MODULE 1

SYLLABUS:

Piston: - material for piston, clearances, piston rings, types, need for two compression rings, oil control ring, piston pin.

Piston for IC engine, piston rings, piston pin, connecting rod, crank shaft, crank pin, cam shaft, valves, fly wheel, fluctuation of energy and size of fly wheel, hub and arms, stress in a fly wheel rim, simple problems.

Petrol fuel injection systems: - comparison petrol injection and carbureted fuel supply systems-comparison –multiport fuel injection (MPFI) and common rail direct injection (CRDI) systems.

Super charging systems: fundamentals, naturally aspirated engines and supercharged engines–Turbo charger, turbo lag.

Hybrid cars, safety overview -Formula-I engine technology: overview, electrical technology, brakes, transmission technology.

PISTON:

- The piston is effectively a pressure-tight plunger that slides up and down the cylinder.
- The piston converts the pressure created by the combustion process into a reciprocating mechanical movement.
- The piston is therefore exposed to extreme forces and temperatures during combustion.
- By connecting a reciprocating piston to a crankshaft with a connecting rod, the reciprocating movement is converted into rotational movement of the crankshaft.

Functions:

- To transmit the force of explosion to the crankshaft.
- To form a seal so that the high-pressure gases in the combustion chamber do not escape into the crankcase.
- To serve as a guide and a bearing for small end of the connecting rod.

Desirable Characteristic:

- It should be silent in operation both during warming up and the normal running.
- The design should be such that the seizure does not occur.
- It should offer sufficient resistance to corrosion due to some products of combustion, e.g. Sulphur dioxide.
- It should have the shortest possible length so as to decrease overall engine size.
- It should be lighter in weight so that inertia forces created by its reciprocating motion are minimum.
- Its material should have a high thermal conductivity for efficient heat transfer so that higher compression ratios may be used without the occurrence of detonation.
- It must have a long life.

Construction:

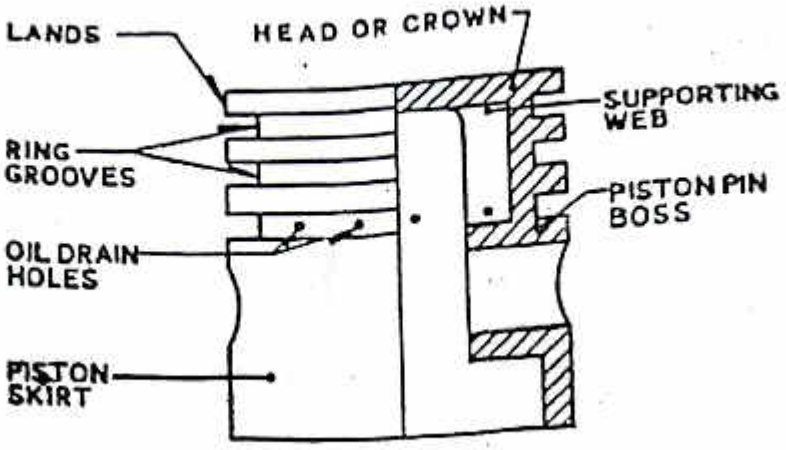


Fig. 2.22. I.C. Engine Piston.

- A typical piston is shown in Fig. 2.22. The top of the piston is called head or crown. Generally, low cost, low-performance engines have flat head as shown.
- The crown forms the upper surface on which the combustion pressure acts.
- Towards the top of the piston a few grooves are cut to house the piston rings. The bands left between the grooves are known as lands.
- These lands support the rings against the gas pressure and guide them so that they may flex freely in the radial direction.
- The supporting webs transmit the force of explosion directly from the crown to the piston pin bosses.
- The part of the piston below the rings is called 'skirt'. Its function is to form a guide suitable for absorbing side-thrust due to gas pressure. The side thrust is produced on account of the inclination of the connecting rod with the cylinder axis.
- The combustion pressure from the piston crown is transmitted to the connecting rod through webs inside the piston.

Material used:

- Early engines had pistons made of **cast iron.** Cast iron has good strength and hardness at operating temperatures. However, cast iron is relatively heavy, rather brittle and liable to develop cracks.
- **Aluminium alloy containing silicon** replaced cast iron as piston material. It is seen that as the percentage of silicon in the alloy increases, its coefficient of expansion decreases. However, silicon is bonded to aluminium at the molecular level only up to about 12%. Aluminium alloys have two distinct advantages. Firstly, it is as much as three times lighter than cast iron. it possesses a higher thermal conductivity, which cause it to run cool. But the aluminium alloy has its own disadvantages, too. It is not as strong as cast iron and hence thicker sections have to be used. Another important drawback of using aluminium alloy pistons for cast iron cylinders is their high coefficients of expansion.
- **Cast steel pistons:** The pistons cast from alloy steel containing silicon and copper, with

cadmium plating have been found to be highly wear and heat resistant.

- **Anodized Pistons:** Anodizing improves the bearing properties of pistons. The anodizing is done by the sulphuric acid process and resulting coating is dark grey in colour. The very hard aluminium coating protects the piston against scoring.

PISTON RINGS:

- The purpose of the piston rings is to prevent gas leakage through the clearance between piston and cylinder walls, but also allow the piston to move freely up and down the cylinder.

Functions:

- To form a seal for the high-pressure gases from the combustion chamber against leak into the crank case.
- To provide easy passage for heat flow from the piston crown to the cylinder walls.
- To maintain sufficient lubricating oil on cylinder walls throughout the entire length of the piston travel, minimizing the ring and cylinder wear.
- The oil is not to be allowed to go up into the combustion chamber where eventually it would bum to leave carbon deposits.

