INTERNAL COMBUSTION ENGINE

Chapter-1

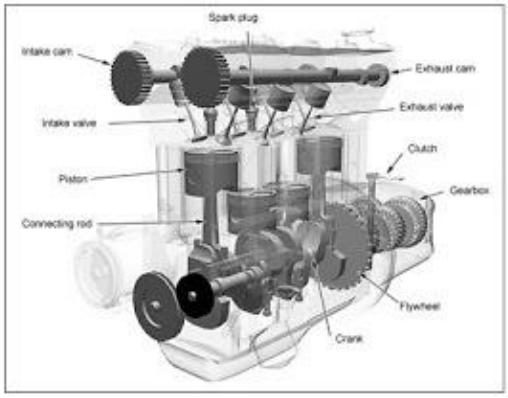
Heat Engine

It is a device that converts chemical energy of fuel into thermal energy that is further used for doing mechanical work.

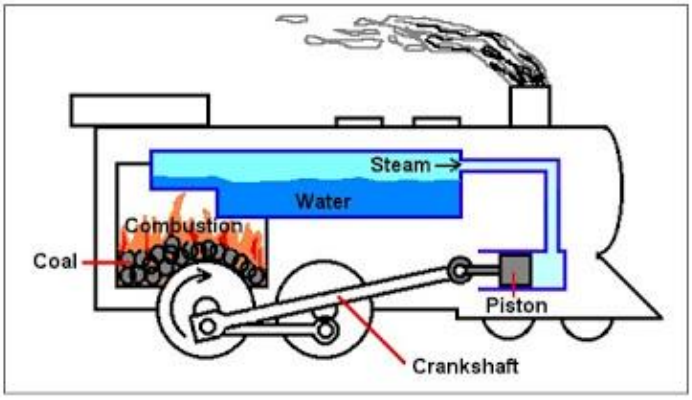
Internal Combustion & External Combustion Engine

In an internal combustion engine, the working fluid consists of a combustible fluid placed inside a cylinder these engines, the fluid undergoes combustion inside the cylinder and expands.

In an external combustion engine, the combustion takes place outside the cylinder. Heat then needs to be transferred to the cylinder where work is done. Steam engines are an example of external combustion engines.



Internal Combustion Engine



External Combustion Engine

Working of a four stroke Diesel engine

Diesel engine, also known as compression ignition (C.I.) engine is widely used in automobile industries. Big vehicles such as truck, bus, locomotive engine etc. used diesel engine as the power unit because of its higher torque and greater mileage than petrol engine.

The ignition temperature of diesel is lower than petrol so the working of diesel engine is slightly different than petrol engine.

Power generation in four stroke is divided into four parts namely suction stroke, compression stroke, expansion stroke (power stroke) and exhaust stroke.

Suction stroke:

In the suction stroke of diesel engine the piston start moves from Top Dead Centre (TDC) of the cylinder to Bottom Dead Centre (BDC) of the cylinder and simultaneously inlet valve opens. At this time air at atmospheric pressure drawn inside the cylinder through the inlet valve due to the suction created. The inlet valve remains open until the piston reaches the BDC of cylinder (not practically but theoretically.).

Compression stroke:

After the piston passes BDC of the cylinder, it starts moving up. Both valves are closed and hence the cylinder is sealed. The piston moves upward. This movement of piston compresses the air into a small space between the piston and TDC of cylinder . The air is compressed into 1/22 (compression ratio: 22, varies from engine to engine) or less of its original volume. Due to this compression a high pressure and temperature is generated inside the cylinder. Both the inlet and exhaust valves do not open during any part of this stroke. At the end of compression stroke the piston is at TDC the cylinder.

Power stroke:

At the end of the compression stroke when the piston is at TDC a pre metered quantity of diesel is injected into the cylinder by the injector. The temperature inside the cylinder is very high which is sufficient to ignite the fuel injected and this generates tremendous energy which is in the form of high pressure which pushes down the piston. The connection rod carries this force to the crankshaft which turns to move the vehicle. At the end of power stroke the piston reaches the BDC.

Exhaust stroke:

When the piston reaches the BDC after the power stroke, the exhaust valve opens. The pressure of the burnt gases is higher than atmospheric pressure. This pressure difference allows burnt gases to escape through the exhaust port and the piston move through the TDC. At the end of exhaust all burn gases escape (theoretically) and exhaust valve is closed.

Components of Engine cylinder

Cylinder Block:-

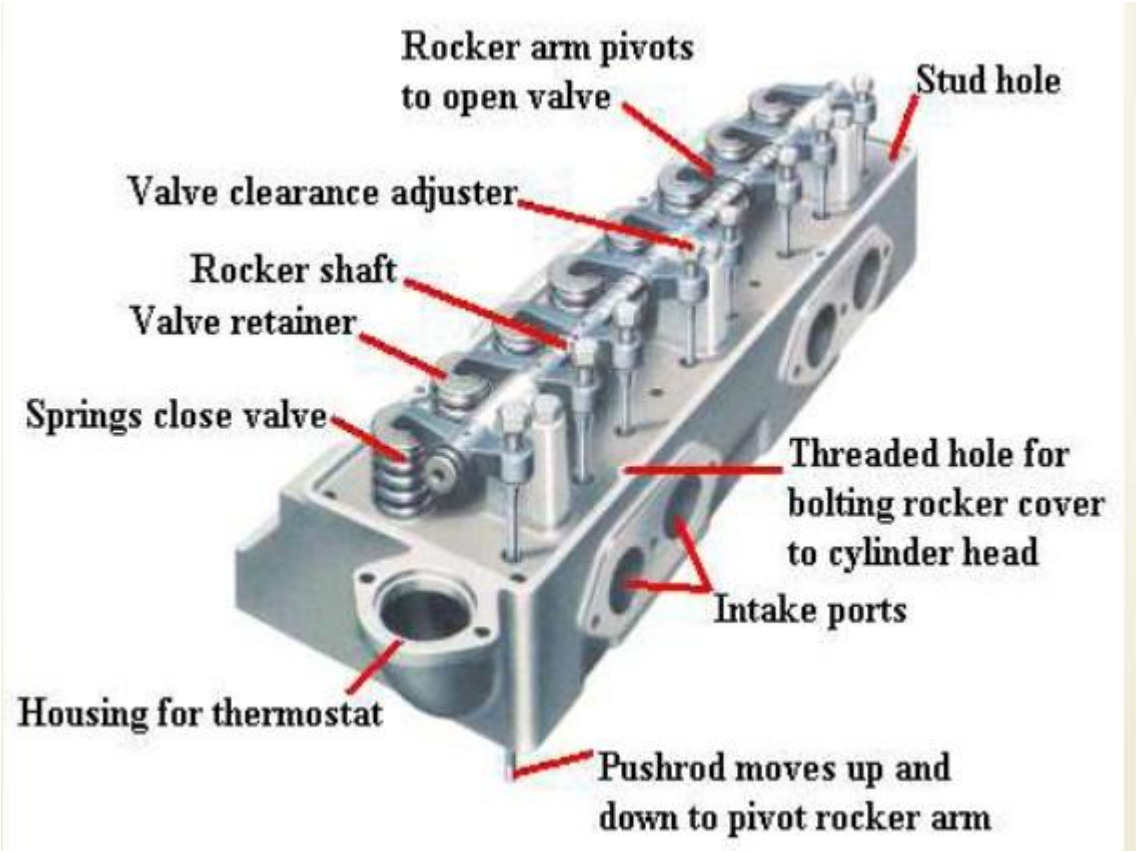
- It is a container fitted with piston, where the fuel is burnt and power is produced.
- Cylinder is the main body of IC engine. Cylinder is a part in which the intake of fuel, compression of fuel and burning of fuel take place. The main function of cylinder is to guide the piston.

