AUTOMOBILE ENGINEERING

Course	Code	Credits	L-T-P	Assessment		Exam duration
				SEE	CIA	
Automobile	17ME655		3-0-0	60	40	3 Hrs

Course learning objectives: The student will be able to learn

- The layout and arrangement of principal parts of an automobile.
- The working of transmission and brake systems.
- The operation and working of steering and suspension systems.
- To know the Injection system and its advancements.
- To know the automobile emissions and its effects on environment.

MODULE 1

ENGINE COMPONENTS AND IT'S PRINCIPLE PARTS: Spark Ignition (SI) &Compression Ignition (CI) engines, cylinder – arrangements and their relatives merits, Liners, Piston, connecting rod, crankshaft, valves, valve actuating mechanisms, valve and port timing diagrams, Types of combustion chambers for S.I.Engine and C.I.Engines, methods of a Swirl generation, choice of materials for different engine components, engine positioning. Concept of HCCI engines, hybrid engines, twin spark engine, electric car.

COOLING AND LUBRICATION: cooling requirements, types of cooling- thermo siphon system, forced circulation water cooling system, water pump, Radiator, thermostat valves. Significance of lubrication, splash and forcedfeed system. **10 Hours**

MODULE 2

TRANSMISSION SYSTEMS: Clutch-types and construction, gear boxes- manual and automatic, gear shift mechanisms, Over drive, transfer box, fluid flywheel, torque converter, propeller shaft, slip joints, universal joints ,Differential and rear axle, Hotchkiss Drive and Torque Tube Drive.

BRAKES: Types of brakes, mechanical compressed air, vacuum and hydraulic braking systems, construction and working of master and wheel cylinder, brake shoe arrangements, Disk brakes, drum brakes, Antilock –Braking systems, purpose and operation of antilock-braking system, ABS Hydraulic Unit, Rear-wheel antilock& Numerical. **08 Hours**

MODULE 3

STEERING AND SUSPENSION SYSTEMS: Steering geometry and types of steering gear box- Power Steering, Types of Front Axle, Suspension, Torsion bar suspension systems, leaf spring, coil spring, independent suspension for front wheel and rear wheel, Air suspension system.

IGNITION SYSTEM: Battery Ignition system, Magneto Ignition system, electronic Ignition system.

08 Hours

MODULE 4

SUPERCHARGERS AND TURBOCHARGERS: Naturally aspirated engines, Forced Induction, Types of superchargers, Turbocharger construction and operation, Intercooler, Turbocharger lag.

FUELS, FUEL SUPPLY SYSTEMS FOR SI AND CI ENGINES: Conventional fuels, alternative fuels, normal and abnormal combustion, cetane and octane numbers, Fuel mixture requirements for SI engines, types of carburetors, C.D.& C.C. carburetors, multi point and single point fuel injection systems, fuel transfer pumps, Fuel filters, fuel injection pumps and injectors. Electronic Injection system, Common Rail Direct Injection System.

08 Hours

MODULE 5

AUTOMOTIVE EMISSION CONTROL SYSTEMS: Different air pollutants, formation of photochemical smog and causes. Automotive emission controls, Controlling crankcase emissions, Controlling evaporative emissions, Cleaning the exhaust gas, Controlling the air-fuel mixture, Controlling the combustion process, Exhaust gas recirculation, Treating the exhaust gas, Air-injection system, Air-aspirator system, Catalytic converter.

EMISSION STANDARDS: Euro I, II, III and IV norms, Bharat Stage II, III, IV norms. Motor Vehicle Act

08 Hours

Course Outcomes: Student will be able

- To identify the different parts of an automobile and it'sworking
- To understand the working of transmission and brakingsystems
- To comprehend the working of steering and suspensionsystems
- To learn various types of fuels and injectionsystems
- To know the cause of automobile emissions, its effects on environment and methods to reduce the emissions.

TEXT BOOKS:

1. Automobile engineering, Kirpal Singh, Vol I and II (12th Edition) Standard Publishers2011
2. Automotive Mechanics, S. Srinivasan, (2nd Edition) Tata McGraw Hill2003.

REFERENCE BOOKS:

1. Automotive mechanics, William H Crouse & Donald L Anglin (10th Edition) Tata McGraw Hill Publishing Company Ltd.,2007
2. Automotive mechanics: Principles and Practices, Joseph Heitner, D Van Nostrand Company,Inc
3. Fundamentals of Automobile Engineering, K.K.Ramalingam, Scitech Publications (India) Pvt.Ltd.
4. Automobile Engineering, R. B. Gupta, SatyaPrakashan, (4th Edition)1984.

MODULE – 1

ENGINE COMPONENTS, COOLING AND LUBRICATION SYSTEMS

INTRODUCTION

An automobile is a self-propelled machine used on the ground for transportation of passengers and goods from one place to another place. Automobile engineering or automotive engineering is the branch of engineering that deals with all types of automobiles like car, bus, truck, jeep, motor cycle etc., and the means of propelling them. Automobile or automotive refers to one which itself can move. The study of aero plane, helicopter, rocket etc., which fly in air, comes under Aeronautical engineering and marine engineering deals with ship, motor boat etc., which sail in water. Today, of course, the automobile vehicle has become a basic necessity and business of making and servicing automobiles has become one of the biggest businesses in theworld.

I.C. Engines are used, in order to obtain motive power of the vehicle. In recent years, a huge changes are made in the design of automobiles to provide safety, ease of operation, reliability, comfort, less fuel consumption etc.

The Automobile consists of following basic components or parts. These are

1. **The power plant:** It is nothing but the source of power or engine which provides motive power to perform various functions in the vehicle. The power plant generally consists of an internal combustion engine (I.C. Engine) which may be either of spark ignition (S.I), or of compression ignition type. Sometimes gas turbines are also used in certaincars.
2. **The basic structure:** This includes frame and wheel assembly, suspension system, axles,etc.
3. **The power train (transmission system):** The power train carries the power from the engine to road wheels. It consists of clutch, (for non-automatic transmissions) gear box, propeller shaft, differential.
4. **The super structure or carbody.**
5. **The accessories** which include electrical system, radio, wind shield wiper, air conditioneretc.
6. **The controls:** It consists of steering system, Brakes,etc.

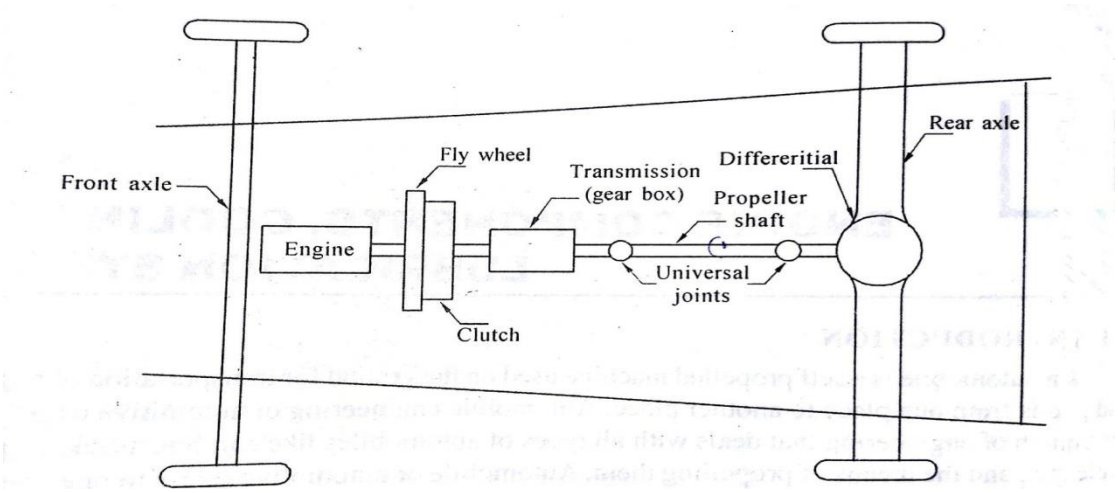


Fig.: Layout of an automobile

S.I. AND C.I.ENGINES

Either S.I. or C.I. engines are used to obtain motive power to perform various functions in the automobile. Modern automotive engines vary greatly in size and design, but the operating principles are essentially the same as those of first models developed early.

In S.I. engine, a spark plug is an essential component which initiates combustion of fuel. The spark plug produces an electric spark of high energy, initiates ignition of fuel. In C.I. engine, the high temperature (greater than ignition temperature of the fuel) of compressed air ignites the fuel and this is called self or auto ignition. The fuel pump and fuel injectors are the essential components of C.I. engine.

BASIC ENGINE TERMINOLOGY

Top dead centre (TDC): When the piston is at its top most position i.e., the position closest to cylinder head, it is called top dead centre.

Bottom dead centre (BDC): When the piston is at its lowest position i.e., the position farthest from the cylinder head, it is called bottom dead centre.

Bore: The 'Bore' is referred to the diameter of engine cylinder. It is denoted by 'D'.

Stroke length or stroke: The distance travelled by the piston between TDC and BDC is called stroke of the piston and is denoted by 'L'.

Clearance volume: When the piston is in TDC position the cylinder volume above it, is called clearance volume and is denoted by 'Vc'.

Swept volume or piston displacement: The volume swept by piston while moving from TDC to BDC is called swept volume.

It is denoted by , Vs' .

$$V_s = \frac{\pi D^2}{4} L$$

Compression ratio: It is the ratio of volume above the piston at BDC to the volume above the piston at TDe. It is the ratio of total volume of the cylinder (V_s + Vc), to the clearance volume. It is denoted by 'r' $V_s + V$

V_c

For Petrol engines, it ranges from 8 to 12.
For diesel engines, it ranges from 15 to 24.

Mean effective pressure: As piston performs power stroke, cylinder pressure decreases. Thus it is required to refer an average effective pressure throughout the whole power stroke. It is expressed in bars.

Power: It is the work done in a given period of time. More power is required to do the same amount of work in a lesser time.

Indicated Power (I.P.): The power developed within the engine cylinders is called indicated power. It is expressed in kilowatts (kW). It is given by area under engine indicator diagram.

Brake Power (B.P.): This is the actual power available at the crank shaft. The indicated power minus various power losses in the engine like friction and pumping losses in the engine, gives Brake power. It is measured by using a Dynamometer and is expressed in kilowatts(kW).

Engine torque

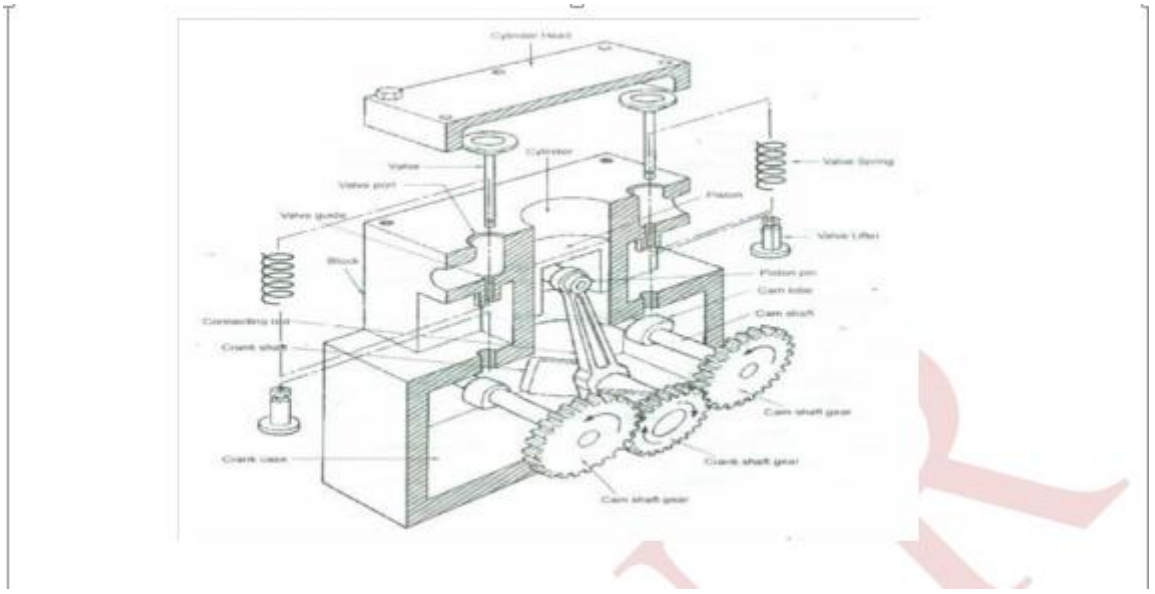
It is the force of rotation acting about the crank shaft axis at any given instant of time.

It is given by T = F.r., where T = engine torque, Nm
F = force applied to the crank, N
r = effective crank radius, m

MAIN COMPONENTS OF AN I.C. ENGINE

1. Cylinders
2. Piston
3. Connectingrod
4. Crankshaft

5. Valves and valve actuatingmechanisms



C**ylinders :**

The cylinder is the main body of an engine in which piston reciprocates to develop power. It has to with stand very high pressure and temperature (around 2800°C). A cylinder block is one which houses the engine cylinders. If cylinder block and crank case are made integral, then the construction is called 'Mono block'. The cylinder material should be such that it should retain strength at higher temperatures, should be good conductor of heat and should resist rapid wear and tear due to reciprocating action of the piston. Generally cast iron is used. For heavy duty engines alloy steels areused.

For cooling water circulation, passages are provided around the cylinders. Cylinder block also carries lubrication oil to various components through drilledpassages.

At the lower end of cylinder block, crank case is made integral with the block. At the top, cylinder block is attached with the cylinder head. It houses inlet and exhaust valves. Besides, other parts like timing gear, water pump, ignition distributor, fly wheel, fuel pump, etc., are also attached to it. The materials used for cylinder block are grey cast Iron and aluminiumalloys.

The cast iron material has the following advantages.

1. It is relatively cheap and posses good foundryproperties.
2. The co-efficient of thermal expansion of cast iron islow.
3. It has high machinability and does not wear toomuch.

The aluminium alloy cylinder blocks have the following advantages.

1. It has higher thermal conductivity than cast-iron. This results in efficient cooling of engine. so that higher compression ratios may beused.
2. The density of aluminium is about one third that of cast iron. It is a lightmaterial

3. Butconsideringlesserstrengthofaluminium,thickersectionshavetobeusedtocarrysame
4. load. Further, in case of any loss of coolant, it cannot with stand high temperature and damage may occur. It wears more than cast iron.
5. The grey cast iron for cylinder block has the composition; carbon - 3.5 %, silicon - 2.5%,manganese
6. - 0.65 %.
7. The Aluminium alloy cylinder blocks have the composition. Silicon - 11%, Manganese 0.5%, Magnesium 0.4%

CYLINDER ARRANGEMENTS

Multi cylinder engines are preferred over single cylinder engines due to reasons like

(i) Giving smooth torque output (ii) Lighter fly wheel (iii) Engine compactness (iv) Easy balancing. In multi cylinder engines, the arrangement of cylinders is very important. The following cylinder arrangements are used to give better performance of the engine. They are,

l. In line arrangement 2.Opposed cylinders type 3.V – engine 4.Radial engine

1. In linearrangement

In this type, a number of cylinders are arranged in a line i.e., placed side by side vertically with a common crank shaft. In this type reciprocating forces are nearly balanced.

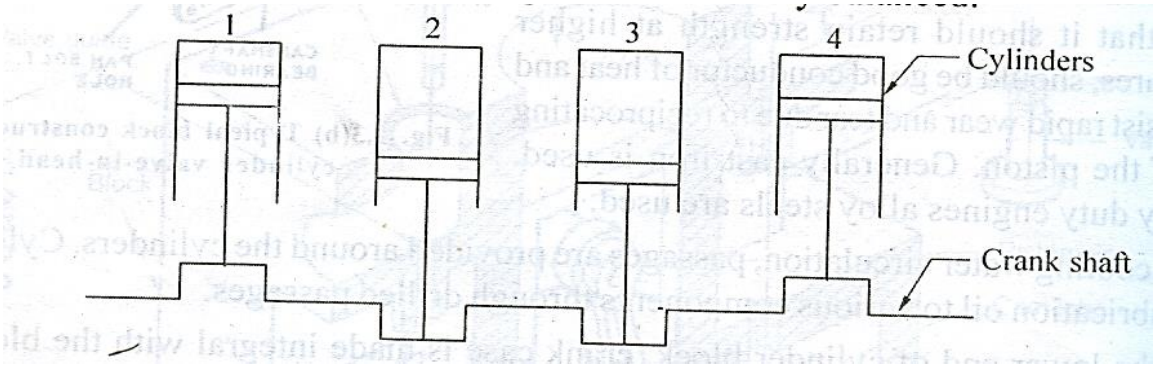


Fig: Inline arrangement

2. Opposed cylinderstype

The two cylinders are arranged horizontally opposite to each other i.e., they are placed 1800 apart facing each other with a common crank shaft. In this type, the reciprocating parts are perfectly balanced. As two cylinders are not in line, the force in connecting rod produces a rocking couple

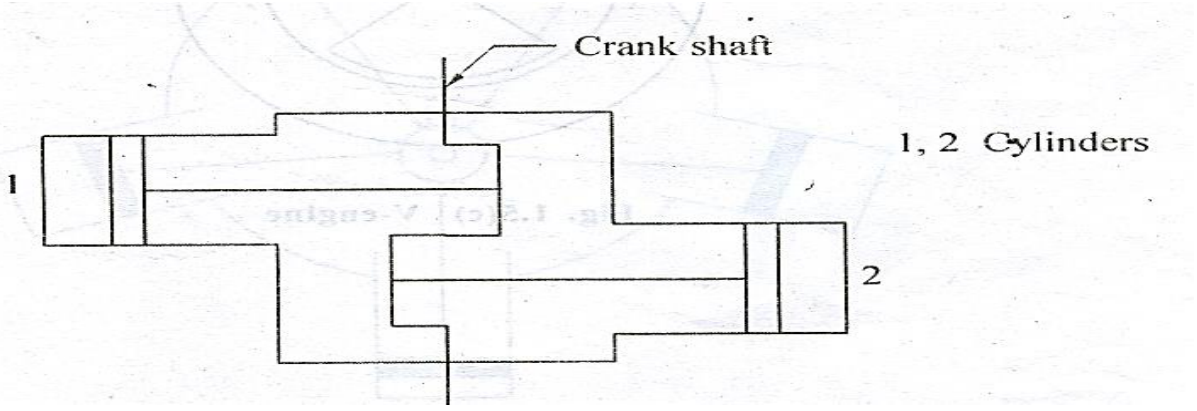
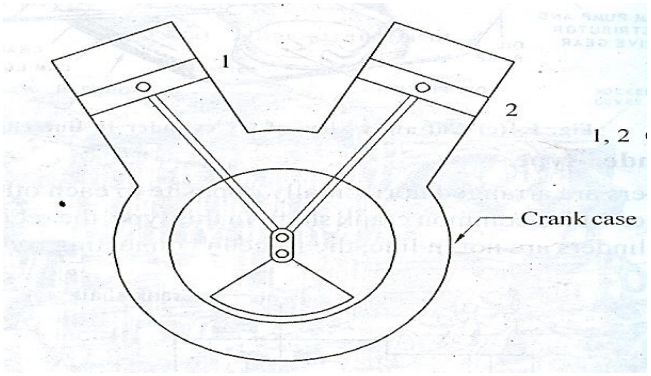


Fig: Opposed type

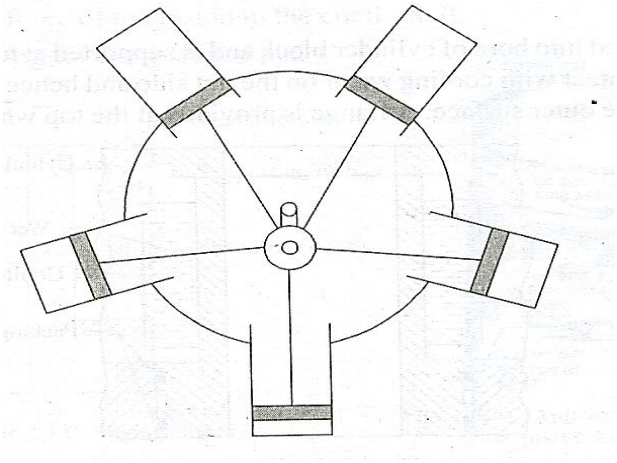
3. V -engine

In this type, two cylinders are placed with their axes at 60°. The cylinders are arranged on two arms of letter "**V**" with a common crank case and crank shaft it is more compact and rigid and hence runs more smoothly at highspeeds.



4.Radialengine

In this type, a number of cylinders are arranged in radial fashion with a common crank shaft which is placed at the center as in figure. The number of cylinders generally used is 5, 7, 9 etc., to obtain uniform firing intervals. This type is compact in size and gives higher Brake power per weight ratio. This is mainly used in air craft engines.



LINERS (SLEEVES)

Engines make use of removable liners which are pressed into cylinder holes. The cylinder liners are in the form of barrels and used to reduce the cylinder wear and hence to increase cylinder bore life. The cylinder wear is more when cylinder block is made up of aluminium alloy. The liners can be inserted in the cylinder bore to reduce this wear. Whenever the liners worn-out, they can be replaced easily. Whenever a cylinder block is re-bored beyond allowable limits, liners are used to restore its original size. These are cast centrifugally and made up of special alloy iron containing silicon, manganese, nickel and chromium.

The liners may be further hardened by nitriding or chromium plating. In nitriding process, liners are exposed to ammonia vapour at 5000 ^{0}C and then quenched. Chromium plating improves their resistance to wear and corrosion. There are two types of liners (1) Dry liners and (2) Wet liners.

1. Dryliners

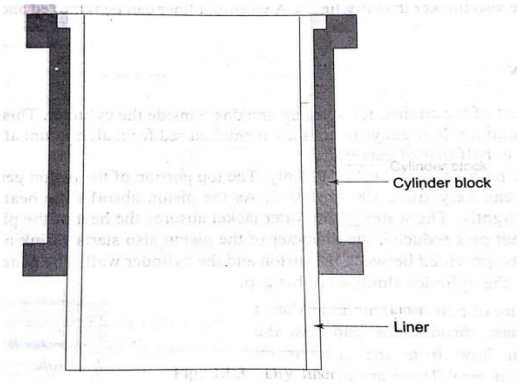
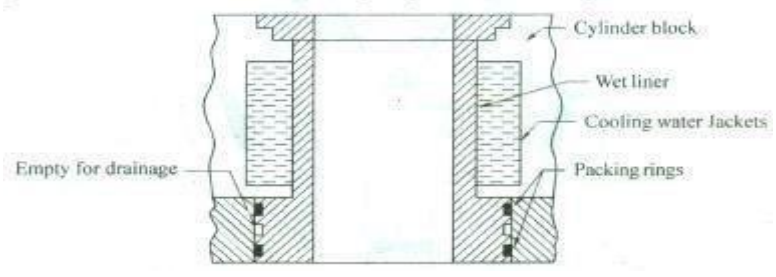


Fig: Dry liners

The dry liners are quite thin and uses block metal to give it full length support. These liners are made in the form of barrel and a flange is provided at the top which keeps the liner in to position. It is necessary to machine the liner surface accurately both from inside and outside, as the outer surface of the liner makes contact with cylinder block. By shrinking the liner, it is put in to the cylinder bore. If the liner is too loose in the cylinder block, results in poor heat dissipation because of absence of good contact between them. This will result in higher operating temperature. Improper lubrication results in piston scuffing. Too tight a liner is even worse than the too loose case. This produces distortion of cylinder block, liner cracking, hot spots and scuffing.

2. Wetliners

Wet liner is pressed into bore of cylinder block and is supported at top and bottom only. These liners make direct contact with cooling water on the outside and hence do not require accurate machining on the entire outer surface. A flange is provided at the top which fits into the groove in the cylinder block. Three grooves are provided at the bottom, middle one is empty and top and bottom grooves are inserted with rubber packing's. For water leakage, drainage arrangements are provided from the middle groove. The wet liners are sometimes coated with aluminium on the outside to make the surface corrosionresistant.



COMPARISON OF DRY AND WET LINERS

Dry liners

1. They may be provided either in the original design or even afterwards.
2. No leak proof joint isrequired.
3. Construction of cylinder block is notsimple.
4. As dry liners does not make direct contact with cooling water, cylinder cooling is ineffective
5. Accurate machining of both block and outer liner surface is required, for perfect contact betweenthem.

Wet liners

1. These have to be included in the original cylinderdesign.
2. A leak proof joint between the cylinder casting & liner isrequired.
3. Construction of cylinder block issimple.
4. As cooling water is in direct contact with liner, better cylinder cooling ispossible.
5. Accurate machining on the outer liner surface is notnecessary

PISTON

The piston is a reciprocating part of the engine and converts the combustion pressure in the cylinder to a force on the crank shaft. Pistons are slightly smaller in diameter than the cylinder bore. The space is provided between piston and cylinder wall and is called "clearance". This 'clearance' is necessary to provide space for a film of lubricant. Pistons are made of aluminium alloys, cast steel, cast iron or chrome nickel. Aluminium alloy pistons are used in modern automobiles.

Functions

1. It forms a seal within the cylinder to avoid entry of high pressure gases from combustion chamber into crankcase.
2. It transmits the force of explosion to the crankshaft.
3. 3.It acts as a bearing for the gudgeonpin.

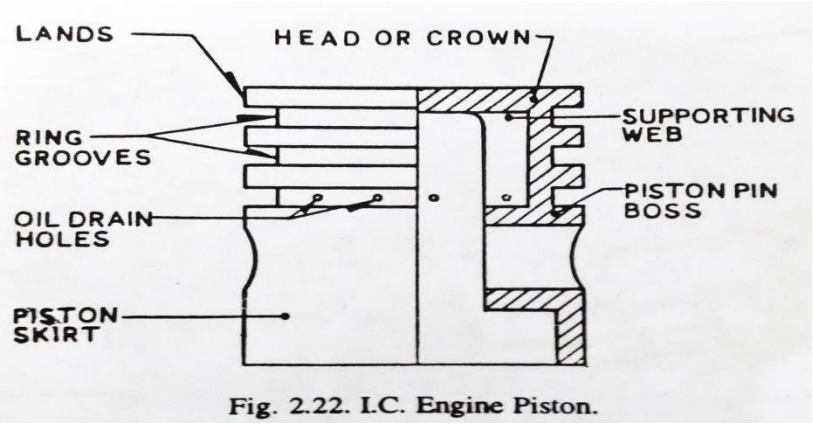


Fig: Typical I.C, engine piston

A typical I.C. engine piston is as shown in figure. The piston almost has the shape of an Inverted bucket. The top portion of the piston is called head or crown. In some engines, pistons may be specially designed to form desired shape of the combustion chamber. At the piston top, few grooves are cut to accommodate the piston rings and the bands left between the grooves are known as "Lands". They support the rings against gas pressure. The portion below rings is called piston skirt. The skirt is provided with bosses on the inside to support the pistonpin.

The Aluminium alloy pistons have the following advantages over cast iron pistons.

1. Lighter in weight, allowing higher rpm. [It is 3 times lighter than C.I. piston which is desirable from inertia point ofview].
2. It has higher thermal conductivity allowing the use of higher compressionratio.

The aluminium alloy pistons have the disadvantages like.

1. It is not as strong as cast iron; hence thicker sections have to beused.
2. Aluminium alloy is soft, fine particles of lubricating oil become embedded in it. It causes a sort ofgrinding.
3. It causes a sort of grinding or abrasion of the cylinder walls thus decreases cylinderlife.
4. The main drawback of using aluminium alloy pistons with cast iron cylinders is their unequal coefficient of expansion which causes engine slap.

CONTROL OF PISTON SLAP

The use of Aluminium alloy piston with cast iron cylinder has a drawback of engine slap. If cold clearance is kept just sufficient, there is danger of seizure at higher operating temperatures and if it is kept larger, the engine knocks or slaps when cold. Different methods are used to overcome this difficult, theyare,

1. **Cutting horizontal slot:**This method keeps the heat away from the lower part of the piston. By cutting horizontal slot in the portion just below the oil control ring, skirt portion does not become very hot and hence does not expand somuch.

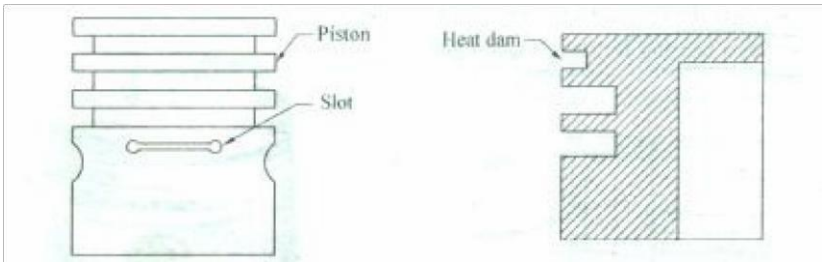


Fig: (a) Piston withhorizontalslot **Fig: (b) Heat damconstruction**

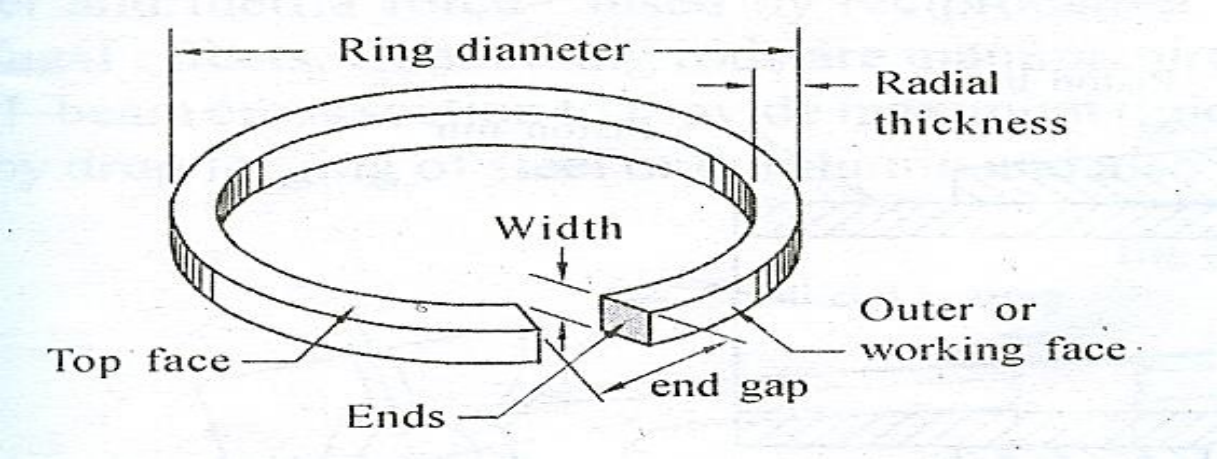
1. **Heat dam:**By making heat dam i.e., by cutting a groove near the top of the piston, the heat flow to lower part of piston can be reduced. Hence the skirt runs cooler and does not expand too much.

2. **Vertical or T slot:**In this type, the top of T tends to retard the heat transfer from head to the piston skirt. The vertical slot allows the skirt of the piston to close when heated i.e., it allows piston skirt to expand without increase in diameter. However mechanical strength is decreased on account of slot. Due to presence of this slot, the diameter reduces permanently which increases engine slap. Hence fully split skirts are notused.
3. **Split skirt:**In a split skirt piston, skirt is either partially or completely split. When the piston warms and begins to expand, it cannot find in the cylinder since the skirt merely closes the split.
4. **Tapered pistons:**Sometimes the pistons are turned taper, the crown side being smaller in diameter than the skirt end. As crown portion is exposed to higher tempt than skirt, that side expands more than skirt and piston diameter becomes uniform under operatingconditions.
5. **Special alloy pistons:**Special alloy having coefficient of expansion nearly equal to that of cast iron (or low value) have been used in the manufacture of pistons. One such alloy is "LOEX" alloy Itis an alloy having 12-15% silicon, 1.5-3% nickel and 1 % of each of magnesium and copper Such pistons arecostlier.
6. **Wire wound pistons:**A band of steel wire is wound between the piston pin and oil controlling, thus restricting the expansion ofskirt.
7. **Bimetal pistons:**The pistons are made from both steel and aluminium. Steel is used to manufacture skirt portion and aluminium alloy cast inside to form piston head and piston pin bosses. For steel, coefficient of thermal expansion is quite small, piston will not expand much and hence smaller cold clearances can bemaintained.

PISTON RINGS

Piston rings are located towards the top of the piston. The top two piston rings are called compression rings and are designed to maintain cylinder pressure. The bottom ring is called oil ring, (may be 1 or 2 in number) they scrape the excess oil from the cylinder walls and return it through slots to the piston ring grooves. A properly constructed and fitted ring will rub against the cylinder

wall with good contact all around the cylinder. The ring will ride in grooves that are cut into the piston head.



The material generally used for piston rings is fine grained alloy cast iron containing silicon and manganese. It has good heat resisting qualities. Rings with molybdenum filled face have also been introduced recently. Alloy steels are also used. The number of rings vary depending on the engine design. It varies from two to four.

Generally the ring is cast and machined and put in position in the ring grooves. It exerts uniform pressure against the cylinder walls. A gap is to be cut at the ends so that while inserting the ring, it can be expanded, slipped over the piston head and released in to the ring groove. The gap is almost closed when the piston is inside the cylinder.

Functions:

1. It forms a seal so that high pressure gases from the combustion chamber will not escape into the crankcase.
2. It provides easy passage for heat flow from piston crown to the cylinderwalls.
3. It maintains enough lubrication oil cylinder walls throughout the stroke length. This reduces ring and cylinder wear. The thickness of oil film is to be controlled and the oil should not go up into the combustion chamber where it would burn and produces carbondeposits.

PISTON PIN

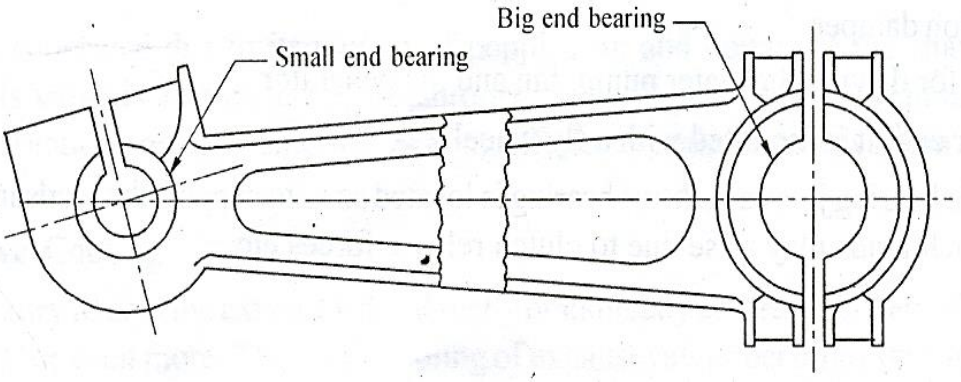
Piston pin is also known as wrist pin or gudgeon pin, used to connect Piston and connecting rod. It transfers combustion chamber pressure and piston forces to the connecting rod. It is in tubular shape to provide adequate strength with minimum weight. It passes through the piston bosses and small end of the connecting rod. It is made of low carbon case hardened steel (carbon - 15%, silicon - 0.3%, manganese - 0.5%).

Piston pins are installed and secured to provide a bearing action in the following three ways.
The pin is fastened to the piston by set screws through the piston boss and has a bearing in the connecting rod small end. This permits the connecting rod to swivel as required by the combined

reciprocal and rotary motion of piston and crankshaft.

CONNECTING ROD

The connecting rods are used to connect pistons to the crank shaft. The upper end of rod oscillates (swing back and forth) while the lower and or big end rotates (turns). It converts reciprocating motion of the piston in to rotary motion of the crank shaft. The upper end of the rod has a hole through it for the piston pin. The lower end must be split type. A combination of axial and bending stresses act on the rod in operation. The axial stresses are due to gas pressure in the cylinder and inertia force caused by reciprocating motion. Bending stresses are caused due to centrifugal effects. Connecting rods are manufactured by casting and forging processes. The rod has an I-beam cross section to provide maximum rigidity with minimum weight. Generally rods are made by drop forging of steel or duralumin and also cast from malleable cast iron.



CRANK SHAFT

The crank shaft provides a constant turning force to the wheels. It receives the power from connecting rods and subsequently transmits to the wheels. Crank shafts are made of alloy steel or castiron.

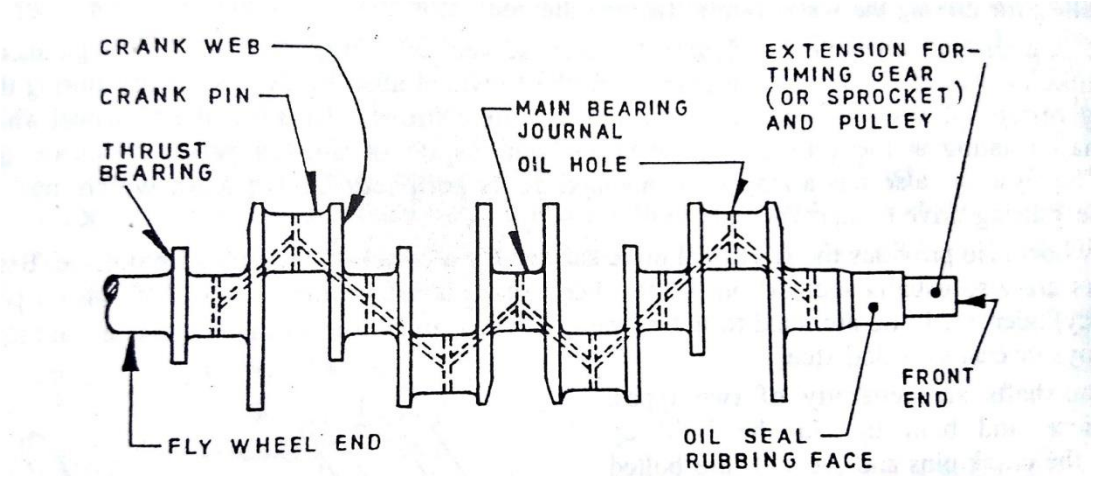


Fig: Crank Shaft

A simplified sketch of the crank shaft for a four cylinder engine is as-in figure. It consists of

1. Mainjournals
2. Crankpins
3. Crankwebs
4. Counterweights
5. Oil holes

The crank shaft is held in position by a number of main bearings and they form axis for the rotation of crank shaft. Their number is always one more or one less than the number of cylinders. The crank pins are the journals for the connecting rod big end bearings and are supported by the crank webs. The distance between the axis of the main journal and the crank pin centre lines is called 'crank through'. Oil holes are drilled from main journals to the crank pins through 'crank webs for lubricating big endbearings.

When the engine is running, due to rotation of both crank shaft and connecting rod big end, each crank pin will be subjected to centrifugal forces. This will tend to bend the crank shaft. To avoid this counter weights are used. The counter weights are formed as integral part of the crank web or may be attached separately as infig.

On the front of the crank shaft, it is mounted with

i. Timing gear or sprocket which drives the crankshaft.

ii. Vibrationdamper

iii. Pulley for driving the water pump, fan and the generator. On the rear end, it is mounted with a flywheel.

On the main bearing journals, thrust bearing is located so as to support the loads in the direction of shaft axis. Such loads may arise due to clutch release forces etc.

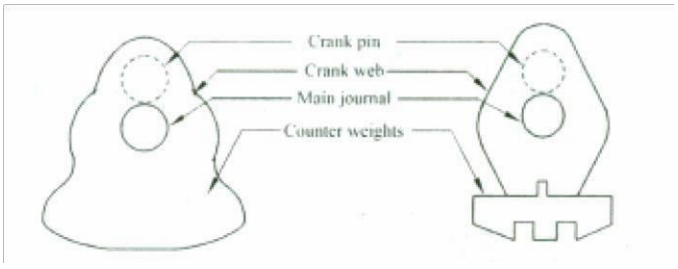


Fig:Integral Fig: Attachedseparately

VALVES

Each engine cylinder has two valves however some special racing engines use four valves per

cylinder. Air fuel mixture is admitted to the engine through inlet valve and burned gases escape through the exhaust valve. The valves also must seal the combustion space tightly.

Since air-fuel mixture admits into cylinder with lesser speed compared to velocity of exhaust gases which leaves under pressure, inlet valves are made larger than exhaust valves. The inlet and exhaust valves are 45% and 38% of the cylinder bore respectively. The valve face angle with the plane of valve head is usually kept 45° or 30°. The movement of the valves is actuated by an eccentric projection called a cam moving on a rotating shaft - the cam shaft.

The inlet and exhaust valves use different materials as they are subjected to different operating conditions. The inlet valves are exposed to a temperature of 5000 ^{0}C and exhaust valves have to operate in more severe conditions. To prevent burning, the valve must give off heat to the valve guide and to the valveseat.

Silicon - Chrome steel (Carbon - 0.4%, nickel- 0.5%, manganese - 0.5%, silicon - 3.5%, chromium - 8%) is the material used for inlet valves. For exhaust valves, molybdenum is added to it. Recently austenitic steels are used for exhaust valves. To make it corrosion resistant, the valve may be coated with aluminium.

The engine valves may be classified into

1. Poppet valve 2.Sleeve valve 3.Rotaryvalve

Poppet valve is universally used for automobile engines.

Poppet Valve

Its name is derived due to its motion of popping up and down. As the shape resembles a mushroom, this valve is also called as 'mushroom' valve. It consists of a head and a stem. It is simple in construction and self centering. Seal ing efficiency maintenance is much easier with this poppet valve.

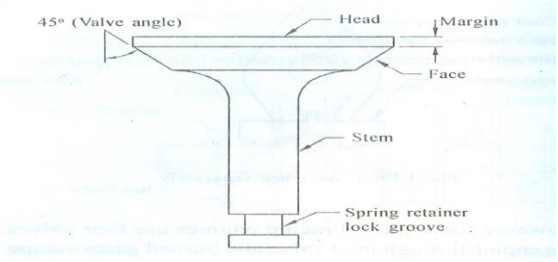


Fig: (a)PoppetValve

Valve Cooling

It is necessary to cool the exhaust valve directly or indirectly as it reaches very high temperature i.e. about 750°C or even more. Therefore cooling of exhaust valves becomes very important and is done by providing cooling water jackets near the valve.