Constructions:

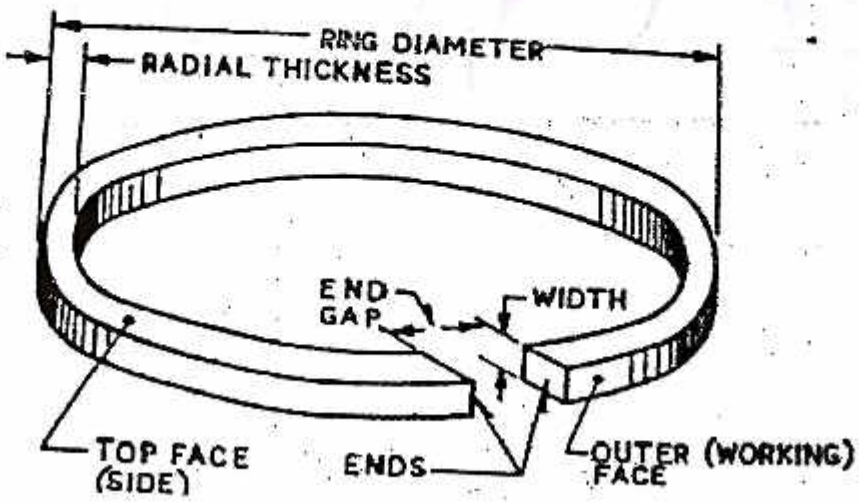


Fig. 2.58. Ring construction.

- The ring is generally cast individually and machined carefully so that when in position, it is able to exert uniform pressure against the cylinder walls.
- A gap has to be cut at the ends so that while inserting the ring onto the piston, it can he expanded, slipped over the piston head and released into the ring groove. Further, the gap is almost closed when the piston is inside the cylinder, due to which the ring is able to exert pressure on cylinder walls.
- Moreover, any circumferential expansion of the ring at higher operating temperatures may also be accommodated by the end gap.
- The sealing action of the top ring is due to the fact that the high pressure in the combustion chamber presses the top ring tightly on the base of the piston ring groove, thus sealing the ring.

also reduc
decreased
Oil control

- However, some leakage will take place through the end gap of the top compression ring. This leakage is useful in that it provides the pressure for sealing action of the second piston ring.
- The amount of end gap should, however, be determined cautiously. Excessive end gap would result in blow-by and scuffing of the rings.
- On the other hand, lesser clearance would cause the ring ends to butt at higher temperatures, resulting in excessive and non-uniform pressure on the cylinder walls causing excessive wear.

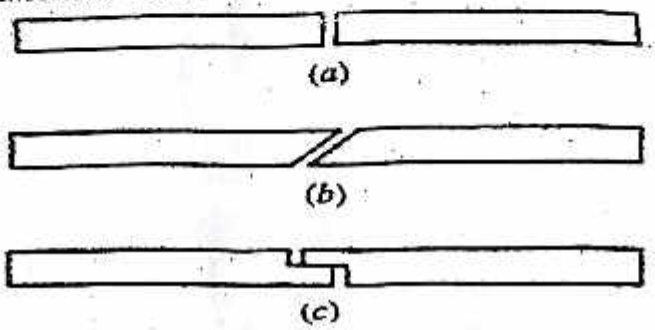


Fig. 2.59. Types of piston ring end gaps.
(a) Butt type, (b) Tapered type,
(c) Seal cut type.

- The ring end gaps may be either straight butt type or tapered or seal cut type. Out of these, butt type is most common mainly on account of its cheapness.
- The tapered and the seal-cut types are more effective in preventing leakage but are costlier. Therefore, such joints are used only in case of some low-speed engines, where high pressure combustion gases have more time to leak through the gap.

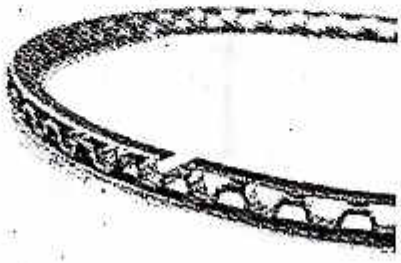
Materials used:

- The material generally used for piston rings is **fine-grained alloy cast iron containing silicon and manganese**. It has good heat and wear resisting qualities.
- **Chromium-plated rings** are usually used as the top ring, which is subjected to the highest working temperatures and the corrosive action of the combustion products.
- The rings are provided generally, a **porous phosphate coating** to reduce the scoring of the surfaces during running in.
- **Rings with molybdenum-filled face** have also been introduced recently. The molybdenum surface has larger oil carrying capacity. It, therefore, provides better cylinder wall lubrication with resultant longer engine life. The higher melting point of molybdenum (2620°C) enables the ring to stand higher temperatures than other ring metals and thus resist scuffing.
- **Stainless steel oil rings** resist pitting and corrosion to remain clean and do not clog with carbon as quickly as other rings. Further, these resist excessive tension loss at engine operating temperatures.

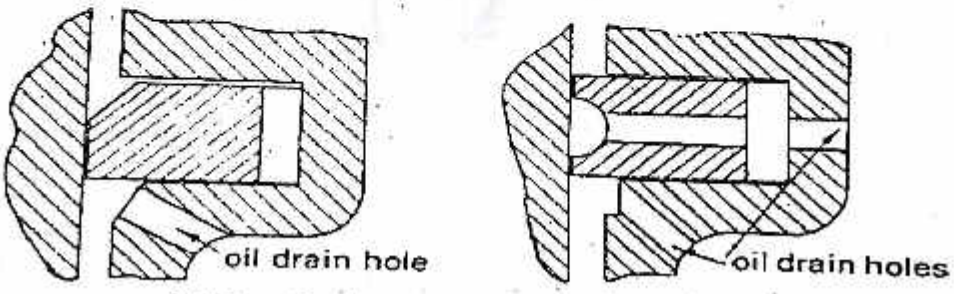
Note: A minimum of two compression rings are required because of the high pressure. This may be as high as 70 atmospheres. A single piston ring cannot take such high pressure, which necessitates the use of at least two compression rings, which divide the pressure between themselves. Increasing the number of rings (which is restricted by the maximum piston height)

also reduces the design pressure between the rings and the cylinder walls which results in decreased wear and consequently increased life.

Oil control ring:

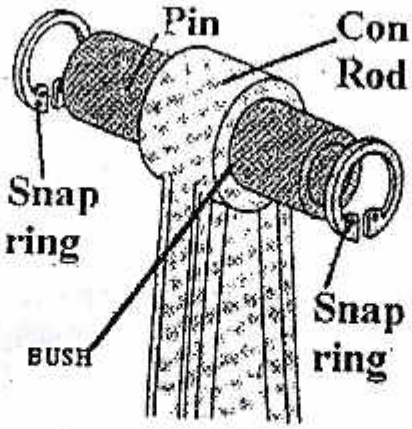


- It designed to control the oil film on the cylinder wall. They permit adequate lubrication of the piston against the cylinder wall, without excessive quantities of oil getting past the piston and into the combustion chamber.
- These rings are intended to glide over the oil film as the piston moves upward, but to scrape off all but a very thin film of oil on the downward stroke and are thus known as **'oil-control rings'**.
- Holes at the back of the ring groove can allow the oil collected by the scraper ring to return to the underneath of the piston.
- Figure shows sections of several types of oil control rings and their grooves. The bevelled scraper is the least severe in its action; the grooved type the most severe.