- For cooling of cylinder a water jacket (for liquid cooling used in most of cars) or fin (for air cooling used in most of bikes) are situated at the outer side of cylinder.
- At the upper end of cylinder, cylinder head and at the bottom end crank case is bolted.
- Material : Ductile (Nodular) Cast Iron ,30C8 (Low Carbon Steel)
- Manufacturing method : Casting, Forging and after that heat transfer , Machining

Cylinder Block

2.Cylinder Head/Cylinder Cover:-

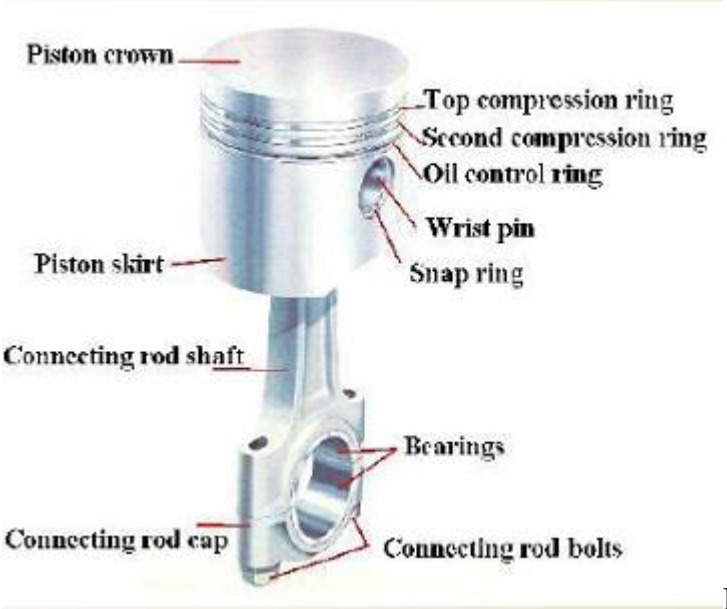
- One end of the cylinder is closed by means of cylinder head. This consists of inlet valve for admitting air fuel mixture and exhaust valve for removing the products of combustion.
- The inlet valve, exhaust valve, spark plug, injector etc. are bolted on the cylinder head. The main function of cylinder head is to seal the cylinder block and not to permit entry and exit of gases on cover head valve engine.
- Material: Aluminium alloys
- Manufacturing Method: Casting



Cylinder Cover

3. Piston:-

- Piston is used to reciprocate inside the cylinder.
- It transmits the energy to crankshaft through connecting rod.
- Material : Aluminum Alloy 4652 because of its Low Specific Gravity.
- Manufactuirng Method: Casting



Piston

4. Piston Rings:-

- These are used to maintain a pressure tight seal between the piston and cylinder walls and also it transfer the heat from the piston head to cylinder walls.
- These rings are fitted in grooves which have been cut in the piston. They are split at one end so they can expand or slipped over the end of piston.
- Material: cast iron of fine grain and high elastic material
- Manufacturing Method: Pot casting method

Piston rings

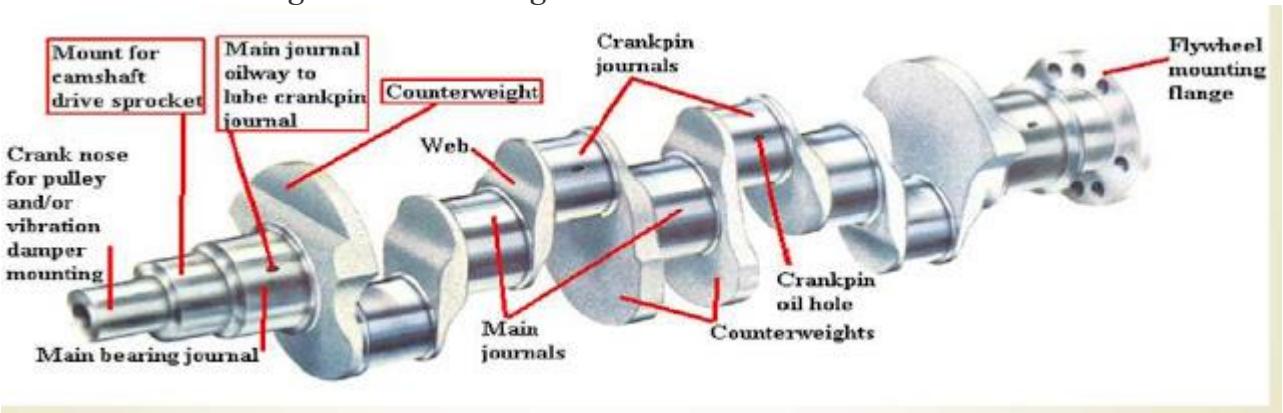
5. Connecting Rod:-

- One end of the connecting rod is connected to piston through piston pin while the other is connected to crank through crank pin.
- It transmits the reciprocatory motion of piston to rotary crank.
- There are two end of connecting rod one is known as big end and other as small end. Big end is connected to the crankshaft and the small end is connected to the piston by use of piston pin.
- Material: Low Carbon steel 30C8
- Manufacturing Methods : Forging and after that heat heat treatment.


Connecting Rod

6. Crank:-
   - It is a lever between connecting rod and crank shaft.

7. Crank Shaft:-
   - The function of crank shaft is to transform reciprocating motion in to a rotary motion.
   - The crankshaft of an internal combustion engine receives the efforts or thrust supplied by piston to the connecting rod and converts the reciprocating motion of piston into rotary motion of crankshaft.
   - The crankshaft mounts in bearing so it can rotate freely.
   - The shape and size of crankshaft depends on the number and arrangement of cylinders.
   - Material: 37C15 Alloy Steel.
   - Manufacturing Method: Casting



Crank Shaft

8. Fly wheel:-
   - Fly wheel is a rotating mass used as an energy storing device.

- A flywheel is secured on the crankshaft. The main function of flywheel is to rotate the shaft during preparatory stroke. It also makes crankshaft rotation more uniform.
- Material : cast Iron
- Manufacturing Method : Casting

Flywheel

9. Crank Case:-

- It supports and covers the cylinder and the crank shaft. It is used to store the lubricating oil.
- The main body of the engine to which the cylinder are attached and which contains the crankshaft and crankshaft bearing is called crankcase. It serves as the lubricating system too and sometime it is called oil sump. All the oil for lubrication is placed in it.

Crankcase

10.Poppet Valves

- A valve is a device that regulates, directs or controls the flow of a fluid (gases, liquids, fluidized solids, or slurries) by opening, closing, or partially obstructing various passageways.
- The intake and exhaust valves open at the proper time to let in air and fuel and to let out exhaust.
- Note that both valves are closed during compression and combustion so that the combustion chamber is sealed.
- Materials: Phosphorus Bronze and Monel metal.

POPPET valve

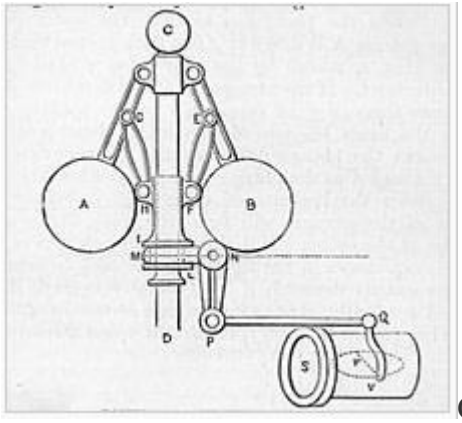
11. Spark Plug:

- The main function of a sparkplug is to conduct the high potential from the ignition system into the combustion chamber.
- It provides the proper gap across which spark is produced by applying high voltage , to ignite the mixture in the ignition chamber.
- Manufacturing Method: Each major element of the spark plug—the center electrode, the side electrode, the insulator, and the shell—is manufactured in a continuous in-line assembly process. Then, the side electrode is attached to the shell and the center electrode is fitted inside the insulator. Finally, the major parts are assembled into a single unit.

Spark Plug

12. Engine Bearing:
    - The crankshaft is supported by bearing .
    - Everywhere there is rotary action in the engine , bearings are used to support the moving parts.
    - Its purpose is reduce the friction and allow parts to move freely.

