the cloud point.

**Pour Point:** It is the lowest temperature at which the lubricating oil will pour. The pour point of an oil is lubrication of its ability to move at low temperatures. This property must be considered because of its effort on starting an engine in cold weather and on free circulation of oil through exterior feed pipes when pressure is not applied.

**Oiliness:** It is the characteristic property of the oil when it has oiliness. This property is highly desirable in helping the lubricant to adhere to the cylinder walls.

**Corrosion:** The corrosion has been defined as the destruction of a solid body by chemical or electrochemical action which starts intentionally from its
outer surface. A lubricant should not corrode the working parts and it must retain its properties even in the presence of foreign matter and additives.

**Color:** Color of a lubricating oil is not of so much importance for its property expects as a test for checking the uniformity of any given grade or brand of oil.

**Dilution:** During the combustion petrol vapor may escape past the piston rings if the rings are worn or broken out considerable amount such fuel is mixed with the crank case oil and dilutes it. Thus affecting its lubricating property. The rest to determine the amount of dilution in crankcase oil indicated how far the oil could be used when mixed with petrol vapor.

**Emulsification:** The lubricating oil, when mixed with water is emulsified and loses its lubricating property. The emulsification number is an index of the tendency of an oil to emulsify with water.

**Physical stability:** The lubricating oil must be stable physical at the lower and the highest temperatures between which the oil is to be used. At the lowest temperature there should not be any separation of solids and at the highest temperature it should not vaporize beyond a certain limit.

**Chemical stability:** The lubricating oil should also be stable chemical when there should not be any tendency for oxide formation. The oxidation produced being sticky clog the working parts, cause the faulty piston rings and valve action. The oil should also not decompose at high temperatures to form carbon which makes spark plug and valves faulty to function.

**Sulphur content:** If sulphur is present in considerable amount in the lubricating oil it promotes corrosion. The corrosion test shows the amount of sulphur content.

**Specific Gravity:** The specific gravity is a measure of the density of the oil. It is determined by a hydrometer that floats in the oil. And the gravity is read on the scale of the hydrometer at surface of the oil. The scale used is the recommended by the American petrol institute and the result is called the API gravity.

**Neutralization number:** The oil may contain impurities that are not removed while refining. It may contain alkaline or acid products. The neutralization number test is a simple procedure to determine acidity or alkaline of the oil.

**Adhesiveness:** It is the property of the lubricating oil due to which the oil particles stick to the metal surfaces.
**Film Strength**: It is the property of a lubricating oil due to which the oil retains thin film between the two surfaces even at high speed and load. The film does not break and the two surfaces do not come in direct contact.

**Cleanliness**: The lubricating oil must be clean. It should not contain dust and dirt particles. These impurities may either be filtered out or removed with the change of the oil at periodic intervals.

**S A E number**: The Society of Automotive Engineers (S A E) rates oil viscosity in two different ways, for winter and for other than winter. Winter grade oils are tested at 0°F and 210°F. There are 3 grades, SAE SW, SAE 10W and SAE 20W. The W indicates the oil is winter grade. For other than winter the grades are SAE 20, SAE 30, SAE 40 and SAE 50, all without the W suffix. Some oil had multiple ratings which mean they are equivalent in viscosity, to several rating oils.

For example – SAE 30W oil is comparable to SAE 10W, SAE 20W and SAE 30W oil.

### 6.3 Requirements of Lubricants for Automobiles

1. To minimize the friction and wear.
2. To cool by carrying away heat.
3. To seal the pistons and thus preventing escape of gases in the cylinders with consequent loss of power.
4. To cushion the parts against vibration and impact.
5. To clean the parts as it lubricates them, carrying away impurities.
6. Lubrication is mainly required for main crankshaft bearings.
7. To lubricate the big end bearings.
8. Lubrication for the small end bearings.
9. Crankshaft bearings, piston rings and cylinder wall, timing gears, valve mechanism are lubricated.

### 6.4 Different Systems of Lubricating Systems

The various systems of lubrication adopted in automobiles are

1. Petroil lubricating system
2. Splash lubricating system
3. Forced feed lubricating system

4. Dry sump lubricating system.

**Petroil lubricating system:** This system of lubrication is generally adopted in two stroke petrol engines like scooters, mopeds and motor cycles. It is the simplest form of lubricating system. It does not consist of any separate part like oil pump for the purpose of lubrication. The lubricating oil is mixed into the petrol itself while filling in the petrol tank of the vehicle, in a specified ratio. When the fuel goes into the crank chamber during the engine operation, the oil particles go deep into the bearing surfaces and lubricate them. The piston rings, cylinder walls, piston pin etc. are lubricated in the same way.

If the engine is allowed to remain unused for a considerable time, the lubricating oil separates off from petrol and leads to clogging of passages in the carburetor, resulting in the engine starting trouble.