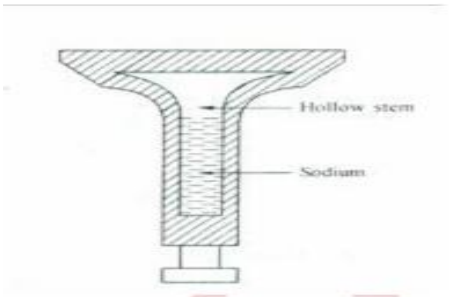


Fig: (b) Sodium Cooled Valve

VALVE ACTUATING MECHANISMS

The valves located in .he cylinder head are operated by an eccentric projection called cam which is driven at half the crank shaft speed. Different valve operating mechanisms are used and are classified into

a) Side valvemechanism

b) Over head valvemechanism

c) Over head inlet and side exhaust valve mechanism.

a) Side Valve Mechanism: This mechanism is used for L-head engines. In this type, inlet and exhaust valves are mounted in a single row and operated from the same crank shaft. Nowadays, this mechanism is obsolete due to complicated shape of the combustion chamber which leads todetonation.

b) Over Head Valve Mechanism: This mechanism is suitable for I and F head designs. The cam operates the valve lifter which in turn actuates the push rod. This action rotates the rocker arm about a shaft or a ball joint in some designs, to cause one end to push down on the valve stem to open thevalve.

Advantages

a) Higher volumetricefficiency.

b) Leaner air-fuel mixtures can beburnt.

c) Higher compressions can be used.

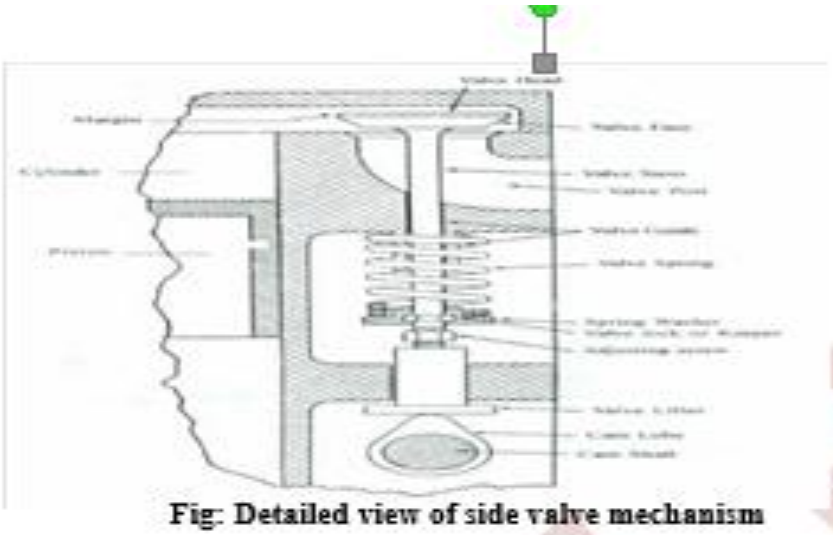


Fig: Detailed view of side valve mechanism

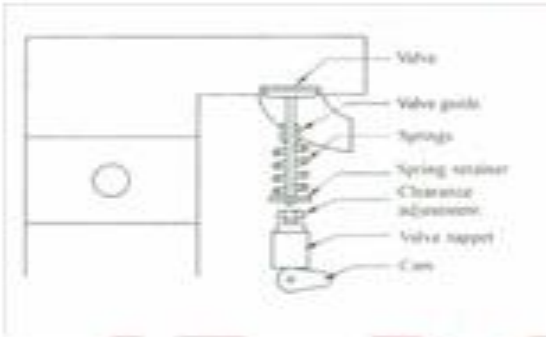


Fig: (a) Side valve mechanism.

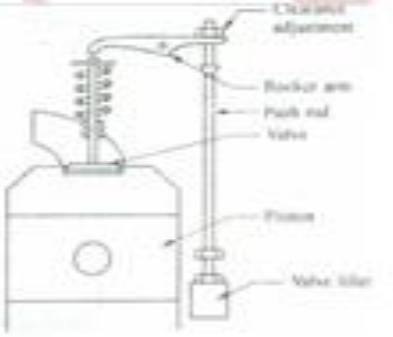


Fig: (b) Over head valve mechanism

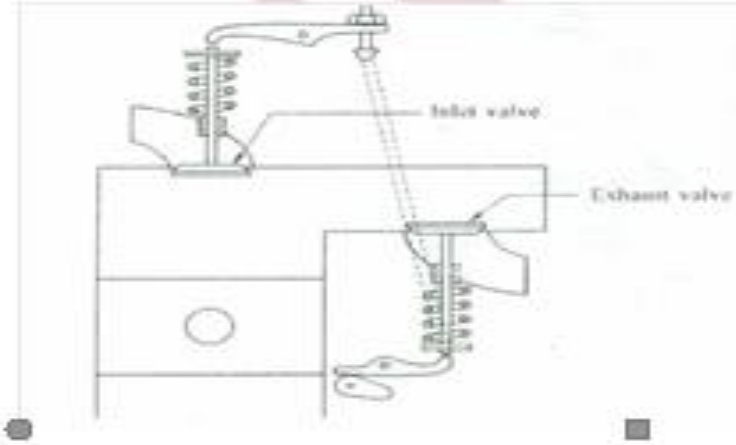


Fig: (c) Overhead inlet and side exhaust

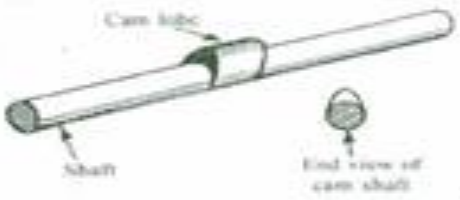


Fig: (d) Cam shaft valve mechanism

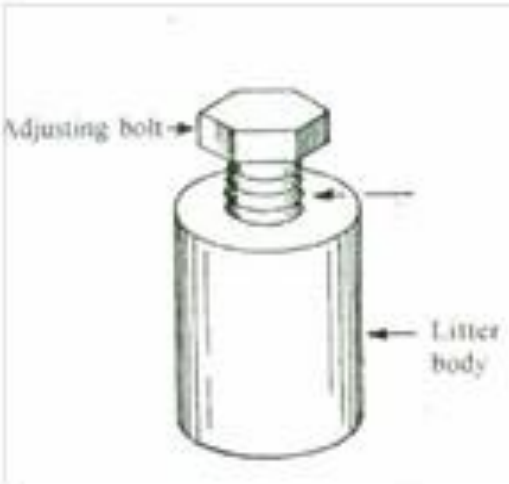


Fig: (e) Valve lifter

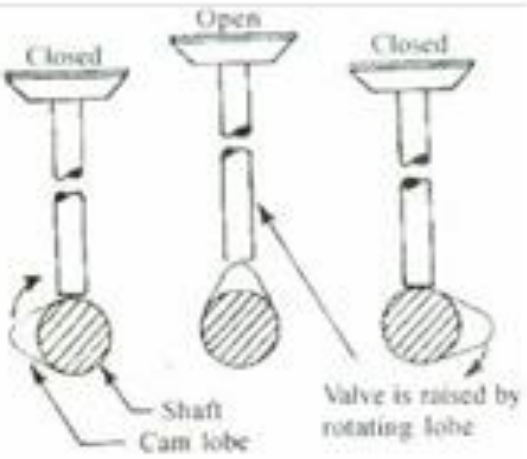


Fig: (f) Valve operation

COMPONENTS OF THE VALVE ACTUATING MECHANISMS

The essential components of a valve actuating mechanism are

a) **Cam Shaft:** It provides a means for opening the valves. It carries one cam for each valve to be operated. It also provides a drive for the ignition distributor and the mechanical fuel pump. The cam shaft is driven by the crank shaft by means of timing gears or chain drive at half the speed of crank shaft. It is forged from alloy steel or cast from hardenable cast iron and is case hardened.

b) **Valve tappet (valve lifter or cam follower) :**It follows the shape of the cam lobe on the cam shaft and hence converts angular movement of the cam in to a reciprocating motion. This is placed slightly eccentric with earn to make the cam wear uniform and is located between push rod andcam.

c) **Push Rod:** This is placed between valve tappet and rocker arm and transmits reciprocating motion of valve tappet to the rocker arm. Push rods are made of steel and may be either solid or hollow. Hollow push rod is lighter and results in reduced inertia forces. It provides a passage for the oil to lubricate the valve actuatingmechanism.

d) **Rocker Arm:** It may be solid or hollow and changes (reverse) the upward motion of the push rod to down ward motion of the valve and vice versa. It is made of steel (forged or stamped) or iron(cast).

VALVE AND PORT TIMING DIAGRAMS

The valve timing diagram is one which represents position of crank when the valves (both inlet and exhaust) opens and closes.

When a valve opens or closes, how fast it will rise, how long it will stay open and how fast it will close depends on the shape of cam lobe and position of cam shaft in relation to the crank shaft.

The exact number of degrees that a valve will open or close before top or bottom dead centre varies widely, depending on engine design. This diagram shows the crank position when various operation (suction, compression etc.) in an engine begin and end.

Theoretically, we know that inlet valve should open when piston is at TOC before suction and close when piston is at BOC after performing suction stroke. The exhaust valve should open when piston is at BOC before exhaust stroke and should close at the end of exhaust, when the piston is at TDC to complete a cycle. But the valves require a finite period of time to open and close without abruptness. Therefore, a slight lead time is necessary for proper operation of theengine.

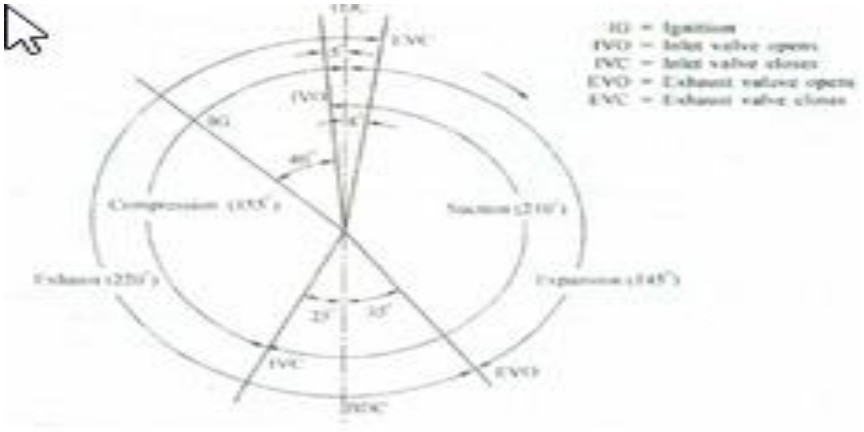
The actual valve timing diagrams for a 4-stroke Spark-Ignition engine and diesel engines are as shown in figures.

a) Inlet Valve: The inlet valve should open few degrees prior to the arrival of the piston at TOC during exhaust stroke of previous cycle. This ensures full open of the valve and entry of fresh charge in to the cylinder as soon as the piston begins to descend. If the inlet valve closes at BOC, the cylinder would receive less charge. To avoid this inlet valve is kept open for few degrees of rotation of the crank after suction stroke i.e., the inlet valve closing is delayed. As engine speed increases, the inlet valve closing is delayedlonger.

b) Exhaust Valve: It is necessary to open the exhaust valve before the piston reaches end of expansion stroke. Even though this wastes some of the force of expansion, it removes greater part of burned gases, reducing the amount of work to be done by the piston on its-returnstroke.

It is seen from the valve timing diagram that both the valves (inlet and exhaust) overlap for 13 degrees of crank rotation. In petrol engine, more overlapping is not advisable, because air and fuel mixture may pass out with the exhaust gases and is uneconomical. But in diesel engine, only air is drawn during suction stroke and hence such problem will notarise.

This overlapping helps in scavenging, resulting in an increased output.



(a) Actual valve timing diagram for a 4S - S.I. Engine

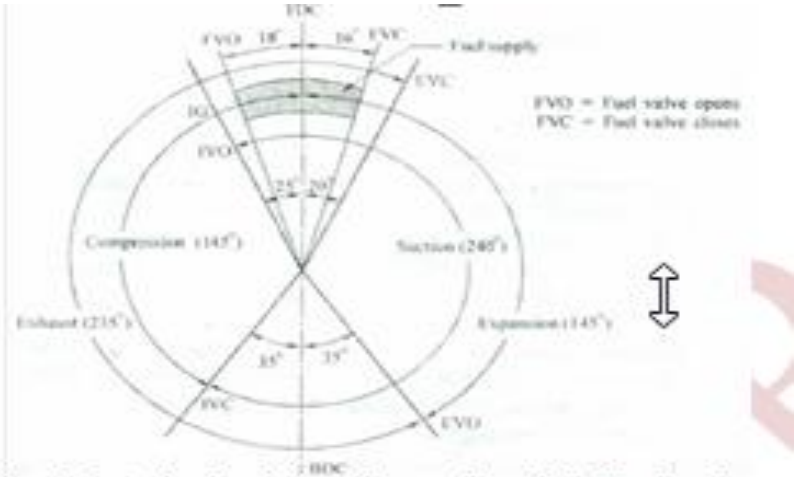


Fig: (b) Actual valve timing diagram for a 4S - Diesel engine

1. Ignition: There is always a time lag between the spark and ignition of the charge. The chargetakes some time to burn after giving the spark. Therefore, it is necessary to produce the spark early to obtain proper combustion without losses. The angle through which the spark is given earlier is 'Ignition advance' or 'angle of advance'. In diesel engines, the opening of fuel valve before TDC is necessary for better evaporation and mixing of the fuel. There is always lag between ignition and supply of fuel results in early supply offuel.

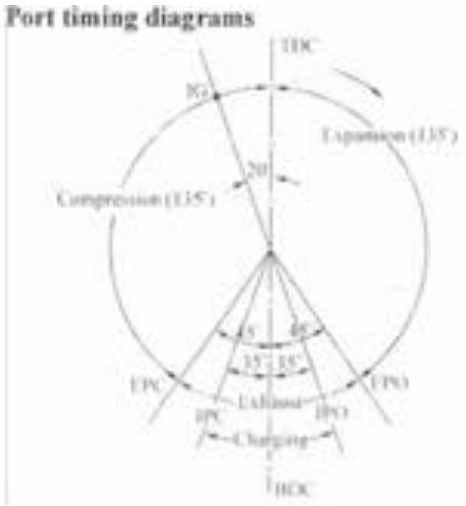


Fig: (a) Port timing diagram for 2Spetrol engine engine

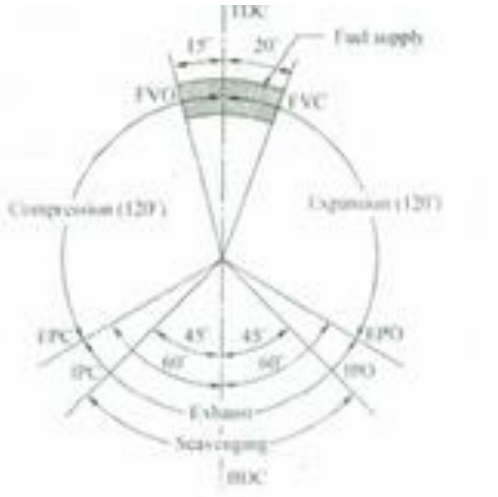


Fig: (b) Port timing diagram for 2S diesel

IG Ignition

EPO - Exhaust port opens EPC - Exhaust port closes

IPO (TPO) -Inlet or transfer port opens IPC (TPC) -Inlet or transfer port closes FVO - Fuel valve opens FVC Fuel valve closes.

The port timing diagrams for two stroke petrol and diesel engines are as shown in figures (a) and (b).

The main difference between these two is, the charging and scavenging period in the diesel engine is (90°) greater than that off or petrol engine (70°). This is because there is no danger of loss of fuel during scavenging of diesel engine.

COMBUSTION CHAMBER DESIGNS FOR S.I. AND C.I. ENGINES

(a) In S.I.Engines

The combustion chamber design includes shape of combustion chamber, spark plug location and deposition of inlet and exhaust valves and it affects on the engine performance and it's knocking properties.

The three basic requirements of a SI Engine combustion chamber are high power output with minimum octane requirement, High thermal efficiency and smooth engine operation.

These requirements can be achieved by the following design principles.

a) Largest possible valve should be provided with ample clearance to obtain high volumetric efficiency.

b) The heat flow should be minimum in the zone around sparking plug to obtain high thermal efficiency.

c) To prevent detonation the length of flame travel from the spark plug to 'the farthest point in the combustion space should be as short as possible. This involves spark plug location, valve position, shape of the combustionchamber.

d) The combustion chamber should be shaped such that the largest mass of the charge burns in a short time afterignition.

e) Short combustion time is achieved by creating the highest flame front velocity through the creation of highturbulence.

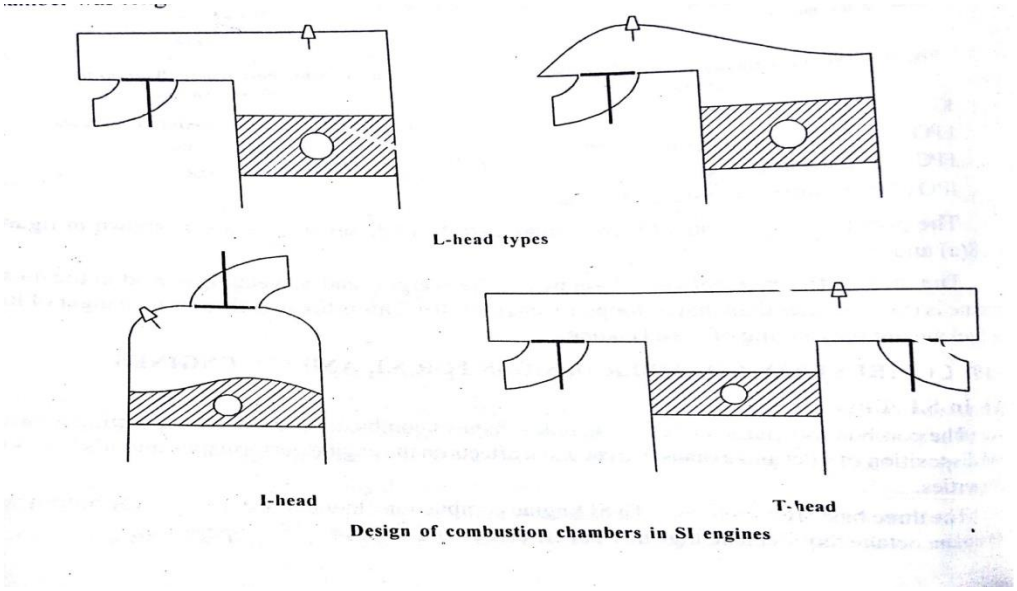
f) The compression ratio can be increased as far as possible for a given type of fuel to obtain maximum thermalefficiency.

g) The figure a, b, c & d shows different types of combustion chambers and are designed to obtain high combustion rate at the start, a high surface to volume ratio near the end of burning and centrally located sparkplug.

h) The T -head design was introduced in ford T model in 1908. It had thedisadvantages

(i) Having two camshaft;

Being very prone to detonation, the distance across the combustion chamber waslong.



Side valve engine was introduced in petrol engines, in 1910 - 30. In this type valves are placed side by side. It is easy to lubricate the valve mechanism. It had the defects like lack of turbulence, extremely prone to detonation, slow combustion process etc.

(b) In C.I.Engines

There are many types of combustion chambers used in C.I. Engines. Anyone of these combustion chambers may produce good results in one field of application, but poor results or less desirable results in another application

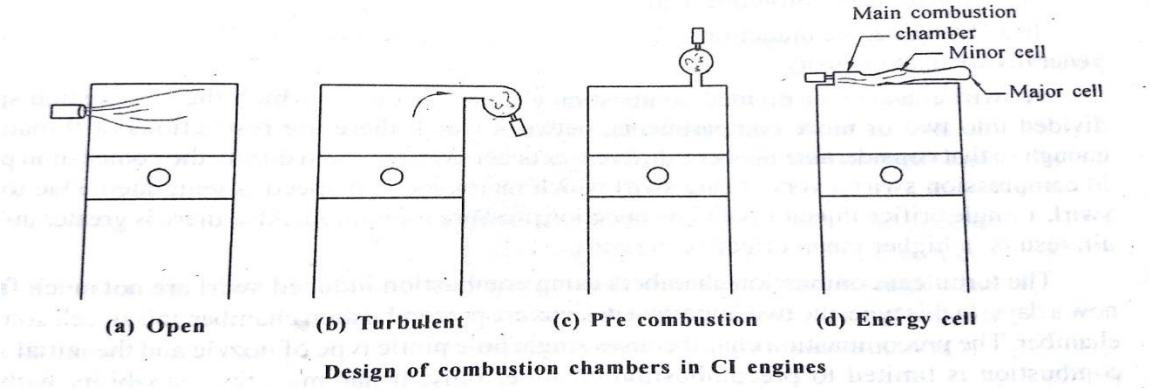


Fig: Design of combustion chambers in CI engines

The open combustion chamber is a non-turbulent type. This is ordinarily used on low speed engines. Less costly fuels with longer ignition delay may be used with this design.

The turbulent chamber, pre combustion chamber and energy cell are variations of turbulent type of chamber. All these types tend to exhibit the same general characteristics.

This type depends on turbulence to produce the required mixing of fuel and air. This does not require as much excess air as non turbulent type. These are suitable for variable speed operation and also produce smoother operating engines.

METHODS FOR SWIRL GENERATION

In C.I. engine fuel is injected near the end of compression and mixing of fuel and air take place inside the combustion chamber. Thus combustion chamber has to perform duty of a carburetor, within a period of some20 to 35 degrees of crank angle. The combustion chamber design should be such that it has to provide proper mixing of fuel and air in a short time. To achieve this, an organized air movement, called air swirl is provided to produce high relative velocity between the fuel droplets and air. Different methods are used to generate air swirl in a CI engine combustion chamber. They are

a) By directing air flow during its entry to the cylinder known as induction swirl. This method is used in open combustionchambers.
b) During compression, air is forced through a tangential passage in to a separate swirl Chamber known as compression swirl. This method is employed in swirlchambers.
c) By use of the initial pressure rise due to partial combustion to create swirl turbulence, known as combustion induced swirl. This method is used in pre combustion chambers and air cell chambers.

Open combustion chamber is one in which the combustion space is essentially a single cavity with little restriction and hence there are no pressure differences between different parts of the chamber during the combustion process. There are many designs of open combustion chambers used in conjunction with induction swirl. In a 4S 'engine induction swirl can be obtained by

i) Careful formation of the air intakepassages

ii) By making or shrouding a portion of the circumference of the inletvalve.

In a 2S engine, the induction swirl is created by suitable inlet port forms. The induction swirl is generally weak in intensity.

A swirl chamber or divided combustion chamber is one in which the combustion space is divided into two or more compartments, between which there are restrictions or throats small enough so that considerable pressure differences occur between them during the combustion process. In compression swirl a very strong swirl which increases with speed is generated. Due to strong swirl, a single orifice injector with lo**w** injection pressure is required. Also there is greater utilization air, results in higher mean effective pressure.

The turbulent combustion chambers using combustion induced swirl are not much favoured now a days. In this type, the two important designs are pre combustion chamber and air cell combustion chamber. The pre combustion chamber uses single holepintle type of nozzle and the initial shock of combustion is limited to pre combustion chamber only. It has multi fuel capability without any modification in the injection system. The air cell chamber design is smooth running and easy starting.

ENGINE RATING

All engines are rated in Power - the measure of rate at which they can do work. There are two ways of measuring engine power - (1) The power developed by expansion of gases in the cylinder can be determined by using indicator cards (indicated power) ; (2) By means of measuring instruments like a prony brake or a dynamometer, the actual power which an engine delivers can be determined (brakepower).

The general methods used to define rated power of an automobile engine are

1) Maximum load carried by the engine continuously. This load is indicated on the basis of mean effective pressure kpa. for petrol engines M.E.P varies from 640kpa.
2) Maximum power developed by the engine. In this case the engines are rated in terms of their maximum capacity. i.e, maximum B.P. that can bedeveloped.
3) Using conventional formula (RAC Ring). For taxation purposes, the Royal Automobile club made certain assumption for finding out B.P. for a 4S automobile engines. This B.P. is much less than obtained in case (2) represents the RAC rating ofengine.

The assumptions are

Piston Speed:- 1000 ft/min mep - 90 psi

Mechanical efficiency – 75%

Bp – $(d^2n)/2.5$ Where d = diameter of the cylinder, inches n = number of cylinders.

Engine Components

1) Cylinders
2) Oil Pan
3) Inlet and exhaustmanifold
4) Cylinderliners
5) Piston
6) Piston ring
7) Piston pin
8) Connectingrod
9) Crankshaft

Materials & their composition

1) Grey cast iron (carbon present in the form of flakes of graphite which makes it more Wear and corrosions resistant) carbon - 3.5%, silicon -2.5%, manganese - 0.65%. Carbon serves to provide graphite which improves lubrication; silicon provides wear resistance while manganese increases the strength andtoughness.
2) Aluminium alloys-silicon - II %, manganese - 0.5%, magnesium - 0.4%. Silicon reduces expansion and increases strength and wear resistance, manganese and magnesium improves strength of aluminium structure. Pressed steel sheet Cast Iron Special alloy iron containing

silicon, manganese, nickel and chromium Cast-iron, aluminium alloy containingsilicon.

Special alloy (La - ex alloy).

Fine- grained alloy cast iron containing silicon and manganese, chromium plated types. Low carbon case hardened steel; carbon-I 5%, silicon - 0.3%, manganese - 0.5% and remainder iron

a) Drop forging of steel orduralumin
b) Cast from malleable or spherical graphite cast iron. Cast steel, S.G. Iron (in case of casting) SAE steels, 1045 and 3140, chrome-vanadium and chrome molybdenum steels(forging)

ENGINE POSITION

The engine may be conveniently placed on the chassis in different positions as given below

(a) Front Position

In most of the lighter vehicles (both private and commercial), the engine is placed at the front and conventionally rear wheel drives are used. In some of the vehicles drive is also given to front wheels only. The engine position remains 'the same in heavy commercial vehicles, but the cab is brought forward over the engine to increase the pay load. The engine position at the front with rear wheel drive system needs greater length of propeller shafts, as it has to run from front (engine side)

to the rear (road wheels) of the vehicle. Also, in this system, the number of universal joints required are more.

(b) Rear Position

In this system, the engine is mounted close to the back axle, thereby reducing the length of drive from engine to the axle. In this position, length of propeller shaft required is reduced and is suitable for small cars. This position provides more space to the passengers, results in economy of drive parts and also better engine service is possible. The fixing of gear shift lever, oil gauge and fuel gauges, accelerator linkage is very complicated due to missing of natural draft of air during forward motion of vehicle to the radiator.

The major portion of total weight of the vehicle lies on the rear wheels and hence helping in traction up the hill. With rear position of the engine, the luggage has to be accommodated at front, near the driver seat, which is a problem as wheel arches are already occupied a large place there.

(c) Under FloorPosition

This position of the engine is in the centre, under the chassis and is used in public service vehicles and heavy lorries. This position of the engine eliminates the heat and noise in the cab. In this position the advantages of gravitational flow of the fuel and lubricants are also taken. It also reduces length of the drive shaft from engine to rear axle. The engine repairs and hence maintenances are easy.

ENGINE COOLING:

- As a result of combustion high temperatures are produced in the engines which tend to damage the engine parts unless cooled adequately
- The cooling system maintains the temperature of the engine components within certain limits and increases engine performance

A part of total fuel energy is converted in to mechanical work and rest is rejected in the form of

1. Heat from engine surface by combined action of conduction, convection andradiation.
2. Heat lost toexhaust.
3. Heat rejected in to thecoolant.

NEED FOR ENGINE COOLING

The engine cooling is necessary due to following reasons.

1. As engine temperature increases, the strength of materials used for various engine components decreases. As an example, in water cooled engines the temperature of cylinder head should not exceed 270°C, and for air cooled engines, uses light alloys, the temperature should not exceed 200°C.
2. The lubricating oil used in the engine also decides the maximum temperature that can be used. For different lubricating oils, this temperature range varies from 1600°C to 200°C. If the engine temperature exceeds this limit, it may deteriorates the lubricating oil or evaporate and burn to cause piston and cylinder damage. Over heating results in piston seizingalso.
3. High cylinder head temperature result in loss of volumetric efficiency and reduces poweroutput.
4. High engine temperature may cause pre ignition anddetonation.

METHODS OF COOLING

1. Aircooling

2. Watercooling

1) <u>Air Cooling:</u>Here, the air stream flows continuously over the heated metal surface and the rate of heat dissipation depends on surface area of metal, air mass flow rate, thermal conductivity of metal, temperature difference between metal surface andair.

To increase the effectiveness, the metal surface area which is in contact with air should be increased. This is done by providing fins over cylinder barrels. The fins may be cast integral with the cylinder or may be attached separately.

Advantages:

1. Absence of radiator cooling jackets and coolant reduces weight of thesystem.
2. Air cooled engines are useful in extreme climates, where water mayfreeze.
3. These engines warm up earlier than water cooledengines.
4. Easy maintenance as there is no leakageproblem.

Disadvantages:

1. These are noisier, because of absence of cooling water which acts as soundinsulator.
2. Heat transfer co-efficient for air is less. Hence less efficient cooling and results in decrease of highest useful compression ratio.
3. Distortion of cylinder may occur due to uneven cooling all around thecylinder.

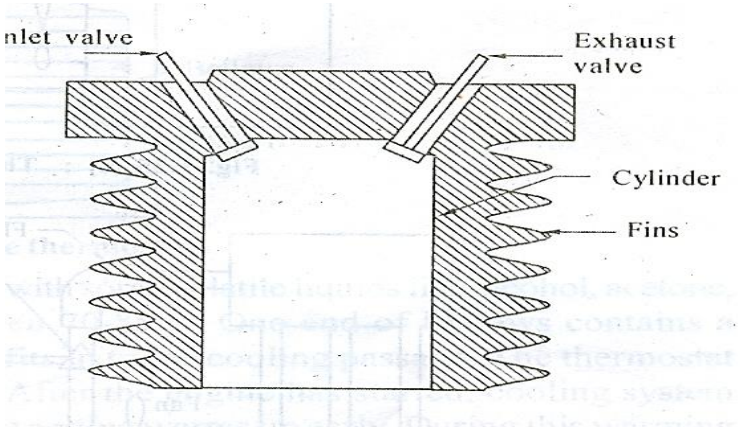


Fig. Cylinder with Fins

2) <u>Water Cooling:</u>In these systems, the water jackets surrounds engine cylinders ana cooling water flows through these jackets. Heat is conducted through the cylinder walls to the water in the jackets which removes the excess heat as it circulates through theradiator.

Water cooling systems are classified into two types.

a. Thermo syphonsystem.

b. Pump circulation system.

(a) Thermo syphon system: In this system the engine is connected to radiator through flexible hoses. The difference in densities of hot and cold regions of cooling water causes water circulation between engine and radiator. The water in circulation absorbs heat from engine cylinder and hence cool it. The heat from the water is then dissipated into atmosphere through the radiator by conduction and convection. This cools the water which is required for further circulation. Sometimes fans are used behind the radiator to increase the air mass flow rate and- hence to increase coolingefficiency

(b) Pump circulation system: This system is similar to thermo syphon system explainedabove. The only difference is cooling water circulation is affected by means of a pump and a thermostat valve controls the temperature of water.

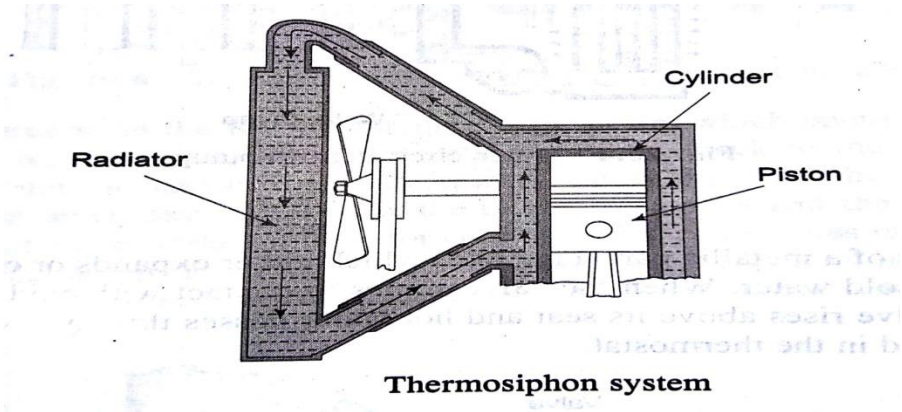


Fig (a): Thermosyphon Cooling System

- Thermo siphon system consists of a radiator , cylinder and piston
- The radiator is connected to the engine block by means of hose pipes
- Water Falls down in the radiator and then goes to the cylinder block, then again to the radiator
- The difference in densities of hot and cold regions of cooling water causes the circulation of water between engine and radiator
- The water in circulation absorbs heat energy from the cylinder and hence cool it, the heat of the water is given out to atmosphere through the radiator
- This cools the water and then it is circulated again to the cylinder and the process continues

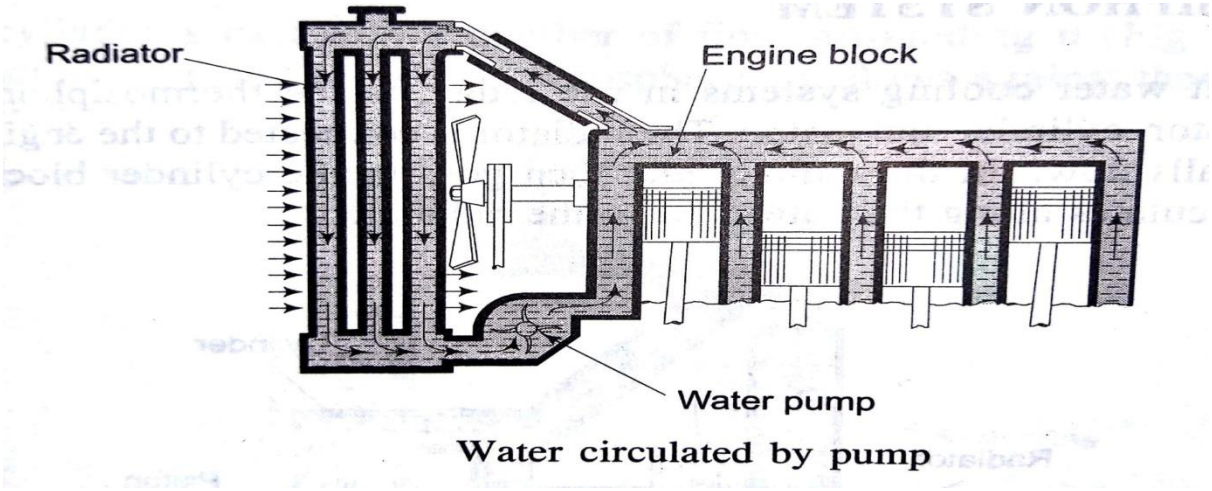


Fig (b): Pump Circulation System

- This principle is similar to thermo siphon system but the heat dissipated by the engine is so large that it is not possible to cool the engine by thermo siphon principle
- To enable faster cooling , a pump is introduced to the system between the radiator and the engine block
- When the pump rotates water is circulated with some force, therefore heat of the engine block is removed quickly without any difficulty

Advantages of this system over Thermo syphon system are:

(a) No need to place the radiator header tank above the engine level, as water circulation is effected bypump.

(b) Radiator may be placed on the side or on the rear, ifnecessary.

(c) Cooling water circulation is proportional to both load andspeed.

(d) Because of efficient cooling, water jacket size can be reduced. This results in overall decrease in enginesize.

THERMOSTAT VALVES

It is to be noted that the cooling beyond optimum limits is not desirable as it decreases the overall efficiency of the engine. A thermostat is used to regulate the rate of cooling. It keeps the cooling water temperature at a predetermined value.
Two types of thermostats are used in automobiles.

1. Bellows or aueroidtype

2. Wax or hydrostatictype

Bellows typethermostat:

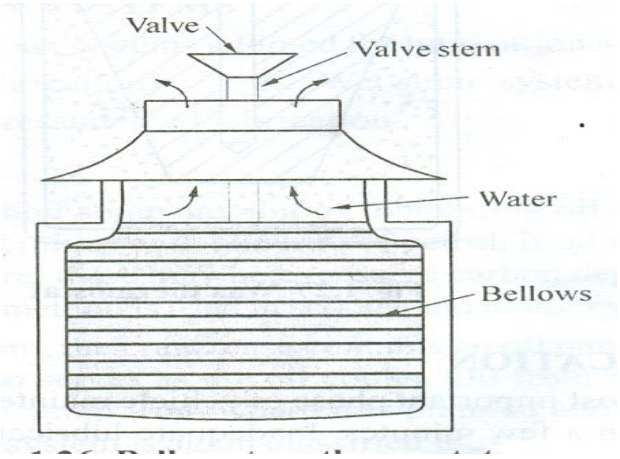


Fig. Bellows type thermostats

This thermostat consists of metallic bellows filled with some volatile liquids like alcohol, acetone, ether etc., whose boiling temperature ranges between 70-85°C. One end of bellows contains a valve and to the other end a frame is attached' which fits in to the cooling passage. The thermostat is fitted in the water hose pipe at the engine outlet. After the engine has started, cooling system should not operate during warming up duration~ that engine warms up early. During this warming up period, the liquid inside the bellows has not yet changed its state and hence does not exert any pressure on the valve. Therefore the valve remains in closedposition.

If the temperature of the cooling water exceeds a pre-determined as 80°C the liquid inside the bellows. Vaporizes and exerts a pressure on the valve. The valve opens and allows water circulation through the radiator, as water temperature rises, valve opens gradually, thus controls the flow of water through the radiator according to engine cooling requirement.

Wax thermostat

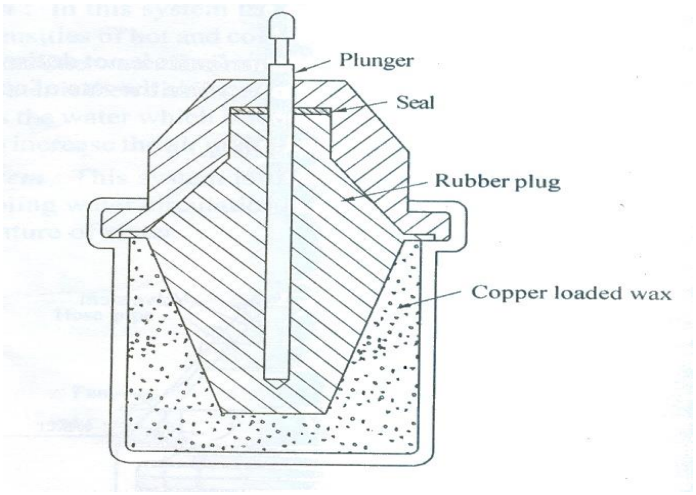


Fig: Wax thermostat

- Wax thermostat is also called as dole thermostat
- This is more reliable to operate within the specified temp range and is not sensitive to pressure variations
- Heat carried out by the coolant is transmitted to the copper loaded wax having high thermal expansion co-efficient
- The expansion of wax makes rubber plug contract therby exerting a pressure on plunger in upward direction. Allowing the coolent to flow through the radiator

ENGINE LUBRICATION

Lubrication is the most important phase of vehicle maintenance. Without lubrication, engine cannot run smoothly even a few minutes. Inadequate lubrication results in engine troubles like scored cylinders, burned out bearings, misfiring cylinders, dirty spark plugs, stuck piston rings, engine deposits and sludge and more fuel consumption.

Dry or solid friction is a result of direct contact between two metallic surfaces or due to inter locking of irregularities on metal surfaces, produces lot of heat and causes wear of the metal surface.

Hydrodynamic lubrication means, introduction of lubricating oil between two surfaces. There is no physical contact between them and only resistance to motion is resistance offered by the oil itself.

In boundary lubrication, the introduction of lubricant between surfaces will not cause complete separation between them. The surfaces touch at their high spots. Boundary lubrication exist in piston rings and valve train.

OBJECTS OF LUBRICATION

The main objects of lubrication are

(a) It reduces power loss by minimizing friction between movingparts.

(b) Decreases wear and tear of the moving components. The lubrication also serves other purposeslike.

Cooling effect: The lubricant absorbs heat from hot moving parts and dissipates it tothesurrounding air through the crank case.

1. **Cushioning effect:**The lubricant serves as a good cushion against shocks present in the engine. For example, instant combustion causes sudden pressure rise and the resultant shock goes to the bearings through piston, piston pin and connecting rod. Then the lubricant present in the main bearings absorbs thisshock.
2. **To act as cleaning agent:**As lubricating oil circulates, it absorbs so many impurities and oil may be further purified by filtration. Ex.: oil dissolves carbon particles during itscirculation.
3. **Sealing action:**It maintains an effective seal on the piston rings and avoids entry of high pressure gases into the crank case

ENGINE LUBRICATION SYSTEMS

In an automobile engine, various systems adopted for lubrication are classified in to

1. Petrol-oil system (Mistlubrication).
2. Wet sumpsystem.
   (a) Splashlubrication b) Pressure feedlubrication
3. Dry sumpsystem

1. **Petro-oil System:** In this method some amount of lubricating oil is directly mixed with the petrol. i.e., about 25 to 30ml. of oil mixes with one litre of petrol. If oil is less, it causes damage to the engine. If addition of oil is more, there may be excessive carbon deposits in the cylinder head and produces poor emissions. This method is used in scooter and motor cycles [two-strokeengines].
2. **Wet Sump System:** In this system, the crank case contains an oil pan or sump that serves as the oil supply or reservoir tank. It also serves as the oil cooler. Oil from the cylinders and bearings flows by gravity back into the wet sump from where it is pumped and recirculated to the engine lubricating system. The wet sump system is again classified into a) Splash lubricationsystem.
   a) Pressure feedsystem.
   b) Semi pressure feedsystem.