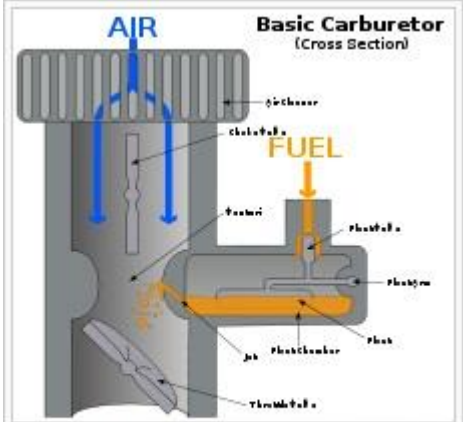
13. Governor:
    - A device for regulating automatically output of a machine by regulating the supply of working fluid.
    - When the speed decreases due to increase in load the supply valve is opened by mechanism operated by governor and the engine therefore speeds up again to its original speed.
    - Thus the function of a governor is to control the fluctuations of engine speed due to changes of load.
    - See: Introduction To Governors | Classification / Types Of Governors



Governer

14. Carburetor :
    - The function of a carburetor is to atomize and meter the liquid fuel and mix it with the air as it enters the induction system of the engine .

- Maintaining fuel-air proportion under all conditions of operation appropriate to the conditions.



Cross-sectional schematic of a downdraft carburetor

15. Fuel Atomizer or Injector

- Fuel injection is a system for mixing fuel with air in an internal combustion engine. It has become the primary fuel delivery system used in automotive petrol engines, having almost completely replaced carburettors in the late 1980s.
- The primary difference between carburettors and fuel injection is that fuel injection atomizes the fuel by forcibly pumping it through a small nozzle under high pressure, while a carburettor relies on low pressure created by intake air rushing through it to add the fuel to the airstream.
- The fuel injector is only a nozzle and a valve: the power to inject the fuel comes from a pump or a pressure container farther back in the fuel supply.

16. Manifold

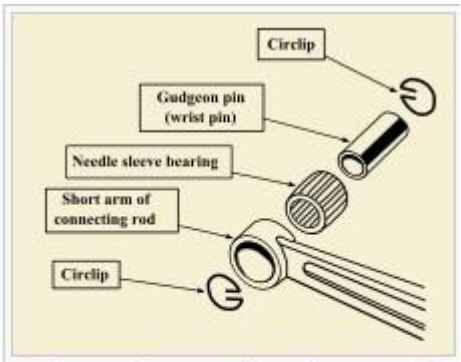
- The main function of manifold is to supply the air fuel mixture and collects the exhaust gases equally form all cylinder. In an internal combustion engine two manifold are used, one for intake and other for exhaust.
- Material : Aluminium alloy -Alloy 4600

Manifold

17. Gudgeon pin or piston pin

- These are hardened steel parallel spindles fitted through the piston bosses and the small end bushes or eyes to allow the connecting rods to swivel. It connects the piston to connecting rod. It is made hollow for lightness.

- Material: Plain Carbon steel 10C4



Gudgeon pin connection at connecting rod. Gudgeon pin fits into gudgeons inside piston.

18. Pushrod

- Pushrod is used when the camshaft is situated at the bottom end of cylinder. It carries the camshaft motion to the valves which are situated at the cylinder head.

Push rod

19. Rocker Arm :

- Rocker Arms are typically in between the pushrod and the intake and exhaust valves. They allow the pushrods to push up on the rocker arms and therefore push down on the valves.
- Material : Medium Carbon steel
- Manufacturing methods : Forging

Rocker arm

20.Cam Shaft:

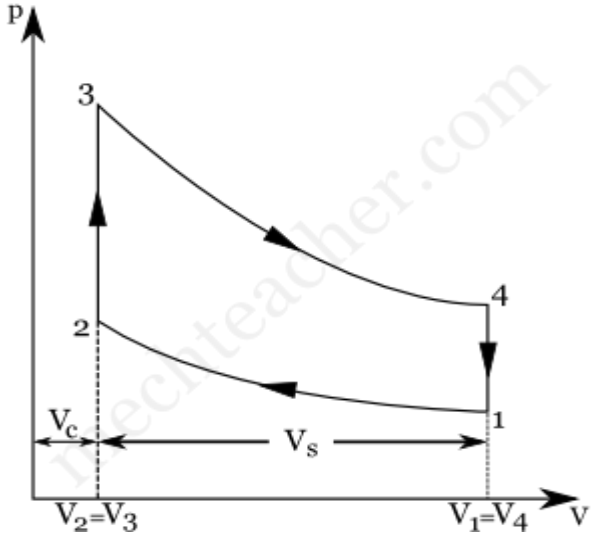
- Camshaft is used in IC engine to control the opening and closing of valves at proper timing.
- For proper engine output inlet valve should open at the end of exhaust stroke and closed at the end of intake stroke.
- So to regulate its timing, a cam is use which is oval in shape and it exerts a pressure on the valve to open and release to close.
- It is drive by the timing belt which drives by crankshaft. It is placed at the top or at the bottom of cylinder.
- Material: Plain Carbon steel 10C4
- Manufacturing Method: Grinding, Case Hardening

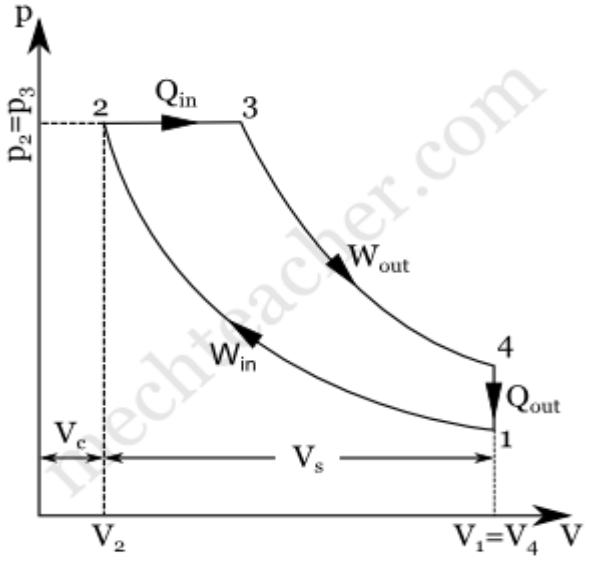
Chapter- 2

OTTO CYCLE & DIESEL CYCLE

Difference Between Otto Cycle and Diesel Cycle

S.no	OTTO CYCLE	DIESEL CYCLE
1.	Heat addition takes place at constant volume.	Heat addition takes place at constant pressure.
2.	Petrol engines work on this cycle.	Diesel engines work on this cycle.
3.	At constant volume, heat rejection takes place.	In diesel cycle also the heat rejection takes place at constant volume.
4.	Compression ratio is less. It is 7:1 to 10:1.	Compression ratio is more. It is 11:1 to 22:1.
5.	Efficiency is less.	Efficiency is more.
6.	Adiabatic expansion takes place during the complete backward stroke of the piston.	After the heat addition is cut-off in the backward stroke, the adiabatic expansion takes place during the remaining portion of stroke.