**Splash Lubrication system:** In this system of lubrication, the lubricating oil is stored in an oil trough or sump. A scoop or dipper is made in the lowest part of connecting rod. When the engine runs, the dipper dips in the oil once in every revolution of the crankshaft and causes the oil to splash in the cylinder walls. This action effects the lubrication of the engine walls, piston rings, crankshaft bearings and big end bearings. Splash system mostly works in connection with the pressure system in an engine, some ports being lubricated by splash system and other by pressure system.

![Fig 6.1 Splash Lubrication](image)
Pressure system: In this system of lubrication, the engine ports are lubricated under pressure feed. The lubricating oil is stored in a separate tank on the sump, from where an oil pump takes the oil through a strainer and delivers it through a filter to the main oil gallery at a pressure of 2-4 kg/cm². The oil from the main gallery, goes to the main bearings, falls back to the sump, some is splashed to lubricate the cylinder walls and the remaining goes through a hole to the crankpin. From the crankpin it goes into the piston pin through a hole in the connecting rod web, where it lubricates the piston rings.

For lubricating camshaft and timing gears, the oil is led through a separate oil line from the oil gallery. The valve tappets are lubricated by connecting the main oil gallery to the tappet guide surfaces through drilled holes. An oil pressure gauge at the instrument panel indicates the oil pressure in the system clear off the oil from dust metal particles and other harmful particles.

Pressure system of Lubrication

![Fig 6.2 Forced lubrication](image)

Parts of Lubricating System

- Oil sump or tank
- Oil pump
- Oil cooler
- Oil filter and strainer
- Oil pressure gauge
- Oil level indicator
- O.P. indicating light
**Dry Sump Lubricating System:** The system in which the lubricating oil is stored in the oil sump is called wet sump system, like the pressure system. But the system in which the lubricating oil is not kept in the oil sump is known as dry sump system. In this system the oil is carried and separate tank from where it is fed to the engine. The oil which falls into the oil sump after lubrication is sent back to the oil tank by a separate delivery pump. The system consists of two pumps, one to feed the oil and the other to deliver it back to the oil tank. This system is used in saturation where the vehicle has to change its position continuously, like in air crafts. The main advantage of this system is that there is no chance of break down the oil supply during up and down movement of the vehicle.

![Fig 6.3 Dry Sump](image)

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**6.5 Function of Oil Filters**

The main function of the oil filters is to filter out the dirt or grit particles from the oil. The oil filters clears the dust particles settled in the oil through the burning of the fuel. Thus the oil filters are helpful to clean the various parts of an engine from dust and dirt.

**6.6 Types of Filtering Systems**

There are two types of filtering systems. They are

1. Full flow system
2. By pass flow system.

In **Bypass filter system**, the whole of the oil does not pass through the filter at the same time, but some of the oil without being filtered goes to the bearings. Remaining oil passes through the filter and then goes to bearings. When the engine is running continuously for a long period, the whole oil is however filtered.
In **full flow system**, the whole oil passes first through the filters and then goes to the bearings. If the filter is clogged due to any reason, the system fails completely and bearings would be starved.

![Fig 6.4 Lub Oil Filters](image)

### 6.7 Types of Filtering Elements

Different types of filtering elements are used in automotive engines.

1. Cartridge type
2. Edge type
3. Centrifugal type.
The Cartridge type consists of a filtering element placed in a metallic casing. The casing has inlet and outlet oil pump enters casing through the filtering element, which takes up all the impurities. The filtered oil then comes out from the casing and goes to the oil gallery. The filtering element may be cleared when clogged. The Edge type filtering element consists of a number of discs in a casing through which the oil passes. The alternate discs are mounted over a spindle and discs, between these are fixed to a separate square rod. The clearance between the discs is only a few thousand of centimeter. When the oil flows through this small clearance, it leaves impurities on the disc peripherals.

The Centrifugal type consists of a stationary casing, rotor casing, central spindle and tubes with jets. The important oil enters the hollow central spindle and through holes around its periphery, the oil goes to the rotor casing. From the rotor casing the oil goes in the tubes, at the ends of which jets under pressure, the reaction of which gives the motion to the rotor casing so that it starts rotating. The oil from the jets impinges on the walls of the stationary casing under heavy pressure, where the impurities are retained and the clean oil falls below which is taken for use. The filter walls are cleared periodically.

**6.8 Necessity of Crankcase Ventilation**

The products of combustion contain mainly nitrogen, water and carbon dioxide, sulphuric acid articles may also be present due to sulphur content in the fuel. It is quite possible that the product of combustion may leak through the piston rings into the crankcase oil by slipping past the piston rings. Thus the lubricating oil in the crankcase becomes dilute when mixed with water and gasoline which leak past the piston rings. The acid causes corrosion of the crankcase
metals as water does. If either or both are allowed to enter and remain in the crankcase, the crankcase ventilation removes all these unwanted particles from the crankcase, which leak past the piston rings. It prevents the lubricating oil from becoming dilute and corrosion of crankcase metals due to acid formation. In a positive crankcase ventilation, the crankcase vapor are returned to the engine through the intake manifold, instead of being exhausted into the atmosphere. The crankcase outlet tube is connected to the manifold just beneath the carburetor. So that the vapors are drawn into the intake manifold and utilized into the cylinder during the operation.