(a) Bevelled *(c) Grooved*

PISTON PIN OR GUDGEON PIN:



- It is a member which connects piston and connecting rod.
- It should have the strength necessary to carry the high loads imposed by gas pressure on the piston.
- They are made of steel, usually alloyed with 3–4% of nickel to increase toughness, and then case-hardened to obtain a wear-resistant surface.
- Gudgeon pins are usually made tubular to reduce weight.
- The two types of gudgeon pin used are:
  - **Semi-floating:** These are securely fixed in either the piston or the connecting rod.
  - **Fully-floating:** This type of gudgeon pin is free to turn in both piston and connecting rod and is generally used in modern engines in which the loads are particularly high.

CONNECTING ROD:

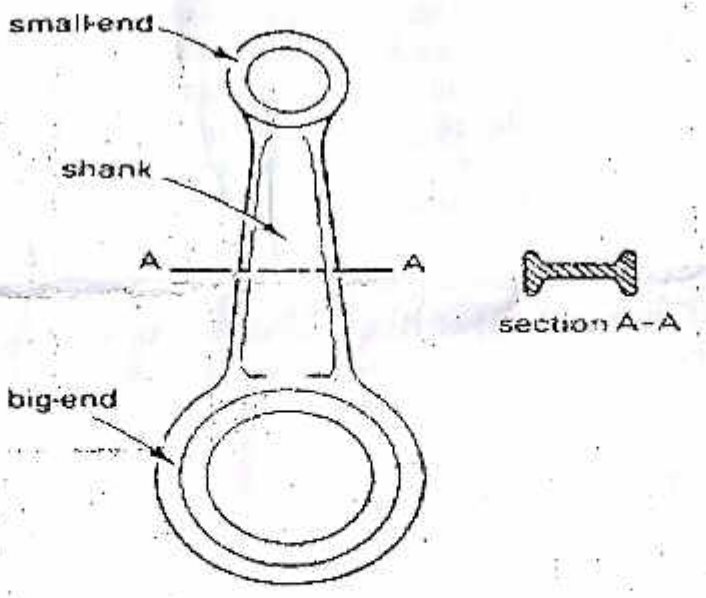


Figure 2.39 A simple connecting rod

- The connecting rod connects the piston to the crankshaft.
- The function of the connecting -rod is to convert the reciprocating motion of the piston into the rotary motion of the crankshaft.
- When combustion pressure forces the piston down the cylinder, the connecting rod must transfer the force through to the crankshaft, which is then made to rotate.
- To reduce the obliquity of the rod with the cylinder axis, its length should be kept as large as possible.
- On account to reduce the overall height of the engine, the length of the connecting rod has been decreased from 4 to 4.5 times the crank throw to about 3.5 times
- A combination of axial and bending stresses act on the rod in operation.
- The axial stresses are produced due to cylinder gas pressure (compressive only) and the inertia force arising on account of reciprocating motion (both tensile as

well as compressive), whereas bending stresses are caused due to the centrifugal effects.

- To provide maximum rigidity with minimum weight the main cross-section of the connecting rod is made an I-section.
- The small end of the rod holds the piston pin and the big end works on the crank pin.
- The connecting rods are generally made by **drop forging of steel or duralumin.** However, the connecting rods these days are also cast **from malleable or spheroidal graphite cast iron.**
- In general, forged connecting rods are compact and lighter which is an advantage from inertia view point, whereas cast connecting rods are comparatively cheaper, but on account of lesser strength their use is limited to small and medium size petrol engines.

CRANKSHAFT:

- Crankshaft is the engine component from which the power is taken. It receives the power from the connecting rod and transmits to the clutch and subsequently to the wheels.

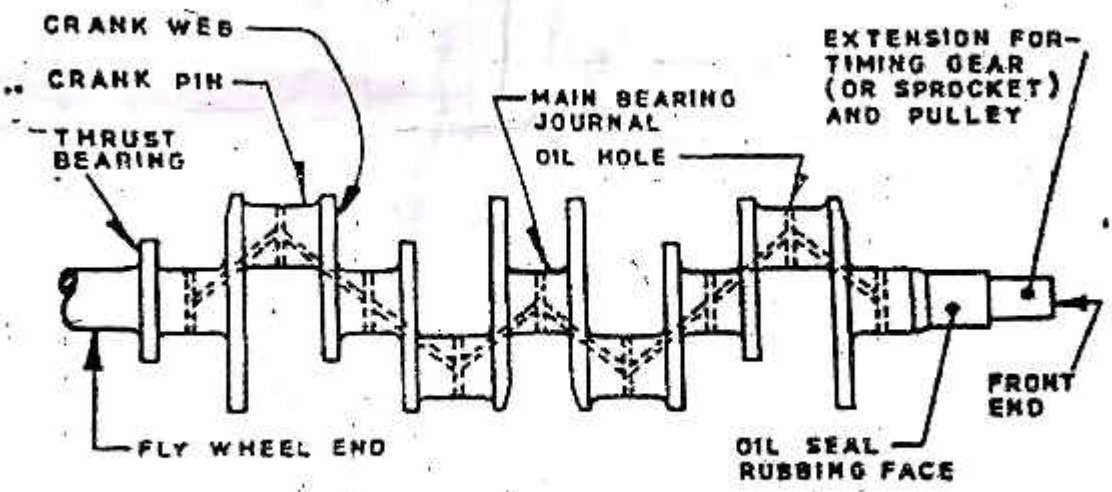


Fig. 3.1. Crankshaft.

