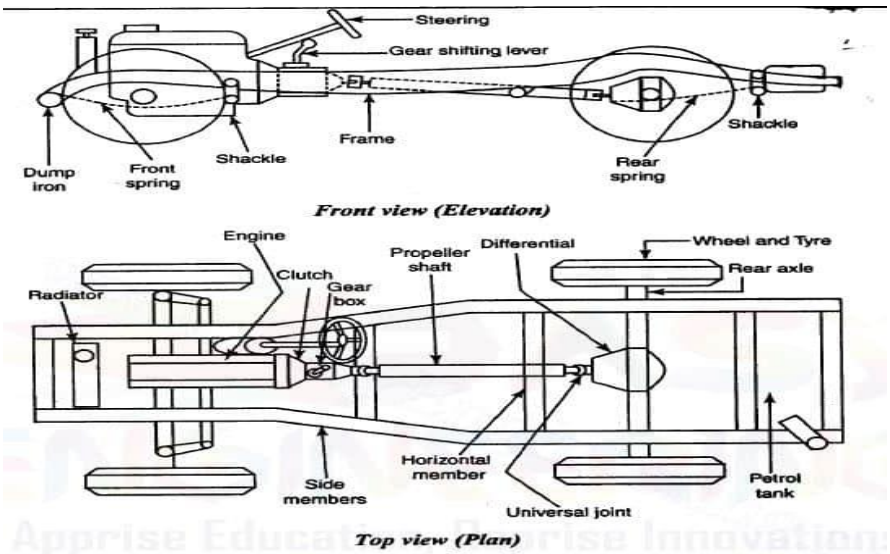
UNIT – I

Introduction to vehicle structure and engine components

- Vehicle structure comprises the chassis, which provides support and houses essential components.
- The chassis connects to the suspension system, ensuring stability and ride comfort.
- Body panels, made of materials like steel or aluminum, form the outer structure of the vehicle.
- The engine, a central component, converts fuel into mechanical energy to propel the vehicle.
- Engine components include cylinders, pistons, and a crankshaft, crucial for power generation.
- The transmission system transfers power from the engine to the wheels, enabling movement.
- Fuel systems manage the delivery and combustion of fuel to optimize engine performance.
- Exhaust systems expel combustion byproducts, enhancing engine efficiency.
- Cooling systems, like radiators, prevent engine overheating by regulating temperature.
- The intricate interplay of these components ensures a vehicle's functionality and performance.

VEHICLE CONSTRUCTION



Vehicle construction involves assembling structural components to create a durable and safe framework. The frame or chassis is the foundation, providing support for the entire vehicle structure. Body panels, made from various materials, give shape and protection to the vehicle. Suspension systems, including shocks and struts, contribute to ride comfort and handling. Interior components, such as seats and dashboard, enhance the user experience.

Safety features like airbags and crumple zones are integrated to protect occupants during collisions. The windshield, windows, and mirrors form the vehicle's visibility and awareness elements. Wiring and electrical systems power lights, sensors, and other electronic components. Advanced materials like high-strength steel and aluminum are used to optimize strength-to-weight ratios. Rigorous testing ensures vehicles meet safety and quality standards before reaching the market.

Chassis and body

The chassis of an automobile consists of following components suitably mounted:

(i) Engine and the radiator.

(ii) Transmission system, consisting of the clutch, gear box, propeller shaft and the rear axle.

(iii) Suspension system.

(iv) Road wheels.

(v) Steering system.

(vi) Brakes.

All the components listed above are mounted in either of the two ways, viz., the conventional construction, in which a separate frame is used and the frameless or unitary construction in which no separate frame is employed. Out of these, the conventional type of construction is being used presently only for heavy vehicles whereas for car the same has been replaced by the frameless type or the monologue chassis is manufactures, who still find it economical to use frame.

Chassis are classified as

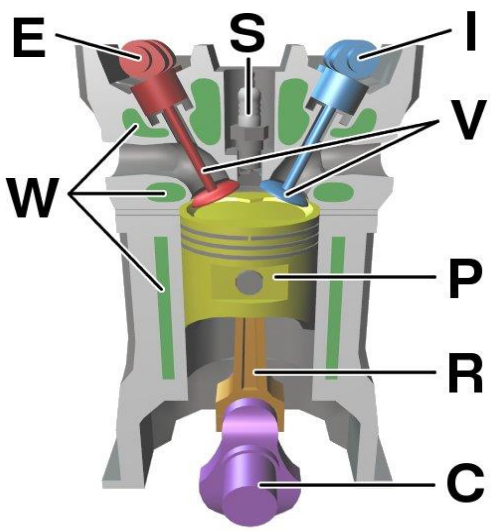
(1) Conventional control chassis: in which engine is mounted in front of the driver's cabin. This type of arrangement avoids full utilization of the space.

(2) Semi-forward control chassis: in which engine is so mounted that half of it is in the driver's cabin whereas the other half is in front, outside the driver's cabin. Tata SE series of vehicles are example of this type of chassis.

(3) Full-forward control chassis: in which the engine is mounted completely inside the driver's cabin. Obviously maximum utilization of space is achieved in this type of arrangement. Tata E series of vehicles are example of this type of chassis.

ENGINE: -

An engine is an energy converting device. Used to convert the heat energy produced by the combustion of fuel into mechanical energy. This mechanical energy is utilized for moving an automobile.



Engine Constructional Details:

The main parts of an engine are

- Cylinder or Cylinder block
- Cylinder liner
- Piston
- Connecting rod

- Crank shaft
- Piston pin
- Main bearings
- Valves …etc.,

LOCATION OF ENGINE

The engine in a vehicle is typically located in the front, either in the front-center or front-left part of the car. In some vehicles, especially those with rear-wheel or all-wheel drive, the engine may be situated towards the rear.

Cylinder arrangement

Automobiles commonly feature engines with cylinders arranged in configurations such as inline, V-shaped, or horizontally opposed. An inline arrangement has cylinders positioned in a single line, offering simplicity and compactness. V-shaped configurations involve cylinders arranged in two banks, forming a V shape, providing a balance between space and performance. Horizontally opposed layouts have cylinders positioned opposite each other, contributing to a lower center of gravity and better balance. The number of cylinders varies, with four, six, and eight-cylinder engines being common in different vehicles. Engine design impacts factors like power delivery, fuel efficiency, and overall vehicle performance. The arrangement affects the engine's smoothness, with some configurations providing better balance and reduced vibrations. V8 engines, with eight cylinders in a V-shaped configuration, are often associated with high-performance and sports cars. Inline-four configurations are widely used in compact and fuel-efficient vehicles. The choice of cylinder arrangement depends on the vehicle's intended use, performance goals, and design considerations.

Cylinder Block: -

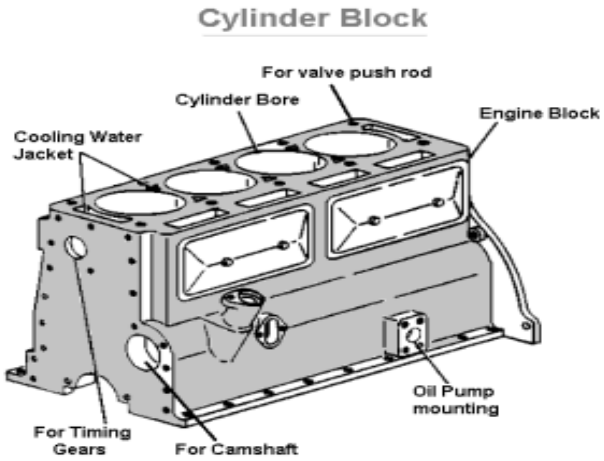
Cylinder block forms the very base of the engine with cylinders formed in it

- Cylinder block consists of three parts:
- The Cylinders in which pistons move up and down
- The ports or openings for the valves

- The passages for the flow of cooling water
- In modern engines Cylinder block and Crank case form a single casting.
- This gives advantages like increased rigidity and reduced cost.
- Sheet metal core plugs made of steel, copper or brass are used to close the holes in the casting.

Based on Number of Cylinders

- Single-Cylinder Engines
- Multi-Cylinder Engines
  1. In-Line
  2. Radial
  3. V-type
  4. Opposed-Piston
  5. Opposed-Cylinder



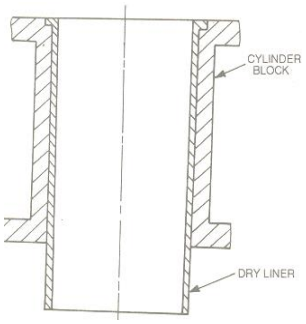
Cylinder Head;

- The top of the cylinder is covered by a separately cast piece known as the Cylinder Head
- It is bolted to the top of the Cylinder Block
- It contains combustion chamber, spark plug and sometimes valves
- It also incorporates passages for cooling water circulation
- The cylinder head is usually made of Grey Cast Iron or Aluminum Alloy
- To retain compression in the cylinder, a flat piece of gasket is placed between the cylinder head and cylinder block.

Cylinder Liners:-

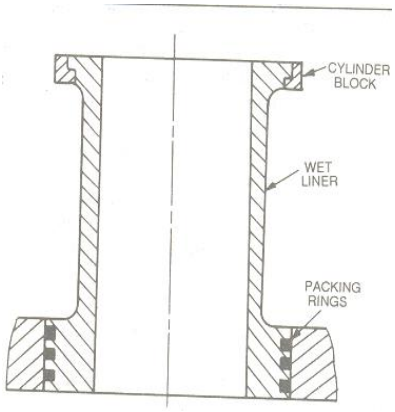
- The cylinder block is usually made of grey cast iron
- Grey cast iron has good cast ability and machining quality but do not have a good wear resistance
- Cylinders are subjected to high temperatures requiring wear resistant properties elevated temperatures. In order to fulfill such a condition Cylinder Liners are used.
- Cylinder liners are made of special alloy cast iron.
- Cylinder liners are of two types:
  - Dry Liners
  - Wet Liners

Dry Liners;



- Dry liner is made in the shape of a barrel having a flange at the top which keeps it into position in the cylinder block
- The entire outer surface of the dry liner bears against the cylinder block casting
- Thus it is not in direct contact with the cooling water; hence it is called as dry liner.
- Therefore, a dry liner has to be machined accurately on outer surface also
- Dry liners thickness usually ranges from 1.5 to 3 mm
- These liners are replaced when worn out.

Wet Liners;

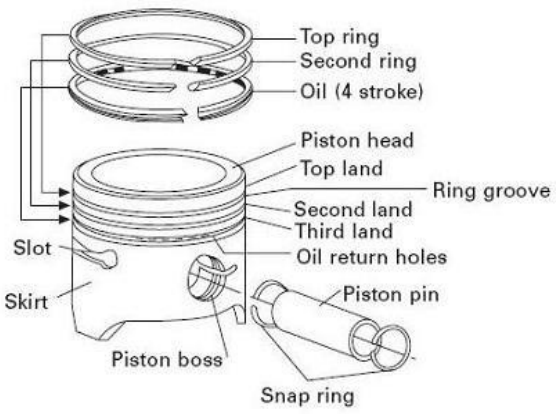


- The outer surface of these liners have direct contact with the cooling water Therefore they are called as Wet Liners
- A wet liner is provided with a flange at the top which fits into the groove in the cylinder block.
- At the bottom either a block or the liner is provided with grooves, generally three in numbers
- Packing rings made of rubber are inserted into the bottom grooves
- The outer surface of a wet liner does not require accurate machining

Piston;

- It is an important component of an engine
- It helps in converting chemical energy of fuel into mechanical energy
- Main function of piston is to provide a means of conveying expansion of gases to the crank shaft through connecting rod

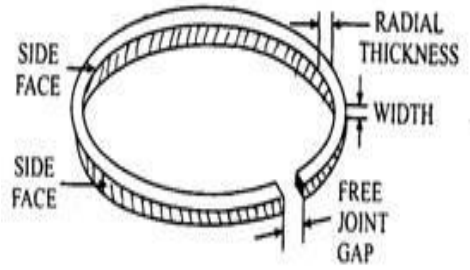
Parts of a Piston



- Piston Head or Crown
- Top Land
- Ring Groove
- Skirt
- Piston Boss
- Slots
- Oil return holes

Piston rings;

- Piston rings are of two types
    - Compression Rings
    - Oil Control Rings



Compression Rings;

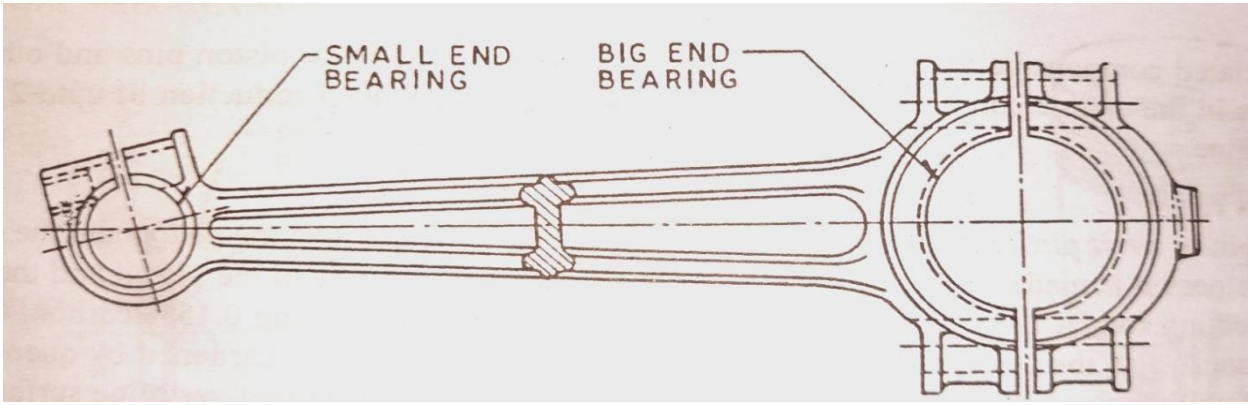
- Compression Rings seal in the air-fuel mixture as it is compressed
- Also seal the combustion pressure as the air-fuel mixture burns.

Piston Pin;

- Must be strong to withstand forces of combustion
- Must be free to rotate in piston and connecting rod
- To connect Piston with small end of the connecting rod
- Piston pin are made up of Nickel Chromium Alloy steel

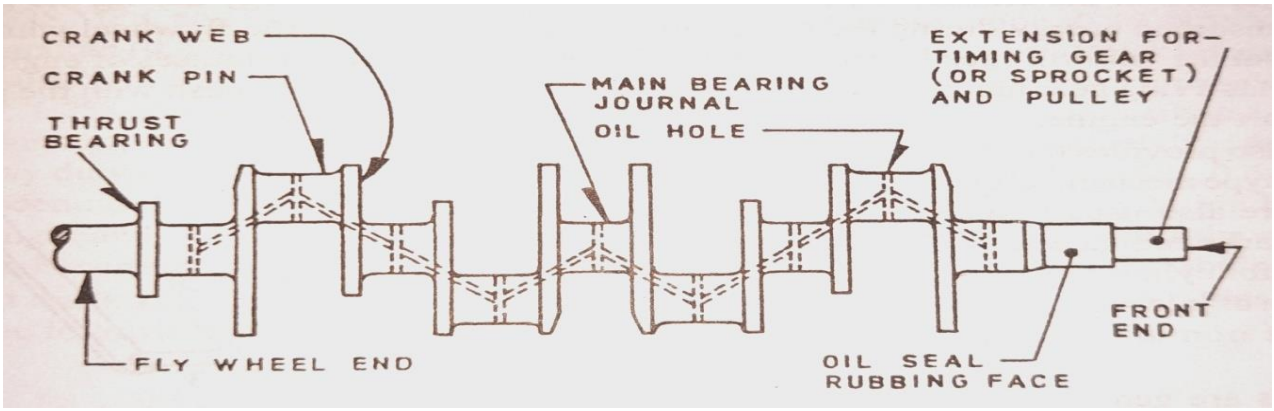
Connecting Rod;

- Connecting Rod is connected between Piston and the Crank shaft
- It has Small end and big end
- The small end is connected to Piston through piston pin
- The big end is connected to the Crank Pin of the Crankshaft.
- The function of connecting rod is to convert reciprocating motion of the piston into the rotary motion of the crank shaft.
- To reduce the obliquity of the rod with the cylinder axis, its length should be kept as large as possible.
- It possesses oscillatory motion.
- It usually has I-beam cross section
- Connecting rod is made up of Drop forged Alloy Steel



Crankshaft;

- The engine component from which the power output is taken to drive wheels
- The crank shaft assembly includes:
    - Main Journals
    - Crank Pins
    - Crank Webs
    - Counter Weights
    - Oil Holes. And Flywheel mounting flange



The function of a crank shaft is to convert the reciprocating motion of the piston into rotary motion.

- Should have high fatigue and creep strengths
- Should withstand the thrust of Piston
- It is free to revolve in the main bearings of the engine.
- Oil holes are provided in the crank shaft to carry lubricating oil to main bearings
- The counter weights are to balance the rotary masses.
- The crankshaft is manufactured by drop forging process or in some cases it is machined and then heat treated.

Crankshaft is made by the material of Forged Steel or Heat –treated Alloy Steel

ENGINE VALVES

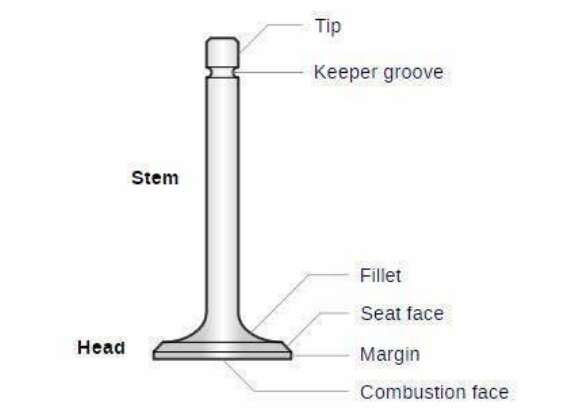
To admit the air-fuel mixture in the engine cylinder and to force the exhaust gases out at correct timings, some control system is necessary, which is provided by the valves.

The engine valves may be broadly divided into 3 main categories:

1. Poppet valve

2. Sleeve valve

3. Rotary valve



Out of these three, poppet valve is the one which is being universally used for automobile engines. It will be discussed.

Construction:

The poppet valve derives its name from its motion of popping up and down. This is also called "mushroom valve" because of its shape which is similar to a mushroom. It consists of a head and a stem as shown in Fig. 4.13. It possesses certain advantages over the other valve types because of which it is extensively used in the automotive engines:

1. Simplicity of construction.

2. These are self-centering.

3. These are free to rotate about the stem-axis to new position.

4. Maintenance of sealing efficiency is relatively easier in their case.

Lubrication system

Lubrication circuit is one of the most important ones in the engine. The engine cannot run smoothly for more than a few minutes without lubricating oil.

Types of Lubricants

- Animal oils
- Vegetable oils
- Mineral oils
- Synthetic lubricants
- Greases
- Solid lubricants

Animal Oil;

- Obtained from animal fat
- Becomes gummy after some time, so not suitable for Automobile lubrication.

Vegetable oil;

- Produced from seeds, fruits of plants and trees
- Castor oil was used in olden days because of its high viscosity and high film strength
- They oxidize easily, becomes gummy, so not suitable for Automobile Lubrication

Mineral oil;

- Derived from petroleum

Most widely used in automobiles because of it's:

- Greater chemical stability at high temperatures
- Less tendency to form emulsions with water
- Abundantly available and cheap

Synthetic oil;

- Consisting of chemical compounds which were not originally present in petroleum but were artificially made.
- Examples of synthetic oil are:
- Silicon fluids
- Polyglycol ethers

Advantages of Synthetic Oil over Mineral Oils

- Higher viscosity
- Reduced lacquer formation
- Reduced loss due to evaporation
- Less engine deposits
- Increased fuel economy
- Less frequent changes of lubricating oil
- Less oil consumption

Limitations of Synthetic Lubricants

- High cost

Greases;

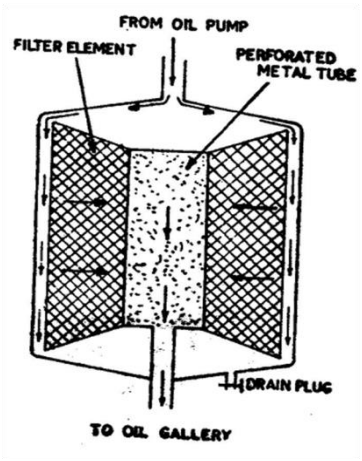
- They are suspensions of metallic soaps (calcium or sodium soaps of fatty acids) dispersed in lubricating oil
- Find use at places where retention of liquid lubricants is difficult and where high temperatures are encountered. Ex: axles, wheel bearings, chains etc

There are two types of filters they are:

- Primary filter
- Secondary filter

Primary Filters;

- Primary filters are also known as Surface Filters since the impurities are retained on the outer surface of the filters
- It uses wire gauze or coarse filter material
- It is installed on the inlet side of the oil pump
- Strainers are primary filters



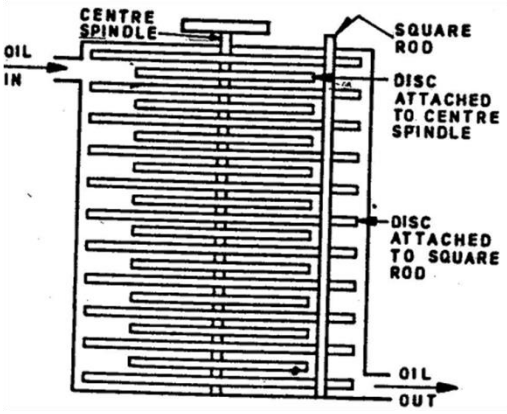
Secondary Filters;

- Secondary filters are also called as depth filters because impurities are retained along the depth of filter material
- It is installed on the outlet side of oil pump
- There are different types of secondary filters

Types of oil filters:

1) Cartridge type
2) Edge type
3) Centrifugal type

Cartridge Type Oil Filter;



- Most widely used
- The element is given pleated form to increase surface area
- The impure oil is made to pass through the filter element which takes up all the impurities
- Latest filter elements made of fine pores can arrest particles of size down to 5 microns
- Filter elements available are two types. One can be cleaned and the other cannot be cleaned.

- Impure oil enters from the top and passes through the filter element as shown by arrows. The pure oil then goes through the porous metallic tube from there goes to the outlet for circulation

Edge Type Oil Filter;

- It is also called as Stack type filter
- Oil pass through a number of closely spaced discs
- The alternate discs are mounted over a central spindle
- The discs in between these are attached to a separate fixed spindle as shown in Fig 10
- The clearance between two successive discs is a few microns
- The oil is made to flow through the spaces between these discs and because of very small spaces impurities are left on the disc peripheries
- The collected impurities are periodically removed by simply operating the central knob.
- This may be done either manually or the knob may be connected to clutch system and operated periodically by means of clutch action.

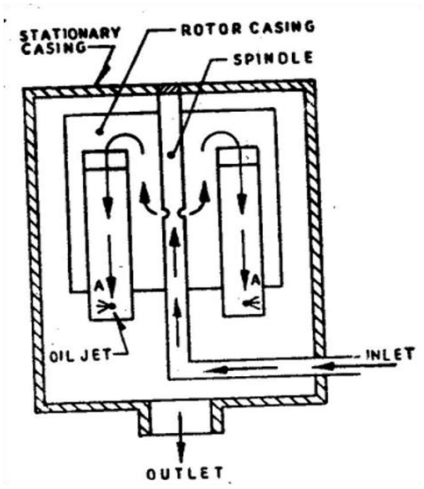
Centrifugal Type Oil Filter;

- In this impure oil from the engine enters the hollow central spindle having holes around its periphery.
- The dirty oil comes out of these holes and fills the rotor casing.
- Then the oil passes down the tubes **A** at the ends of which jets is attached.
- The oil under pressure passes through these jets, the reaction of which gives the motion to the rotor casing opposite direction so that it starts rotating
- The oil impinges on the outer stationary casing with heavy pressure, where the impurities are retained.
- Clean and filtered oil falls below from where it is taken out and supplied to the Oil gallery
- The working speed of rotor is usually between 2000 to 7000 rpm
- The filter walls have to be cleaned at intervals of about 70,000 kms.

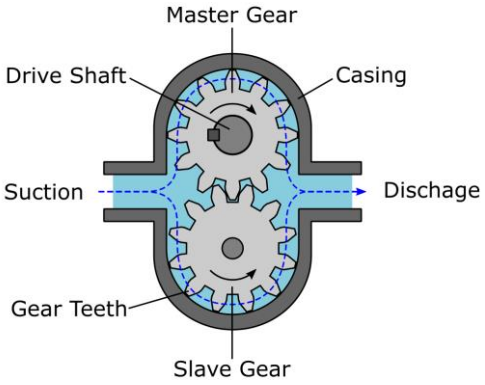
Oil pumps

The different types of pumps used in engine lubrication are:

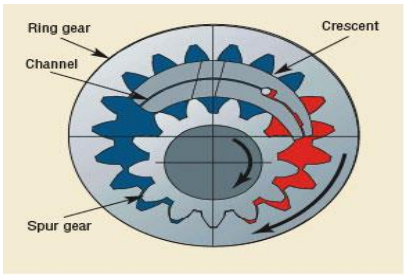
- Gear pump
- Crescent type gear pump
- Rotor pump
- Plunger pump
- Vane pump



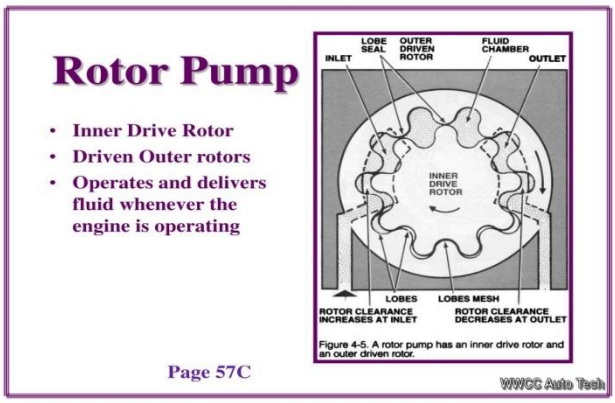
Gear pump: Gear pumps in automobiles utilize meshing gears to circulate oil, driven by the engine's mechanical motion. These pumps are reliable and cost-effective, providing essential lubrication for engine components.



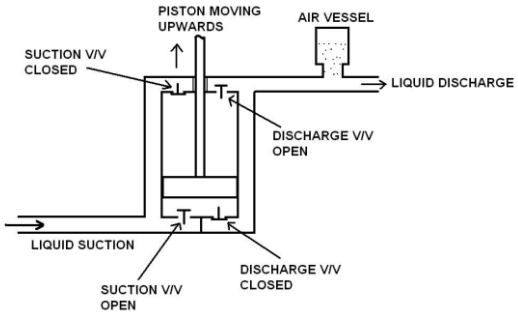
Crescent type gear pump: Crescent pumps in automobiles, featuring a crescent-shaped space between a rotor and stator, ensure efficient oil circulation, enhancing lubrication and minimizing friction for optimal engine performance.



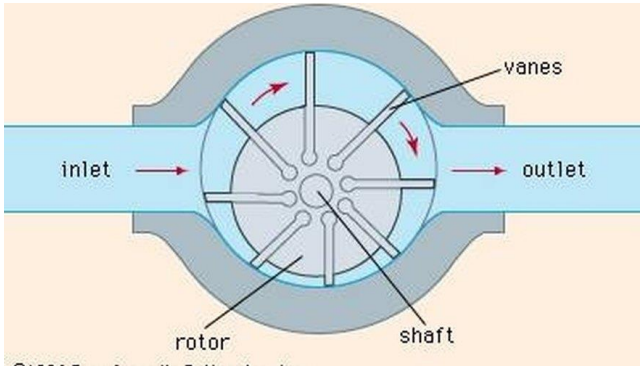
Rotor pump: A rotor pump in automobiles is a positive displacement pump used to circulate fluids, such as oil or fuel, within the engine. It consists of rotors that create a continuous flow, ensuring efficient lubrication and cooling for various engine components. This design enhances overall performance and longevity.



Plunger pump: In automobiles, a plunger pump is commonly used as a high-pressure fuel pump in fuel injection systems. It plays a crucial role in delivering fuel with precision to the engine's combustion chamber. The plunger pump operates by reciprocating plungers to create high-pressure pulses that ensure efficient fuel atomization for combustion. This design enhances engine performance and fuel efficiency.



Vane pump: A vane pump in automobiles is a type of hydraulic pump that uses rotating vanes to generate fluid flow, commonly employed in power steering systems for smooth and controlled steering assistance.



Crankcase Ventilation:

Crankcase Ventilation (CV) is a system used in internal combustion engines to manage and control the gases that accumulate in the crankcase, the area where the engine’s pistons move up and down. The CV system helps prevent the buildup of harmful fumes, oil vapors, and blow-by gases that result from the combustion process. It consists of a valve, typically located in the engine’s valve cover, and a series of tubes or hoses.

UNIT – II

Ignition and fuel supply System

The function of the ignition system is to produce a spark in the engine cylinder towards the end of the compression stroke. In a four-stroke engine, a spark should occur in each cylinder after two revolutions of the crankshaft, whereas in a two-stroke engine a spark in each cylinder is required every revolution of the crankshaft. Thus, for instance, in a 6-cylinder 4 stroke engine running at 5000 rpm., the number of sparks required per minute will be 15000 and these have to be timed very accurately.

The ignition system in an automobile is a crucial component responsible for initiating the combustion process in the engine. It ensures the timely and controlled ignition of the fuel-air mixture, allowing the engine to generate power. The system typically consists of a battery, ignition switch, ignition coil, distributor, spark plugs, and related wiring.

1. *Battery:* The electrical energy needed for the ignition system is supplied by the car's battery.

2. *Ignition Switch:* This switch activates the ignition system and controls the flow of electrical current.

3. *Ignition Coil:* Converts low-voltage electrical power from the battery into high-voltage energy needed for spark generation.

4. *Distributor:* Distributes high-voltage electricity from the ignition coil to the spark plugs in a specific firing order.

5. *Spark Plugs:* Small devices that create sparks to ignite the fuel-air mixture in the engine cylinders.

6. *Spark Plug Wires:* Connect the distributor to the spark plugs, ensuring the transfer of high-voltage electricity.

7. *Rotor and Cap:* In distributor-based systems, these components aid in the precise distribution of high-voltage current to each spark plug.

8. *Ignition Timing:* The system regulates when the spark plugs fire, optimizing engine performance and fuel efficiency.

9. *Crankshaft Position Sensor:* Modern systems use sensors to determine the position of the crankshaft, aiding in accurate ignition timing.

10. *Camshaft Position Sensor:* Provides additional information about the engine's position, contributing to precise ignition timing.

11. *Engine Control Unit (ECU):* The ECU manages the ignition system, processing data from various sensors to optimize performance.

12. *Coil-on-Plug System:* Some modern engines feature individual ignition coils for each spark plug, eliminating the need for a distributor.

13. *Electronic Ignition System:* Replaced traditional mechanical points with electronic components for more precise ignition control.

14. *Knock Sensor:* Detects engine knocking and adjusts ignition timing to prevent damage and improve efficiency.

15. *Misfire Detection: * Monitors the firing of spark plugs, identifying and correcting misfires to maintain smooth engine operation.

Together, these components form a complex yet integral system that plays a vital role in the overall functioning of an automobile's engine.

Types of Ignition System

Following are the types of ignition system:

- Battery ignition system or coil ignition system
- Magneto ignition system.
- Electronic Ignition System.

Both the ignition system is based on the principle of common electromagnetic induction. The battery ignition system is mostly used in passenger cars and light trucks.

In the battery ignition system, the current in the primary winding is supplied by the battery. In the magneto to the ignition system, the magneto produces and supplies the current in the primary winding.

Ignition System Parts

- Battery,
- Switch ignition distributor
- Ignition coil
- Spark plugs and
- Necessary wiring.

Some system uses transistors to reduce the load on the distributor contact points. Other systems use a combination of transistors and magnetic pickup in the distributor.

Compression ignition engine does not have such an ignition system. In a compression ignition engine, only air is compressed in the cylinder. And at the end of the compression stroke, the fuel is injected which catch fire due to the high teratu

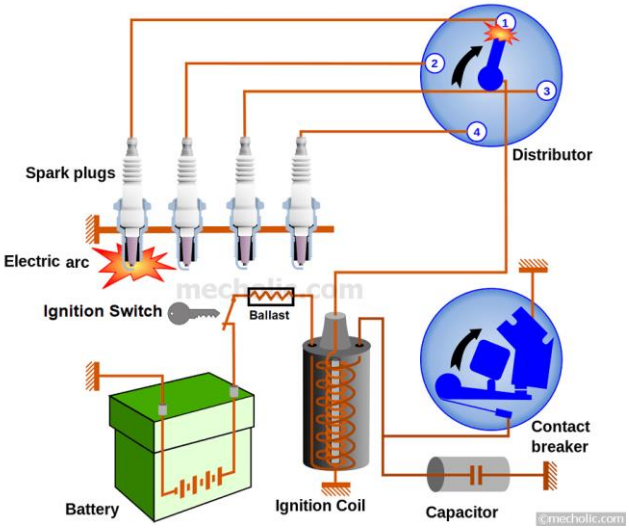
Battery Ignition System

The figure shows the battery ignition system for a 4 cylinder engine. A battery of 12 volts is generally employed. There are two basic circuits in the stem circuits.

The first circuit has the battery, primary winding of the ignition coil, condenser, and contact breaker from the primary circuit. Whereas the secondary winding of the ignition coil, distributor, and spark plugs forms the secondary circuits.

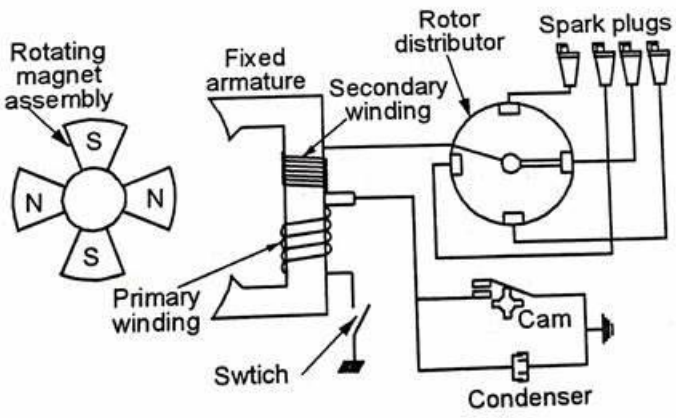
The value of the voltage depends upon the number of turns in each coil. The high voltage, 10,000 to 20,000 volts, then passes to a distributor.

It consists of the cylinder's spark plug in rotation depending upon the engine's firing order. This causes a high-intensity spark jumps across the gap. Thereby ignition of the air-fuel mixture takes place in all the cylinders. The battery ignition system has massive use in cars, light trucks, buses, etc.



Magneto Ignition System

The magneto ignition system has the same principle of working like that of the battery ignition system. In this, no battery is required, as the magneto acts as its own generator.

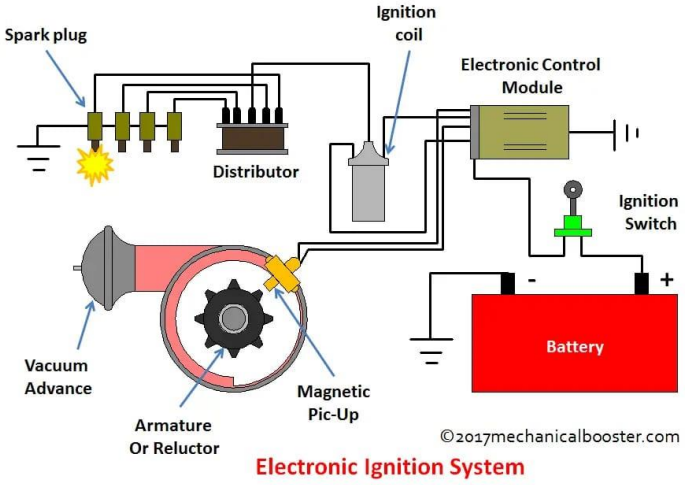


It consists of either rotating magnets in fixed coils or rotating coils in fixed magnets. The current produced by the magneto flows to the induction coil, which works like that of the battery ignition system.

This high voltage current is then made to flow to the distributor, which connects the sparking plugs in rotation depending upon the engine's firing order. This type of ignition system is used in small spark-ignition engines, for example, Scooters, Motorcycles, and small motorboat engines.

Electronic Ignition System

The conventional electro-mechanical ignition system uses mechanical contact breakers. Though it is very simple, it suffers from certain limitations as follows.



Electronic Ignition System

The contact breaker points handle the heavy current. This results in burn out of contact points. Thus it requires periodical servicing and settings.

The mechanically operated contact breaker has inertial effects. Hence at higher speeds, the make or break of contact may not be timed.

At higher speeds, the dwell time for building up the current in the coil to its maximum value is low. Thus the spark strength may be reduced.

To overcome the above drawbacks, in modern automobiles, electronic ignition systems are used. This electronic ignition system performs best at all varying conditions and speeds, unlike electro-mechanical systems.