**6.9 Sludge Formation in the Lubrication Oil**

When the water is mixed in oil and the mixture is churned up for a certain time, a thick, creamy black substance is formed known a water sludge. In the crankcase, the water collects in two ways. First, the water is formed as a product of combustion. Second the water enters through the crankcase ventilation system with moist air which the engine is cold, the water drops into the crankcase and mixes with the lubricating oil. By the action of the crankshaft the mixture is churned up and water sludge is formed. Dirt and carbon also mix in the water sludge making it black.

The water sludge clogs oil screws and oil lines, preventing normal circulation of lubricating oil to engine parts. This can result in engine failure from oil starvations.

**Summary**

- Lubrication plays an important role in smooth running of the automobile.
- Lubrication provides the engine reciprocating parts neat and clean.
- Proper lubrication helps to maintain the correct nomenclature of the engine parts for a long timer.
- With proper lubrication the life of an engine as well as the vehicle can be increased.
- Lubrication decreases the noises inside the engine.
- The engine reciprocating parts are to be lubricated by the lubricating oil supplied from the sump or through the fuel.
- The oil filters filter out the dust and dirt entering the engine.
- Society of Automobiles had given different grades to the lubricating oils to be used for various engine parts and according to the load and climatic conditions.
• The engine parts will be damaged with the usage of wrong grade lubricating oil.

Questions

1. What are the types of lubricants used in automobiles?
2. Mention any four important properties of lubricating oils.
3. What is meant by S A E Number?
4. Mention the requirements of lubricating system.
5. Explain the types lubricating systems.
6. Explain the splash lubricating system with the help of a neat sketch.
7. With the help of a neat sketch explain the pressure lubricating system.
8. Explain the filtering elements used in lubricating system.
9. How do you explain the crankcase lubrication.
10. Write about sludge formation in lubrication.

Practical Work/O.J.T

1. Observe different lubricate points
2. Identify different lubricants used in automobile components
3. Study c&w of oil filters
4. Study c&w of lubricating systems used in vehicle
5. Study c&w of oil pumps
Learning Objectives

After studying this unit, you will be able to

Know about necessity of air and water cooling in IC engines

Know about construction and working of Air cooling

Know about construction and working of water cooling.

Know about Viscous fan

7.1. Necessity of Cooling System

If the temperature developed is not dissipated out, it may cause severe damages to the engine. The excess heat developed inside the engine should be removed out frequently so as to prevent the engine from overheating. If the engine is not dissipated its excess heat, which may cause to break the lubricating film between the moving parts. If the lubricating oil film is broken it causes the engine parts to weld. At about 15% of the total heat produced is utilized for useful work at the crankshaft. Remaining amount of heat is absorbed in friction, removed by exhaust gases and taken by cooling system the cooling system is designed to remove above 30 to 35% of heat produced in the engine cylinder. As the temperature should not reach excessive values, they should be cooled sent out of the engine surroundings. It is also to be noted that the engine is quite in efficient when cold. The cooling system is so designed that it prevents cooling until the engine reaches to its normal operating temperature. When the engine warms up, the cooling system begins to function. It controls rapidly when the
engine is too hot, and it cools slowly or not at all when the engine is cooled or is warming up. Most engines are designed to operate in a definite temperature range which will insure correct clearances between parts, promote vaporization of the fuel, keep the oil at its best viscosity and prevent the condensation of harmful vapor. Thus the duty of the cooling system is to keep the engine from getting too hot and not to keep it too cool.

### 7.2 Disadvantages of Overcooling and Undercooling

Engine should be cooled within a particular temperature limits. It should not be too cooled or too heated up. Getting the engine too much cooled is called overcooling. And if the engine is over heated it is to under cool. Both under cooling and over cooling have individual disadvantages. Over cooling results in the increase of viscosity of the lubricating oil, which in turn result in the increase of friction between the moving parts.

If the engine gets warmed up excessively, it should be cooled so as to keep the correct alignment of the engine. Under cooling also keeps the engine in correct position and increase the life of the engine. Evaporation of lubricating oil that lubricates the piston and cylinder wall is also another reason of under cooling. This will result in metal to metal contact of the piston and cylinder wall leading to piston crown. Burning of and warping of exhaust valves setting up of thermal stresses in the cylinder, cylinder head and piston. This may lead to cracking of them.

### 7.3 Types of Cooling System

Engine cooling is of two types. They are air cooling and water cooling.

#### A. Direct or air cooling

Air cooling is used on engines in scooters, motorcycles, aero planes, small stationary engines. This system employs air as the cooling medium.
The air remains indirect contact with the exterior of engine surface and transfers heat from cylinders to the atmosphere. Air cooling system is simple in layout, occupies small area on the vehicle. It contains much less spare parts and has almost no moving components.