OTTO CYCLE **DIESEL CYCLE**

An Otto cycle consists of four processes:

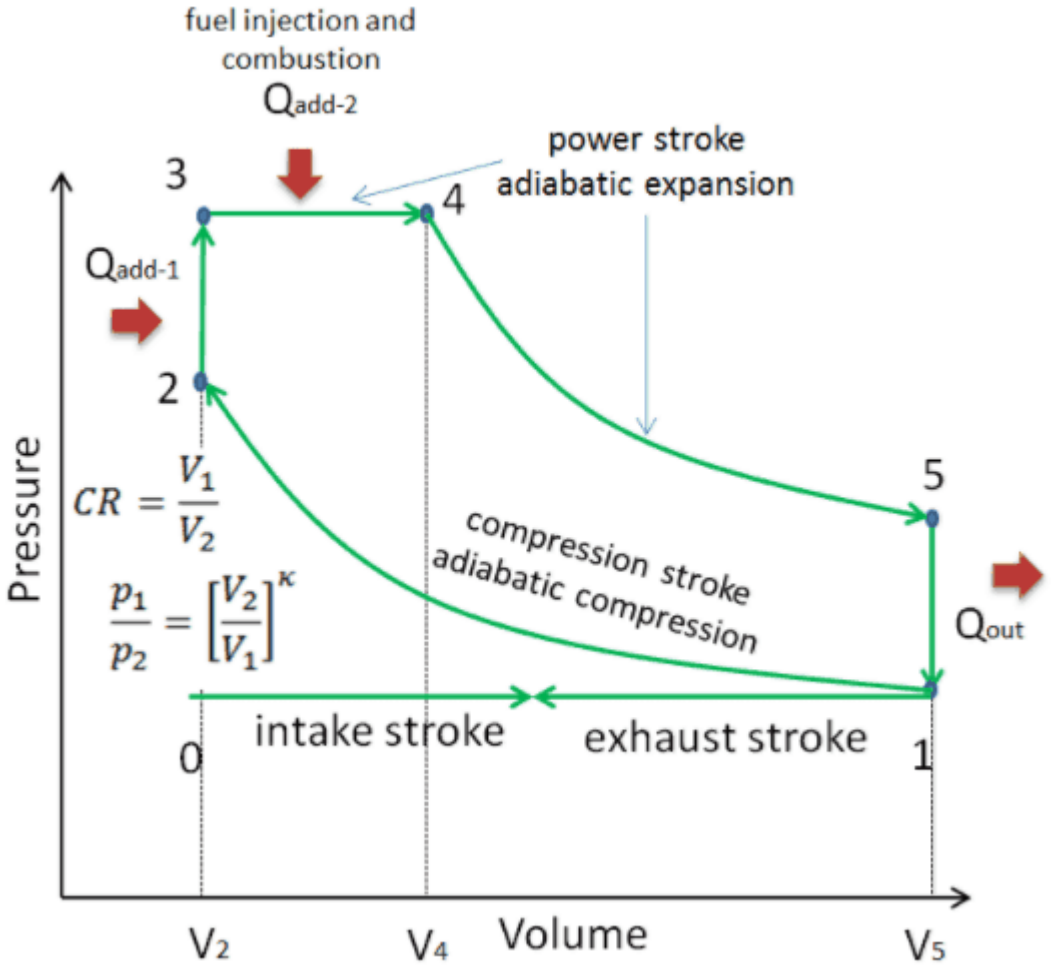
1. Two isentropic (reversible adiabatic) processes
2. Two isochoric (constant volume) processes

Diesel cycle has four processes:

1. Process 1-2: Isentropic (Reversible adiabatic) Compression
2. Process 2-3: Constant Pressure (Isobaric) Heat Addition
3. Process 3-4: Isentropic Expansion
4. Process 4-1: Constant Volume (Isochoric) Heat Rejection

DUAL CYCLE

In a **dual cycle**, the system executing the cycle undergoes a series of five processes: two isentropic (reversible adiabatic) processes alternated with two isochoric process and one isobaric process:



Difference Between Petrol and Diesel Engine	
Diesel Engine	**Petrol Engine**
These engines work on the Diesel cycle	Works on the Otto cycle
The fuel is mixed with air inside the cylinder	Air and the fuel are mixed in a carburettor
Ignition is achieved with the help of the hot, compressed air.	Fuel is ignited with an electric spark
High compression ratio	Relatively low compression ratio
High power production	Relatively low amounts of power are produced in a Petrol engine
These engines work with fuels that have low volatilities	Highly volatile fuels are used in these internal combustion engines
Generally used in heavy vehicles such as trucks and buses	Used in light vehicles such as motorcycles and cars.
Relatively low fuel consumption	High fuel consumption.
High initial and maintenance costs	Comparatively low initial cost and maintenan

Chapter-4

Fuel Supply system

PROPERTIES OF FUEL : Fuel is a substance consumed by the engine to produce energy. The common fuels for internal combustion engines are: 1. Petrol 2. Power kerosene 3. High speed diesel oil 4. Light diesel oil.

The important properties of these fuels are given below:

QUALITY OF FUEL: The quality of the fuel mainly depends upon the following properties:

1. Volatility of the fuel

2. Calorific value of the fuel

3. Ignition quality of the fuel Volatility: Volatility of fuel has considerable effect on the performance of the engine by affecting the following:

(i) Ease of starting the engine. (ii) Degree of crankcase oil dilution, (iii) Formation of vapour lock in the fuel system, (iv) Accelerating characteristics of the engine, (v) Distribution of fuel in multi-cylinder engine.

In I. C. engine, all the liquid fuel must be converted into vapour fuel before burning. High speed diesel oil is most difficult to vapourise. Vapourising temperature of high speed diesel oil is higher than that of the petrol, hence the petrol vapourises quicker than diesel oil in the engine cylinder. This helps in easy starting of petrol engines.

Calorific value: The heat liberated by combustion of a fuel is known as calorific value or heat value of the fuel. It is expressed in kcal /kg of the fuel. The heat value of a fuel is an important measure of its worth, since this is the heat which enables the engine to do the work.

Ignition quality: Ignition quality refers to ease of burning the oil in the combustion chamber.

Octane number and cetane number are the measures of ignition quality of the fuel.

(a) Octane number: It is a measure of knock characteristics of a fuel. The percentage of iso-octane (C8 H18) in the reference fuel consisting of a mixture of iso-octane and normal heptane (C7H16), when it produces the same knocking effect as the fuel under test, is called octane number of the fuel. Iso-octane has excellent antiknock qualities and is given a rating of 100. Normal heptane would knock excessively and hence it is assigned a value of zero.

(b) Cetane number: The percentage of cetane in a mixture of cetane (C16 H34) and alphamethyl naphthelene (C11 H16) that produces the same knocking effect as the fuel under test is called cetane number of the fuel. Diesel fuels are rated according to cetane number which is the indication of ignition quality of the fuel. The higher the cetane number the better the ignition quality of the diesel fuel. The commercial diesel fuels have got cetane rating varying from 30 to 60.

Detonation (Knocking): Detonation or engine knocking refers to violent noises, heard in an engine, giving a pinging sound during the process of combustion.

Pre-ignition: Burning of air-fuel mixture in the combustion chamber before the piston has reached the top dead centre is called pre-ignition. Pre-ignition occurs when the charge is fired too far ahead of the top dead centre of the piston due to excessive spark advance or excessive heat in the cylinder.

FUEL SUPPLY SYSTEM IN SPARK IGNITION ENGINE

The fuel supply system of spark ignition engine consists of: (i) Fuel tank (ii) Fuel filter (iii) Sediment bowl (iv) Fuel lift pump (v) Carburettor (vi) Fuel pipes (vii) Inlet manifold In some spark ignition engine, the fuel tank is placed above the level of the carburettor.

The fuel flows from the fuel tank to the carburettor under the action of gravity. There are one or two filters between the fuel tank and the carburettor. A transparent sediment bowl is also provided to hold the dust and dirt of the fuel. If the tank is below the level of the carburettor, a lift pump is provided in between the tank and the

carburettor for forcing fuel from the tank to the carburettor of the engine. The fuel comes from the fuel tank to the sediment bowl and then to the lift pump. From there the fuel goes to the carburettor through suitable pipe. From the carburettor, the fuel goes to the engine cylinder, through the inlet manifold of the engine.

CARBURETTOR: The process of preparing an air-fuel mixture away from the cylinders of an engine is called carburetion and the device in which this process take place is called carburettor. Principle of carburettor: The basic principle of all carburettor design that when air flows over the end of a narrow tube or jet containing liquid, some liquid is drawn into the air stream. The quantity of liquid drawn into the air stream increases as the speed of air flow over the jet increases and also the quantity is greater if the jet is made larger.