(a) Splash Lubrication System: It is the cheapest method of lubrication and was used in early motor cycles. The lower end of the connecting rod consists of a scoop like structure as in the figure. The oil is stored in the oil trough (being delivered from the crank case oilsump).

When the engine runs, the connecting rod oscillates and the scoop takes the oil from oil trough and splashes on to the cylinder walls each time when it passes through BDC position. This lubricates engine walls, gudgeon pin, main crank shaft bearings, big end bearings etc. The oil dripping from the cylinder walls, collects in the tank where it is cooled by air flow

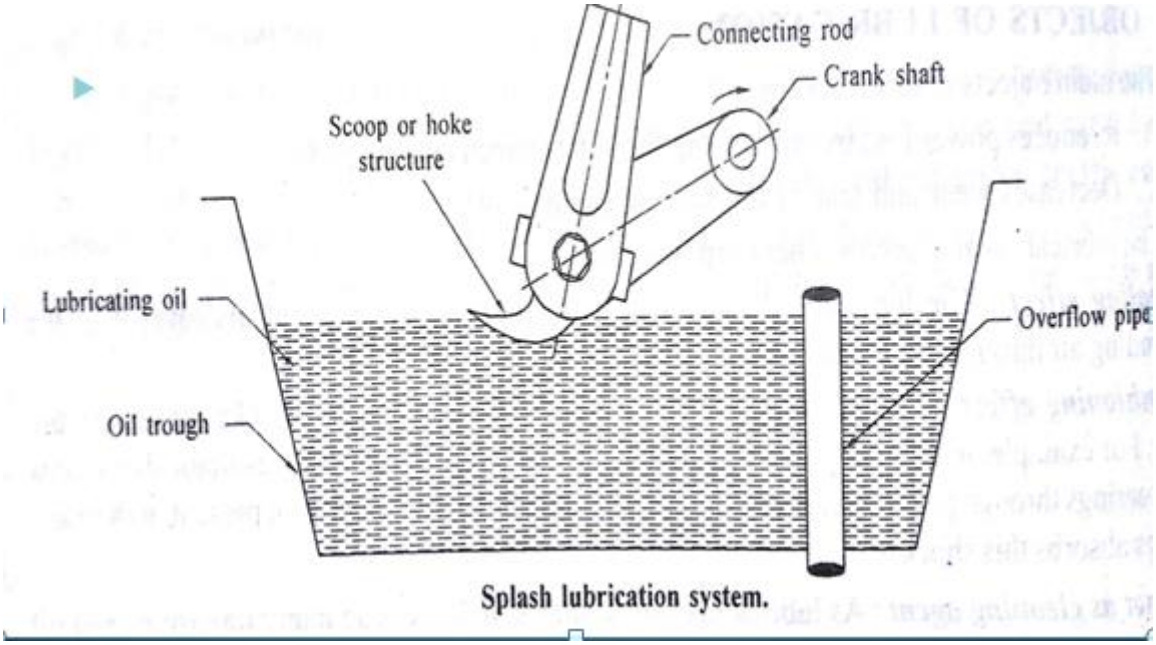
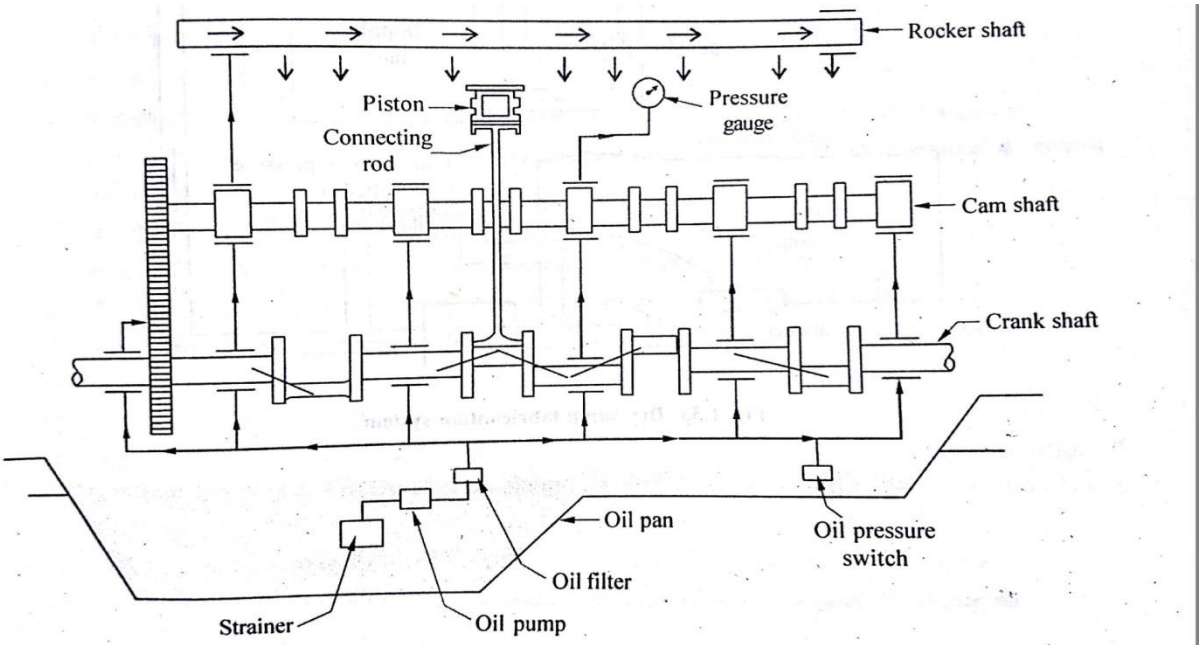


Fig: Splash lubrication system

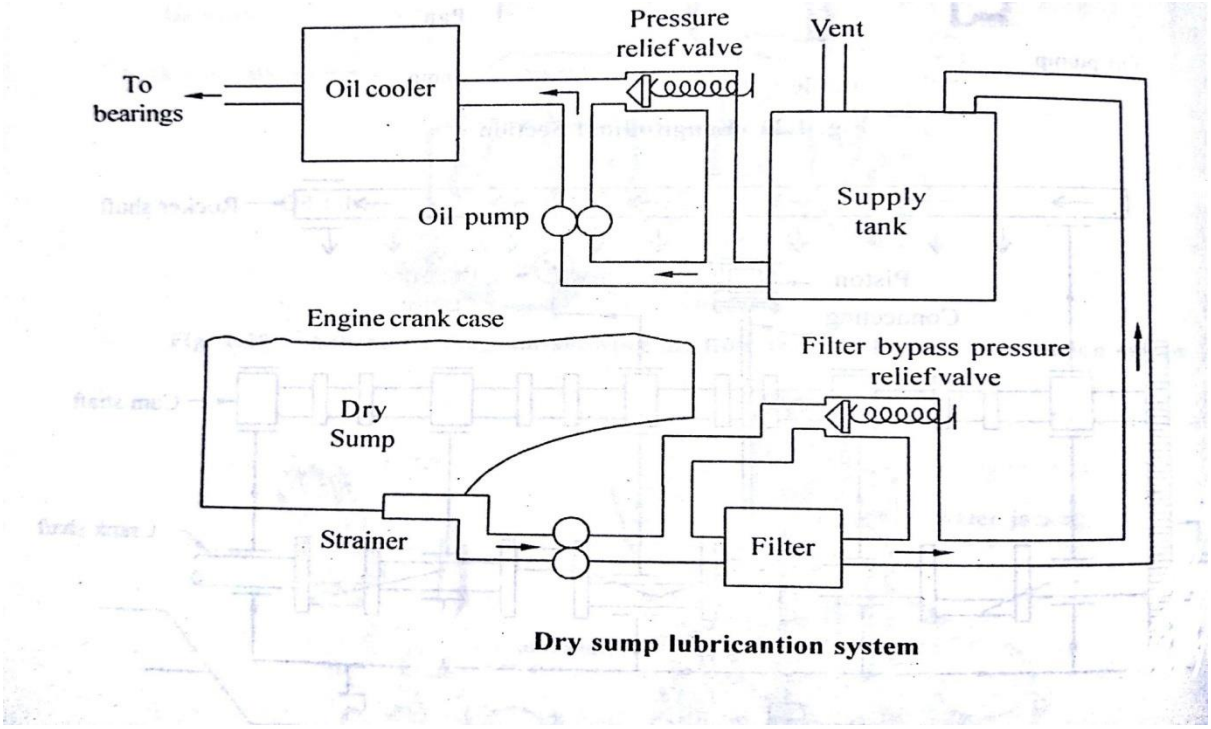
(b) Pressure Feed System: This system is most commonly used in modern car engines. In this system, the oil forces oil under pressure to the main bearings, connecting rod and cam shaft bearings and also to the timing gears. Drilled assuages in the crank shaft carry oil from the main bearings to the connecting rod bearings. The cylinder walls, piston pin, piston and piston rings are lubricated by oil spray from the connecting rod and crank shaft. For the cam shaft and timing gears, there is a separate oil line from the main oil gallery. The basic components of the wet lubricating system are pump, strainer, pressure regulator, filteretc.



Full pressure feed lubrication system

- This system is most commonly used in modern car engines
- The oil pump forces oil under pressure to the main bearings connecting rod and camshaft bearings
- The piston , piston pin , piston rings are lubricated by the oil spray from the connecting rod and crank shaft

Dry Sump Lubricating System: In this system, two pumps are used. The Pump 'A' is called scavenging pump and is located in the crank case portion as in figure. The oil from this pump is carne to an external tank i.e., reservoir. The pressure urn '8' urn s the oil through filter to the cylinder and bearings. Oil dripping from cylinder and bearings in to the sump is again removed by scavenging pump (sump pump), which supplies oil to the reservoir. As the capacity of sump pump is greater than oil pump, oil will not be accumulated in the engine base. The oil pump draws oil from the supply tank and delivers it under pressure to the engine bearings and oil pressure of 400- 500 kpa is maintained in main and big end bearings. A pressure of about 50-100 kpa is maintained in timing gears and cam shaft bearings etc. This system is suitable for lubricating sport cars, jeeps etc



Dry sump lubricantion system

- This system is employed for sports car, jeeps etc. There are two pumps used in this system, the oil from the first pump is carried to the reservoir
- The pressure pump pumps the oil to the cylinder and bearings. The oil dripping from cylinder and bearings in to the sump is again supplied to the reservoir by the first pump
- The oil pump draws the oil from the supply tank and delivers it under pressure to te engine bearings

IMPORTANT QUESTIONS:

1. Sketch and explain the constructional features of the engine cylinder block. mention the typical composition of cast iron and aluminum cylinder block
2. With the help of PV diagram Compare SI and CI Engine.
3. List out the components of automotive engine; give its function, materials and method of manufacturing.
4. Sketch and explain any four types of combustion chamber of SI engines, with their relative advantages and disadvantages.
5. Explain the various methods of cylinder arrangements used in multi-cylinder engine.
6. What are the advantages of multi-cylinder engine over single cylinder engine?
7. What are the functions of cylinder liners? State the advantages of aluminum as cylinder liner.
8. Differentiate between the following:
    1. Wet liner and dry liner
    2. Air cooler and Water cooler
9. What is swirl? Explain the different methods of swirl generation.
10. With a neat sketch explain normal and abnormal combustion in SI engine.
11. With the help of neat sketch give constructional details of connecting rod.
12. What are the functions of piston rings? Explain briefly.
13. Explain valve timing diagram of 4 stroke petrol engine
14. Classify valve operating mechanism and with the help of diagram explain, over head inlet valve and side exhaust valve mechanism.
15. With the help of neat sketch, explain pre chamber type of combustion chamber.
16. What are the advantages and disadvantages of pre-combustion chamber?
17. Why cooling is necessary, and what are the different methods of cooling.
18. Explain dry sump lubrication system, with neat sketch explain.
19. Explain thermo siphon cooling with neat sketch.
20. Write a note on splash lubrication.

MODULE 2

Transmission Systems: Clutch-types and construction, gear boxes- manual and automatic, gear shift mechanisms, Over drive, transfer box, fluid flywheel, torque converter, propeller shaft, slip joints, universal joints ,Differential and rear axle, Hotchkiss Drive and Torque Tube Drive.

Brakes: Types of brakes, mechanical compressed air, vacuum and hydraulic braking systems, construction and working of master and wheel cylinder,
brake shoe arrangements, Disk brakes, drum brakes, Antilock –Braking systems, purpose and operation of antilock-braking system, ABS Hydraulic Unit,
Rear-wheel antilock & Numerical **08 Hours**

INTRODUCTION

A Transmission system uses a clutch, gear box, propeller shaft and a differential gear to transmit power from engine to the road wheels. The power may be transmitted to rear or front wheels or all the four wheels, depending on the type of drive used in automotive. The clutch and gear box varies the leverage i.e. ratio of torque output to torque input. The propeller shaft transmits final torque to the rear axle from gear box, and a differential gear equally distributes the final torque between the road wheels (driving wheels).
A Transmission system has to perform following functions.

1. It disconnects engine from driving wheels when required.
2. The engine is connected to driving wheels without jerk.
3. It changes ratio of torque output to torque input, as desired.
4. It turns the drive through a right angle.

CLUTCH

Clutch is a device used in the transmission system of a motor vehicle to engage and disengage the engine to the transmission. Thus the clutch is located between the engine and the transmission. Typically a clutch consists of clutch fork, thrust bearing, diaphragm, cover, pressure plate, clutch plate, and a flywheel

Functions of a clutch are as follows,

- When the clutch is engaged, the power flows from the engine to the rear wheels through the transmission system and the vehicle moves.
- When the clutch is disengaged, the power is not transmitted to the rear wheels and the vehicles stops while the engine is still running.
- The clutch is disengaged when starting the engine, when shifting the gears, when stopping the vehicle and when idling the engine. The clutch is kept engaged when the vehicle is moving.
- The clutch also permits the gradual taking up of the load. When properly operated, it prevents

jerky motion of the vehicle.

FRICTION CLUTCHES & FLUID FLYWHEEL

Clutches are mainly classified into.

1. Friction Clutches
2. Fluid Fly-Wheel.

Friction Clutches are again made in dry and wet type. In this type, the transmission of power is caused due to friction between two rotating members. However, in the wet type, coefficient of friction is less. A fluid fly wheel causes energy transfer between two members due to movement of fluid.

PRINCIPLE (OPERATION) OF FRICTION CLUTCHES

- The clutch works on the principle of friction. When two friction surfaces are brought in contacts with each other and pressed they are united due to the friction between them.
- If one revolves, the other will also revolve. The friction between the two surfaces depends upon the area of the surfaces, pressure applied upon them and coefficient of friction of the surface materials. The two surfaces can be separated and brought into contact when required.
- One surface is considered as driving member and the other as driven member, the driving member is kept rotating.
- When the driven member is brought in contact with the driving member, it also starts rotating.
- When the driven member, it also starts rotating. When the driven member is separated from the driving member it does not revolve.

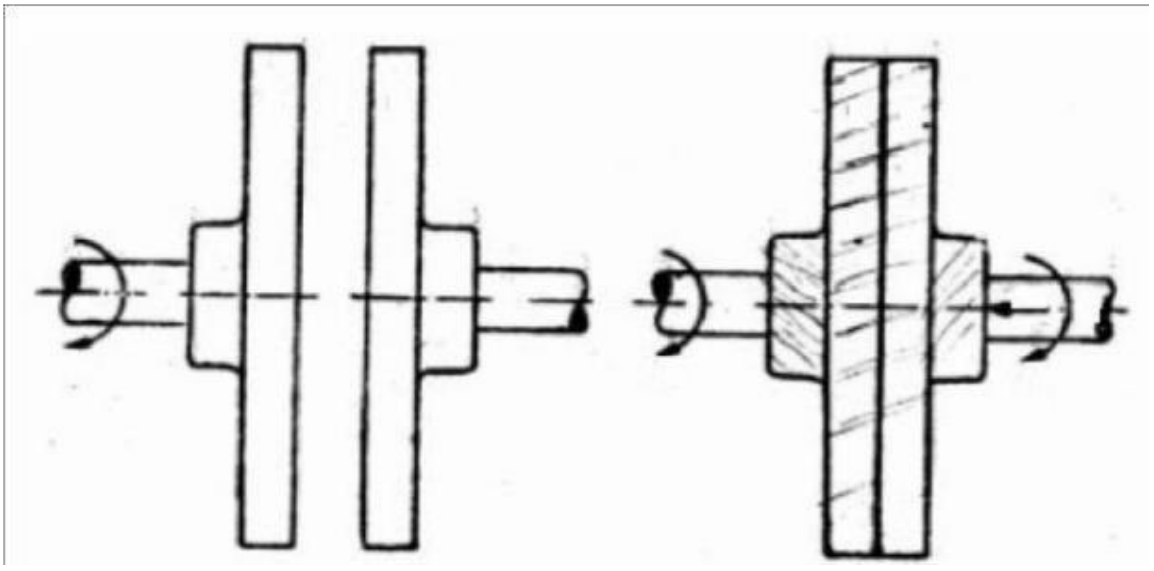


Fig: Friction clutches

Dog Clutches

- A dog clutch is a type of clutch that couples two rotating shafts or other rotating components not by friction but by interference.
- The two parts of the clutch are designed such that one will push the other, causing both to rotate at the same speed and will never slip.
- Dog clutches are used where slip is undesirable and/or the clutch is not used to control torque. Without slippage, dog clutches are not affected by wear in the same way that friction clutches are.
- Dog clutches are used inside manual automotive transmissions to lock different gears to the rotating input and output shafts.
- A synchromesh arrangement ensures smooth engagement by matching the shaft speeds before the dog clutch is allowed to engage.
- A good example of a simple dog clutch can be found in a Sturmey-Archer bicycle hub gear, where a sliding cross-shaped clutch is used to lock the driver assembly to different parts of the planetary gear train.

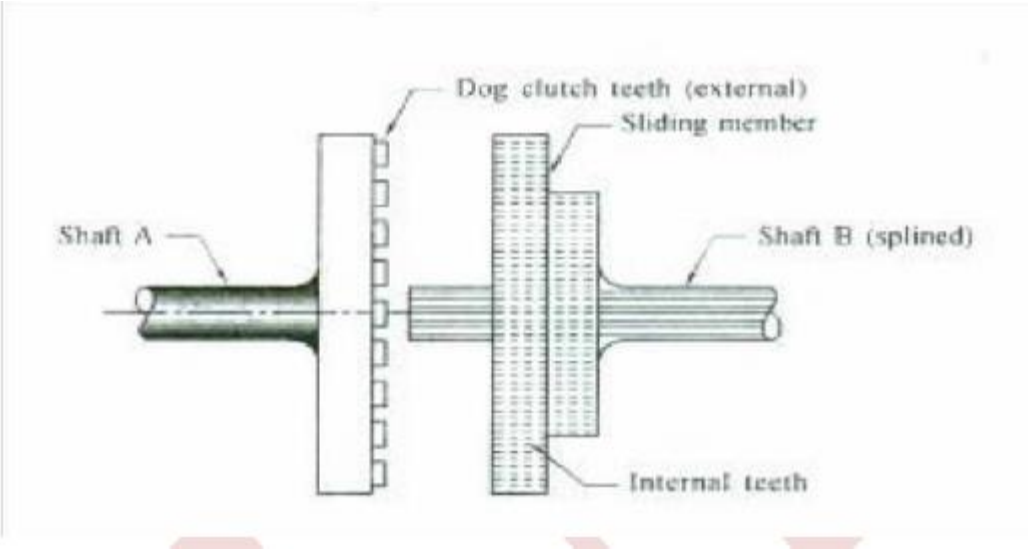


Fig. Dog Clutch

- A cone clutch serves the same purpose as a disk or plate clutch. However, instead of mating two spinning disks, the cone clutch uses two conical surfaces to transmit torque by friction.
- The cone clutch transfers a higher torque than plate or disk clutches of the same size due to the wedging action and increased surface area.
- Cone clutches are generally now only used in low peripheral speed applications although they were once common in automobiles and other combustion engine transmissions.
- They are usually now confined to very specialist transmissions in racing, rallying, or in extreme off-road vehicles, although they are common in power boats.
- This is because the clutch does not have to be pushed in all the way and the gears will be changed quicker. Small cone clutches are used in synchronizer mechanisms in manual

transmissions.

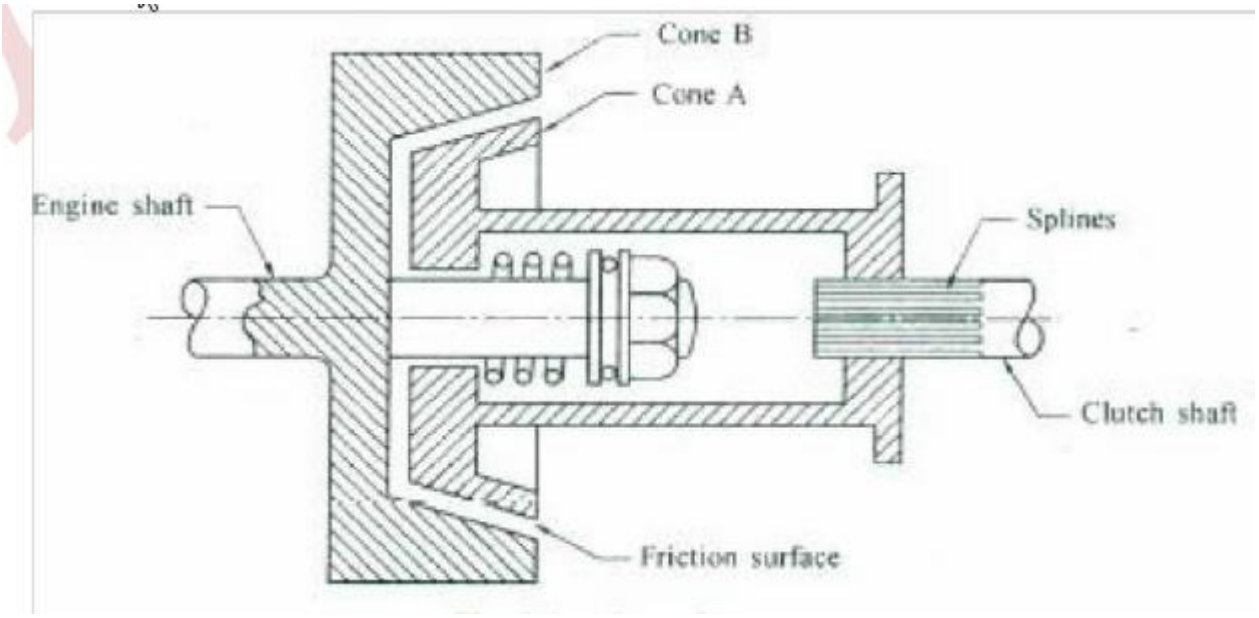


Fig: Cone clutch

Advantages

- When compared to single plate clutch, the normal force on friction surfaces is greater than axial force.

Disadvantages ,

- It is difficult to disengage the clutch if cone angle is less than 20°, as one cone tends to bind in the other.
- Even a small amount of wear on friction surface results in more axial movement of the cones.

Centrifugal clutch

Centrifugal clutch is an automatic clutch which is controlled by the engine speed through the accelerator. When the engine speed increases above the certain limit, the clutch engages and when the engine speed decreases, the clutch disengages automatically.

This type of clutch design essentially consists of two members. One is the driving member which is fitted on the driving shaft. The other one is a driven member, which is just a drum and encloses the driving member. The driving member consists of two curved shoes or flyweights having frictional linings on them. The shoes are anchored at one end to the back plate and are kept in position be means of coil springs.

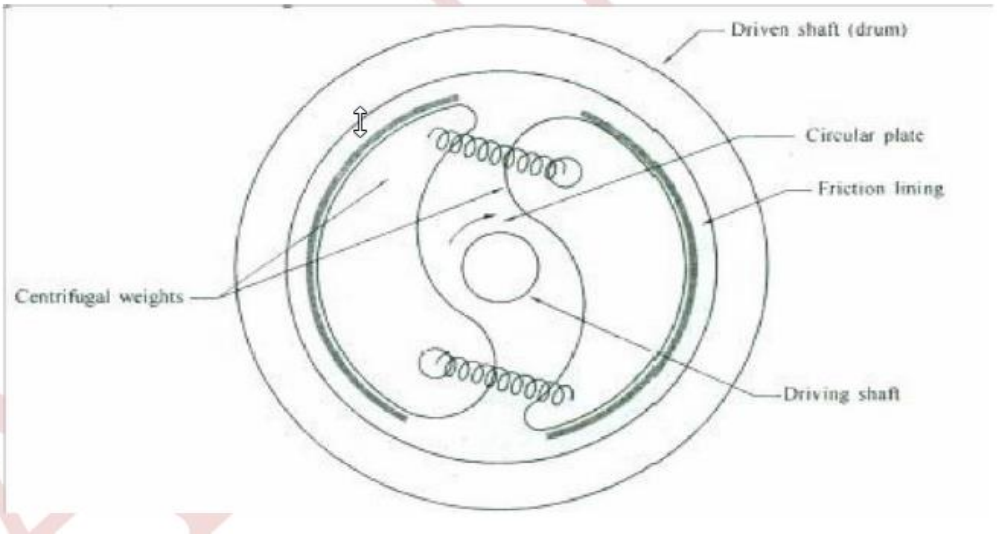


Fig. Centrifugal Clutch

Operation of centrifugal clutch:

- The driving member rotates along with the engine shaft. When the engine speed increases, the centrifugal force also increases.
- At certain engine speed the shoes fly outwards due to increased centrifugal force and they come in contact with the driven member.
- Now both driving and driven members rotate together and the clutch is said to be engaged.
- When the engine speed decreases, the centrifugal force also decreases. Now, the shoes return back to their original position due to spring force, which results in a disengagement of clutch.
- This type of clutch is used in mopeds.

Single Plate Clutch:

- A single disc or plate clutch consists of a clutch plate whose both sides are faced with a frictional material. It is mounted on the hub which is free to move axially along splines of the driven shaft.
- The pressure plate is mounted inside the clutch body which is bolted to the flywheel. Both the pressure plate and the flywheel rotate with the engine crank shaft or the driving shaft.
- The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body.
- The three levers (also known as release levers or fingers) are carried on pivots suspended from the case of the body.
- These are arranged in such a manner so that the pressure plate moves away from the flywheel by the inward movement of a trust bearing.
- The bearing is mounted upon a forked shaft and moves forward when the clutch pedal is pressed

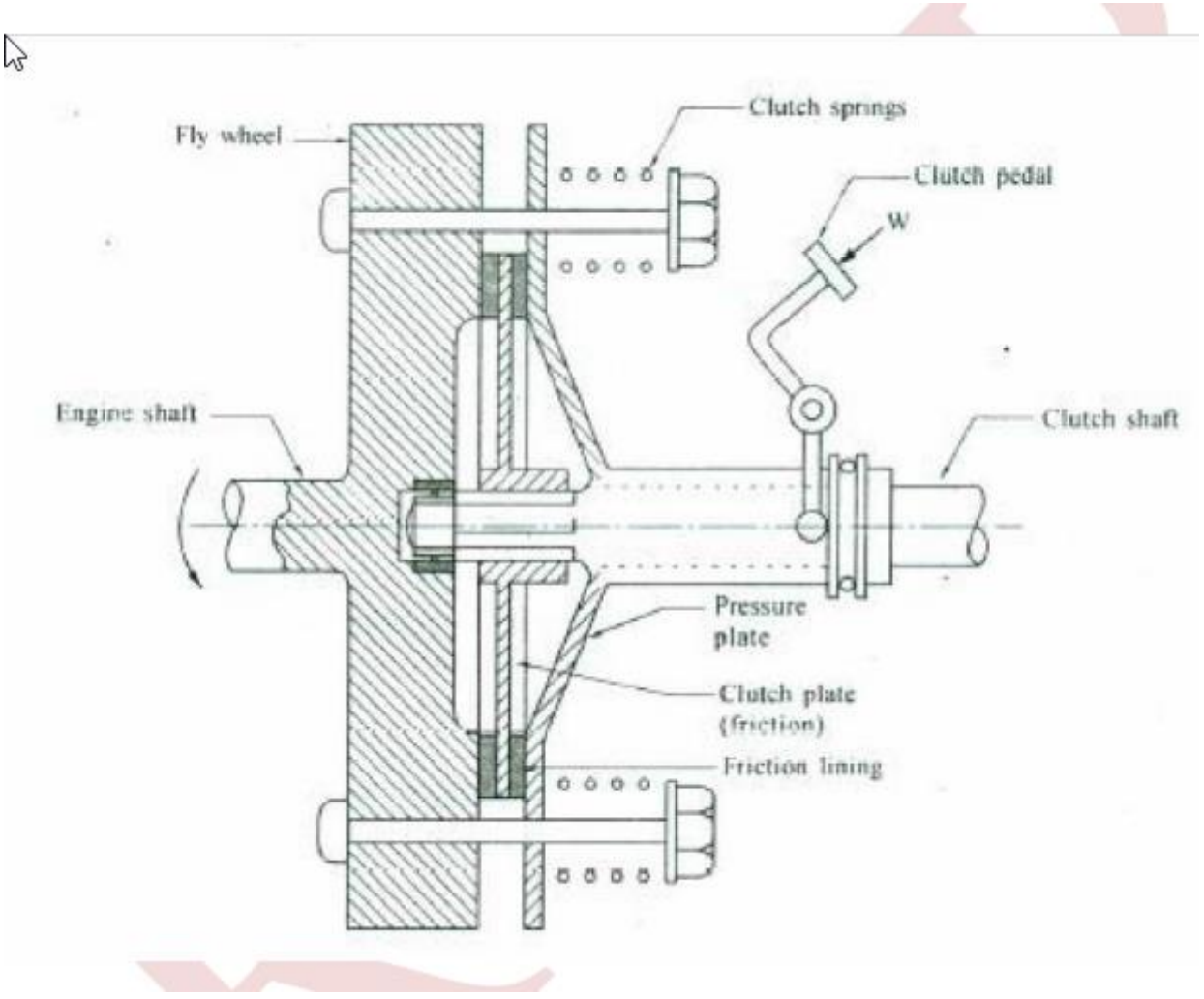


Fig: Single Plate Clutch

- When the clutch pedal is pressed down, its linkage forces the thrust release bearing to move in towards the flywheel and pressing the longer ends of the levers inward.
- The axial pressure exerted by the spring provides a frictional force in the circumferential direction when the relative motion between the driving and driven members tends to take place.
- If the torque due to this frictional force exceeds the torque to be transmitted, then no slipping takes place and the power is transmitted from the driving shaft to the driven shaft.

Advantages

1. Pedal movement is less and hence gear changing is easier.
2. It is more reliable.

Disadvantages

1. The spring stiffness required is more; hence greater force is required for disengaging the clutch.

Multi plate Clutch:

A multi-plate clutch has more than one driven plate. Although this type of clutch has been widely used on cars up to about 1930, the several advantages of the single-plate clutch, specifically its ability to completely disengage the drive has caused a very rare use of a multi plate unit as a main transmission clutch installed between the engine and gearbox.

However, a multi-plate type of clutch finds a use in automatic gearboxes. In these gearboxes, a number of clutches hold the various gear elements, and as the clutch diameter in these units is limited, a multi-plate clutch is suitable.

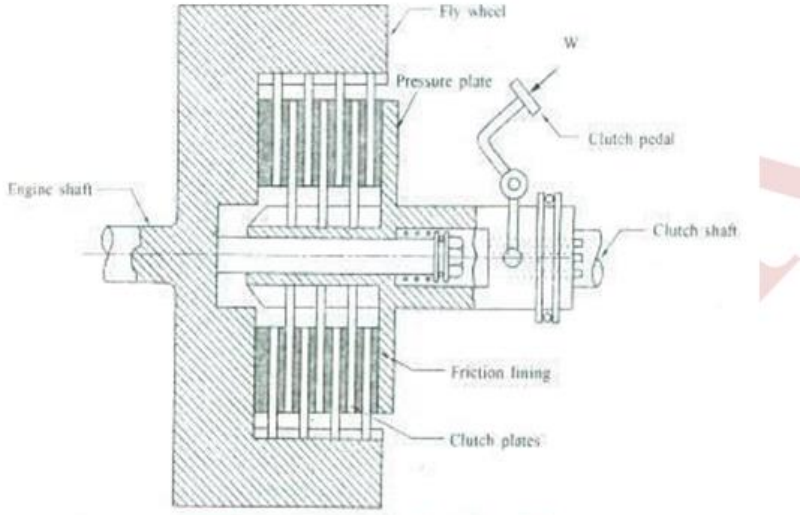


Fig: Multi-plate clutch

Multi-plate Spring Type Clutch

Figure illustrates the layout of a multi-plate spring type clutch, fitted on early motor cars. A cover, bolted to the flywheel, engages by means of slots with a series of lugs on the outer plates. These steel plates may be plain or fitted with cork or friction material inserts and acts on inner plates, splined to a hub. Thrust springs push the plates together to form a drive.

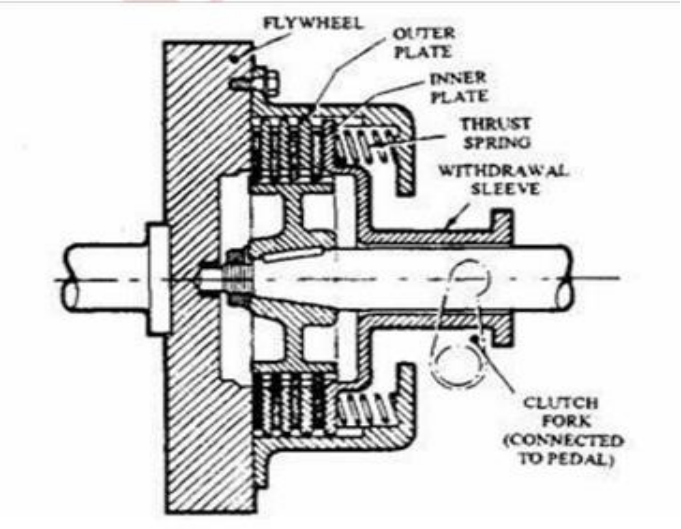


Fig: Multi-plate spring type clutch.

- For the clutch disengagement, the end plate is withdrawn to compress the springs and release the other plates. In this arrangement it is difficult to ensure the disengagement of all plates.
- To overcome this problem the plates are either dished or fitted with small springs to push the plates apart.
- Generally wet type clutch is used in automatic gearboxes, and is operated by a piston governed by hydraulic pressure.
- Sintered bronze plates of partially fusing powdered bronze or compressed paper are used in many designs.
- The porous surface of this plate traps the oil, to provide long life and smooth operation.

TRANSMISSION

- The engine would have power, enough to operate a vehicle without a transmission, provided the vehicle operated on reasonably level roads and maintained sufficient speed.
- When the vehicle must be started from a standstill or when attempting to negotiate steep grader, the engine would not provide sufficient power and the vehicle would stall.
- Much less torque is required to move the vehicle on level ground than to drive the same vehicle up on a steep hill.
- To enable the engine to: increase the torque to the drive line, a torque multiplier (transmission) is needed.
- Different types of semiautomatic and automatic transmissions are used in recent years. As discussed early, transmission is the mechanism which transmits power from engine to the road wheels.
- From here onwards transmission is used in the sense that, a mechanism which provides suitable variation of the engine torque at the road wheels. This may be a gear box or manual transmission or an automatic transmission.

NECESSITY FOR GEAR RATIOS IN TRANSMISSION

The Necessity for gear ratios in a vehicle can be explained by considering,

1. Variation of resistance to the vehicle motion at different speeds.
2. Variation of tractive effort of the vehicle available at different speeds.

Total resistance to the motion of vehicle, this includes

1. Wind resistance: It is directly proportional to the square of vehicle speed.

2. Gradient resistance: At all vehicle speeds, this remains constant.

3. Other resistances: The miscellaneous factors contribute to the vehicle resistance are types of road, tyre friction etc. All these are assumed to be constant, irrespective of vehicle speed. The figure (a) Shows variation of different types of resistances with speed.

For a particular type of road, the variation of total resistance on different gradients is as shown in fig. (b).

The fig (c) shows tractive effort (torques) available in different gears. It is clear that high torque is available in the low gear.

The fig. (d) Shows superimposition of total resistance and tractive effort curves for different gears.

Let us consider the vehicle is moving on a gradient for which total resistance curve is I. Let the vehicle be in the top gear and the curve 3 shows the available torque in the top gear. The inter section of curves I and 3 gives the stabilizing speed 'OA'. At any instant, if the vehicle speed decreases to say '08', the excess of tractive effort will accelerate it to speed 'OA'. Similarly if the speed increases to 'OC', the excess of resistance will decelerate the speed to 'OA'. So when the tractive effort over comes the total resistance, the vehicle speed increases such that the tractive effort becomes equal to the total resistance.

Suppose if the vehicles move on a steeper gradient than curve I, the stabilizing speed decreases to '00'.

Suppose, if we consider curve III, no where it crosses curve 3 (top gear). This means vehicle will not move on the gradient with the top gear. We have to pass on to second gear to get stabilizing speed '00'. Similarly on gradient IV, we have to shift to first gear.

During starting, more acceleration is required to gain speed quickly. In the first gear, torque available is maximum and hence during starting, we have to shift to first gear to gain speed quickly. Once the necessary speed has attained, the vehicle speed has to be simply maintained and acceleration is not required. We may shift into higher gears where less torque is available.

Types of Transmission system

The automobile transmission system can be classified into two types including manual and automatic transmission. In case of the manual transmission system, the vehicle is driven with the assistance of gearshift and foot clutch. The other components, which are used in this process, are flywheel, pressure plate and ring gears.

In case of the automatic transmission system, the gears are changed automatically corresponding with the vehicle's speed. The basic components essential for this process are modulator, torque converter, planetary gears, governor, computer, seals and hydraulic designs.

MANUAL TRANSMISSION

All manual transmission has a reverted gear train which consists of an input (clutch shaft) and output shaft (main shaft) whose axes are in the same line. A lay shaft (counter shaft) is located directly below these shafts. From the clutch disc, engine power goes in to the transmission through the input shaft (clutch shaft). In direct drive, clutch shaft is coupled to the main shaft, so that power transmission takes place directly between them. In reduction, power goes to lay shaft and then reverts back to the main shaft.

Manual transmission

Sliding mesh gear box Constant mesh gear box Synchromesh gear box (3, 4 and 5 speed)
In sliding mesh type, all the gears on the lay shaft are fixed. All the time they are rotating when the

engine is running and clutch is engaged. The gears on the main shaft are free to slide on the splines. Different gear ratios can be obtained by moving the main shaft gears to the left or right by means of selector mechanism. This gear box gives 3-direct and 1-reverse speeds.

In constant mesh type, all the gears on the main shaft and layshaft are in constant mesh with each other. The lay shaft gears are fixed to it as usual and main shaft gears are free on the splines of the main shaft. The two dog clutches are moved either to the left or to the right to get different gear ratios.

SYNCHROMESH GEAR BOX

This gear box is similar to constant mesh type i.e. all the gears on the main shaft and lay shaft are in constant mesh with each other. The gears on the main shaft are free to rotate and gears on the lay shaft are fixed to it. It is obvious that for one gear to mesh with another quietly and without damage, they must have to rotate at nearly the same speed. In constant mesh type, the dog clutches to engage smoothly, the speed of main shaft gear and the dog which is sliding must be equal. Therefore, for obtaining lower gear, speed of clutch shaft, lay shaft and main shaft gear must be increased and is accomplished by double declutching.

Double declutching procedure is as follows,

- Disengage the clutch and brought the gear to neutral position.
- Engage the clutch and increase the speed of main shaft gears by operating accelerator pedal.
- Disengage the clutch and put the required lower gear.
- Engage the clutch.

As the clutch is disengaged twice, this process is called double declutching.

For obtaining higher gear, we have to go in the reverse manner. For smooth engagement of tile gear, we have to wait with neutral gear till the main shaft speed is decreased sufficiently.

But most of the transmissions are equipped with a synchronizer to avoid the process of double declutching. The members to be engaged are first brought into frictional contact. This makes their speed equal, and then the members may be engaged smoothly. However, these devices are not fitted to all the gears; they are used only on higher gears. Dog clutches are used on low and reverse gears to reduce the cost.

The typical diagram of a synchronizer is as shown in figure.

The fig. shows the simplified view of a synchronizer which is used on the higher gear side.

The sliding hub 'C' is free to slide on the splines of the main shaft. A ring member 'D' having internal teeth fit on to the external teeth of sliding hub 'C'. 'H' is a dog teeth on the clutch gear 'B' and these also fit on to the teeth of 'D'. 'E' is the fork fitted on ‘D’; 'G' is the ball supported by spring and prevents sliding of 'D' on 'C'. When axial force applied on 'D' through 'E', exceeds certain value, the

balls are over come and 'D' slides over 'C'. FI, F2' are the friction surfaces.

To obtain direct gear ring member (D) and hence sliding hub (C) is slid towards left till friction surfaces FI and F2 rob against each other and friction makes their speed equal. Further pushing of 'D', towards left causes the ring member to override the balls and gets engaged with dog 'H' and provides direct drive from gear B via 'C' and the splines. Similarly second gear is obtained by sliding the sliding hub 'C' to the right.