B. Forced Air Cooling

It is well known fact that the rate of heat transfer due to convection increases with an increase in the velocity of the air flowing over a hot body.

Engine mounted on sunny zip, Bajaj auto vehicle, LML, Kinetic Honda employ this kind of cooling.

C. Natural Cooling

In normal course, large part of an engine exposed to the atmospheric air, when the vehicle runs the air at certain relative velocity impinges upon the engine and sweeps away its heat. The heat carried away by the air is due to natural convention. Therefore this method is known as natural air cooling. As the heat dissipation is a function of frontal cross-sectional area of the engine, therefore there exists a need to enlarge this area.

D. Air Jacket Cooling

In this cooling arrangement, the air is made to pass through the small passages formed in the cylinder block and the cylinder head. The air is passed through a singular multi passages, either naturally or by artificial means.

7.4 Water Cooling or Liquid Cooling System

Air cooling of an engine tends to became less effective when number of cylinders increases in one engine. This is because of reduced effective surface area around each cylinder. This inefficiency can be over-come by use of water cooling system on multi cylinder engines.

a. Thermo Siphon Cooling System.

b. Pump Circulation or Forced Water Cooling System.

a. Thermo Siphon Cooling System

This system involves flow of water under gravity. It does not depend on any external source to circulate the liquid coolant. Convective currents carry heat from bottom to the top of the system as cold water is heavier than the hot water. Since the water in the jackets surrounding the cylinder is heated. It becomes lighter and rises up. The heated water enters into the radiator through
the upper connection and when cooled by the air passing through the radiator core. It becomes heavier and settled to the bottom of the radiator.

**Thermostat Water Cooling System**

In this system of water cooling, the circulation of water is obtained due to the difference in densities of hot and cold regions of the cooling water. There is no pump to circulate the water. The hot water from the engine jacket being lighter, rises up in the hose pipe and goes in the radiator from the top side. It is cooled there and hence goes down at the bottom of the radiator, from where it goes again in the engine jackets. The system is quite simple and cheap, but the cooling is rather slow. To maintain continuity of the water flow, the water must be maintained up to a certain minimum level. If the water level falls down, the circulation will discontinue and the cooling system will fail. A thermostat valve is used in the water cooling system to regulate the circulation of water in system to maintain the normal working temperature of the engine parts during the different operating conditions. The thermostat valve automatically work in the cooling system. When the engine is started from cold, the thermostat valve prevents the flow of water from engine to radiator so that the engine readily reaches to its normal working temperature, after which it automatically comes into action. Generally the thermostat valve does not permit the water below 700°C.

There are two types of thermostats used in automobiles. They are bellow type and pellet type thermostat. Both the thermostat valves works on the same principle as a heat unit operating a valve. The working of bellow type thermostat is explained with the help of figure. The heat unit consists of a closed bellows filled with a volatile liquid under reduced pressure. When the bellows is heated, the liquid vaporizes and creates enough pressure to expand the bellows. The
movement of the bellows operate a linkage which open the valve to pass the water through it. When the bellows is cooled, the gas condenses, the pressure is reduced and the bellows collapse to close the valve thus stopping the water circulation.

![Diagram of a water cooling system]

In the pellet thermostat, the heat unit consist of a sealed in wax pallet, which expands on heating and contracts on cooling. The pellet is connected by piston and flange to a valve so that on expansion of the pellet it opens the valve. When the pellet contract on cooling, a coil spring closes the valve.

### 7.5 Construction and Working of Water Pump, Radiator

**Water Pump**

A pump is used in the water cooling system to increase the velocity of the circulating water. Impeller type pump is mounted at the front end of the cylinder block between the block and the radiator. The pump consists of a housing with inlet and outlet, and an impeller. The impeller is a flat plate mounted on the pump shaft with a series of flat or curved blades or vanes. When the impeller rotates, the water between the blades is thrown outwards by centrifugal force, and is forced through the pump outlet and into the bottom of the radiator, and the water from the radiator is drawn into the pump to replace the water forced through the outlet. The pump is driven by a belt to the drive pulley mounted on the front end of the engine crankshaft. The impeller shaft is supported on one or more bearings. A seal prevents water from leaking out around the bearing.
The packless type pump is used in modern engines. The packing gland type pump is found only in older models.

**Radiator**

The radiator is a device for having a large amount of cooling surface to the large amount of air so that the water circulating through it is cooled efficiently. It consists of a upper tank and a lower tank and between them a core. The upper tank is connected in the water outlet or outlets from the engine jackets inlet through the water pump. The core is a radiating element, which cools the water. There are two basic types of radiator cores – tubular type and cellular type. In tubular type core the upper and lower tanks are connected by a series of tubes through which water passes. Fins are placed around the tubes to improve heat transfer. Air passes around the outside of the tubes, between the fins, absorbing heat from the water in passing. In cellular type core, air passes through the tubes and the water flows in the spaces between them. The core is composed of a large number of individual air cells which are surrounded by water. Because of its appearance the cellular type usually is known as a honeycomb radiator, especially when the cells in front are hexagonal in form.