- The crankshaft assembly includes the crankshaft and bearings, the flywheel, vibration damper, sprocket or gear to drive camshaft and oil seals at the front and rear.
- A simplified sketch of the crankshaft for a 4 cylinder in-line engine is shown in Figure.
- The main journals are supported in main bearings in crankcase. These form the axis of rotation of the crankshaft.
- The crank pins are the journals for the connecting rod big end bearings.
- The distance between the axis of the main journal and the crankpin center is exactly one half of the engine stroke and is called the 'crank-throw', which determines the crankshaft turning effort.
- Oil holes are drilled from main journals to the crankpins through crank webs to provide lubrication of big end bearings. Main bearings are lubricated from oil galleries in the cylinder block.

- Crankshafts are made of high quality steel or iron. These materials are processed by either forging or casting.

VALVES:

- Valves are used to admit the air-fuel mixture in the engine cylinder and to force the exhaust gases out at correct timings.
- The engine valves may be broadly divided into 3 main categories:
  - Poppet valve
  - Sleeve valve
  - Rotary valve
- Out of these three, poppet valve is the one which is being universally used for engines.

Poppet Valve:

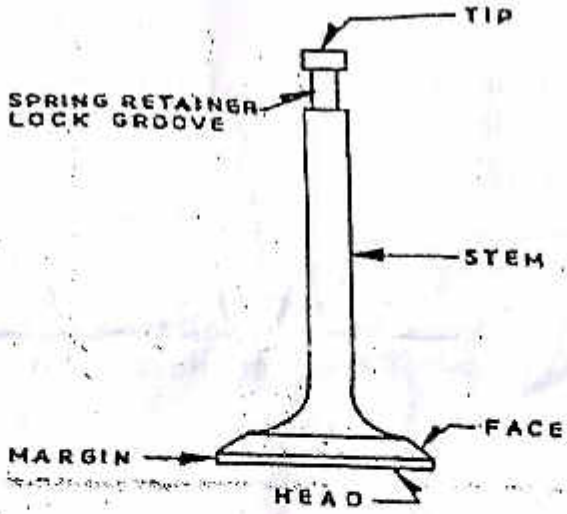


Fig. 3.13. Poppet valve

- The poppet valve derives its name from its motion of popping up and down.
- It consists of a head and stem as shown in fig.
- Advantages:
  - Simplicity of construction
  - Self-centering
  - Free to rotate about the stem to new position.
  - Maintenance of sealing efficiency is easier.
- Generally, inlet valves are larger than the exhaust valves, because speed of incoming air-fuel mixture is less than the velocity of exhaust gases which leave under pressure.
- The valve face angle is generally kept 45° or 30°.
- A smaller face angle provides greater valve opening for a given lift, but poor sealing because of the reduced seating pressure for a given valve spring load.
- The exhaust valve is the hottest part of the engine, and it is estimated that under full power conditions it reaches a temperature of around 700°C.
- A special high-tensile steel is required for the exhaust valve, containing varying amounts of manganese, silicon, nickel and chromium.

- The inlet valve is also made of high-tensile alloy steel usually containing nickel, chromium and molybdenum.

VALVE ACTUATING MECHANISM:

- In all the valve actuating mechanisms i.e. valve trains, a cam driven at half the crankshaft speed is used to operate each valve, inlet or exhaust, However, there are different methods of operating the valves from the cam.
- These may be broadly divided into two types viz., mechanisms with side camshaft and the mechanisms with overhead camshaft. These will now be explained further.

1. **Mechanism with side camshaft:**

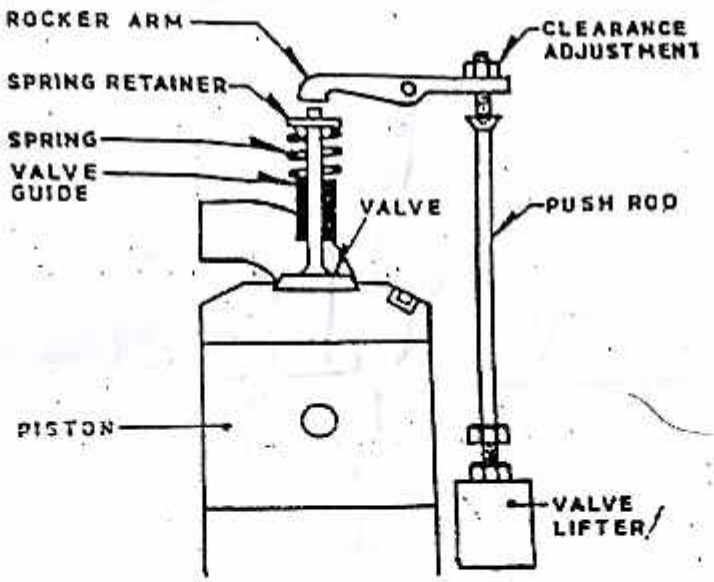


Fig. 3.25. Single row overhead valve mechanism.

- In these, the camshaft is on the side of the engine and the valves are operated either directly by the cams or through the push rods and rocker arms.
- The cam operates the valve lifter which in turn actuates the pushrod. The push rod further operates the rocker arm, which actuates the valve.
- This type of mechanism is having the following advantages:
  - Higher volumetric efficiency.
  - Higher compression ratios can be used.
  - Leaner air fuel mixture can be burnt.

Disadvantages:

- Valve timing is not precise at high speeds due to large mechanical linkages.
- Noisy operation.
- Greater maintenance is required due to more wear at joints.

2. Mechanism with overhead camshaft:

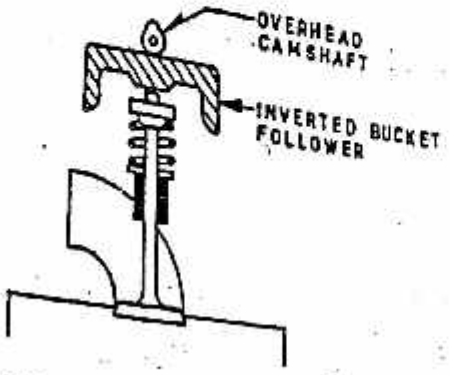


Fig. 3.28. Overhead camshaft-operated mechanism with inverted bucket type follower (Single row valves).