IGNITION COIL

An ignition coil is an induction coil that is used to increase the low voltage of the battery (12 Volt) to a very high voltage (about 50,000 Volt) to produce a spark within the engine cylinder for the combustion of fuel. It is used in automobile ignition systems The ignition coil mainly consists of a primary winding, a secondary winding, and an iron core. When the current through the primary winding makes and breaks repeatedly by contact breaker, it induces a very high voltage in the secondary winding (about 50000 V). This high voltage from the secondary winding is transferred to the spark plug through ignition distributor to produce spark within the cylinder 1. The various main parts of the ignition coil are:

- Primary Winding
- Secondary Winding
- Iron Core

The primary winding is made up of thick copper wire having 200 to 300 turns insulated from each other. The secondary winding is made up of thin copper wire having a large number of turns about 21000 turns. The wires in the secondary winding are insulated from each other by enamel on the

wire. The iron core consists of a laminated iron core. It is used to store energy in the form of a magnetic field .

MAGNETO IGNITION

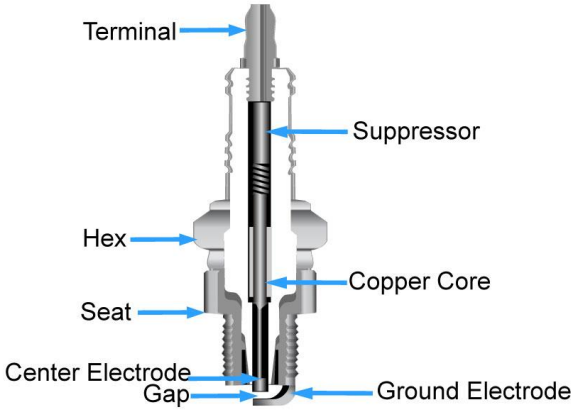
The Magneto Ignition system does not require a battery. It generates its own voltage for the primary. Magneto Ignition system is being extensively used in mopeds, scooters, wheelers, motorcycles, stationary engines, and aircraft reciprocating engines.

Spark plug:

Spark plugs play a crucial role in the functioning of internal combustion engines within automobiles. These small but essential components are responsible for igniting the air-fuel mixture in the engine cylinders, initiating the combustion process that powers the vehicle. A spark plug consists of a center electrode, an insulator, and a ground electrode. When high voltage is applied to the spark plug, a spark jumps the gap between the center and ground electrodes, igniting the fuel and air mixture.

Regular maintenance of spark plugs is vital for optimal engine performance. Over time, spark plugs can accumulate carbon deposits and wear out, leading to inefficient combustion and reduced fuel efficiency. Mechanics often recommend checking and, if necessary, replacing spark plugs at regular intervals to ensure smooth engine operation. Upgrading to higher-quality or performance-oriented spark plugs can sometimes enhance combustion efficiency, leading to improved power output and fuel economy.

In summary, spark plugs are indispensable components in the internal combustion process of automobiles. Their proper maintenance and periodic replacement contribute to the overall health and efficiency of the engine, ensuring reliable performance and extending the lifespan of the vehicle.



Distributor:

Situated in the same housing as the contact breaker, is the ignition distributor. However, in practice, the whole housing is called the distributor which contains the contact breaker, condenser, ignition advance mechanism and the distributor proper. The function of the distributor is to distribute the high voltage impulses to each of the sparking plugs at regularly timed intervals in the sequence of the engine's firing order. The common firing orders are:

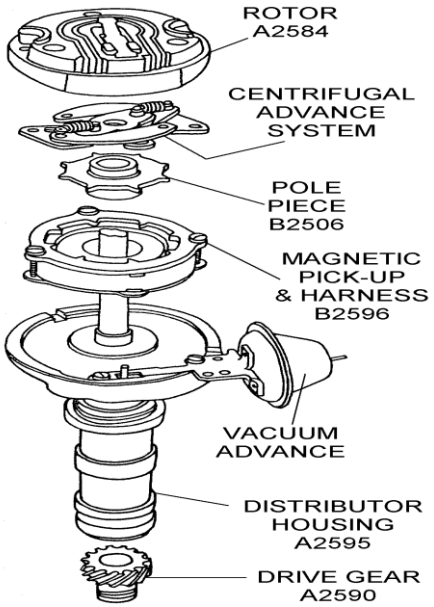
4-cylinder in-line engine 1-3-4-2 or 1-2-4-3

6-cylinder in-line engine 1-5-3-6-2-4

8-cylinder in-line engine1-4-7-3-8-5-2-6

8-cylinder v-type engine1-5-4-8-6-3-7-2

Working principle of distributor:



The distributor in an automobile plays a pivotal role in the ignition system. Its primary function is to manage the timing and distribution of high-voltage electrical pulses to the engine's spark plugs, ensuring efficient combustion. Connected to the ignition coil, the distributor rotates as the engine operates. As it spins, it directs the electrical current to each spark plug in the engine's firing order, promoting synchronized and timed ignition. This sequential firing prevents misfires and optimizes engine performance. While older vehicles commonly feature distributors, many modern cars utilize distribute or less ignition systems (DIS) for enhanced reliability and precision in spark timing. The distributor's significance lies in its ability to coordinate the ignition process, contributing to the overall efficiency and smooth operation of the automobile engine.

Fuel supply system;

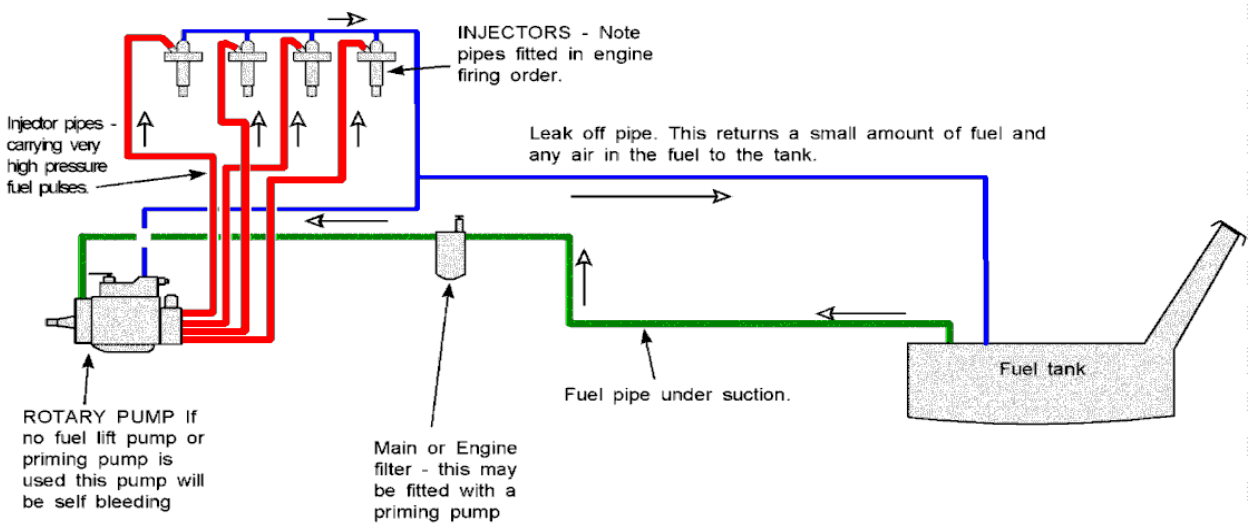
- To supply fuel as per the required quantity and required air fuel ratio to the engine.

Types of Fuel supply systems

1. Gravity System
2. Pressure System
3. Vacuum System
4. Pump System
5. Petrol Injection System

Requirements of Diesel Engine Fuel Supply System

- Fuel supply should be in a defined period of cycle
- Fuel should be metered very accurately
- Quantity of fuel should vary to meet changing speed and load.
- Fuel must be broken in to very fine droplets



Components of Diesel Engine Fuel System

- ***Fuel tank*:** To store the diesel usually made of pressed steel
- ***Feed Pump*:** To supply fuel from the fuel tank to the fuel injection pump through fuel filters
- ***Fuel Filters:*** To filter fuel before supplying to Fuel Injection Pump. Usually two filters are used; Primary and Secondary
- ***Fuel Injection Pump (FIP):*** To deliver diesel under pressure to the injectors.
- ***Hand Primer***: A hand priming pump to feed fuel from tank to FIP for starting the engine and to bleed air from the system.

- ***Fuel Injector***: To inject fuel into the combustion chamber in atomized state and with high pressure.
- ***Governor***: To regulate the input fuel supply in accordance with engine load
- ***Fuel lines***: To carry fuel through different components of the fuel system

Carburetion;

- Introduction No Substance can burn in the vacuum.
- Any fuel cannot burn without the presence of oxygen.
- Petrol alone cannot burn.
- Petrol plus air mixture is required for combustion.
- Petrol plus air mixture is prepared outside the combustion chamber of a petrol engine.

It is the process of:

- Mixing of air with petrol in a stochiometric ratio is called carburetion.
- During this process the fuel is Atomized and Vaporized and then mixed with air.
- Carburetion process is achieved in the carburetor or in the inlet manifold.
- Due to volatility most of the fuel vapors and forms fuel air mixture.

Factors Effect The Process of Carburetion:

- Time available for preparation of mixture
- Temperature of the incoming air into the carburetor
- Quality of the fuel is supplied
- Design of the carburetor and intake manifold
- Design of the combustion chamber of engine cylinder and head.

Carburetor;

- It is a device used in petrol fuel supply system.
- It keeps a small reserve of petrol at a constant head.
- It atomizes and vaporizes the petrol.
- It mixes the vaporized petrol with air to the engine cylinder.
- It supplies the air petrol mixture in different ratios as per engine requirement.
- During the suction stroke vacuum is created in the cylinder.
- It causes the air to flow to the carburetor and the fuel to be spray from the fuel jets.

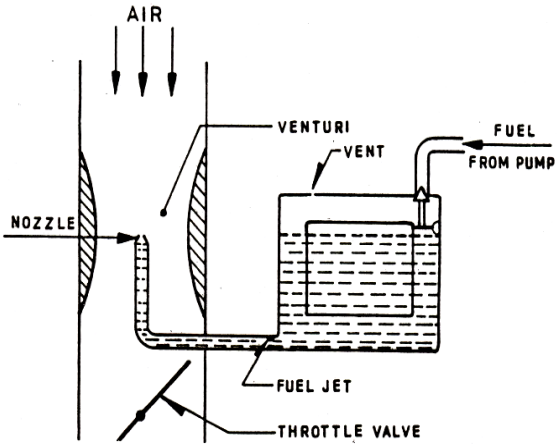
Air Fuel Ratios for different Operating Conditions of the Engine:

- Idling : 12.5 A\f
- Normal power : 16.5 A\f
- Maximum power : 13 A\f

Working of a Simple Carburetor:

It consists of a

- Float chamber
- Nozzle with metering orifice
- Venturi
- Throttle valve
- Float and needle valve



- It maintains a constant height of petrol in the float chamber.
- Float chamber is vented to the atmosphere.
- During suction stroke air is drawn through the venturi tube.
- Venturi has a minimum cross section at the throat.
- Tip of the discharge jet is located in the throat of the venturi tube.
- Due to pressure difference fuel discharges in to air stream.
- Rate of flow is metered by the size of smallest section in fuel passage.

Defects in Simple Carburetor;

- Starting difficulty
- Idling difficulty
- Acceleration difficulty
- Running difficulty
- Weather difficulty
- Altitude difficulty
- Icing difficulty

Arrangement of Carburetors;

- According to the direction in which the mixture is supplied by them
- There are three types of arrangements :
    - Up draught

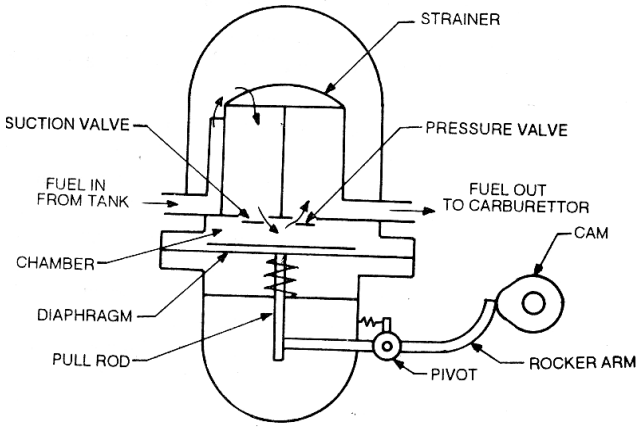
- Down draught
- Side draught

Fuel Pump;

- Mechanical fuel pump
- Electrical fuel pump

Mechanical fuel pump;

- The diaphragm is made up of high grade cotton impregnated with synthetic rubber.
- The valves are made up of Bakelite which being lighter keeps the inertia stress minimum.
- The drive for the pump is taken from camshaft means of eccentric.
- The eccentric operates the rocker arm which in turn diaphragm return spring pushes the diaphragm up and down
- Downward movement of the diaphragm causes vacuum in the chamber.



- It causes the inlet valve to open and the fuel enters into the fuel pump chamber
- Upward movement of the diaphragm causes the inlet valve to close while the outlet valve opens.
- Then the fuel goes out to the carburetor float chamber.

Electrical Fuel Pump;

- *In this type also diaphragm is used.*
- *Alternate vacuum and pressure are produced this is due to the moment of the diaphragm which is caused electrically.*
- *Closing the ignition switch energizes the solenoid winding.*
- *In turn magnetic flux is generated which pulls the armature to which the diaphragm is attached.*
- *Diaphragm moves to cause suction in the pump chamber and fuel is drawn into the chamber.*
- *As soon as the armature moves it interrupts the electric supply by disconnecting the break points.*

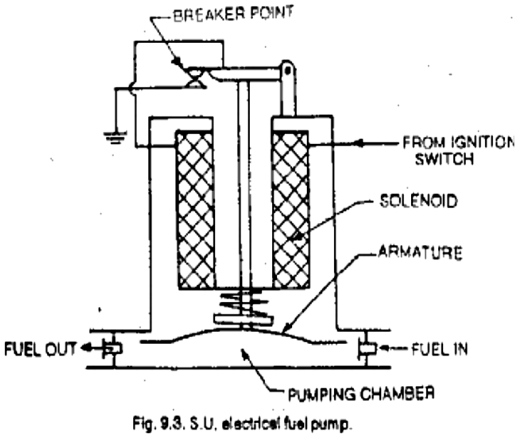


Fig. 9.3. S.U. electrical fuel pump.

- *Then the solenoid is de-energized and the armature falls back.*

- *Which causing the diaphragm to moves to create pressure in the pump chamber.*
- *In turn outlet valves opens and the fuel goes out to the carburetor float chambers.*
- *This movement of the armature completes the circuit again and the solenoid again gets energized*
- *Whole cycle is again repeated and the fuel continues to be pumped.*
- *Electrical pump need not wait for the engine to start.*
- *It starts operating immediately as the ignition is switched on.*

Fuel Injection;

Injecting diesel at high pressure into the high pressure and high temperature compressed air in the cylinder at the end of compression stroke.

- Diesel engines compress pure air during the compression stroke.
- Diesel must be introduced into this high pressure and high temperature compressed air.
- This requires that Diesel must be injected at a higher pressure than that is prevailing in the cylinder.
- Fuel Injection system is designed to supply diesel at a pressure which is higher than that of compression pressure.
- Different methods of fuel injection are adopted to achieve this.

Requirements of Fuel Injection System;

- Fuel supply should be in accordance with the various load and speed requirements of the engine
- Correct Injection timing
- Constant supply of fuel
- Proper atomization and equal distribution of fuel to all the injectors.

Requirements of A Fuel Injection System can be summarized as:

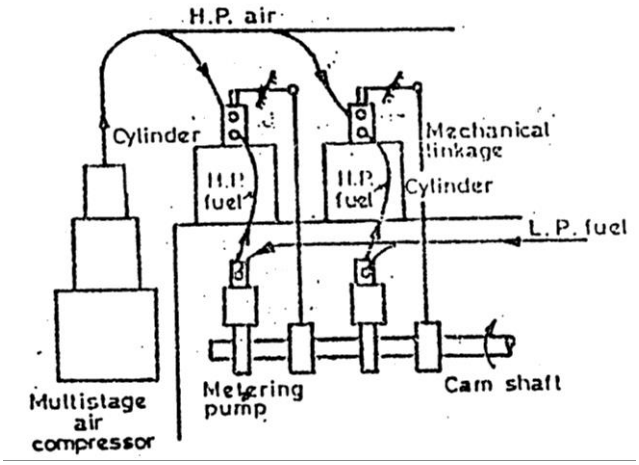
- Meter
- Time
- Pressurize
- Atomize
- Distribute and Control, start and Stop Injection

Types of fuel injection system:

- Air injection system
- Solid injection system

Air injection system;

Working Principle of Air Injection system;



- In this system, the air is first compressed to a very high pressure.
- A blast of this air is then injected carrying the fuel along with it into the cylinder.
- The rate of fuel injection is controlled by varying the pressure of air.
- This method of fuel injection is expensive and complicated.

Advantages of Air Injection;

- It obtains good atomization
- Heavy and viscous fuels can be injected
- Only small pressure need to develop by fuel pump

Disadvantages of Air Injection system;

- It requires high pressure air compressor
- Air compressor consumes lot of engine power
- A separate mechanical linkage is required
- Reduced power of engine

Solid Injection;

- In this system the fuel under high pressure is injected directly in to the combustion chamber without atomization
- It burns due to the heat of compression of the air.
- It is also called air less mechanical injection
- It employs a fuel injection pump and injector

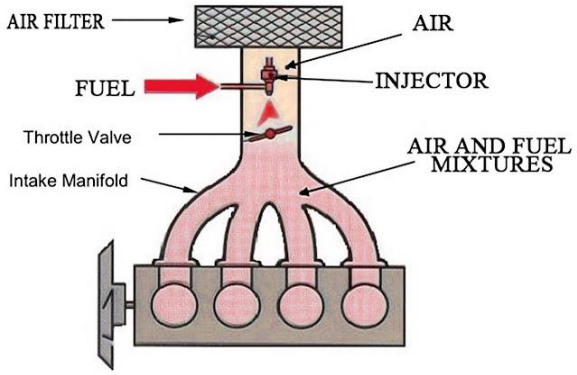
The Solid Injection is mainly classified into the following types

- Individual Pump System
- Common rail System

mono Injection System:

Injectors are electrically operated valves which accurately control the quantity of fuel delivered. By adding the fuel to the air sucked in by the engine, a mixture is created with the required fuel/air ratio.

Single-point injection (SPI) uses a single injector at the throttle body (the same location as was used by carburetors). This system features one centrally positioned fuel injection nozzle. It was introduced in the 1940s in large aircraft engines (then called the pressure carburetor) and in the 1980s in the automotive world (called Throttle-body Injection by General Motors, Central Fuel Injection by Ford, PGM-CARB by Honda, and EGI by Mazda). Since the fuel passes through the intake runners (like a carburetor system), it is called a "wet manifold system". The justification for single-point injection was low cost. Many of the carburetor's supporting components such as the air cleaner, intake manifold, and fuel line routing could be reused. This postponed the redesign and tooling costs of these components. Single-point injection was used extensively on American-made passenger cars and light trucks during 1980-1995, and in some European cars in the early and mid-1990s.



Principle of operation of the mono injector

In the beginning, because of the lower supply pressure of 0.75 to 1 bar, only a single-stage turbine pump is installed. The system pressure regulator has, as opposed to the Multi-point injection, no vacuum connection, because the system pressure regulation is independent of the vacuum pressure. The injection amount is exclusively dependent on the injection time, because the injection takes place above the throttle flap and not in the vacuum area. Apart from the Lambda sensor, the throttle flap potentiometer is an important sensor for the determining of the injection amount. In addition, the control device still also needs the air or the coolant temperature and the relationship to the crankshaft. The Mono-Jetronic (Bosch) controls the idling through a servo-motor with worm-drive and only relies on a throttle position sensor for judging the engine load. There are no sensors for air flow, or intake manifold vacuum. Mono-Jetronic always had adaptive closed-loop lambda control, and due to the simple engine load sensing, it is heavily dependent on the lambda sensor for correct functioning. The Multec (GM) controls the idling through a bypass.

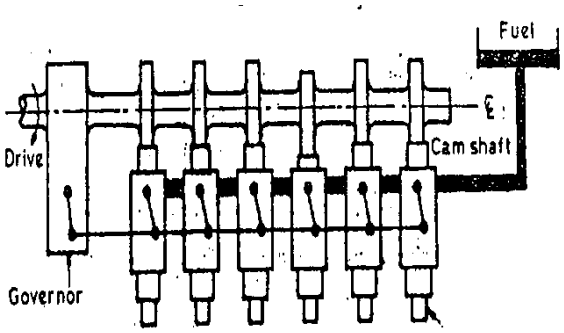
Possible damage to the injectors:

- Open circuit or short to positive or to ground in wire(s);
- No or poor plug connection conduction;
- Ground connection is loose or corroded;
- Mechanical fault in component.

Unit Injection System*:*

What is the necessity of Fuel Injection System?

To supply the diesel with high pressure into the combustion chamber where high pressure and high temperature air is present in atomized form.



Working Principle of Unit Injector;

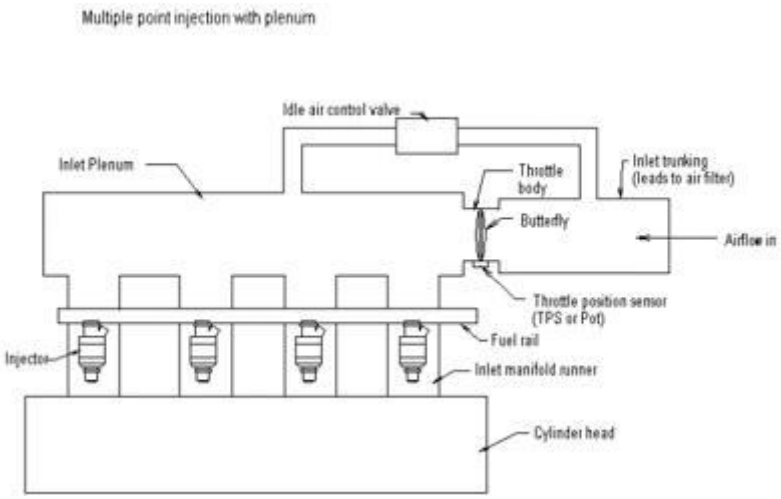
- In this both the pump and injector are combined in to one unit.
- Each cylinder has one such unit injector.
- This arrangement requires push rod and rocker arm to operate the unit injector.
- As shown in figure the system being a 6-cylinder engine has 6 unit injectors.
- Each of this is operated from a Cam operated Rockers.
- Fuel from filters enters into the gallery.
- The Unit injector is fitted into the engine cylinder head, where the fuel is supplied via integral ducts machined directly into the cylinder head.
- Each injector has its own pumping element.
- In case of electronic control, each injector will have an electronic fuel solenoid valve.
- A low pressure fuel pump supplies fuel from tank to the cylinder head fuel ducts through filters.
- This fuel is injected into engine cylinder by constant stroke plunger injector which is operated by overhead cam shaft.

Advantages

- Design of Unit Injector eliminates the need for high pressure fuel pipes and with that their associated failures.
- It allows much high injection pressures.
- This system allows accurate injection timing and quantity of fuel delivered as in Common rail system.

Multi Point Fuel Injection or MPFI

If you compare MPFI system/MPFI engine with single-point fuel injection, single-point fuel injection has only one centrally located fuel injector which supplies fuel to all cylinders, but in a multi point fuel injection system, each cylinder has a separate fuel injector that supplies fuel from the fuel tank to the cylinders.



There are different components used in the MPFI system as follows:

A mechanical solenoid injector

The electronic control unit (ECU) – It controls ignition timing and quality of the fuel.

Electronic sensors to monitors different output such as exhaust gas temperature, coolant temperature, speed, and throttle position.

Air filters to remove solid particles from the atmospheric air.

Working of MPFI System:

In the MPFI system, using the fuel pump which is driven by the electric motor is used to spray fuel into the engine intake manifold.

This technique helps to provide an accurate air-fuel ratio at all operating conditions.

The suction pressure of the engine is used to spray the fuel into the cylinders (In carburetors, the vacuum is used to provide the fuel).

As shown in the figure, you can see that a single injector is placed on the intake port of the different cylinders.

Using the electrical fuel pump, fuel from the fuel tank supplies to each fuel injector equally.

The process of fuel injection occurs simultaneously in each injector once in every rotation.

Advantages of MPFI system:

The power generated by the engine is more than the carburetion system.

Due to the accurate mixture of air-fuel supplied to each cylinder, the difference between power generated at each cylinder is negligible.

Engine vibrations from MPFI equipped engines are very less, hence the life of MPFI system equipped engines is high.

This system is very responsive in case of sudden acceleration or deceleration.

Lower fuel consumption leads to better mileage.

The volumetric efficiency of MPFI is high.

Disadvantages of MPFI system:

The system is complex hence costly.

It requires more space.

Nozzle;

- This is also known as, atomizer or fuel valve.
- This injects the fuel in the cylinder in atomized form and in proper quantity

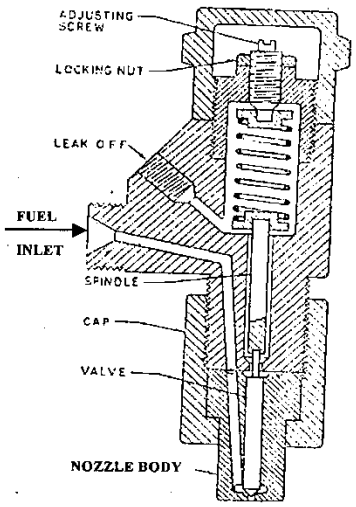
Automatic Injector;

Working Principle of Automatic Injector

It consists of two main parts

1. Nozzle 2.Nozzle holder

- The nozzle is connected to holder by means of a screw cap.
- A spring loaded spindle in the nozzle holder keeps the nozzle valve in the nozzle body.
- Till the fuel supplied by the fuel injection pump enters with sufficient pressure.
- To lift the nozzle valve against the spring.
- This makes a spray of atomized fuel in to cylinder.
- The fuel spray continues till the delivery from Injection pump is continued.
- When the fuel delivery is stopped the pressure falls back closing nozzle valve back on its seat.
- Over flow is drained back to the fuel tank through the leak off connection.

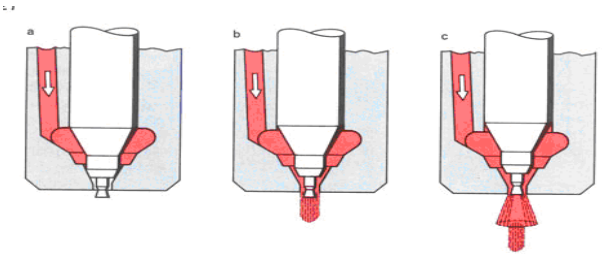


Fuel injection nozzles:

- The main function of nozzle is to deal with many hundreds of fuel charges per minute with widely varying conditions of pressure and temperature.

Fuel Injection nozzles are classified into the following types:

1. Single hole nozzle
2. Multi hole nozzle
3. Long stem nozzle
4. Pintle nozzle



Single Hole Nozzle:

- It has one hole drilled centrally through its body which is closed by the nozzle valve.
- The hole can be of any diameter from 0.2 mm up wards.

Multi Hole Nozzle:

- A multi hole nozzle can have a varying number of holes drilled in its bulbous and under the valve seating.
- Their actual number, size depends upon the engine requirement.

Long Stem Nozzle:

- These nozzles are mainly used, where limited space between the valves in the cylinder head.
- It is used where it is not possible to provide adequate cooling for the short stem.

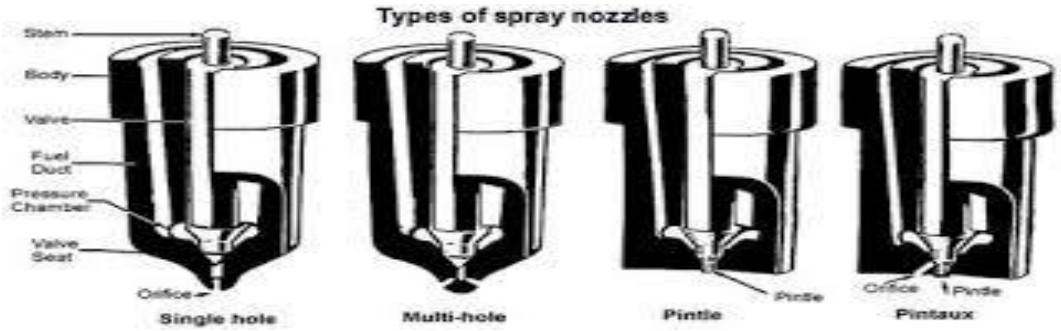
Pintle nozzle;

- This mainly used in engine combustion chambers of the air cell, swirl chamber.
- The valve stem is extended to form a pin which protrudes through the mouths of the of the nozzle body.

a) Closed

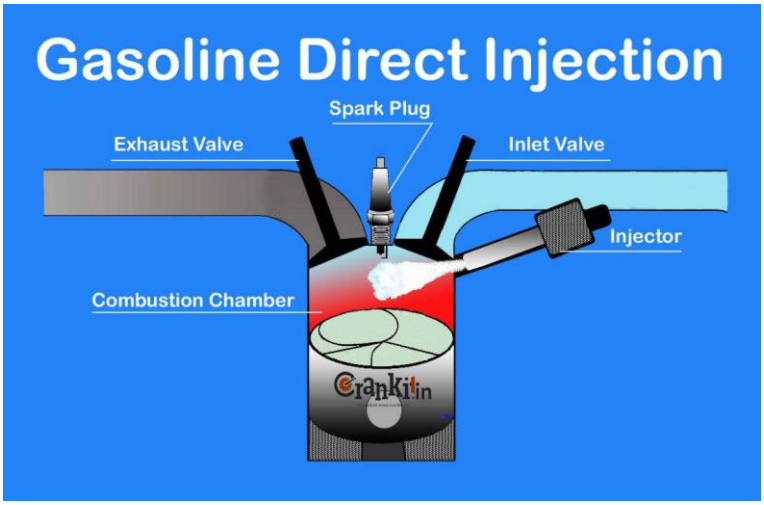
b) Slightly open (pre spray)

c) Fully open (main spray)



Gasoline Direct Injection (GDI)

In internal combustion engines, Gasoline Direct Injection (GDI), also known as Petrol Direct Injection or Direct Petrol Injection or Spark Ignited Direct Injection (SIDI) or Fuel Stratified Injection (FSI), is a variant of fuel injection employed in modern two-stroke and four-stroke gasoline engines. The gasoline is highly pressurized, and injected via a common rail fuel line directly into the combustion chamber of each cylinder, as opposed to conventional multi-point fuel injection that happens in the intake tract, or cylinder port.



Operation

The major advantages of a GDI engine are increased fuel efficiency and high power output. Emissions levels can also be more accurately controlled with the GDI system. The cited gains are achieved by the precise control over the amount of fuel and injection timings that are varied according to engine load. In addition, there are no throttling losses in some GDI engines, when compared to a conventional fuel-injected or carbureted engine, which greatly improves efficiency, and reduces 'pumping losses' in engines without a throttle plate. Engine speed is controlled by the engine control unit/engine management system (EMS), which regulates fuel injection function and ignition timing, instead of having a throttle plate that restricts the incoming air supply. Adding this function to the EMS requires considerable enhancement of its processing and memory, as direct injection plus the engine speed management must have very precise algorithms for good performance and drivability.

UNIT – III

Steering and Suspension System

Principle of steering - Steering Geometry and wheel alignment - Steering linkages – Steering gearboxes - Power steering - front axle.

Suspension system - Independent and Solid axle – coil, leaf spring and air suspensions - torsion bar - shock absorbers.

3.1 Introduction to steering system

What is the main function of steering?

The steering system in an automobile is a crucial component that **allows the driver to control the direction in which the vehicle moves**. Its primary function is to enable the driver to steer the vehicle with ease and precision.

*The front wheels are supported on the front axle so that they can swing to the left or right for steering This movement is produced by gearing and linkage between the steering wheel in front of the driver and steering knuckle or wheel.

This complete arrangement is called steering system.

Requirements of steering system

- The steering mechanism should be very accurate and easy to handle.
- The effort required to steer should be minimum.
- The effort required to steer must not be tiresome to the driver.
- The steering mechanism should Provide directional stability.

3.2 Principle of steering: -

The steering wheel turns a pinion gear, which moves a rack back and forth to steer the wheels. This mechanism converts the circular motion of the steering wheel to linear motion, which is applied to the wheels of the car via tie rods and a steering knuckle.

The Main parts of the steering system

1. **Steering Wheel**: The user interface for the driver to input steering commands, connected to the steering column.
2. **Steering Column**: Connects the steering wheel to the steering gearbox or rack, transmitting the driver's input.
3. **Steering Shaft**: Transfers the rotational movement from the steering column to the steering gearbox or rack.

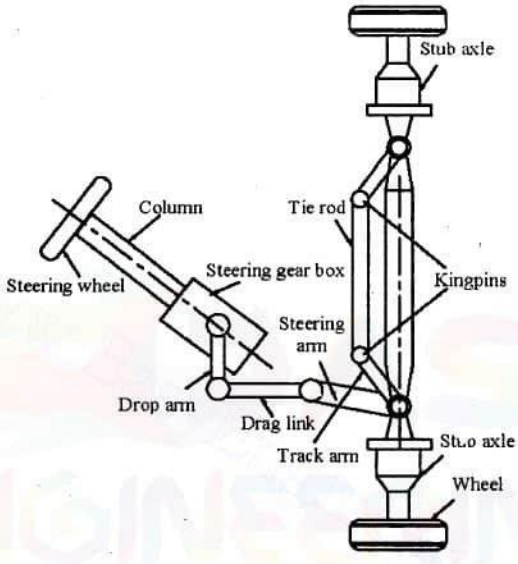


Figure 3.1

4. **Steering Gear Box**: Converts the rotational motion from the steering shaft into lateral motion, determining the direction of the vehicle.
5. **Steering Pinion**: In rack-and-pinion systems, this small gear meshes with the rack, facilitating the conversion of rotation to lateral movement.
6. **Steering Rack**: In rack-and-pinion systems, it's a toothed bar connected to the wheels, allowing lateral movement when engaged with the pinion gear.
7. **Tie Rod Ends**: Connect the ends of the steering rack to the steering knuckles, transmitting steering input to the wheels.
8**. Knuckle**: Forms part of the wheel assembly; it connects the tie rod ends and provides a pivot point for wheel movement in response to steering input.

3.3 Steering Geometry and wheel alignment

Steering geometry refers to the arrangement and design of the components in a vehicle's steering system that determine how the wheels respond to driver input and how the vehicle handles. Proper steering geometry is crucial for achieving good stability, handling, and safety. There are several key parameters and concepts associated with steering geometry:

1. **Caster Angle**: The caster angle is the angle between the steering axis (an imaginary line drawn through the upper and lower pivot points of the front suspension) and the vertical axis when viewed from the side of the vehicle. Positive caster enhances straight-line stability and steering return ability.

2. **Toe Angle**: Toe angle is the angle formed by the longitudinal axis of the vehicle and the centerline of the wheels. There are two types of toe angles: toe-in and toe-out. Toe-in means that the front of the wheels is closer together than the rear, while toe-out means the front is farther apart. Proper toe alignment is essential for tire wear and vehicle stability.

3. **Camber Angle**: Camber is the tilt of the wheels from the vertical when viewed from the front. Positive camber means the top of the wheels is tilted outward, and negative camber means the top is tilted inward. Camber affects tire wear and cornering stability.

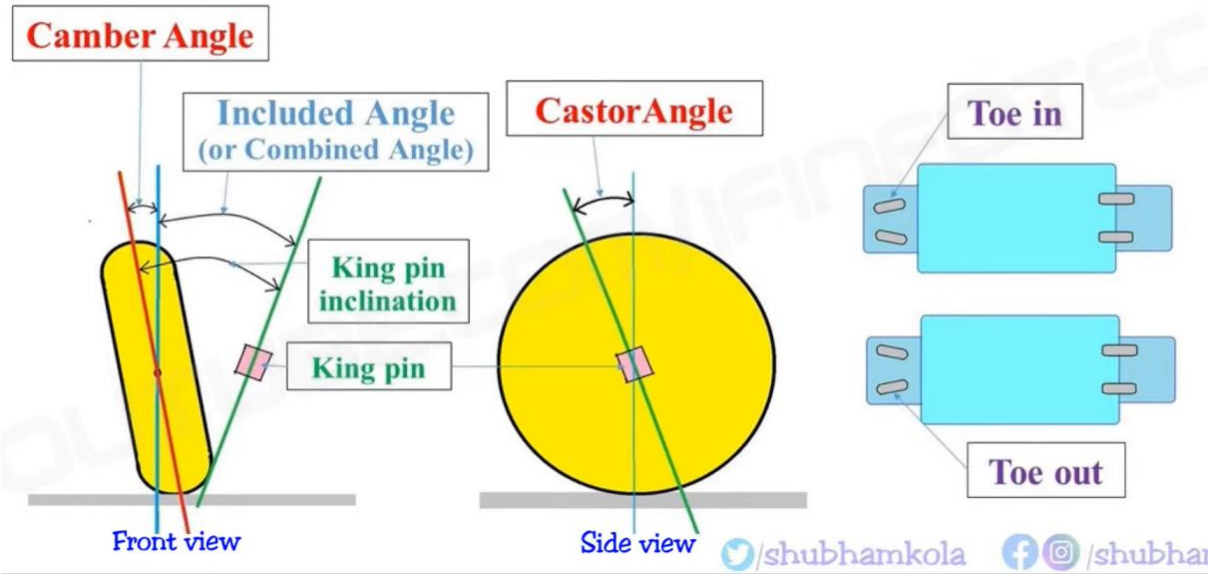


Figure 3.2 Caster Angle, Toe Angle, Camber Angle

4. **Ackermann Steering Geometry**: This is a design principle that ensures the inside and outside wheels of a vehicle follow different turning radii when steering. This helps to reduce tire scrubbing during turns, providing smoother and more predictable handling.