![Fig 7.4](image)

In tubular radiator, because the water passes through all the tubes, if one tube becomes clogged, the cooling of any passage results in a loss but of a small part of the total cooling surface. Radiators are also classified according to the
direction of the water flow through them. In some, the water flows from top to bottom – down flow type radiators. In other, the water flows horizontally from an input tank on one side to another tank on the other side – cross flow type radiator. Radiators are usually made of copper and brass because of their high heat conductivity. The various sections of the radiator are most completely joined together by soldering.

### 7.6 Anti Freezing and Anti Rusting Additives

When water in the cooling system freezes it may cause cracking the cylinder block, pipes and the radiator. Freezing of water occurs where the atmospheric temperature is very less. To prevent freezing, antifreeze mixtures or solutions are added in the water. The most commonly used antifreeze materials are Wood alcohol, denatured alcohol, glycerin, Ethylene glycol, propylene glycol and mixture of alcohol and glycerin. The alcohol evaporates quickly. So it should be checked frequently. Ethylene glycol is a permanent type antifreeze material. Glycerin and glycol are although costly but do not evaporate readily and hence prove cheaper in long run. But they should not enter the engine parts as they seizure of the moving parts. The lower the temperature, the higher is the percentage of antifreeze material.

Anti rusting additives prevent the engine parts from rusting and Corrosion. these are the chemicals which prevent the corrosion of the metallic parts of the cooling system. Commonly used corrosion-inhibitors are silicates and chromates. It should prevent freezing of the mixture at lowest temperatures. It should circulate freely in the cooling system. It should not deposit any foreign material.

### 7.7 Viscous Fan

When the engine is cool or even at normal operating temperature, the fan clutch partially disengages the engine’s mechanically-driven radiator cooling fan, generally located at the front of the water pump and driven by a belt and pulley connected to the engine’s crankshaft.

![Fig 7.5](image-url)
This saves power, since the engine does not have to fully drive the fan. However, if engine temperature rises above the clutch’s engagement temperature setting, the fan becomes fully engaged, thus drawing a higher volume of ambient air through the vehicle’s radiator, which in turn serves to maintain or lower the engine coolant temperature to an acceptable level. Mechanical fans are most common in trucks and SUVs, and some RWD cars. This is easier to accomplish because the engine is mounted longitudinally, with the belt accessory components mounted facing the radiator. The fan will spin in between the radiator and the engine to help with cooling.

Summary

- An efficient cooling system removes 30 to 35% of the heat generated in the combustion chamber.
- Too much removal of the heat decreases thermal efficiency of the engine.
- Excess heat can be cooled by air cooling, water cooling, liquid cooling and stream cooling.
- The amount of heat dissipated depends on the surface area of metal, rate of air flow, conductivity of material.
- Air cooling is cheaper and faster.
- Air cooled engines more noise.
- The total length of the finned cylinder barrel is from 1 to 1 ½ times the cylinder bore.
- The length of the fins varies from one-quarter to one-third of the cylinder diameter.
- The cooling radiator fan usually absorbs about 1 H.P. for every 15 to 20 H.P. output.
- Sometimes, the flywheel is designed to function as a cooling fan.
- Water cooling is of two types – thermo siphon and pump circulation system.
- Radiator is the main component of cooling system.
- The water pump is used in the water cooling system to increase the velocity of the circulating water.
- The water pump is used in heavy duty engines.
The radiator fan is rotated by the crankshaft.

Water jackets are cast in the cylinder blocks and cylinder heads.

Higher boiling point liquids like glycerine, ethylene glycol are used in liquid cooling system.

A temperature indicator is mounted on the instrument panel.

Model Questions

1. Explain the necessity of cooling system.
2. Explain the disadvantages of over cooling over under cooling.
3. Enumerate the air cooling system.
4. With the help of a neat diagram explain water cooling system.
5. How do you study the radiator?
6. Explain the construction of water pump.
7. Write a short note on anti freeze and anti rust materials.

Practical Work/O.J.T

1. Observe construction & working of air cooling system used in two wheelers?
2. Study construction and working of radiator, pump, thermostat, viscous fan
3. Study c&w of forced cooling system used in 4 wheelers.
4. Observe which type of solutions used for anti rust & anti freezing
Learning Objectives

After studying this unit, you will be able to

- Know about different manifolds used in IC engines
- Know about different exhaust manifold used in IC engines
- Know about construction and working of Silencer and Air cleaners

8.0 Introduction

Manifold is a pipe used for the sending or passing through of the air fuel mixture or the exhaust gases. These are pipe like structures. Heavy engines are constructed with through passages which are used as manifolds. Muffler is a device used for the absorption of the noises created by the exhaust gases. The mufflers minimize the sound and velocity intensity and thereby help in minimizing the sound pollution.