FUEL SYSTEM OF DIESEL ENGINE

During engine operation, the fuel is supplied by gravity from fuel tank to the primary filter where coarse impurities are removed. From the primary filter, the fuel is drawn by fuel transfer pump and is delivered to fuel injection pump through second fuel filter. The fuel injection pump supplies fuel under high pressure to the injectors through high pressure pipes. The injectors atomise the fuel and inject it into the combustion chamber of the engine. The fuel injection pump is fed with fuel in abundance. The excess fuel is by-passed to the intake side of the fuel transfer pump through a relief valve. The main components of the fuel system in diesel engine are: (1) fuel filter (2) fuel lift pump (3) fuel injection pump (4) atomisers and (5) high pressure pipe. Flow diagram of fuel in diesel tractor Cylinder Injector Diesel Tank

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

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

FUEL INJECTION PUMP: It is a pump, which delivers metered quantity of fuel to each cylinder at appropriate time under high pressure. Tractor engines may use two types of fuel injection pump: (i) Multi-element pump and (ii) Distributor (Rotary) type pump. Fuel Injector: It is the component, which delivers finely atomised fuel under high pressure to the combustion chamber of the engine. Modern tractor engines use fuel injectors, which have multiple holes. Main parts of injector are: nozzle body and needle valve. The nozzle body and needle valve are fabricated from alloy steel. The needle valve is pressed against a conical seat in the nozzle body by a spring. The injection pressure is adjusted by adjusting the screw.

FUEL INJECTION SYSTEM: Diesel fuel is injected in diesel engine through injectors with the help of fuel injection pump. The system using injectors, fuel injection pump, fuel filter, and fuel lines is called fuel injection system. The main functions of fuel injection system are: (i) To measure the correct amount of fuel required by engine speed and load, (ii) To maintain correct timing for beginning and end of injection, (iii) To inject the fuel into the combustion space against high compression pressure. (iv) To atomise the fuel for quick ignition. Process of fuel injection in diesel engine is of two types: (i) Air injection (ii) Solid injection. Air injection: In this process, the engine uses compressed air to force the fuel into the cylinder. It is a bulky system and hence it is not considered very suitable for vehicles and tractors. It is mostly heavy-duty stationary engines. Solid injection: A high-pressure pump is used for forcing the fuel into the combustion chamber.

COMBUSTION CHAMBER: A combustion chamber is a space inside the engine, where the combustion of fuel takes place. In diesel engine, the fuel is atomised, vapourised and burnt inside combustion chamber, whereas in spark ignition engine, atomisation of fuel takes place in the carburettor and vaporisation occurs in carburettor as well as the inlet manifold. Combustion chamber is classified as: (a) Direct injection chamber (b) Indirect injection chamber.

TURBOCHARGER: It is a turbo-compressor driven by the exhaust gases of the engine to supply air under pressure to the cylinders of the engine. Turbocharger is useful because the power output of a diesel engine can be increased by supplying compressed air to the engine cylinders. If more air is delivered to the cylinders the fuel charge can also be increased and will release more energy. The turbocharger consists of a centrifugal compressor with impellers and a gas turbine unit. The compressor impeller and the turbine wheel are rigidly fixed on a common shaft. Compressor impeller draws air from the atmosphere and delivers it to the intake manifold and from there it goes to the engine cylinders thus improving the volumetric efficiency of the engine.

FUEL FILTER: It is a device to remove dirt from fuel oil. Solid particles and dust in diesel fuel are very harmful for giving a fine degree of filtration. Fuel injection equipment in diesel engines is extremely sensitive to dirt and solid particles present in fuel. A filter is used to remove the dirt and solid particles from the fuel to ensure trouble free fuel supply. It consists of a hollow cylindrical element contained in a shell, an annular space being left between the shell and the element. The filtering element consists of metal gauge in conjunction with various media such as packed fibres, woven cloth, felt, paper etc. These filters are replaced at certain intervals, specified by the manufacturer. Usually there are two filters in diesel engine: (1) Primary filter and (2) Secondary filter. The primary filter removes water and coarse p

Working of fuel pump:

Diesel is pumped from the diesel tank by a low pressure pump. It is passed through a filter. The filter removes any unwanted impurities in the diesel.

Filtered diesel is supplied to the inlet port of the fuel injection pump. The fuel injection pump automatically pressurizes the diesel to the required level and supplies it to the fuel injector. The fuel injector forces the fuel into the cylinder at the end of the compression stroke, during each cycle of operation of the engine.

Fuel injection pump is operated by means of a cam shaft. CAV fuel injection is the most common fuel injection pump used in diesel engines.

Any leak-off diesel from the fuel injection pump is supplied back into the filter as shown in the diagram above.

Characteristics of a good fuel supply system:

A good fuel supply system should be able to deliver the fuel correctly at the end of the compression stroke.

It must be able to properly atomize the fuel.

It must operate smoothly and sharply during each cycle of operation of the engine.

It must be able to supply the fuel above atmospheric pressure.

Chapter- 5

Cooling System

We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150-200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling. It is also to be noted that : (a) About 20-25% of total heat generated is used for producing brake power (useful work). (b) Cooling system is designed to remove 30-35% of total heat. (c) Remaining heat is lost in friction and carried away by exhaust gases. Objectives After studying this unit,

you should be able to • understand the methods of cooling of IC engine, • explain the air cooling system, and • know the water cooling system of IC engine.

There are mainly two types of cooling systems

Air Cooled System

Air cooled system is generally used in small engines say up to 15-20 kW and in aero plane engines. In this system fins or extended surfaces are provided on the cylinder walls, cylinder head, etc. Heat generated due to combustion in the engine cylinder will be conducted to the fins and when the air flows over the fins, heat will be dissipated to air. The amount of heat dissipated to air depends upon : (a) Amount of air flowing through the fins. (b) Fin surface area. (c) Thermal conductivity of metal used for fins.

Cylinder with Fins Advantages of Air Cooled System Following are the advantages of air cooled system : (a) Radiator/pump is absent hence the system is light. (b) In case of water cooling system there are leakages, but in this case there are no leakages. (c) Coolant and antifreeze solutions are

Advantages of Air Cooled System

(a) Radiator/pump is absent hence the system is light.

(b) In case of air cooling system there are no leakages.

(c) Coolant and antifreeze solutions are not required.

(d) This system can be used in cold climates, where if water is used it may freeze.

Disadvantages of Air Cooled System

(a) Comparatively it is less efficient. (b) It is used in aero planes and motorcycle engines where the engines are exposed to air directly.

WATER COOLING SYSTEM

In this method, cooling water jackets are provided around the cylinder, cylinder head, valve seats etc. The water when circulated through the jackets, it absorbs heat of combustion. This hot water will then be cooling in the radiator partially by a fan and partially by the flow developed by the forward motion of the vehicle. The cooled water is again recirculated through the water jackets.

Types of Water Cooling System There are two types of water cooling system : Thermo Siphon System In this system the circulation of water is due to difference in temperature (i.e. difference in densities) of water. So in this system pump is not required but water is circulated because of density difference only. Thermo Siphon System of Cooling Pump Circulation System In this system circulation of water is obtained by a pump. This pump is driven by means of engine output shaft through V-belts.

Components of Water Cooling System

Water cooling system mainly consists of : (a) Radiator, (b) Thermostat valve, (c) Water pump, (d) Fan, (e) Water Jackets, and (f) Antifreeze mixtures.

Radiator: It mainly consists of an upper tank and lower tank and between them is a core. The upper tank is connected to the water outlets from the engines jackets by a hose pipe and the lower tank is connect to the jacket inlet through water pump by means of hose pipes.

When the water is flowing down through the radiator core, it is cooled partially by the fan which blows air and partially by the air flow developed by the forward motion of the vehicle.

Thermostat Valve: It is a valve which prevents flow of water from the engine to radiator, so that engine readily reaches to its maximum efficient operating temperature. After attaining maximum efficient operating temperature, it automatically begins functioning. Generally, it prevents the water below 70°C. It contains a bronze bellow containing liquid alcohol. Bellow is connected to the butterfly valve disc through the link. When the temperature of water increases, the liquid alcohol evaporates and the bellow expands and in turn opens the butterfly valve, and allows hot water to the radiator, where it is cooled.