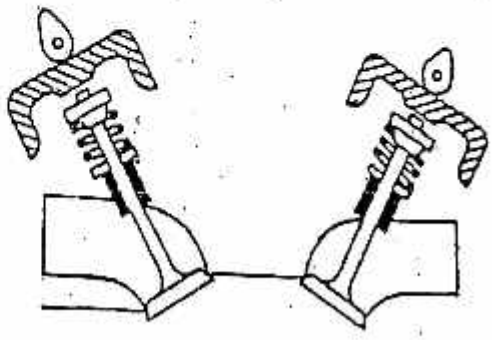


Fig. 3.31. Double overhead camshaft-operated mechanism with inverted bucket type followers

- The valve operating mechanisms with overhead single or double camshafts are highly efficient.
- Overhead camshaft means that the distance between the cam and the valves is much shorter due to which the valve response is quicker and valve adjustment can be more accurate.
- Moreover, due to fewer valve train components compared to the side camshaft engine, this system permits higher engine speed.
- Moreover, they have the disadvantage of higher initial costs.
- Fig. 3.28 shows single row valves operated by a single overhead camshaft (SOHC) and an inverted bucket type follower. With this type of follower, the camshaft is arranged directly over the valve stems.
- Fig 3.31 shows double overhead camshaft arrangement (DOHC) in which both inlet and exhaust valves are driven by individual camshaft.

CAMSHAFT:

- A camshaft is a shaft with a cam for each intake and exhaust valve.
- Each cam has a high spot called cam lobe which controls the valve opening.
- The camshaft controls the opening and closing intervals of the inlet and exhaust valves.

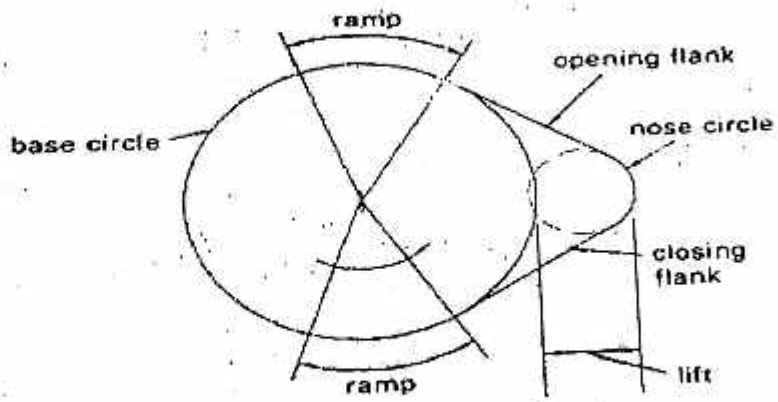


Figure 2.83 Details of cam

- The cam act directly on the cam follower (sometimes referred to as a tappet).
- The follower then transmits the movement to the valve (either directly or via a pushrod or rocker mechanism).
- The cam follower remains stationary during that part of the cam's rotation when it rests upon the base circle, and its 'lift' begins at the point where the opening flank joins the base circle. At the peak of the cam (highest point of the cam lobe) the lift is maximum, and the follower then falls as the closing flank passes beneath it.
- The camshaft is forged from alloy steel or cast from hardenable cast iron and is case hardened.

PETROL FUEL INJECTION SYSTEM

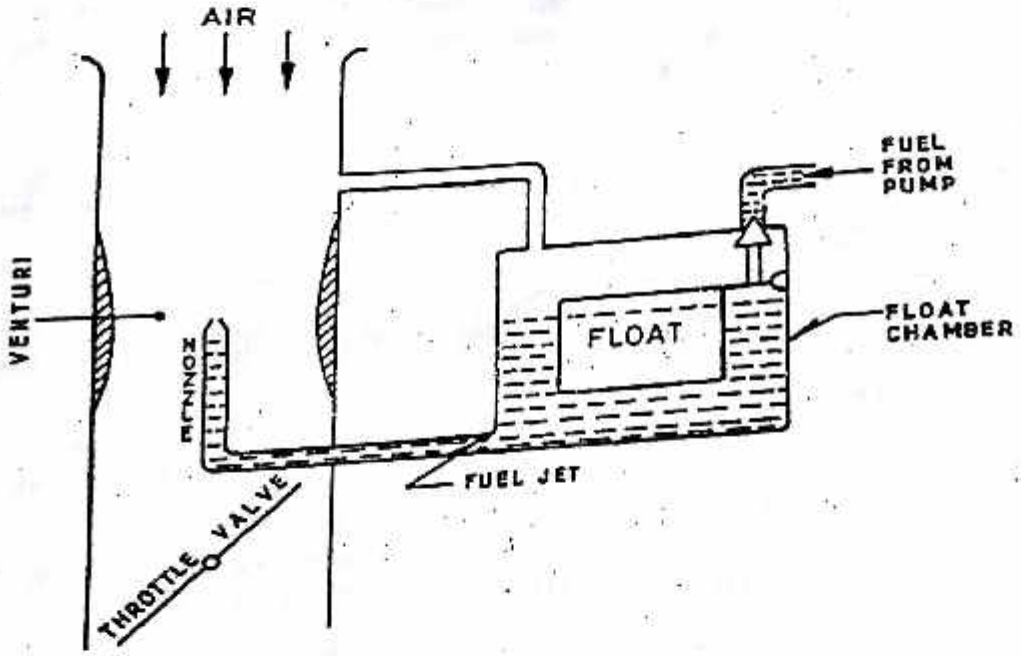
CARBURETION:

- Spark-ignition engines normally use volatile liquid fuels. Preparation of fuel-air mixture is done outside the engine cylinder.
- The process of mixture preparation is extremely important for spark-ignition engines.
- The purpose of carburetion is to provide a combustible mixture of fuel and air in the required quantity and quality for efficient operation of the engine under all conditions.