8.1 Necessity of Inlet and Exhaust Manifold

The inlet manifold is used to guide or send the charge into the cylinder. The inlet manifold is a passage made in the casting in case of heavy engine blocks. The necessity of inlet manifold came into existence for the supply of charge (air in case of diesel engine and air fuel mixture in case of petrol engine). The exhaust manifold guides the exhaust or burnt out gases to pass into the muffler. The exhaust manifold should be strong enough to withstand the heat liberated by exhaust gases.
It is only the manifolds which are used to send the charge into and out of the cylinder.

**8.2 Consideration for a Good Manifold Design**

The following things are to be considered while designing the manifold of an engine.

1. The amount of charge required into the engine cylinder.
2. The quantity of charge entering into the cylinder.
3. Scope for the entry of fuel into the cylinder easily. Design should be smooth such that the fuel should enter easily.
4. Ability to resist to high temperatures those are developed by heat of compression or heat of ignition.
5. The material of the manifold should be such that it should send more of the exhaust heat to the surroundings.

### 8.3 Types of Manifolds

There are two types of manifolds viz. Inlet manifold and exhaust Manifold.

**Inlet Manifold**

The inlet manifold is to distribute the air and petrol equally to all the cylinders through inlet valves. There are usually made out of aluminum alloy and have smooth finish in its air passage so that there is no restriction due to rough surface. Intake manifold is fixed to cylinder head with studs or bolts with packing seal placed at each opening to ensure airtight joint.
Functions of intake manifold

1. It should distribute air-fuel mixture properly.

2. It should supply equal amount of charge to each cylinder.

3. It should maintain the proportion of air-fuel mixture properly.

4. It accommodates air cleaner.

Exhaust Manifold

It is like inlet manifold but is made of cast iron. It connects exhaust ports of cylinder head with the exhaust packing in between to make it gas tight fitting. On the other end it is connected to exhaust pipe and muffler. It is a collection agency for exhaust gases let out by the engine having many joining flanges each connected to exhaust port of cylinder head. The exhaust gases coming out of different exhaust ports of cylinder block are gathered in exhaust manifold and rushed out with high velocity to exhaust pipe.

Exhaust Pipe

The exhaust pipe is round curved pipe whose one end is fixed with the manifold with suitable flange and the other end clamped with exhaust muffler. In most of the exhaust pipes as used on automobile is placed a flexible conduit pipe so that engine vibrations are taken care of and are not transmitted to the muffler which is fixed with the chassis.
8.4 Construction and Working Principle of Air Cleaner – Necessity of Air

Air Cleaners

It cleans the air going to the cylinder. We know that air contains lot of minute particles of dust and dirt which sometimes are not visible to the naked eye. The vehicle running on kucha road quarries, mines etc. are subjected to heavy duty conditions.

The dust has to be trapped from the air before it gets into the cylinder with the help of air cleaner.

There are various types of air cleaners used now a day. These are generally classified as under.

(a) Wet type air cleaner

(b) Dry type air cleaner
c) centrifugal type cleaner.

**Wet Type Aircleaner**

It consists of a filtering element generally wire mesh, coated with an oil film. The air passes through this element, and the dust particles of the air adhere to the oil film.

**Dry Type Aircleaner**

It is a light-duty air cleaner. It consists of a cleaning element only and not the oil bath. The cleaning element is a specially pleated paper element, over which is put a fire mesh screen to provide strength. This cleaning element is enclosed in a silence chamber.

**Centrifugal Aircleaner**

This type of air cleaner, a whirling motion is given to the air due to which heavy dust particulars are thrown out by the centrifugal force to the periphery of the casing, where they leave through slots. The main air flow passes through vanes set at an angle, to correct the air flow to a straight direction, and then enters the main air cleaner. The air is not perfectly cleaned by this cleaner and hence it acts as a first stage cleaner on installation dealing with heavy dust concentrations.

**Necessity of Air Cleaner**

The air is likely to contain dust and dirt. If the air is not cleaned before it, exerts the carburettor, the dust and dirt particles will seriously damage the engine. They will foul the carburettor parts and spark plug, increase abrasive wear on piston, piston rings, cylinder walls, bearings and any relative moving parts.

**8.5 Construction and Working Principle: Different Types of Silencers**

Function of silencer or muffler: silencers is to reduce the noise that would be produced if the exhaust gases were allowed to pass directly through pipes to the rear of the vehicle. It contains a series of holes, passages and resonance chambers to absorb high pressure surges.

Types of silencers; 1. Baffle type. 2. Wave cancellation type. 3. Resonance type. 4. Absorber type. 5. Combined resonance and absorber type.