Water Pump: It is used to pump the circulating water. Impeller type pump will be mounted at the front end. Pump consists of an impeller mounted on a shaft and enclosed in the pump casing. The pump casing has inlet and outlet openings. The pump is driven by means of engine output shaft only through belts. When it is driven water will be pumped.

Fan: It is driven by the engine output shaft through same belt that drives the pump. It is provided behind the radiator and it blows air over the radiator for cooling purpose.

Water Jackets: Cooling water jackets are provided around the cylinder, cylinder head, valve seats and any hot parts which are to be cooled. Heat generated in the engine cylinder, conducted through the cylinder walls to the jackets. The water flowing through the jackets absorbs this heat and gets hot. This hot water will then be cooled in the radiator

Antifreeze Mixture: In western countries if the water used in the radiator freezes because of cold climates, then ice formed has more volume and produces cracks in the cylinder blocks, pipes, and radiator. So, to prevent freezing antifreeze mixtures or solutions are added in the cooling water. The ideal antifreeze solutions should have the following properties :

(a) It should dissolve in water easily.

(b) It should not evaporate.

(c) It should not deposit any foreign matter in cooling system.

(d) It should not have any harmful effect on any part of cooling system.

(e) It should be cheap and easily available. (f) It should not corrode the system. No single antifreeze satisfies all the requirements.

Normally following are used as antifreeze solutions :

(a) Methyl, ethyl and isopropyl alcohols.

(b) A solution of alcohol and water.

(c) Ethylene Glycol.

(d) A solution of water and Ethylene Glycol.

(e) Glycerin along with water, etc.

Advantages of Water Cooling System

(a) Uniform cooling of cylinder, cylinder head and valves.

(b) Specific fuel consumption of engine improves by using water cooling system.

(c) If we employ water cooling system, then engine need not be provided at the front end of moving vehicle.

(d) Engine is less noisy as compared with air cooled engines, as it has water for damping noise.

Disadvantages of Water Cooling System

(a) It depends upon the supply of water. The water pump which circulates water absorbs considerable power.

(b) If the water cooling system fails then it will result in severe damage of engine.

(d) The water cooling system is costlier as it has more number of parts. Also it requires more maintenance and care for its parts.

LUBRICATION SYSTEM

Lubrication is the process of applying the lubricant between the surfaces of contact of two moving parts.

In an IC engine, parts moving rub each other causing wear and tear and reduces the power almost. so , lubricantion is necessary for an IC engine.

PURPOSE OF LUBRICATION

1. To reduce the friction between moving parts
2. To minimize the vibration .
3. To reduce the wear and tear.
4. To reduce the corrosion and carbon deposits.
5. To reduce the heat of moving parts.

6. To minimise the power lost due to friction.
7. To reduce the noise created by the moving parts.

THE ENGINE PARTS THAT REQUIRE FREQUENT LUBRICATION ARE

1. Cylinder piston and piston rings
2. Main bearings
3. Crankshaft, Crank pin and piston pin
4. Big end and small end connecting rod .
5. Cam shaft & Valves.

TYPES OF LUBRICATING SYSTEM

The lubrication system is classified into

1.Petroil lubrication is classified into

2.Wet sump lubrication.

1.PETROIL (OR) MIST LUBRICATION

This type of lubrication is used for two stroke cycle engines. The lubrications oil (2 to 3 percent) is mixed with petrol in the fuel tank. The oil and fuel mixture is inducted through the carburettor. Petrol gets evaporated and the oil lubricates the main parts of the cylinder.The fuel -oil ratio used is important for good performance. the optimum fuel -oil ratio used is 50:1.

ADVANTAGE

1. Separate lubricating system is not needed.
2. No maintenance cost for lubriction system.
3. Weight of engine is reduced by avoiding separate lubricating system.

DISADVANTAGE

1. If oil is less there is chance for seizure of engine.
2. More oil makes excess smoke in the exhaust.

2.WET SUMP LUBRICATION

In this system a big oil sump is provided at the base of crank case.From the sump the oil is pumped to different parts of the engine.The main types of wet sump lubrication system are

Splash lubrication system.

Pressure lubrication system.

Semi pressure lubrication system.

a) SPLASH LUBRICATION SYSTEM

The lubricating oil is filled in the sump and scoop are attached to the big end of connecting rod.When every time the piston reaches bottom dead center (BDC) the scoop dip into the sump and carries the lubricating oil . The lubricating oil is splashed to the piston, cylinder , small & big end of connecting rod, main bearing and can shaft bearing. The splashed oil settle on the engine parts and then falls into the sump.

b)PRESSURE LUBRICATION SYSTEM

In this system lubrication oil is applied to the engine parts under pressure using a pressure pump . The oil pump is submerged in the sump . the oil from the sump is delivered to the oil filter . The pressure of oil is increased by the punp. The oil is forced under pressure to different parts of engine through oil tubes (or) oil holes. Seperate oil tubes carry oil to the bearing.

From the bearing oil floats to the connecting rod through the oil hole between the connecting rod and crank shaft.Then this oil flows to the piston pin though oil hole and sprayed over the piston ,piston rings, cylinder valves and other engine parts.

c) SEMI PRESSURE LUBRICATION

This system is a combination of splash lubrication and pressure lubrication. In this system, oil under pressure is sent to main bearings only. It is assisted by means of splash system, which is used for lubrication of gudgeon pin bearings, cylinder walls, timing gears, camshaft bearings, etc. Insome design camshaft bearings also receive pressure lubrication from main bearings as in full pressure system.

Properties of lubricants:

a. Viscosity:

   It is the ability of a fluid to flow. It is the measure of resistance of liquid to the internal deformarion and shear. Viscosity decreases with increase in tempt.

b. Pour point:

   It is an indication of its ability to move at low temperature. It is defined as the lowest temperature at which oil will flow.

c. Flash and Fire points:

   The flash point of an oil is the temperature at which an oil ignites momentarily. The fire points is the temperature at which vapours burn continuously.

d. Cloud point or Turbidity point:

   The cloud point of a petroleum oil is the temperature at which parafin wax or other substances begin to crystallize or seperate out from solution .

e. Specific gravity:

   It is a numerical values, an index of the weight of oil compared without the weight of analyst equal volume of water.

f. Colour:

   Oils vary in colour from deformed black to yellow. Some axes completely transparent.

g. Sediments:

   The presence of sediments will degrade the lubricating qualities.

h. Emulsification:

   It is the dispersion of fine particles of a liquid in another liquid. An oil water emulsion is prepared and the time of separation is determined.

i. Carbon residue

   The carbon residue is the result of decomposition of an oil in absence of air.

j. Oxidation of oils: Oil in contact without air at high temperature oxidizes and produces carbon sediments and gums in engines.

Selection of lubricants

Viscosity is a single quality of a lubricant which determines the lubricating value. A following of oil must remain at all times between the surfaces in contact so that the lubrication is perfect. This can be provided when the viscosity is most suitable. If the viscosity is low, the lubricant will not stand in position, giving contact to surfaces. If the viscosity is high, the lubricant itself will offer frictional resistance.

A good lubricant has the following qualities:

a. It flows freely into the position.

b. It effectively reduces friction.

c. It stands up under the working pressure and temperature.

d. It does not leave residues at the bottom.

e. It does not change viscosity by continuous use.

f. Fairly high flash point and low freezing point.

Chapter-6

Testing of IC Engines

Engine power or horsepower is the maximum power that an engine can put out. It can be expressed in kilowatts or horsepower. The power output depends on the size and design of the engine, but also on the speed at which it is running and the load or torque.

Since the internal combustion engine is a complex machinery, with a multitude of components and systems, there are a lot of sources for the energy losses:

- **mechanical rubbing losses**: piston assembly, connecting rod, crankshaft, balance shaft, valve train system
- **pumping losses**: intake and exhaust
- **auxiliary device losses**: oil pump, fuel pump, water pump, alternator, AC compressor, etc.