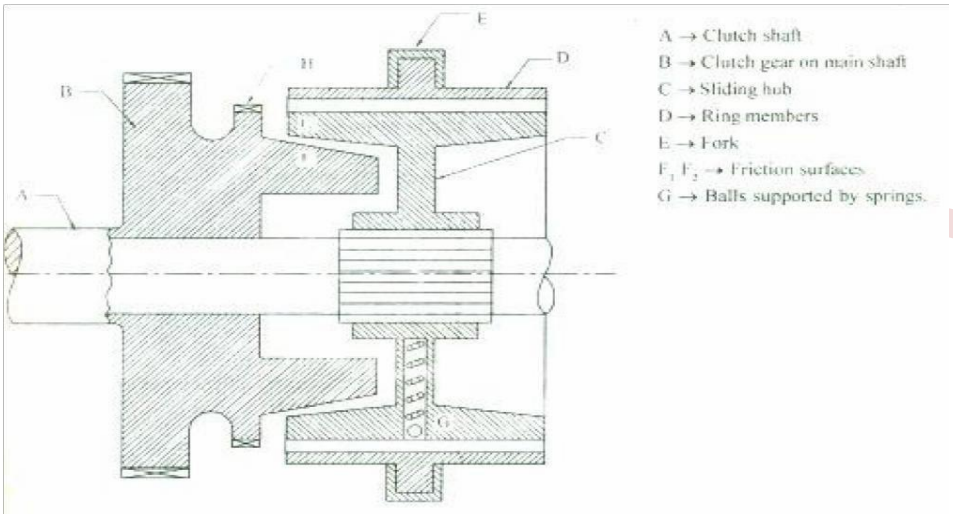


Fig. 5.9 Synchromesh device on higher gear side in a gear box.

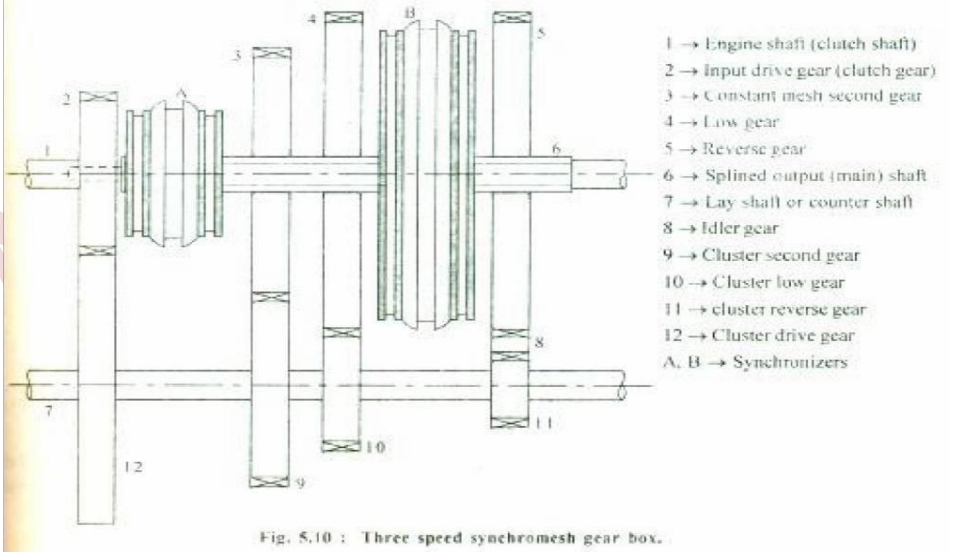


Fig. 5.10 : Three speed synchromesh gear box.

THREE SPEED SYNCHROMESH TRANSMISSION

In this type, all the gears on the main shaft are in constant mesh with the corresponding gears on the counter shaft. The main shaft gears are free to rotate, while counter shaft gears are fixed to it. Since all the gears are in constant mesh, the gears on the input (clutch) shaft, main shaft (output

shaft) and counter shaft are rotating with the running condition of engine i.e., when the clutch gear is rotating. The figure shows a fully synchronized transmission, with all forward speeds having synchronizing devices. The different gear ratios are obtained as follows:

Low Gear (First Gear)

Low gear is obtained by moving the synchronizer' 8' to the left and synchronizer' A' is still in the neutral position. A friction surface rubs against each other and the friction makes their speed equal. Further pushing of synchronizer '8', causes it to mesh with teeth of low gear (No. 4) and the drive is transmitted through 1-2-12-10-4-8-6 (input shaft - gear 2, 12, 10,4 - Synchronizer '8' through the splines to the output shaft) and low gear is obtained.

Second Gear

When the synchronizer' A' slid to the right it meshes with gear 3 and second gear is obtained. The drive is transmitted through 1-2-12-9-3-A-6 [8 is in neutral].

Third (High) Gear {Direct Gear]

When the synchronizer 'A' slid towards left with '8' is in neutral, it meshes with teeth of gear 2. This locks the input and output shaft together and the power flow is direct. The cluster is driven and still turns the second gear which is free to turn on the output shaft.

Reverse Gear

Reverse gear is obtained by moving synchronizer '8' to the right with 'A' in the neutral position. The input shaft turns the cluster which in turn drives the gear' 5' through' II 'and '8'.

The idler gear '8', changes the direction of rotation of input shaft [1-2-12-11-8-5-6].

SYNCHROMESH GEAR BOX (4 SPEED)

The figure shows four forward and one reverse speed transmission. It contains additional gearing to provide for the fourth speed. All forward gears are synchronized.

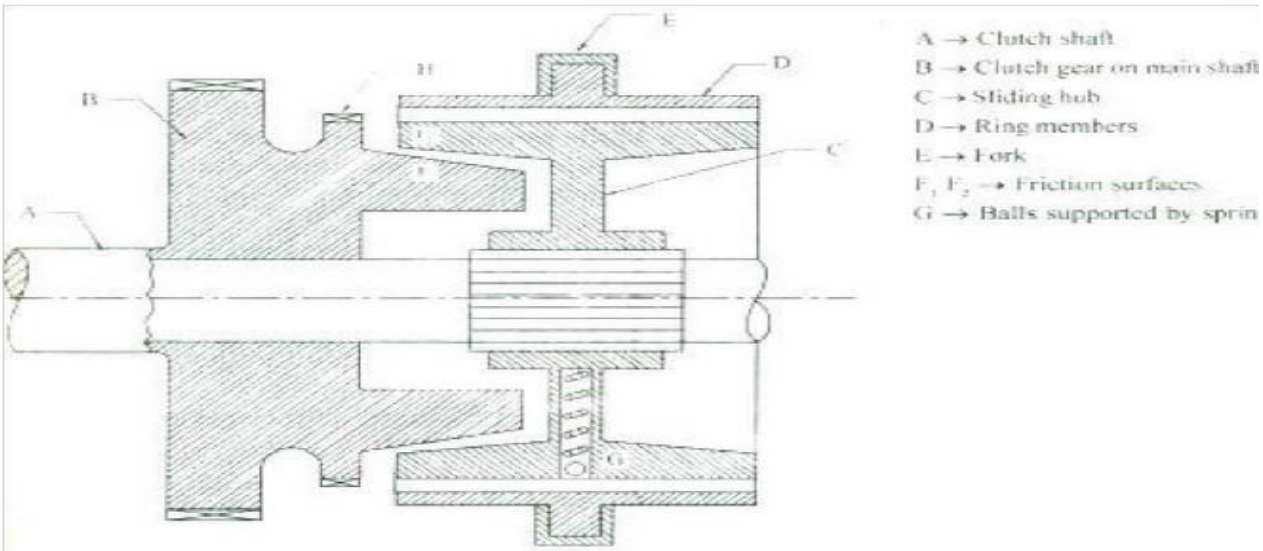


Fig. 5.9 Synchromesh device on higher gear side in a gear box.

Gear teeth are helical cut, with the exception of the reverse sliding gear and rear reverse idler gear. Figure (a) to (e) shows gear drive positions for various speeds.

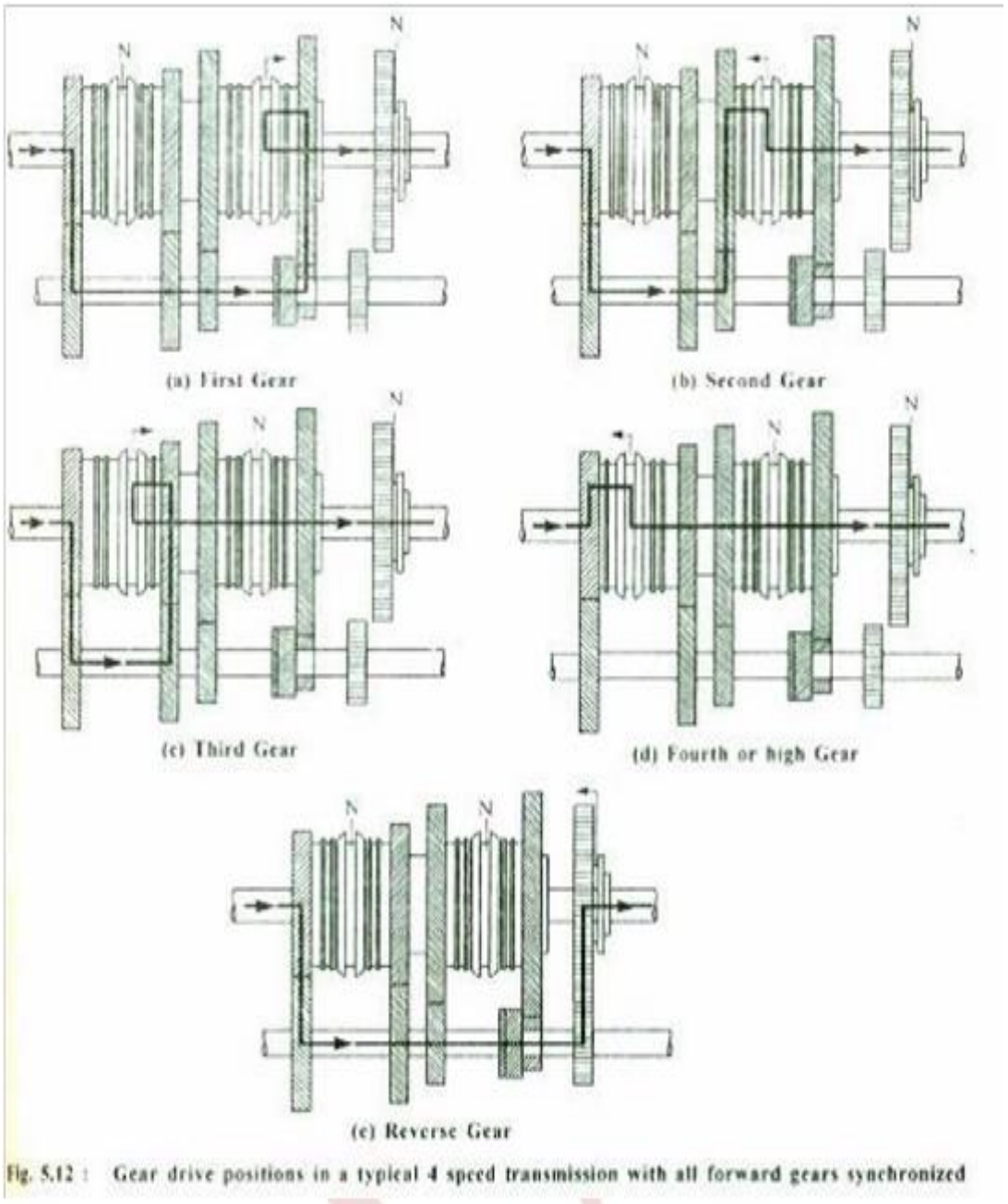
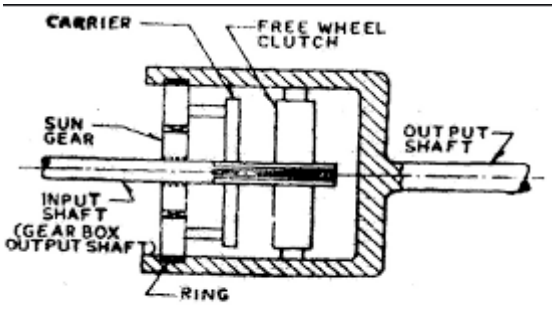


Fig. 5.12 : Gear drive positions in a typical 4 speed transmission with all forward gears synchronized

OVER DRIVE

When the standard transmission has been shifted into high gear, the ratio between the clutch shaft and the transmission main shaft is 1:1. The unit over drive is located on the back of transmission, between the transmission and the propeller shaft, provides a speed ratio over that of direct or high speed ratio. The over drive allows the engine to operate at only about 70% of the propeller shaft speed, when the vehicle is running at higher speeds.

Over drive mechanism is special equipment, causes the main shaft to over drive or turn more rapidly than the clutch shaft. When the over drive is put into operation, it drops (decreases) the engine speed by about 30 percent without changing vehicle speed. Suppose if a vehicle runs 40 kmph. in direct gear with an engine rpm of 2000 rpm, the use of over drive would decrease the engine speed to 1400 rpm without changing the vehicle speed. (It maintains 40 kmph. vehicle speeds). Essentially, the over drive consists of a planetary gear system and a freewheeling mechanism.



cut-away view of the overdrive.

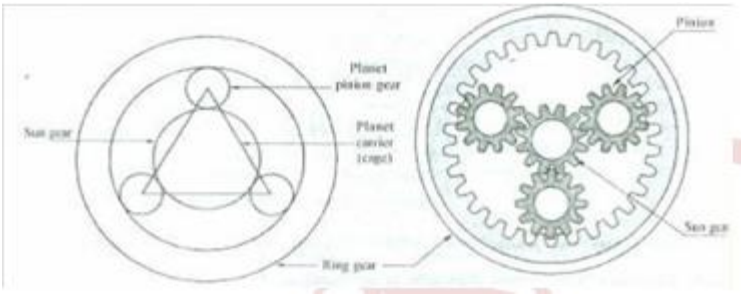
Overdrive

Overdrive is the highest gear in the transmission. Overdrive allows the engine to operate at a lower RPM for a given road speed. This allows the vehicle to achieve better fuel efficiency, and

often quieter operation on the highway. When it is switched on, an automatic transmission can shift into overdrive mode after a certain speed is reached (usually 70+ km/h depending on the load).When

it is off, the automatic transmission shifting is limited to the lower gears. For an automatic transmission, it is almost always best to select overdrive and allow the transmission to control engagement of the overdrive. (It may be necessary to switch it off if the vehicle is being operated in a mountainous area, carrying a heavy load, or when the driver wishes to intentionally keep the engine running at higher RPM for quicker acceleration). With a manual transmission, overdrive should usually be selected when the average speed is above 70 km/h (40-45 mph).

The automatic transmission automatically shifts from OD to direct drive when more load is present. When less load is present, it shifts back to OD. Under certain conditions, for example driving uphill, or towing a trailer, the transmission may "hunt" between OD and the next highest gear, shifting back and forth. In this case, switching it off can help the transmission to "decide". It may also be advantageous to switch it off if engine braking is desired, for example when driving downhill. The vehicle's owner's manual will often contain information and suitable procedures regarding such situations, for each given vehicle.



Simplified view of planetary gear system (b) Planetary gear system

1. **Speed Reduction:** Assume that the sun gear is stationary; turning of ring gear will cause the planet pinion cage to turn slowly, than ring gear.
   This is exactly opposite to previous condition and the system functions as speed reduction mechanism. The driving member (ring gear) drives the driven member (cage) slowly.

2. **Speed Increase:** Hold the ping gear stationary and turn the planet pinion cage to drive sun gear. The sun gear is forced to rotate faster than the 'cage, i.e. driven member (sun gear) turns faster than driving member (planet pinion cage) and the system becomes speed increasing mechanism

3. **Speed Reduction:** If we turn the sun gear to drive planet pinions on their shafts, by keeping ring gear stationary, the pinions walk around the ring gear, as they are in mesh with it. The planet pinion cage is also carried around and hence rotates at lesser speed than the sun gear speed. The sun gear becomes driving member and turns the planet pinion cage (driven member) slowly and a speed reduction is obtained.

4. **Reverse:**Keep the planet pinion cage stationary and turn the ring gear. The planet pinions becomes idlers-and turns the sun gear in the opposite direction to the rotation of ring gear. We get a reverse rotation system and sun gear is turning faster than the ring gear. Ring gear is the driving member and sun gear takes the drive and turns in opposite direction to the ring gear.

5. **Reverse**: Hold the cage stationary and turn the sun gear to drive the ring gear in the reverse direction, but slower than the sun gear.

6. **Direct drive:** The input and output shafts turns at the same speed by locking any two or three members in the planetary gear system. The whole is locked and there is no speed change through the reduction gear system, a direct ratio of 1:1 is obtained. However, if no member is held stationary and no two members are locked together, then the system will not transmit power. The input shaft will turn, without driving out put shaft.

OVER DRIVE OPERATION

In the over drive, the over running clutch is splined to the transmission output shaft in the back of splined pinion carrier. The ring gear is attached to the over drive output shaft and three planet pinions mounted on a cage which is splined to the transmission main shaft. The sun gear may be allowed to turn or may be locked to keep it stationary. The output shaft over drives the transmission main shaft, when the sun gear is locked.

When the transmission main shaft and over drive output shaft are turning at the same speed (or when transmission shaft turning faster than internal gear or over drive alp shaft), the sun gear is free, the over running clutch or free wheel mechanism will drive the internal gear or over drive output shaft. The power directly goes to the clutch cam, which is splined to the transmission main shaft. The clutch cam transmits power through the rollers to the outer race, which is attached to the output shaft. When sun gear is stopped, the planetary action will drive the internal gear faster than cage and clutch hub and the over running clutch will remaindisengaged.

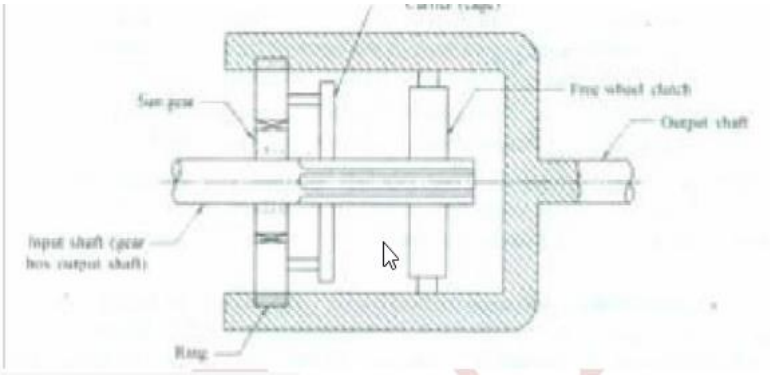


Fig: Overdrive

Fluicoupling (fluidflywheel)

It is a device for transmitting rotation between shafts by means of the acceleration anddecelerationa hydraulic fluid. Structurally, a fluid coupling consists of an impeller on the input or driving shaft and a runner on the output or driven shaft. The two contain the fluid (see illustration).Impeller and runner are bladed rotors, the impeller acting as a pump and the runner reacting as aturbine. Basically, the impeller accelerates the fluid from near its axis, at which the tangentialcomponent of absolute velocity is low, to near its periphery, at which the tangential component ofabsolute velocity is high. This increase in velocity represents an increase in kinetic energy. The fluidmass emerges at high velocity from the impeller, impinges on the runner blades, gives up its energy,and leaves the runner at low velocity.

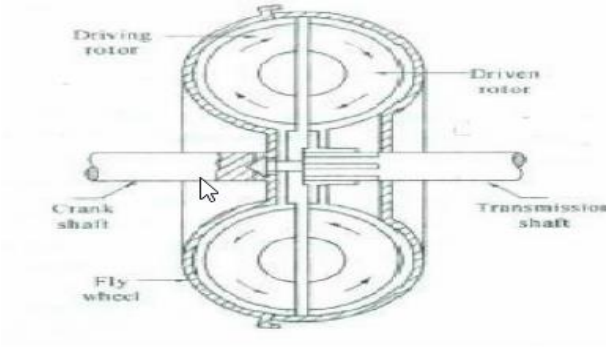


Fig: Fluid flywheel

Construction and working of fluid coupling as follows:

An automotive fluid coupling consists of a split housing which is rotate by the engine crankshaft. Inside the housing is a driven member is called runner and the driven member is connected by a shaft to the gear box. The driving member is mounted on the crankshaft and it is called impeller.

The driving (input) and driven (output) members are very close with their ends facing each other and enclosed in housing, so that they can be turned without touching each other. The liquid or oil is filled in the housing. The fly wheel housing is divided into a number of cells by means of radial vanes. These cells correspond to similar openings in the driven member.

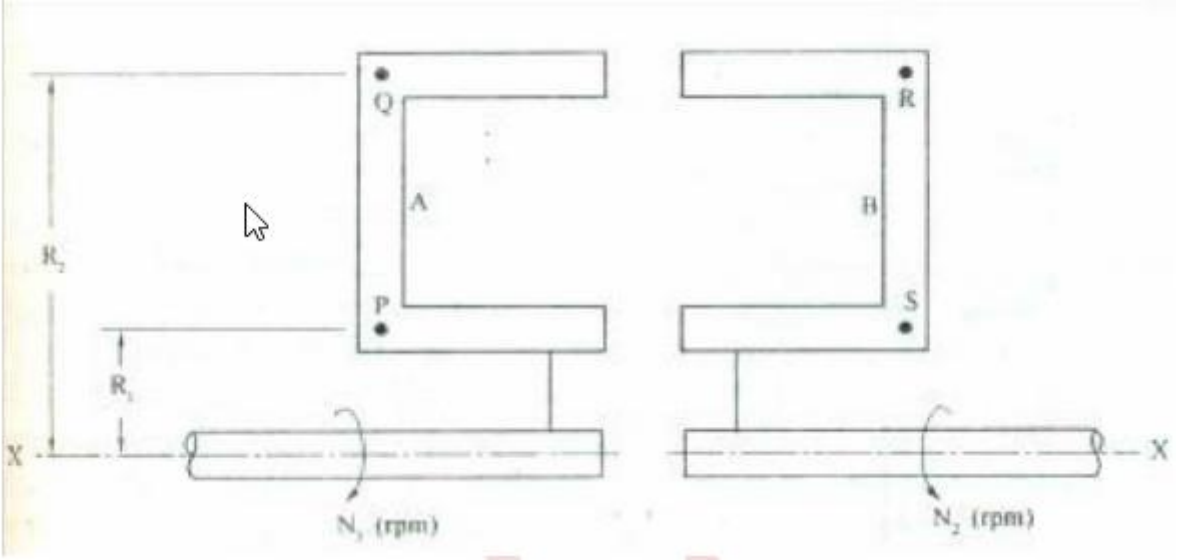


Fig: Principal of fluid flywheel

When the crankshaft turns, the driving member or impeller also rotates. The fluid flows outwards due to the centrifugal force and circulates from the flywheel to the driven member. Now, the fluid tends to rotate the driven member because the fluid is also carried out round by the driving member. The fluid is also carried out round by the driving member. The fluid is also carried out round by the driven member so; the fluid tends to rotate the driven member. Thus the torque is transmitted from the crankshaft to the gear box shaft. The liquid coupling is not suited for use with an ordinary gear box. It is generally used in conjunction with epicyclical gears to provide a semi or fully automatic gearbox.

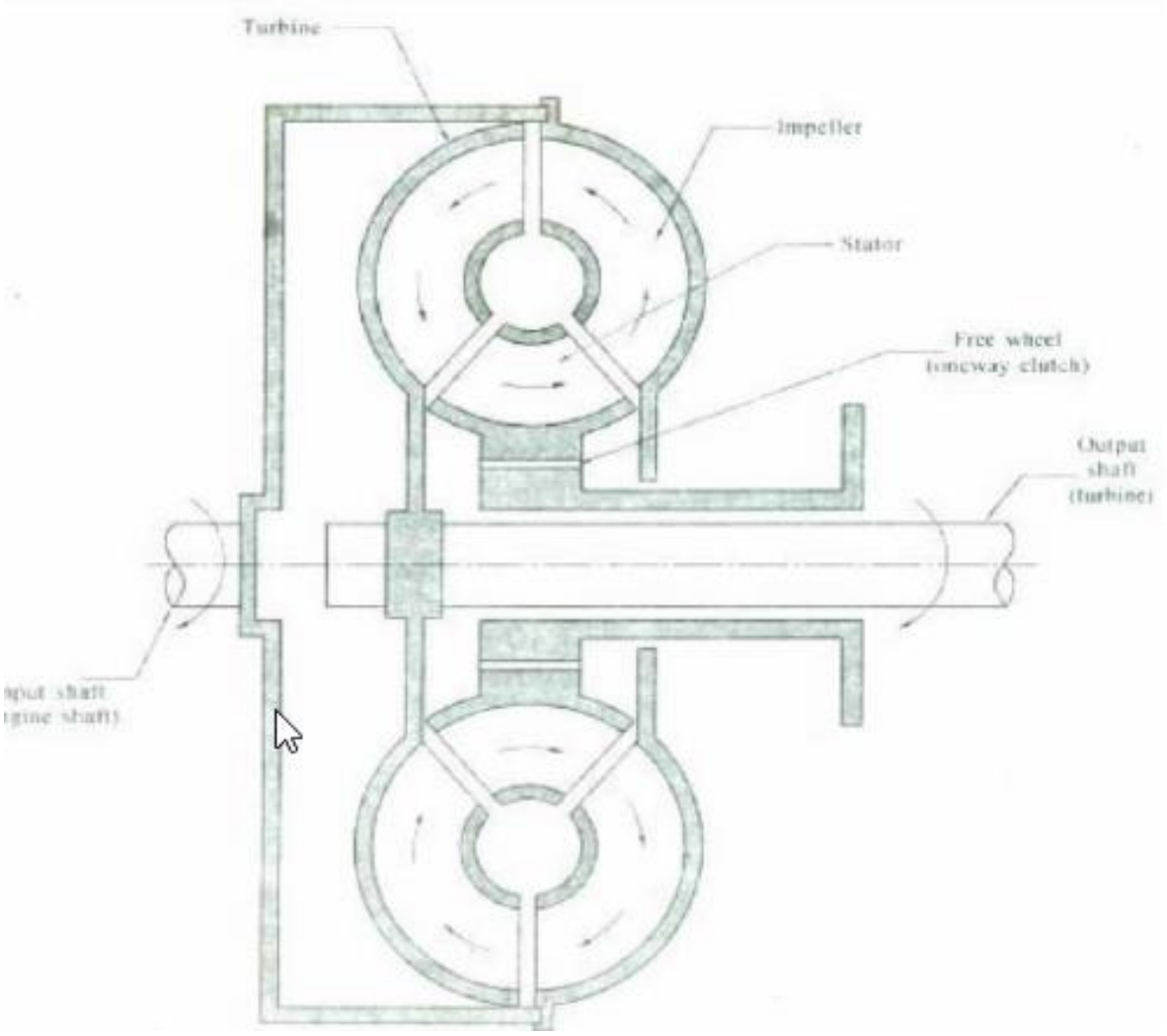
Torque converter

A torque converter is generally a type of fluid coupling (but also being able to multiply torque) that is used to transfer rotating power from a prime mover, such as an internal combustion engine or electric motor, to a rotating driven load. The torque converter normally takes the place of a mechanical clutch in a vehicle with an automatic transmission, allowing the load to be separated

from the power source. It is usually located between the engine's flex plate and thetransmission.

The key characteristic of a torque converter is its ability to multiply torque when there is a substantial difference between input and output rotational speed, thus providing the equivalent of a reduction gear. Some of these devices are also equipped with a temporary locking mechanism which rigidly binds the engine to the transmission when their speeds are nearly equal, to avoid slippage and a resulting loss of efficiency.

Torque converters are sealed units; their innards rarely see the light of day, and when they do, they're still pretty hard to figure out



Imagine you have two fans facing each other. Turn one fan on, and it will blow air over the blades of the second fan, causing it to spin. But if you hold the second fan still, the first fan will keep right on spinning.

That's exactly how a torque converter works. One "fan," called the impeller, is connected to the engine (together with the front cover, it forms the outer shell of the converter). The other fan, the turbine, is connected to the transmission input shaft. Unless the transmission is in neutral or park, any motion of the turbine will move thevehicle.

Instead of using air, the torque converter uses a liquid medium, which cannot be compressed oil, otherwise known as transmission fluid. Automatic transmission cars use a torque converter. This article will discuss why automatic transmission cars need a torque converter and how a torque converter works.

The torque converter in an automatic transmission serves the same purpose as the clutch in a manual transmission.

The engine needs to be connected to the rear wheels so the vehicle will move, and disconnected so the engine can continue to run when the vehicle is stopped. One way to do this is to use a device that physically connects and disconnects the engine and the transmission – a clutch. Another method is to use some type of fluid coupling, such as a torque converter, which is located between the engine and the transmission.

There are three components inside the very strong housing of the torque converter which work together to transmit power to the transmission:

- Pump
- Turbine
- Stator

The **pump** inside a torque converter is a type of centrifugal pump. As it spins, fluid is flung to the outside, much as the spin cycle of a washing machine flings water and clothes to the outside of the wash tub. As fluid is flung to the outside, a vacuum is created that draws more fluid in at the center.

The fluid then enters the blades of the **turbine**, which is connected to the transmission (the spline in the middle is where it connects to the transmission.) The turbine causes the transmission to spin, which basically moves your car. The blades of the turbine are curved so that the fluid, which enters the turbine from the outside, has to change direction before it exits the center of the turbine. It is this directional change that causes the turbine to spin.

As the turbine causes the fluid to change direction, the fluid causes the turbine to spin.

The fluid exits the turbine at the center, moving in a different direction than when it entered. The fluid exits the turbine moving opposite the direction that the pump (and engine) are turning. If the fluid were allowed to hit the pump, it would slow the engine down, wasting power. This is why a torque converter has a stator

The **stator** resides in the very center of the torque converter. Its job is to redirect the fluid returning from the turbine before it hits the pump again. This dramatically increases the efficiency of the torque converter.

Operation

A torque converter has three stages of operation

- **Stall:** The prime mover is applying power to the impeller but the turbine cannot rotate. For example, in an automobile, this stage of operation would occur when the driver has placed the transmission in gear but is preventing the vehicle from moving by continuing to apply the brakes. At stall, the torque converter can produce maximum torque multiplication if sufficient input power is applied (the resulting multiplication is called the *stall ratio*). The stall phase actually lasts for a brief period when the load (e.g., vehicle) initially starts to move, as there will be a very large difference between pump and turbine speed.
- **Acceleration:** The load is accelerating but there still is a relatively large difference between impeller and turbine speed. Under this condition, the converter will produce torque multiplication that is less than what could be achieved under stall conditions. The amount of multiplication will depend upon the actual difference between pump and turbine speed, as well as various other design factors.
- **Coupling:** The turbine has reached approximately 90 percent of the speed of the impeller. Torque multiplication has essentially ceased and the torque converter is behaving in a manner similar to a simple fluid coupling. In modern automotive applications, it is usually at this stage of operation where the lock-up clutch is applied, a procedure that tends to improve fuel efficiency

During the stall and acceleration phases, in which torque multiplication occurs, the stator remains stationary due to the action of its one-way clutch. However, as the torque converter approaches the coupling phase, the energy and volume of the fluid returning from the turbine will gradually decrease, causing pressure on the stator to likewise decrease. Once in the coupling phase, the returning fluid will reverse direction and now rotate in the direction of the impeller and turbine, an effect which will attempt to forward-rotate the stator. At this point, the stator clutch will release and the impeller, turbine and stator will all (more or less) turn as a unit.

Unavoidably, some of the fluid's kinetic energy will be lost due to friction and turbulence, causing the converter to generate waste heat (dissipated in many applications by water cooling). This effect, often referred to as pumping loss, will be most pronounced at or near stall conditions. In modern designs, the blade geometry minimizes oil velocity at low impeller speeds, which allows the turbine to be stalled for long periods with little danger of overheating.

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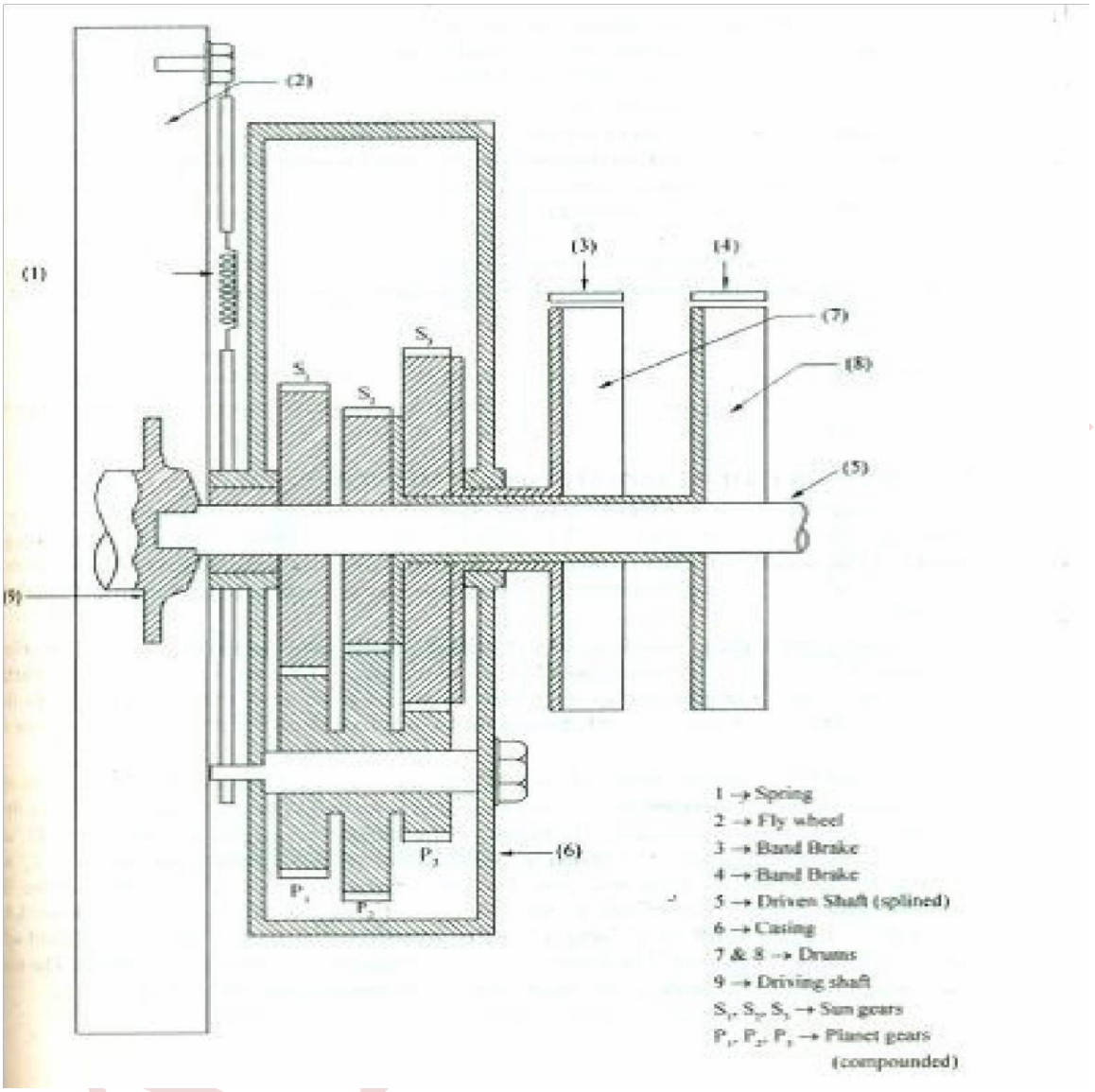
EPICYCLIC GEAR BOX

An Epicyclic gear box consists of two, three or even four epicyclic or planetary gear sets each giving a definite gear ratio, when the brakes are applied, one of the member may become stationary and the train to which that member belongs comes into operation. If that member is released and another one brought to rest by using its brake, another train will be brought in to operation. The top gear or direct gear is obtained by clutching the driving member direct to the driven member by means of an ordinary cone clutch or plate clutch. The direct drive is also obtained by locking two members together. In this case all wheels and arms will revolve as one solid mass and planet gears will be at rest on their pins, but they will be rotating bodily with thearms.

This consists of a casing (6) which forms common arm for all the trains and carries the compound planet gears PI' P2 and P3 on pins as shown. A number of springs (I) are used between casing and fly wheel, to smooth out torque fluctuations of the engine. The planet 'P.' meshes with sun wheel '(S)', which is splined to the driven shaft (5). The planets P2 and P3 are in mesh with sun wheels S2 and S, which are mounted on the sleeves integral with brake drums '8' and '7' respectively. The sun gear S2 will be held stationary by applying brake '4' on brake drum '8' and (S2 - P2 - P, - S) will constitute a train, the fixed sun being smaller than the driven sun. This gives a forward gear and turns the driven shaft' 5' in the same direction as the engine shaft, but at a slower speed.

If brake '3' is applied to the brake drum '7', then sun gear 'S' will become stationary and this constitutes a gear train S3 - P3 - P, - S) and a reverse gear is obtained. '

By locking both brake drums '7' & '8' together, a direct drive is obtained and the whole gear rotates as "Solid".


(1)
(2)
(3)
(4)
(5)
(6)
(7)
(8)
(9)
S_1
S_2
S_3
P_1
P_2
P_3
1 → Spring
2 → Fly wheel
3 → Band Brake
4 → Band Brake
5 → Driven Shaft (splined)
6 → Casing
7 & 8 → Drums
9 → Driving shaft
S_1, S_2, S_3 → Sun gears
P_1, P_2, P_3 → Planet gears (compounded)

PRINCIPLE OF AUTOMATIC TRANSMISSION

The automatic transmission systems are efficient, convenient, easy to operate, but they are relatively expensive to manufacture. The automatic transmission shifts in accordance with engine speed and load conditions. The essential components are converter housing, case oil pan, extension housing. Essentially it is a combination of torque converter and epicyclic gear train and multi plate clutches.

The automatic transmission is broadly classified into (1) Semi-automatic - clutch operation is automatic, gear selection is manual and (2) Fully automatic - clutch operation and, gear selection both are automatic and gear changing is done by pressing the accelerator pedal only. In fully automatic transmission there are only two controls, accelerator and brake. In addition there is a selector lever.

The figure shows layout of Borg Warner automatic transmission. This consists of a single stage (three members) torque converter coupled to an epicyclic gear box which gives three forward and one reverse speed ratio. The turbine of the impeller is integral with the drums 'D)' and' 'D/ of the clutches 'C)' and 'C/. When 'C)' is engaged, the drive goes to the sun gear 'S/ and if brake 'B)' is applied, it gives low gear. The second gear is obtained by applying brake 'B/ instead of 'B)'. The one way clutch 'F' prevents planet carries 'R' from rotating back ward, but allows it to rotate forwards. If 'C)' and 'C/ are engaged simultaneously, the gear is locked solid and a direct drive is obtained. For reverse gear, C2 is engaged and brake B2 is applied. The drive then goes from S) to P, and hence to the annulus A, the planet carrier being fixed.

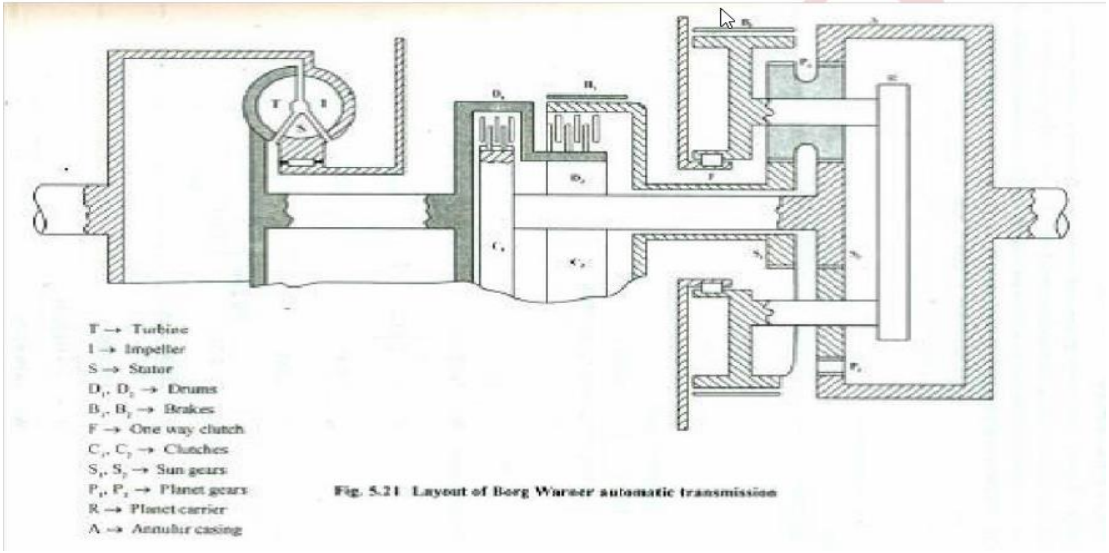


Fig. 5.21 Layout of Borg Warner automatic transmission

BRAKES

Brakes are used as a stopping medium to stop or slow down the vehicle or to prevent the vehicle movement when it is parked (parking brakes). During braking the kinetic energy of the vehicle is dissipated as heat and is the reverse of accelerating a vehicle. When driving a vehicle engine torque produces a tractive effort at the driving wheels, and during braking, the braking torque at the brake drums produces a negative tractive effort or retarding force at the braking wheels. Similar to acceleration, the retarding force and rate of deceleration are also limited by adhesion available between tyre and the ground.

The brakes must be capable of decreasing vehicle speed faster than the engine accelerates it. While moving down a steep gradient, the brakes are used to control the vehicle and brakes remain in action for a longer period. This needs efficient cooling of the braking system.

BRAKING REQUIREMENTS

The function of the brakes is to develop suitable retarding force to stop the vehicle within minimum possible distance and converts kinetic energy of the vehicle in to heat which is being dissipated to atmosphere.

To perform the above function, the brake system has to satisfy the following requirements.