It is generally cylindrically in shape with a number of baffles spot welded inside. Major drawback of the mufflers is their low efficiency. Because of the restriction provided to the flow by the baffles, the back pressure is increased, thus causing loss in engine horse power. This type Texas gases are divided into two parts. The length of these paths are so adjusted that after they come out of...
the muffler, the crest of one wave coincide with the thoughts of the second wave, thus cancelling each other and reducing the noise to zero theoretically.

3. it consists of a number of resonators in series, through which a pipe containing access ports passes. The exhaust gases flow through this type and thus experience no resistance. Series of resonators eliminate the fundamental and higher harmonics of the engine noise.

4. the sound absorbing material, usually fiber glass, is placed in this case around the perforated tube through which the exhaust gases pass. During high pressure fluctuations the gases pass through the perforations to the sound absorbing material, when these fluctuations are reduced and thus the noise gets reduced in intensity.

5. it is seen that the absorber type muffler, has a drawback in that

It is not efficient in reducing noise of low frequency. This type is more efficient than either the simple resonance or the absorber type.

Summary

- Manifold is a passage for the flow of charge or air into and out of the cylinder.
- In the Manifold design care should be taken towards the material and strength of the material used.
- Every engine is constructed with an inlet and an outlet manifold.
- The manifolds are constructed within the engine block for the heavy duty engines.
- Air cleaner is used to clean the foreign particles in the air.
- Muffler is also called as silencer.
• A silencer is used to minimize the velocity of the exhaust gases by sending it through a number of baffle plates.

• A muffler reduces the noise of the exhaust gases.

• The baffle plates are frequently cleaned of to avoid the carbon particles.

**Short Answer Type Questions**

1. What is a manifold?
2. What is the main criterion taken in the design of a manifold?
3. Is a manifold attached to the engine block externally for a heavy duty engine?
4. How many types of manifolds are used in an engine?
5. What is the use of a muffler?
6. How the silencer of a vehicle is cleaned?

**Long Answer Type Questions**

1. Explain the construction and working of the manifolds of an engine.
2. Explain the construction and working of the air cleaner of an engine.
3. Explain the construction of a silencer used in a vehicle.

**Practical Work/O.J.T**

1. Identify the inlet and exhaust manifolds (both petrol & diesel)
2. Observe muffler construction and working
After studying this unit, you will be able to

Know about engine performance parameters

Know about the power developed in the engine and actual power utilized for the running and the power losses during working of the engine.

9.1 Need for Engine Performance Testing

To study the various performances, engine construction, maintenance the performance testing is required. The correct running of the engine and comfort to the passengers etc can be easily found out by studying the performance of an engine. For the performance testing the concept of TDC, BDC, Stroke, Bore of the cylinder etc are to be known.

**Top Dead Centre:** The top most position refers to T.D.C. as shown in Figure.

**Bottom Dead Centre:** The bottom most position refers to B.D.C. as shown in figure.

**Stroke and Bore:** The displacement of piston with in a cylinder between T.D.C. and B.D.C. is called as Stroke. The stroke is denoted by ‘L’. It is
measured in mms. The bore ‘D’ is inner diameter of the cylinder. It is measured in mms.

![Fig. 9.1](image)

**Clearance Volume:** The space above the piston, when the piston is at TDC is known as clearance volume.

**Cylinder Volume:** The volume above the piston when the piston is at BDC is called cylinder volume or cylinder volume is the sum of the clearance volume and stroke volume.

**Cubic Capacity:** The cubic capacity of an engine, or engine displacement or engine size is the product of the stroke volume in one cylinder and the number of cylinders in the engine.

**Compression ratio:** The compression ratio is the ratio of the cylinder volume to the clearance volume. The compression ratio represents the ratio of the volume occupied by the charge before compression to that after compression.

**Torque:** Torque is the turning moment. In the case of an engine it is usually referred at the crank shaft of the engine. Torque refers to the average turning moment or rotation exerted on the crankshaft by the gases acting on the piston during a cycle. Torque (T) is measured in Kgf m or Nm.

### 9.2 Different Types of Engine Powers i.e. BHP, IHP, FHP.

#### Indicated Horse Power

The power actually developed inside the engine cylinder by the combustion of fuel is called “Indicated Horsepower”. It is given by the relation.
Mean Effective Pressure = Pressure developed in power stroke - (power utilized in section, compression and exhaust stroke).

**Brake Horse Power (B.H.P.):** The power which the engine actually delivers to do the outside work is called Brake Horse Power. It can be measured by some measuring instrument like Prony brake dynamometer. It is the actual power delivered at the flywheel.

\[
\text{B.H.P.} = \frac{2\pi NR(W-S)}{4500}
\]

Where \(D\) = Diameter of the Brake Drum = 2\(R\) in meters.

\(N\) = No. of revolutions/mm of the crankshaft.

\(W\) = load on the brake in Kg.