5. **Kingpin Inclination (KPI**): KPI is the angle formed by the steering axis and a line perpendicular to the ground. It contributes to the stability of the steering system and influences the self-centering behavior of the wheels.

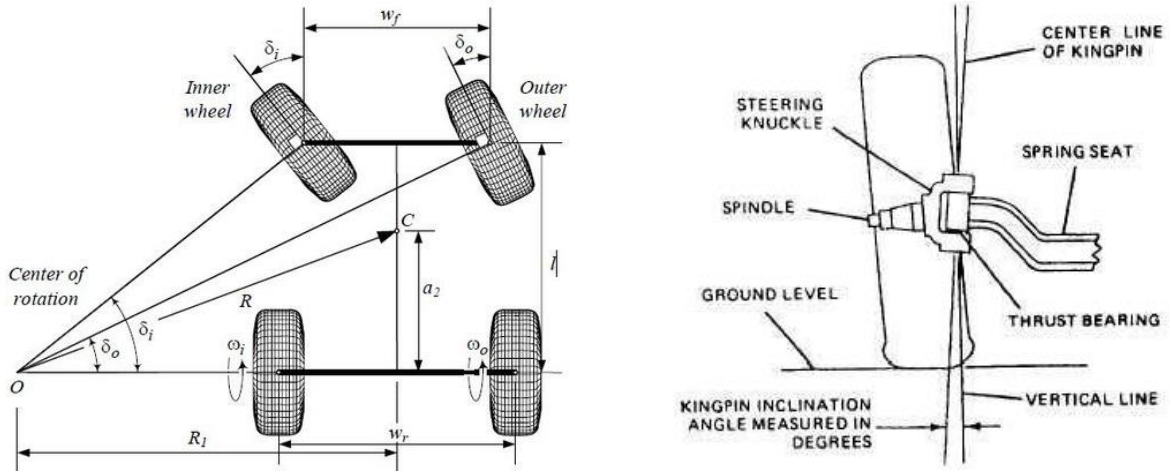


Figure 3.3 Ackermann Steering Geometry Kingpin Inclination (KPI):

6. **Scrub Radius**: The scrub radius is the distance between the tire's contact patch and the point where the steering axis intersects the ground. It influences steering effort and is related to the tendency of the steering wheel to return to the center after a turn.

7. **Trail**: Trail is the distance between the point where the steering axis intersects the ground and the tire's contact patch. It affects the stability of the vehicle and contributes to self-centering.

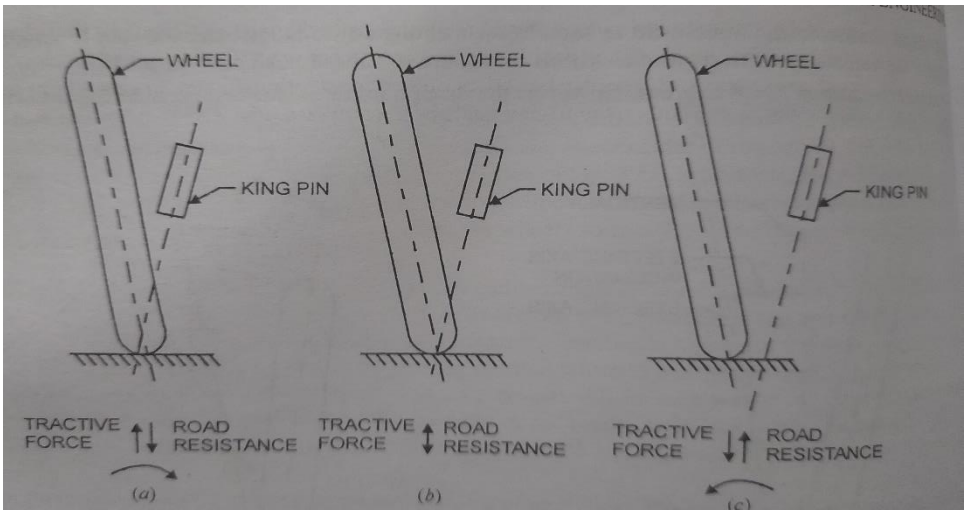


Figure 3.4 Effect of combined angle variation in rear wheel drive vehicle. The point of intersection of the wheel and king pin center lines (a) above the ground (negative scrub radius)-tendency to toe-in, (b) just at the ground (zero scrub radius) no effect and (c) below the ground (positive scrub radius)-tendency to toe-out

wheel alignment, also known as tire alignment, refers to the adjustment of the angles of the wheels relative to each other and to the car's frame or body. Proper wheel alignment is crucial for several reasons, including ensuring that the vehicle drives straight, preventing uneven tire wear, and optimizing steering response. There are three main components of wheel alignment: toe, camber, and caster.

1. **Toe:**
   Toe-In: The front edges of the tires are closer together than the rear edges. This helps with straight-line stability.
   Toe-Out: The front edges of the tires are farther apart than the rear edges. This setup can enhance cornering performance.

2. **Camber:**
   Positive Camber: The top of the tire is tilted outward. This can improve stability in certain situations but excessive positive camber may lead to uneven tire wear.
   Negative Camber: The top of the tire is tilted inward. This is often used to improve cornering performance and is common in high-performance or sports cars.

3. **Caster**:
   Positive Caster: The steering axis is tilted backward, contributing to stability at high speeds and aiding in steering return ability.
   Negative Caster: The steering axis is tilted forward. This is less common but can be found in some off-road or heavy-duty applications.

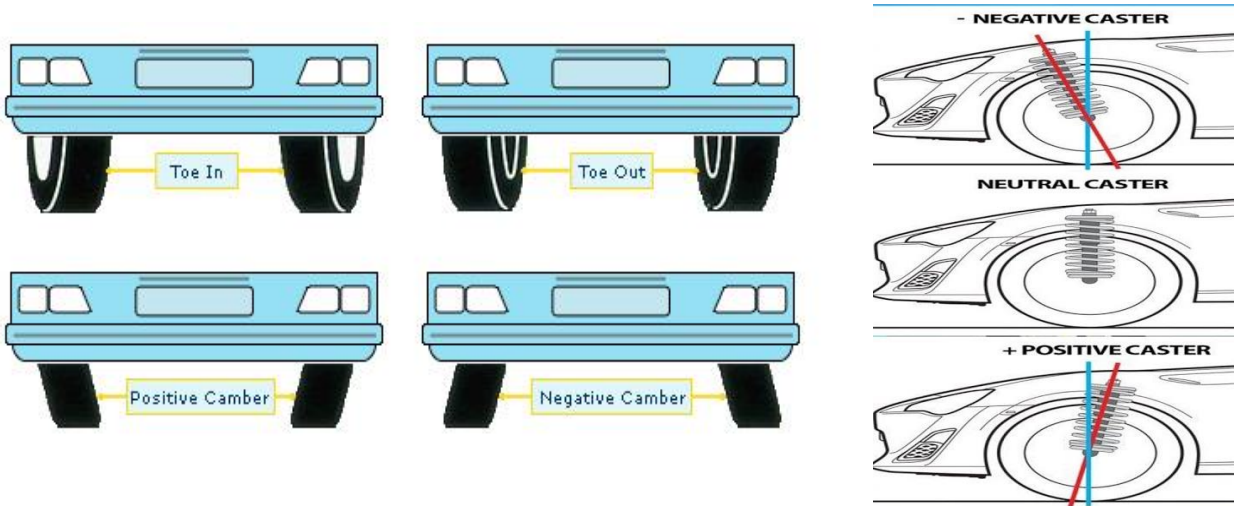


Figure 3.5 Caster Angle, Toe Angle, Camber Angle adjustment in wheel alignment

Wheel alignment is typically checked and adjusted by automotive technicians using specialized equipment. Here's how the process generally works:

1. **Inspection**: Technicians inspect the tires, suspension components, and steering system to identify any issues that might affect alignment.

2. **Measurement**: Using alignment equipment, the technician measures the current alignment settings of the wheels.

3. **Adjustment**: If the measurements indicate that the alignment is out of specification, adjustments are made to the suspension components to bring the wheels back into alignment. This may involve adjusting tie rods, control arms, or other components.

4. **Recheck**: After adjustments, the technician rechecks the alignment to ensure that it now falls within the specified tolerances.

5. **Test Drive**: In some cases, a test drive may be conducted to ensure that the vehicle handles properly and that there are no unusual noises or vibrations.

Regular wheel alignment checks and adjustments are essential for maintaining vehicle safety, tire longevity, and optimal handling. It's recommended to have the wheel alignment checked whenever you notice uneven tire wear, if the vehicle pulls to one side, or after hitting a significant pothole or curb.

3.4 Steering Linkages

Steering linkages are the components that connect the steering system to the wheels of a vehicle, translating the driver's input into the movement of the wheels. These linkages play a crucial role in the overall steering mechanism, allowing for controlled and precise steering. The main steering linkages include:

1. **Tie Rods:**
   Inner Tie Rods: These are connected to the steering gearbox or rack and are responsible for transmitting the steering input to the outer tie rods.
   Outer Tie Rods: These connect to the inner tie rods on one end and the steering knuckle on the other end. They transmit the steering movement to the wheels.
2. **Steering Pitman Arm**: The pitman arm is connected to the steering gearbox in a recirculating ball steering system or the steering rack in a rack-and-pinion system. It converts the rotational movement from the steering gearbox or rack into linear movement, which is then transmitted to the tie rods.
3. **Idler Arm**: In some steering systems, especially in older vehicles, an idler arm is used to support the other end of the center link (also known as the relay rod). The center link connects the pitman arm to the steering linkage on the passenger side.
4. **Center Link (Relay Rod):** The center link, also known as the relay rod, connects the pitman arm to the steering linkage on the passenger side. It helps transmit steering input to the wheels on the passenger side of the vehicle.
5. **Drag Link**: The drag link connects the pitman arm to the steering linkage on the driver's side. It helps transmit steering input to the wheels on the driver's side of the vehicle.
6. **Ball Joints and Bushings**: Ball joints are used at the ends of tie rods and sometimes in other steering components. They provide pivot points for the movement of the steering linkages. Bushings are used to reduce friction and allow for smooth movement in various joints.
7. **Steering Column:** The steering column is the shaft that connects the steering wheel to the steering gearbox or rack. It contains the necessary linkages, such as universal joints, to transmit the driver's input to the steering mechanism.

Types of Steering Linkages

There are several types of steering linkages used in vehicles, each with its own design and configuration. The choice of steering linkage depends on the vehicle's type, size, and intended use. Here are some common types:

1. **Rack and Pinion Steering:**

Description: In this system, a pinion gear attached to the steering shaft engages with a rack, which is a flat, toothed bar. As the steering wheel turns, the pinion gear moves the rack left or right, translating the rotational motion into lateral motion to turn the wheels.

Advantages: Simple design, direct and responsive steering, commonly used in smaller and lighter vehicles.

2. **Recirculating Ball Steering:**

Description: This system uses a worm gear inside a steering box. As the steering wheel turns, it causes the worm gear to rotate, moving a recirculating ball mechanism that turns the pitman arm, which is connected to the drag link and tie rods.

Advantages: Robust design, suitable for larger and heavier vehicles, provides power steering assistance.

3. **Parallelogram Steering Linkage:**

Description: This linkage consists of a center link, idler arm, and two tie rods. The center link connects the pitman arm to the idler arm, while the tie rods connect the center link to the steering knuckles.

Advantages: Common in older vehicles, offers simple and effective steering control.

4. **Four-Bar Linkage**:

Description: This linkage system uses four control arms to connect the steering gear to the steering knuckles. It provides a stable and predictable steering response.

Advantages: Often used in heavy-duty trucks and some off-road vehicles, offers good stability and control.

Steering linkage for vehicle with rigid Independent front suspension.

5. **Strut (Wishbone) Suspension**:

Description: In this design, the steering knuckles are connected to the vehicle's frame or body through two control arms resembling a wishbone or an A-shape. The tie rods connect the steering system to the steering knuckles.

Advantages: Commonly used in modern independent suspension systems, provides good handling and ride comfort.

6. **McPherson Strut Suspension**:

Description: In this design, a single, vertical strut combines the shock absorber and the coil spring, while the steering knuckle is attached to the bottom of the strut. The tie rods connect the steering system to the steering knuckles.

Advantages: Common in front-wheel-drive vehicles, provides a compact and space-efficient design.

The choice of steering linkage depends on factors such as vehicle size, weight, handling characteristics, and manufacturing considerations. Modern vehicles often use rack and pinion steering for its simplicity and responsiveness, while larger or heavy-duty vehicles may utilize recirculating ball or parallelogram linkages to meet their specific requirements.

Steering Linkages are depending on the type of vehicle's front suspension:

- Steering linkage for vehicle with rigid axle front suspension (Parallelogram type)
- Steering linkage for vehicle with rigid Independent front suspension.

Rigid axle type front suspension

In a vehicle with a rigid axle front suspension, the steering linkage is designed to connect the steering wheel to the wheels mounted on a solid (rigid) front axle. This type of suspension system is often found in trucks, SUVs, and some off-road vehicles. The steering linkage components work together to transmit the driver's input to the wheels, allowing for controlled and predictable steering.

Here's a basic explanation of how the steering linkage works in a vehicle with a rigid axle front suspension:

Pitman Arm:

Location: Connected to the steering gear (commonly a recirculating ball steering box) on one end and to the steering linkage on the other.

Function: Converts the rotational motion from the steering gear into lateral motion. As the pitman arm moves, it pushes or pulls the other components in the steering linkage.

Center Link (or Relay Rod):

Location: Extends horizontally across the vehicle and connects the pitman arm to the steering arms on the steering knuckles.

Function: Transfers the lateral motion from the pitman arm to the steering arms, initiating the movement of the front wheels.

Steering Arms:

Location: Attached to the steering knuckles on each side of the front axle.

Function: Transmit the lateral motion from the center link to the steering knuckles, causing the front wheels to turn.

Tie Rods:

Location: Connect the steering arms to the steering knuckles.

Function: Transmit the steering input from the center link to the wheels. The tie rods are adjustable, allowing for alignment adjustments to ensure proper toe settings.

Drag Link:

Location: Connects the pitman arm to one of the steering arms.

Function: Assists in transmitting the lateral motion from the pitman arm to the steering arms, helping to control and guide the movement of the front wheels.

As the driver turns the steering wheel, the rotational motion is transferred through the pitman arm to the center link. The center link, in turn, moves the steering arms, and the tie rods transmit this motion to the front wheels, causing them to turn left or right.

It's worth noting that the rigid axle front suspension, while robust and capable, can result in a less smooth ride compared to independent front suspension systems. However, it is often preferred in off-road or heavy-duty applications where durability and load-carrying capacity are crucial. Regular maintenance, including inspections and adjustments of the steering linkage components, is important to ensure proper steering performance and tire wear.

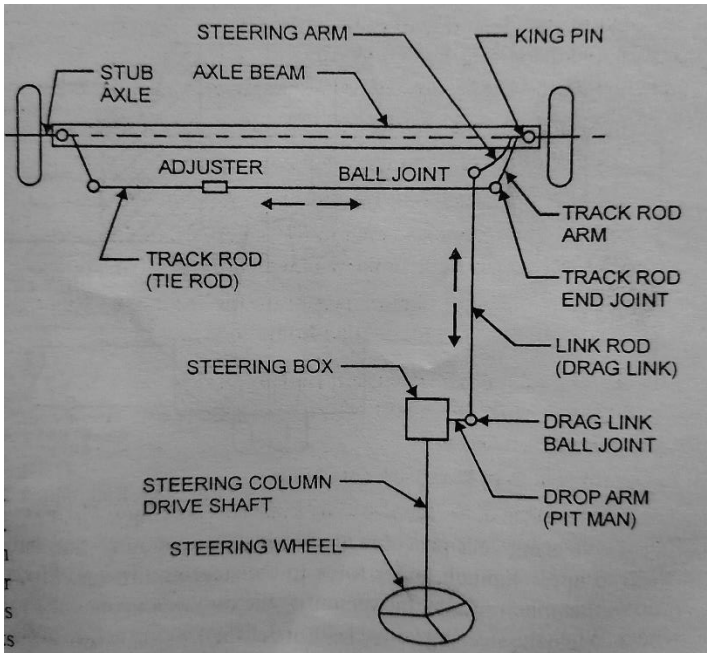


Figure 3.6 Rigid axle type front suspension

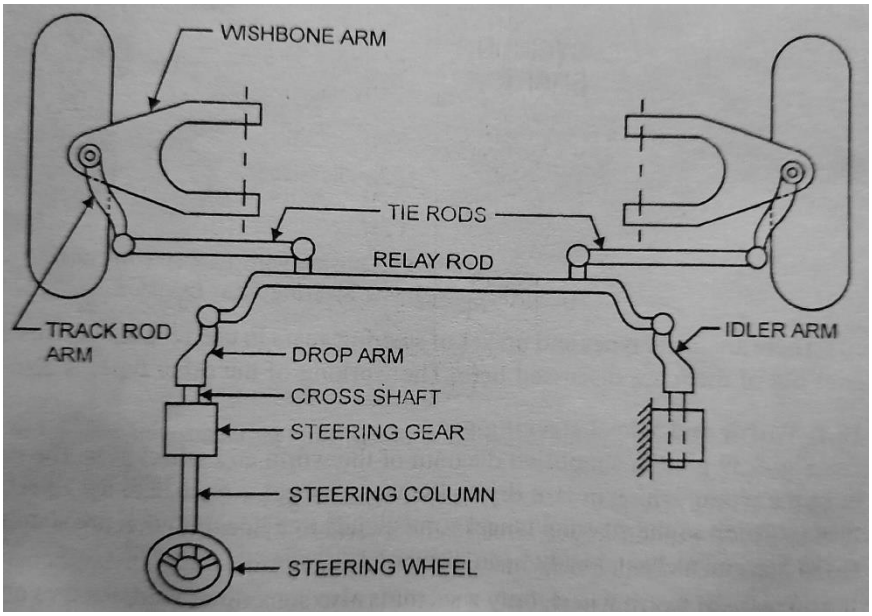


Figure 3.7 Independent front suspension

Independent front suspension

In a vehicle with independent front suspension (IFS), each front wheel can move independently of the other, providing improved ride comfort and handling compared to a rigid front axle suspension. This type of suspension system is often found in most of the light vehicles (cars).The steering linkage in a vehicle with independent front suspension is designed to allow for this independent movement while still enabling effective control and steering.

Here's an overview of the typical components and their functions:

Rack and Pinion Steering System:

Description: In many vehicles with independent front suspension, a rack and pinion steering system is commonly used.

Function: The steering wheel is connected to a shaft with a small pinion gear. This pinion gear engages with a long, horizontal toothed bar known as the rack. As the pinion gear turns, it moves the rack left or right, translating the rotational motion of the steering wheel into lateral motion.

Tie Rods:

Location: Tie rods connect the ends of the rack to the steering knuckles on each wheel.

Function: Transmit the lateral motion from the rack to the steering knuckles, causing the front wheels to turn.

Steering Knuckles:

Location: Attached to the wheel hubs and capable of rotating with the movement of the tie rods.

Function: The steering knuckles pivot as the tie rods move, allowing the wheels to turn left or right.

Ball Joints:

Location: Connect the steering knuckles to the control arms.

Function: Allow for the vertical movement of the suspension while maintaining a connection between the steering system and the wheels.

Control Arms:

Location: Positioned between the frame or body of the vehicle and the steering knuckles.

Function: Control arms provide the necessary support and guide the vertical movement of the wheel and suspension.

Struts or Shock Absorbers:

Location: Typically mounted between the control arms and the vehicle's frame or body.

Function: Dampen and control the vertical movement of the suspension, contributing to ride comfort and handling.

In vehicles with independent front suspension, the movement of one wheel does not directly affect the other, allowing each wheel to react independently to road irregularities. The steering linkage, consisting of the rack and pinion system and associated components, facilitates precise and responsive steering control.

The construction and design of the steering linkage in independent front suspension systems contribute to better handling, improved road feel, and enhanced ride comfort compared to rigid front axle suspensions. Regular maintenance, including inspections of components such as tie rods and ball joints, is important for ensuring proper steering performance and safety.

3.5 Steering gearboxes

A steering gearbox, also known as a steering gear or steering box, is a crucial component in a vehicle's steering system. Its primary function is to translate the rotational motion of the steering wheel into lateral motion that directs the movement of the front wheels.

There are different types of steering gearboxes used in vehicles, each with its own design and characteristics. Here's a brief explanation of some common types:

1. **Recirculating Ball Steering Gearbox:**

Design: This type uses a worm gear inside a steering box. The worm gear engages with a sector gear, and as the steering wheel turns, it causes the worm gear to rotate. The rotation of the worm gear moves recirculating balls, which then move a nut connected to the pitman arm.
Application: Commonly used in larger and heavier vehicles, such as trucks and some SUVs.
Advantages: Robust design, provides a mechanical advantage, making it suitable for heavy-duty applications.
Disadvantages: Can have more play and friction compared to rack and pinion systems.

2. **Rack and Pinion Steering Gearbox:**

Design: In this system, a pinion gear attached to the steering shaft engages with a toothed rack. As the steering wheel turns, the pinion gear moves the rack laterally, transmitting the motion to the tie rods and turning the front wheels.
Application: Commonly used in smaller and lighter vehicles, as well as many modern cars.
Advantages: Simpler design, provides more precise steering response, and offers a direct mechanical connection between the steering wheel and the wheels.
Disadvantages: May not be as well-suited for heavy-duty applications as recirculating ball systems.

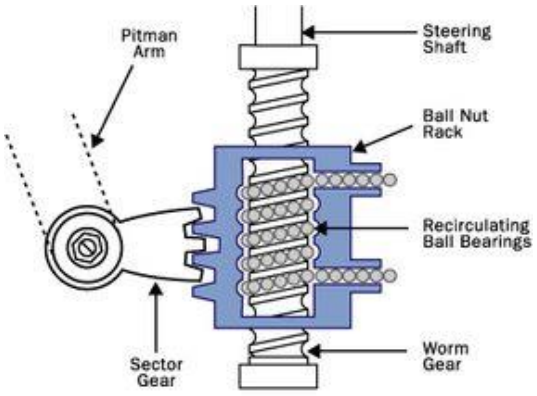
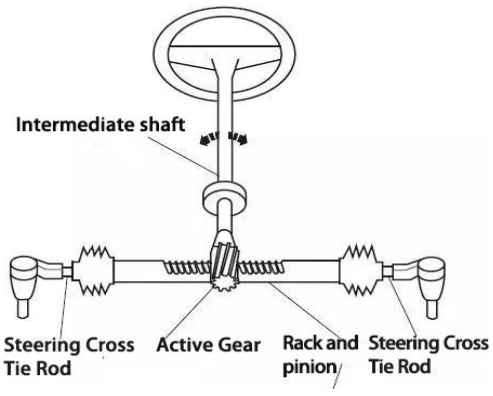


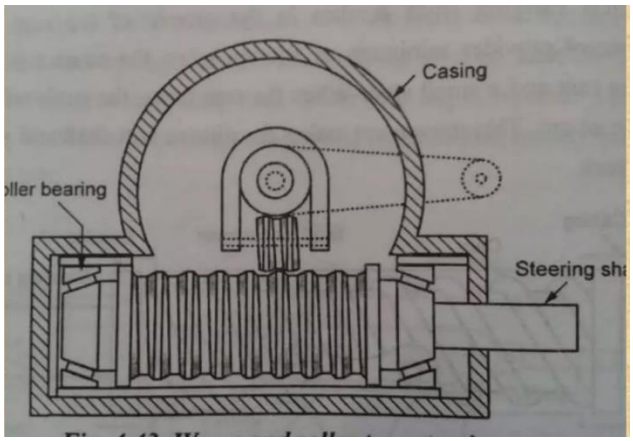
Figure 3.8 Recirculating Ball Steering Gearbox



Rack and Pinion Steering Gearbox

3. **Worm and Roller Steering Gearbox:**

Design: Similar to recirculating ball systems, but instead of balls, it uses rollers. The worm gear engages with a sector gear, and the motion is transmitted to the pitman arm through rollers.
Application: Used in some older vehicles and industrial applications.
Advantages: Provides smoother operation compared to recirculating ball systems.
Disadvantages: Less common than rack and pinion or recirculating ball systems.



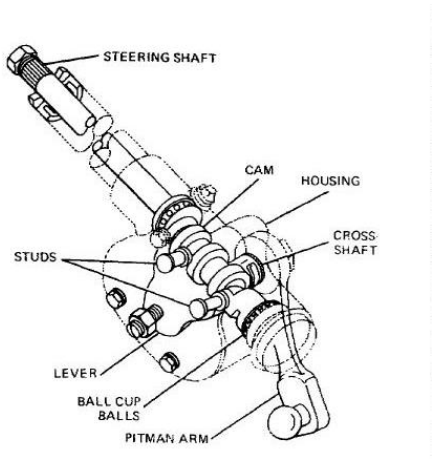


Figure 3.9 Worm and Roller Steering Gearbox: Cam and Lever Steering Gearbox:

4. Cam and Lever Steering Gearbox:

Design: This system uses a rotating cam and lever mechanism to convert rotary motion into lateral motion, turning the front wheels.

Application: Historically used in some vintage and early vehicles.

Advantages: Simple design.

Disadvantages: Not commonly used in modern vehicles due to limitations in precision and efficiency.

5. Electric Power Steering (EPS):

Design: EPS systems can be integrated with either rack and pinion or recirculating ball steering gearboxes. Instead of relying solely on mechanical linkages, EPS systems use an electric motor to assist in providing steering assistance.

Application: Widely used in modern vehicles for its efficiency and flexibility.

Advantages: Offers variable assistance, improves fuel efficiency, and enables advanced driver-assistance features.

Disadvantages: Requires electrical power, and potential electronic system complexities.

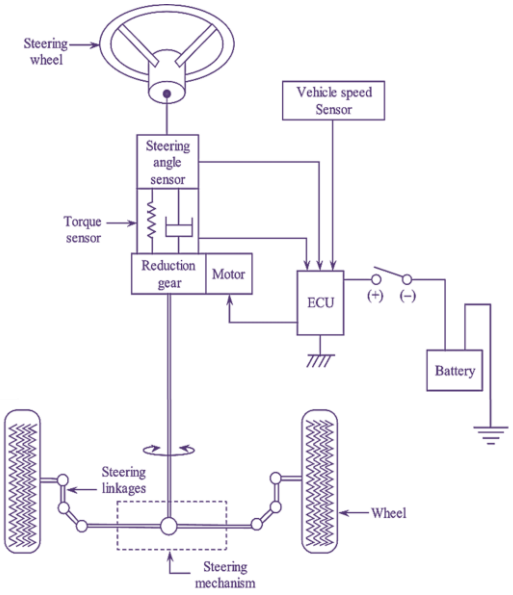


Figure 3.9 Electric Power Steering (EPS):

The choice of steering gearbox depends on factors such as the type of vehicle, intended use, and technological preferences of the manufacturer. Advances in technology, such as EPS, have introduced new possibilities for enhancing steering performance and efficiency.

3.6 Power steering

Power steering is a technology in vehicles that assists the driver in steering the vehicle by augmenting the force applied to the steering wheel. The primary purpose of power steering is to reduce the effort required by the driver to turn the steering wheel, especially at low speeds or when the vehicle is stationary. This enhancement in steering ease is particularly beneficial in larger or heavier vehicles.

There are two main types of power steering systems:

- Hydraulic power steering (HPS)
- Electric power steering (EPS).

Hydraulic Power Steering (HPS):

Mechanism: In hydraulic power steering systems, a pump, typically driven by the engine, pressurizes hydraulic fluid. This fluid is then used to assist in turning the steering mechanism.

Components: Hydraulic power steering systems include a power steering pump, fluid reservoir, hydraulic hoses, and a power steering gear (either rack and pinion or recirculating ball).

Operation: As the driver turns the steering wheel, hydraulic pressure is applied to one side of the power steering gear, assisting in the movement of the wheels.

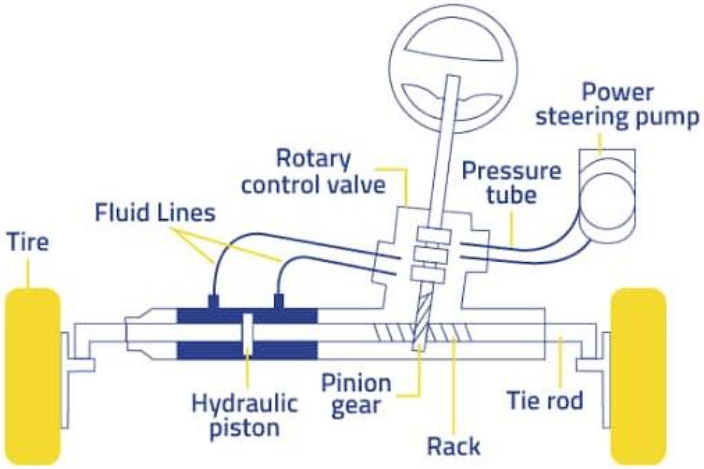


Figure 3.10 Hydraulic Power Steering (HPS):

Electric Power Steering (EPS):

Mechanism: Electric power steering systems replace the hydraulic pump with an electric motor integrated into the steering system.

Components: EPS systems include an electric motor, control module, torque sensor, and electronic components.

Operation: The electric motor provides variable assistance to the steering based on driving conditions, speed, and steering input. EPS systems are more energy-efficient as the electric motor only operates when assistance is needed.
Figure 3.9 shows the line diagram of Electric Power Steering (EPS):

Advantages of Power Steering:

Reduced Effort: Power steering significantly reduces the physical effort required by the driver to turn the steering wheel, especially in situations such as parking or navigating tight spaces.
Enhanced Maneuverability: Vehicles equipped with power steering systems are more maneuverable and responsive, providing better control.
Comfort: Power steering contributes to a more comfortable driving experience by minimizing driver fatigue.
Variable-Assist Power Steering: Some power steering systems offer variable assistance, adjusting the level of assistance based on driving conditions. For example, assistance may be higher at low speeds for easier maneuvering and parking, while decreasing at higher speeds for improved stability.

Disadvantages of Power Steering:
Cost of Repair and Maintenance: Power steering systems, especially those with hydraulic components, can be more complex than manual steering systems. Repairing or replacing power steering components can be more expensive.
Dependency on Engine: Hydraulic power steering systems rely on the engine to drive the power steering pump. If the engine fails, it can result in a loss of power steering assistance, making steering more challenging.
Reduced Road Feel: Power steering systems, especially electric power steering (EPS), may reduce the feedback or "road feel" that some drivers prefer. This can lead to a perception of decreased connection to the road, affecting the driving experience for enthusiasts.
Fuel Consumption: In hydraulic power steering systems, the power steering pump draws power from the engine, potentially contributing to a small decrease in fuel efficiency. However, modern systems are designed to minimize this impact.
Complexity: Power steering systems, particularly those with electronic components, can be more intricate and may involve more complex diagnostics and repairs compared to manual steering systems.

Power steering has become a standard feature in the majority of modern vehicles, contributing to improved safety, comfort, and ease of handling. The specific type of power steering system varies among vehicles, and advancements such as electric power steering have become more prevalent due to their efficiency and flexibility.

Types of Power Steering System

Integral Power Steering:

Integral power steering is designed to provide power assistance when the steering wheel requires between two and five pounds of effort.

It comprises a steering gear with a worm-and-ball bearing nut and a hydraulic rack piston along the worm shaft. Hydraulic pressure assists in moving the nut in any direction.

A reaction contact valve connected to the worm shaft thrust bearing controls the oil flow between the valve body and the gear and pinion assembly.

When the vehicle moves straight ahead, oil flows from the pump through open center valves and back to the reservoir. Oil also circulates the rack piston to cushion road shocks. When the vehicle turns right, the worm's movement causes the control valve to restrict fluid flow to the right turn cylinder, increasing pump pressure on the right side of the rack piston and causing the ball nut to move right. The fluid flow shifts to the left-turn power cylinder for left turns, moving the rack piston and ball nut leftward.

Linkage Power Steering

Linkage power steering separates the power cylinder from the steering gear and connects it to the steering linkage. The power assistance directly affects the steering linkage.

In the neutral position (straight-ahead motion), a centering spring holds the spool valve in the control valve assembly at the center, allowing oil to flow to both sides of the power cylinder.

When the vehicle turns left with significant wheel force, Pitman's arm moves the spool control valve, removing centering spring pressure. It shifts the valve to the right side of the body, directing oil pressure to the right side of the power cylinder and turning the wheels left. When making a right turn, the process reverses, forcing the relay rod to turn the wheels right.

Hydraulic Power Steering

Hydraulic power steering system, used from the 1950s to 2000s, relies on hydraulic assistance driven by a continuous pump. This system has drawbacks, including energy wastage when the vehicle requires no assistance.

The hydraulic pump, powered by the engine, pressurizes hydraulic fluid. This fluid increases the input force on the steering wheel, reducing the effort needed to turn the front wheels.

When the driver turns the wheel, the hydraulic pump pressurizes the fluid, which acts on a piston, transferring the driver's input force to the front wheels through a rack and pinion mechanism.

Electric Power Steering (EPS)

EPS is a modern power steering system that replaces hydraulic components with electric motors and sensors.

Instead of hydraulic force, an electric motor powered by the vehicle's battery assists the steering gear. Sensors detect the steering column's position and control the motor's torque.

When the driver turns the wheel, electronic sensors transmit the input to the vehicle's electric control unit. The unit analyses these inputs and sends voltage signals to the electric motor, which engages with the pinion gear and provides the necessary torque to the rack. This rotation of the rack steers the front wheels.

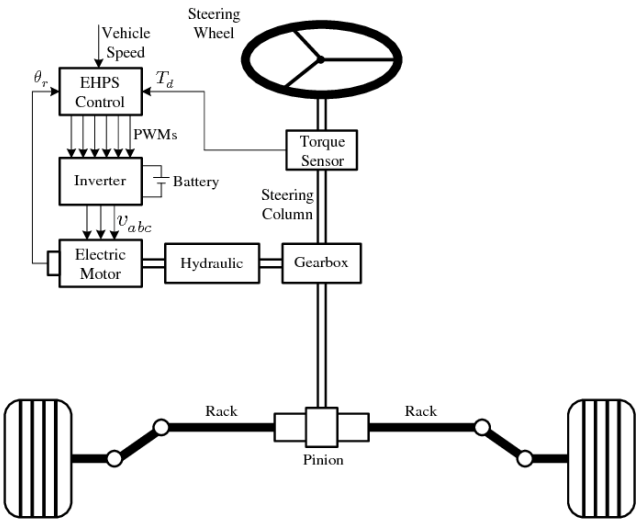


Figure 3.11 Electro-hydraulic Power Steering

Electro-hydraulic Power Steering

Electro-hydraulic power steering is a hybrid system that combines hydraulic and electric power steering elements.

Unlike traditional hydraulic systems, it uses an electric motor to drive the hydraulic pump, reducing energy waste. However, it does not offer all the features of full-electric power steering.

In this system, the hydraulic motor is powered by an electric motor instead of being run by the engine. It is employed in some heavy pickup trucks and a few other vehicles.

3.7 front axle.

Front Axle: Located in the front of the vehicle, this axle is responsible for assisting with steering and processing shocks from the uneven surface of the road. They have four main parts, which are the beam, the swivel pin, the track rod, and the stub axle. Front axles must be as sturdy as possible, and that's why they're usually made from carbon steel or nickel steel.

Functions

♣ It supports the weight of front part of the vehicle.
♣ It facilitates steering knuckles and suspension springs.
♣ It transmits weight of vehicle through springs to the front wheels.
♣ It absorbs torque applied on it due to braking of vehicle.

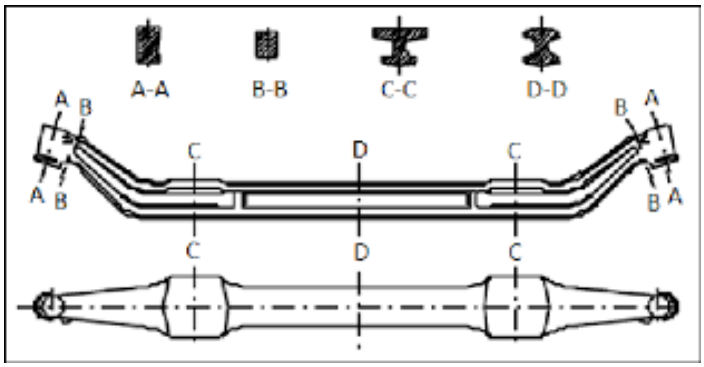


Figure 3.12 front axle

Types of Front Axle

According to Meineke, vehicles have two main types of front axle. These are:

Dead Front Axle: These axles stay in place and don't rotate with the wheels. Most dead front axles and differentials have housings that prevent them from coming into contact with water or dirt.

Live Front Axle: Unlike dead front axles, live front axles deliver driving power from the gearbox to the front wheels.

Figure 3.13 dead axle live axle

The front axle is designed to transmit the weight of the automobile from the springs to the front wheels, turning right or left as required. To prevent interference due to front engine location, and for providing greater stability and safety at high speeds by lowering the center of gravity of the road vehicles, the entire center portion of the axle is dropped.