1. Irrespective of vehicle speed, load conditions, type of road, the brakes must produce maximum possible retarding force anddeceleration.
2. Irrespective of road condition and load, the pedal effort required should besame.
3. The response time of the braking system should be minimumpossible.
4. The brakes must have good anti fade characteristics. The brake effectiveness should not decrease due to prolonged application (While descending hills). This needs efficient cooling of the brake system.
5. In an emergency, the brakes must be strong enough to stop the vehicle and in the mean time, driver must have proper control over the vehicle. The vehicle should not skid and should be consistent withsafety.
6. The brake system should not be affected by water, dust, road gritetc.
7. The braking system should be as light as possible, easy to maintain and should give long, economicallife.
8. The braking system should produce less noise andvibrations.
9. The system should facilitate the use of independent secondary brake and parkingbrake.

TYPES OF BRAKES

The automobile brakes are classified by considering several factors.

(i) Primary and SecondaryBrakes

Primary brakes are the service or main brakes which are used to stop the vehicle within a minimum possible distance, when the vehicle is in motion.

Secondary brakes are the parking brakes which are used to hold the vehicle on a slope, when it is stationary.

(ii) Transmission Brakes and Wheel Brakes

The location of brakes may be either at the transmission or at the wheels. In transmission brakes, heat dissipation rate is very poor and it consists of only one brake drum. In this type, the braking torque has to be transmitted through universal joints, propeller shaft, differential and back axle. This needs additional care while designing these components and also sizes have to be increased proportionately. The differential distributes the braking torque equally between two wheels. These brakes are stronger than wheel brakes.

In wheel brakes, each wheel may consist of one brake drum andthis increases the area

available for heat dissipation and thus provides efficient cooling of brake drums. (Also the brake drums are exposed to atmosphere).

The automobiles are usually provided with wheel brakes.

(iii) Drum Brakes and DiscBrakes

Depending on the construction, brakes are classified in to disc and drum brakes and these have been explained in detail at later portions of thischapter.

(iv) Mechanical, Hydraulic, Electric, Vacuum and AirBrakes

Depending on the method of actuating the brake shoe, the brakes are classified into mechanical, Hydraulic, vacuum and air brakes.

BRAKE SHOE ARRANGEMENTS

The drum brakes essentially consist of brake shoes and the arrangement of brake shoes is very important. The relative braking torque acting at the brake shoes for the same force applied by the pedal changes depending on whether expander which forces the brake shoe is fixed to the back plate or kept floating; whether anchor is fixed or floating and whether the brake shoes are leading or trailing.

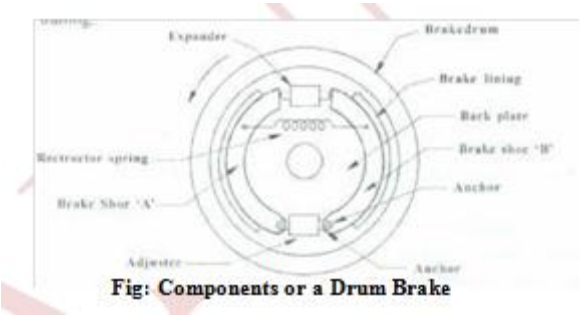


Fig: Components or a Drum Brake

(i) Fixed ExpanderType

The expander unit provides the necessary force required to apply the brakes. If it is fed to the back plate, the brake shoe' A' will become leading shoe and shoe' B' will become trailing shoe. Lending shoe means, even when there is no braking force, the shoe will tend to drag along the brake drum. Trailing shoe means, it will tend to drag opposite to the direction of rotation of brake drum (refer fig.). Thus, when brakes are applied, the net force on the leading shoe becomes more than that of on the trailing shoe. This would result in unequal braking effect at the two shoes. The trailing shoe has better anti fade characteristic than leading shoe. At higher temperature due to increased braking effect, with prolonged application of brake, the friction coefficient decreases in case of leading shoe and it fades quicker.

(ii) Floating ExpanderType

In this type, the expander unit is kept floating and automatically balances the braking effect at the two shoes and thus produces equal braking effect on two shoes. The floating expander also compensates lining wear by moving to one side so that both the shoes receive equal actuating force. However the lining wear on both the shoes is still unequal.

(iii) Floating AnchorType

In this type, the two brake shoes are connected together at the anchor which is kept floating. These two shoes have a common anchor fixed to the back plate. The floating anchor makes both shoes leading.

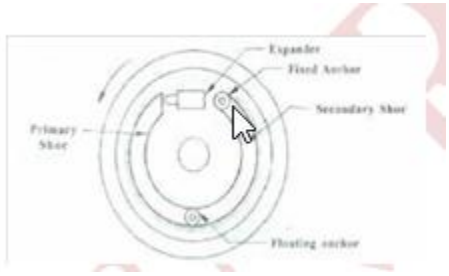


Fig: Brake in which anchor is kept floating

(iv) Two Leading ShoeType

When anchor is kept floating, both the shoes tend to act as leading type. It has a high degree of self energisation and this increases the braking torque. The lining wear is also uniform on both the shoes. These brakes are very sensitive [0 friction changes and thus will not be best suited for brakes meant f r prolonged application. Also both the shoes acts as trailing shoes when the vehicle moves reverse and this reduce the breaking effect. These brakes have better fadingcharacteristics.

(v) Two Trailing ShoeType

When both the shoes are trailing, braking effort at the wheels decreases. For this reason, trailing brakes are generally used with servo brakes or power brakes to reduce driver's fatigue. These brakes have better anti fade properties and thus provides more consistent braking.

DRUM BRAKES

These brakes are most commonly used and brake shoes are actuated by mechanical means am or toggle lever) and makes contact with the inside of the brake drum. The rods and levers decreases the pedal effort required by the driver through mechanical advantage or lever.

This consists of a brake drum which is fixed to the hub of the road wheel and the back plate is mounted on the axle casing. On the front a .le side, the back plate is fixed to the steering knuckle through bolts. The expander, anchor and brake shoes all are supported on the back plate which is made from pressed steel sheet. It protects the drum and shoe assembly from mud and dust. As it absorbs the complete torque reaction of the shoes, it is also called as "torque plate". Two brake shoes

which are semi circular in shape are anchored on the back plate. Friction linings are attached on the

outer periphery of the brake shoes, through which it makes contact with the drum. The brake shoe rubs against wheel rim through friction lining and locks the wheel. One or two retractor springs are used which keeps the brake shoes away from the drum, when brakes are not applied. The brake shoes are anchored at one end and on the other ends force is applied by using some brake actuating mechanism, may be an expander or wheel cylinder. The expander is operated by using a link rod which is connected to the brake pedal. The expander forces the brake shoe to rub against revolving wheel drum from inside, there by applying the brakes. An adjuster serves to adjust the wear of friction lining withuse.

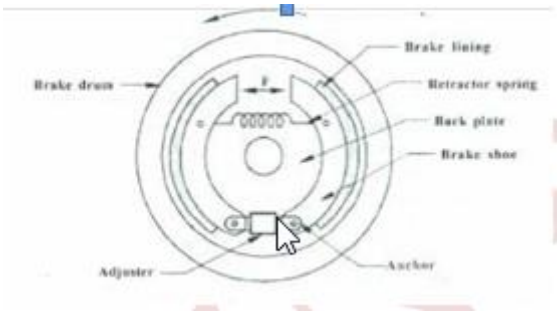


Fig: Drum Brakes

DISC BRAKES

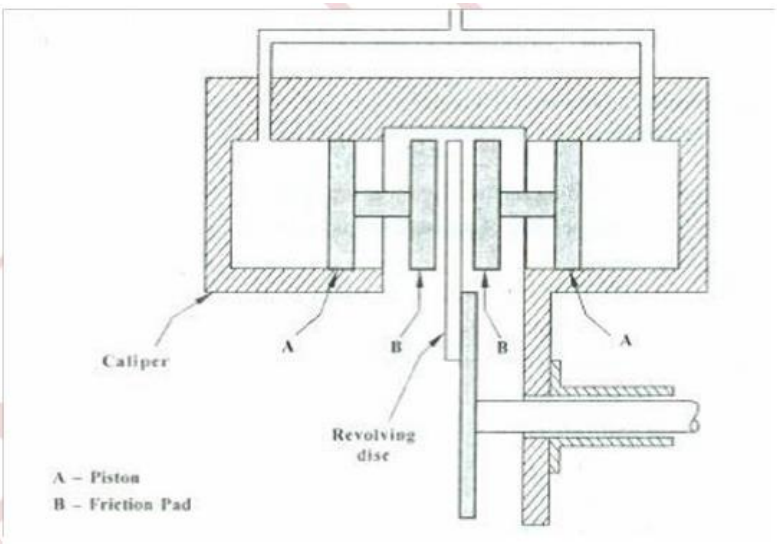


Fig: Disc brake (fixed caliper type)

The disc brake differs from drum brakes in the use of heavy disc or rotor (a circular plate) which replaces the drum. The disc is bolted to the wheel hub and revolves with it. The caliper is a stationary housing connected to axle casing or stub axle and consists of two hydraulic pistons, to the end of which brake friction pad are attached, one on each side of the disc. Passages are drilled in the caliper for the fluid to enter and .leave each housing. Disc brake has excellent cooling characteristics, making it highly resistant to brake “fade". When the brakes are applied, hydraulic pressure is built up behind the pistons and the friction pads are forced inward against the revolving disc, providing braking effort. This force of the friction pad on both side, will retard the disc. On releasing the

brakes,therubbersealingrings(notshowninfigure)actsasreturnspringsandcausesthepistons

and hence friction pads to move away from the disc, there by releasing it.

This requires higher operating force than drum type. More than one caliper may be used, but this reduces the cooling rate.

The torque output of the disc brake is given by T = 11. W. R n,

Where, W - Force applied to each of friction pads.

n - Number of friction pads.

R- Mean radius of friction pad (r1+r2)

This torque output is not affected by the direction of disc rotation.

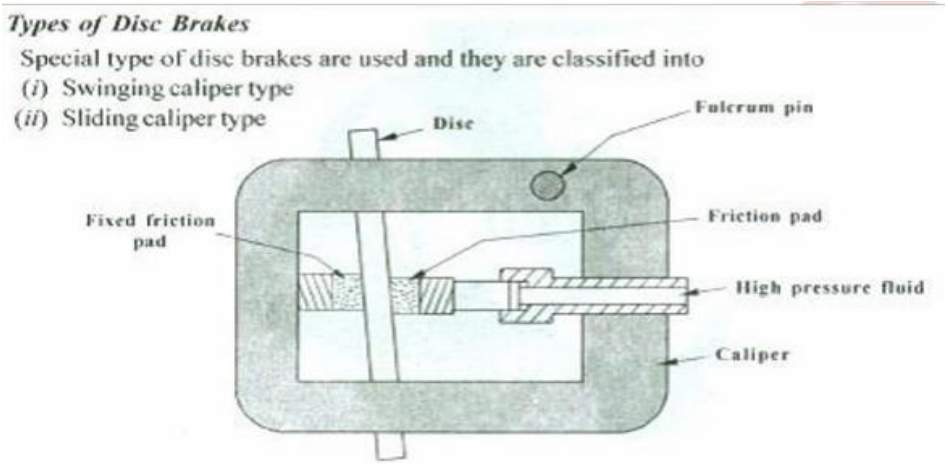


Fig: Disc brake of swinging caliper type

A swinging caliper type disc brake uses a single piston on one side only. One friction pad is fixed to the caliper which is hinged about a fulcrum point as shown in fig. When brakes are applied, the high pressure fluid presses the other friction pad against the revolving disc and caliper exerts reaction from opposite side and causes the fixed friction pad to move slightly inward. The caliper automatically changes its position by swinging about the fulcrum pin and thus exerts pressure- on the other side of the disc, thus provides brakingeffort.

A sliding caliper type as shown in fig, uses two pistons "PI and P/' and the high pressure fluid directly exerts pressure on one friction pad "8" through the piston "P I". The piston P2 causes the caliper to move slightly to right, there by moving the friction pad' A', attached to it. Thus the friction pad' A' exerts pressure on the disc, through the sliding motion of the caliper, and required braking effort can be obtained.

Comparison of Disc and Drum Types of Brakes

Sl.No	*Disc Brakes*	*Drum Brakes*
1	More efficient cooling	Less efficient cooling
2	As flat friction pads are used, wear is more uniform.	Semi-circular friction linings on the brake results in non uniform wear.
3	The weight is less, resulting in lower inertia.	Comparatively, the weight of the drum is more
4	These are more stable.	Comparatively less stable.
5	Maintenance and service of the drum is to be brakes is easy.	For service and other works, the drum should be removed which takes more time.
6	These have better anti-fade characteristics.	The braking effect decreases with prolonged application of brakes.
7	These do not have self-servo action and decreases the braking force required.	The brake shoes experience self-servo action and hence require greater operating force.
8	Total frictional area available is less.	Total frictional area available is more.

MECHANICAL BRAKES

All modern cars have been using hydraulic brakes as service brakes since 1940, but mechanical brakes are still used in parking and emergency brakes. In the mechanical brakes, the pressure from the brake pedal is transmitted to the wheel brakes through rods and shafts or cables andshafts.

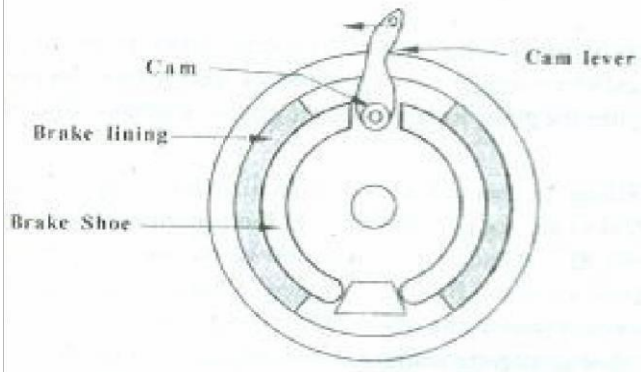


Fig. 8.11 (a) : Mechanical brake (cam operated)

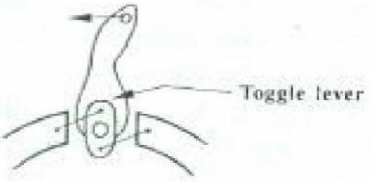


Fig. 8.11 (b) : Toggle lever operated

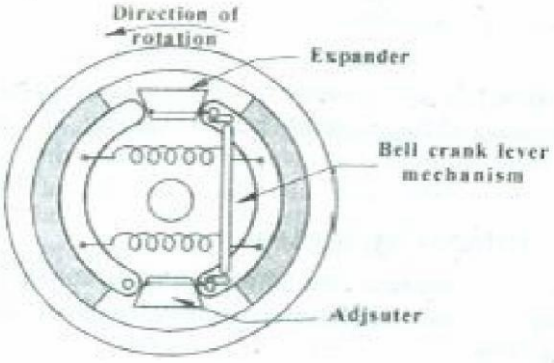


Fig. 8.11 (c) : Two leading shoe brake (mechanical type)

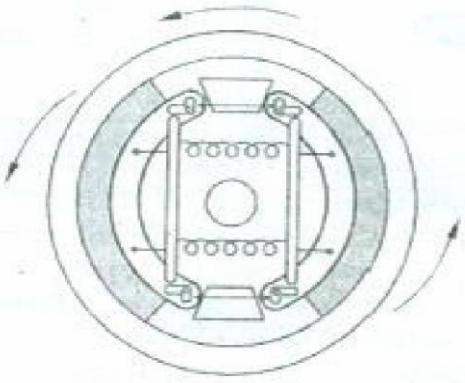


Fig. 8.11 (d) : Two leading shoe brake in both directions

Brake Shoe Operation

The shoes are operated against the revolving drum by cams or toggle lever as shown in fig. (a) and (b). These cams or toggles levers are in turn operated by various mechanical linkages. The mechanical linkage also multiplies the pedal force through leverage to obtain effective braking effort against thedrum.

The fig. (c) Shows the use of Girling mechanism in mechanical brake system which makes both the shoes leading type. When brakes are applied, the force at the expander pushes the arm of upper bell crank lever, this transmits its motion to the lower part of the mechanism and causes lower arm of the bell crank to move towards left. But the presence of adjuster mechanism gives a reaction and makes the whole of the brake shoe at the lower end to move toward right, thus making it to act as leading type. The other shoe is already leading. Hence the Girling mechanism makes both the shoes of leading type. The drawback of the system is, when the automobile is moving reverse, both the shoes will become trailing and the braking effect available at the shoes is considerably reduced. This is not the point to be considered, as on reverse, vehicle moves slowly and braking effort required is also less.

Fig. (d) Shows one method of making both the shoes leading in both the direction of rotation of the drum. When the vehicle is moving in reverse direction, the brake shoes bear against the expanding mechanism and consequently become leading. This overcomes the disadvantage of one - struct arrangement in reverse. Anyhow two leading shoe system are used only on front brakes, where more braking effort is required due to weight transfer.

GIRLING MECHANICAL BRAKE

It mainly consists of expander and adjuster unit as known in fig. (c). the expander provides the actuating force required to operate the brake shoes and the adjuster compensates for wear of friction lining.

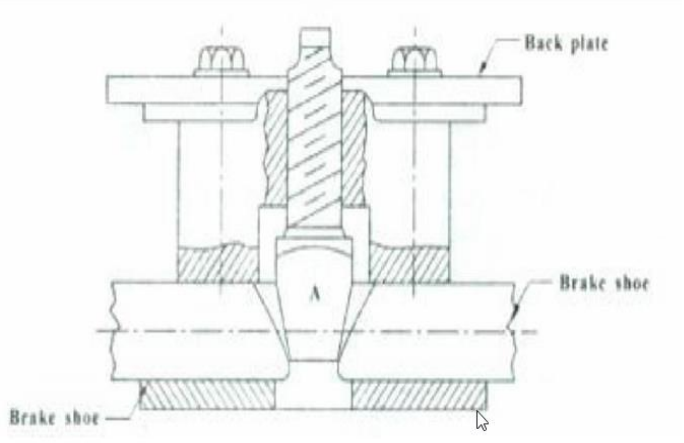


Fig: Expander

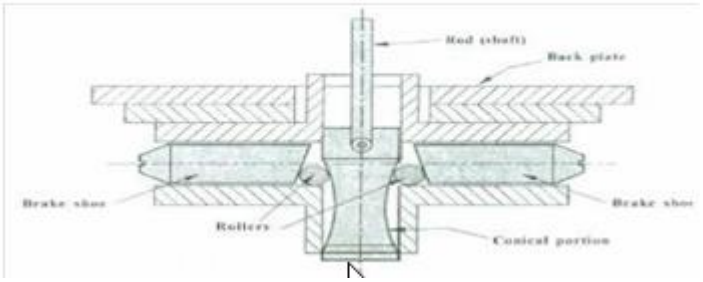


Fig: Adjuster

The expander consists of a shaft, the end portion of which is made conical shape as in fig. (a). The rollers are- used between arc portion of the shaft and brake shoes to reduce the friction. When the shaft is pulled, conical portion moves up, moves the shoes apart through rollers. Thus the brake shoes tend to drag on the inner surface of the brake drum, there by applying thebrakes.

The adjuster is used to compensate the lining wear on the brake shoes. By screwing the conical portion' A', brake shoes moves apart, thus taking the wear of lining.

HYDRAULIC BRAKES

Basically, the car hydraulic braking system consists of a master cylinder, steel tubing to form connecting lines and one or two wheel cylinders for each wheel. In this type, the pedal force is transmitted to the brake shoes through brake fluid. The force applied to the pedal is multiplied and is transmitted to all the brake shoes. The brake fluid is incompressible and it exerts equal pressure in all directions. The brake pedal force is equally applied on all the wheel cylinders and produces equal braking effect on all the wheels. This force transmission is based on pascal's law which states that "when pressure is exerted on a confined liquid, it transmits pressure without loss, equally in all directions".

When the driver operates the brake pedal, it exerts a force on the piston of master cylinder which is being transmitted to each wheel cylinder. The piston in the wheel cylinder transfer this force [increased or decreased, depending on piston area, (mechanical advantage)] to the brake shoes.

The movement of piston in master cylinder causes the pistons in wheel cylinders to move until the brake shoes engage the revolving brake drum. If an attempt is made to depress the master cylinder piston beyond this point will transmit only pressure, but notmotion.

The fig. shows schematically the hydraulic system of a car having drum brakes on all four wheels. On the front wheels disk brakes may be used, instead of drum brakes. In Hindustan Ambassador car, on front wheels, a separate wheel cylinder is used to operate each brake shoe (both shoes leading) and on the rear wheels only one wheel cylinder is used to operate both the shoes (one leading - other trailing). Here all the shoes are of floating anchor type.

A small pressure of about 50 kpa is maintained in the steel piping to keep the wheel cylinder pistons in the expanded position, when brakes are not applied. This avoids entry of air in to wheel cylinders when the brakes arereleased.

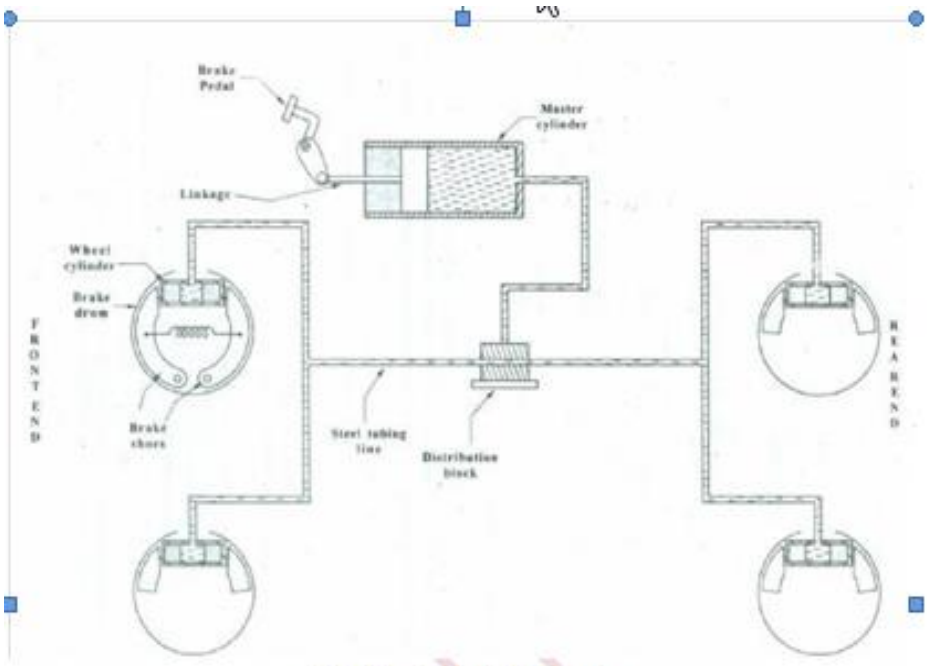


Fig: Hydraulic Brake system

Master Cylinder

Master cylinder is the heart of the hydraulic braking system in which hydraulic pressure is developed. Its working is similar to a pump and converts the mechanical force on the brake pedal in to hydraulic pressure. It is rigidly fastened to the car frame and linked by means of a pedal rod to the service brake foot pedal. Pressure of the driver's foot on the brake pedal is transmitted through various linkage arrangements, to a piston in the master cylinder. The forward motion of the piston in the cylinder pushes the brake fluid. Since the brake lines and wheel cylinders are filled with brake fluid, the piston acts on a solid column of fluid, thus forcing the wheel cylinder pistons. When the wheel cylinder pistons have pressed the brake shoes against the drums, fluid movement ceases and pressure increases depending on force on the piston of master cylinder.

Construction

The fig. illustrates the construction of master cylinder. Essentially it consists of a supply tank or a reservoir and compression chamber in which the piston operates. The reservoir will supply additional fluid, when needed, to compensate for loss of fluid in the pipe lines due to temperature variations and due to minute leakage. The air vent provided in the cap will keep the brake fluid always at atmospheric pressure and allows expansion and contraction of the fluid without forming pressure or vacuum.

The compression chamber consists of an aluminums piston which is covered with rubber seals on both the ends to prevent leakage of brake fluid. The inner face of the piston presses against a rubberprimarysealandthispreventsleakagepastthepiston.Theouterpistonendhasarubber

secondary seal to prevent fluid from leaving the master cylinder. The inner piston head has several small bleeder ports (piston holes) that pass through head to the base of the rubber primary seal. The piston is prevented from coming out by using stop washer and circlip as shown in figure. A push rod is used to apply the pressure and it connects the piston to the brake pedal linkage. A fluid check valve with a rubber cup inside is held against a rubber seat by a coil spring. The spring presses against the check valve, while the other end is against the piston primary seal. This serves to retain the residual pressure in the brake lines, even when the brakes arereleased.

On the primary seal side, a number of holes are located in the piston head. The bypass port (compensation or relief port) and intake (recuperation or filler port) port are used to connect the fluid reservoir to the compression chamber.

Working

When the brake pedal is pressed, push rod moves the piston inward (left) against the spring force, till it covers the bypass port. With bypass port closed, the further movement of the piston builds up the pressure in the compression chamber. This pressure forces the check valve inner rubber cup to open and pass fluid in to the lines. This fluid enters the wheel cylinder and causes the pistons in it to move out ward and force the shoes tightly against the rotating drum, thereby applying the brakes.

When the brake pedal is released, pressure from the brake shoe return springs forces fluid back against the check valve and the master cylinder piston moves outward (right) due to spring action in the master cylinder. The fluid under pressure will lift the check valve off its seat, allowing fluid to return to the cylinder.

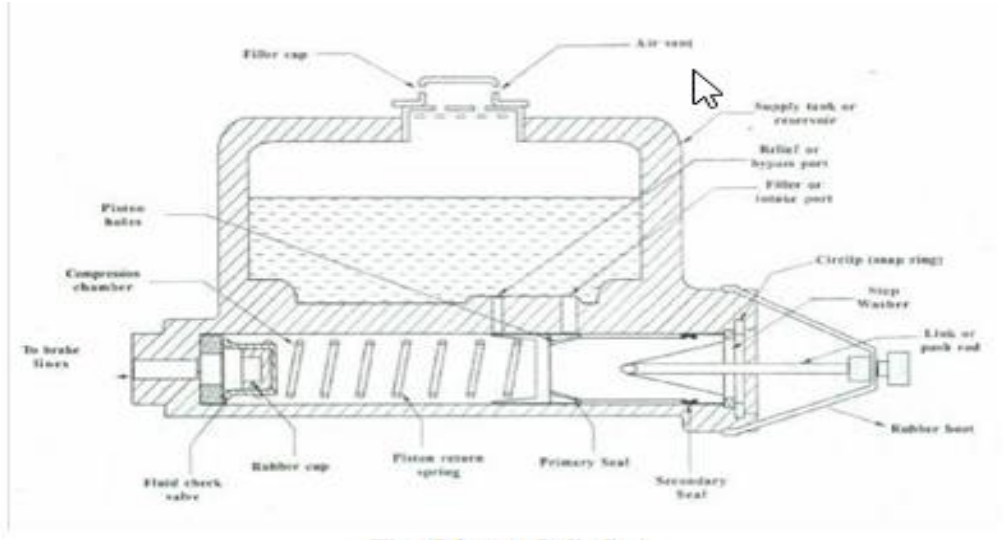


Fig: Master Cylinder

The spring force in the master cylinder keeps the fluid check valve pressed on its seat for some time and hence delays the return of fluid from lines to the compression chamber. Some delay is also caused by fluid inertia in the lines. This creates a vacuum in the compression chamber and

would result in air leakage in to the system and makes the brake useless. This problem is avoided by having an intake port as shown. As vacuum is created, the fluid reservoir in which the fluid is at atmospheric pressure, forces the fluid through intake port and holes in the piston which deflects the rubber cup and enters the compression chamber, thereby destroying the vacuum. In this way a complete column of liquid is always maintained between master cylinder piston and wheel cylinder pistons, ready for the next brakeapplication.

But, by the time fluid from reservoir fills the vacuum; the fluid from the lines comes back and lifts the check valve of its seat. But compression chamber is already full and this extra fluid has to be accommodated somehow. Otherwise, this would cause the brakes to jam, as pressure in the lines has not been relieved fully. This problem is solved by means of a bypass port. The extra fluid from the lines passes through the bypass port to the reservoir, where atmospheric pressure is maintained.

Wheel cylinder

In the brake system, wheel cylinder is used to transmit the pressure of the fluid in master cylinder to the brake shoes and force them against the revolving drum. One wheel cylinder (in some system, two) is used to each wheel to operate the brake shoes.

The figure shows the construction of wheel cylinder and the figure shows the simplified view of the wheel cylinder which is forcing the brake shoes outward against the drum. It consists of cast iron housing, two aluminum pistons (in some cases sintered iron pistons are used), rubber seals (cups), cup spreaders, coil spring and rubber boot (dust cover). The brake line from the master cylinder is connected to the inlet port. The cylinder is drilled to provide a bleeder screw, to bleed the air from the system, whenever required. The wheel cylinder is usually bolted to the brake backing plate.

When brakes are applied, master cylinder forces fluid in to wheel cylinder through inlet port and forces the pistons to move apart. This outward movement of the pistons pushes the brake shoes against the drum.

When the brakes are released, the piston move inward due to spring force and forces the brake fluid out of wheel cylinder.

ADVANTAGES AND DISADVANTAGES OF HYDRAULIC BRAKING SYSTEM

Advantages

1. The fluid pressure is same everywhere in its circuit and thus equal braking effort is obtained at all the fourwheels.
2. Comparatively, rate of wear is less due to absence of joints.
3. The system is selflubricating.
4. Due to absence of joints, brake linkages, it is simple inconstruction.

Disadvantages

1. It is suitable for intermittent brake applications. Mechanical linkage has to be provided for parkingpurposes.
2. Even a small leakage of air in to the system makes the brakeuseless.

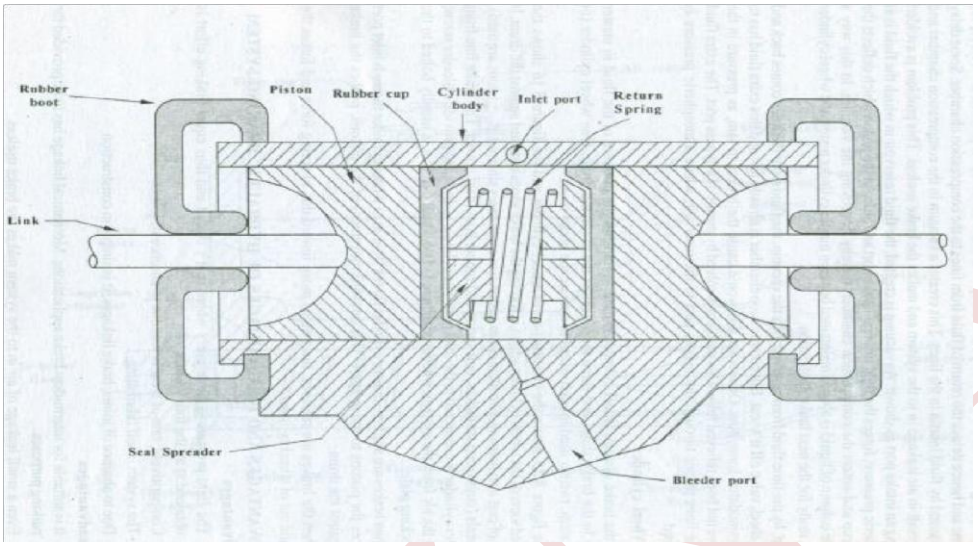


Fig: Wheel Cylinder

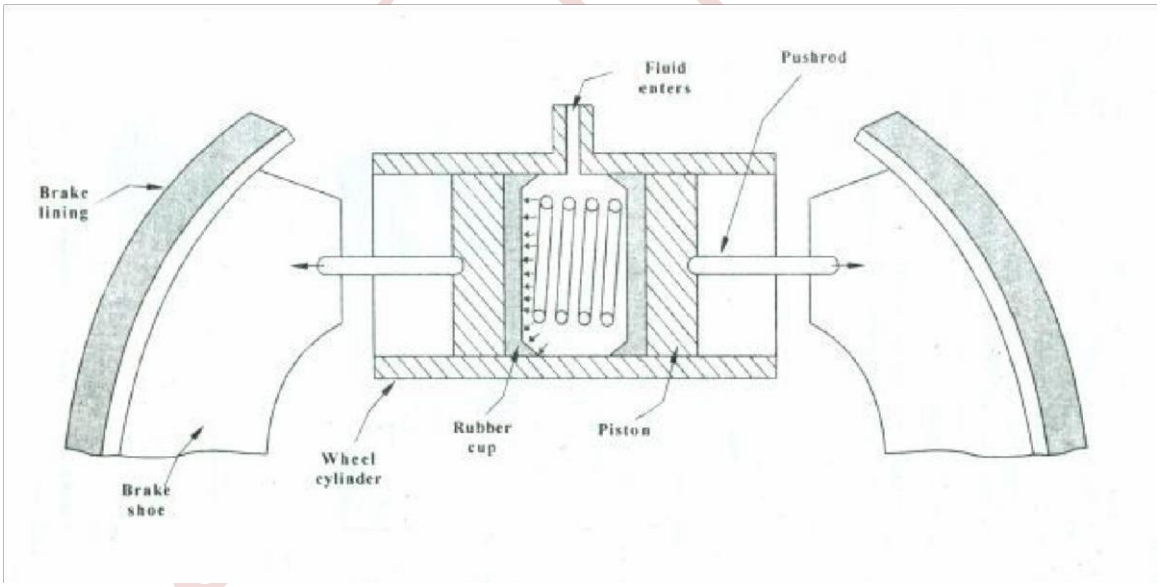


Fig: Simplified wheel cylinder action, arrow marks shows fluid pressing on rubber cup

POWER BRAKES

When the vehicle weight is more, driver cannot apply the brakes comfortably without fatigue, some external source of energy is used-to supplement his effort which makes the brake application easier. For this reason, many of the vehicles are equipped with power brakes. The power brakes are used to reduce the amount of pedal pressure necessary to stop the vehicle. If energy for these brakes are taken from the transmission of the vehicle itself, which partly helps the driver i.e., driver still has

to put some effort while applying the brakes, then such brakes are 'called "Servo brakes or Power assisted brakes". Practically when none of the braking effort is applied by the driver, then the brakes 'are termed as "Power brakes or Power operated brakes".

The mechanism which supplements the driver's effort in applying the brakes is called a "servo mechanism". This servo action or self energization of brakes helps the driver to apply the brakes withoutfatigue.

Mechanical servos were used initially, but these have become obsolete after the introduction of vacuum operated servos. In vacuum servo brakes, the brakes are applied by utilizing engine suction from inlet manifold, A small vacuum reservoir may be provided to have enough vacuum for several brake applications even after engine has stopped. Vacuum servo brakes are of two types, both types consists of a piston or a diaphragm operating in a cylinder and are incorporated with suitable linkage for brake application. In the first type, on both the sides, piston is exposed to atmosphere, when the brakes are not applied. When the brakes are applied, engine vacuum will act on one side of piston and the differential pressure on both sides of the piston causes the linkage to operate the brakes. In the second type, both sides of the piston are subjected to vacuum when the brakes are in the released position. When brakes are applied, one side of piston is exposed to atmospheric pressure and the differential pressure on both sides of the piston, causes the linkage to operate. This system is more rapid in operation and hence preferred over the first type. The second type is called "Suspended Vacuum"system.

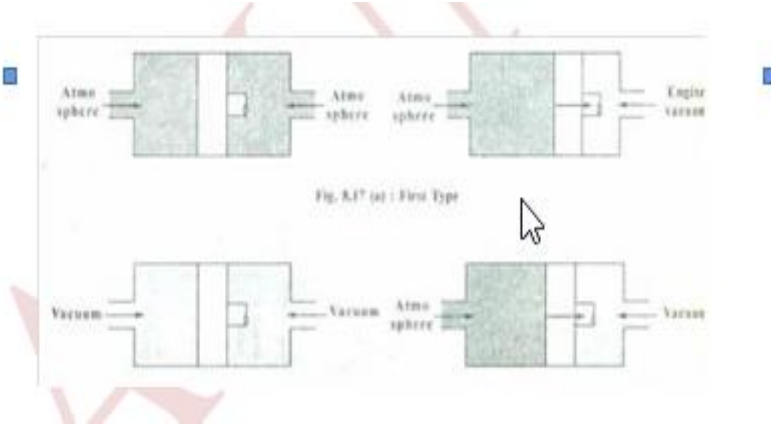


Fig: Second type; suspended vacuum type Brakes in released position & when brakes are applied.

The figure shows one type of servo vacuum or power brake. It consists of a piston and cylinder arrangement as in figure. Master cylinder piston is connected to the one side of the piston and the other side of it is connected to the brake pedal. A vacuum control valve is placed between the brake and the piston. This valve admits vacuum to one side of the piston, while the other side is kept at atmospheric pressure. This valve can also allow atmospheric pressure to reach both sides of the piston.

When brakes are applied, the control valve closes off the atmospheric pressure to the master cylinder side of the piston (i.e. on the right side of the piston). Further movement of the brake pedal opens a vacuum inlet passage to this same side, and thus vacuum acts on this side of the piston. So, ontheleftsideatmosphericpressureisactingandapartialvacuumisactingontherightsideofthe

piston. This differential pressure forces the piston to move to the vacuum side. 'As the master cylinder piston is connected to this piston (say P), it moves toward right and thus apply pressure to the brakesystem.

The power brakes have three stages of operation.

1. Brakesreleased
2. Applyingbrakes
3. Holding constant applypressure.

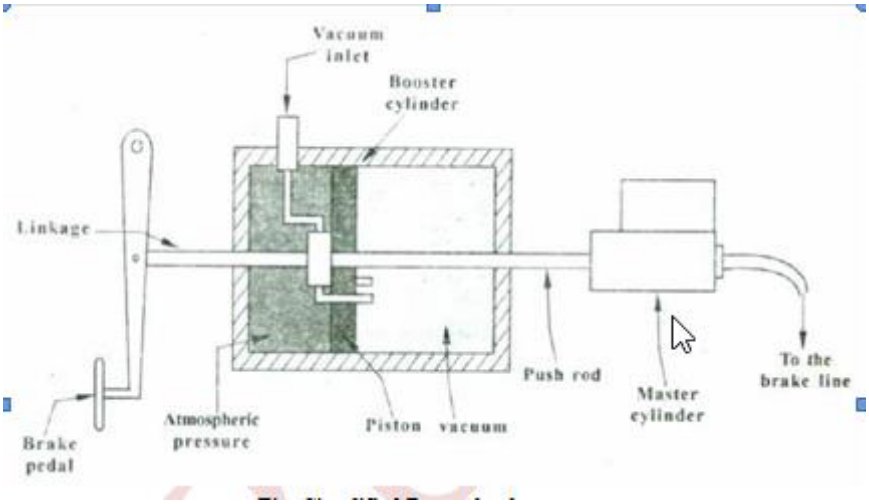


Fig: Simplified Power brake system

Another type of vacuum servo brake is as shown in figure .It consists of a vacuum reservoir which is connected to the inlet manifold between carburetor and engine. It also consists of a servo cylinder, one side of which is connected to vacuum reservoir through control unit, while the other side, it is direct connection. The control unit is provided with a piston and two valves 'A' and '8'. Through upper valve (A) atmospheric pressure acts on the left side of the piston in servo cylinder, when valve' A' is open. When lower valve (8) opens and' A' closes, vacuum acts on the left side of the piston in the servo cylinder. On the right side of the piston in the servo cylinder, always vacuum will be acting. Through master cylinder, the brake pedal operates the piston in the controlunit.

When the brake is in released position, valve' A' is closed and valve' 8' is open. Thus engine vacuum is acting on both sides of the piston in servo cylinder.

When brake is applied, the pressure of the brake fluid pushes the control unit piston up and hence closes valve '8' and opens valve 'A'. This opens left side of the piston in servo cylinder to atmospheric pressure, while on the right side vacuum is already acting. The differential pressure causes "the piston to move towards right and is used to apply the brakes through suitable linkages, which may be mechanical or hydraulic. This system reduces the driver's fatigue considerably and practically engine vacuum supplies whole of the braking effort.

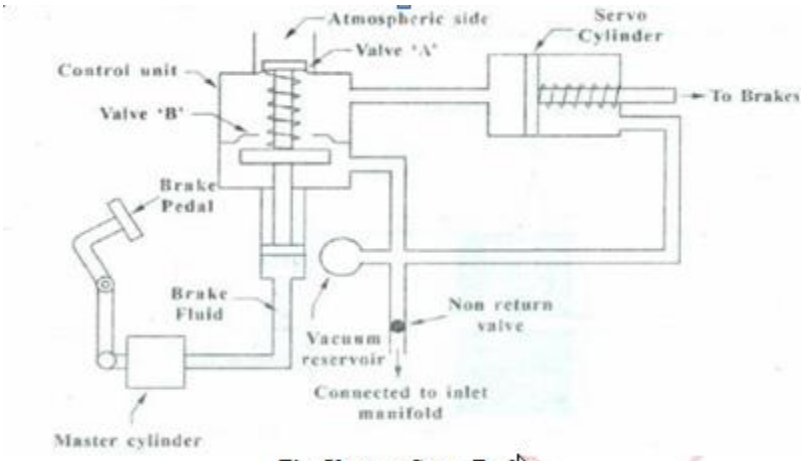


Fig: Vacuum Servo Brak

AIR BRAKES

As vehicle weight increases (like heavy buses and trucks), heavier braking effort is required to stop the vehicle. Compressed air powered brakes are suitable for these heavy vehicles. These brakes consist of flexible diaphragms in brake chambers and are connected to the brake rods and controlled by hand or foot operated valve. The compressed air pressure acts on flexible diaphragm. The brake rods connect to brake operating cams on the wheel brakes. The braking operation is controlled by a brake valve which directs the air flow from reservoir against the diaphragms in the brake chambers during brake application and from brake chambers to the atmosphere, when brake is released. When the pressure in the reservoir falls below certain value, air compressor which is driven by engine, supplies the compressedair.

The layout of an air brake system is as shown in figure. The filtered air from the compressor passes to the reservoir through the unloaded valve which sends the air at a predetermined reservoir pressure (about 900 kpa). The reservoir supplies air to various accessories and diaphragm units (brake chambers) at each wheel through the brake valve.