Indicated power is defined as the total power developed by combustion of fuel in the combustion chamber. Indicated power produced inside the IC engine cylinder will be transmitted through the piston connecting rod and crank.

Brake power is defined as the power developed by an engine at the output shaft.

Mean effective pressure is defined as the hypothetical pressure which is thought to be acting on the piston

Efficiency of an IC engine (Internal Combustion Engine) is defined as the ratio of workdone to the energy supplied to an engine. The following efficiencies of an I.C. engine are important:

(a) Mechanical efficiency : It is the ratio of brake power (B.P.) to the indicated power (I.P.)

$$\eta_m = \text{Brake Power} / \text{Indicated Power}$$

Since B. P. is always less than I.P. , therefore mechanical efficiency is always less than unity (i.e. 100%).

(b) Overall efficiency. It is the ratio of the work obtained at the crankshaft in a given time to the energy supplied by the fuel during the same time. Mathematically, overall efficiency,

(c) Indicated thermal efficiency. It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per I.P. hour, Mathematically, indicated thermal efficiency,

(d) Brake thermal efficiency. It is the ratio of the heat equivalent to one kW hour to the heat in the fuel per B.P. hour. Mathematically, brake thermal efficiency,

(f) Relative efficiency. It is also known as efficiency ratio. The relative efficiency of an I. C. engine is the ratio of the indicated thermal efficiency to the air standardefficiency.

(g) Volumetric efficiency. It is the ratio of the actual volume of charge admitted during the suction stroke at N.T.P to the swept volume of the piston.

Method to find Indicated power

The **Indicated Power** is defined as the power produced due to combustion of fuel within the cylinder in an **IC Engine.** It is essentially the sum of the Friction and the Brake Powers.

To measure the **IP** of an IC engine (**SI Engine** here**)** we use the **Morse Test**.

The **Morse Test** is conducted in a *multi-cylinder spark ignition type of engine(cyl.>3)* . First the brake power generated at a certain load and rpm is calculated by a dynamo meter. Then the combustion in one of the cylinders is stopped , by removing the *spark plug or* disconnecting it .As a result ,the speed of the engine decreases due to inadequate combustion. To tackle this some amount of load is withdrawn so that the engine may run in the same speed as before. The *brake power* is then calculated. The difference in the *brake powers* measured gives the ***Indicated Power*** developed in the first cylinder. This is continued for the other cylinders by removing the spark plugs one at a time,and the **IP** of each cylinder is calculated. The total ***Indicated Power*** of the engine is the summation of the indicated powers of each cylinder.

This may be summed as...

BP = (IP1 – F1) + (IP2– F2) + (IP3 – F3) + ... (i)

BP1 = (0 – F1) + (IP2– F2) + (IP3 – F3) + ...(ii) [spark plug of cyl 1 cut off]

BP2 = (IP1– F1) + (0– F2) + (IP3 – F3) + ...(iii) [spark plug of cyl 2 cut off]

BP3 = (IP1 – F1) + (IP2– F2) + (0 – F3) + ...(iv) [spark plug of cyl 3 cut off]

BP – BP1 = IP1

BP – BP2 = IP2

BP – BP3 = IP3

IP= IP1 + IP2 +IP 3...

where **F** denotes the friction power.

To minimize chances of error an engine with more than 3 cylinders is chosen.

Indicated Power is the Theoretical Power Output of an IC Engine. The Actual Power output (Brake Power) differs from Indiacted Power due to frictional losses.

Theoretically,

IP = 1/60 * P*L*A*N*k

where, P : Mean Effective Pressure of Gas exerted on to the Piston during Power Stroke

L : Stroke (From TDC to BDC)

A : Area of Cylinder

N : Number of revolutions per minute of the Crankshaft

k : Factor, It is 1/2 for Four Stroke Engine whereas 1 for Two Stroke Engine

Practically, if Frictional Power losses can be accessed, then Indicated Power will be the sum of Brake Power and Frictional Power Loss.

Heat balance sheet: It is an account of heat supplied and heat utilized in various ways in the system. Necessary information concerning the performance of the engine is obtained from the heat balance.

The heat supplied to the engine is only in the form of fuel-heat and that is given by

Qs = mf X CV

Where mf is the mass of fuel supplied per minute or per sec. and CV is the lower calorific value of the fuel.

ENGINE MAINTENANCE – REPAIR AND OVERHAULING

1**. What do you mean by engine overhauling and explain its necessity**? Overhauling a machine, strictly speaking, means going over it. When a vehicle engine is being overhauled, it is completely taken apart, every piece is inspected and what ever piece shows appreciable wear is reconditioned to its original shape and dimensions or replaced by a new one. After this the engine is reassembled, put on a test stand, started, tuned up, and carefully tested. Since it is difficult to keep and accurate maintenance log for a vehicle away from the garage sometimes for days or week and since the operators of these vehicles need not be first class mechanics, and because nobody is concerned how efficiently an engine works as long as it runs and pulls the lead, a general overhauling of the engine is done at regular intervals, every 12 or 18 months as the case may be. In general, the methods of overhaul do not differ from maintenance procedure, except that in overhauling a more strict examination is in order as the intervals are considerably greater than in maintenance work, a part even slightly worn, if it is not subject to maintenance inspection periodically, should be either reconditioned or replaced.

2**. What is the precaution to be taken before dismantling engine.**

1. Dismantling: One of the important rule to be adhered in dismantling an engine is to mark all parts and identify them as the engine is dismantled. It is particularly important

to mark camshaft gears and valves if manufacturer's marks cannot be found. Centre and punch markings will serve the purpose. Changing the tyres around: In order to obtain the greatest mileage from a set of new tyres (including the spare one too) it is necessary to change then round at intervals of about 3000 miles for rear drive vehicles and 2000 miles for front drive vehicles during this useful life. Cuts in tyre treads: Since water and grit penetrate and destroy the cords, small cuts in tyre has to be plugged with readily available "plastic tyre stopping large cuts should be vulcanized at tree. Punctures: When a puncture occurs, on the road, the vehicle should be stopped and the when changed Tube less tyres can be driven to a safe distance even though they puncture, because, they lose their air more slowly. Small punctures can be repaired with rubber patches and rubber solution. Minimum amount of solution is to be applied and it is allowed to dry for 5 to 10 minutes before placing the prepared patch: After this some talc is sprinkled over the patch to prevent sticking to the outer cover major repairs of the tubes are to be done with a professional vulcanizer. When the vehicle is stored for a long period all the tyres are to be removed and stored an cool dry place, or the vehicle can be jacked off the ground and the tyres can be rubbed with French chalk.

3. Write down the step by step procedure for engine removing and dismantling

Removal of Engine from the vehicle

A. general procedure for removing the engine from vehicle can be summed up as follows:

1. Drain oil from the sump

2. Drain water from radiator and jackets, opening all taps in the cooling system.

3. Remove engine bonnet and where filled vertical side members. Remove radiator Disconnect cable from battery Disconnect fuel fed supply line .