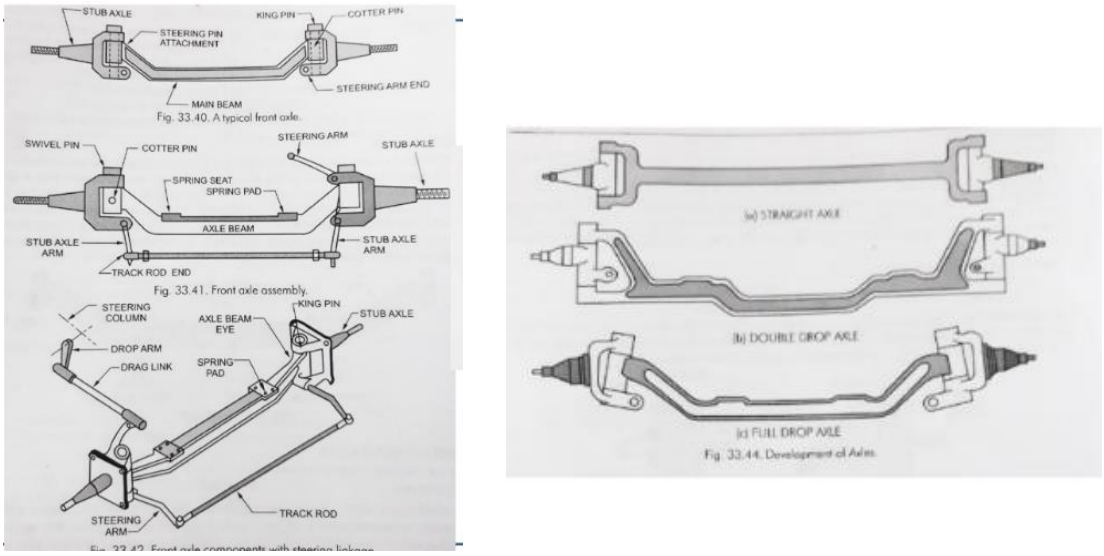


Figure 3.14 front axle assembly development of front axle

3.7 suspension system

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other.

Objects of suspension

- To prevent the road shocks from being transmitted to the vehicle components.
- To safeguard the occupants from road shocks.
- To preserve the stability of the vehicle in pitching or rolling, while in motion.

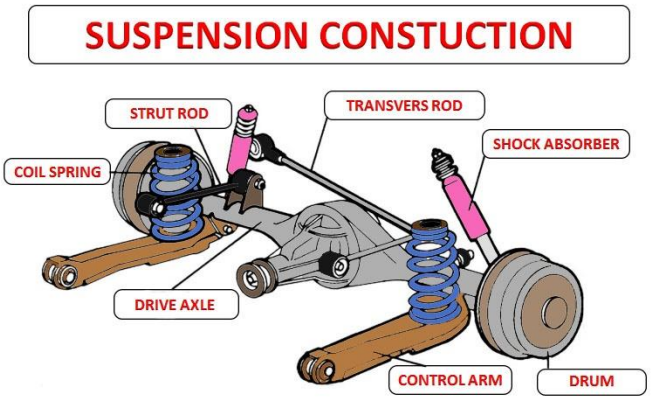


Figure 3.15

TYPES OF SUSPENSIONS SPRINGS

The various suspension springs may be classified as follows:

1. Steel Springs
   - (a) leaf spring
   - (b) tapered leaf spring
   - (c) coil spring
   - (d) Torsion bar
2. Rubber Springs
   - (a) Compression spring
   - (b) compression shear spring
   - (c) Steel-reinforced spring
   - (d) Progressive spring
   - (e) Face-shear spring
3. Plastic Spring
4. Air spring
5. Hydraulic spring

3.8 Independent and Solid axle

Independent suspension and solid axle suspension are two different approaches to the design of a vehicle's suspension system. Each has its advantages and is suited to different types of vehicles and driving conditions.

Independent Suspension:

Definition: Independent suspension allows each wheel on the same axle to move independently of the other. This means that when one wheel encounters a bump or uneven terrain, it doesn't directly affect the other wheel on the same axle.

Types:

MacPherson Strut: A common type of independent front suspension where a single vertical strut supports the weight of the vehicle and controls its movement.

Double Wishbone (Double A-arm): In this design, each wheel is attached to the vehicle using two separate control arms, providing more precise control over wheel movement.

Multi-link Suspension: Utilizes multiple links and control arms to independently manage wheel movement and control.

Advantages:

- Improved ride quality: Independent suspension systems can provide a smoother ride because each wheel reacts independently to road irregularities.
- Better handling: Independent suspension can contribute to better handling and cornering performance.
- Enhanced traction: Each wheel can maintain better contact with the road surface, especially in uneven terrain.

Applications:

Most modern passenger cars

- SUVs
- Performance vehicles
- Off-road vehicles

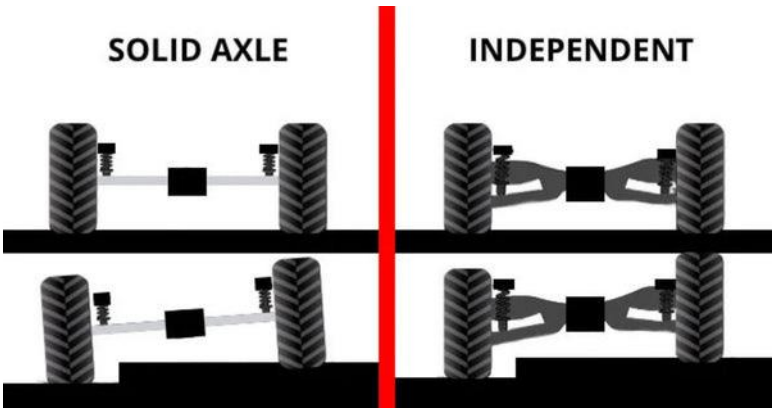


Figure 3.16

Solid Axle (Live Axle):

Definition: A solid axle connects both wheels on the same axle, and their movement is synchronized. When one wheel moves, the other wheel on the same axle is affected.

Types:

Rigid Axle: A simple and robust design where both wheels are connected to a single, solid axle.

Beam Axle: Commonly found in the rear suspension of some trucks and older vehicles, where the axle is a solid beam.

Advantages:

Durability: Solid axles are known for their durability and strength, making them suitable for heavy-duty applications.

Simplicity: Solid axles are mechanically simpler than independent suspension systems, which can make them easier to maintain.

Applications:

- Heavy-duty trucks
- Some off-road and utility vehicles
- Older model cars

Disadvantages:

- Potentially rougher ride: Solid axles may transmit more road imperfections to the vehicle, resulting in a rougher ride compared to independent suspension.
- Limited wheel independence: In extreme off-road conditions, a solid axle may not provide the same level of wheel articulation as independent suspension.

The choice between independent suspension and solid axle depends on the intended use of the vehicle and the balance between ride comfort, handling, and load-carrying capability. Modern vehicles often feature a combination of both, with independent suspension at the front and a solid axle at the rear, providing a balance between comfort and load-carrying capacity.

3.9 coil, leaf spring and air suspensions

Coil Springs:

Description: Coil springs are helical springs made of coiled steel. They compress and expand to absorb shocks and provide support to the vehicle.

Placement: Coil springs can be found in both independent and solid axle suspension systems. They are often used in conjunction with shock absorbers.

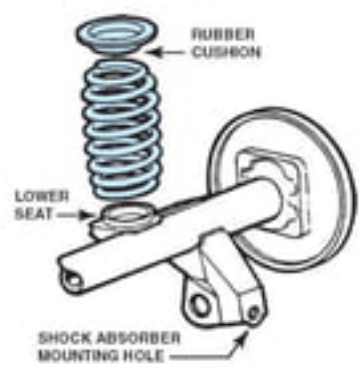


Figure 3.17

Advantages:

- Provide a smooth and comfortable ride.
- Allow for more flexibility in suspension design.

  Effective in controlling body roll during cornering.

Disadvantages:

- May not provide as much load-carrying capacity as some other types of springs.
- Susceptible to coil bind if compressed too much, potentially causing damage.

Coil springs come in various types, each designed to meet specific requirements based on the vehicle's application, suspension design, and performance needs. Here are some common types of coil springs:

Compression Coil Springs:

Description: This is the most common type of coil spring. It is designed to compress and absorb energy when a force is applied. Compression coil springs are used in various vehicle suspension systems.

Torsion Springs:

Description: Torsion coil springs are designed to resist twisting forces. They are often used in applications where rotational motion needs to be counteracted, such as in some suspension systems.

Tension (Extension) Coil Springs:
Description: Tension or extension coil springs are designed to stretch or extend when a force is applied. They are less common in vehicle suspension systems but may be used in certain applications.

Progressive Rate Coil Springs:
Description: Progressive rate coil springs have a variable spring rate, meaning the resistance to compression increases as the spring is compressed further. This design allows for a softer initial response and a firmer feel as the spring compresses more, providing a balance between comfort and performance.

Linear Rate Coil Springs:
Description: Linear rate coil springs have a constant spring rate throughout their compression range. They provide a consistent level of resistance to compression, making them predictable and straightforward in their performance.

Variable Pitch Coil Springs:
Description: Variable pitch coil springs have coils with varying distances between them. This design helps distribute stress and load more evenly, providing a smoother and more controlled ride.

Leaf Springs:
Description: Leaf springs consist of multiple layers (leaves) of spring steel bound together. They are typically mounted longitudinally on the vehicle.
Placement: Commonly used in solid axle suspension systems, especially in the rear of trucks and some SUVs.
Advantages:

- Provide excellent load-carrying capacity, making them suitable for heavy-duty applications.
- Simplicity of design and durability.
- Tend to resist axle wrap (rotation of the axle under torque).

Disadvantages:

- Can result in a rougher ride compared to coil springs.
- Limited flexibility in design compared to coil springs.

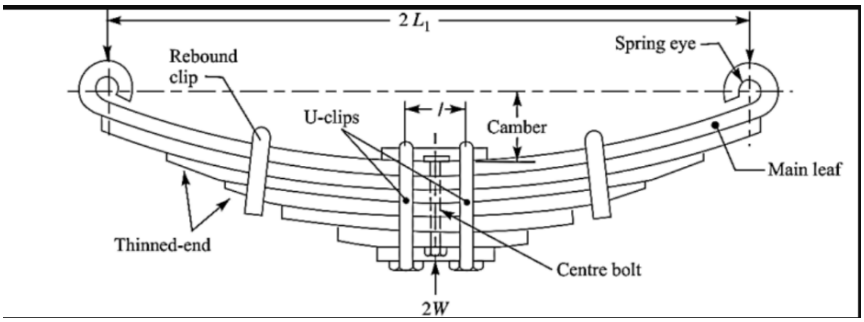


Figure 3.18

Leaf springs, also known as carriage or cart springs, have been a common suspension component in various vehicles for many years. There are several types of leaf springs, each with its own characteristics and applications. Here are some of the main types:

Elliptical or Semi-Elliptical Leaf Springs:
Description: This is the most common type of leaf spring and consists of multiple thin, curved leaves of varying lengths stacked on top of each other and secured by a center bolt. The longest leaf is typically the main leaf.
Applications: Often used in rear suspension systems of trucks, SUVs, and older cars.

Quarter-Elliptic Leaf Springs:
Description: These leaf springs are typically used in pairs, with each spring mounted longitudinally, resembling a quarter of an ellipse. They are commonly used in the front suspension of older vehicles or in certain compact cars.
Applications: Found in some vintage and compact car suspensions.

Cantilever Leaf Springs:
Description: Cantilever leaf springs are similar to semi-elliptical springs but have one end attached to a fixed point, while the other end is free to move. They are less common in automotive applications but may be found in some specialty vehicles or trailers.
Applications: Specialized applications, trailers, and certain types of off-road vehicles.

Multi-Leaf Springs:
Description: Multi-leaf springs consist of multiple thin leaves of varying lengths stacked on top of each other. They provide increased load-carrying capacity and are often used in heavy-duty applications.
Applications: Commonly found in the rear suspension of trucks, vans, and heavy-duty vehicles.

Mono-Leaf Springs:
Description: Instead of multiple leaves, mono-leaf springs have a single, thicker leaf. They are often used in sports cars and high-performance vehicles to reduce unspring weight.
Applications: Sports cars and some high-performance vehicles.

Parabolic Leaf Springs:
Description: Parabolic leaf springs have a tapered, curved design that provides a progressive spring rate. This design allows for a softer initial response and a firmer feel as the spring compresses further.
Applications: Used in various vehicles where a balance between comfort and load-carrying capacity is desired.

Reversed-Eye Leaf Springs:
Description: In reversed-eye leaf springs, the eyes, or attachment points, are turned in the opposite direction. This design is used to achieve specific ride height or suspension characteristics.
Applications: Custom or modified suspension setups.

Air Suspension:

Description: Air suspension uses air-filled bags or bellows as the primary springing element. Compressed air is used to support the vehicle's weight and adjust ride height.

Placement: Can be used in various suspension configurations, including both independent and solid axle systems.

Construction of Air Suspension:

The layout of an air suspension system has been shown in Fig. The four air springs, which may be either the bellows-type or the piston type, are mounted on the same position where generally the coil springs are mounted. It also consists of an air compressor, air accumulator, relief valve, lift control valve, leveling valve, and pipeline.

Working of Air Suspension:

An air compressor takes the atmospheric air through a filter and compresses it to a pressure of about 240 MPa, at which pressure the air in the accumulator tank is maintained, which is also provided with a safety relief valve. This high-pressure air goes through the lift control valve and the leveling valves, to the air springs as shown. Each air spring is filled with compressed air which supports the weight of the vehicle. The air gets further compressed and absorbs the shock when the wheel encounters a bump on the road.

Advantages:

Adjustable ride height: Allows for dynamic adjustment of the vehicle's height for improved aerodynamics, ground clearance, and load leveling.

Improved ride comfort: Air suspension can provide a smoother ride by adjusting the air pressure in the springs.

Load leveling: Maintains a consistent ride height, even with varying loads.

Disadvantages:

Complexity: Air suspension systems are more complex and can be more expensive to repair than traditional spring systems.

Potential for air leaks: Air springs may develop leaks over time, affecting performance.

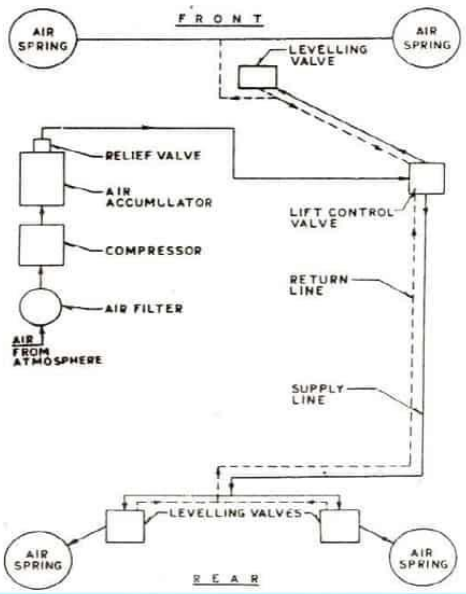


Figure: Schematic diagram showing the layout of an air suspension system.

Types of Air Suspension

There are different types of air suspension systems based on the design of the air spring used:

(i) Bellow Type Air Suspension (Spring)

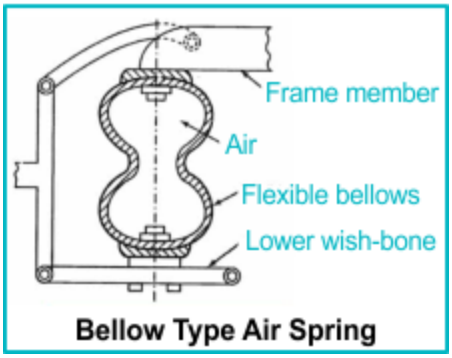


Fig: Bellow-type air spring

This type of air spring consists of rubber bellows made into circular sections with two convolutions for proper functioning, as depicted in Figure. It replaces the conventional coil spring and is commonly employed in air suspension setups.

(ii) Piston Type Air Suspension (Spring)

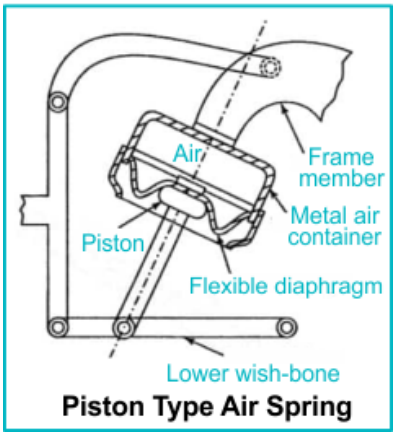


Fig: Piston-type air suspension

In this system, a metal-air container resembling an inverted drum is connected to the frame. A sliding piston is linked to the lower wishbone, while a flexible diaphragm ensures a tight seal. The diaphragm is connected at its outer circumference to the drum's lip and at the center of the piston, as shown in Figure.

(iii) Elongated Bellows Air Suspension

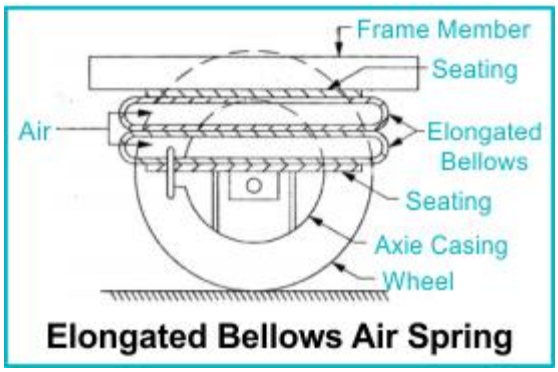


Fig: Elongated Bellows Air Suspension

For rear axle applications, elongated bellows with approximately rectangular shapes and semi-circular ends, typically having two convolutions, are used. These bellows are arranged between the rear axle and the vehicle frame and are reinforced with radius rods to withstand torques and thrusts, as required for efficient suspension functioning.

3.10 torsion bar

A torsion bar is a type of suspension system component used in some vehicles to provide spring-like support and resist the movement of the vehicle's wheels in response to road irregularities. Torsion bars are commonly used in both front and rear suspensions, but for the purpose of this explanation, I'll focus on their application in front suspensions.

Here's an overview of torsion bars:

Design:

A torsion bar is a long, straight, or slightly curved metal bar that is connected to the vehicle's frame at one end and to the control arm or suspension member at the other end.
The bar is usually mounted longitudinally along the vehicle, parallel to the ground.

Function:

Torsion bars work on the principle of torsion, which is the twisting or rotation of an object due to torque applied to it. In this case, the torsion bar absorbs and resists the twisting forces generated when the wheels encounter bumps or uneven surfaces.

Construction:

Torsion bars are typically made of a high-strength steel alloy.
The diameter and length of the torsion bar, as well as the material properties, play a crucial role in determining its spring rate and overall performance.

Adjustability:

Some vehicles with torsion bar suspensions have adjustable torsion bars. This feature allows for fine-tuning the vehicle's ride height and suspension characteristics.
Adjusting the torsion bar preload can influence the vehicle's front-end height and, to some extent, the stiffness of the suspension.

Advantages:

Torsion bars can provide a relatively compact and lightweight solution for front suspension systems. They are known for their durability and resistance to sagging over time, making them suitable for heavy-duty applications.

Disadvantages:

Torsion bar suspensions may transmit more road imperfections to the vehicle compared to some other suspension types, potentially affecting ride comfort.
While adjustable, torsion bars may not offer as much fine-tuning capability as coilover or air suspension systems.

Applications:

Torsion bar suspensions have been used in a variety of vehicles, including trucks, SUVs, and some passenger cars.
They are often found in off-road and heavy-duty applications due to their robust design.

Maintenance:

Torsion bars require periodic inspection to ensure they are functioning correctly and are not showing signs of fatigue or damage.

If a vehicle with a torsion bar suspension has an adjustable setup, adjustments should be made carefully according to the manufacturer's specifications.

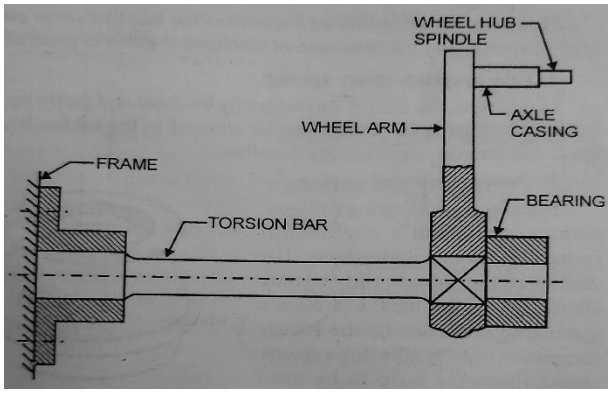


Figure 3.19 torsion bar

3.11 shock absorbers

Shock absorbers, also known as dampers, are essential components in a vehicle's suspension system. They play a crucial role in controlling the movement of the springs and managing the impact and rebound of the vehicle's wheels.

Here's an overview of shock absorbers:

Function:

Absorbing and Damping: The primary function of shock absorbers is to absorb and dampen the energy generated by the springs during compression and extension. They help control the oscillations of the springs, preventing the vehicle from bouncing excessively after encountering bumps or dips in the road.

Components:

Cylinder and Piston: Shock absorbers typically consist of a cylinder filled with hydraulic fluid and a piston that moves within the cylinder.

Valves: The piston has valves that regulate the flow of hydraulic fluid as it moves through the cylinder, controlling the speed and force of the piston's motion.

Types:

- Twin-Tube Shock Absorbers: This common type features two cylinders - an inner working cylinder and an outer reserve cylinder. The two cylinders are connected by an internal dividing piston.
- Mono-Tube Shock Absorbers: In this design, the working fluid and gas are separated by a floating piston, resulting in a single tube. Mono-tube shocks are often used in high-performance and off-road applications.
- Coil over Shocks: Coil over shocks integrate a coil spring around the shock absorber, combining the functions of the shock and the spring. They are commonly used in performance and racing applications.

- Gas-Charged Shocks: Gas-charged shocks have nitrogen gas in addition to hydraulic fluid. The gas helps prevent foaming of the fluid, reducing the risk of shock fade during continuous use.

Adjustability:

Some shock absorbers are adjustable, allowing the driver to fine-tune the damping characteristics. This adjustability is often used in performance and racing applications.

Roles in Vehicle Dynamics:

- Cornering Stability: Shock absorbers contribute to the stability of the vehicle during cornering by controlling body roll.
- Braking and Acceleration: They help maintain tire contact with the road during braking and acceleration, improving traction and control.
- Ride Comfort: Properly functioning shock absorbers contribute to a smoother and more comfortable ride by minimizing excessive body movement.

Signs of Wear or Failure:

- Leaks: Visible oil leaks around the shock absorber may indicate internal damage.
- Excessive Bouncing: If the vehicle continues to bounce excessively after hitting a bump, the shock absorbers may be worn.
- Uneven Tire Wear: Worn shock absorbers can contribute to uneven tire wear.

Maintenance:

- Shock absorbers should be inspected regularly, and any signs of wear or damage should be addressed promptly.
- They are typically replaced in pairs (both front or both rear) to maintain balanced performance.

Applications:

- Shock absorbers are used in various types of vehicles, including cars, trucks, motorcycles, and bicycles.
- Different applications may require shock absorbers with specific characteristics based on the vehicle's weight, intended use, and performance requirements

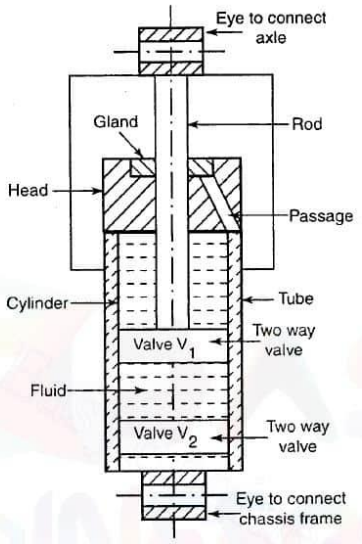


Figure 4.55 Telescopic shock absorber

UNIT – IV

Wheels, Tyres and Braking System

Wheels and Tyres - Construction - Type and specification - Tyre wear and causes - Brakes - Needs – Classification –Drum and Disc Mechanical - Hydraulic and pneumatic - Vacuum assist – Retarders – Anti-lock Braking System(ABS).

4.1 Wheels and Tyres (Construction, Type and specification)

Wheels

Wheel Assembly

- It consists of hub, disc or spokes, tire and tube
- It Supports the weight of the vehicle
- Flexible, to absorb the road shocks
- Able to grip the road surface
- It resists the braking stresses and withstand side thrust

figure 4.1 wheel

Functions of wheel

- It should be lightest possible, so that the unsprung weight is minimum
- Balanced both statically as well as dynamically
- Possible to remove or mount the wheel easily
- Its material should not deteriorate with weathering and age
- Good ability of heat dissipation

Types of wheels

1. Pressed steel disc wheel
2. The wire wheel
3. The light alloy cast wheel
4. Composite wheel

1. Pressed Steel Disc Wheel

- **Disc wheel**: This type of wheel consists of two parts
  - A steel rim which is generally well based to receive the tyre and a pressed steel disc
  - The rim and the disc may be integral permanently attached or attachable, depending upon design

2. Wire Wheel

- The wire wheel has a separate hub, which is attached to the rim through a number of wire spokes
- The spokes carry the weight, transmit the driving and braking torques and with stand the side forces while cornering, in tension
- Spokes are long, thin wires and as such these cannot take any compressive or bending stresses

3. Light Alloy Cast or Forged Wheel

- Cast wheels are generally used for car while forged wheels are preferred for wheels of heavier vehicles
- The main advantage of light alloy wheels is their reduced weight, which reduces unspring weight

- A magnesium alloy wheel weighs about 50 percent of an aluminium alloy wheel for similar strength
- Moreover, light alloys are better conductors of heat

4. Composite Wheel

- Exhibit combination of strength, lightweight and styling
- They are made of steel and aluminum alloys
- The rim is generally made of steel while the center portion consist of cast aluminum alloy

Figure 4.2 types of wheels

1. Pressed steel disc wheel
2. The wire wheel
3. The light alloy cast wheel
4. Composite wheel

Rim

- The part of the wheel on which the tire is mounted and supported
- The outer circular portion of the wheel on which the tire and tube are fitted

<u>Types of Rims</u>

The rims are of two types

- Drop center Rim: - Mostly used on cars
- Flat base Rim: - Mostly used on trucks &HCVS

Drop Centre Rim

- The center portion of the rim is rolled to a smaller diameter to form a well
- The rim allows the removal or mounting of the tire by squeezing the beads of the tire together on one side and dropping them into the well, while the opposite side is pulled over the flange
- The rim is designed so that the well allows the beads of the tire to pass over the edge of the opposite side of the rim
- The rim is tapered from the edge of the well to the rim

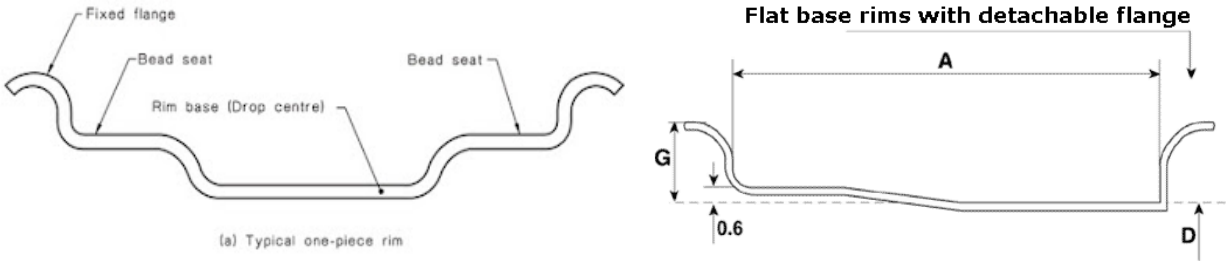


Figure 4.2 *Drop Centre Rim* *Flat Based Rim*

Flat Based Rim

- The flat base rim has its center portion flat
- One side of the rim is removable so that the tire can be installed or removed without stretching the bead
- They are suitable for large tyres
- The tyres having bulky bead region
- Used almost on all trucks and other heavy duty vehicles

specifications of Wheels:

Size: Measured in inches (e.g., 17x7.5), indicating diameter and width. Size influences the overall look and performance of the vehicle.

Bolt Pattern: Describes the number of bolts and the diameter of the imaginary circle they form. For example, 5x114.3 indicates a wheel with 5 bolts spaced 114.3 mm apart.

Offset: The distance between the wheel's mounting surface and its centerline. Positive offset moves the wheel inward, negative offset outward. It affects the wheel's position within the wheel well.

Backspacing: The distance from the wheel's mounting surface to the back edge of the wheel. It is another measure of the wheel's positioning within the wheel well.

Hub Bore: The diameter of the hole at the center of the wheel. It must match the hub diameter of the vehicle for proper fitment.

Load Rating: Specifies the maximum weight a wheel can safely support. It is crucial for ensuring the wheel can handle the vehicle's weight and load.
Material: Wheels can be made of steel or alloy. Alloy wheels, typically aluminum or magnesium, are lighter and offer better heat dissipation.

Finish: Describes the wheel's appearance. Common finishes include painted, polished, chrome, or machined.

Construction: Wheels can be one-piece or multi-piece. One-piece wheels are simpler and more common, while multi-piece wheels allow for customization.

Design: Refers to the visual aesthetics of the wheel. Designs vary widely, from simple and classic to intricate and sporty.

Lug Nut Seat Type: Describes the shape of the lug nut seat, such as conical, spherical, or flat. It must match the type of lug nuts used.

Tyres

- Tyre is mounted on wheel Rim
- It consists of tube fitted inside
- The tire-tube assembly is mounted over the wheel rim
- Air filled inside the tube carries the entire load and provides the cushion

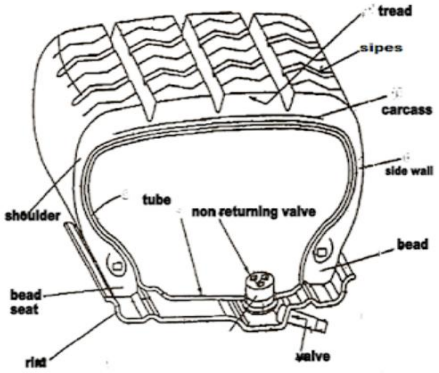


Figure 4.3 Tyre

Function of Tyres

- To support the vehicle load
- To provide cushion against shocks
- To transmit driving and braking forces to the road
- To provide cornering power for smooth steering

Desirable Tyre Properties

Non-skidding

- The tread pattern on the tire must be suitably designed to permit least amount if skidding even on wet road

Uniform Wear

- The wear on the tire must be uniform

Load-carrying

- The tire is subjected to alternating stresses during each revolution of the wheel. The tire design must be able to ensure that the tire is able to sustain these stresses

Cushioning

- The tire should be able to absorb small high frequency vibrations set up by the road surface and thus provide cushioning effect

Power Consumption

- The automotive type tire does absorb some power which is due to friction between the thread rubber and road surface and also due to hysteresis loss on account of tire being continuously fixed and released. Synthetic tyres consume more power while rolling than the ones made out of natural rubber

Tyre Noise

- The tire noise may be in the form of definite pattern sing, a sequel or a loud roar. In all these cases, it is desirable that the noise be minimum

Balancing

- The tire being rotating part of the automobile, it must be balanced statically as well as dynamically

Type of Tyres

- On the basis of cushioning medium
    1. Solid or Non-pneumatic tyres
    2. Pneumatic tyres
- On the basis of air storage system
    1. Tubed or Conventional Tyres.
    2. Tubeless tire
- On the basis of Skelton of tire
    1. Cross-ply or bias ply tyres
    2. Radial ply tyres
    3. Belted-bias tyres

On the basis of cushioning medium

1. Solid tyres;

- Solid cross-section of tire material
- Unable to provide cushioning and comfort to the riders
- They are obsolete now

2. Pneumatic Tyres

- Air filled tyres are known as pneumatic tyres
- It consists of outer body (the main tire) and a tube inside
- The tire tube combination is mounted on the wheel rim
- The inside tube is filled with the air

Function of Pneumatic Tyres

- They support the weight of the vehicle
- They provide traction for driving and braking
- They allow steering control and the directional stability
- They offer cushion to the vehicle over the ground surface irregularities and against road shocks
- They transmit driving and braking forces to the road

On the basis of air storage system

A) Conventional tube tyres

- It consists of two main parts, carcass and Tread
- The carcass is the basic structure taking mainly the various loads
- It consists of a number of plies
- The plies wound in a particular fashion from the cards of rayon
- Each card in each ply is covered with resilient rubber compound
- All plies insulated against each other
- The plies are attached to two high tension steel wire, these are called beads

B) Tubeless tyres

- This type of tire does not need a separate tube
- Instead the air under pressure is filled in the tire
- A non-return valve is fitted to the rim
- The inner construction of the tire is almost same as that of tubed tire
- Except that it is lined on inside with a special air-retaining liner

Advantage over the Conventional Tubed Tyres

- Lesser unsprung weight
- Better cooling
- Slower leakage of air
- Simpler assembly
- Improved safety

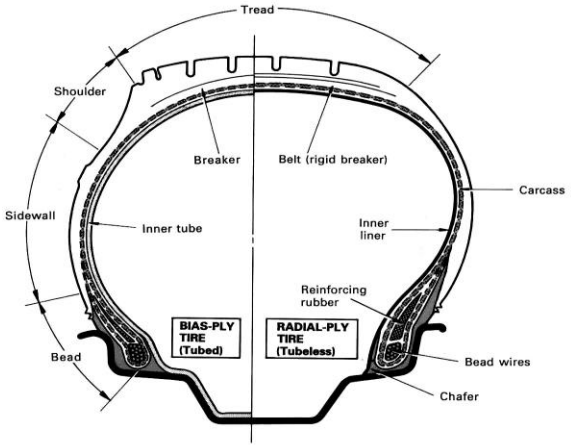


Figure 4.4 tube and tubeless tyre

On the basis of Skelton of tire

Depends upon the Skelton of the tire (carcass), tyres are classified into

- Cross-ply or bias-ply
- Radial-ply
- Belted-bias type

Cross ply Type

- The ply cords are woven at an angle (30-40degree) to the tire axis
- There are '2' layers which run in opposite direction
- That lead to rubbing of the two layers
- Thus produce heat which would damage the tire material

Radial ply tire

- The ply cords run in the radial direction in the direction of the axis
- Run a number of breaker strips in circumferential direction
- The material for the breaker strips must be flexible
- Without breaker strips radial tyres would give soft ride

Belted bias type

- It is a combination of the cross and radial types
- The belts construction is the bias-ply over which a number of breaker belts run
- The stress in the carcass are restricted
- The tread area is stabilized due to belts
- Results in reduction of tread –scrubbing. Increase the tire life

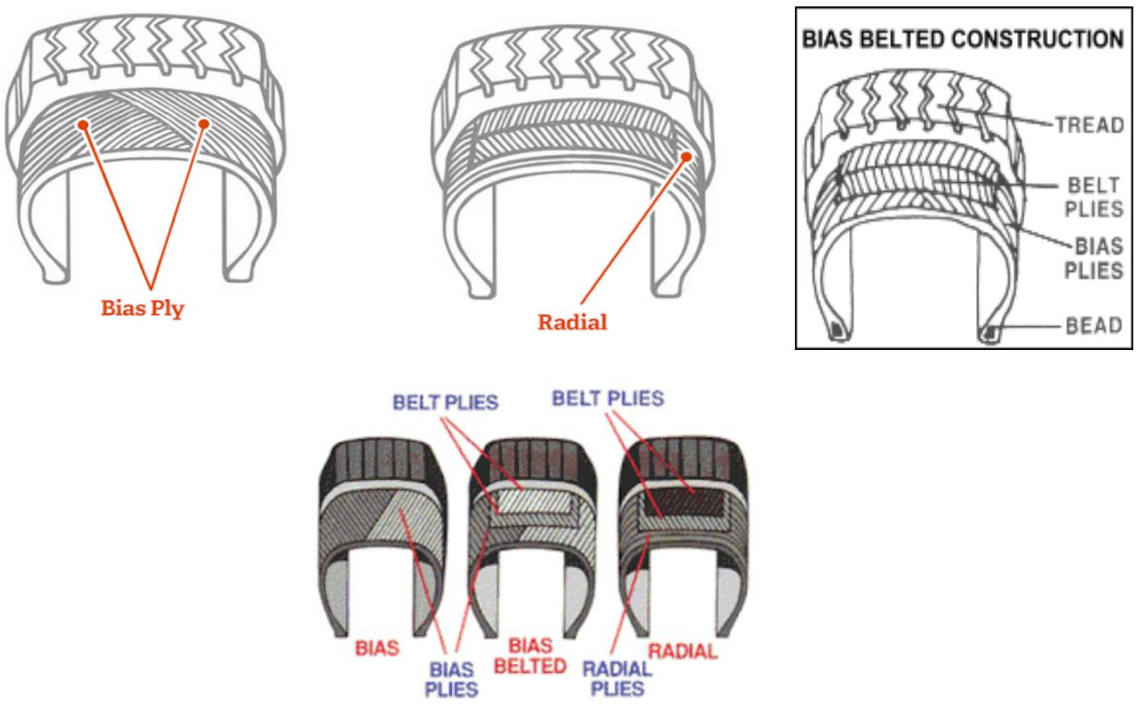


Figure 4.5 types of tyres On the basis of Skelton of tire

Various Components of the Tyres

- Tread
- Breaker
- Casing
- Side walls
- Beads

Tread

- The shoulder to shoulder width of the tire represents the tread
- Natural rubber as well as synthetic rubber is used
- The natural rubber helps the tire to stay cooler during running

Breaker

- The two top plies of the tire are referred as breakers
- They are widely spaced as compared to other plies
- These plies help in spreading the shocks received from the road

Casing

- The tire casings are made up of layers of cord impregnated with rubber
- The number of layers of cord varies according to the use of Tyre
- Motor car tyres usually have 4 to 6 plies
- Heavy-duty truck and bus tyres may have up to 22 plies
- Earth moving machinery the tyres may have up to 34 plies

Side wall

- The side wall consists of rubber compound
- Which serve as protective covering to the casing
- A tire may have a black or white side wall
- Both the side walls have the same performance

Beads

- Coil of wire represent the beads
- These wires are of high-tensile steel
- Which are built in the edge of the tire
- Give strong edges to press against the inner edge of the rim

Constituents of a Tyre

1.**Rubber**: natural synthetic compounded with a large number of chemicals to ensure the necessary characteristics

2**. Nylon**: rayon cord fabric for the tire body

3. Steel for High tensile bead wires

Considerations in Tread Design

Grip

- The braking grip of a tire depends upon two factors
  a) Tread material
  b) Tread pattern
- The grip for a particular tread pattern is effected mechanically as well as through friction
- The tread must provide suitable sharp edges that will engage with the road

Noise

- Various type of vibrations caused by roughness of the road surface
- By the distortion of the tire carcass also produce noise
- The type of tread pattern also contributes to tire noise

- Noise depends upon the nature of the rubber compound

Wear

- For less wear the tire must be such that the individual elements which undergo minimum distortion during running
- Tread wear indicators are provided at the bottom of the tread grooves

Tread Pattern

- The grooves of different layouts on tire
- Styles and orientations cut on the tread of a tire are termed as tread pattern
- A proper tread pattern helps in smooth steering, better mileage
- lower noise level, Increased road grip, Improved driving comfort, less wear
- Tyres have numerous varieties of tread pattern
- Special synthetic rubber is used for making tread on the tire surface
- It has a high co-efficient of friction
- It provides good grip on wet and dry road surface

Different Types of Tread Patterns

A. Good midways adhesion, Good grip
B. Good fore and aft grip Rapid, irregular wear and noisy running
C. Good sideways, fore and aft grip Irregular wear on hard roads, noisy running
D. Good wear resistance and steering characteristic
E. Maximum grip and sideways stability

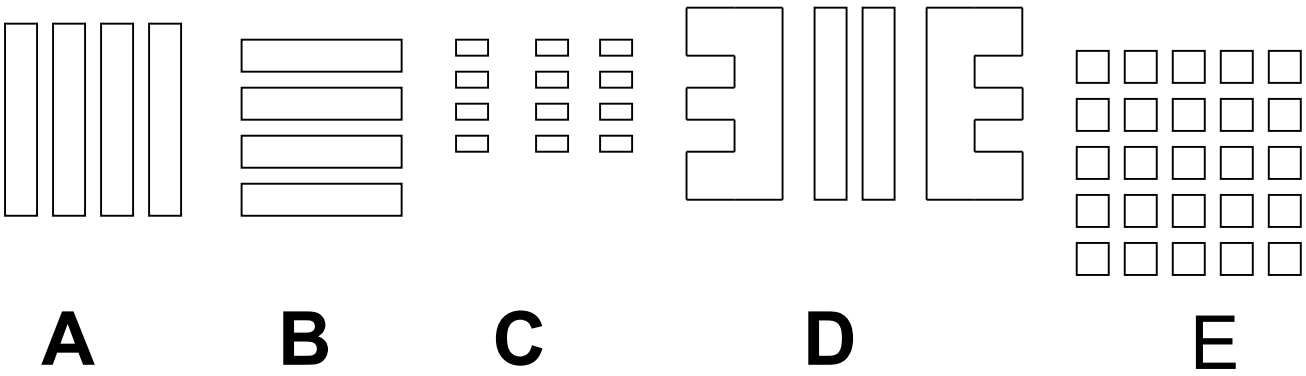


Figure 4.6 types of tyres On the basis of

Tyre Tread Pattern

Features	**Benefits**
• Flat tread radius	• Slow wear, higher mileage
• Deep radial grooves	• Better traction, tear resistance
• Smooth center rib	• Higher impact resistance.
• Long sidewall flutes	• Cooler running
• Wider foot print	• Better road contact and grip
• Biting edges on sidewall	• Quick start and stop
• Extra (rubber) depth tread	• More life, greater safety

- Sidewall branding
- Circumferential rib
- Centre groove
- Aesthetic appearance
- Excellent wear resistance
- Directional stability

Factors Affecting Tyre Life

The main factors which affect tire performance and consequently their life

- Tyre inflation
- Vehicle maintenance
- Manner of driving
- Miscellaneous factors (heat, Position in which tire fitted, road conditions, Seasons)
- Inflation pressure

4.3 Tyre wear and causes

Causes of Tyre Wear

- Incorrect inflation
- Incorrect caster, camber, or toe-in
- Excessive braking or violent acceleration
- Worn steering mechanism
- Worn king pins
- Out of balance wheel
- Misalignment
- Over-loading
- Wrong loading
- Defective brakes
- Toe-out incorrect on turn
- Bleeding of air in tire
- Careless driving
- Unequal tire
- Incorrect rotation of tyres

CAUSES OF IRREGULAR TYRE WEAR

Fault	**Causes**
• rapid wear	• Oval or eccentric brake drums
• Wear on one shoulder more than the other	• Excessive wheel camber or misalignment
• Heel and toe wear on individual studs	• Road slip in one direction only
• One half of the tread circumference worn more than the other half	• Unbalancing

4.4 Brakes (Needs, Classification)

The act or process of slowing or stopping a vehicle, wheel, shaft, etc., or for keeping it stationary, esp. by means of friction

Braking, response and handling are all very good.