In the air brake system, dust and other matter present in air is removed by passing it through an air filter. An air compressor driven by the engine, raise the pressure of air to the required level and supplies high pressure air to brake chambers at wheels through un loader valve. This valve mainly consists of a governor valve, plunger and non-return valve and regulates the brake line pressure in the system. A reservoir or air tank made from steel sheet stores the compressed air at the specified pressure and is used for brake application. The reservoir is also provided with a safety valve to control the air pressure in it. The brake valve (application valve) is used to regulate the braking intensity in an air pressure system. Tile brake valve supplies air to the various brake chambers at the required pressure. One brake chamber is installed on each wheel. In the brake chambers the pressure energy of compressed air is converted in to useful mechanical work (piston movements) and is used for brakeapplication.

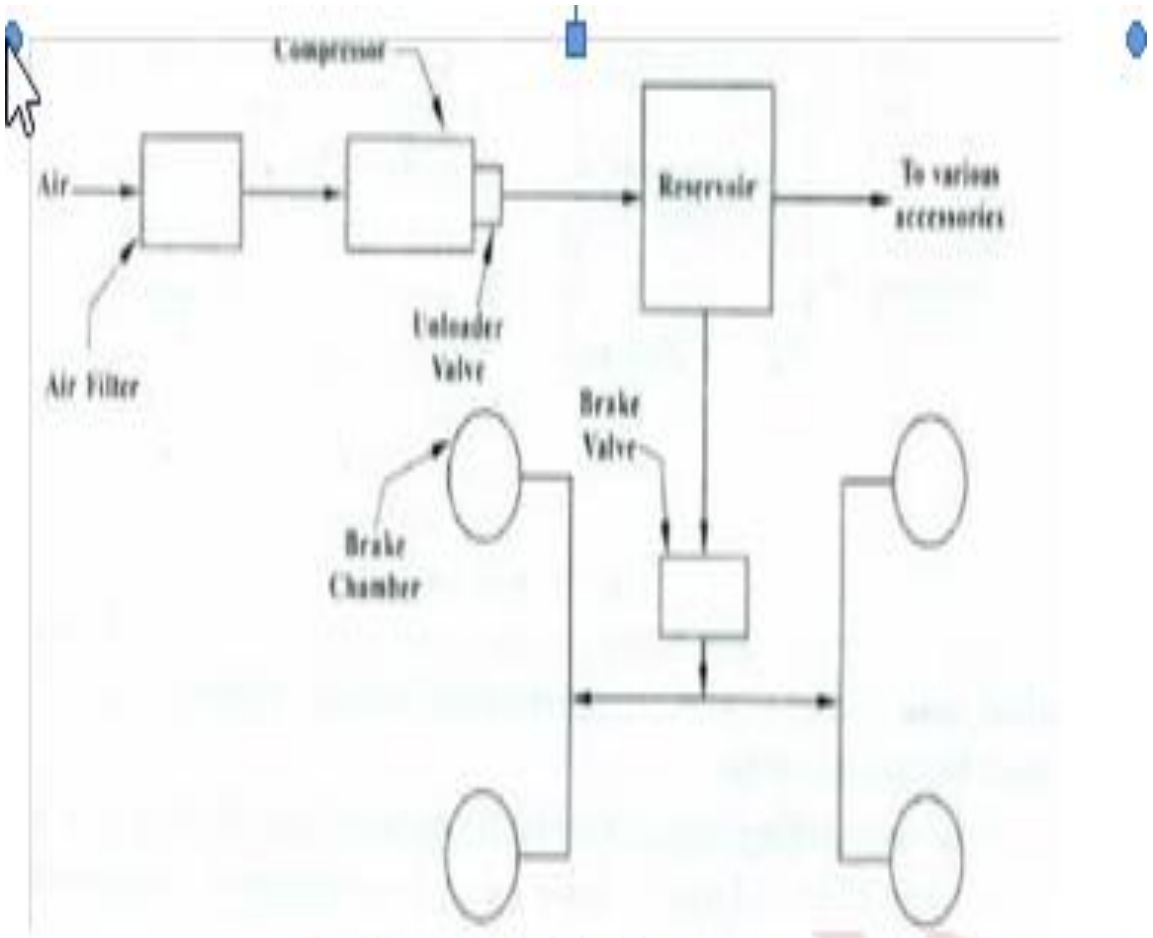


Fig: Layout of air brake system

Important questions

1. What are the requirements of good clutch
2. Explain why a clutch and a gearbox are necessary in an automobile.
3. With a neat sketch, explain the construction and working o single plate clutch.
4. With a neat sketch, explain the construction and working multi plate clutch.
5. With a neat sketch, explain the construction and working centrifugal plate clutch.
6. Why are changes of gears necessary in a motor vehicle? Describe constant mesh gear box giving necessary function and working of gear box.
7. With a neat sketch, explain the construction and working of sliding mesh gear box.
8. Explain working of a constant mesh gear box with sketch.
9. What is a synchromesh device? Explain working of a synchromesh gear box with sketch.
10. What is the function of universal joint and propeller shaft?
11. How different speeds are obtained by using planetary gear system.
12. Sketch and explain the two essential devices o an overdrive unit. Also explain the exact location, and function of an overdrive unit.
13. Briefly describe the construction and working of fluid coupling.
14. With the help of a neat sketch describe the Hotchkiss drive.
15. With the help of a neat sketch explain the Torque tube drive.
16. Write a short note on , i)differential ii) universal joint iii)torque converter
17. What is the principle of automatic transmission?

MODULE 3

Steering And Suspension Systems: Steering geometry and types of steering gear box-Power Steering, Types of Front Axle, Suspension, Torsion bar suspension systems, leaf spring, coil spring, independent suspension for front wheel and rear wheel, Air suspension system.

Ignition System: Battery Ignition system, Magneto Ignition system, electronic Ignition system.

STEERING

It is necessary to run the automobile in a desired direction; this can be accomplished by providing steering system. Besides brakes and accelerator, steering is very much essential to control the vehicle, without which an automobile will never exist.

The main purpose of a steering system is to provide angular motion to the front wheels, when the vehicle is taking a turn. Different steering gears and linkages are used to steer the front wheels.

The purpose of a steering system is to convert rotary motion of the steering wheel in the driver's hands into angular motion of the front road wheels, and to multiply the driver's effort by leverage or mechanical advantage so as to make it fairly easy to turn the wheels. The steering system also absorbs large part of the road shocks, thus preventing them being transmitted to the driver.

Apart from the above object, the steering system also serves other purposes like,

1. It gives perfect steering condition. It means perfect rolling motion of road wheels under all conditions.
2. When the car is moving in a straight line, it gives directional stability.
3. To reduce tyre wear.
4. To facilitate straight ahead recovery after completing the turn.

The steering system has to fulfill the following requirements.

1. The system used should be very accurate and should be easy to handle.
2. The steering effort (for driver) should be minimum.
3. It must give directional stability.

Till recently front wheel steered vehicles were designed. In these vehicles front wheels were steered with rear wheels followed them. However, lately all-wheel steering or four- wheel steering has been designed and used in some selected vehicles.

GENERAL ARRANGEMENT OF STEERING LINKAGES

Based on vehicle type i.e., a 'vehicle which has independent front suspension or a vehicle which has a rigid axle type front suspension (commercial car), different steering linkages are used.

Steering Linkage used in the Vehicle with rigid axle front suspension

It consists of a drop arm or pitman arm connected between steering gear and link rod. The link rod in turn connects steering arm through 1 a ball joint and the stub axle mounted with road wheel is rigidly attached to the steering arm as shown in figure O. Each stub axle has a forged track rod arm rigidly fixed to the wheel axis. To the ends of track rod arms, a track rod is attached by using '0' ball joints as in figure. An adjuster is also used in the track rod and it changes length of the track rod for adjusting wheel alignment.

The steering gear provides the required leverage (mechanical advantage), so that driver's effort required is less at the steering wheel to apply much larger force to the steering linkage. It also

gives the desired velocity ratio so that larger angular movement of the steering wheel gives much smaller movement of the stub axle.

By turning the steering wheel, drop arm swings and imparts a linear movement to the link rod. The steering arm transmits this movement to the stub axle, and turns it about pivot (may be a king pin or ball joints). The other wheel is steered through the track rod; hence only one wheel is positively steered.

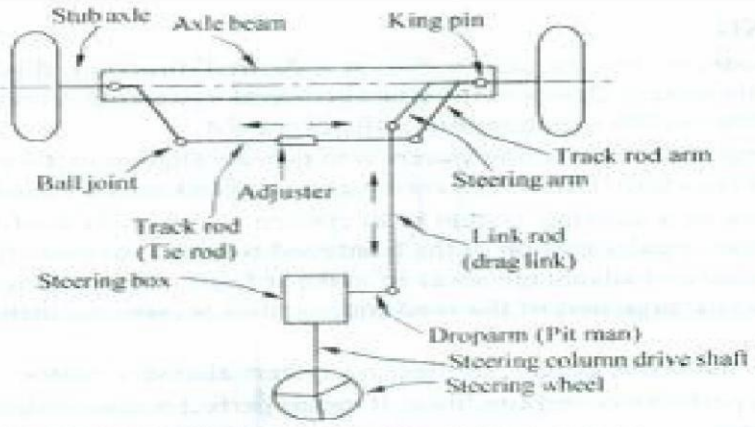


Fig. 6.10 Steering linkage for rigid axle suspension.

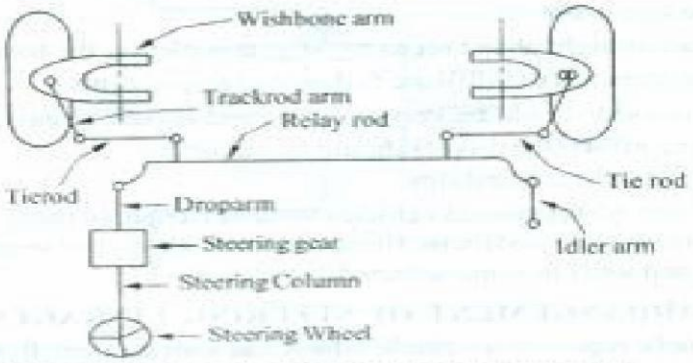


Fig. 6.11(a) Steering linkage for independent suspension.

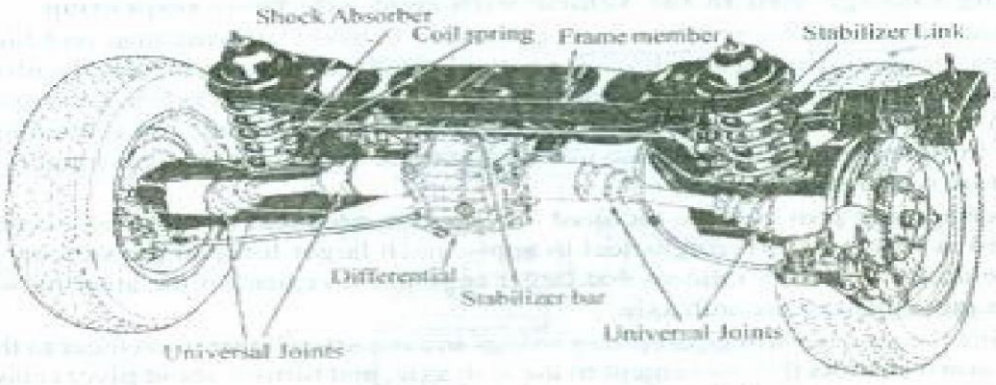


Fig. 6.11(b) Independent rear suspension.

Steering Linkage used for Independent front suspension

In the previous type, the main axle beam allows the stub axle to move in the horizontal plane only. The effective track rod length does not change as there is no vertical deflection of the

suspension.

In the independent suspension, the two stub axles can move up and down independent of each other and causes the length of the track rod to change. For this reason, a single track rod is not suitable.

The arrangement consists of a three piece track rod, the centre being called relay rod, one end of which is connected to idler arm supported on body structure. The other end of the relay rod is connected to the drop arm of the steering gear through ball joints. The relay rod is confined to move in horizontal plane only. Movement in vertical plane is provided by the tie rods about the end ball joints.

STUB AXLE

Stub axle is one on which the front road wheels are mounted. The king pin connects main axle beam to the stub axle. Stub axles are made up of Nickel steels and alloy steels containing chromium and molybdenum. Usually front axle is a dead axle and is manufactured by drop forging of steel. As it has to withstand bending loads due to vehicle weight and torque loads due to braking of wheels the central portions is made 'I' section and the ends of the beam are made either circular or elliptical. This dead front axle is used in heavier vehicles.

The figure shows the arrangement of the stub axle in which king pin has been replaced by ball joints.

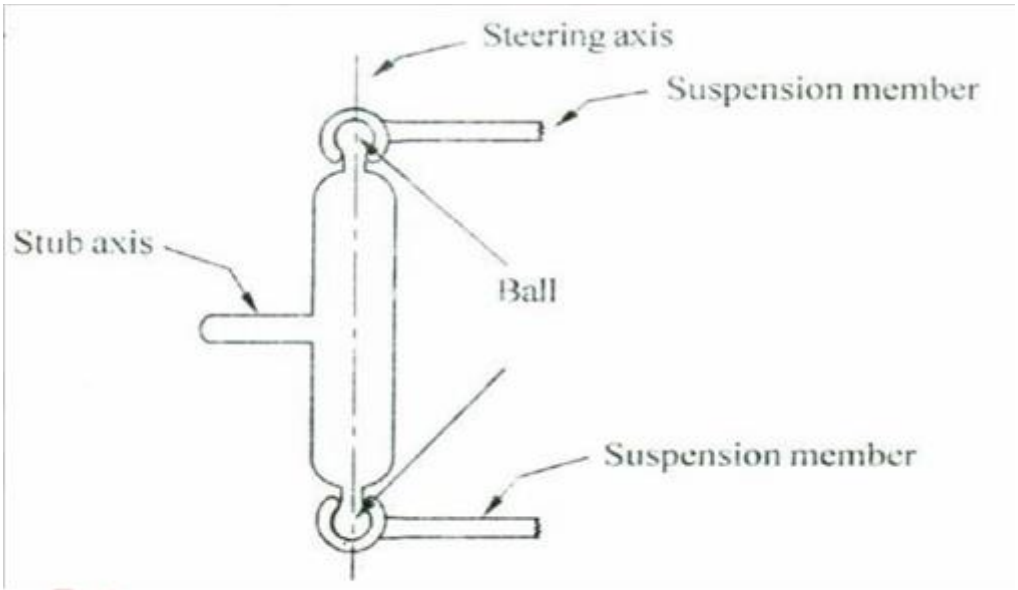


Fig: Stub axle arrangement with king ball joints

STEERING GEOMETRY

It is not enough to simply place the front wheels on hubs, stand them up straight and device a

mechanism to swivel them left or right. The car could be driven but it would steer very poorly and at higher speeds it would become dangerous to handle, and also tire life would be short.

Wheel alignment refers to the positioning of the front wheels and steering mechanism that promotes easy of steering, provides directional stability, reduces tire wear to a minimum. To secure easy steering, smooth operation and several front wheel alignment factors must be considered such as camber, king-pin or steering axis inclination, caster, toe in and toe out and turning circles (angles) etc.

(a) Camber

Camber angle is the inclination between the centre line of the tyre and the vertical. If the wheels are inclined or tilted outward at the top, it is called "positive camber", and if the wheels are inclined inward at the top, it is called "negative camber". t is also called as 'wheel rake angle:.

Front wheels are not mounted parallel to each other; instead they are tilted slightly outward at the top. This is done to prevent the top of the wheels from tilting inward too much due to excessive loads or play in the king pins and wheel bearings.

Effect: It is noted that, to make the tyre wear more uniform, tyre should roll vertically on the ground. Tyre will wear more on one side than the other side, when it is tilted inward or outward. The positive camber causes the tyre to roll like a truncated cone. The positive camber makes the wheel to toe out and tyre will wear more on the outer side. Similarly the negative camber makes the wheels to and tyre will wear more on the inner side. Initially the wheels are provided with positive camber, after loading automatically they come to vertical position.

It is clear that, when the vehicle is running with average load, zero camber angle gives maximum tyre life. If the two front wheels are not provided with equal camber, the vehicle will try to pull towards the side where the camber is higher. In the same way, if the wheels are provided with equal camber, the crowned road has a tendency to pull away the vehicle to the side of the road. To obviate this, usually slight higher camber is provided on the right wheel in case of right drive vehicles which have to move on the left side. For left hand drive vehicles, left wheel is sided with higher camber.

Camber angle is usually less than 2° and exact amount depends upon king pin inclination.

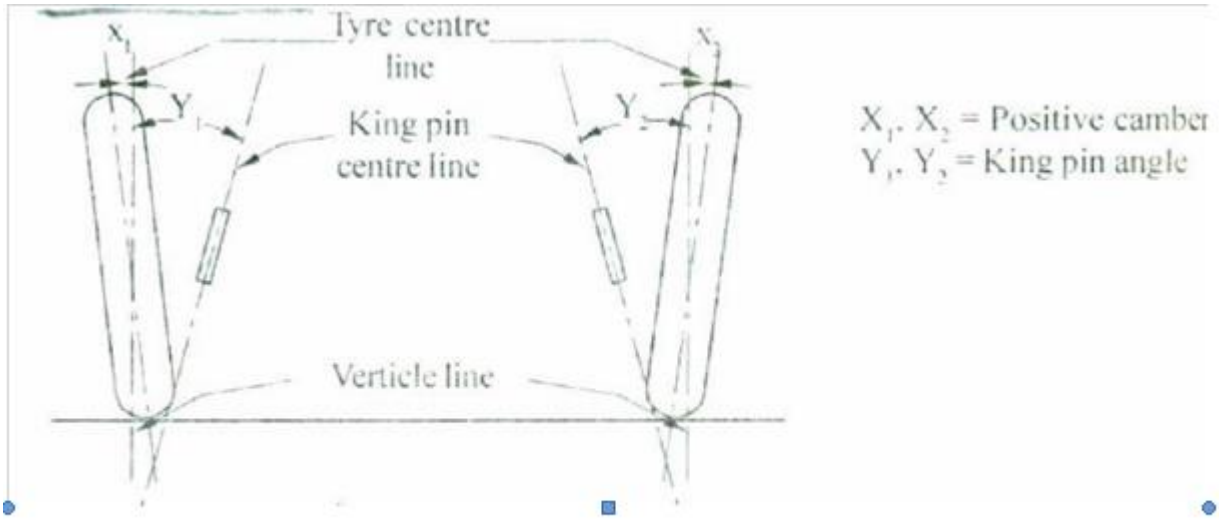


Fig (a): Camber and king pin inclination

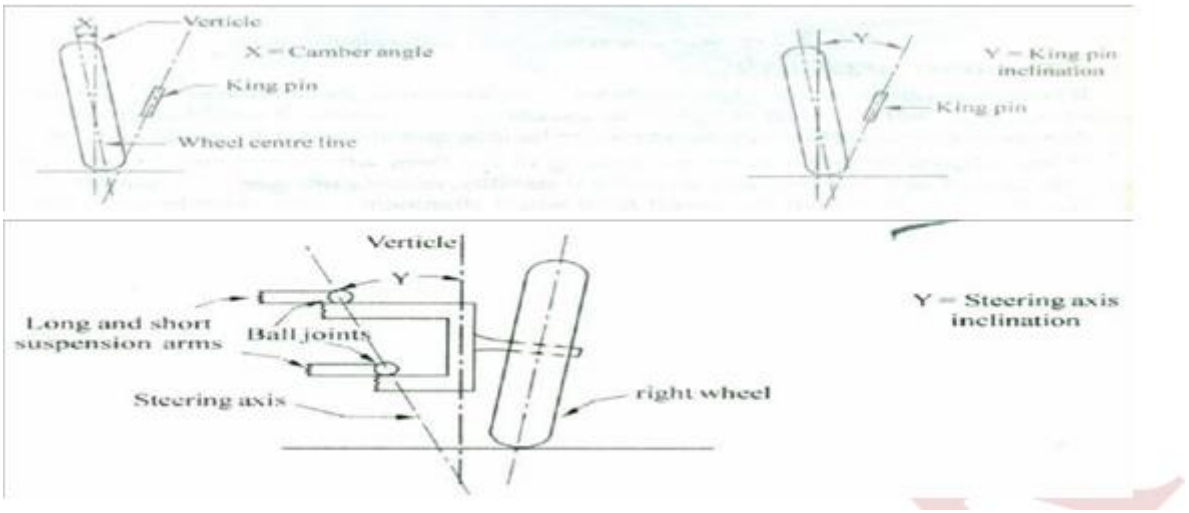


Fig: Camber and king pin angle (steering axis inclination) on exaggerated scale.

(b) Kingpin angle or Steering axis inclination

The kingpin or Ball joints are mounted in such a way that they slant inward. The kingpin inclination is the inward tilt of the kingpin or ball joint centre line from the vertical i.e., the angle between vertical and kingpin or ball joint centre line]. In case of kingpin, this is called king pin angle and if ball joints are used, then it is called steering axis inclination.

Effect: Kingpin inclination in combination with caster provides directional stability. When the vehicle turns, the vehicle body is lifted up slightly due to kingpin inclination. After completing the turn, driver leaves the steering wheel and vehicle weight causes the wheels to recover straight ahead position. The kingpin angle is kept about 7^0 to 8^0 and exact amount depends upon wheel rake angle. This kingpin angle also; uses suspension shocks to be transmitted to and absorbed by the heavy inner spindle and knuckle assembly.

(c) Included angle and Scrub radius

It is the angle obtained in the vertical plane between the wheel centre line and the king pin or ball joint centre line. It is equal to camber plus king pin inclination (X + Y).

The king pin centre line when extended meets the road surface near the tyre centre line. The distance between these two centre lines at the point where they intersect on the road surface is called "Scrub Radius". It is positive when steering axis or ball joint centre line meets the road surface inside the tyre centre line. If it meets the road surface outside the tyre centre line, the scrub radius is negative. A small scrub radius is desirable as it reduces steering wheel shock from road irregularities and reduces steering effort.

Effect: The figure explains, how the combined angle affects scrub radius and hence' forces acting to turn the wheel in a rear wheel drive vehicle. It is seen that unless scrub radius is zero, a torque acts to turn the wheel away from the straight ahead position.

A negative scrub radius causes the wheel to toe in as in figure (a). A positive scrub radius

causes the wheel to toe out as in figure (c)

A zero scrub radius keeps the wheel in straight position without any tendency to toe in or toe out as in figure (b). In this case, wheel centre line and king pin or ball joint centre line exactly meets on the ground. This condition is called "centre point steering".

By experience, it has been proved that, if the ball joint centre line and wheel centre line meets below the ground, it gives best results.

If both the wheels are not provided with equal combined angle, the vehicle will pull towards the side where scrub radius is high.

Combined angle varies from 9^0 to 10^0 and scrub radius ranges up to 12 mm.

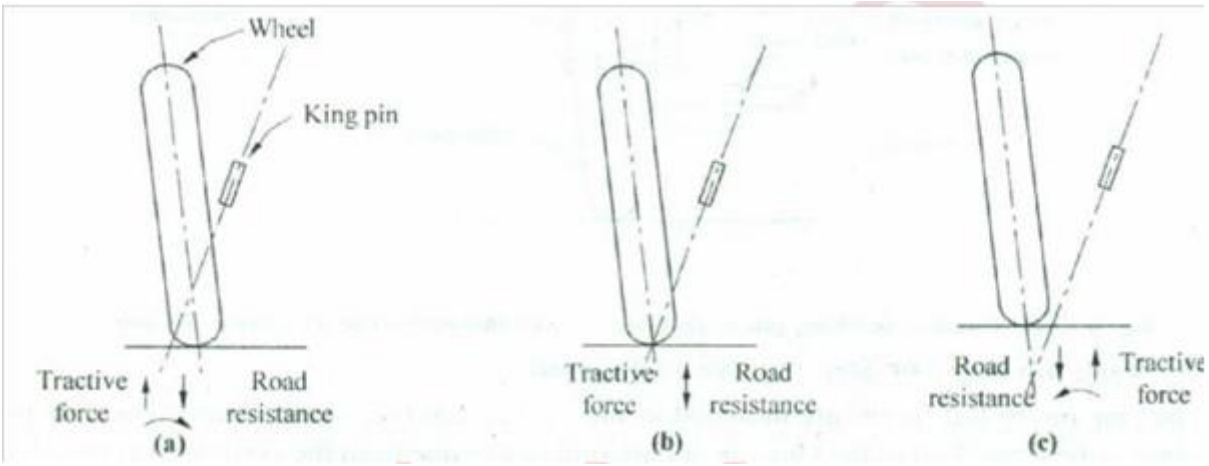


Fig: The wheel and king pin centre line meet (a) above the ground (negative scrub radius) - wheels toe in (b) Exactly on the ground (zero scrub radius - 0 effect and (c) below the ground (positive scrub radius) - wheels toe out

(d) Castor

The kingpins are tilted slightly from the vertical as shown in figure 6.15 (a) and (b). The angle between the kingpin centre line and vertical, obtained in the plane of wheel is called the castor angle. If the kingpin centre line contacts the ground at a point in front of the wheel centre, it is called Positive Castor and if it meets behind the wheel centre line it is called Negative Castor. The castor angles should not exceed 3^0. In modern vehicles negative castor ranges from 2^0 to 8^0.

Effect: Castor produces a trailing effect and hence gives directional stability by making the wheels to lead or follow in the same direction as the vehicle moves. Incorrect castor angle results in-hard steering, when brakes are applied vehicle pulls to one side, tendency to wander due to lack of directional stability.

Example: Castor angle provided on the furniture rollers and on the front wheels of the bicycles, the positive castor provided in both these cases causes the wheels to be pulled in any direction.

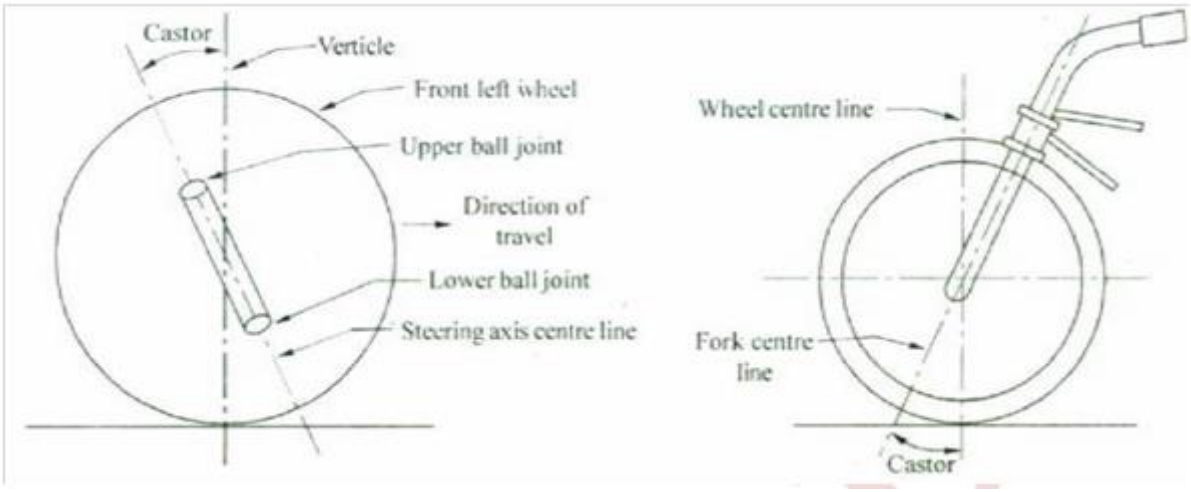


Fig: (a) Castor; (b) Castor on front wheel of the bicycle.

TOE IN AND TOE OUT CONDITIONS

Toe in is accomplished by placing the front of the wheels closes together than the back, when viewed from the top and vehicle is stationary. Toe in is nothing but the difference between the centre to centre distances of the rear ends and the front ends i.e. (B - A)

If the wheels are set closer at the back end than at the front, i.e. (A - B), then the difference of distances between the wheels at the front and at the rear is called Toe out.

Effect: When the wheel is cambered, the tire engages the road at an angle. Since the tire will adopt itself to the road, the rolling edge of the tire will not be at right angles to the centre line of the wheel. This will cause it to roll in the form of truncated cone and thus causes more wear on outer surface of the wheel, the purpose of toe in is to neutralize the cone rolling effect of front wheels caused by camber angle. Therefore, the amount of toe in depends up on the camber angle, and in modern cars it is usually kept 2 to 4 mm.

In some front wheel drive cars, initial toe out has been provided to counter the tendency to toe in. Excessive steering linkage looseness will allow the wheels to toe out under dynamic loads. Excessive toe in or toe out will cause tyre wear.

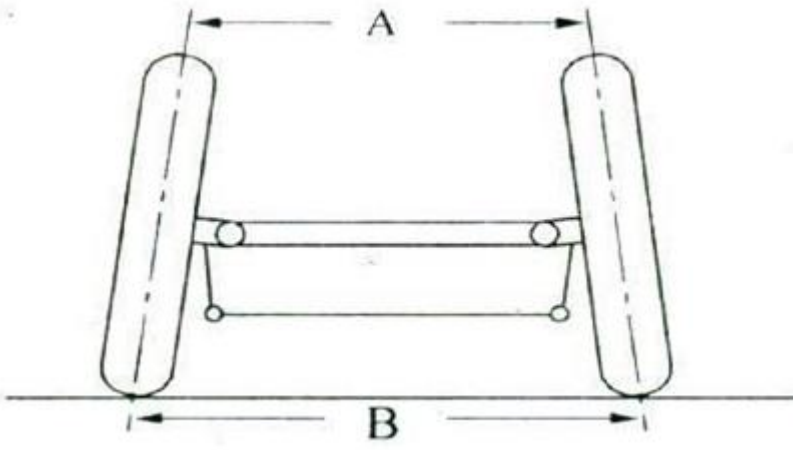


Fig: Toe - in

TOE OUT ON TURNS

When a vehicle takes a turn, the inner wheel must turn on a smaller turning circle than the outer wheel. This causes the wheels to toe out on turns due to difference in their turning angles .: This essential action is allowed by bending both steering arms so they angle slightly towards the centre of the vehicle.

When the vehicle takes turn, the steering arm on the inside of the turn swivels more sharply, due to angle of the arm at this point.

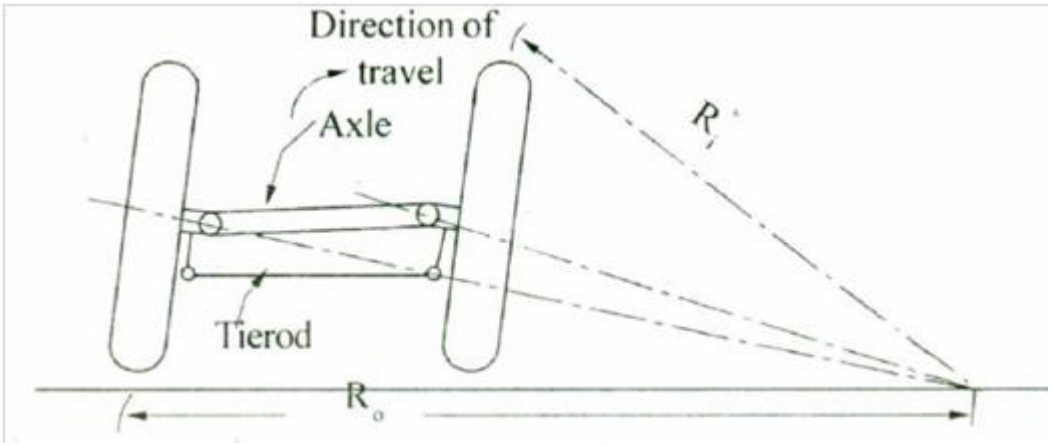


Fig: Toe out on turns as viewed from top

STEERING GEARS

Steering gear is the heart of steering system and the driver controls the direction of front wheels with the steering gear. It converts rotational motion of the steering wheel into to and fro motion (arc motion) of the link rod of the steering linkage which in turn swivel the front wheels.

Steering gear also provides torque multiplication. It multiplies the drives steering effort to provide adequate force for steering column. For cars, the steering ratio or torque multiplication factor ranges between 10 : 1 to 22 : 1 and for trucks it ranges between 24 : 1 to 32 : 1.

There are many types of steering gears used in automobiles. The important steering gears are

a) Worm and Wheel steering gear

It consists of a worm and worm wheel. In place of worm wheel, only a sector may also be used. As the steering wheel turns, the rotation of the worm drives the worm wheel. A drop arm is rigidly attached to the wheel spindle. So rotation of worm wheel through steering wheel causes the drop arm to move to and fro, thereby, actuates the link rod connected to it and swivels the front wheels.

b) Worm and Nut steering gear

It consists of a worm and a ball nut and these are arranged as shown in figure. The rotation of steering wheel turns the worm and hence the nut moves along its length. This movement of the nut actuates the drop arm end to move linearly and thus actuates the link rod and swivels the wheels.

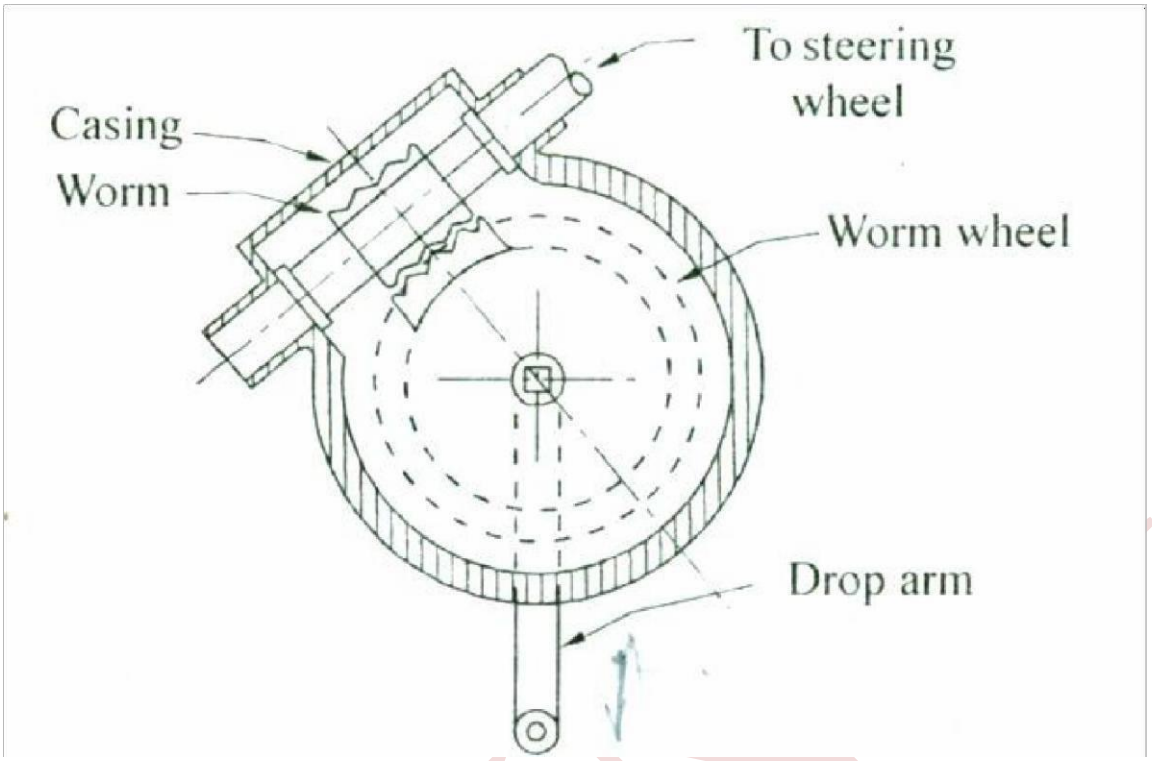


Fig: Worm and wheel steering gear.

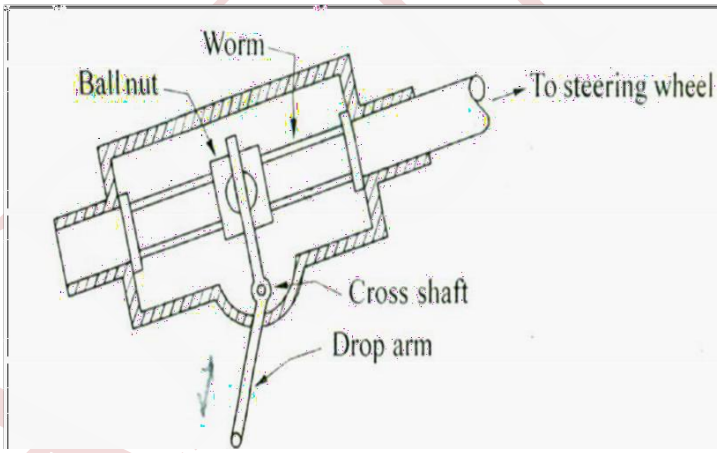


Fig: Worm and out type steering gear.

c) Recirculating ball type steering gear

The figure shows a recirculating ball type steering gear. It consists of a worm and nut arrangement as in figure. The steering shaft carries the worm and a nut rides on the worm with two sets of balls in the grooves in between nut and worm. These balls reduce friction during movement of the nut on the worm. The drop arm is rigidly attached to the wheel sector and the teeth of wheel sector meshes with teeth of the nut. The drop arm in turn connected to the link rod, through which it swivels the road wheels.

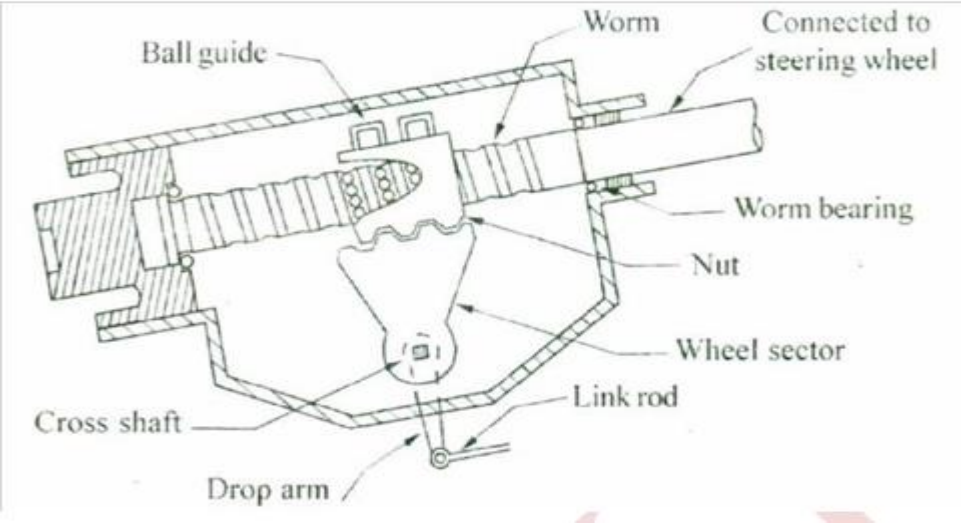


Fig: Recirculating ball type steering gear.

When the steering wheel is turned, the nut rides on the worm and the balls roll in the groove and makes the nut to travel along the length of the worm. These two sets of balls are recirculated through the guides. As the nut rides on the worm, its movement drives the wheel sector and hence link rod and thus steers the wheels.

CONDITION FOR TRUE ROLLING

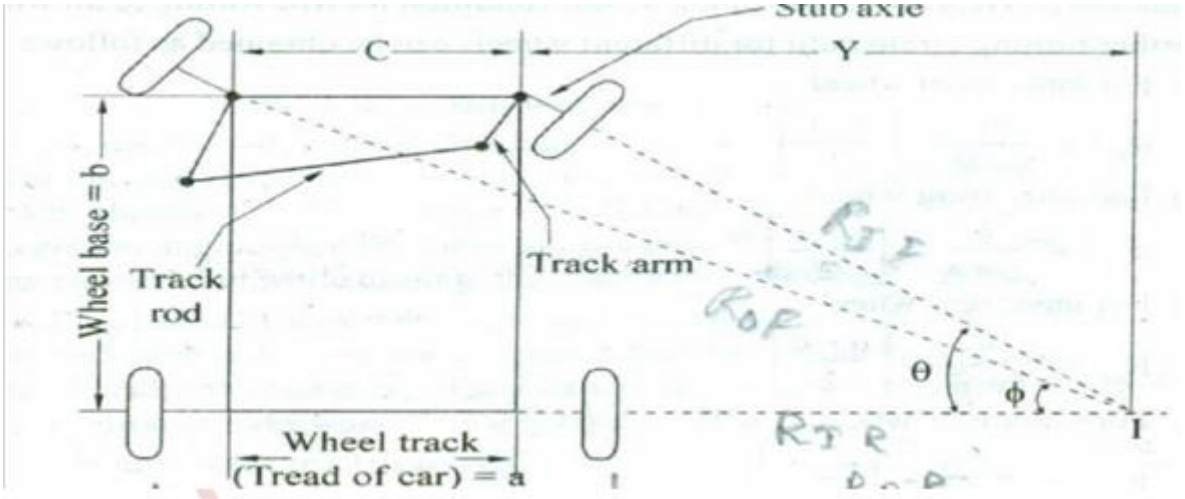


Fig: Condition for exact steering

The condition for true rolling is obtained when all four wheels are rolling perfectly under all conditions of running. If the vehicle takes a turn, this fundamental condition of correct steering is satisfied when all four wheels rotate about a common centre called as Instantaneous centre. The axes of front wheels when produced meet the rear wheel axis at this point 'I'. It is also seen that, the inside wheel turns through a greater angle than the outer wheel. The larger the steering angle, the smaller is the turning circle. However, there is maximum limit to the steering angle, and is limited to 44^0. The extreme positions on both sides are called 'Lock' positions.