4. Remove L.T. cables from ignition system and disconnect wiring to horn.

5. Disconnect radiator hose from the engine side Disconnect oil pipe to instrument pressure gage and thermometer pipe Remove electric horn if liable to obstruct engine removal

6. Take off cable connections to dynamo and starting meter (It is better to remove both starting motor (It is better to remove both starting motor and dynamic if readily accessible, as this allows better access to engine mounting nuts)

7. Remove exhaust pipe flange nuts

8. Take off accelerator and air choke controls

9. Take out all foot boards as far back as rear of gear box

10. Disconnect clutch pedal operating rod and pull of spring.

11. Disconnect foot brake pedal and hand brake, if anchored to engine unit

12. As the engine, clutch, and gear box are built as integral unit an most medium vehicles, it is more convenient to remove the complete unit than gear box; these

operations can be performed better on the bench than on the chassis and much time save thereby

What are the special tools and basic instruments required for maintenance?
Basic Instruments Needed

For Engine: 1. Compression Gauge 2. Vacuum Gauge 3. Tachometer For Ignition System 1. Power Timing Light 2. Dwell meter 3. Voltmeter 4. Ohm meter

For Electric System: 1. Voltmeter 2. Ammeter (0-30 Amps) 3. Tachometer 4. Hydrometer 5. Battery Load Tester

For Fuel System 1. Fuel pump Pressure Gauge

For Emission Checking Exhaust Gas Analyzer

For Cooling System Coolant Thermometer

What are the common troubles / Faults that normally occur in an automobile?
Cooling System Problems and Causes:

Engine Overheating

1. Loss of coolant 2. Defective Thermostat 3. Defective water pump 4. Collapsed Radiator Hose 5. Excessive Rust & Scales 6. Obstructed air passage through Radiator 7. late Ignition timing 8. Combustion leak into cooling system 9. Improper coolant mix 10. Defective Temperature Gauge

Engine Runs Too Cool 1. Defective Thermostat 2. Defective Gauge

Fuel System Problems and Causes :

Carburetor flooding 1. Worn needle and sear 2. Leaky float 3. Excessive fuel pump pressure 4. Improper float adjustment

Rough Idle: 1. Improper idle Mixture 2. Poor Compression 3. Intake manifold leak 4. Defective spark plug wires 5. Cracked distributor cap 6. Stuck PCV valve

Stumbling During Acceleration 1. Defective accelerator pump 2. Improper adjustment of Acc. Pump 3. Ignition Misfire

Sluggish Performance 1. Late Ignition Timing 2. Too rich or too lean mixture 3. Defective advance mechanism

Ignition system Troubles & causes 1. Low Battery 5. Open Capacitor 6. Ignition Timing too much advanced Starting System Problems & Causes

Battery Not holding charge

1. Internal defect of battery 2. Dirt on Terminals / Loose Terminals 3. Electrical leakage/ shorts 4. Excessive Electrical usage with car stopped / idling 5. Battery not used for long periods.

Battery Always undercharged

1. Defective alternator / Generator 2. Low voltage regulator setting 3. Infrequent or slow driving with heavy electrical loads 4. Excessive charging circuit resistance 5. Sulphated Battery 6. Too Many Electrical Accessories

Battery Uses Excessive Water

1. High voltage regulator setting 2. Sulphated Battery 3. High temperature

Slow Cranking Speed

1. Excessive starter circuit resistance 2. Dragging starter armature 3. Shorted armature or field 4. Excessive engine friction 5. Worn starter Bushes

Starter Spins without Engaging 1. Defective Bendix drive 2. Dirt or Burr on starter shaft

Starter Clicks without Cranking 1. Defective solenoid switch2. Open starter cable 3. Defective starter

Starter Switch or Solenoid Chatter 1. Poor battery connection 2. Defective solenoid 3. Excessive starter circuit resistance

No Cranking, No Solenoid Click 1. Defective starter or ignition switch 2. Broken wire, solenoid or switch 3. Defective solenoid or switch

Charging System Problems & Causes

No Charge Rate: 1. Defective alternator /Generator 2. Defective voltage regulator 3. Open or grounded field wire 4. Open circuit 5. Worn or stuck brushes

Low Charge Rate 1. Regulator out of adjustment 2. Defective regulator 3. Excessive field circuit resistance 4. Defective alternator/ Regulator 5. Worn Brushes 6. Sulfated Battery

High Charge Rate 1. Regulator out of adjustment 2. Defective regulator 3. Defective Battery 4. High battery temperature. 5. An accessory drawing excessive current even when the engine is not running.

Problem:

Due to open primary circuit: 1. Burned or oxidized ignition points 2. Ballast Resistor burned or open 3. Ignition points not closing 4. Breaker arm binding on pivot post, preventing closing of points 5. Breaker arm spring weak or broken 6. breaker arm distorted or bent 7. Dirty ignition points 8. Primary lead connection loose 9. Primary winding open 10. Open ignition switch circuit

Due to short circuited Primary Circuit Grounded primary coil winding, grounded ignition switch or a lead will cuase excessive current flow and will usually cause wires to burn.

Possible causes for Grounded primary circuit: 1. Ignition points not opening or closing due to improper adjustment. 2. Ignition points not opening due to worn rubbing, block on Breaker A.R.M 3. Faulty insulating bushing on breaker ARM 4. Cracked or faulty insulator at Distributor, Primary Terminal 5. Grounded condenser. 6. Distributor-To-Coil lead grounded 7. Primary coil winding grounded

Due to Faulty secondary ignition circuit 1. Corroded spark plug cable terminal 2. Cracked insulation on cables (H.T) 3. Ignition so weak or ineffective 4. Moisture on ignition coil , terminals, distributor , 5. Improper type of spark plugs 6. Cracked distributor cap or burned carbon brush in the CAP. 7. Improper connection to spark plugs (not correct as per firing order) 8. Spark plugs damaged, Dirty or wet porcelain cracked or gaps improperly adjusted. 9. Rotor contact spring Bent or Broken 10. Distributor rotor grounded 11. Distributor cap centre terminal broken or missing

Due to Battery 1. Battery run down 2. Terminal loose or badly corroded 3. Improper ground 4. Battery cable undersize.

Due to Excessive fuel supply (flooding) Accumulation of liquid fuel in the intake manifold as well as cylinder. The engine won't start until, the rich mixture formed by flooding

Reason

1. Choke not operating properly 2. Automatic choke not properly set 3. Float level set too high 4. Dirty worn or faulty needle valve seat 5. Float sticking or rubbing against side of fuel bowl. 6. Leak in float allowing fuel inside 7. Fuel pump pressure too high

Due to insufficient fuel supply 1. Carburetor inlet needle stuck in its seat due to gum in fuel 2. Float level too low 3. Clogged inlet filter at carburetor 4. Faulty or insufficient capacity fuel pump 5. fuel pump strainer clogged 6. Faulty fuel pump Bowl Gasket 7. Fuel line from tank clogged or restricted.

When Engine is Hot

Hard starting of engine under hot conduction is mainly due to over supply of fuel (flooding) in rare cases an ignition coil may loose its efficiency when it is hot and cause ignition failure.

When Engine is cold Apart from the conditions listed under engine won't start the following conditions are also to be checked. 1. Choke setting too lean 2. Fuel may have kerosene, water or ice 3. Ice in fuel lines 4. Engine is cranked too slowly or won't turn because: a) Engine oil too thick in sub-zero weather b) Battery too weak due to very low temp 5. Another possibility even though remote is that the water pump is jammed with ice, which will interfere with cranking engine if fan belt is tight.

Due to vapour lock Flow of fuel to the mixing chamber is stopped (locked) By the formation of vapourrized fuel pockets or bubbles caused by overheating the fuel by hot

fuel pump, hot fuel lines or hot carburetor. High ambient temperature, hard driving defective engine cooling and high altitudes are contributing to vapour lock.

After long period of non usage of vehicle

1. More volatile components in the fuel, have evaporated and the remaining ones are not sufficiently volatile to form a combustible mixture. 2. Low or run down battery 3. Corrosion of engine moving parts

These troubles are more humidity climate and near salt water.

Reasons for the stalling of engine 1. Engine idle speed set too low. 2. Large air leakage intake manifold.3. ignition points need attention 4. Vapour lock 5. Over supply of fuel (flooding) 6. Valves set too tight 7. Needle/ seat of carburetor inoperative 8. Contaminated fuel 9. Choke sticking or improperly adjusted 10. Faulty ignition system 11. Spark plugs damp/Dirty or incorrect gap 12. In operative distributor advance 13. Restricted exhaust system 14. Burned, warped or sticking valves 15. Low compression 16. Engine over heating 17. Loose or corroded wire connections 18. Incorrect idle mixture adjustment 19. Incorrect carburetor float setting 20. Leaking EGR valve