Functions of Braking System

The braking system in automotive engines performs the following functions:

- Halting the Vehicle: The brake system is responsible for bringing vehicles to a stop in the shortest distance feasible by converting the vehicle's kinetic energy into heat energy.
- Mechanical Control: Operating as a mechanical mechanism, the brake system intervenes in motion to swiftly and effectively halt a moving entity within a brief span of time.

Requirements of Brakes

- The Brakes must be strong enough to stop the vehicle with in a minimum distance in an emergency, consistent with safety
- The driver must have proper control over the vehicle during emergency Braking and the vehicle must not skid.
- The Brakes must have good anti fade characteristics i.e. their effectiveness should not decrease constant prolonged application
  Ex: while descending hill
- The above requirement demands that the cooling of the brakes should be very efficient

Classification of brakes

The brakes for automotive use may be classified according to the following considerations.

- According to purpose:
  - Service or primary brakes
  - Parking or secondary brakes
- According to location:
  - Transmission brakes
  - Wheel brakes
- According to Construction:
  - Drum brakes
  - Disc brakes
- According to method of Actuation:
  - Mechanical brakes
  - Hydraulic brakes
  - Electric brakes
  - Vacuum brakes
  - Air brakes
- According to Extra braking effort:

- Power brakes
- Power assisted brakes

4.5 Drum and Disc brakes

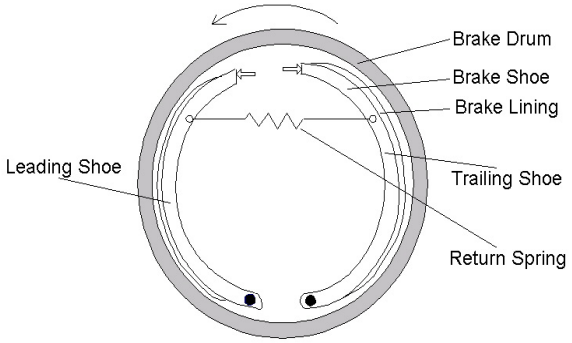
Drum Brakes:

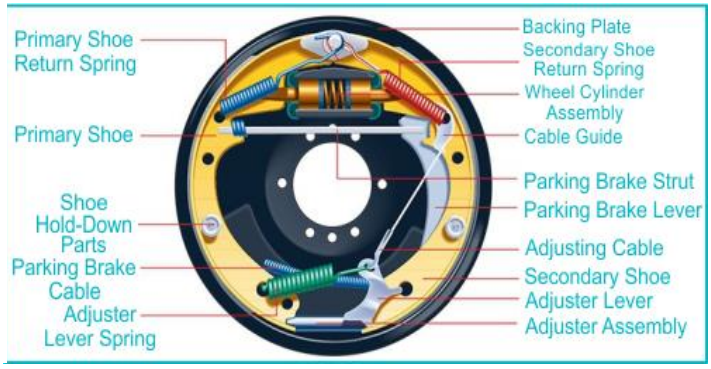
Drum brakes are a type of braking system used in some vehicles, particularly for rear-wheel braking. Although disc brakes are more common in modern vehicles, drum brakes have certain applications and characteristics:

1. Components:

- Brake Drum:
- Description: A cylindrical-shaped component attached to the wheel hub. When the brakes are applied, the brake shoes press against the inner surface of the drum, generating friction and slowing down the rotation of the wheel.
- Function: Provides a surface against which the brake shoes can press to create the necessary friction for braking.
- Back Plate:
- Description: A metal plate located on the inner side of the brake assembly. It serves as a support structure for other components and provides a mounting point for the wheel cylinder, brake shoes, and other hardware.
- Function: Supports and houses various components of the drum brake system.
- Brake Shoes:
- Description: Curved metal plates with friction material (brake lining) on the outer surface. When the brake pedal is applied, the brake shoes are pushed against the inner surface of the brake drum to create friction and facilitate braking.
- Function: Act as the primary friction elements in the drum brake system.
- Brake Liners:
- Description: The friction material attached to the outer surface of the brake shoes. It comes into direct contact with the brake drum, generating friction and converting kinetic energy into heat during braking.
- Function: Provides the necessary friction for slowing down or stopping the vehicle.
- Retaining Springs:
- Description: Springs that hold the brake shoes in place and help to return them to their rest position when the brakes are released.
- Function: Maintain proper positioning and alignment of the brake shoes within the brake assembly.
- Cam:
- Description: A cam mechanism that is part of the brake adjuster. As the brake shoes wear down, the cam adjusts to maintain the proper clearance between the brake shoes and the brake drum.
- Function: Facilitates automatic adjustment of the brake shoes to compensate for wear.

- Brake Linkages:
- Description: Rods or levers that connect various components of the brake system, including the brake pedal, brake shoes, and the cam adjuster.





- Function: Transmit the force from the brake pedal to the brake shoes and facilitate the movement and adjustment of various components within the drum brake assembly.

Figure 4.7 typical drum brake

2. Operation:
- When the driver applies the brakes, hydraulic pressure forces the brake shoes against the inner surface of the drum.
- The friction between the brake shoes and drum generates heat and slows down the rotation of the wheel.

3. Advantages:
- Cost-Effective: Drum brakes are generally simpler and more cost-effective to manufacture.
- Parking Brake Functionality: The design of drum brakes makes them well-suited for use as parking brakes.

4. Disadvantages:
- Heat Dissipation: Drum brakes can be more prone to heat buildup compared to disc brakes, potentially leading to reduced braking performance under heavy use.
- Self-Adjustment Complexity: Drum brakes may require periodic manual adjustment to maintain optimal performance.

5. Applications:
- Drum brakes are often used in the rear wheels of smaller and lighter vehicles.
- They are still found in some trucks, entry-level cars, and older vehicle models.

6. Maintenance:
- Regular inspection and adjustment are essential to ensure even wear of the brake shoes and maintain braking efficiency.
- Drum brakes may require more maintenance compared to disc brakes.

7. Transition to Disc Brakes:
- While drum brakes are still in use, especially in certain applications, many modern vehicles favor disc brakes for improved performance, heat dissipation, and overall efficiency.

Despite being less common in newer vehicles, drum brakes remain a viable braking solution, particularly for rear-wheel applications in certain automotive contexts. Advances in disc brake technology have led to their widespread adoption, but drum brakes continue to be utilized in specific vehicle designs.

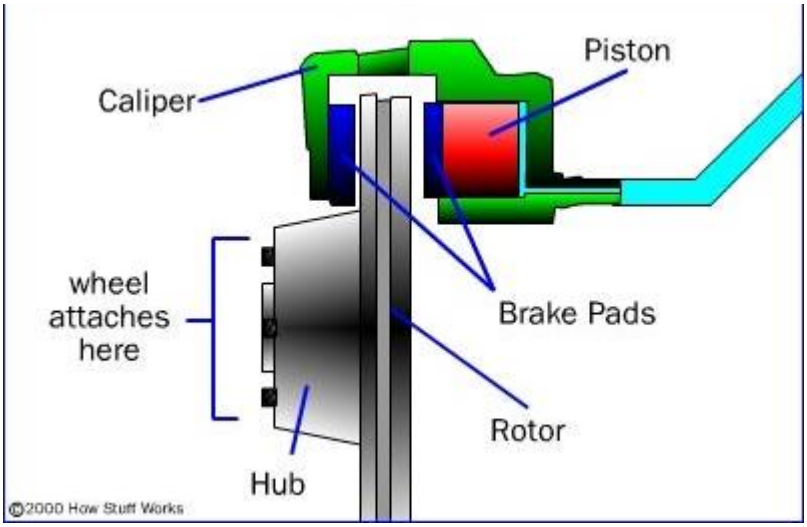
Disc brakes

Disc brakes are a common type of braking system used in modern vehicles. They provide efficient and reliable braking performance and are often used on both the front and rear wheels, although front disc brakes are more prevalent. Here are the key components and features of disc brake systems:

1. Components and working:

- Brake Disc (Rotor):
  - Description: A flat, circular metal disc mounted on the wheel hub. When the brakes are applied, brake pads clamp onto the disc to create friction and slow down the rotation of the wheel.
  - Function: Converts kinetic energy into heat during braking, providing the surface against which brake pads can generate friction.
- Brake Caliper:
  - Description: A hydraulic or mechanical component that houses pistons and brake pads. The caliper is mounted over the brake disc.
  - Function: When the brake pedal is pressed, hydraulic pressure (in hydraulic systems) or mechanical force (in some older or simpler systems) causes the caliper pistons to push the brake pads against the disc, creating friction.
- Brake Pads:
  - Description: Flat plates with friction material on one side. They are housed within the brake caliper and come into contact with the brake disc when braking.
  - Function: Generate friction against the rotating disc, causing the vehicle to slow down.
- Brake Lines:
  - Description: Hydraulic lines that carry brake fluid from the master cylinder to the brake calipers.
  - Function: Transmit hydraulic pressure to the calipers, initiating the braking process.
- Master Cylinder:
  - Description: Converts mechanical force from the brake pedal into hydraulic pressure.
  - Function: Initiates the flow of brake fluid through the brake lines, pressurizing the system and activating the brake calipers.
- Brake Fluid:
  - Description: Hydraulic fluid that transfers force within the brake system.
  - Function: In response to pressure from the master cylinder, brake fluid flows through the brake lines to engage the caliper pistons and brake pads.
- Brake Bleeder Valve:
  - Description: A small valve on the brake caliper or wheel cylinder used to release air or brake fluid during the bleeding process.
  - Function: Ensures the removal of air bubbles from the brake system, maintaining brake performance.
- Ventilated Discs (Optional):
  - Description: Some high-performance or heavy-duty vehicles may have ventilated (slotted or drilled) brake discs.

- Function: dissipation, of brake fade braking.



Enhances heat reducing the risk during intense

Figure 4.8 typical disc brake

2. Advantages of Disc Brakes:
   - Better Heat Dissipation:
   - Consistent Performance:
   - Quick Cooling:
   - Reduced Stopping Distances:
   - Ease of Maintenance:

3. Disadvantages of Disc Brakes:
   - Cost:
   - Complexity:
   - Hydraulic System Vulnerability:

4.Applications:
   - Automotive Vehicles:
     - Commonly used on both front and rear wheels in various types of vehicles, including passenger cars, trucks, and SUVs.
   - High-Performance Vehicles:
   - Heavy-Duty and Commercial Vehicles:

4.6 Mechanical, Hydraulic and pneumatic brakes

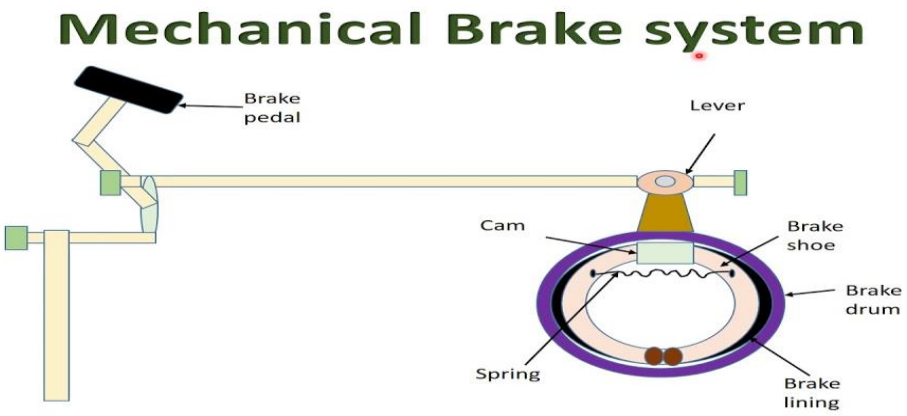
Mechanical Braking System:

A mechanical braking system relies on mechanical components, such as cables, levers, and linkages, to transmit force from the driver's input to the braking elements. While less common in modern

passenger vehicles, these systems are found in applications such as bicycles, motorcycles, and some older vehicles.

Here's a brief overview:

1.



Components:

- Brake Pedal or Lever: The driver's input device to initiate braking.
- Mechanical Linkage: Cables or rods transmitting force to the braking elements.
- Brake Drum or Disc: Rotating component providing the surface for friction.
-Brake Shoes or Pads: Friction material pressed against the drum or disc to generate braking force.
- Return Springs: Assist in returning the brake shoes or pads to their rest position.
- Adjusting Mechanism: Allows manual adjustment for compensating wear.
- Parking Brake Mechanism: Engages the brakes for parking.

Figure 4.9 mechanical braking

2. Operation:

- When the driver presses the brake pedal or pulls the brake lever, it activates the mechanical linkage.
- The mechanical linkage transmits the force to the brake shoes or pads, pressing them against the rotating brake drum or disc.
- Friction is generated, converting kinetic energy into heat and slowing down the rotation of the wheel.

3. Advantages:

- Simplicity: Mechanical systems are generally simple in design.
- Cost-Effective: They tend to be more cost-effective in manufacturing and maintenance.
- Reliability: Can be robust and reliable in certain applications.

4. Disadvantages:
- Limited Performance: Mechanical systems may have limitations in performance compared to hydraulic or electronic systems.
- Adjustment Required: Manual adjustments may be needed to maintain optimal braking.
- Potential for Wear: Mechanical components, especially cables, may experience wear over time.

5. Applications:
- Bicycles: Many bicycles use mechanical rim brakes or disc brakes.
- Motorcycles: Some motorcycles, especially older models, may have mechanical drum or disc brakes.
- Older Vehicles: Mechanical braking systems were common in older cars and trucks.

While modern vehicles often utilize hydraulic or electronic braking systems for enhanced performance, mechanical braking systems continue to serve in various applications where simplicity, cost-effectiveness, and reliability are prioritized.

Hydraulic Braking System:

A hydraulic braking system is a widely used method for slowing down or stopping vehicles. It employs fluid pressure to transmit force from the driver's input to the braking components.
Here's a brief overview:
1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Master Cylinder: Converts mechanical force from the brake pedal into hydraulic pressure.
- Brake Lines: Hydraulic tubes or hoses that carry brake fluid from the master cylinder to the brake calipers or wheel cylinders.
- Brake Calipers (Disc Brakes) or Wheel Cylinders (Drum Brakes):
- Hydraulic components that house pistons. In disc brakes, calipers squeeze brake pads against the brake disc, while in drum brakes, wheel cylinders press brake shoes against the brake drum.
- Brake Fluid: Hydraulic fluid that transmits force within the braking system.
- Brake Discs or Drums: Rotating components on the wheel. In disc brakes, the calipers press against the disc; in drum brakes, the wheel cylinders press against the drum.

2, Operation:

- When the driver presses the brake pedal, it activates the master cylinder.
- The master cylinder pressurizes the brake fluid.
- The pressurized brake fluid is transmitted through the brake lines.
- In disc brakes, the calipers squeeze brake pads against the disc, generating friction and slowing down the wheel. In drum brakes, the wheel cylinders press brake shoes against the drum.

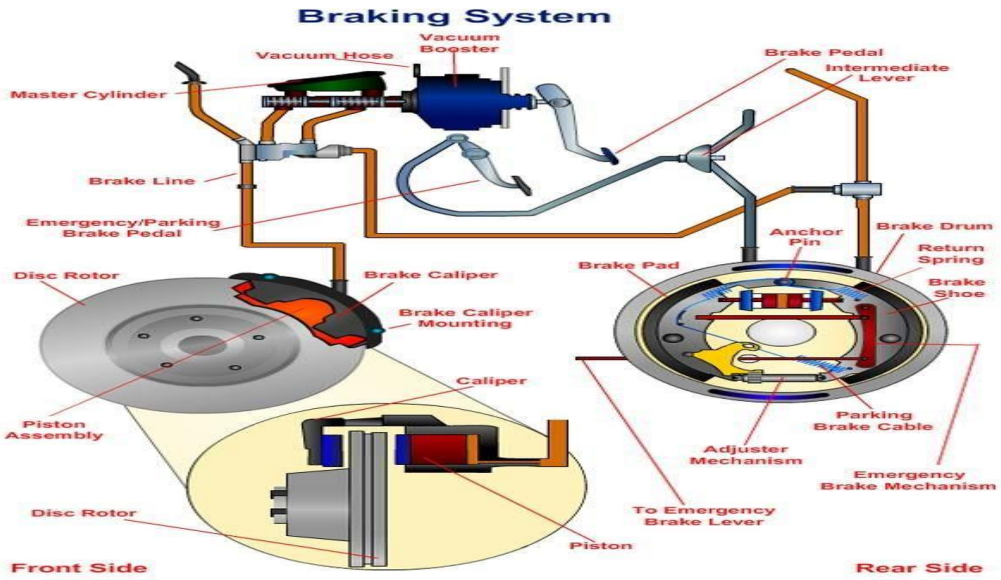
- The kinetic energy is converted into heat through friction, and the vehicle slows down.

Figure 4.10 hydraulic braking

3, Advantages:

- Efficiency: Provides reliable and efficient braking performance.
- Consistency: Maintains consistent braking performance under various conditions.
- Heat Dissipation: Disc brakes, in particular, offer effective heat dissipation.

4, Disadvantages:



- Complexity: Hydraulic systems are more complex than mechanical systems.
- Maintenance: Requires periodic checks for brake fluid levels and potential leaks.
- Cost: Hydraulic braking systems can be more expensive to manufacture and maintain.

5, Applications:

- Automotive Vehicles: Used in cars, trucks, motorcycles, and most modern vehicles.
- High-Performance Vehicles: Common in sports cars and high-performance vehicles.
- Commercial Vehicles: Found in heavy-duty trucks and commercial vehicles.

The hydraulic braking system is a standard feature in modern vehicles due to its effectiveness and reliability in providing controlled and consistent braking performance.

Pneumatic Braking System:

A pneumatic braking system utilizes compressed air to transmit force from the driver's input to the braking components. Commonly found in heavy-duty vehicles, such as trucks and buses, it offers efficient and reliable braking performance.

Here's a concise overview:
1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Air Compressor: Compresses air from the atmosphere and maintains a pressurized air supply.
- Air Storage Tanks: Store compressed air to ensure a readily available and consistent supply.
- Brake Chambers: Devices that convert compressed air pressure into mechanical force. They are usually found in each wheel brake assembly.
- Brake Drums or Discs: Rotating components on the wheels against which the braking force is applied.
- Brake Shoes or Pads: Friction material attached to plates (shoes) or backing plates (pads) that press against the brake drums or discs.
- Air Lines: Tubes that carry compressed air from the air storage tanks to the brake chambers.

2, Operation:

- When the driver presses the brake pedal, it signals the release of compressed air.
- Compressed air is supplied by the air compressor and stored in the air tanks.
- The pressurized air is transmitted through air lines to the brake chambers.
- In the brake chambers, the air pressure forces mechanical components (pushrods or diaphragms) to move, activating the brake shoes or pads.
- The brake shoes or pads generate friction against the rotating brake drums or discs, converting kinetic energy into heat and slowing down the wheels.

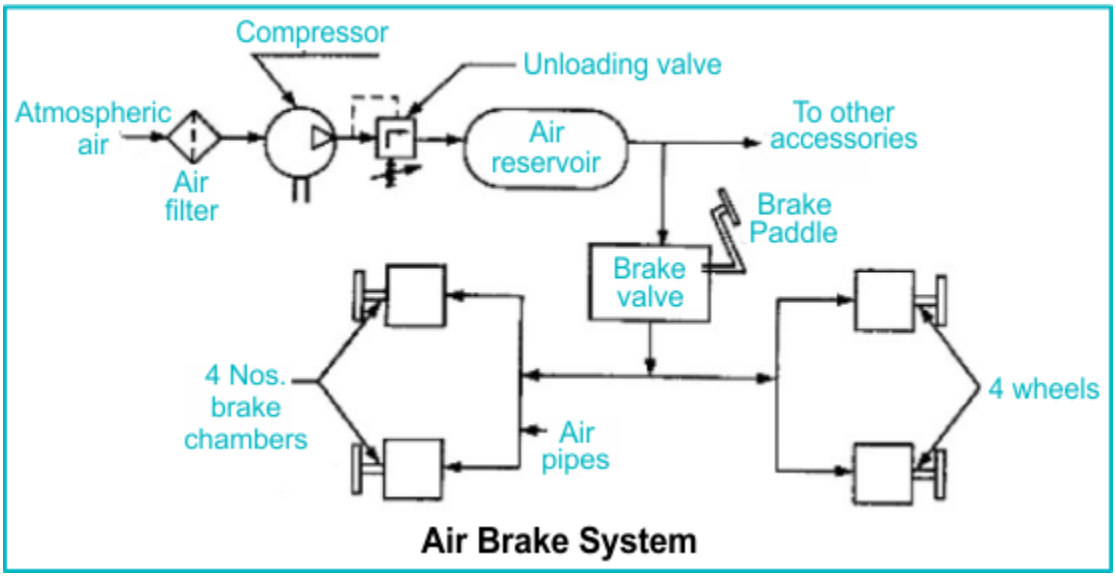


Figure 4.11 pneumatic braking system

3, Advantages:

- Consistent Performance: Provides consistent braking performance, especially in heavy-duty applications.
- Reduced Fade: Effective in minimizing brake fade during prolonged use.
- Powerful Braking: Well-suited for large and heavy vehicles.

4, Disadvantages:

- Complexity: Pneumatic systems are more complex than hydraulic or mechanical systems.
- Maintenance: Requires periodic checks for air leaks and system integrity.
- Initial Cost: Installation and maintenance costs can be higher compared to other braking systems.

5, Applications:

- Heavy-Duty Vehicles: Commonly used in trucks, buses, and other large commercial vehicles.
- Railway Systems: Pneumatic braking systems are employed in certain railway applications.

The pneumatic braking system is favored in heavy-duty applications where its reliability and consistent performance make it an ideal choice for ensuring safe and effective braking in large and powerful vehicles.

4.7 Vacuum assist braking system

A vacuum-assist braking system, commonly known as a vacuum booster or power brake system, is a braking system that utilizes engine vacuum to enhance the force applied by the driver on the brake pedal. This system is designed to reduce the amount of pedal effort needed for effective braking. Here's a brief overview:

1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Vacuum Booster: A cylindrical device located between the brake pedal and the master cylinder.

Function: Uses engine vacuum to amplify the force applied to the brake pedal by the driver, making braking easier.

- Master Cylinder: Converts the force from the brake pedal into hydraulic pressure.
  Function: Distributes brake fluid to the brake calipers or wheel cylinders.
- Brake Lines: Hydraulic tubes carrying brake fluid from the master cylinder to the brake calipers or wheel cylinders.
- Brake Calipers (Disc Brakes) or Wheel Cylinders (Drum Brakes):
- Hydraulic components that house pistons. In disc brakes, calipers squeeze brake pads against the brake disc, while in drum brakes, wheel cylinders press brake shoes against the brake drum.
- Brake Discs or Drums: Rotating components on the wheels against which the braking force is applied.

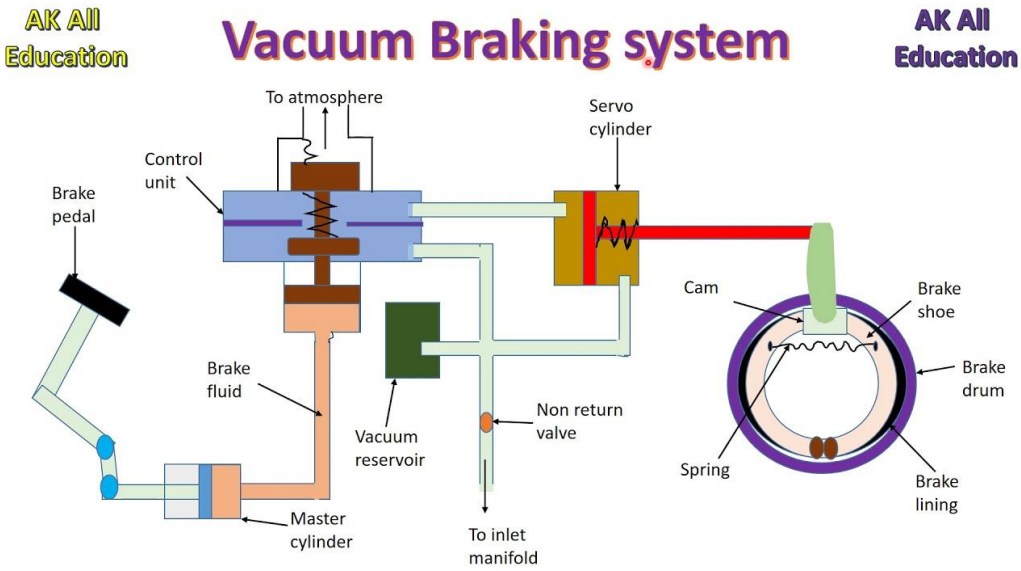


Figure 4.11vaccum assisted braking system

2, Operation:

- When the driver presses the brake pedal, the vacuum booster is activated.
- The vacuum booster uses engine vacuum to assist in applying additional force to the brake pedal.
- The increased force is transmitted to the master cylinder.
- The master cylinder converts this force into hydraulic pressure.
- The hydraulic pressure is transmitted through the brake lines to the brake calipers or wheel cylinders.
- In the brake calipers or wheel cylinders, the hydraulic pressure forces mechanical components to move, activating the brake shoes or pads.
- The brake shoes or pads generate friction against the rotating brake drums or discs, converting kinetic energy into heat and slowing down the wheels.

3, Advantages:

- Reduced Pedal Effort: Engine vacuum assistance reduces the amount of force the driver needs to apply to the brake pedal.
- Ease of Operation: Makes braking more comfortable and less fatiguing for the driver.

4, Disadvantages:

- Dependency on Engine Vacuum: If the engine stalls or there is a vacuum system failure, the braking performance may be compromised.
- Potential for Vacuum Leaks: Vacuum hoses or the booster itself may develop leaks, affecting braking efficiency.

Applications:

- Most Passenger Vehicles: Commonly found in a wide range of cars and light trucks.

The vacuum-assist braking system is a standard feature in many modern vehicles, providing a balance between effective braking performance and ease of operation for the driver.

4.8 Retarders

Retarders are systems used in vehicles to assist in slowing down or controlling speed, particularly in heavy-duty applications such as large trucks and buses. They work by providing additional resistance to the vehicle's motion, helping to reduce speed without relying solely on the traditional friction brakes.

Here are the main types of retarders:

- Exhaust Brake:

Description: The exhaust brake restricts the flow of exhaust gases, creating backpressure in the engine. This backpressure works against the engine's pistons, causing a reduction in speed.
Operation: When activated, the exhaust brake closes a valve in the exhaust system, creating resistance and slowing down the vehicle.

- Engine Brake (Jake Brake):

Description: The engine brake, commonly known as a Jake Brake, alters the operation of the engine's exhaust valves to release compressed air in the cylinders. This released air creates resistance in the engine, leading to reduced speed.
Operation: When engaged, the engine brake momentarily opens the exhaust valves near the end of the compression stroke, allowing compressed air to escape, and this compression resistance aids in slowing down the vehicle.

- Hydraulic Retarder:

Description: A hydraulic retarder is a separate unit installed in the vehicle's drivetrain. It uses hydraulic fluid to create resistance and slow down the vehicle.
Operation: When activated, the hydraulic retarder generates resistance by forcing hydraulic fluid through a series of vanes or disks. The resulting drag on the drivetrain helps to control speed.

- Eddy Current Retarder:

Description: An eddy current retarder uses electromagnetic induction to create resistance and slow down the vehicle.
Operation: When activated, the retarder induces eddy currents in a rotating metal disk. The interaction of these currents with the magnetic field generates resistance, creating a braking effect.

Advantages of Retarders:

- Reduced Brake Wear: Retarders help reduce wear on traditional friction brakes, extending their lifespan.
- Improved Brake Performance: By supplementing traditional brakes, retarders contribute to more effective braking, especially in downhill or heavy-load situations.
- Enhanced Safety: Retarders contribute to improved vehicle control and stability during descents, reducing the risk of brake fade.

Disadvantages:

- Additional Complexity: Retarders add complexity to the vehicle's drivetrain system.
- Cost: Installation and maintenance of retarders can be expensive.
- Noise: Some types of retarders, such as engine brakes, can generate increased noise during operation.

Applications:

- Heavy-Duty Trucks: Commonly used in commercial trucks, especially those involved in long-haul transportation or hauling heavy loads.
- Buses: Often employed in buses to enhance safety and control during descents.
- Off-Road Vehicles: Utilized in certain off-road and industrial vehicles to improve braking efficiency.

Retarders are valuable components in the world of heavy-duty vehicles, providing an additional layer of control and safety in challenging driving conditions. Their application is particularly critical for vehicles operating on steep gradients or carrying substantial loads.

4.9 Anti-lock Braking System(ABS).

The Anti-Lock Braking System (ABS) is a safety feature designed to prevent wheel lockup during braking, offering enhanced vehicle control and reducing the risk of skidding.

Functions of ABS

- The anti-lock braking system (ABS) comes as a standard safety feature in all modern cars.
- This is where the anti-lock braking system (ABS) comes in.
- It prevents the wheels from locking up and helps them maintain grip with the road below.

Here's a brief overview:
Components:

- Wheel Speed Sensors: Monitor the speed of each wheel.
- Hydraulic Control Unit (HCU): Manages brake fluid pressure.
- Pump Motor: Assists in maintaining optimal brake pressure.
- Valves: Control the brake fluid flow to prevent wheel lockup.
- Electronic Control Unit (ECU): Processes data from wheel speed sensors and controls the HCU.

Operation:

- Wheel Speed Monitoring:
  ABS constantly monitors the speed of each wheel using wheel speed sensors.
- Detection of Wheel Lockup:

The system detects when a wheel is about to lock up during braking.

- Brake Pressure Modulation:
  The HCU modulates brake pressure by adjusting the valves in the brake lines.
- Pulsating Brakes:
  ABS causes the brakes to pulsate rapidly, preventing wheel lockup.
- Maintained Steering Control:
  By preventing lockup, ABS helps the driver maintain steering control during hard braking.

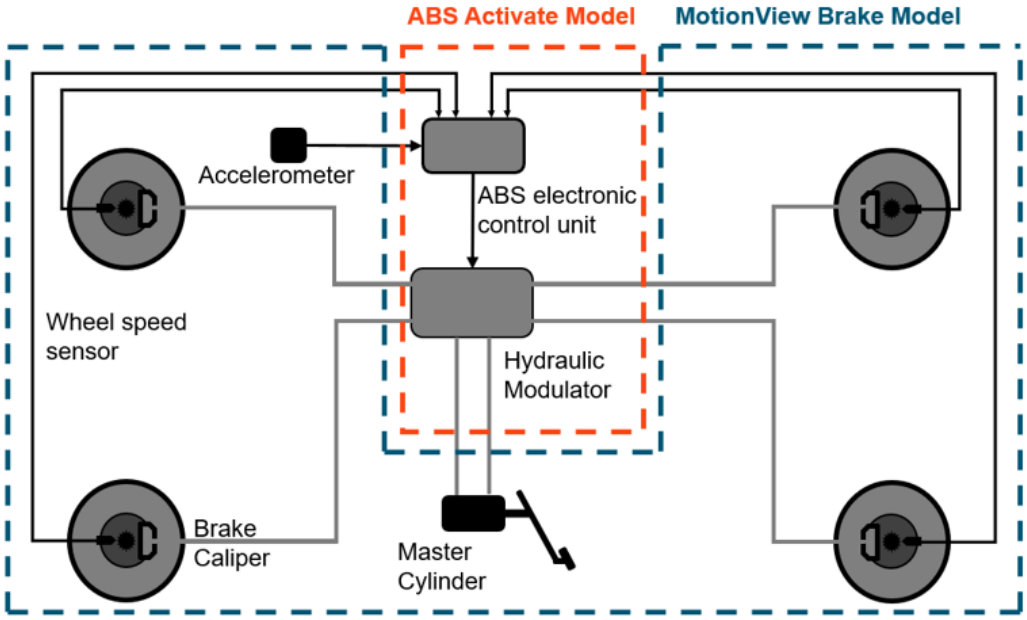


Figure 4.12 anti-lock braking system(ABS)

Advantages:

- Improved Steering Control: Prevents wheel lockup, allowing the driver to maintain control during braking.
- Shorter Stopping Distances: Reduces stopping distances, especially on slippery surfaces.
- Enhanced Stability: Contributes to vehicle stability and reduces the risk of skidding.
- Effective in Various Conditions: Works well on different road surfaces, including wet or icy conditions.