The turning circle is defined as the diameter of the smallest circle which the outer front wheel of an automobile can traverse and obtained when the wheels are at lock positions.

STEERING MECHANISM

We know that for perfect steering all four wheels must rotate about Instantaneous centre. To achieve this, inner wheel has to turn more than outer wheel. Several mechanisms are used, among which two are important.

1. Ackermann Mechanism
2. Davis Mechanism.

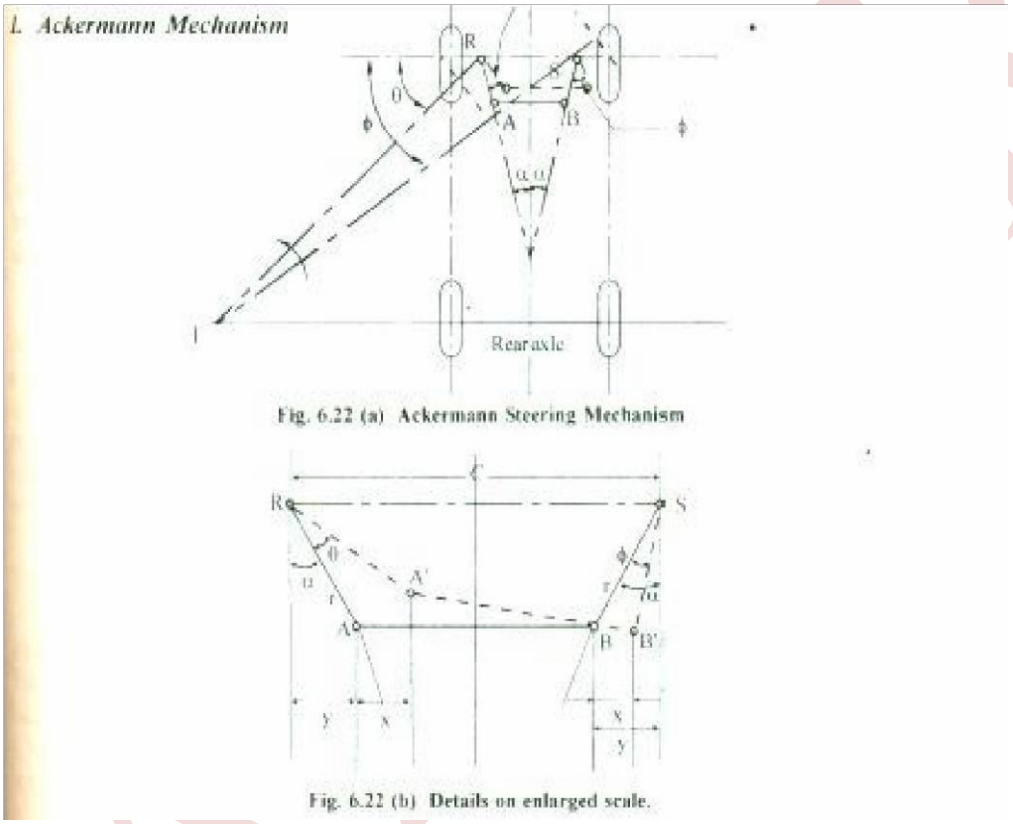


Fig. 6.22 (a) Ackermann Steering Mechanism

Fig. 6.22 (b) Details on enlarged scale.

The Ackermann mechanism is based on a four- bar chain mechanism, which has two longer links RS and AB of unequal length and other two shorter links 'RA' and 'SB' of equal lengths. By using track rod 'AB' shorter than RS (distance C or distance between kingpins), the inner wheel is forced to turn a greater angle, when the car is taking a turn. When the car is going straight ahead, all four wheels are parallel, but while turning, the inner and outer wheel angles become different.

The figure (a) and (b) shows the Ackermann's mechanism. It is seen that shorter links are made integral with stub axles and are connected together through track rod. In the straight ahead position, the shorter links makes equal inclination 'a' with the centre line of the vehicle. The dotted line shows position of links when the car is taking left turn.

Let, **I** = length of the track rod 'AB' and **r** = Length of shorter links RA and SB.

From figure (b), after neglecting obliquity of link AB in the turned position, the pivots A and B moves through same distance 'X' in horizontal direction.

Then from figure 5.22 (b)

$$\sin(\alpha + \theta) = \frac{y + x}{r} \quad \ldots\ldots (A)$$

$$\sin(\alpha - \phi) = \frac{y - x}{r} \quad \ldots\ldots (B)$$

(A) + (B) gives•

$$\sin(\alpha + \theta) + \sin(\alpha - \phi) = \frac{2y}{r} = 2 \sin \alpha.$$

POWER STEERING

In heavy duty trucks and tractors, driver has to apply inadequate effort to turn the wheels. The use of booster arrangement in steering system overcomes this drawback. The booster is put in to operation when the steering wheel is turned. It does most of the work for steering. The power steering system uses compressed air, electrical mechanisms, and hydraulic pressure.

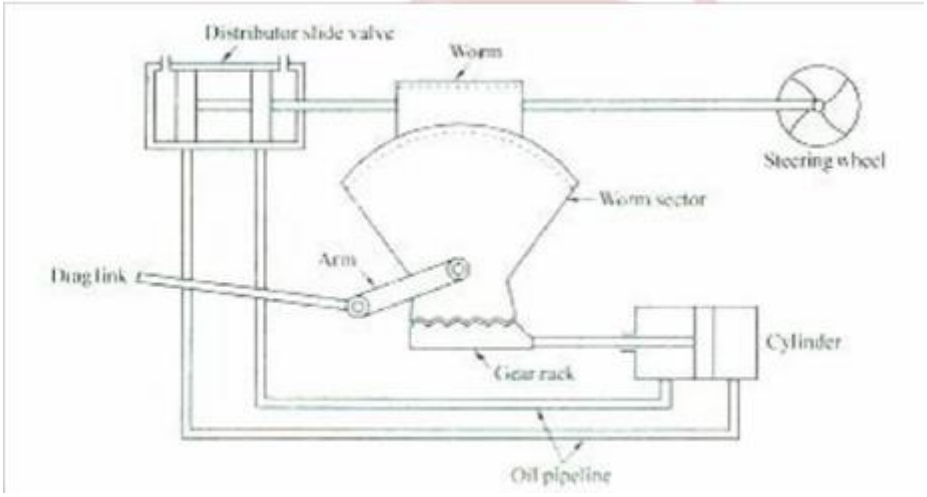
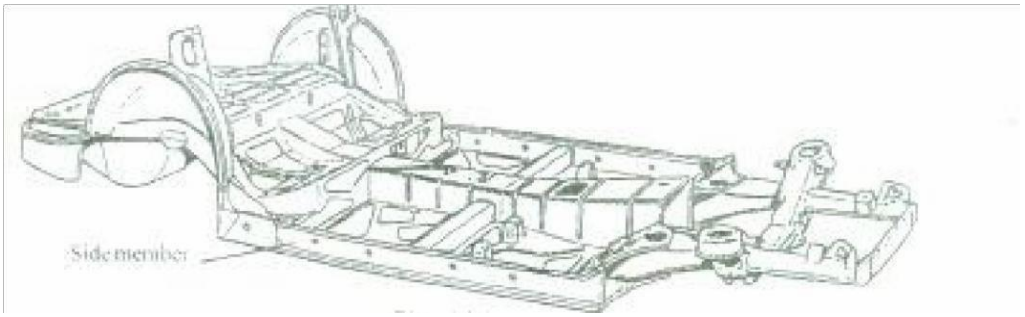


Fig: Oil assisted power steering

The figure shows a simplified diagram of hydraulic booster. The arrangement consists of a worm and worm-wheel, distributor slide valve, booster cylinder etc. When the steering wheel is turned, the worm turns the sector of worm wheel and hence actuates the arm. The arm in turn actuates the road wheels through drag link. If the resistance offered to turn the wheels is too high and driver's effort to the steering wheel is too weak, then the worm, like a screw in a nut will be displaced axially together with the distributor slide valve. This axial movement will admit compressed air or oil in to booster cylinder through the pipeline. The piston in the booster cylinder will turn the road wheels via the gear rack, the toothed worm sector, arm and drag link. In the mean time, the worm sector will actuate the worm and will shift it along with distribution slide valve to its initial position. This movement of slide valve will stop the piston travel in the booster cylinder. Here the system uses power assistance in proportion to the effort needed to turn the wheels.


Side member

SUSPENSION & SPRINGS

INTRODUCTION

The ability of vehicles to negotiate rough roads and handle well at high speeds is mainly due to proper design of suspension system. If the axles are bolted directly to the body, any uneven spot in the road would transmit adjoining force to the vehicle which in turn results in discomfort for riding. Hence the automobile chassis is mounted on the axle through springs. This is done to isolate shocks on the vehicle body from road. The parts which perform the function of isolating the vehicle from road shocks are called suspension system.

The main objectives of the suspension system are:

1. To prevent the road shocks from being transmitted to the vehicle parts, thereby providing suitable riding and cushioning effect to the occupants.
2. Reduces wear on the tyre.
3. To keep the vehicle stable while in motion by providing good road holding during driving, cornering and braking.
4. Provides safe vehicle control and free of irritating vibrations.

REQUIREMENTS

1. **Vertical vibrations and pitching:** The damper present in suspension system eliminates the vibrations caused due to striking of front wheel to a bump. However, rear wheel also experiences similar vibrations as it reaches the bump after some time and this depends on wheel base and vehicle speed. There are three possible relations of front and rear suspension frequencies.

   (i) Front frequency higher than the rear - After the initial vibration i.e., after one or two vibrations the maximum amplitude occurs.

   (ii) Front frequency equal to rear - The amplitude collapses throughout, though pitching tendency still exists

   (iii) Front frequency lesser than the rear - Practically there is no pitching tendency.

So, it is-clear that in order to reduce pitching tendency of the vehicle, the (iii) condition is suitable.

2. **Rolling:** The centre of gravity of the vehicle will be at certain height above the ground level. A turning couple about the longitudinal axis of the vehicle will be induced during cornering because of the centrifugal force acting at C.G. and forces at tyre - road contact surface. This result in a motion called rolling. The manner in which the vehicle is sprung determines the axis about which the vehicle will roll.

3. **Brake dip:** When the brakes are applied, the vehicle nose has a tendency to be lowered or to dip.

This in turn depends up on C.G position relative to the ground, wheel base, and other suspension characteristics

4. Unsprung weight: When the wheels hit a bump, they vibrate along with the unsprung parts which store the vibration energy and transmit it to the sprung parts through the springs. When the weight of unsprung parts if greater, it increases energy stored due to vibrations and thus transmits greater shocks to the sprung parts. Therefore it is necessary to keep the unsprung weight as low as possible.

TYPES OF SUSPENSION PRINGS

1. Steel springs

a) Leaf spring b) tapered leaf spring c) coil spring d) torsion bar

2. Rubber Spring

a) Compression spring b) compression - shear spring c) Steel reinforced spring d) progressive spring e) Face shear spring.

3. Air springs

a) Bellow type b) piston type.

Torsion bars

It is a simple rod which is acting in torsion and takes stresses only. It nearly stores the same amount of energy per unit weight as that of coil spring. Torsion bar is often used with independent suspensions.

When compared with other systems, it is lighter and occupies less space. Torsion tubes may also be used instead of torsion bars. One end of torsion bar is fixed to the frame, while the other end is fixed to the end of the wheel arm the supported in bearing. The wheel arm is connected to the wheel hub when the wheel hits a bump; it starts vibrating up and down and produces a torque on torsion bar, which acts as a spring.

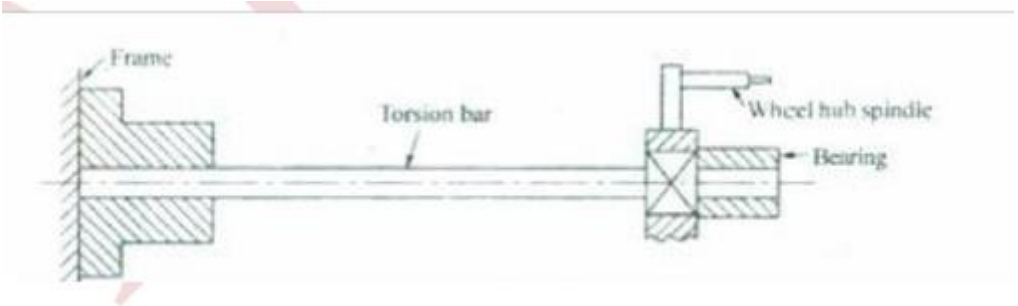


Fig: Torsion bars

The two disadvantages associated with the use of torsion bar are.

(i) It does not take braking or driving torque. This necessitates the use of additional linkages for the same purpose.

(ii) No friction force exist, no damping and hence no control of vibrations produced due to road shocks.

TYPES OF FRONT WHEEL SUSPENSION

There are two types:

1. Rigid axle free wheel suspension.
2. Independent front wheel suspension.

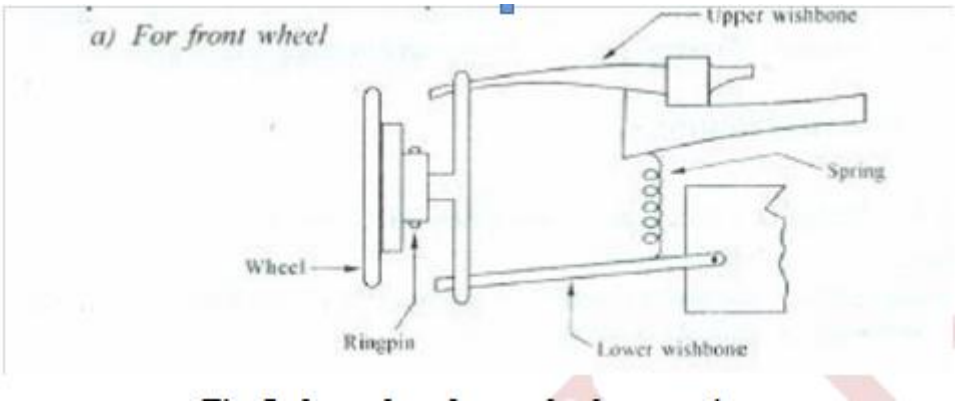


Fig: Independent front wheel suspension

In Independent suspension each front wheel is supported by a coil spring and a torsion bar. The independent suspension is confined only to the front wheels in the majority of vehicles because of its high cost. The independent front system has the following advantages.

1. It provides more space for the engine.
2. It provides softer suspension.
3. It reduces the tendency of wheels to turn about the king pin axis due to gyroscopic action.
4. It also reduces the tendency of tilting the vehicle on one side when the vehicle is lifted or dropped due to uneven road surface.

b) Rear Suspension

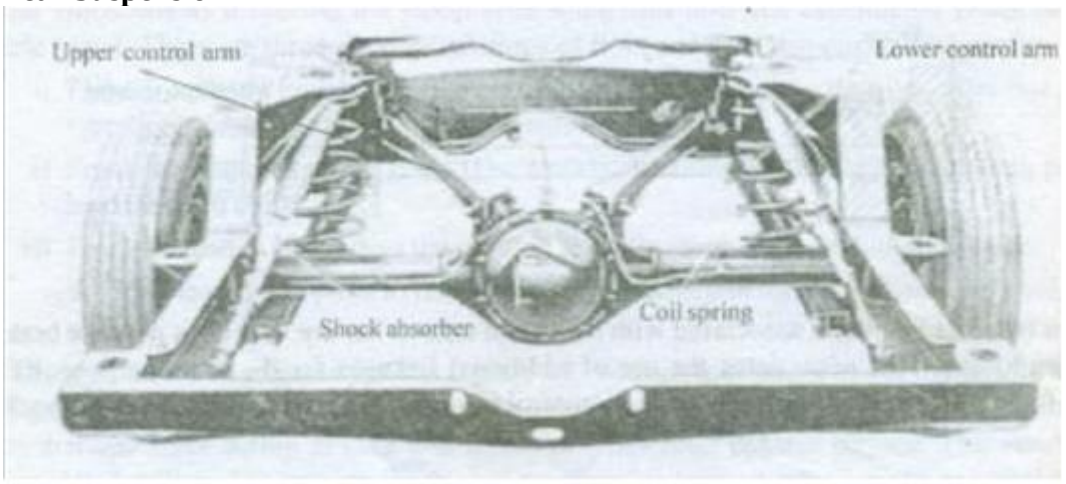


Fig: Coil spring rear suspension system.

In rear suspension systems the coil springs and leaf springs are extensively used. Fig. illustrates a typical suspension system utilizing coil springs. The rear axle housing is mounted on springs and is attached to a set of upper and lower control arms. Universal Coupling shown

(represented in fig. by A & B, keep the wheel vertical and the sliding coupling "C" maintains the wheel track constant. This method is used in Dedoin type of axle, the control arm pivot points are rubber bushed. One end of the arm is connected to housing and the other to the frame. The arm arrangement allows the rear axle housing to move up and down, but prevents excessive Fore and Aft and side-to-side movement.

The main disadvantages are

1. Ignition lost is high.
2. As there is large number of parts, maintenance required is more.
3. The steering geometry is misaligned with the wear of component.

PITCHING AND BOUNCING

The centre of gravity of the vehicle will be at certain height above the ground level. A turning couple about the longitudinal axis of the vehicle will be induced during cornering because of the centrifugal force acting at C.G and forces at tyre-road contact surface. This result in a motion called rolling. This causes the left hand suspension move out of phase with the right hand suspension. The tendency of the front portion (Nose) of the vehicle to dip due to braking is known as Brake Dip.

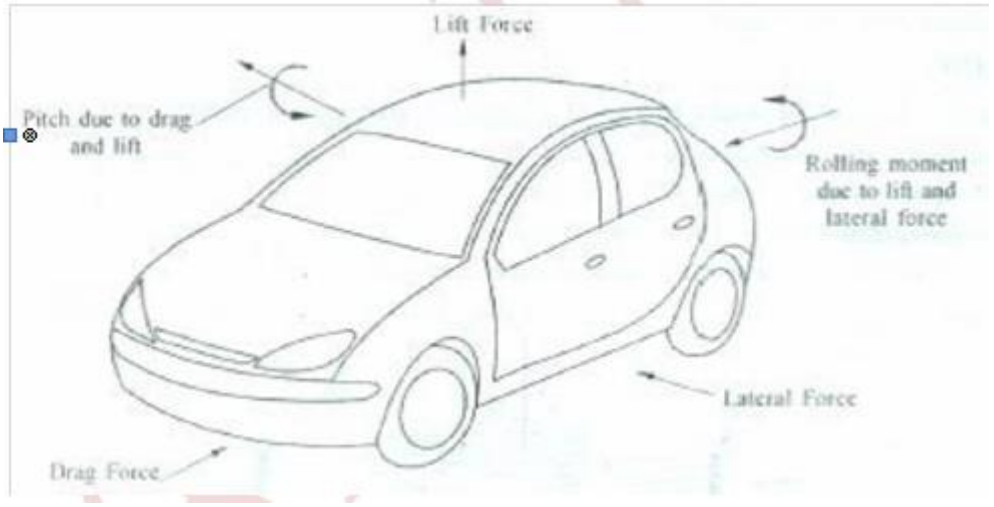


Fig: Vehicle with different forces acting on it.

In Figure are shown the different types of the spring mass motions. Pitching is the rotary motion about the transverse direction through the vehicle parallel to the ground. This causes front suspensions to move out of the phase with the rear.

Bouncing is the motion of centre of gravity in the vertical direction. It can be front end or rear end bounce. Diagonal pitching is the combination of pitch and roll.

SPRINGS

The following are the commonly used suspension springs in Cars and Trucks.

1. Leaf or Laminated Springs.
2. Helical or Coil springs.
3. Torsion Bar
4. Rubber or elastic springs.
5. Hydro elastic springs.
6. Air springs.

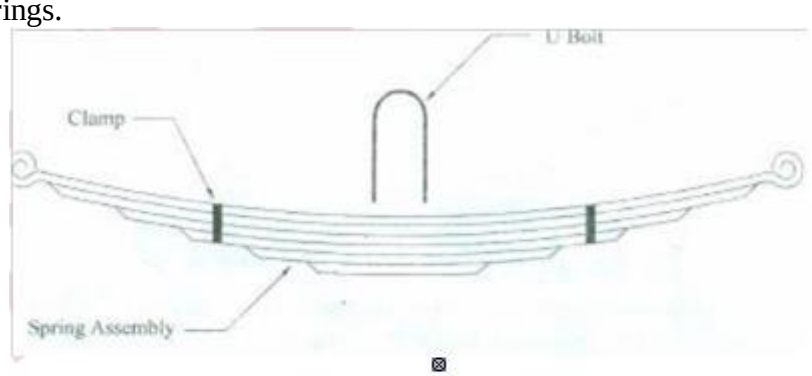


Fig: Semi elliptical leaf spring

Fig: Semi elliptical leaf spring

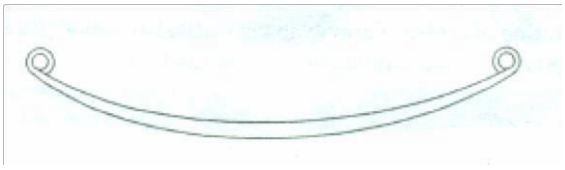


Fig: Long, wide and quite thin. Entire spring is made up of one leaf.

1. Leaf or Laminated Springs

The leaf springs are made up of steel plates of leaves as shown in fig. These are commonly used in automobile rear suspensions. The leaves are held together at centre by a bolt which passes through holes in the leaves. Many leaf springs have special springs have special inserts between the leaves to permit the leaves to slip over one another when the spring bends. The spring leaves are of graduated length as shown; the front end of the largest leaf is bent into a circle to form a spring eye and is attached to the spring hanger by a bolt. Rubber bushings are used to provide the insertion to the bolt from the spring hanger. The rubber bushings serve two purposes.

a) Absorb vibration and thus prevent it from getting up to the vehicle frame.

b) Allow the spring eye to twist back and forth as the leaf spring bends.

The rear end of the spring is also bent to form a spring eye. This spring eye is attached to the car frame through a spring shackle. The shackle allows for changes in the length of the leaf spring as it bends. As when the springs pushed upward or downward by bumps or holes in the road, the distance between the two spring eye changes. The shackle acts as a swinging support that permits this change in length.

2. Coil Springs

Nowadays coil springs have become very popular because of the limitations involved in leaf spring. Fig shows a front suspension system using coil springs. In the system shown, the coil spring is held between a spring seat in the car frame and a lower control arm. The inner ends of control arms are pivoted on the car frame, the outer ends are connected to the steering knuckle. This in turn is attached to the control arms. The ball joints used to allow the steering knuckles to swing to the left or right for steering. In the assembled car, the wheels are mounted from left to right pivots the front wheels, so that the car can be steered.

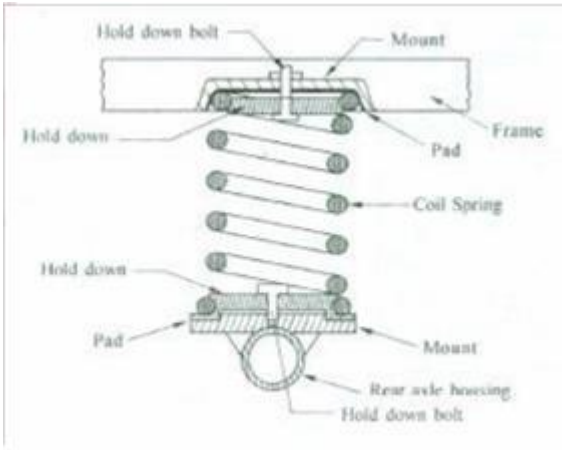


Fig: Coil Spring.

SHOCK ABSORBERS

Shock absorbers are necessary as the springs do not 'settle down' fast enough. In other words, after a spring has been compressed and released, it continues to shorten and lengthens or oscillates for a time.

If a wheel of car hits a bump, the spring compresses. Then the spring expands after the wheel passes bump, the expansion. of the spring causes the car to be thrown upward. Now, having over-expanded, the spring shortens again. This action causes the wheel to momentarily leave the road and the car drops down. The action is repeated until the oscillation gradually dies out.

Such spring action on a car would produce a very bumpy and uncomfortable ride. It could also be dangerous because a bouncing wheel would make the car impossible to control. This would be especially dangerous on a curve. It is obvious, therefore, that a device is needed to control the oscillating action of the spring. This device is known as the Shock absorber.

Out of so many types of shock absorbers available such as Vane type, opposed piston etc, telescopic shock absorber is most commonly used.

The telescopic shock absorber consists of an outer cylinder, inner cylinder, piston and piston rod and in some cases an outer dust and rock shield. At the bottom of the inner cylinder and in the piston a series of valves controls the movements of the hydraulic fluid within the shock absorber.

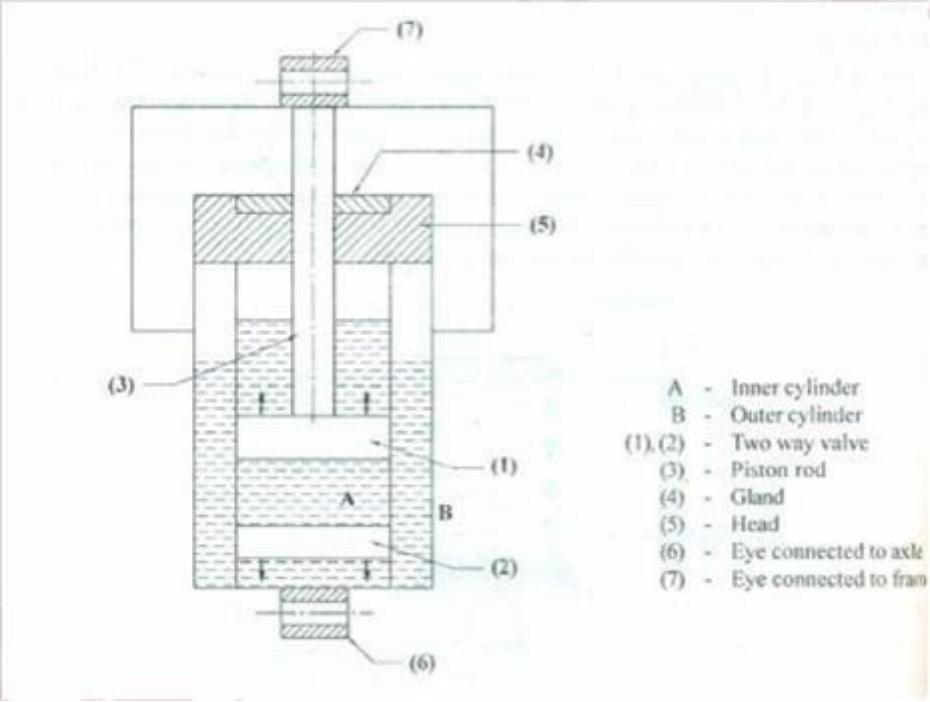


Fig: Illustrates the working of telescopic shock absorber

Fig illustrates the working of Telescopic shock absorber. In this, piston rod is attached to the two way valve' 1', while valve '2' which is also a two way valve is attached between cylinder and tube as shown in fig. The inner and outer cylinders are filled with oil. When the vehicle comes across a bump, the eye connected to axle will move up. With this the oil below valve' I' will moves up. Due to the resistance to the flow of oil through valve '1' it exerts pressure on valve '2'. This allows oil to flow through valve '2' also.

The flow of oil through valves 1 & 2 will be slow because of damping effect. In the similar way, for the down ward movement of the eye connected to axle, because of road irregularities, the oil will move from the upper side of valve '1 ' to the lower side and vice - versa.

AIR SUSPENSION SYSTEM

Air or pneumatic suspension is incorporated in some tourist buses to improve the riding comfort of the passengers. The air suspension system possesses the following advantages over conventional metal springs.

1. The spring rate varies much less between laden and un-laden conditions, this decreases dynamic loading.
2. Changes in head lamp alignment due to change in load are avoided.
3. It improves riding comfort to the passengers.
4. Longer service life of the vehicle due to improved smoothness of run.

In air suspension system, four air springs (air bags) which may be of bellow type or piston type are used instead of coil springs. The atmospheric air passes through a filter and compressor raises its pressure to about 24kg / mm- and air at this pressure is accumulated in an accumulator. The relief valve in the accumulator tank acts as a safety valve. This high pressure air then enters to the air springs through lift control valve and leveling valves.

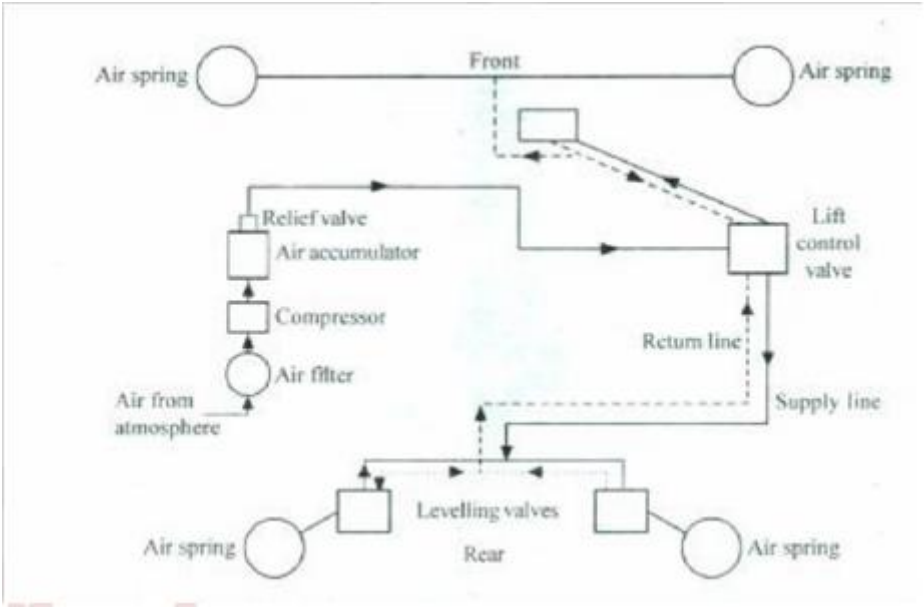


Fig: Layout of air suspension system

IGNITION SYSTEMS

INTRODUCTION

We know that in case of Internal Combustion (IC) engines, combustion of air and fuel takes place inside the engine cylinder and the products of combustion expand to produce reciprocating motion of the piston. This reciprocating motion of the piston is in turn converted into rotary motion of the crank shaft through connecting rod and crank. This rotary motion of the crank shaft is in turn used to drive the generators for generating power. We also know that there are 4-cycles of operations viz.: suction; compression; power generation and exhaust.

These operations are performed either during the 2-strokes of piston or during 4-strokes of the piston and accordingly they are called as 2-stroke cycle engines and 4-stroke cycle engines.

In case of petrol engines during suction operation, charge of air and petrol fuel will be taken in. During compression this charge is compressed by the upward moving piston. And just before the end of compression, the charge of air and petrol fuel will be ignited by means of the spark produced by means of for spark plug. And the ignition system does the function of producing the spark in case of spark ignition engines.

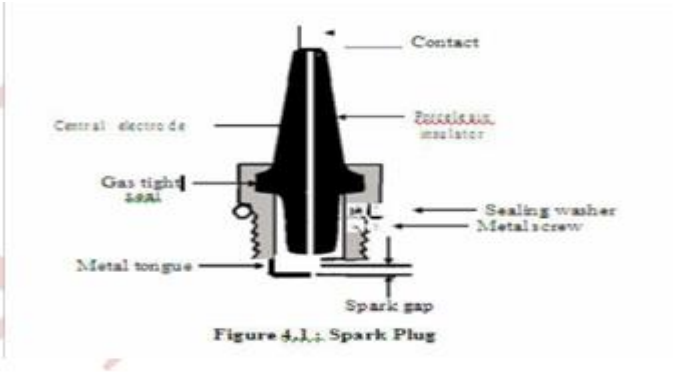


Figure 4.1.: Spark Plug

Figure shows atypical spark plug used with petrol engines. It mainly consists of a central electrode and metal tongue. Central electrode is covered by means of porcelain insulating material. Through the metal screw the spark plug is fitted in the cylinder head plug. When the high tension voltage of the order of 30000 volts is applied across the spark electrodes, current jumps from one electrode to another producing a spark.

Whereas in case of diesel (Compression Ignition-CI) engines only air is taken in during suction operation and in compressed during compression operation and just before the end of compression, when diesel fuel is injected, it gets ignited due to heat of compression of air.

Once the charge is ignited, combustion starts and products of combustion expand, i.e. they

force the piston to move downwards i.e. they produce power and after producing the power the gases are exhausted during exhaust operation.

Objectives

After studying this unit, you should be able to

- Explain the different types of ignition systems,
- Differentiate between battery and magneto ignition system
- Know the drawbacks of conventional ignition system, and
- Appreciate the importance of ignition timing and ignition advance.

IGNITION SYSTEM TYPES

Basically Convectional Ignition systems are of 2 types :

(a) Battery or Coil Ignition System, and

(b) Magneto Ignition System.

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

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

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

Battery or Coil Ignition System

Figure shows line diagram of battery ignition system for a 4-cylinder petrol engine. It mainly consists of a 6 or 12 volt battery, ammeter, ignition switch, auto-transformer (step up transformer), contact breaker, capacitor, distributor rotor, distributor contact points, spark plugs, etc. Note that the Figure 4.1 shows the ignition system for 4-cylinder petrol engine, here there are 4-spark plugs and contact breaker cam has 4-corners. (If it is for 6cylinder engine it will have 6-spark plugs and contact breaker cam will be a perfect hexagon).

The ignition system is divided into 2-circuits:

1. **Primary Circuit :** It consists of 6 or 12 V battery, ammeter, ignition switch, primary winding it has 200-300 turns of 20 SWG (Sharps Wire Gauge) gauge wire, contact breaker, capacitor.
2. **Secondary Circuit:** It consists of secondary winding. Secondary winding consists of about 21000 turns of 40 (S WG) gauge wire. Bottom end of which is connected to bottom end of primary and top end of secondary winding is connected to centre of distributor rotor. Distributor rotors rotate and make contacts with contact points and are connected to spark plugs which are fitted in cylinder heads (engine earth).

WORKING

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

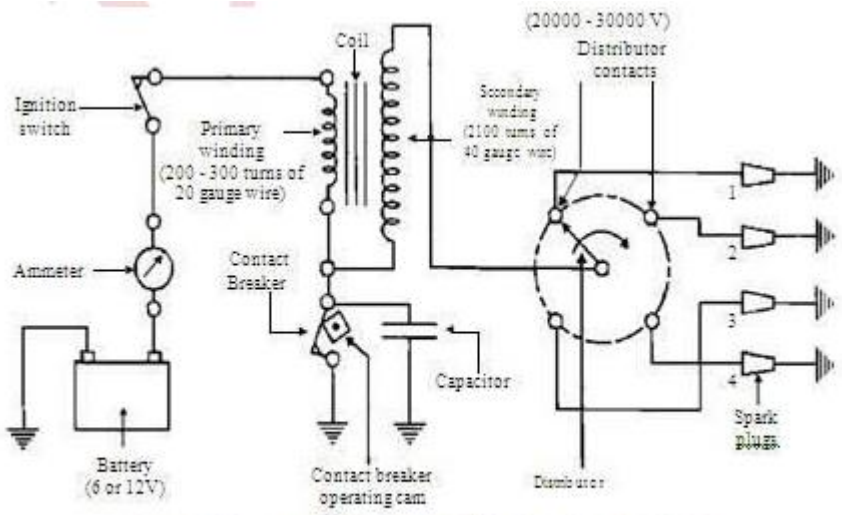


Figure 4.2 : Schematic Diagram of Coil/Battery Ignition System

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

Note:

The Function of the capacitor is to reduce arcing at the contact breaker (CB) points. Also when the CB opens the magnetic field in the primary winding begins to collapse. When the magnetic field is collapsing capacitor gets fully charged and then it starts discharging and helps in building up of voltage in secondary winding. Contact breaker cam and distributor rotor are mounted on the same shaft. In 2-stroke cycle engines these are motored at the same engine speed. And in 4-stroke cycle engines they are motored at half the engine speed.

Magneto Ignition System

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

Figure shows the line diagram of magneto ignition system.

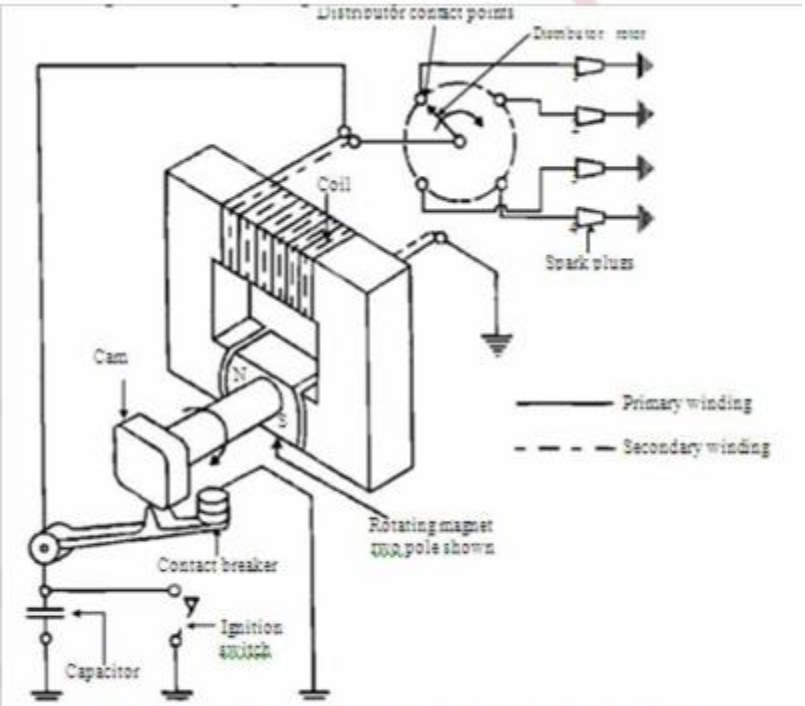


Figure 4.3.: Schematic Diagram of Magneto Ignition System

COMPARISON BETWEEN BATTERY AND MAGNETO IGNITION SYSTEM

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

DRAWBACKS (DISADVANTAGES) Of CONVENTIONAL IGNITION SYSTEMS

Following are the drawbacks of conventional ignition systems:

1. Because of arcing, pitting of contact breaker point and which will lead to regular maintenance problems.
2. Poor starting: After few thousands of kilometers of running, the timing becomes inaccurate, which results into poor starting (Starting trouble).
3. At very high engine speed, performance is poor because of inertia effects of the moving parts in the system.
4. Sometimes it is not possible to produce spark properly in fouled spark plugs.

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

ADVANTAGES OF ELECTRONIC IGNITION SYSTEM

Following are the advantages of electronic ignition system:

1. Moving parts are absent-so no maintenance.
2. Contact breaker points are absent-so no arcing.
3. Spark plug life increases by 50% and they can be used for about 60000 km without any problem.
4. Better combustion in combustion chamber, about 90-95% of air fuel mixture is burnt compared with 70-75% with conventional ignition system.
5. More power output.
6. More fuel efficiency.

TYPES OF ELECTRONIC IGNITION SYSTEM

Electronic Ignition System is as follows:

1. Capacitance Discharge Ignition system
2. Transistorized system
3. Piezo-electric Ignition system
4. The Texaco Ignition system

Capacitance Discharge Ignition System

It mainly consists of 6-12 V battery, ignition switch, DC to DC convertor, charging resistance, tank capacitor, Silicon Controlled Rectifier (SCR), SCR-triggering device; step up transformer, spark plugs. A 6-12 volt battery is connected to DC to DC converter
i.e., power circuit through the ignition switch, which is designed to give or increase the voltage to 250-350 volts. This high voltage is used to charge the tank capacitor (or condenser) to this voltage through the charging resistance. The charging resistance is also so designed that it controls the required current in the SCR.

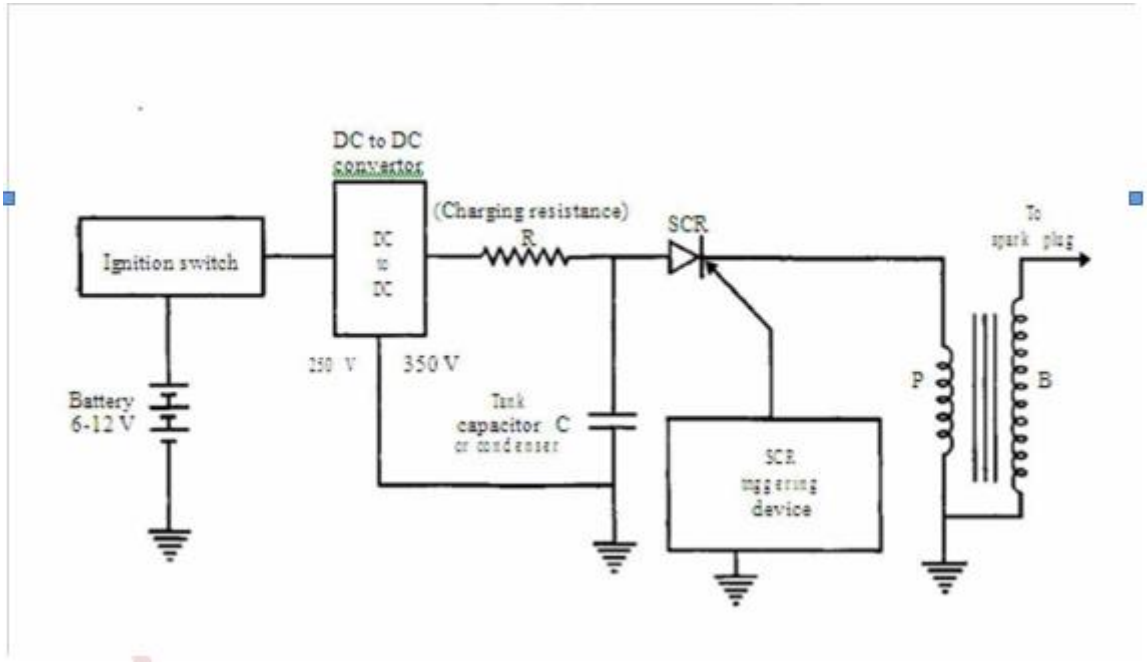


Figure: Capacitance Discharge Ignition System

Depending upon the engine firing order, whenever the SCR triggering device, sends a pulse, then the current flowing through the primary winding is stopped. And the magnetic field begins to collapse. This collapsing magnetic field will induce or step up high voltage current in the secondary, which while jumping the spark plug gap produces the spark, and the charge of air fuel mixture is ignited.