\(S\) = spring balance reading in Kg.
Frictional Horse Power (F.H.P.): The indicated power of an engine is always greater than its brake power because there is a loss of power between the cylinder and the crank shaft due to friction between the moving parts. The power loss in this way is known as friction power. Thus,

\[ \text{F.H.P.} = \text{I.H.P.} - \text{B.H.P.} \]

### 9.3 Different Types of Efficiencies

#### Engine Efficiencies

The term efficiency means the relationship between the effort exerted and the results obtained. Engine efficiency, the efficiency as applied to engine, is the relationship between the power delivered and the power obtained.

**Mechanical efficiency**

The mechanical efficiency is the ratio of brake horse power to indicated horse power.

Mechanical efficiency = \( \frac{\text{B.H.P.}}{\text{I.H.P.}} = \frac{\text{B.H.P.}}{\text{B.H.P.} + \text{F.H.P.}} \)

**Thermal efficiency**

It is the ratio of B.H.P. or I.H.P. to that heat energy of the fuel supplied during the same interval of time. Efficiency based on I.H.P. is called Indicated Thermal efficiency and is given by

\[
\text{Indicated thermal efficiency (} \eta_{\text{th}} \text{)} = \frac{\text{I.H.P.} \times 4500}{W \times Q \times J}
\]

Where:
- \( W \) = Weight of the fuel supplied in Kg / minute.
- \( Q \) = heating value or calorific value of fuel in K Cal / Kg.
- \( J \) = Mechanical equivalent of heat = 427.

**Brake Thermal Efficiency**: The efficiency calculated on Brake Horse Power is called Brake Thermal Efficiency.

\[
\text{Brake Thermal Efficiency} = \frac{\text{B.H.P.} \times 4500}{W \times Q \times J}
\]

**Volumetric efficiency**

The volume of air-fuel mixture drawn into the cylinder at atmospheric pressure during the intake stroke compared to the volume of the cylinder is known as volumetric efficiency.
9.4 Performance Terms Relating to an I.C. Engine

Specific Fuel Consumption

In engine test the fuel consumption by an engine is measured as flow rate i.e. mass flow per unit time. The more important parameter is the specific fuel consumption (SFC). This is the fuel flow rate per unit power output. It indicates how efficiently an engine is using the fuel supplied to it in producing work. The SFC is defined as the amount of fuel consumed per unit of power produced in certain time.

\[ SFC = \frac{\text{fuel consumed in litres/km}}{\text{Brake Horse Power}} = \frac{fc}{BHP} \]

Heat Balance Sheet

During a specific period, the total heat produced inside the cylinder must be equal to the sum of the various heat losses and that utilized for useful work. All these items are recorded in a tabular form called the heat balance sheet.

<table>
<thead>
<tr>
<th>S.No</th>
<th>Item</th>
<th>kW</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Heat Supplied by fuel</td>
<td>x</td>
<td>100%</td>
</tr>
<tr>
<td>2.</td>
<td>Heat absorbed in I.P.</td>
<td>a=m_i*C_v</td>
<td>( \frac{a}{X} \times 100 )</td>
</tr>
<tr>
<td>3.</td>
<td>Heat taken away by cooling water</td>
<td>b=m_w<em>C_pw</em>(t_2- t_1)</td>
<td>( \frac{b}{X} \times 100 )</td>
</tr>
<tr>
<td>4.</td>
<td>Heat carried away by exhaust gases</td>
<td>c=m_g<em>C_pg</em>(t_e- t_r)</td>
<td>( \frac{c}{X} \times 100 )</td>
</tr>
<tr>
<td>5.</td>
<td>Heat unaccounted for</td>
<td>X-(a+b+c)</td>
<td>( \frac{X-(a+b+c)}{X} \times 100 )</td>
</tr>
</tbody>
</table>

Performance Curves

The word performance for an engine is generally used for designating the relationship between power, speed and fuel consumption. For variable speed engines the rated horse power at a certain speed does not given enough information. The performance curve helps to obtain necessary information.
Summary

- It is the primary responsibility to know about the performance of an engine.
- The maintenance of a vehicle engine is proper if the performance is good.
- The power of an engine is expressed in terms of Horse Power.
- The fuel consumption given by an engine is given by the IHP of the engine.
- Brake thermal power is the horse power developed by the engine at the flywheel.
- Dynamometer is a device used to measure the brake thermal power.
- IHP is the theoretical power developed by the engine.
- If the FHP is minimized the efficiency of the engine can be improved.
- Performance curves give clear idea of the engine position.

Questions

1. What is bore and stroke?
2. Define cubic capacity.
3. Define t.d.c & b.d.c.
4. Define total cylinder volume.
5. What is compression ratio?
6. How do you find the need of performance testing of an engine?
7. Define the terms Brake Thermal efficiency, Indicated Thermal Efficiency and Volumetric efficiency.
8. What do you mean by the terms – BHP, IHP and FHP?
9. Expand the terms – BHP, IHP and FHP.
10. What is meant by Specific Fuel Consumption? Write its units.