Disadvantages:

- Increased Complexity: Adds complexity to the braking system.
- Cost: Installation and maintenance can increase overall vehicle costs.
- Maintenance Dependence: Proper maintenance is crucial for effective ABS operation.

Applications:

- Passenger Cars: Standard feature in most modern cars.
- Commercial Vehicles: Common in trucks, buses, and commercial vehicles.
- Motorcycles: Increasingly integrated into motorcycle braking systems.

ABS has become a standard safety feature, significantly improving braking performance and vehicle control in diverse road conditions. Its implementation reflects a commitment to enhancing overall road safety and preventing accidents.

UNIT – V

Automobile Electrical System and Advances in Automobile Engineering

Battery-General electrical circuits- Active Suspension System (ASS) - Electronic Brake Distribution (EBD) – Electronic Stability Program(ESP), Traction Control System (TCS) - Global Positioning System (GPS), Hybrid vehicle, Fuel Cell.

5.1 Battery

A battery is a device that stores and releases electrical energy through electrochemical reactions. It typically consists of one or more electrochemical cells, each composed of a positive electrode (cathode), a negative electrode (anode), and an electrolyte that allows ions to move between the electrodes. During discharge, chemical reactions within the battery generate electric current, and during charging, the process is reversed. Batteries serve as portable sources of power for a variety of electronic devices and applications.

The working principle of a battery involves electrochemical reactions that convert chemical energy into electrical energy. Here's a simplified explanation of how a battery works:

- Chemical Reactions:
- Electrolyte:
- Electron Flow:
- Ion Movement:
- Load Connection:
- Discharge and Recharge:

The overall process involves a continuous cycle of chemical reactions during discharge and recharge, allowing the battery to provide electrical energy over time.

Types of batteries

1. Primary Batteries (Disposable Batteries):

- Chemistry: Primary batteries are designed for single use and cannot be recharged. The chemical reactions that produce electrical energy in these batteries are typically not reversible.

Common Types:

- ✓ Alkaline batteries (e.g., AA, AAA)
- ✓ Zinc-carbon batteries
- ✓ Lithium batteries (e.g., CR2032)

Application:

Primary batteries are commonly used in low to moderate power consumption devices such as remote controls, flashlights, clocks, and other everyday household items.

Advantages:

- Convenient for portable, low-power devices.
- Generally, less expensive than rechargeable batteries.
- No need for a charging device.

Disadvantages:

- Once depleted, primary batteries must be replaced.
- Not environmentally friendly due to disposable nature.

2. Secondary Batteries (Rechargeable Batteries):

Chemistry: Secondary batteries are rechargeable, meaning the chemical reactions that produce electricity can be reversed by applying an external electrical current.

Common Types:

- Lithium-ion batteries (e.g., laptop batteries, electric vehicle batteries)
- Nickel-cadmium (NiCd) batteries
- Nickel-metal hydride (NiMH) batteries

Application:

- Rechargeable batteries are used in devices with higher power requirements, such as smartphones, laptops, cameras, power tools, and electric vehicles.

Advantages:

- Can be recharged and reused multiple times.
- More cost-effective in the long run.
- Generally better for the environment due to reduced waste.

Disadvantages:

- Typically, more expensive upfront.
- Require a compatible charging device.
- Self-discharge rate may be higher than primary batteries.

components in battery

A battery is a complex electrochemical device composed of several key components that work together to generate and store electrical energy.

Here are the main components of a typical battery:

Anode:

- The anode is the negative electrode of the battery.
- It releases electrons during the chemical reaction that occurs during discharging.

Cathode:

- The cathode is the positive electrode of the battery.
- It accepts electrons during the discharging process.

Electrolyte:

- The electrolyte is a chemical substance (liquid or gel) that facilitates the movement of ions between the anode and cathode.
- It allows the flow of electrons within the battery, completing the electrochemical circuit.

Separator:

- The separator is a physical barrier that prevents direct contact between the anode and cathode.
- It ensures that electrons flow through the external circuit and ions move through the electrolyte.

Collector:

- Collectors are conductive materials connected to the anode and cathode, allowing the flow of electrons to and from the external circuit.

Terminal:

- Terminals are the external connections of the battery that allow it to be connected to an electrical circuit.
- The positive terminal is connected to the cathode, and the negative terminal is connected to the anode.

Current Collector:

- Current collectors are metallic foils or grids that collect current from the active materials in the electrodes.
- In lithium-ion batteries, for example, current collectors are typically made of copper for the anode and aluminum for the cathode.

Case or Housing:

- The case or housing encloses the internal components of the battery, protecting them from external factors and providing structural support.

Vent:

- Some batteries have a vent to release excess pressure and prevent the build-up of gases during extreme conditions.

Thermal Management System (Optional):

- In some advanced batteries, especially those used in electric vehicles, a thermal management system may be included to regulate the temperature and prevent overheating.

Current Pathways:

- These are pathways within the battery that allow the flow of electrons and ions during discharge and recharge cycles.

Different types of batteries may have variations in these components, and advanced battery technologies may incorporate additional features for safety, efficiency, and performance. The specific materials used in the anode, cathode, and electrolyte also vary depending on the type of battery chemistry, such as lithium-ion, lead-acid, nickel-metal hydride, etc.

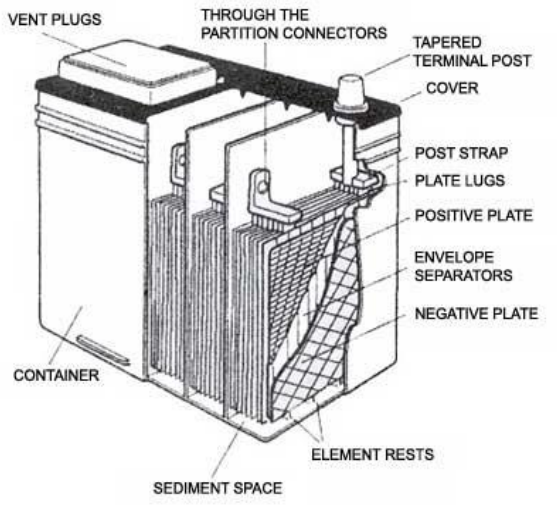


Figure 5.1 components in a battery

5.2 General electrical circuits

5.3 Active Suspension System (ASS)

5.4 Electronic Brake Distribution (EBD)

5.5 Electronic Stability Program(ESP)

5.6 Traction Control System (TCS)

5.7 Global Positioning System (GPS)

5.8 Hybrid vehicle

5.9 Fuel Cell.

UNIT – III

Steering and Suspension System

Principle of steering - Steering Geometry and wheel alignment - Steering linkages – Steering gearboxes - Power steering - front axle.

Suspension system - Independent and Solid axle – coil, leaf spring and air suspensions - torsion bar - shock absorbers.

3.1 Introduction to steering system

What is the main function of steering?

The steering system in an automobile is a crucial component that **allows the driver to control the direction in which the vehicle moves**. Its primary function is to enable the driver to steer the vehicle with ease and precision.

*The front wheels are supported on the front axle so that they can swing to the left or right for steering This movement is produced by gearing and linkage between the steering wheel in front of the driver and steering knuckle or wheel.

This complete arrangement is called steering system.

Requirements of steering system

- The steering mechanism should be very accurate and easy to handle.
- The effort required to steer should be minimum.
- The effort required to steer must not be tiresome to the driver.
- The steering mechanism should Provide directional stability.

3.2 Principle of steering: -

The steering wheel turns a pinion gear, which moves a rack back and forth to steer the wheels. This mechanism converts the circular motion of the steering wheel to linear motion, which is applied to the wheels of the car via tie rods and a steering knuckle.

The Main parts of the steering system

1. **Steering Wheel**: The user interface for the driver to input steering commands, connected to the steering column.
2. **Steering Column**: Connects the steering wheel to the steering gearbox or rack, transmitting the driver's input.
3. **Steering Shaft**: Transfers the rotational movement from the steering column to the steering gearbox or rack.

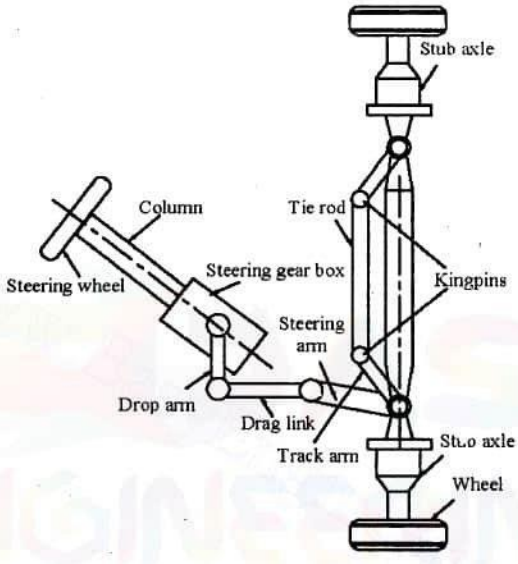


Figure 3.1

4. **Steering Gear Box**: Converts the rotational motion from the steering shaft into lateral motion, determining the direction of the vehicle.
5. **Steering Pinion**: In rack-and-pinion systems, this small gear meshes with the rack, facilitating the conversion of rotation to lateral movement.
6. **Steering Rack**: In rack-and-pinion systems, it's a toothed bar connected to the wheels, allowing lateral movement when engaged with the pinion gear.
7. **Tie Rod Ends**: Connect the ends of the steering rack to the steering knuckles, transmitting steering input to the wheels.
8**. Knuckle**: Forms part of the wheel assembly; it connects the tie rod ends and provides a pivot point for wheel movement in response to steering input.

3.3 Steering Geometry and wheel alignment

Steering geometry refers to the arrangement and design of the components in a vehicle's steering system that determine how the wheels respond to driver input and how the vehicle handles. Proper steering geometry is crucial for achieving good stability, handling, and safety. There are several key parameters and concepts associated with steering geometry:

1. **Caster Angle**: The caster angle is the angle between the steering axis (an imaginary line drawn through the upper and lower pivot points of the front suspension) and the vertical axis when viewed from the side of the vehicle. Positive caster enhances straight-line stability and steering return ability.

2. **Toe Angle**: Toe angle is the angle formed by the longitudinal axis of the vehicle and the centerline of the wheels. There are two types of toe angles: toe-in and toe-out. Toe-in means that the front of the wheels is closer together than the rear, while toe-out means the front is farther apart. Proper toe alignment is essential for tire wear and vehicle stability.

3. **Camber Angle**: Camber is the tilt of the wheels from the vertical when viewed from the front. Positive camber means the top of the wheels is tilted outward, and negative camber means the top is tilted inward. Camber affects tire wear and cornering stability.

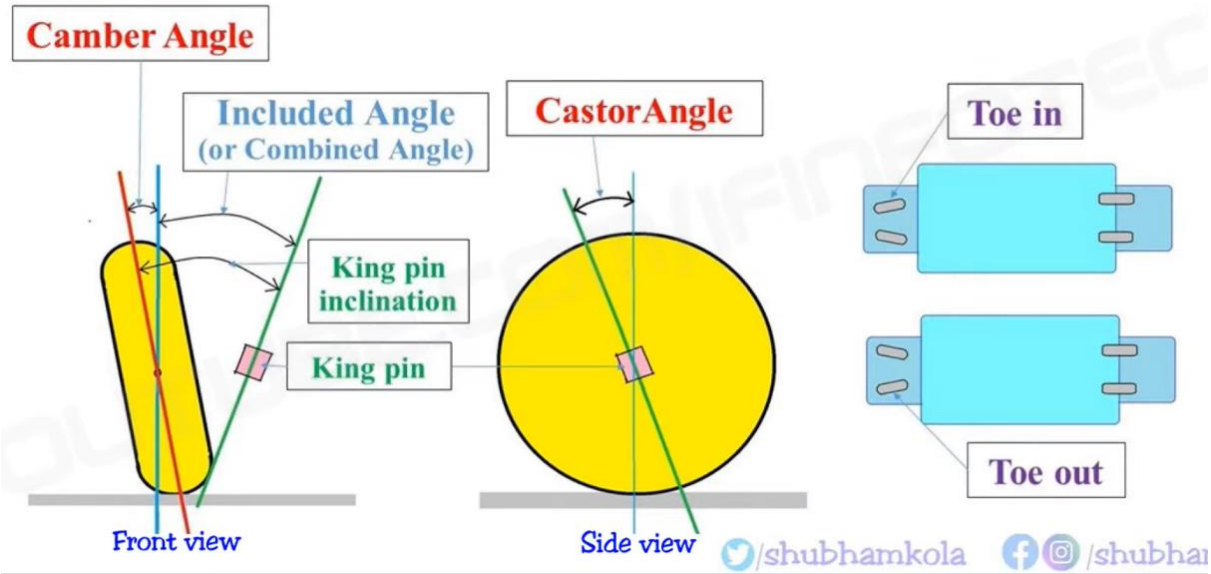


Figure 3.2 Caster Angle, Toe Angle, Camber Angle

4. **Ackermann Steering Geometry**: This is a design principle that ensures the inside and outside wheels of a vehicle follow different turning radii when steering. This helps to reduce tire scrubbing during turns, providing smoother and more predictable handling.

5. **Kingpin Inclination (KPI**): KPI is the angle formed by the steering axis and a line perpendicular to the ground. It contributes to the stability of the steering system and influences the self-centering behavior of the wheels.

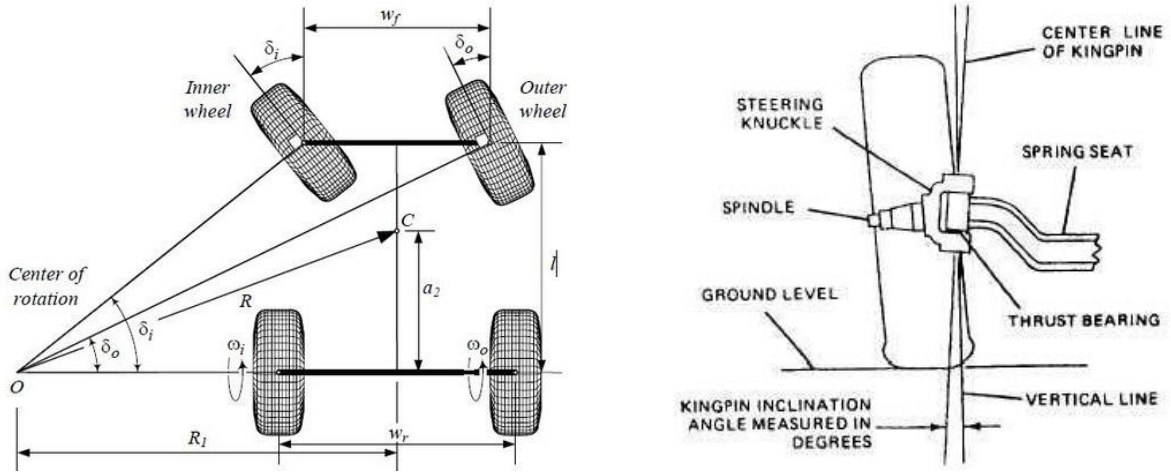


Figure 3.3 Ackermann Steering Geometry Kingpin Inclination (KPI):

6. **Scrub Radius**: The scrub radius is the distance between the tire's contact patch and the point where the steering axis intersects the ground. It influences steering effort and is related to the tendency of the steering wheel to return to the center after a turn.

7. **Trail**: Trail is the distance between the point where the steering axis intersects the ground and the tire's contact patch. It affects the stability of the vehicle and contributes to self-centering.

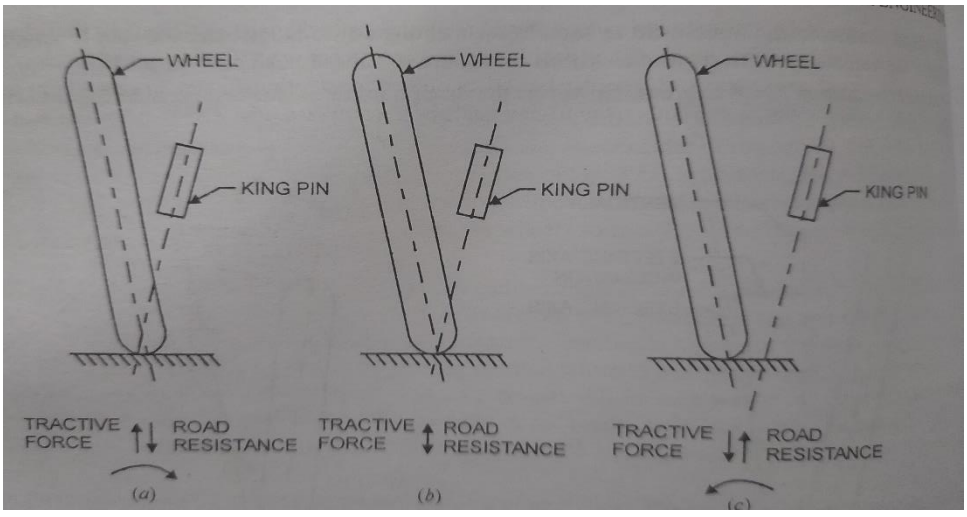


Figure 3.4 Effect of combined angle variation in rear wheel drive vehicle. The point of intersection of the wheel and king pin center lines (a) above the ground (negative scrub radius)-tendency to toe-in, (b) just at the ground (zero scrub radius) no effect and (c) below the ground (positive scrub radius)-tendency to toe-out

wheel alignment, also known as tire alignment, refers to the adjustment of the angles of the wheels relative to each other and to the car's frame or body. Proper wheel alignment is crucial for several reasons, including ensuring that the vehicle drives straight, preventing uneven tire wear, and optimizing steering response. There are three main components of wheel alignment: toe, camber, and caster.

1. **Toe:**
   Toe-In: The front edges of the tires are closer together than the rear edges. This helps with straight-line stability.
   Toe-Out: The front edges of the tires are farther apart than the rear edges. This setup can enhance cornering performance.

2. **Camber:**
   Positive Camber: The top of the tire is tilted outward. This can improve stability in certain situations but excessive positive camber may lead to uneven tire wear.
   Negative Camber: The top of the tire is tilted inward. This is often used to improve cornering performance and is common in high-performance or sports cars.

3. **Caster**:
   Positive Caster: The steering axis is tilted backward, contributing to stability at high speeds and aiding in steering return ability.
   Negative Caster: The steering axis is tilted forward. This is less common but can be found in some off-road or heavy-duty applications.

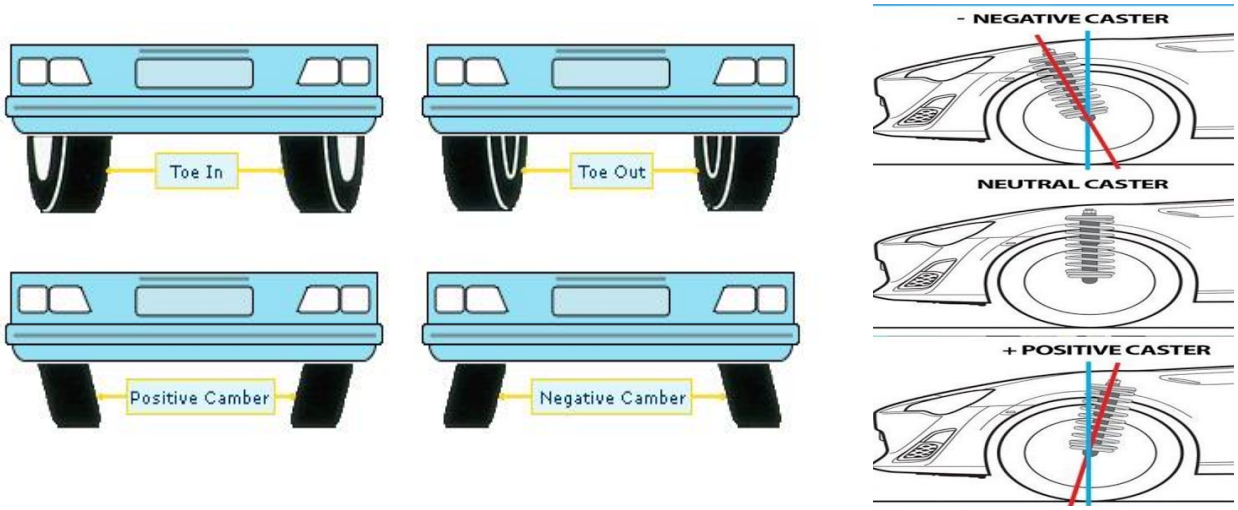


Figure 3.5 Caster Angle, Toe Angle, Camber Angle adjustment in wheel alignment

Wheel alignment is typically checked and adjusted by automotive technicians using specialized equipment. Here's how the process generally works:

1. **Inspection**: Technicians inspect the tires, suspension components, and steering system to identify any issues that might affect alignment.

2. **Measurement**: Using alignment equipment, the technician measures the current alignment settings of the wheels.

3. **Adjustment**: If the measurements indicate that the alignment is out of specification, adjustments are made to the suspension components to bring the wheels back into alignment. This may involve adjusting tie rods, control arms, or other components.

4. **Recheck**: After adjustments, the technician rechecks the alignment to ensure that it now falls within the specified tolerances.

5. **Test Drive**: In some cases, a test drive may be conducted to ensure that the vehicle handles properly and that there are no unusual noises or vibrations.

Regular wheel alignment checks and adjustments are essential for maintaining vehicle safety, tire longevity, and optimal handling. It's recommended to have the wheel alignment checked whenever you notice uneven tire wear, if the vehicle pulls to one side, or after hitting a significant pothole or curb.

3.4 Steering Linkages

Steering linkages are the components that connect the steering system to the wheels of a vehicle, translating the driver's input into the movement of the wheels. These linkages play a crucial role in the overall steering mechanism, allowing for controlled and precise steering. The main steering linkages include:

1. **Tie Rods:**
   Inner Tie Rods: These are connected to the steering gearbox or rack and are responsible for transmitting the steering input to the outer tie rods.
   Outer Tie Rods: These connect to the inner tie rods on one end and the steering knuckle on the other end. They transmit the steering movement to the wheels.
2. **Steering Pitman Arm**: The pitman arm is connected to the steering gearbox in a recirculating ball steering system or the steering rack in a rack-and-pinion system. It converts the rotational movement from the steering gearbox or rack into linear movement, which is then transmitted to the tie rods.
3. **Idler Arm**: In some steering systems, especially in older vehicles, an idler arm is used to support the other end of the center link (also known as the relay rod). The center link connects the pitman arm to the steering linkage on the passenger side.
4. **Center Link (Relay Rod):** The center link, also known as the relay rod, connects the pitman arm to the steering linkage on the passenger side. It helps transmit steering input to the wheels on the passenger side of the vehicle.
5. **Drag Link**: The drag link connects the pitman arm to the steering linkage on the driver's side. It helps transmit steering input to the wheels on the driver's side of the vehicle.
6. **Ball Joints and Bushings**: Ball joints are used at the ends of tie rods and sometimes in other steering components. They provide pivot points for the movement of the steering linkages. Bushings are used to reduce friction and allow for smooth movement in various joints.
7. **Steering Column:** The steering column is the shaft that connects the steering wheel to the steering gearbox or rack. It contains the necessary linkages, such as universal joints, to transmit the driver's input to the steering mechanism.

Types of Steering Linkages

There are several types of steering linkages used in vehicles, each with its own design and configuration. The choice of steering linkage depends on the vehicle's type, size, and intended use. Here are some common types:

1. **Rack and Pinion Steering:**

Description: In this system, a pinion gear attached to the steering shaft engages with a rack, which is a flat, toothed bar. As the steering wheel turns, the pinion gear moves the rack left or right, translating the rotational motion into lateral motion to turn the wheels.

Advantages: Simple design, direct and responsive steering, commonly used in smaller and lighter vehicles.

2. **Recirculating Ball Steering:**

Description: This system uses a worm gear inside a steering box. As the steering wheel turns, it causes the worm gear to rotate, moving a recirculating ball mechanism that turns the pitman arm, which is connected to the drag link and tie rods.

Advantages: Robust design, suitable for larger and heavier vehicles, provides power steering assistance.

3. **Parallelogram Steering Linkage:**

Description: This linkage consists of a center link, idler arm, and two tie rods. The center link connects the pitman arm to the idler arm, while the tie rods connect the center link to the steering knuckles.

Advantages: Common in older vehicles, offers simple and effective steering control.

4. **Four-Bar Linkage**:

Description: This linkage system uses four control arms to connect the steering gear to the steering knuckles. It provides a stable and predictable steering response.

Advantages: Often used in heavy-duty trucks and some off-road vehicles, offers good stability and control.

Steering linkage for vehicle with rigid Independent front suspension.

5. **Strut (Wishbone) Suspension**:

Description: In this design, the steering knuckles are connected to the vehicle's frame or body through two control arms resembling a wishbone or an A-shape. The tie rods connect the steering system to the steering knuckles.

Advantages: Commonly used in modern independent suspension systems, provides good handling and ride comfort.

6. **McPherson Strut Suspension**:

Description: In this design, a single, vertical strut combines the shock absorber and the coil spring, while the steering knuckle is attached to the bottom of the strut. The tie rods connect the steering system to the steering knuckles.

Advantages: Common in front-wheel-drive vehicles, provides a compact and space-efficient design.

The choice of steering linkage depends on factors such as vehicle size, weight, handling characteristics, and manufacturing considerations. Modern vehicles often use rack and pinion steering for its simplicity and responsiveness, while larger or heavy-duty vehicles may utilize recirculating ball or parallelogram linkages to meet their specific requirements.

Steering Linkages are depending on the type of vehicle's front suspension:

- Steering linkage for vehicle with rigid axle front suspension (Parallelogram type)
- Steering linkage for vehicle with rigid Independent front suspension.

Rigid axle type front suspension

In a vehicle with a rigid axle front suspension, the steering linkage is designed to connect the steering wheel to the wheels mounted on a solid (rigid) front axle. This type of suspension system is often found in trucks, SUVs, and some off-road vehicles. The steering linkage components work together to transmit the driver's input to the wheels, allowing for controlled and predictable steering.

Here's a basic explanation of how the steering linkage works in a vehicle with a rigid axle front suspension:

Pitman Arm:

Location: Connected to the steering gear (commonly a recirculating ball steering box) on one end and to the steering linkage on the other.

Function: Converts the rotational motion from the steering gear into lateral motion. As the pitman arm moves, it pushes or pulls the other components in the steering linkage.

Center Link (or Relay Rod):

Location: Extends horizontally across the vehicle and connects the pitman arm to the steering arms on the steering knuckles.

Function: Transfers the lateral motion from the pitman arm to the steering arms, initiating the movement of the front wheels.

Steering Arms:

Location: Attached to the steering knuckles on each side of the front axle.

Function: Transmit the lateral motion from the center link to the steering knuckles, causing the front wheels to turn.

Tie Rods:

Location: Connect the steering arms to the steering knuckles.

Function: Transmit the steering input from the center link to the wheels. The tie rods are adjustable, allowing for alignment adjustments to ensure proper toe settings.

Drag Link:

Location: Connects the pitman arm to one of the steering arms.

Function: Assists in transmitting the lateral motion from the pitman arm to the steering arms, helping to control and guide the movement of the front wheels.

As the driver turns the steering wheel, the rotational motion is transferred through the pitman arm to the center link. The center link, in turn, moves the steering arms, and the tie rods transmit this motion to the front wheels, causing them to turn left or right.

It's worth noting that the rigid axle front suspension, while robust and capable, can result in a less smooth ride compared to independent front suspension systems. However, it is often preferred in off-road or heavy-duty applications where durability and load-carrying capacity are crucial. Regular maintenance, including inspections and adjustments of the steering linkage components, is important to ensure proper steering performance and tire wear.

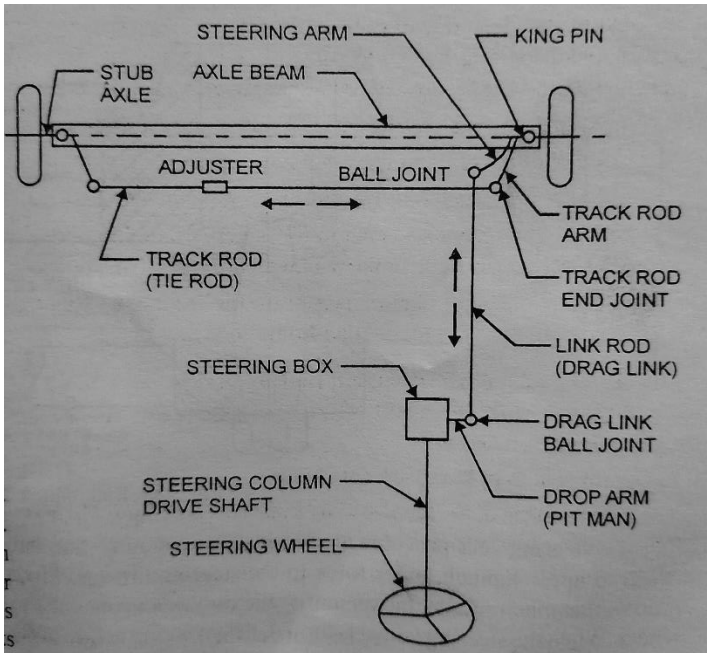


Figure 3.6 Rigid axle type front suspension

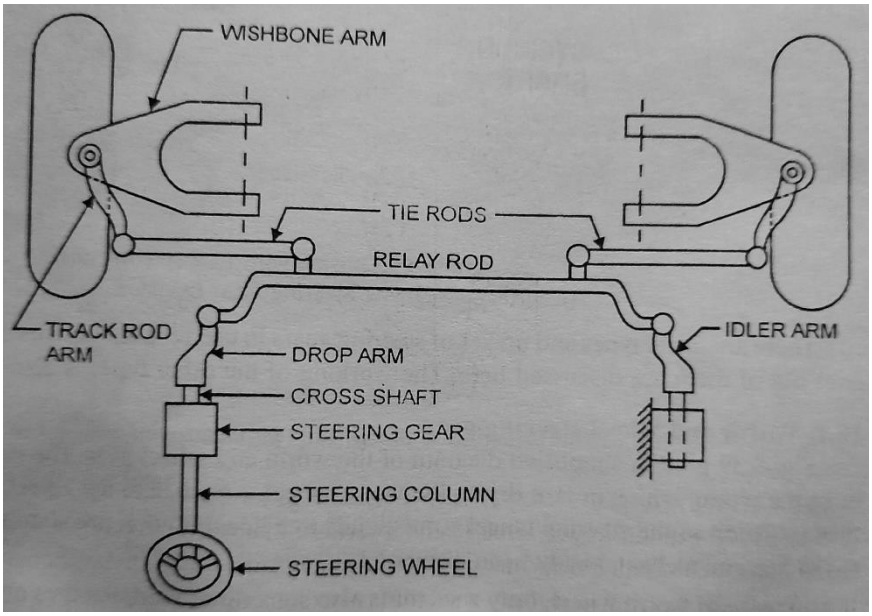


Figure 3.7 Independent front suspension

Independent front suspension

In a vehicle with independent front suspension (IFS), each front wheel can move independently of the other, providing improved ride comfort and handling compared to a rigid front axle suspension. This type of suspension system is often found in most of the light vehicles (cars).The steering linkage in a vehicle with independent front suspension is designed to allow for this independent movement while still enabling effective control and steering.

Here's an overview of the typical components and their functions:

Rack and Pinion Steering System:

Description: In many vehicles with independent front suspension, a rack and pinion steering system is commonly used.

Function: The steering wheel is connected to a shaft with a small pinion gear. This pinion gear engages with a long, horizontal toothed bar known as the rack. As the pinion gear turns, it moves the rack left or right, translating the rotational motion of the steering wheel into lateral motion.

Tie Rods:

Location: Tie rods connect the ends of the rack to the steering knuckles on each wheel.

Function: Transmit the lateral motion from the rack to the steering knuckles, causing the front wheels to turn.

Steering Knuckles:

Location: Attached to the wheel hubs and capable of rotating with the movement of the tie rods.

Function: The steering knuckles pivot as the tie rods move, allowing the wheels to turn left or right.

Ball Joints:

Location: Connect the steering knuckles to the control arms.

Function: Allow for the vertical movement of the suspension while maintaining a connection between the steering system and the wheels.

Control Arms:

Location: Positioned between the frame or body of the vehicle and the steering knuckles.

Function: Control arms provide the necessary support and guide the vertical movement of the wheel and suspension.

Struts or Shock Absorbers:

Location: Typically mounted between the control arms and the vehicle's frame or body.

Function: Dampen and control the vertical movement of the suspension, contributing to ride comfort and handling.

In vehicles with independent front suspension, the movement of one wheel does not directly affect the other, allowing each wheel to react independently to road irregularities. The steering linkage, consisting of the rack and pinion system and associated components, facilitates precise and responsive steering control.

The construction and design of the steering linkage in independent front suspension systems contribute to better handling, improved road feel, and enhanced ride comfort compared to rigid front axle suspensions. Regular maintenance, including inspections of components such as tie rods and ball joints, is important for ensuring proper steering performance and safety.

3.5 Steering gearboxes

A steering gearbox, also known as a steering gear or steering box, is a crucial component in a vehicle's steering system. Its primary function is to translate the rotational motion of the steering wheel into lateral motion that directs the movement of the front wheels.

There are different types of steering gearboxes used in vehicles, each with its own design and characteristics. Here's a brief explanation of some common types:

1. **Recirculating Ball Steering Gearbox:**

Design: This type uses a worm gear inside a steering box. The worm gear engages with a sector gear, and as the steering wheel turns, it causes the worm gear to rotate. The rotation of the worm gear moves recirculating balls, which then move a nut connected to the pitman arm.
Application: Commonly used in larger and heavier vehicles, such as trucks and some SUVs.
Advantages: Robust design, provides a mechanical advantage, making it suitable for heavy-duty applications.
Disadvantages: Can have more play and friction compared to rack and pinion systems.

2. **Rack and Pinion Steering Gearbox:**

Design: In this system, a pinion gear attached to the steering shaft engages with a toothed rack. As the steering wheel turns, the pinion gear moves the rack laterally, transmitting the motion to the tie rods and turning the front wheels.
Application: Commonly used in smaller and lighter vehicles, as well as many modern cars.
Advantages: Simpler design, provides more precise steering response, and offers a direct mechanical connection between the steering wheel and the wheels.
Disadvantages: May not be as well-suited for heavy-duty applications as recirculating ball systems.

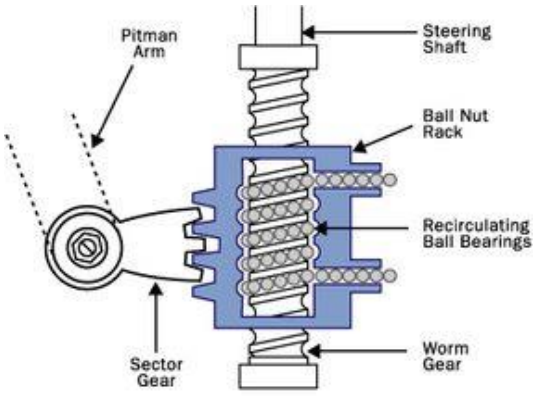
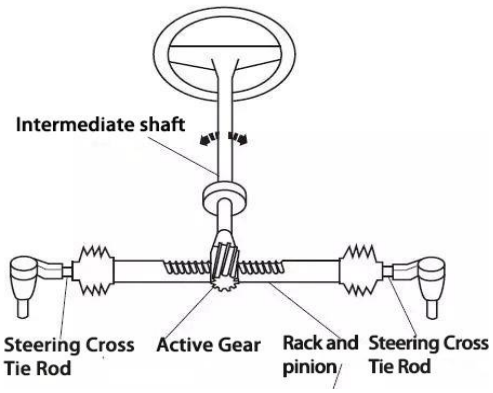


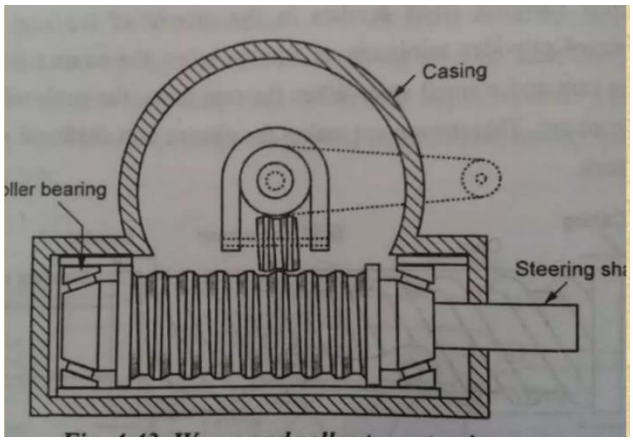
Figure 3.8 Recirculating Ball Steering Gearbox



Rack and Pinion Steering Gearbox

3. **Worm and Roller Steering Gearbox:**

Design: Similar to recirculating ball systems, but instead of balls, it uses rollers. The worm gear engages with a sector gear, and the motion is transmitted to the pitman arm through rollers.
Application: Used in some older vehicles and industrial applications.
Advantages: Provides smoother operation compared to recirculating ball systems.
Disadvantages: Less common than rack and pinion or recirculating ball systems.