Transistorized Assisted Contact (TAC) Ignition System

Figure shows the TAC system.

Advantages

- The low breaker-current ensures longer life.
- The smaller gap and lighter point assembly increase dwell time minimize contact bouncing and improve repeatability of secondary voltage.
- The low primary inductance reduces primary inductance reduces primary current drop-off at high speeds.

Disadvantages

- As in the conventional system, mechanical breaker points are necessary for timing the spark.
- The cost of the ignition system is increased.
- The voltage rise-time at the spark plug is about the same as before.

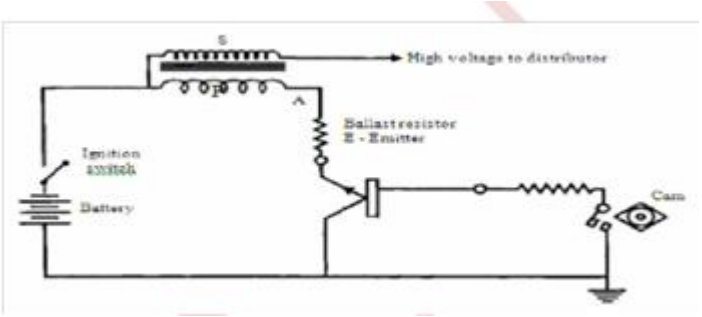


Figure: Transistorized Assisted Contact (TAC) Ignition System Piezo-electric

Ignition System

The development of synthetic piezo-electric materials producing about 22 kV by mechanical loading of a small crystal resulted in some ignition systems for single cylinder engines. But due to difficulties of high mechanical loading need of the order of 500 kg timely control and ability to produce sufficient voltage, these systems have not been able to come up.

The Texaco Ignition System

Due to the increased emphasis on exhaust emission control, there has been a sudden interest in exhaust gas recirculation systems and lean fuel-air mixtures. To avoid the problems of burning of lean mixtures, the Texaco Ignition system has been developed. It provides a spark of controlled duration which means that the spark duration in crank angle degrees can be made constant at all engine speeds. It is a AC system. This system consists of three basic units, a power unit, a control unit and a distributor sensor. This system can give stable ignition up to A/F ratios as high as 24

FIRING ORDER

The order or sequence in which the firing takes place, in different cylinders of a multi cylinder engine is called Firing Order.

In case of SI engines the distributor connects the spark plugs of different cylinders according to Engine Firing Order.

Advantages

- A proper firing order reduces engine vibrations.
- Maintains engine balancing.
- Secures an even flow of power.

1. 3 cylinder = 1-3-2

2. 4 cylinder engine (inline) = 1-3-4-2, 1-2-4-3

3. 4 cylinder horizontal opposed engine = 1-4-3-2 (Volkswagen engine)

4. 6-cylinder in line engine = 1-5-3-6-2-4 (Cranks in 3 pairs) 1-4-2-6-3-5, 1-3-2-6-4-5,

i. 1-2-4-6-5-3

5. 8 cylinder in line engine = 1-6-2-5-8-3-7-4, 1-4-7-3-8-5-2-6

6. 8 cylinder V type 1-5-4-8-6-3-7-2, 1-5-4-2-6-3-7-8, 1-6-2-5-8-3-7-4, 1-8-4-3-6-5-7-2

Cylinder 1 is taken from front of inline and front right side in V engines

MODULE 5

AUTOMOTIVE EMISSION CONTROL SYSTEMS

Automotive Emission Control Systems: Different air pollutants, formation of photochemical smog and causes. Automotive emission
controls, Controlling crankcase emissions, Controlling evaporative emissions, Cleaning the exhaust gas, Controlling the air-fuel mixture, Controlling the
combustion process, Exhaust gas recirculation, Treating the exhaust gas, Air-injection system, Air-aspirator system, Catalytic converter.
Emission Standards: Euro I, II, III and IV norms, Bharat Stage II, III, IV norms. Motor Vehicle Act

08 Hours

INTRODUCTION

The purpose of emission control is to reduce amount of pollutants and environmentally damaging substances released by the vehicles. If not controlled, the automobile can emit pollutants from fuel tank, carburetor crank case and exhaust system in the atmosphere. The fuel tank and the-carburetor emit gasoline vapours, crank case releases partly burned air-fuel mixture blown off by piston rings and pollutants from exhaust system consists of partly burned hydrocarbons, carbon monoxide, nitrogen oxides and sulphur oxide. The smoke may be formed due to incomplete burning of fuel [Smoke: particles of unburned fuel and soot called particulates, mixed with air]. It took many years for the public and the automotive industry to address the problem of these pollutants.

It is estimated that in USA alone 200 million tons of manmade pollutants adds to the air. Therefore-these pollutants, if not controlled, adversely affect our health. Automobile manufacturers have been working towards reduction of auto motive air pollutants when auto emissions were found to be part of the cause of smog. The emission of pollutants can be decreased by improving combustion efficiency which in turn needs redesigning of fuel tank, carburetor combustion chamber, cooling system run on and exhaust system. The other way of controlling atmospheric pollution is, destroy the pollutants after they have been formed.

The emission of pollutants in Auto motives can be reduced by

1. Closed crank case ventilation
2. Fuel tank and carburetor ventilation
3. Redesigning the engine
   - **(i)** Combustion chamber,
   - **(ii)** Cooling system,
   - **(iii)** Fuel supply system and
   - **(iv)** Ignition system

CLOSED CRANK CASE VENTILATION [Controlling Crank Case Emissions]:

This system consists of two types:

(i) Positive crank case ventilation and

(ii) Fixed orifice system.

Positive Crank Case Ventilation Systems [PCV Systems]:

When engine is running, some unburned fuel and combustion products leak past the piston rings and move into the crank case. This leakage is called blow by. This blow by must be removed from the engine-Crankcase, before it condenses and reacts with oil to form sludge, which may corrodes and accelerates wear of pistons, piston rings, valves, bearings, etc. Sludge can also clog oil lines and starve the lubricating system. As the engine oil circulates, it also carries blow by and some unburned fuel particles which are formed due to incomplete combustion of air-fuel mixture in to the crank case. If not removed, this dilutes the engine's oil and hence the oil does not lubricate the engine properly resulting in excessive wear. Filtered air from the carburettor air clearer must be circulated through the crank case to remove blow by gases and gasoline vapours from the crank case. To prevent atmospheric pollution modern engines have a closed system called PCV system. The flow by gases and gasoline vapours are picked up by filtered air to the engine inlet manifold through a special PCV valve and from there enters into engine combustion chamber with fresh charge and are burnt there.

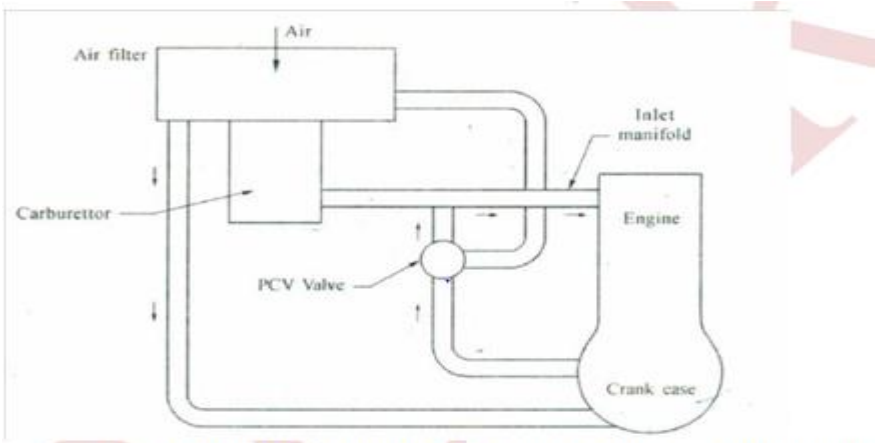


Fig: Schematic diagram of positive crank case ventilation

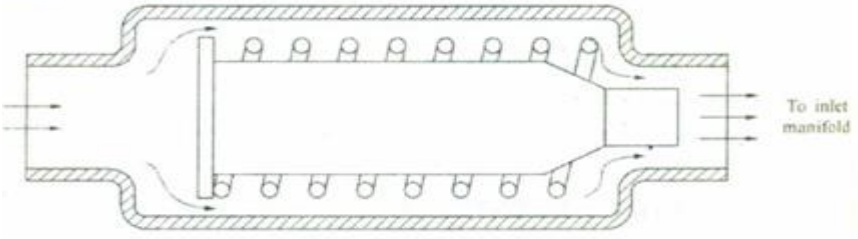


Fig: PCV Valve

The PCV valve consists of a spring loaded tapered valve. The valve is in closed position under the action of crank case pressure and manifold vacuum where as the spring pressure keeps the valve open there by regulate the flow of blow by gases. During idle or deceleration (low speed) amount of blow by gas is less due to lesser engine load and a small PCV valve opening is needed to move blow by gases out of crank case. The high intake manifold vacuum moves the tapered valve against spring pressure, thus provides small opening in the valve for the flow of blow by gases. During part throttling (or normal speed), engine load is higher than at Idle, blow by increases and manifold vacuum decreases. The spring moves the tapered valve to increase the opening. The larger

opening allows the entire blow by gases to enter in to the intake manifold. At high speeds or when the engine is operating under heavy load, the throttle valve opens widely and decreases intake manifold vacuum. The spring moves the tapered valve further down ward to provide a larger opening through the valve. The amount of blow by gases is more, when engine load is high, hence larger PCV valve opening is essential to allow these gases to flow through the valve in to the intake manifold.

Fixed orifice tube PCV System

Some engines are not fitted with PCV valve. The blow by gases is routed in to the intake manifold through a fixed orifice tube. This system works similar to PCV valve, except that the system is regulated only by the vacuum on the orifice. The amount of blow by gas, flows in to the intake manifold is limited by the size.

CONTROLLING EVAPORATIVE EMISSIONS [Evaporative emission control systems]:

The fuel evaporative control system capture the gasoline vapours from the fuel tank and carburetor float bowl and prevents them from escaping in to the atmosphere. This system is called by various names such as active emission control (EEC), evaporative control systems (ECS), cycle vapour recovery and vapour saver (recovery) system (VVS / NRS):Since fuel' injection systems do not have a float bowl, the ECS controls escape of fuel vapours from the fuel tank only.

Vapour recovery system in carbureted engines

If the vehicle is not fitted with VRS, the gasoline vapours from the fuel tank and carburetor escape in to the atmosphere by evaporation or breathing. The fuel tank breathes with change in temperature. As temperature increases, the air inside the tank expands and thus forced out through either the filter cap vent or the tank vent tube. This air carries gasoline vapour. When the temperature decreases, the air inside contracts and hence outside air enters into the tank. This breathing of tank causes loss of gasoline vapour and discharges it into atmosphere.

The gasoline vapour is also escapes from the carburetor float bowl by evaporation. When the engine is running, the cater float bowl is full. When the engine stops, the heat of the engine evaporates some or all of the gasoline stored in the float bowl.

The vapour recovery system reduces atmospheric pollution by preventing gasoline vapour to escape in to atmosphere. All modern cars are fitted with VRS.

The layout of vapour recovery system is as shown in figure. The fuel tank and carburetor are vented to a carbon or charcoal canister instead of vented in to atmosphere. When the engine stops, fuel vapours run the tank and float bowl enters into a carbon or charcoal canister. In the canister, the activated charcoal adsorbs the vapour and stores it [absorb means - vapours are trapped by sticking to the outside of the charcoal particles]. When the engine starts, the gasoline vapour in the canister is picked up by fresh air flowing through it. Then the air flows into engine intake manifold and becomes part of air fuel mixture entering the engine cylinders. This action of flow of fresh air to pick up the trapped gasoline vapour from the canister is called "Purging". The system also consists of a vapour liquid separator on the fuel tank. This chamber separates vapour from the liquid gasoline which in turn returned to the tank. A mechanically operated vent valve or an electrically operated

solenoid valve may be used to control flow of vapours from the fuel tank. The mechanical valves operated by the throttle linkage. During idling, it is open and causes the vapour to flow from float chamber to the canister. The opening of throttle closes the vent valve; likewise, the electrical vent valve is open when ignition is off. When the ignition is on, the vent valve is closed by the energisation of solenoid.

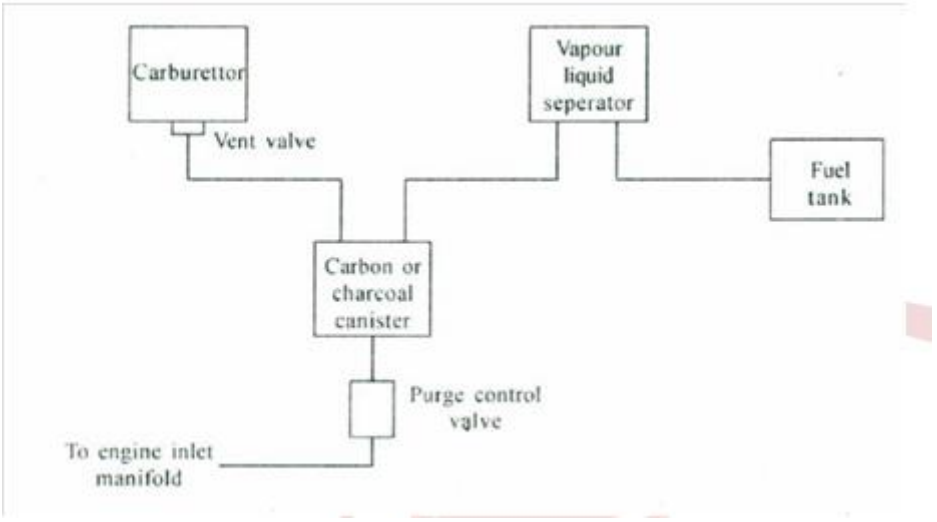


Fig: Schematic diagram of a vapour recovery system Evaporative Control

System (ECS) for fuel injected engines

The fuel injection system do not have float bowl, therefore ECS controls escape of fuel vapour from the fuel tank only. The canister is connected to hose from the fuel tank. The purge line from the canister is connected to the throttle body. An electric purge control solenoid may be used instead of vacuum operated purge valve. The solenoid valve may be fitted on the canister or in the purge line and normally open.

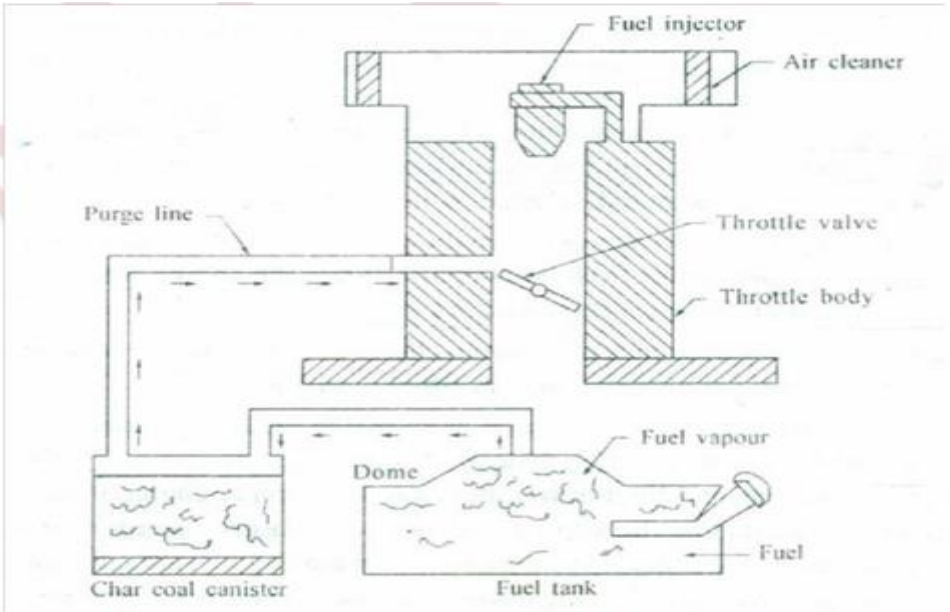


Fig: ECS for an engine with throttle body injection

CLEANING THE EXHAUST GAS

The Automotive engines burns liquid fuel gasoline which is a hydrocarbon (HC), made up of hydrogen (H) and carbon (C). During complete combustion, gasoline produces water vapour and carbon dioxide which are harmless to atmosphere. However, in automotive engines, combustion is never completely takes place. Some unburned hydrocarbon (gasoline) and carbon monoxide (formed due to in complete combustion of gasoline) and nitrogen oxide (formed due to high combustion temperature) will remain in the exhaust gas. Therefore combustion can be represented by

HC + N + 0, ~ co + H,O + CO + NO + HC

The carbon monoxide, HC and NO causes air pollution.

In automotives, sources air pollution are engine crank case, air cleaner or carburetor, fuel tank and tail pipe. The pollutants from each of these sources are controlled by emission control devices like crank case emission control systems, evaporative emission control systems, exhaust emission control system.

The methods used to reduce amount of pollutants in the exhaust gas are

1. Controlling gasoline quality
2. Controlling the air-fuel mixture
3. Controlling the combustion process
4. Treating the exhaust gas

Controlling gasoline quality

The characteristics of the gasoline can be improved by adding some additives during refining.
Good quality gasoline posses following characteristics,

1. **Proper volatility:** This property indicates how easily the gasoline is converted into vapour.
2. **Resistance to detonation or spark knock.**
3. **Oxidation inhibitors:** Avoids gumming tendency in the fuel system.
4. **Anti-rust and Anti-freezers:** To prevent rusting of components in fuel system and avoids blocking of fuels.
5. **Detergents:** To clean carburetor and fuel injector.
6. **Dyes:** gives colour for identification.

Controlling the air-fuel mixture

Controlling the air-fuel mixture is nothing but

i) Modifying the fuel system or carburetor to deliver a leaner air-fuel mixture and

ii) Faster warm up and quicker choke action.

The ideal air-fuel ratio [14.7: 1] required for complete combustion of fuel is called air-fuel ratio. If this air-fuel ratio is lower, say 14: I, it means, there is excess fuel for available oxygen. If it is higher, say 16: 1, it means there is an excess of oxygen. As engines operates mostly at part throttle, the ECM maintain air-fuel ratio at stochiometric ratio during part throttling. The engine performance is better at ideal air-fuel mixture (14.7: 1) and produces minimum exhaust the amount of oxygen in the exhaust gas is indicated oxygen sensor which sends signals to ECM. This shows leanness or richness of air-fuel mixture. Then the ECM adjusts the richness of the mixture.

Faster engine warm up and quicker choke open in reassess exhaust emissions during warm-up. If the carburetor [fuel supply system] supplies cold air-fuel mixture, only a part of fuel will vaporize. This makes the air-fuel mixture lean and extra rich mixture is required. Therefore, when the engine is cold, a thermostatically controlled air cleaner is used to supply heated air quickly to the carburetor. During cold running, air entering carburetor is heated up by thermostatic air cleaner, which allows engine to run on a leaner air-fuel mixture during warm up.

The thermostatic air cleaner consists of a temperature sensing spring which senses temperature of air entering the air cleaner. The air bleeds when air is cold and this applies intake manifold vacuum to the vacuum motor. The diaphragm and hence to control am per assembly moves up due to atmospheric pressure and thus blocks the snorkel tube. This allows all the air to enter through the hot air pipe which is laid near to the exhaust manifold. When the engine starts, the exhaust manifold heats up quickly, and hence allows heated air to enter into the air cleaner. This heated air helps to vaporize the fuel delivered by carburetor or fuel injectors, which in turn improves cold engine performance

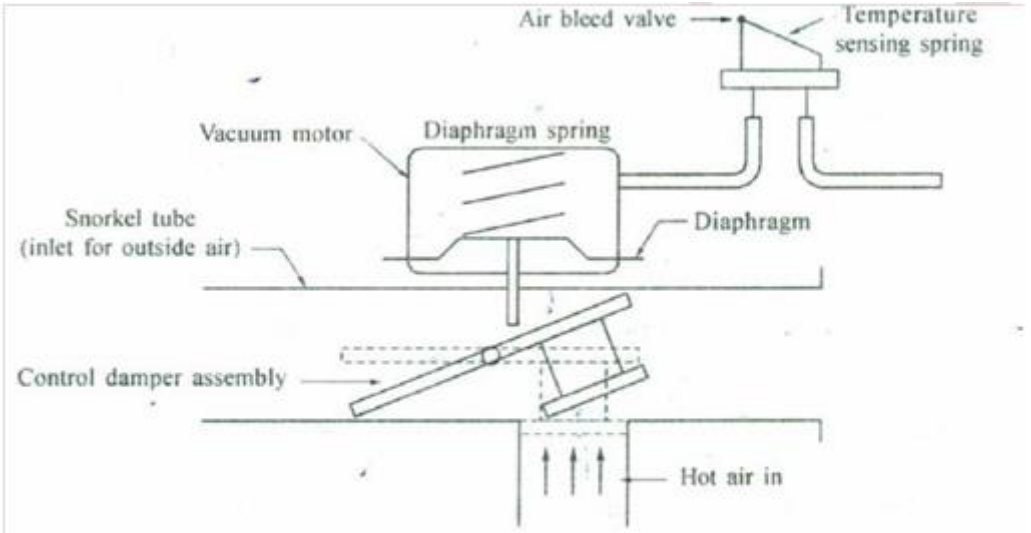


Fig: Thermostatic air cleaner

Controlling Combustion Process

Combustion in the engine cylinders is a complicated phenomenon. The factors which affect the combustion process are:

1) The air-fuel mixture near to the cool cylinder wall, cylinder head, top piston ring and piston head do not burn. The metal surface cools these layers below the combustion point. Therefore, during exhaust stroke, this unburned mixture (fuel) is swept out of the cylinder. This adds polluting HC to the atmosphere. Thlsprooreil1 is rectified by introducing stratified charge in the engine cylinder or by fuel injection method. The other method is providing lesser surface area around the combustion chamber. A hemispherical cam has less surface area and releases less unburned HC in to the exhaust.

2) The combustion temperature results in better combustion in fuel and reduces unburned HC and CO emissions in the exhaust. But this results in formation of more nitrogen oxide (NO) and adds pollutants to the atmosphere.

3) During part throttling, controlled advance provided in the ignition distributor gives the air fuel

mixture a longer time to burn. Under certain operating conditions, this also results in formation of more Nitrogen Oxide. The devices used to prevent vacuum advance are;

(a) Transmission Controlled Spark TCS or Transmission Regulated Spark (TRS) system: It delays vacuum advance when the transmission is in neutral reverse and forward gears.

(b) Spark Delay Valve (SDV): It prevents vacuum advance during certain conditions of vehicle acceleration.

4) The carbon deposits present in the combustion chamber absorb air-fuel mixture and during exhaust releases air-fuel mixture. The HC in the exhaust gas, add pollutants to the atmosphere.

Exhaust gas recirculation

The higher combustion temperature (more than 1927°C) results in the formation of more Nitrogen Oxides. The exhaust gas recirculation of EGR system is used to lower the combustion temperature and hence to reduce NO emissions in the exhaust gas. A small metered quantity (6 to 13%) of inert exhaust gas is sent back in to the intake manifold to reduce combustion temperature and formation of NOx' the exhaust gas is relatively at low temperature and absorbs heat from the much hotter combustion process. there by reduces combustion temperature and hence formation of O.

The simplest form of EGR system is as shown in figure. It consists of a passage which connects exhaust manifold and intake manifold. The EGR valve opens and closes the passage and it consists of a spring loaded diaphragm that forms a vacuum chamber at the top of the valve. A tube connects vacuum chamber and vacuum port in the throttle body as shown in figure. In absence of vacuum, the diaphragm moves down due to spring action, thus closes the passage. In this situation, no exhaust gas re-circulates, engine is idle and formation of NO x is minimum.

When the throttle opens, it moves past the vacuum port. This allows the intake manifold vacuum to act through the port and moves the diaphragm up to open the valve. As the valve raises up, some exhaust gases passes through the valve in to intake manifold. The exhaust gases mixes with air-fuel mixture and then enters into engine cylinders. This reduces combustion temperature and hence formation of NOx.

When the throttle valve is fully opened, a little vacuum exists at the vacuum port and hence EGR valve is nearly closed. However no EGR is needed due to rapid combustion and there is less time for NO_x formation.

In most of the engines, vacuum is applied to the EGR valve through a ported vacuum switch (PV) or thermal vacuum switch (TVS). It prevents EGR until engine temperature reaches $38^{O}C$.

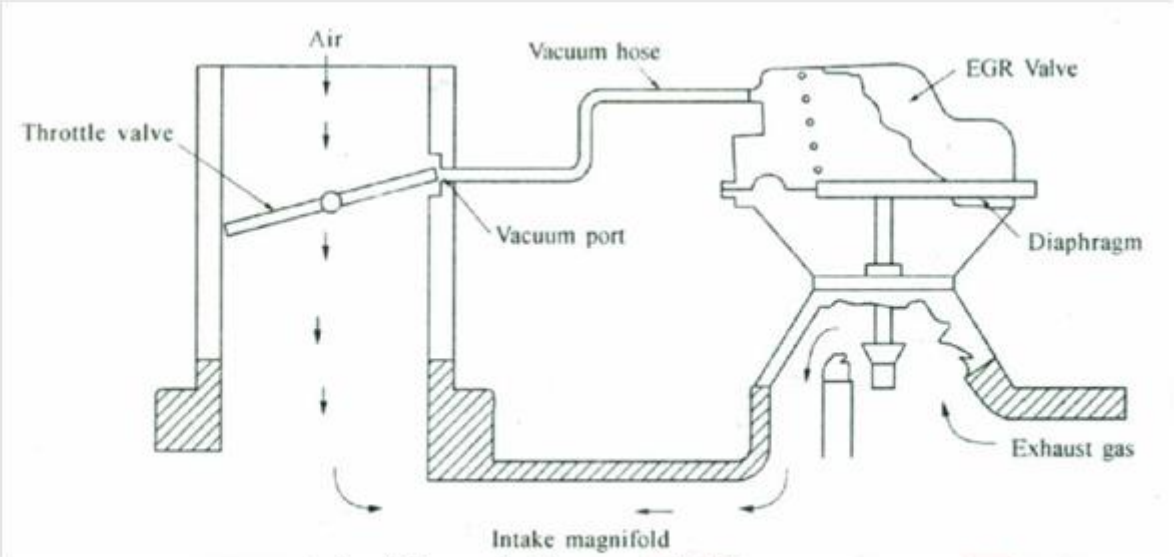


Fig: Schematic diagram of EGR system

TREATING THE EXHAUST GAS

The exhaust gas is treated before it enters in to atmosphere, to reduce amount of HC, CO and NO. This is done by injecting fresh air into the exhaust system and b passing exhaust gas through a catalytic converter.

Air injection system

In this method, the fresh air is blown into the exhaust gases after they exit combustion chamber. This provides additional oxygen to burn HC and CO coming out of cylinders and converts them into water and CO2and reduces amount of these pollutants.

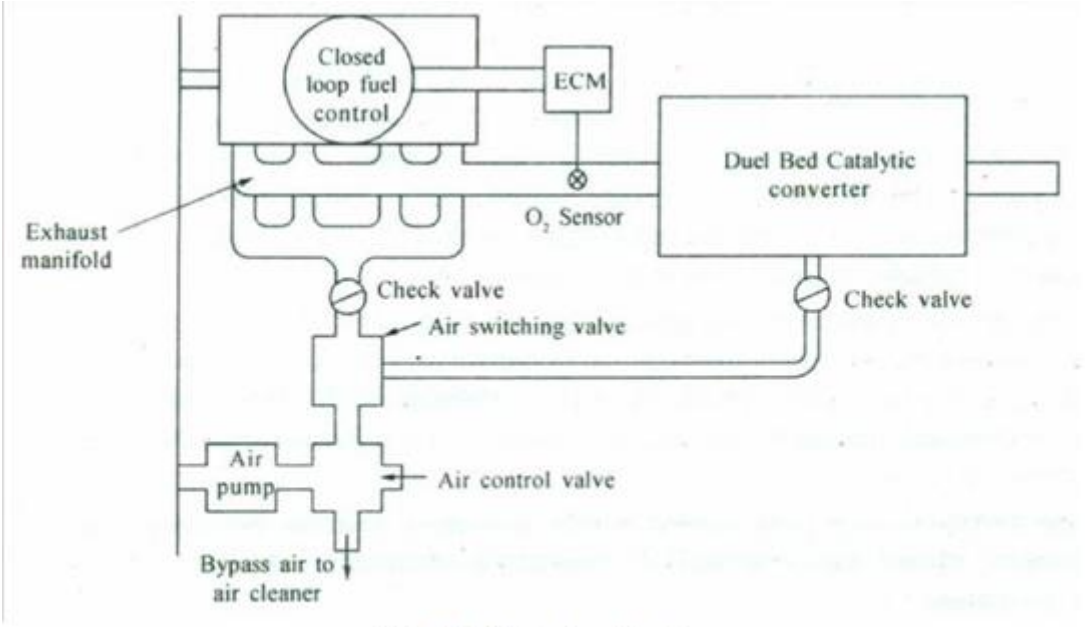


Fig: Air Injection System

The Air injection system consists of air pump, air switching and control valves and the one way check valves. When the engine is cold, the air pump pushes air through nozzles to the exhaust manifold. The nozzles are located opposite to exhaust ports and hence 02 in the air helps to burn any HC and CO in the exhaust gas in the exhaust manifold.

When the engine warms up, ECM causes the air to pass through catalytic converter, where HC and CO are converted into Hp and CO. The check valve avoids back flow of exhaust gases to the air pump incase of back fire. During deceleration, the bypass valve momentarily diverts air from air pump to the air cleaner, instead of to the exhaust manifold. This avoids back firing in the exhaust system.

Air aspirator System

Some Engines uses air aspirator valve in place of air pump. This is a one way check valve. The opening and closing of exhaust valve causes variation in the exhaust manifold pressure. When this exhaust pressure is below atmospheric, fresh air admits through air aspirator valve to the nozzles in the exhaust manifold.

The air aspirator valve closes when exhaust valve opens which causes pressure in the exhaust manifold to increase above atmospheric.

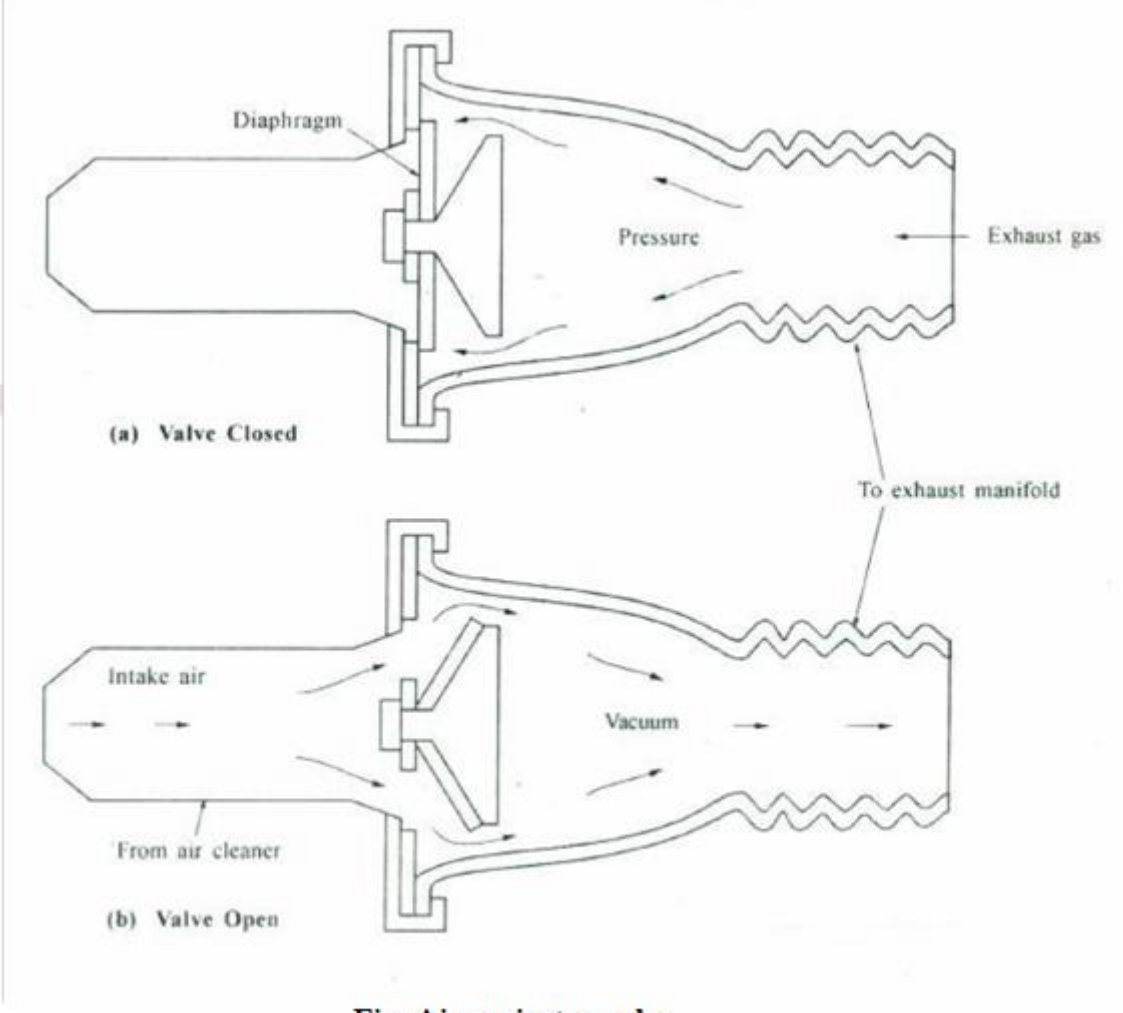


Fig: Air aspirator valve

CATALYTIC CONVERTER

The function of catalytic converter is to treat the exhaust gas to convert harmful pollutants into harmless. All exhaust gases must pass through catalytic converter which is located in exhaust system. The catalytic converter consists of a material called catalyst which causes a chemical change without entering into chemical reaction. It makes two chemicals to react with each other and hence reduces amount of HC, CO and NOx in the exhaust gases.

It consists o(two different catalysts, one to treat HC and CO and other to treat NOx' The first catalyst promotes HC to unite with °2 to produce Hp and CO_2, The second catalyst promotes CO to react with 0_2 and hence to release CO_2, As this converter oxidises HC and CO, it is known as oxidising converter. The platinum and palladium are listed as oxidising catalysts.

The catalyst used for NO, splits 0_2 and N_2 and hence NOx becomes harmless N_2 and 0_2, the converter is known as reducing converter and metal rhodium is used for this purpose. A large surface area of catalytic converter is coated with catalyst. The coated surface a area or substrate is in the form of a .bed of small beads or pellets or a ceramic honey comb. Usually honeycomb converter is round and pellet type converter is flat.

The vehicles fitted with catalytic converter in the exhaust system must use unleaded gasoline otherwise lead in the gasoline coats the catalyst and makes the converter ineffective. The air fuel ratio for the mixture must be stoichiometric ratio for effective working of the catalytic converter.

Dual Bed and Three way catalytic converters

A dual bed catalytic converter consists of two pellet beds, one over the other and are separated by an air chamber The pellets coated with three way catalyst reduce NO, into N2 and 02 is provided on the upper bed. It also helps to oxidise HC and CO. Tile lower bed acts as two way catalyst and oxidises remaining HC and CO. When the vehicle warms up, the air pump supplies secondary air to the air chamber to separate the upper and lower beds.

EMISSION STANDARDS

As vehicle populations grow and cities become more congested the allowable emissions from engines have been lowered to maintain air quality in major cities. The pollutants from vehicles cause several health problems, leads to formation of smog and affects environment. Many countries are aiming at achieving safe concentrations of these pollutants by regulating their level of emissions. Emission standards are requirements that set specific limits to the amount of pollutants that can be released into the environment. These emission standards regulate pollutants released by automobiles, industry, power plants and diesel generators etc. Generally these standards regulate the emissions of nitrogen oxides, sulphur oxides, particulate matter (PM) or soot, carbon monoxide and volatile hydrocarbons. These emission standards puts limits for conventional pollutants and regulate green house gases particularly carbon dioxide. In USA, emission standards are managed by the Environmental Protection Agency. In the state of California, California's emission standards are set to influence emission requirements that major automakers must meet. The European Union has set its own emission standards for all road vehicles, trains, barges etc. No standards apply to seagoing ships or aero planes. The European Union has introduced Euro 4 from 1-1-2008, introducing Euro 5

from 1-1-20 l0 and Euro 6 from 1-1-2014. Many of the other countries also confirm to the euro 4 standards from Jan 2009. In 198~ India introduced first Indian emission regulations to limit idle emissions. From 2000 India started adopting European emission and fuel regulations for four wheeled light duty and for heavy duty vehicles. Indian owned emission regulations still apply to two and three wheeled vehicles. All transport vehicles must have a fitness certificate that is renewed each year after the first five years of new vehicle registration.

On October 6, 2003, the National Auto Fuel Policy has been announced which envisages a phase I-program for introducing Euro 2-4 emission and fuel regulations by 20 I O.

The table shows the implementation schedule of EU emission standards in India.

Standard	Reference	Date	Region
India 2000	Euro 1	2000	Nation wide
Bharat Stage II	Euro2	2001	Delhi, Mumbai, Kolkata, Chennai
Bharat Stage III	Eur03	2005	Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Ahmedabad, Pune, Kanpur and Agra
		2010	Nation wide
Bharat Stage IV	Eur04	2010	Delhi, Mumbai, Kolkata, Chennai, Hyderabad, Ahmedabad, Pune, Kanpur and Agra

For Two and Three wheelers, Bharat Stage II (Euro 2) was recommended from April 1, 2005 and Bharat Stage III (Euro 3) was applied from April 1, 2008.

Emission Standards for Diesel Truck and Bus Engines, g/kWh

Year	Reference	CO	HC	NO	PM
1992	- -	17.3 - 32.6	2.7 - 3.7	x - -	- -
1996	- -	11.20	2.40	14.4	- -
2000	Euro I	4.5	1.1	8.0	0.36
2005	Euro II	4.0	1.1	7.0	0.15
2010	Euro III	2.1	0.66	5.0	0.10

Emission Standards for Light-Duty Diesel Vehicles, g/km

Year	Reference	CO	HC	HC+NO x	PM
1992	-	17.3 - 32.6	2.7 - 3.7	-	-
1996	-	5.0 - 9.0	-	2.0 - 4.0	~
2000	Euro I	2.72 - 6.90	-	0.97 - 1.70	0.14 - 0.25
2005	Euro2	1.0 - 1.5	-	0.7 - 1.2	0.08 - 0.17

Emission Standards for Light-Duty Diesel Engines, g/kWh

Year	Reference	CO	HC	NO	PM
1992	-	14.0	3.5	• 18.0	-
1996	-	11.20	2.40	14.4	-
2000	Euro I	4.5	1.1	8.0	0.36*
2005	Euro II	4.0	1.1	7.0	0.15

Emission Standards for Gasoline Vehicles (GVW s 3,500 kg), g/km

Year	Reference	CO	HC	HC+NO
1991	-	14.3-27.1	2.0 - 2.9	, -
1996	-	8.68 - 12.4	-	3.00 - 4.36
1998*	-	4.34 - 6.20	-	· 1.50 - 2.18
2000	Euro I	2.72 - 6.90	-	0.97 - 1.70
2005	Euro II	2.2 - 5.0	-	0.5 - 0.7

* For catalytic converter fitted vehicles

Emission Standards for 3-Wheel Gasoline Vehicles, g/km

Year	CO	HC	HC+NO x
1991	12 - 30	8 - 12	
1996	6.75	-	5.40
2000	4.00	-	2.00
2005 (BSII)	2.25	-	2.00

Catalytic converters have been instrumental in reducing emissions of harmful gases from vehicles since their inception in response to the US Clean Air Act of 1970. Regulated emissions have been reduced approximately 1/3 while the number of cars on the road have more than doubled. Platinum, palladium and rhodium are essential components in automobile catalytic converters reducing engine-out emissions by well over 90%, and in some cases by over 99%.

Overview of the emission norms in India

1) 1991 - Idle 'CO' Limits for Gasoline Vehicles and Free Acceleration Smoke for Diesel Vehicles, Mass Emission Norms for Gasoline Vehicles.

2) 1992 - Mass Emission Norms for Diesel Vehicles.

3) 1996 - Revision of Mass Emission Norms for Gasoline and Diesel Vehicles, mandatory fitment of Catalytic Converter for Cars in Metros on Unleaded Gasoline.

4) 1998 - Cold Start Norms Introduced.

5) 2000 - India 2000 (Eq. to Euro I) Norms, Modified IDC (Indian Driving Cycle), Bharat Stage II Norms for Delhi.

6) 2001 - Bharat Stage II (Eq. to Euro II) Norms for all Metros, Emission Norms for CNG & LGP Vehicles.

7) 2003 - Bharat Stage II (Eq. to Euro II) Norms for 11 major cities.

8) 2005 - From 1st April Bharat Stage III (Eq. to Euro III) Norms for 11 major cities.

9) 2010 - Bharat Stage III Emission Norms for 4-wheelers for entire country whereas Bharat Stage - IV (Eq. to Euro IV) for 11major cities. Bharat Stage IV also has norms on OBD (similar to Euro III but diluted).