Definition of Carburetion:

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

The Simple Carburetor:



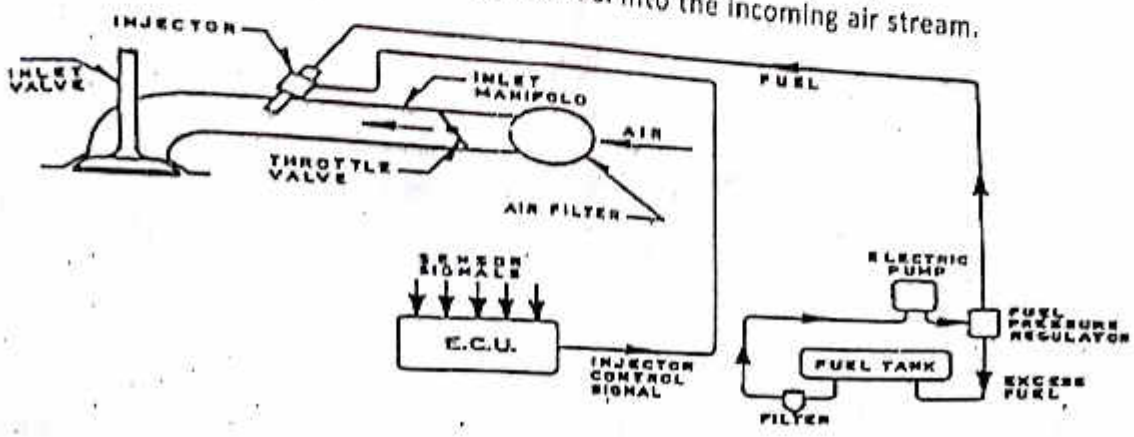
- The simple carburetor mainly consists of a float chamber, fuel discharge nozzle and a metering orifice, a venturi, a throttle valve and a choke.
- The float and a needle valve system maintain a constant level of gasoline in the float chamber. If the amount of fuel in the float chamber falls below the designed level, the float goes down, thereby opening the fuel supply valve and admitting fuel.
- When the designed level has been reached, the float closes the fuel supply valve thus stopping additional fuel flow from the supply system.
- Float chamber is vented either to the atmosphere or to the" upstream side of the venturi.
- During suction stroke air is drawn through the venturi.
- As already described, venturi is a tube of decreasing cross-section with a minimum area at the throat, Venturi tube is also known as the choke tube and is so shaped that it offers minimum resistance to the air flow.
- As the air passes through the venturi the velocity increases reaching a maximum at the venturi throat. Correspondingly, the pressure decreases reaching a minimum.
- From the float chamber, the fuel is fed to a discharge jet, the tip of which is located in the throat of the venturi. Because of the differential pressure between the float chamber and the throat of the venturi, fuel is discharged into the air stream.
- The gasoline engine is quantity governed, which means that when power output is to be varied at a particular speed, the amount of charge delivered to the cylinder is varied.
- This is achieved by means of a throttle valve usually of the butterfly type that is situated after the venturi tube.
- As the throttle is closed less air flows through the venturi tube and less is the quantity of air fuel mixture delivered to the cylinder and hence power output is reduced. As the" throttle is opened, more air flows through the choke tube resulting in increased quantity of mixture being delivered to the engine. This increases the engine power output.

Drawbacks of carburetor:

- **Metering fuel supply of multi cylinder engine:** It becomes difficult for a single carburetor to ensure uniformity of mixture quantity in all cylinders.
- **Venturi throat of carburetor:** It causes a restriction in the passage of air flow to the engine.
- **Low operational efficiency:** Due to presence of several wearing parts, the carburetors operate at a lower efficiency.
- **Reduced volumetric efficiency:** due to non-availability of a free flow passage for the mixture owing to the presence of choke tubes, throttle valves, jets, bends etc.
- At low temperatures, freezing can occur.

MULTI POINT FUEL INJECTION SYSTEM (MPFI):

- The functions of a fuel injection system are:
  - To monitor the engine's operating variables,
  - To transfer this information to a metering control, then
  - To discharge and atomize the fuel into the incoming air stream.



- An electrically driven pump draws the fuel from the tank through a filter and supplies the same to the injectors at a pressure which is held constant by means of a fuel-pressure regulator.
- The pump draws more fuel than the required and the excess fuel is returned to the tank by the fuel pressure regulator.
- The injectors are held closed by means of spring and are opened by means of solenoids energized by the control signal from the electronic control unit (ECU).
- The strength of the ECU control signal, which determines the open time of the injector to control the amount of fuel injected, depends upon the engine requirements which are determined by the ECU from the sensor signals from critical locations.
- The common sensors employed are:
  - **Crankshaft speed sensor:** This registers the speed and angle of crankshaft without contact.
  - **Camshaft speed sensor:** Also called the phase sensor, it measures the speed and position of the camshaft without contact.
  - **Knock sensor:** This is used to recognize the onset of knocking using fuels of varying quality.
  - **Mass Air flow sensor:** to measure quantity of air drawn into the engine.
  - Manifold absolute pressure (MAP) sensor.
  - **Barometric pressure (BARO) sensor:** correction for air density change with height.
  - **Throttle position sensor (TPS)**
  - **Coolant temperature sensor (CTS)**
  - **Manifold air temperature (MAT) sensor**
  - **Exhaust oxygen sensor:** correction for emission control.
  - **Vehicle speed sensor (VSS)**
  - **Battery voltage sensor:** correction for supply voltage to control unit and injectors.

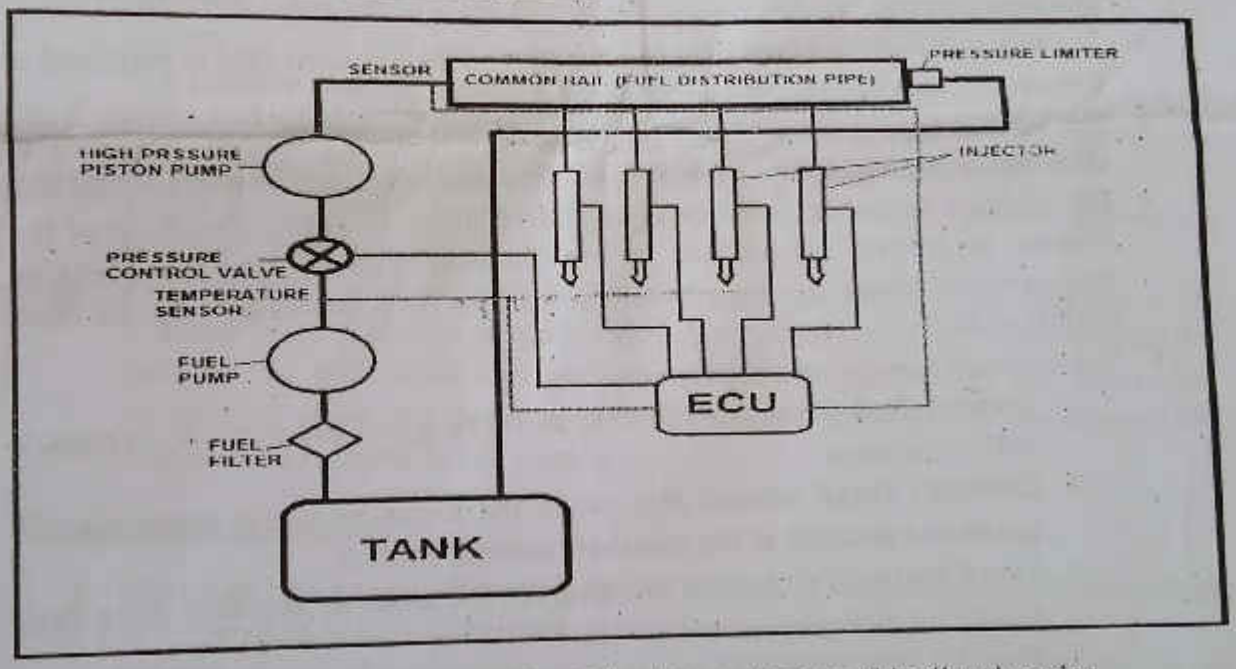
Advantages of MPFI:

- A very high-quality fuel distribution is obtained.
- The restriction imposed by the carburetor venturi is removed in the petrol injection; this improves volumetric efficiency.
- Fuel consumption is less.
- The response of the engine to throttle control is very rapid.
- MPFI does not need time for transportation of fuel in the intake manifold.
- MPFI is more precise in metering of fuel over the complete operating range of speed, load and temperature.
- Due to increased combustion efficiency, the exhaust emissions are less.

Disadvantages of MPFI:

- Initial cost is very high.
- Complicated mechanism.
- Increased maintenance cost.
- There are more mechanical and electrical components liable to go wrong due to wearing.

COMMON RAIL DIRECT INJECTION (CRDI):



- CRDI system is an electronic fuel injection system used in diesel engine.
- The main components of the system are the low pressure, high pressure pump, common rail, ECU, injection lines, injectors and sensors.
- In contrast to conventional mechanical injection system, here the fuel pump and injectors are electronically controlled.
- High injection pressures are possible even at low engine speed which leads to more complete combustion of the fuel.
- Here more than one injection is possible in a single power stroke.

Working:

- The fuel from the fuel tank is pumped by a low pressure electric fuel pump through a filter, to the high-pressure pump.

- This high-pressure pump builds up high pressure in the common rail with the help of a pressure regulator valve which is controlled by an ECU (Electronic Control Unit) through pressure sensor.
- Thus, the fuel pressure in the rail is independent of the engine speed and the injected fuel quantity.
- A pressure limiter valve guards the system against excess pressure.
- The fuel is injected in the engine by the fuel injector which is controlled by ECU.
- The fuel injector used is either solenoid type or piezo electric type.
- The fuel injection pressure in modern CRDI system is up to 2200 bar.
- The injection timing and amount of fuel injected is fully controlled by ECU by measuring various engine parameters with the help of various sensors.
- The various sensors used are:
  - Crankshaft sensor
  - Camshaft sensor
  - Accelerator pedal sensor
  - Air mass and temperature sensor
  - Coolant temperature sensor
  - Oxygen sensor

Advantages of CRDI:

- Increased power and fuel efficiency due to better combustion.
- Reduced emissions due to complete combustion
- Reduced noise and vibration
- Increased engine life

SUPERCHARGING:

- Supercharging is the process of supplying to the engine, air fuel mixture at a pressure above the atmospheric.
- On an ordinary engine (naturally aspirated), the downward piston movement during the intake stroke creates a vacuum in the inlet manifold, which is used to draw in the air-fuel mixture through the carburetor into the cylinders.
- With supercharging, due to higher pressure, the density of charge increases and, therefore, its weight per stroke is increased for the same swept volume.
- It is seen that the power output of an engine is almost directly proportional to the weight of charge per minute.
- Up to 40% increase in power and torque may be obtained by supercharging.

Objectives of supercharging:

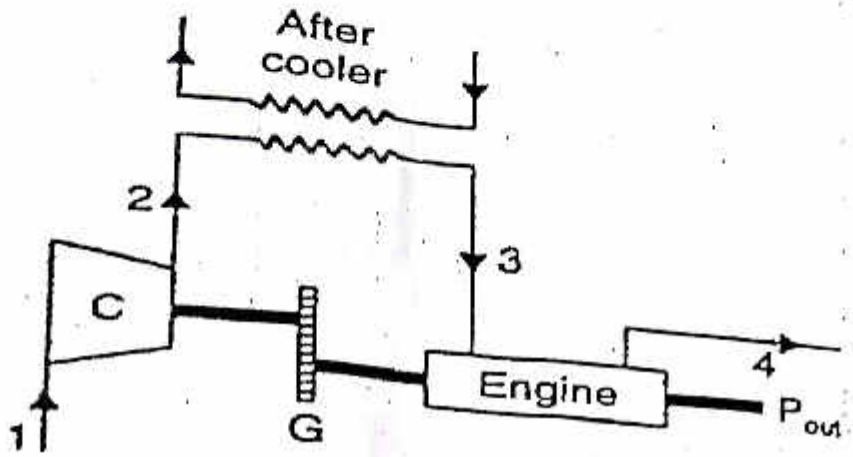
- To increase the power output for a given weight and bulk of the engine.
- To compensate for the loss of power due to high altitude.
- To obtain more power from an existing engine.

Effects of supercharging:

- For same engine displacement, the power output of a supercharged engine is higher than naturally aspirated engine.
- The mechanical efficiencies of supercharged engines are slightly better than the naturally aspirated engines.

- Mechanically supercharged Otto engines always have specific fuel consumption higher than a naturally aspirated engine.

Supercharging of SI engine:



- Figure shows a compressor coupled to the engine with step-up gearing for increasing the speed of the compressor.
- Here, a portion of the engine output is used to drive the compressor. The net output increases due to supercharging is obtained by subtracting this power from the engine gross output.
- The purpose of after cooler is to send cool charge to the engine for further increasing the density of the intake charge.
- In general, supercharger pressure of 1.3 to 1.5 bar is used.