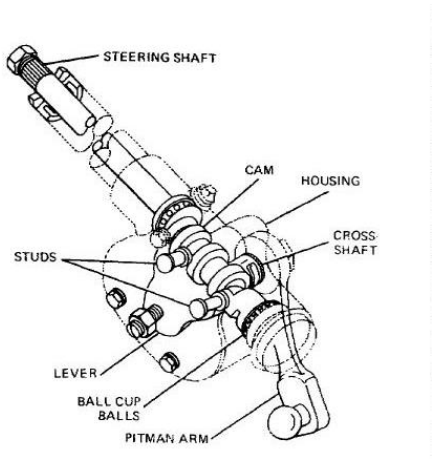


Figure 3.9 Worm and Roller Steering Gearbox: Cam and Lever Steering Gearbox:

4. Cam and Lever Steering Gearbox:

Design: This system uses a rotating cam and lever mechanism to convert rotary motion into lateral motion, turning the front wheels.

Application: Historically used in some vintage and early vehicles.

Advantages: Simple design.

Disadvantages: Not commonly used in modern vehicles due to limitations in precision and efficiency.

5. Electric Power Steering (EPS):

Design: EPS systems can be integrated with either rack and pinion or recirculating ball steering gearboxes. Instead of relying solely on mechanical linkages, EPS systems use an electric motor to assist in providing steering assistance.

Application: Widely used in modern vehicles for its efficiency and flexibility.

Advantages: Offers variable assistance, improves fuel efficiency, and enables advanced driver-assistance features.

Disadvantages: Requires electrical power, and potential electronic system complexities.

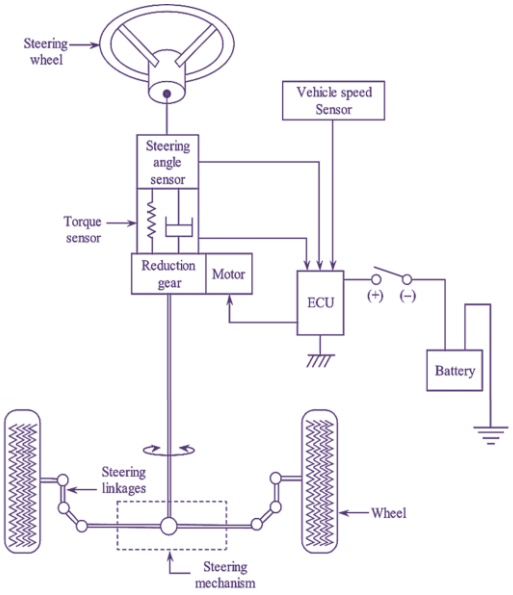


Figure 3.9 Electric Power Steering (EPS):

The choice of steering gearbox depends on factors such as the type of vehicle, intended use, and technological preferences of the manufacturer. Advances in technology, such as EPS, have introduced new possibilities for enhancing steering performance and efficiency.

3.6 Power steering

Power steering is a technology in vehicles that assists the driver in steering the vehicle by augmenting the force applied to the steering wheel. The primary purpose of power steering is to reduce the effort required by the driver to turn the steering wheel, especially at low speeds or when the vehicle is stationary. This enhancement in steering ease is particularly beneficial in larger or heavier vehicles.

There are two main types of power steering systems:

- Hydraulic power steering (HPS)
- Electric power steering (EPS).

Hydraulic Power Steering (HPS):

Mechanism: In hydraulic power steering systems, a pump, typically driven by the engine, pressurizes hydraulic fluid. This fluid is then used to assist in turning the steering mechanism.

Components: Hydraulic power steering systems include a power steering pump, fluid reservoir, hydraulic hoses, and a power steering gear (either rack and pinion or recirculating ball).

Operation: As the driver turns the steering wheel, hydraulic pressure is applied to one side of the power steering gear, assisting in the movement of the wheels.

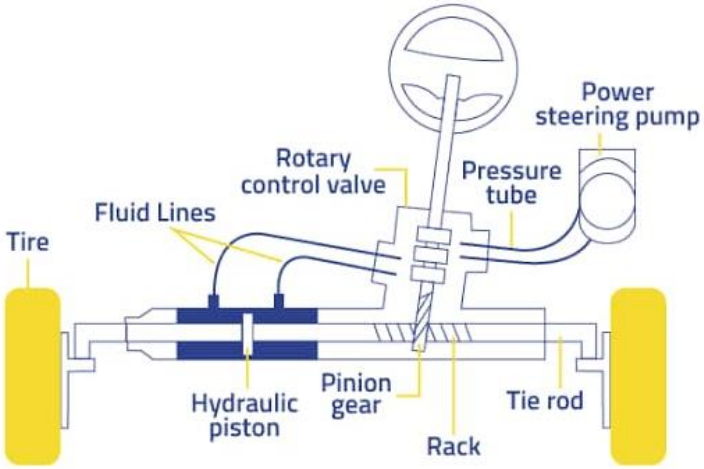


Figure 3.10 Hydraulic Power Steering (HPS):

Electric Power Steering (EPS):

Mechanism: Electric power steering systems replace the hydraulic pump with an electric motor integrated into the steering system.

Components: EPS systems include an electric motor, control module, torque sensor, and electronic components.

Operation: The electric motor provides variable assistance to the steering based on driving conditions, speed, and steering input. EPS systems are more energy-efficient as the electric motor only operates when assistance is needed.
Figure 3.9 shows the line diagram of Electric Power Steering (EPS):

Advantages of Power Steering:

Reduced Effort: Power steering significantly reduces the physical effort required by the driver to turn the steering wheel, especially in situations such as parking or navigating tight spaces.
Enhanced Maneuverability: Vehicles equipped with power steering systems are more maneuverable and responsive, providing better control.
Comfort: Power steering contributes to a more comfortable driving experience by minimizing driver fatigue.
Variable-Assist Power Steering: Some power steering systems offer variable assistance, adjusting the level of assistance based on driving conditions. For example, assistance may be higher at low speeds for easier maneuvering and parking, while decreasing at higher speeds for improved stability.

Disadvantages of Power Steering:
Cost of Repair and Maintenance: Power steering systems, especially those with hydraulic components, can be more complex than manual steering systems. Repairing or replacing power steering components can be more expensive.
Dependency on Engine: Hydraulic power steering systems rely on the engine to drive the power steering pump. If the engine fails, it can result in a loss of power steering assistance, making steering more challenging.
Reduced Road Feel: Power steering systems, especially electric power steering (EPS), may reduce the feedback or "road feel" that some drivers prefer. This can lead to a perception of decreased connection to the road, affecting the driving experience for enthusiasts.
Fuel Consumption: In hydraulic power steering systems, the power steering pump draws power from the engine, potentially contributing to a small decrease in fuel efficiency. However, modern systems are designed to minimize this impact.
Complexity: Power steering systems, particularly those with electronic components, can be more intricate and may involve more complex diagnostics and repairs compared to manual steering systems.

Power steering has become a standard feature in the majority of modern vehicles, contributing to improved safety, comfort, and ease of handling. The specific type of power steering system varies among vehicles, and advancements such as electric power steering have become more prevalent due to their efficiency and flexibility.

Types of Power Steering System

Integral Power Steering:

Integral power steering is designed to provide power assistance when the steering wheel requires between two and five pounds of effort.

It comprises a steering gear with a worm-and-ball bearing nut and a hydraulic rack piston along the worm shaft. Hydraulic pressure assists in moving the nut in any direction.

A reaction contact valve connected to the worm shaft thrust bearing controls the oil flow between the valve body and the gear and pinion assembly.

When the vehicle moves straight ahead, oil flows from the pump through open center valves and back to the reservoir. Oil also circulates the rack piston to cushion road shocks. When the vehicle turns right, the worm's movement causes the control valve to restrict fluid flow to the right turn cylinder, increasing pump pressure on the right side of the rack piston and causing the ball nut to move right. The fluid flow shifts to the left-turn power cylinder for left turns, moving the rack piston and ball nut leftward.

Linkage Power Steering

Linkage power steering separates the power cylinder from the steering gear and connects it to the steering linkage. The power assistance directly affects the steering linkage.

In the neutral position (straight-ahead motion), a centering spring holds the spool valve in the control valve assembly at the center, allowing oil to flow to both sides of the power cylinder.

When the vehicle turns left with significant wheel force, Pitman's arm moves the spool control valve, removing centering spring pressure. It shifts the valve to the right side of the body, directing oil pressure to the right side of the power cylinder and turning the wheels left. When making a right turn, the process reverses, forcing the relay rod to turn the wheels right.

Hydraulic Power Steering

Hydraulic power steering system, used from the 1950s to 2000s, relies on hydraulic assistance driven by a continuous pump. This system has drawbacks, including energy wastage when the vehicle requires no assistance.

The hydraulic pump, powered by the engine, pressurizes hydraulic fluid. This fluid increases the input force on the steering wheel, reducing the effort needed to turn the front wheels.

When the driver turns the wheel, the hydraulic pump pressurizes the fluid, which acts on a piston, transferring the driver's input force to the front wheels through a rack and pinion mechanism.

Electric Power Steering (EPS)

EPS is a modern power steering system that replaces hydraulic components with electric motors and sensors.

Instead of hydraulic force, an electric motor powered by the vehicle's battery assists the steering gear. Sensors detect the steering column's position and control the motor's torque.

When the driver turns the wheel, electronic sensors transmit the input to the vehicle's electric control unit. The unit analyses these inputs and sends voltage signals to the electric motor, which engages with the pinion gear and provides the necessary torque to the rack. This rotation of the rack steers the front wheels.

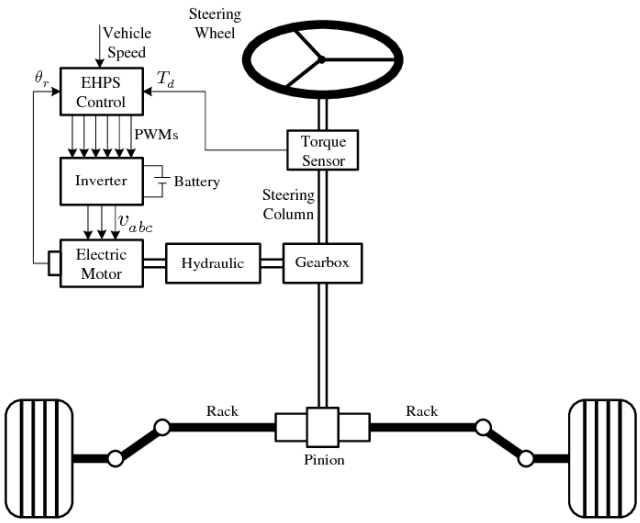


Figure 3.11 Electro-hydraulic Power Steering

Electro-hydraulic Power Steering

Electro-hydraulic power steering is a hybrid system that combines hydraulic and electric power steering elements.

Unlike traditional hydraulic systems, it uses an electric motor to drive the hydraulic pump, reducing energy waste. However, it does not offer all the features of full-electric power steering.

In this system, the hydraulic motor is powered by an electric motor instead of being run by the engine. It is employed in some heavy pickup trucks and a few other vehicles.

3.7 front axle.

Front Axle: Located in the front of the vehicle, this axle is responsible for assisting with steering and processing shocks from the uneven surface of the road. They have four main parts, which are the beam, the swivel pin, the track rod, and the stub axle. Front axles must be as sturdy as possible, and that's why they're usually made from carbon steel or nickel steel.

Functions

♣ It supports the weight of front part of the vehicle.
♣ It facilitates steering knuckles and suspension springs.
♣ It transmits weight of vehicle through springs to the front wheels.
♣ It absorbs torque applied on it due to braking of vehicle.

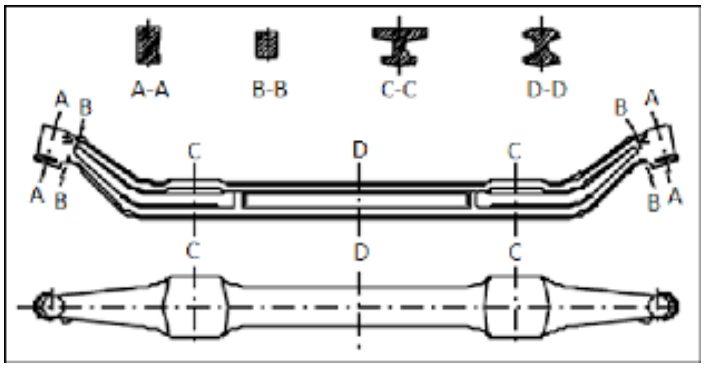


Figure 3.12 front axle

Types of Front Axle

According to Meineke, vehicles have two main types of front axle. These are:

Dead Front Axle: These axles stay in place and don't rotate with the wheels. Most dead front axles and differentials have housings that prevent them from coming into contact with water or dirt.

Live Front Axle: Unlike dead front axles, live front axles deliver driving power from the gearbox to the front wheels.

Figure 3.13 dead axle live axle

The front axle is designed to transmit the weight of the automobile from the springs to the front wheels, turning right or left as required. To prevent interference due to front engine location, and for providing greater stability and safety at high speeds by lowering the center of gravity of the road vehicles, the entire center portion of the axle is dropped.

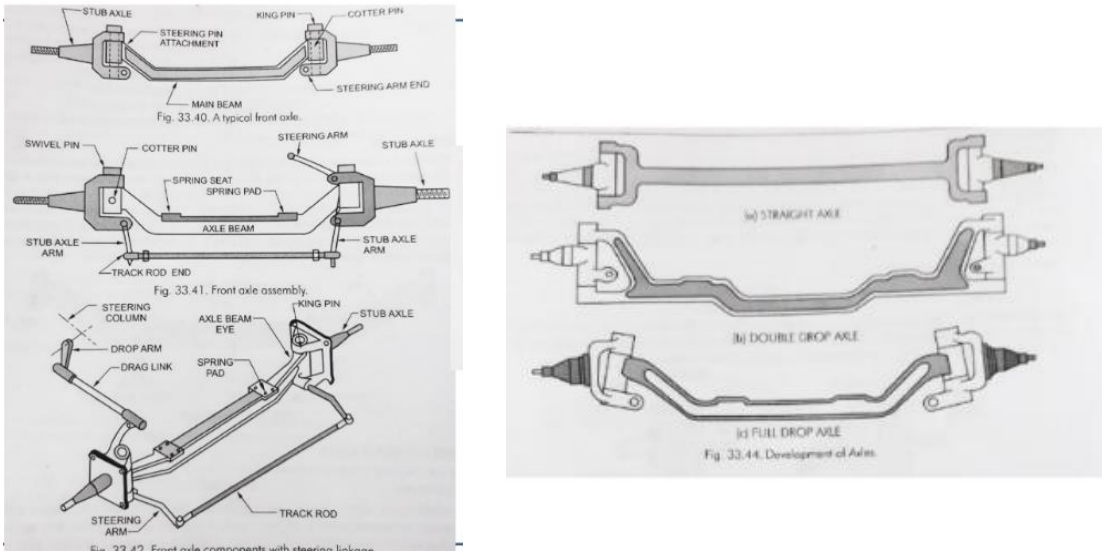


Figure 3.14 front axle assembly development of front axle

3.7 suspension system

Suspension is the system of tires, tire air, springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality, which are at odds with each other.

Objects of suspension

- To prevent the road shocks from being transmitted to the vehicle components.
- To safeguard the occupants from road shocks.
- To preserve the stability of the vehicle in pitching or rolling, while in motion.

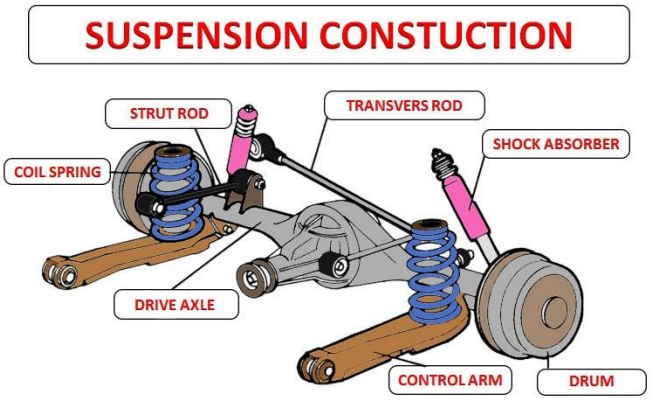


Figure 3.15

TYPES OF SUSPENSIONS SPRINGS

The various suspension springs may be classified as follows:

1. Steel Springs
   - (a) leaf spring
   - (b) tapered leaf spring
   - (c) coil spring
   - (d) Torsion bar
2. Rubber Springs
   - (a) Compression spring
   - (b) compression shear spring
   - (c) Steel-reinforced spring
   - (d) Progressive spring
   - (e) Face-shear spring
3. Plastic Spring
4. Air spring
5. Hydraulic spring

3.8 Independent and Solid axle

Independent suspension and solid axle suspension are two different approaches to the design of a vehicle's suspension system. Each has its advantages and is suited to different types of vehicles and driving conditions.

Independent Suspension:

Definition: Independent suspension allows each wheel on the same axle to move independently of the other. This means that when one wheel encounters a bump or uneven terrain, it doesn't directly affect the other wheel on the same axle.

Types:

MacPherson Strut: A common type of independent front suspension where a single vertical strut supports the weight of the vehicle and controls its movement.

Double Wishbone (Double A-arm): In this design, each wheel is attached to the vehicle using two separate control arms, providing more precise control over wheel movement.

Multi-link Suspension: Utilizes multiple links and control arms to independently manage wheel movement and control.

Advantages:

- Improved ride quality: Independent suspension systems can provide a smoother ride because each wheel reacts independently to road irregularities.
- Better handling: Independent suspension can contribute to better handling and cornering performance.
- Enhanced traction: Each wheel can maintain better contact with the road surface, especially in uneven terrain.

Applications:

Most modern passenger cars

- SUVs
- Performance vehicles
- Off-road vehicles

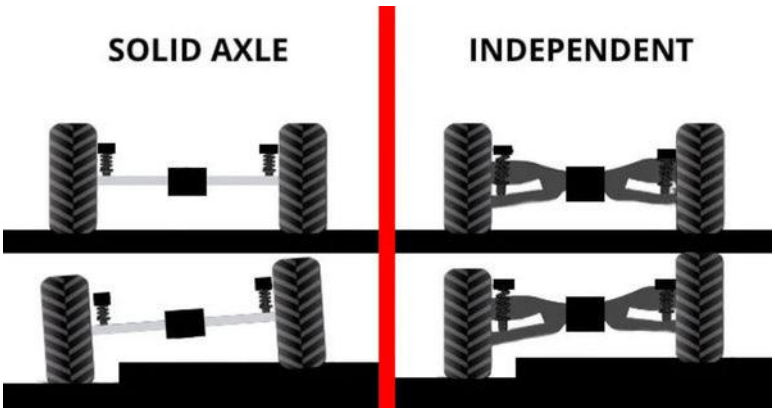


Figure 3.16

Solid Axle (Live Axle):

Definition: A solid axle connects both wheels on the same axle, and their movement is synchronized. When one wheel moves, the other wheel on the same axle is affected.

Types:

Rigid Axle: A simple and robust design where both wheels are connected to a single, solid axle.

Beam Axle: Commonly found in the rear suspension of some trucks and older vehicles, where the axle is a solid beam.

Advantages:

Durability: Solid axles are known for their durability and strength, making them suitable for heavy-duty applications.

Simplicity: Solid axles are mechanically simpler than independent suspension systems, which can make them easier to maintain.

Applications:

- Heavy-duty trucks
- Some off-road and utility vehicles
- Older model cars

Disadvantages:

- Potentially rougher ride: Solid axles may transmit more road imperfections to the vehicle, resulting in a rougher ride compared to independent suspension.
- Limited wheel independence: In extreme off-road conditions, a solid axle may not provide the same level of wheel articulation as independent suspension.

The choice between independent suspension and solid axle depends on the intended use of the vehicle and the balance between ride comfort, handling, and load-carrying capability. Modern vehicles often feature a combination of both, with independent suspension at the front and a solid axle at the rear, providing a balance between comfort and load-carrying capacity.

3.9 coil, leaf spring and air suspensions

Coil Springs:

Description: Coil springs are helical springs made of coiled steel. They compress and expand to absorb shocks and provide support to the vehicle.

Placement: Coil springs can be found in both independent and solid axle suspension systems. They are often used in conjunction with shock absorbers.

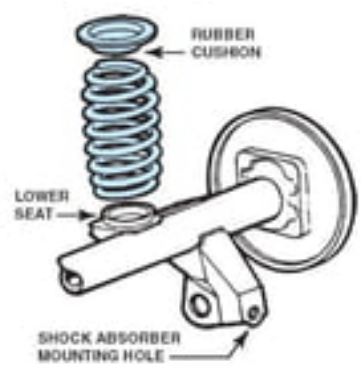


Figure 3.17

Advantages:

- Provide a smooth and comfortable ride.
- Allow for more flexibility in suspension design.

  Effective in controlling body roll during cornering.

Disadvantages:

- May not provide as much load-carrying capacity as some other types of springs.
- Susceptible to coil bind if compressed too much, potentially causing damage.

Coil springs come in various types, each designed to meet specific requirements based on the vehicle's application, suspension design, and performance needs. Here are some common types of coil springs:

Compression Coil Springs:

Description: This is the most common type of coil spring. It is designed to compress and absorb energy when a force is applied. Compression coil springs are used in various vehicle suspension systems.

Torsion Springs:

Description: Torsion coil springs are designed to resist twisting forces. They are often used in applications where rotational motion needs to be counteracted, such as in some suspension systems.

Tension (Extension) Coil Springs:
Description: Tension or extension coil springs are designed to stretch or extend when a force is applied. They are less common in vehicle suspension systems but may be used in certain applications.

Progressive Rate Coil Springs:
Description: Progressive rate coil springs have a variable spring rate, meaning the resistance to compression increases as the spring is compressed further. This design allows for a softer initial response and a firmer feel as the spring compresses more, providing a balance between comfort and performance.

Linear Rate Coil Springs:
Description: Linear rate coil springs have a constant spring rate throughout their compression range. They provide a consistent level of resistance to compression, making them predictable and straightforward in their performance.

Variable Pitch Coil Springs:
Description: Variable pitch coil springs have coils with varying distances between them. This design helps distribute stress and load more evenly, providing a smoother and more controlled ride.

Leaf Springs:
Description: Leaf springs consist of multiple layers (leaves) of spring steel bound together. They are typically mounted longitudinally on the vehicle.
Placement: Commonly used in solid axle suspension systems, especially in the rear of trucks and some SUVs.
Advantages:

- Provide excellent load-carrying capacity, making them suitable for heavy-duty applications.
- Simplicity of design and durability.
- Tend to resist axle wrap (rotation of the axle under torque).

Disadvantages:

- Can result in a rougher ride compared to coil springs.
- Limited flexibility in design compared to coil springs.

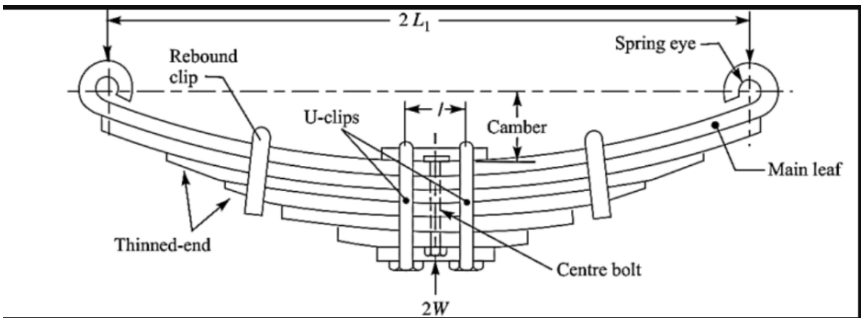


Figure 3.18

Leaf springs, also known as carriage or cart springs, have been a common suspension component in various vehicles for many years. There are several types of leaf springs, each with its own characteristics and applications. Here are some of the main types:

Elliptical or Semi-Elliptical Leaf Springs:
Description: This is the most common type of leaf spring and consists of multiple thin, curved leaves of varying lengths stacked on top of each other and secured by a center bolt. The longest leaf is typically the main leaf.
Applications: Often used in rear suspension systems of trucks, SUVs, and older cars.

Quarter-Elliptic Leaf Springs:
Description: These leaf springs are typically used in pairs, with each spring mounted longitudinally, resembling a quarter of an ellipse. They are commonly used in the front suspension of older vehicles or in certain compact cars.
Applications: Found in some vintage and compact car suspensions.

Cantilever Leaf Springs:
Description: Cantilever leaf springs are similar to semi-elliptical springs but have one end attached to a fixed point, while the other end is free to move. They are less common in automotive applications but may be found in some specialty vehicles or trailers.
Applications: Specialized applications, trailers, and certain types of off-road vehicles.

Multi-Leaf Springs:
Description: Multi-leaf springs consist of multiple thin leaves of varying lengths stacked on top of each other. They provide increased load-carrying capacity and are often used in heavy-duty applications.
Applications: Commonly found in the rear suspension of trucks, vans, and heavy-duty vehicles.

Mono-Leaf Springs:
Description: Instead of multiple leaves, mono-leaf springs have a single, thicker leaf. They are often used in sports cars and high-performance vehicles to reduce unspring weight.
Applications: Sports cars and some high-performance vehicles.

Parabolic Leaf Springs:
Description: Parabolic leaf springs have a tapered, curved design that provides a progressive spring rate. This design allows for a softer initial response and a firmer feel as the spring compresses further.
Applications: Used in various vehicles where a balance between comfort and load-carrying capacity is desired.

Reversed-Eye Leaf Springs:
Description: In reversed-eye leaf springs, the eyes, or attachment points, are turned in the opposite direction. This design is used to achieve specific ride height or suspension characteristics.
Applications: Custom or modified suspension setups.

Air Suspension:

Description: Air suspension uses air-filled bags or bellows as the primary springing element. Compressed air is used to support the vehicle's weight and adjust ride height.

Placement: Can be used in various suspension configurations, including both independent and solid axle systems.

Construction of Air Suspension:

The layout of an air suspension system has been shown in Fig. The four air springs, which may be either the bellows-type or the piston type, are mounted on the same position where generally the coil springs are mounted. It also consists of an air compressor, air accumulator, relief valve, lift control valve, leveling valve, and pipeline.

Working of Air Suspension:

An air compressor takes the atmospheric air through a filter and compresses it to a pressure of about 240 MPa, at which pressure the air in the accumulator tank is maintained, which is also provided with a safety relief valve. This high-pressure air goes through the lift control valve and the leveling valves, to the air springs as shown. Each air spring is filled with compressed air which supports the weight of the vehicle. The air gets further compressed and absorbs the shock when the wheel encounters a bump on the road.

Advantages:

Adjustable ride height: Allows for dynamic adjustment of the vehicle's height for improved aerodynamics, ground clearance, and load leveling.

Improved ride comfort: Air suspension can provide a smoother ride by adjusting the air pressure in the springs.

Load leveling: Maintains a consistent ride height, even with varying loads.

Disadvantages:

Complexity: Air suspension systems are more complex and can be more expensive to repair than traditional spring systems.

Potential for air leaks: Air springs may develop leaks over time, affecting performance.

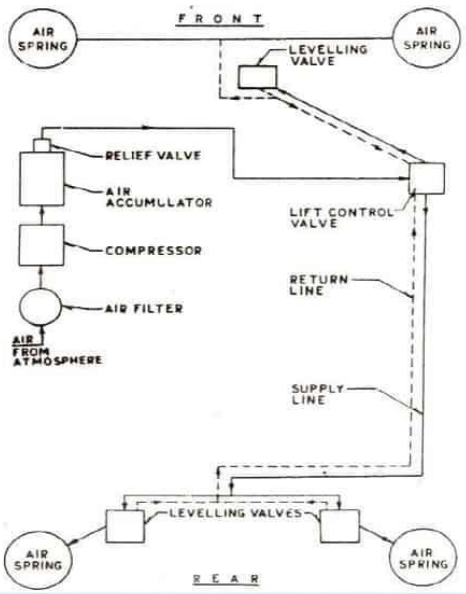


Figure: Schematic diagram showing the layout of an air suspension system.

Types of Air Suspension

There are different types of air suspension systems based on the design of the air spring used:

(i) Bellow Type Air Suspension (Spring)

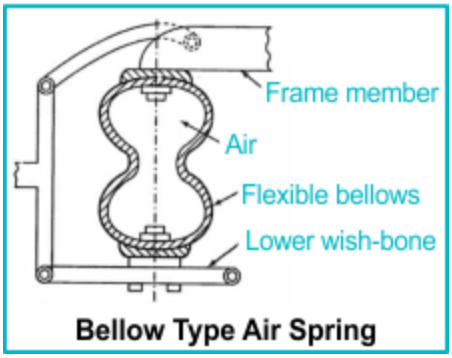


Fig: Bellow-type air spring

This type of air spring consists of rubber bellows made into circular sections with two convolutions for proper functioning, as depicted in Figure. It replaces the conventional coil spring and is commonly employed in air suspension setups.

(ii) Piston Type Air Suspension (Spring)

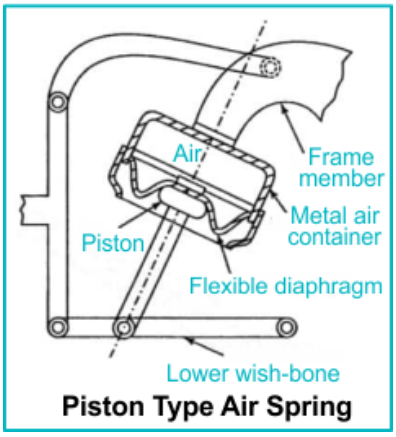


Fig: Piston-type air suspension

In this system, a metal-air container resembling an inverted drum is connected to the frame. A sliding piston is linked to the lower wishbone, while a flexible diaphragm ensures a tight seal. The diaphragm is connected at its outer circumference to the drum's lip and at the center of the piston, as shown in Figure.

(iii) Elongated Bellows Air Suspension

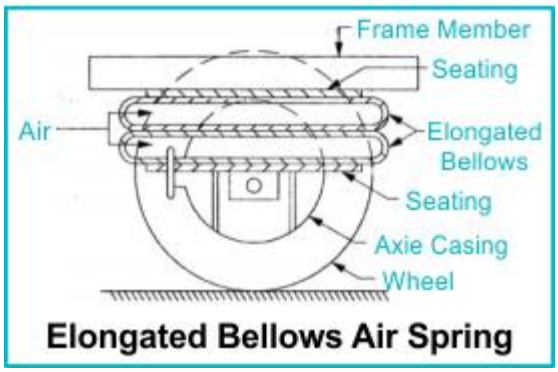


Fig: Elongated Bellows Air Suspension

For rear axle applications, elongated bellows with approximately rectangular shapes and semi-circular ends, typically having two convolutions, are used. These bellows are arranged between the rear axle and the vehicle frame and are reinforced with radius rods to withstand torques and thrusts, as required for efficient suspension functioning.

3.10 torsion bar

A torsion bar is a type of suspension system component used in some vehicles to provide spring-like support and resist the movement of the vehicle's wheels in response to road irregularities. Torsion bars are commonly used in both front and rear suspensions, but for the purpose of this explanation, I'll focus on their application in front suspensions.

Here's an overview of torsion bars:

Design:

A torsion bar is a long, straight, or slightly curved metal bar that is connected to the vehicle's frame at one end and to the control arm or suspension member at the other end.
The bar is usually mounted longitudinally along the vehicle, parallel to the ground.

Function:

Torsion bars work on the principle of torsion, which is the twisting or rotation of an object due to torque applied to it. In this case, the torsion bar absorbs and resists the twisting forces generated when the wheels encounter bumps or uneven surfaces.

Construction:

Torsion bars are typically made of a high-strength steel alloy.
The diameter and length of the torsion bar, as well as the material properties, play a crucial role in determining its spring rate and overall performance.

Adjustability:

Some vehicles with torsion bar suspensions have adjustable torsion bars. This feature allows for fine-tuning the vehicle's ride height and suspension characteristics.
Adjusting the torsion bar preload can influence the vehicle's front-end height and, to some extent, the stiffness of the suspension.

Advantages:

Torsion bars can provide a relatively compact and lightweight solution for front suspension systems. They are known for their durability and resistance to sagging over time, making them suitable for heavy-duty applications.

Disadvantages:

Torsion bar suspensions may transmit more road imperfections to the vehicle compared to some other suspension types, potentially affecting ride comfort.
While adjustable, torsion bars may not offer as much fine-tuning capability as coilover or air suspension systems.

Applications:

Torsion bar suspensions have been used in a variety of vehicles, including trucks, SUVs, and some passenger cars.
They are often found in off-road and heavy-duty applications due to their robust design.

Maintenance:

Torsion bars require periodic inspection to ensure they are functioning correctly and are not showing signs of fatigue or damage.

If a vehicle with a torsion bar suspension has an adjustable setup, adjustments should be made carefully according to the manufacturer's specifications.

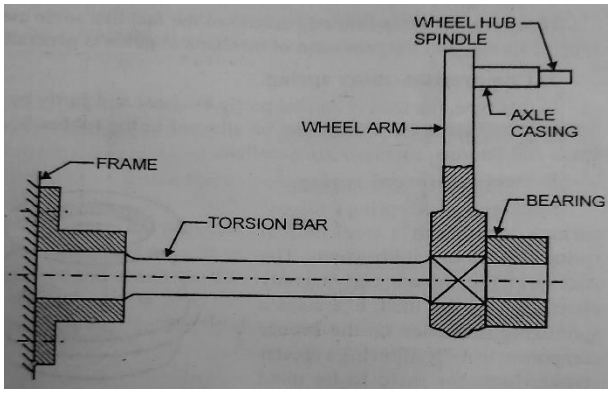


Figure 3.19 torsion bar

3.11 shock absorbers

Shock absorbers, also known as dampers, are essential components in a vehicle's suspension system. They play a crucial role in controlling the movement of the springs and managing the impact and rebound of the vehicle's wheels.

Here's an overview of shock absorbers:

Function:

Absorbing and Damping: The primary function of shock absorbers is to absorb and dampen the energy generated by the springs during compression and extension. They help control the oscillations of the springs, preventing the vehicle from bouncing excessively after encountering bumps or dips in the road.

Components:

Cylinder and Piston: Shock absorbers typically consist of a cylinder filled with hydraulic fluid and a piston that moves within the cylinder.

Valves: The piston has valves that regulate the flow of hydraulic fluid as it moves through the cylinder, controlling the speed and force of the piston's motion.

Types:

- Twin-Tube Shock Absorbers: This common type features two cylinders - an inner working cylinder and an outer reserve cylinder. The two cylinders are connected by an internal dividing piston.
- Mono-Tube Shock Absorbers: In this design, the working fluid and gas are separated by a floating piston, resulting in a single tube. Mono-tube shocks are often used in high-performance and off-road applications.
- Coil over Shocks: Coil over shocks integrate a coil spring around the shock absorber, combining the functions of the shock and the spring. They are commonly used in performance and racing applications.

- Gas-Charged Shocks: Gas-charged shocks have nitrogen gas in addition to hydraulic fluid. The gas helps prevent foaming of the fluid, reducing the risk of shock fade during continuous use.

Adjustability:

Some shock absorbers are adjustable, allowing the driver to fine-tune the damping characteristics. This adjustability is often used in performance and racing applications.

Roles in Vehicle Dynamics:

- Cornering Stability: Shock absorbers contribute to the stability of the vehicle during cornering by controlling body roll.
- Braking and Acceleration: They help maintain tire contact with the road during braking and acceleration, improving traction and control.
- Ride Comfort: Properly functioning shock absorbers contribute to a smoother and more comfortable ride by minimizing excessive body movement.

Signs of Wear or Failure:

- Leaks: Visible oil leaks around the shock absorber may indicate internal damage.
- Excessive Bouncing: If the vehicle continues to bounce excessively after hitting a bump, the shock absorbers may be worn.
- Uneven Tire Wear: Worn shock absorbers can contribute to uneven tire wear.

Maintenance:

- Shock absorbers should be inspected regularly, and any signs of wear or damage should be addressed promptly.
- They are typically replaced in pairs (both front or both rear) to maintain balanced performance.

Applications:

- Shock absorbers are used in various types of vehicles, including cars, trucks, motorcycles, and bicycles.
- Different applications may require shock absorbers with specific characteristics based on the vehicle's weight, intended use, and performance requirements

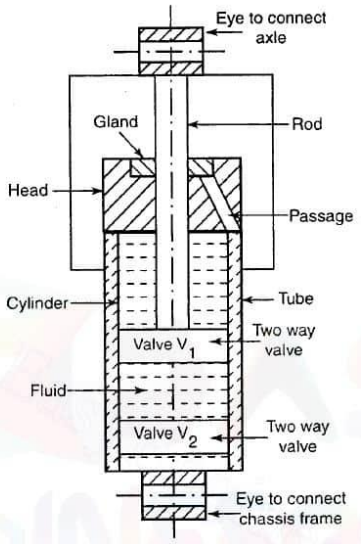


Figure 4.55 Telescopic shock absorber

UNIT – IV

Wheels, Tyres and Braking System

Wheels and Tyres - Construction - Type and specification - Tyre wear and causes - Brakes - Needs – Classification –Drum and Disc Mechanical - Hydraulic and pneumatic - Vacuum assist – Retarders – Anti-lock Braking System(ABS).