TURBOCHARGING:

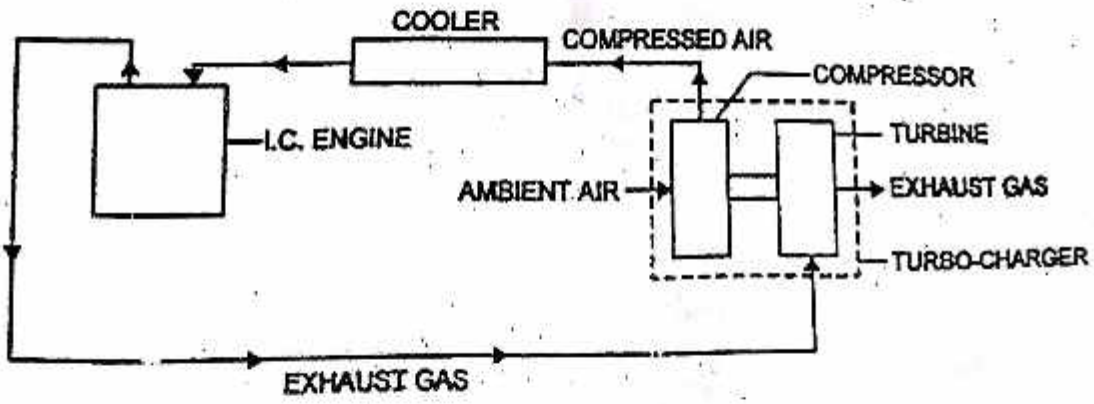


Fig. 9.74. Working of a turbochager

- In a petrol engine, about 35-40% of the energy contained in the fuel goes waste in the outgoing exhaust gases.
- A turbocharger, which employs a centrifugal compressor as a supercharger and a turbine wheel makes use of a part of the energy contained in the exhaust gases.
- The energy extracted from the exhaust gases is also utilized to drive the compressor.

- The turbocharger includes a turbine and a centrifugal compressor coupled together.
- Exhaust gases from the engine enter the turbocharger and run the turbine, which further drives the compressor.
- The atmospheric air enters the compressor which raises its pressure by about 0.5 bar (50 kPa).
- In practice, we obtain 30 to 40 percent increase in power.

Advantages of turbocharging:

- Power output of a given displacement engine is increased.
- Torque characteristic of the turbocharged engines is better.
- Turbocharged engines have more B.P./weight ratio, compared to naturally aspirated engines.
- Power loss due to decrease in air density at higher attitudes is reduced by using turbocharger.
- Reduced fuel consumption.
- Reduced exhaust gas emissions.

Turbo lag:

- A lag is felt by the driver of a turbocharged vehicle as a delay between pressing the accelerator pedal feeling the turbo action. This is known as turbo lag.
- This is due to the time taken for the exhaust system driving the turbine to overcome its rotational inertia and reach the speed required to supply the boost pressure.
- This lag is not there in a supercharger where the compressor is driven directly from the engine.
- Turbo lag can be reduced by the following:
  1. By reducing the rotational inertia of the turbine by using lighter parts.
  2. By changing the aspect ratio of turbine by reducing its diameter and increasing the length of the gas flow path.
  3. By using a precision bearing, which reduces friction, thereby leading to faster acceleration of turbine motor.
  4. By using two small turbos, one always active and the other one operating only at higher speeds.

HYBRID ENGINES:

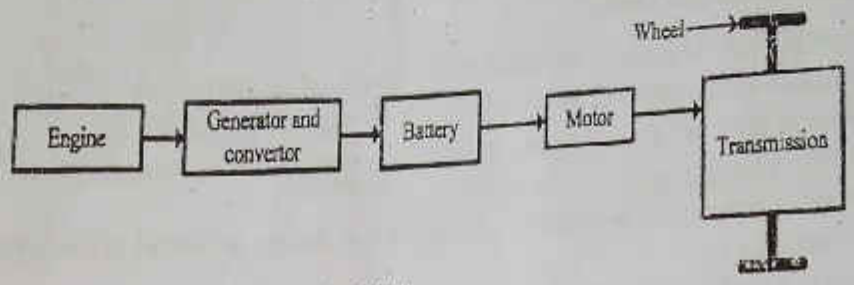
- A hybrid vehicle is a vehicle that uses two or more power sources to move the vehicle.
- eg. A conventional internal combustion engine and also a high voltage electric motor.

Types:

- Series hybrid
- Parallel hybrid

SERIES HYBRID:

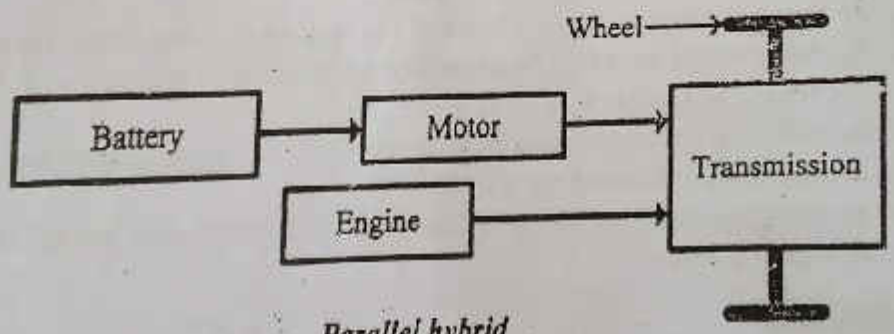
- In series hybrids, only the electric motor drives the vehicle, and the IC engine works as a generator to power the electric motor or to recharge the batteries
- The battery pack can be recharged from the IC engine.
- Series hybrids usually have a smaller combustion engine but a larger battery pack as compared to parallel hybrids, which makes them more expensive than parallels.



Series hybrid

PARALLEL HYBRID:

- In parallel hybrids, the ICE and the ELECTRIC MOTOR are both connected to the mechanical transmission and can simultaneously drive the wheels.
- Usually, parallel hybrids can use a smaller battery pack as they rely more on the internal combustion engine and also act a generator for supplemental recharging.
- Parallel hybrids are more efficient for highway driving than in urban stop-and-go conditions.



Parallel hybrid