4.1 Wheels and Tyres (Construction, Type and specification)

Wheels

Wheel Assembly

- It consists of hub, disc or spokes, tire and tube
- It Supports the weight of the vehicle
- Flexible, to absorb the road shocks
- Able to grip the road surface
- It resists the braking stresses and withstand side thrust

figure 4.1 wheel

Functions of wheel

- It should be lightest possible, so that the unsprung weight is minimum
- Balanced both statically as well as dynamically
- Possible to remove or mount the wheel easily
- Its material should not deteriorate with weathering and age
- Good ability of heat dissipation

Types of wheels

1. Pressed steel disc wheel
2. The wire wheel
3. The light alloy cast wheel
4. Composite wheel

1. Pressed Steel Disc Wheel

- **Disc wheel**: This type of wheel consists of two parts
  - A steel rim which is generally well based to receive the tyre and a pressed steel disc
  - The rim and the disc may be integral permanently attached or attachable, depending upon design

2. Wire Wheel

- The wire wheel has a separate hub, which is attached to the rim through a number of wire spokes
- The spokes carry the weight, transmit the driving and braking torques and with stand the side forces while cornering, in tension
- Spokes are long, thin wires and as such these cannot take any compressive or bending stresses

3. Light Alloy Cast or Forged Wheel

- Cast wheels are generally used for car while forged wheels are preferred for wheels of heavier vehicles
- The main advantage of light alloy wheels is their reduced weight, which reduces unspring weight

- A magnesium alloy wheel weighs about 50 percent of an aluminium alloy wheel for similar strength
- Moreover, light alloys are better conductors of heat

4. Composite Wheel

- Exhibit combination of strength, lightweight and styling
- They are made of steel and aluminum alloys
- The rim is generally made of steel while the center portion consist of cast aluminum alloy




Figure 4.2 types of wheels

1. Pressed steel disc wheel
2. The wire wheel
3. The light alloy cast wheel
4. Composite wheel

Rim

- The part of the wheel on which the tire is mounted and supported
- The outer circular portion of the wheel on which the tire and tube are fitted

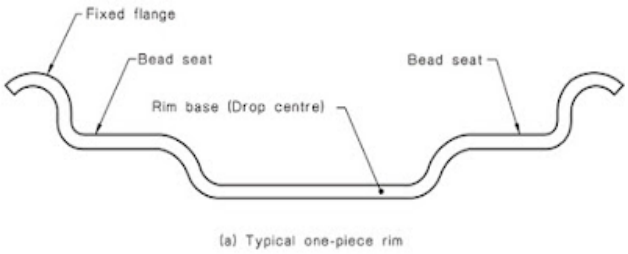
<u>Types of Rims</u>

The rims are of two types

- Drop center Rim: - Mostly used on cars
- Flat base Rim: - Mostly used on trucks &HCVS

Drop Centre Rim

- The center portion of the rim is rolled to a smaller diameter to form a well
- The rim allows the removal or mounting of the tire by squeezing the beads of the tire together on one side and dropping them into the well, while the opposite side is pulled over the flange
- The rim is designed so that the well allows the beads of the tire to pass over the edge of the opposite side of the rim
- The rim is tapered from the edge of the well to the rim



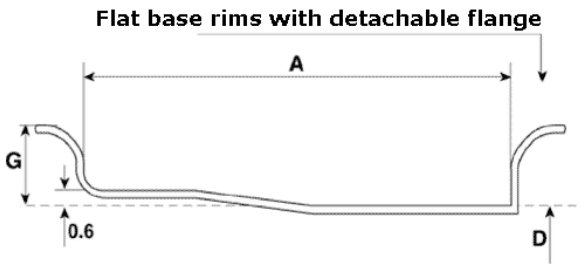


Figure 4.2 *Drop Centre Rim* *Flat Based Rim*

Flat Based Rim

- The flat base rim has its center portion flat
- One side of the rim is removable so that the tire can be installed or removed without stretching the bead
- They are suitable for large tyres
- The tyres having bulky bead region
- Used almost on all trucks and other heavy duty vehicles

specifications of Wheels:

Size: Measured in inches (e.g., 17x7.5), indicating diameter and width. Size influences the overall look and performance of the vehicle.

Bolt Pattern: Describes the number of bolts and the diameter of the imaginary circle they form. For example, 5x114.3 indicates a wheel with 5 bolts spaced 114.3 mm apart.

Offset: The distance between the wheel's mounting surface and its centerline. Positive offset moves the wheel inward, negative offset outward. It affects the wheel's position within the wheel well.

Backspacing: The distance from the wheel's mounting surface to the back edge of the wheel. It is another measure of the wheel's positioning within the wheel well.

Hub Bore: The diameter of the hole at the center of the wheel. It must match the hub diameter of the vehicle for proper fitment.

Load Rating: Specifies the maximum weight a wheel can safely support. It is crucial for ensuring the wheel can handle the vehicle's weight and load.
Material: Wheels can be made of steel or alloy. Alloy wheels, typically aluminum or magnesium, are lighter and offer better heat dissipation.

Finish: Describes the wheel's appearance. Common finishes include painted, polished, chrome, or machined.

Construction: Wheels can be one-piece or multi-piece. One-piece wheels are simpler and more common, while multi-piece wheels allow for customization.

Design: Refers to the visual aesthetics of the wheel. Designs vary widely, from simple and classic to intricate and sporty.

Lug Nut Seat Type: Describes the shape of the lug nut seat, such as conical, spherical, or flat. It must match the type of lug nuts used.

Tyres

- Tyre is mounted on wheel Rim
- It consists of tube fitted inside
- The tire-tube assembly is mounted over the wheel rim
- Air filled inside the tube carries the entire load and provides the cushion

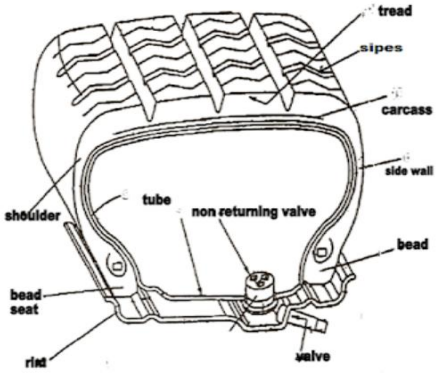


Figure 4.3 Tyre

Function of Tyres

- To support the vehicle load
- To provide cushion against shocks
- To transmit driving and braking forces to the road
- To provide cornering power for smooth steering

Desirable Tyre Properties

Non-skidding

- The tread pattern on the tire must be suitably designed to permit least amount if skidding even on wet road

Uniform Wear

- The wear on the tire must be uniform

Load-carrying

- The tire is subjected to alternating stresses during each revolution of the wheel. The tire design must be able to ensure that the tire is able to sustain these stresses

Cushioning

- The tire should be able to absorb small high frequency vibrations set up by the road surface and thus provide cushioning effect

Power Consumption

- The automotive type tire does absorb some power which is due to friction between the thread rubber and road surface and also due to hysteresis loss on account of tire being continuously fixed and released. Synthetic tyres consume more power while rolling than the ones made out of natural rubber

Tyre Noise

- The tire noise may be in the form of definite pattern sing, a sequel or a loud roar. In all these cases, it is desirable that the noise be minimum

Balancing

- The tire being rotating part of the automobile, it must be balanced statically as well as dynamically

Type of Tyres

- On the basis of cushioning medium
    1. Solid or Non-pneumatic tyres
    2. Pneumatic tyres
- On the basis of air storage system
    1. Tubed or Conventional Tyres.
    2. Tubeless tire
- On the basis of Skelton of tire
    1. Cross-ply or bias ply tyres
    2. Radial ply tyres
    3. Belted-bias tyres

On the basis of cushioning medium

1. Solid tyres;

- Solid cross-section of tire material
- Unable to provide cushioning and comfort to the riders
- They are obsolete now

2. Pneumatic Tyres

- Air filled tyres are known as pneumatic tyres
- It consists of outer body (the main tire) and a tube inside
- The tire tube combination is mounted on the wheel rim
- The inside tube is filled with the air

Function of Pneumatic Tyres

- They support the weight of the vehicle
- They provide traction for driving and braking
- They allow steering control and the directional stability
- They offer cushion to the vehicle over the ground surface irregularities and against road shocks
- They transmit driving and braking forces to the road

On the basis of air storage system

A) Conventional tube tyres

- It consists of two main parts, carcass and Tread
- The carcass is the basic structure taking mainly the various loads
- It consists of a number of plies
- The plies wound in a particular fashion from the cards of rayon
- Each card in each ply is covered with resilient rubber compound
- All plies insulated against each other
- The plies are attached to two high tension steel wire, these are called beads

B) Tubeless tyres

- This type of tire does not need a separate tube
- Instead the air under pressure is filled in the tire
- A non-return valve is fitted to the rim
- The inner construction of the tire is almost same as that of tubed tire
- Except that it is lined on inside with a special air-retaining liner

Advantage over the Conventional Tubed Tyres

- Lesser unsprung weight
- Better cooling
- Slower leakage of air
- Simpler assembly
- Improved safety

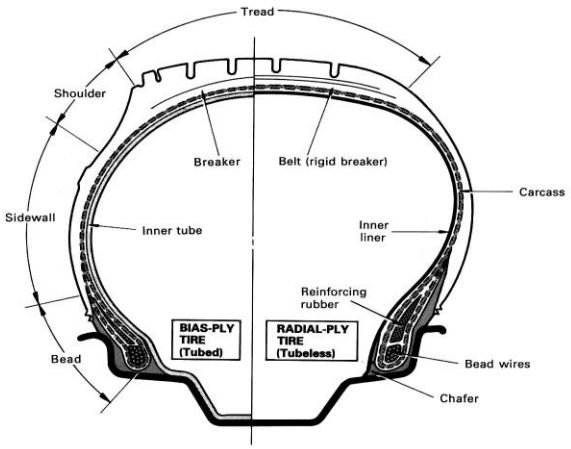


Figure 4.4 tube and tubeless tyre

On the basis of Skelton of tire

Depends upon the Skelton of the tire (carcass), tyres are classified into

- Cross-ply or bias-ply
- Radial-ply
- Belted-bias type

Cross ply Type

- The ply cords are woven at an angle (30-40degree) to the tire axis
- There are '2' layers which run in opposite direction
- That lead to rubbing of the two layers
- Thus produce heat which would damage the tire material

Radial ply tire

- The ply cords run in the radial direction in the direction of the axis
- Run a number of breaker strips in circumferential direction
- The material for the breaker strips must be flexible
- Without breaker strips radial tyres would give soft ride

Belted bias type

- It is a combination of the cross and radial types
- The belts construction is the bias-ply over which a number of breaker belts run
- The stress in the carcass are restricted
- The tread area is stabilized due to belts
- Results in reduction of tread –scrubbing. Increase the tire life

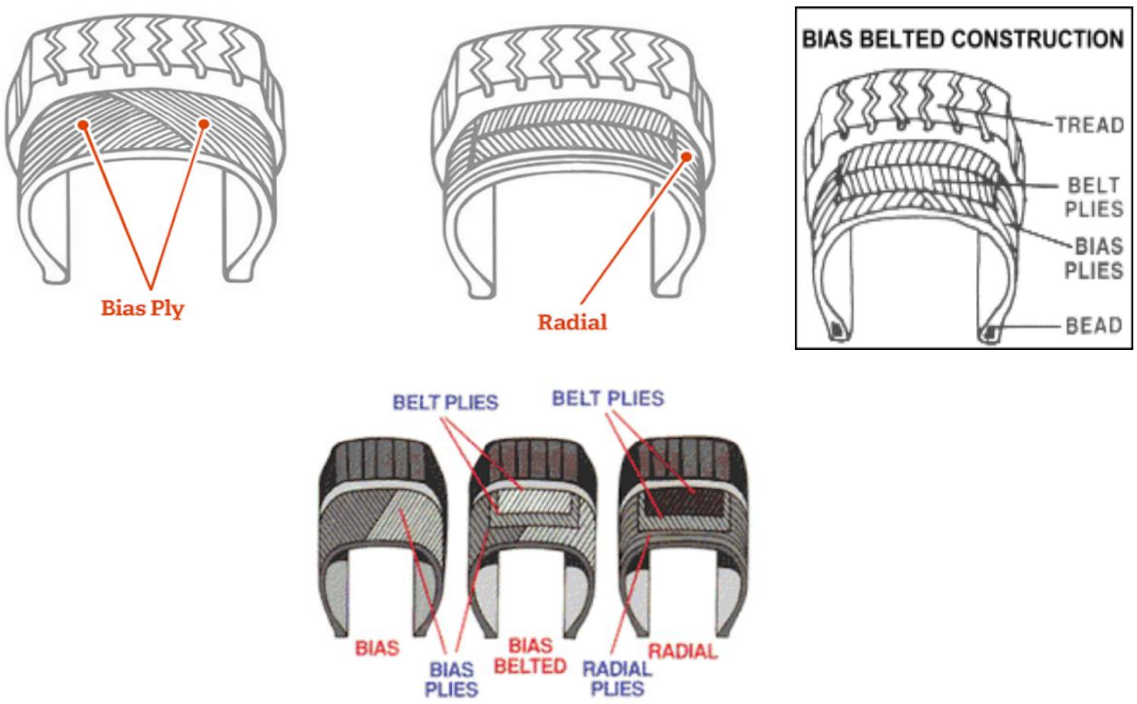


Figure 4.5 types of tyres On the basis of Skelton of tire

Various Components of the Tyres

- Tread
- Breaker
- Casing
- Side walls
- Beads

Tread

- The shoulder to shoulder width of the tire represents the tread
- Natural rubber as well as synthetic rubber is used
- The natural rubber helps the tire to stay cooler during running

Breaker

- The two top plies of the tire are referred as breakers
- They are widely spaced as compared to other plies
- These plies help in spreading the shocks received from the road

Casing

- The tire casings are made up of layers of cord impregnated with rubber
- The number of layers of cord varies according to the use of Tyre
- Motor car tyres usually have 4 to 6 plies
- Heavy-duty truck and bus tyres may have up to 22 plies
- Earth moving machinery the tyres may have up to 34 plies

Side wall

- The side wall consists of rubber compound
- Which serve as protective covering to the casing
- A tire may have a black or white side wall
- Both the side walls have the same performance

Beads

- Coil of wire represent the beads
- These wires are of high-tensile steel
- Which are built in the edge of the tire
- Give strong edges to press against the inner edge of the rim

Constituents of a Tyre

1.**Rubber**: natural synthetic compounded with a large number of chemicals to ensure the necessary characteristics

2**. Nylon**: rayon cord fabric for the tire body

3. Steel for High tensile bead wires

Considerations in Tread Design

Grip

- The braking grip of a tire depends upon two factors
  a) Tread material
  b) Tread pattern
- The grip for a particular tread pattern is effected mechanically as well as through friction
- The tread must provide suitable sharp edges that will engage with the road

Noise

- Various type of vibrations caused by roughness of the road surface
- By the distortion of the tire carcass also produce noise
- The type of tread pattern also contributes to tire noise

- Noise depends upon the nature of the rubber compound

Wear

- For less wear the tire must be such that the individual elements which undergo minimum distortion during running
- Tread wear indicators are provided at the bottom of the tread grooves

Tread Pattern

- The grooves of different layouts on tire
- Styles and orientations cut on the tread of a tire are termed as tread pattern
- A proper tread pattern helps in smooth steering, better mileage
- lower noise level, Increased road grip, Improved driving comfort, less wear
- Tyres have numerous varieties of tread pattern
- Special synthetic rubber is used for making tread on the tire surface
- It has a high co-efficient of friction
- It provides good grip on wet and dry road surface

Different Types of Tread Patterns

A. Good midways adhesion, Good grip
B. Good fore and aft grip Rapid, irregular wear and noisy running
C. Good sideways, fore and aft grip Irregular wear on hard roads, noisy running
D. Good wear resistance and steering characteristic
E. Maximum grip and sideways stability

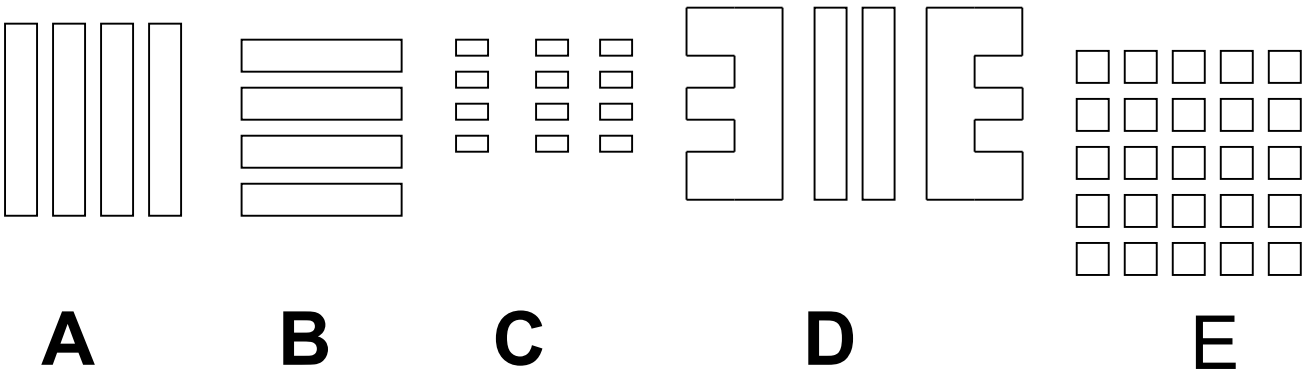


Figure 4.6 types of tyres On the basis of

Tyre Tread Pattern

Features	**Benefits**
• Flat tread radius • Deep radial grooves • Smooth center rib • Long sidewall flutes • Wider foot print • Biting edges on sidewall • Extra (rubber) depth tread • Sidewall branding • Circumferential rib • Centre groove	• Slow wear, higher mileage • Better traction, tear resistance • Higher impact resistance. • Cooler running • Better road contact and grip • Quick start and stop • More life, greater safety • Aesthetic appearance • Excellent wear resistance • Directional stability

Factors Affecting Tyre Life

The main factors which affect tire performance and consequently their life

- Tyre inflation
- Vehicle maintenance
- Manner of driving
- Miscellaneous factors (heat, Position in which tire fitted, road conditions, Seasons)
- Inflation pressure

4.3 Tyre wear and causes

Causes of Tyre Wear

- Incorrect inflation
- Incorrect caster, camber, or toe-in
- Excessive braking or violent acceleration
- Worn steering mechanism
- Worn king pins
- Out of balance wheel
- Misalignment
- Over-loading
- Wrong loading
- Defective brakes
- Toe-out incorrect on turn
- Bleeding of air in tire
- Careless driving
- Unequal tire
- Incorrect rotation of tyres

CAUSES OF IRREGULAR TYRE WEAR

Fault	**Causes**
• rapid wear • Wear on one shoulder more than the other • Heel and toe wear on individual studs • One half of the tread circumference worn more than the other half	• Oval or eccentric brake drums • Excessive wheel camber or misalignment • Road slip in one direction only • Unbalancing

4.4 Brakes (Needs, Classification)

The act or process of slowing or stopping a vehicle, wheel, shaft, etc., or for keeping it stationary, esp. by means of friction

Braking, response and handling are all very good.

Functions of Braking System

The braking system in automotive engines performs the following functions:

- Halting the Vehicle: The brake system is responsible for bringing vehicles to a stop in the shortest distance feasible by converting the vehicle's kinetic energy into heat energy.
- Mechanical Control: Operating as a mechanical mechanism, the brake system intervenes in motion to swiftly and effectively halt a moving entity within a brief span of time.

Requirements of Brakes

- The Brakes must be strong enough to stop the vehicle with in a minimum distance in an emergency, consistent with safety
- The driver must have proper control over the vehicle during emergency Braking and the vehicle must not skid.
- The Brakes must have good anti fade characteristics i.e. their effectiveness should not decrease constant prolonged application
  Ex: while descending hill
- The above requirement demands that the cooling of the brakes should be very efficient

Classification of brakes

The brakes for automotive use may be classified according to the following considerations.

- According to purpose:
  - Service or primary brakes
  - Parking or secondary brakes
- According to location:
  - Transmission brakes
  - Wheel brakes
- According to Construction:
  - Drum brakes
  - Disc brakes
- According to method of Actuation:
  - Mechanical brakes
  - Hydraulic brakes
  - Electric brakes
  - Vacuum brakes
  - Air brakes
- According to Extra braking effort:
  - Power brakes
  - Power assisted brakes

4.5 Drum and Disc brakes

Drum Brakes:

Drum brakes are a type of braking system used in some vehicles, particularly for rear-wheel braking. Although disc brakes are more common in modern vehicles, drum brakes have certain applications and characteristics:

1. Components:

- Brake Drum:
- Description: A cylindrical-shaped component attached to the wheel hub. When the brakes are applied, the brake shoes press against the inner surface of the drum, generating friction and slowing down the rotation of the wheel.
- Function: Provides a surface against which the brake shoes can press to create the necessary friction for braking.
- Back Plate:
- Description: A metal plate located on the inner side of the brake assembly. It serves as a support structure for other components and provides a mounting point for the wheel cylinder, brake shoes, and other hardware.
- Function: Supports and houses various components of the drum brake system.
- Brake Shoes:
- Description: Curved metal plates with friction material (brake lining) on the outer surface. When the brake pedal is applied, the brake shoes are pushed against the inner surface of the brake drum to create friction and facilitate braking.
- Function: Act as the primary friction elements in the drum brake system.
- Brake Liners:
- Description: The friction material attached to the outer surface of the brake shoes. It comes into direct contact with the brake drum, generating friction and converting kinetic energy into heat during braking.
- Function: Provides the necessary friction for slowing down or stopping the vehicle.
- Retaining Springs:
- Description: Springs that hold the brake shoes in place and help to return them to their rest position when the brakes are released.
- Function: Maintain proper positioning and alignment of the brake shoes within the brake assembly.
- Cam:
- Description: A cam mechanism that is part of the brake adjuster. As the brake shoes wear down, the cam adjusts to maintain the proper clearance between the brake shoes and the brake drum.
- Function: Facilitates automatic adjustment of the brake shoes to compensate for wear.

- Brake Linkages:
- Description: Rods or levers that connect various components of the brake system, including the brake pedal, brake shoes, and the cam adjuster.
- Function: Transmit the force from the brake pedal to the brake shoes and facilitate the movement and adjustment of various components within the drum brake assembly.

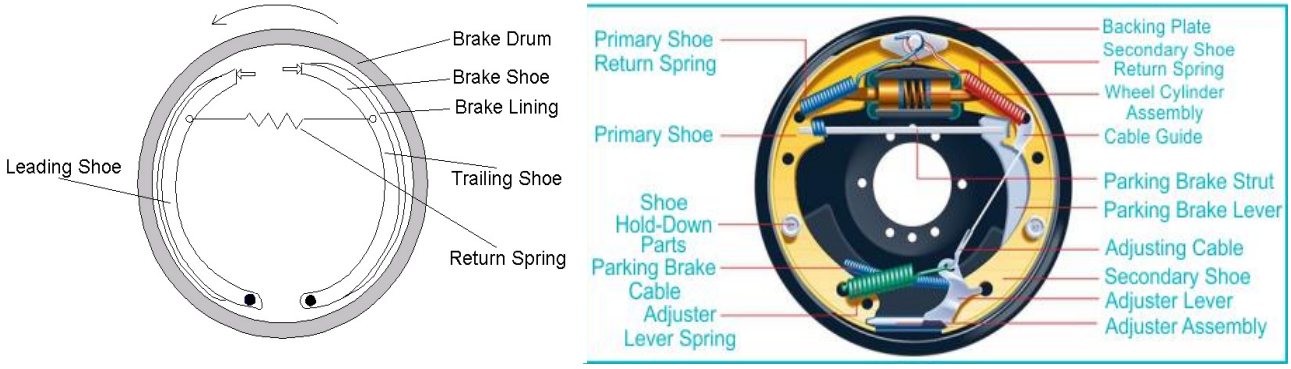


Figure 4.7 typical drum brake

2. Operation:
- When the driver applies the brakes, hydraulic pressure forces the brake shoes against the inner surface of the drum.
- The friction between the brake shoes and drum generates heat and slows down the rotation of the wheel.

3. Advantages:
- Cost-Effective: Drum brakes are generally simpler and more cost-effective to manufacture.
- Parking Brake Functionality: The design of drum brakes makes them well-suited for use as parking brakes.

4. Disadvantages:
- Heat Dissipation: Drum brakes can be more prone to heat buildup compared to disc brakes, potentially leading to reduced braking performance under heavy use.
- Self-Adjustment Complexity: Drum brakes may require periodic manual adjustment to maintain optimal performance.

5. Applications:
- Drum brakes are often used in the rear wheels of smaller and lighter vehicles.
- They are still found in some trucks, entry-level cars, and older vehicle models.

6. Maintenance:
- Regular inspection and adjustment are essential to ensure even wear of the brake shoes and maintain braking efficiency.
- Drum brakes may require more maintenance compared to disc brakes.

7. Transition to Disc Brakes:
- While drum brakes are still in use, especially in certain applications, many modern vehicles favor disc brakes for improved performance, heat dissipation, and overall efficiency.

Despite being less common in newer vehicles, drum brakes remain a viable braking solution, particularly for rear-wheel applications in certain automotive contexts. Advances in disc brake technology have led to their widespread adoption, but drum brakes continue to be utilized in specific vehicle designs.

Disc brakes

Disc brakes are a common type of braking system used in modern vehicles. They provide efficient and reliable braking performance and are often used on both the front and rear wheels, although front disc brakes are more prevalent. Here are the key components and features of disc brake systems:

1. Components and working:

- Brake Disc (Rotor):
- Description: A flat, circular metal disc mounted on the wheel hub. When the brakes are applied, brake pads clamp onto the disc to create friction and slow down the rotation of the wheel.
- Function: Converts kinetic energy into heat during braking, providing the surface against which brake pads can generate friction.
- Brake Caliper:
- Description: A hydraulic or mechanical component that houses pistons and brake pads. The caliper is mounted over the brake disc.
- Function: When the brake pedal is pressed, hydraulic pressure (in hydraulic systems) or mechanical force (in some older or simpler systems) causes the caliper pistons to push the brake pads against the disc, creating friction.
- Brake Pads:
- Description: Flat plates with friction material on one side. They are housed within the brake caliper and come into contact with the brake disc when braking.
- Function: Generate friction against the rotating disc, causing the vehicle to slow down.
- Brake Lines:
- Description: Hydraulic lines that carry brake fluid from the master cylinder to the brake calipers.
- Function: Transmit hydraulic pressure to the calipers, initiating the braking process.
- Master Cylinder:
- Description: Converts mechanical force from the brake pedal into hydraulic pressure.
- Function: Initiates the flow of brake fluid through the brake lines, pressurizing the system and activating the brake calipers.
- Brake Fluid:
- Description: Hydraulic fluid that transfers force within the brake system.
- Function: In response to pressure from the master cylinder, brake fluid flows through the brake lines to engage the caliper pistons and brake pads.
- Brake Bleeder Valve:
- Description: A small valve on the brake caliper or wheel cylinder used to release air or brake fluid during the bleeding process.
- Function: Ensures the removal of air bubbles from the brake system, maintaining brake performance.
- Ventilated Discs (Optional):
- Description: Some high-performance or heavy-duty vehicles may have ventilated (slotted or drilled) brake discs.
- Function: Enhances heat dissipation, reducing the risk of brake fade during intense braking.

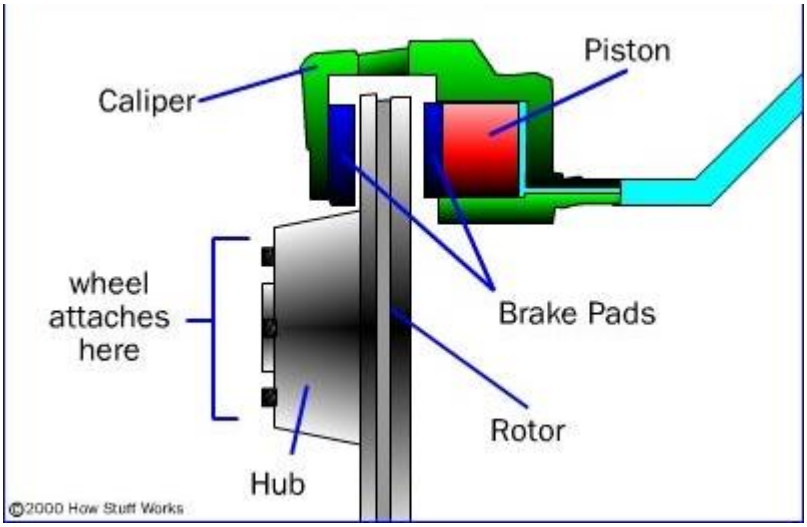


Figure 4.8 typical disc brake

2. Advantages of Disc Brakes:

- Better Heat Dissipation:
- Consistent Performance:
- Quick Cooling:
- Reduced Stopping Distances:
- Ease of Maintenance:

3. Disadvantages of Disc Brakes:

- Cost:
- Complexity:
- Hydraulic System Vulnerability:

4.Applications:

- Automotive Vehicles:
  - Commonly used on both front and rear wheels in various types of vehicles, including passenger cars, trucks, and SUVs.
- High-Performance Vehicles:
- Heavy-Duty and Commercial Vehicles:

4.6 Mechanical, Hydraulic and pneumatic brakes

Mechanical Braking System:

A mechanical braking system relies on mechanical components, such as cables, levers, and linkages, to transmit force from the driver's input to the braking elements. While less common in modern passenger vehicles, these systems are found in applications such as bicycles, motorcycles, and some older vehicles.

Here's a brief overview:

1. Components:

- Brake Pedal or Lever: The driver's input device to initiate braking.
- Mechanical Linkage: Cables or rods transmitting force to the braking elements.
- Brake Drum or Disc: Rotating component providing the surface for friction.
-Brake Shoes or Pads: Friction material pressed against the drum or disc to generate braking force.

- Return Springs: Assist in returning the brake shoes or pads to their rest position.
- Adjusting Mechanism: Allows manual adjustment for compensating wear.
- Parking Brake Mechanism: Engages the brakes for parking.

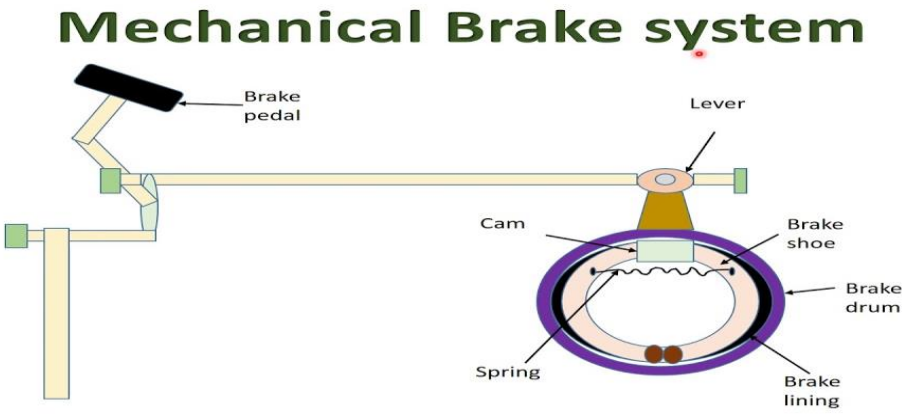


Figure 4.9 mechanical braking

2. Operation:

- When the driver presses the brake pedal or pulls the brake lever, it activates the mechanical linkage.
- The mechanical linkage transmits the force to the brake shoes or pads, pressing them against the rotating brake drum or disc.
- Friction is generated, converting kinetic energy into heat and slowing down the rotation of the wheel.

3. Advantages:

- Simplicity: Mechanical systems are generally simple in design.
- Cost-Effective: They tend to be more cost-effective in manufacturing and maintenance.
- Reliability: Can be robust and reliable in certain applications.

4. Disadvantages:

- Limited Performance: Mechanical systems may have limitations in performance compared to hydraulic or electronic systems.
- Adjustment Required: Manual adjustments may be needed to maintain optimal braking.
- Potential for Wear: Mechanical components, especially cables, may experience wear over time.

5. Applications:

- Bicycles: Many bicycles use mechanical rim brakes or disc brakes.
- Motorcycles: Some motorcycles, especially older models, may have mechanical drum or disc brakes.
- Older Vehicles: Mechanical braking systems were common in older cars and trucks.

While modern vehicles often utilize hydraulic or electronic braking systems for enhanced performance, mechanical braking systems continue to serve in various applications where simplicity, cost-effectiveness, and reliability are prioritized.

Hydraulic Braking System:

A hydraulic braking system is a widely used method for slowing down or stopping vehicles. It employs fluid pressure to transmit force from the driver's input to the braking components.
Here's a brief overview:
1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Master Cylinder: Converts mechanical force from the brake pedal into hydraulic pressure.
- Brake Lines: Hydraulic tubes or hoses that carry brake fluid from the master cylinder to the brake calipers or wheel cylinders.
- Brake Calipers (Disc Brakes) or Wheel Cylinders (Drum Brakes):
- Hydraulic components that house pistons. In disc brakes, calipers squeeze brake pads against the brake disc, while in drum brakes, wheel cylinders press brake shoes against the brake drum.
- Brake Fluid: Hydraulic fluid that transmits force within the braking system.
- Brake Discs or Drums: Rotating components on the wheel. In disc brakes, the calipers press against the disc; in drum brakes, the wheel cylinders press against the drum.

2, Operation:

- When the driver presses the brake pedal, it activates the master cylinder.
- The master cylinder pressurizes the brake fluid.
- The pressurized brake fluid is transmitted through the brake lines.
- In disc brakes, the calipers squeeze brake pads against the disc, generating friction and slowing down the wheel. In drum brakes, the wheel cylinders press brake shoes against the drum.
- The kinetic energy is converted into heat through friction, and the vehicle slows down.

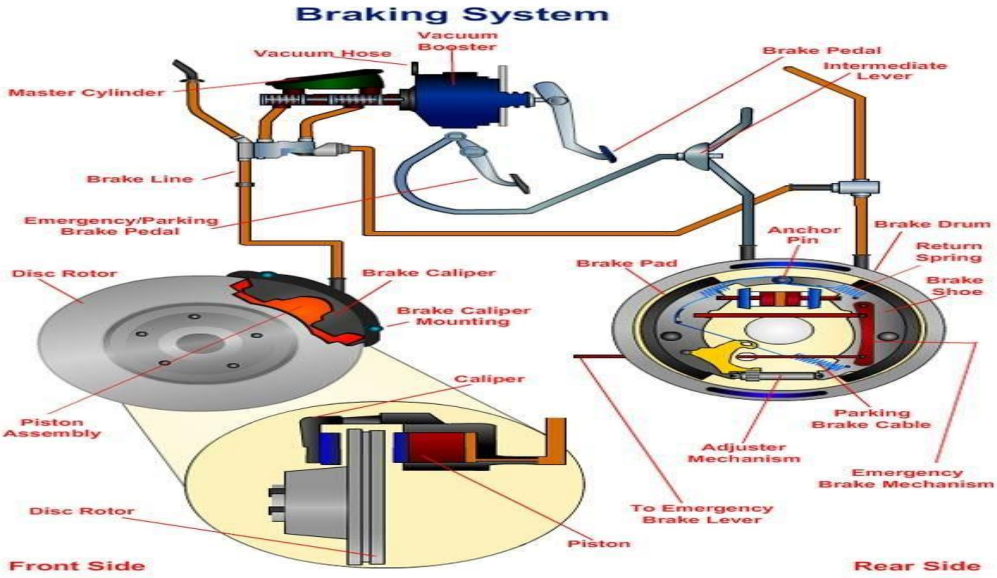


Figure 4.10 hydraulic braking

3, Advantages:

- Efficiency: Provides reliable and efficient braking performance.
- Consistency: Maintains consistent braking performance under various conditions.
- Heat Dissipation: Disc brakes, in particular, offer effective heat dissipation.

4, Disadvantages:

- Complexity: Hydraulic systems are more complex than mechanical systems.
- Maintenance: Requires periodic checks for brake fluid levels and potential leaks.
- Cost: Hydraulic braking systems can be more expensive to manufacture and maintain.

5, Applications:

- Automotive Vehicles: Used in cars, trucks, motorcycles, and most modern vehicles.
- High-Performance Vehicles: Common in sports cars and high-performance vehicles.
- Commercial Vehicles: Found in heavy-duty trucks and commercial vehicles.

The hydraulic braking system is a standard feature in modern vehicles due to its effectiveness and reliability in providing controlled and consistent braking performance.

Pneumatic Braking System:

A pneumatic braking system utilizes compressed air to transmit force from the driver's input to the braking components. Commonly found in heavy-duty vehicles, such as trucks and buses, it offers efficient and reliable braking performance.

Here's a concise overview:

1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Air Compressor: Compresses air from the atmosphere and maintains a pressurized air supply.
- Air Storage Tanks: Store compressed air to ensure a readily available and consistent supply.
- Brake Chambers: Devices that convert compressed air pressure into mechanical force. They are usually found in each wheel brake assembly.
- Brake Drums or Discs: Rotating components on the wheels against which the braking force is applied.
- Brake Shoes or Pads: Friction material attached to plates (shoes) or backing plates (pads) that press against the brake drums or discs.
- Air Lines: Tubes that carry compressed air from the air storage tanks to the brake chambers.

2, Operation:

- When the driver presses the brake pedal, it signals the release of compressed air.
- Compressed air is supplied by the air compressor and stored in the air tanks.
- The pressurized air is transmitted through air lines to the brake chambers.
- In the brake chambers, the air pressure forces mechanical components (pushrods or diaphragms) to move, activating the brake shoes or pads.
- The brake shoes or pads generate friction against the rotating brake drums or discs, converting kinetic energy into heat and slowing down the wheels.

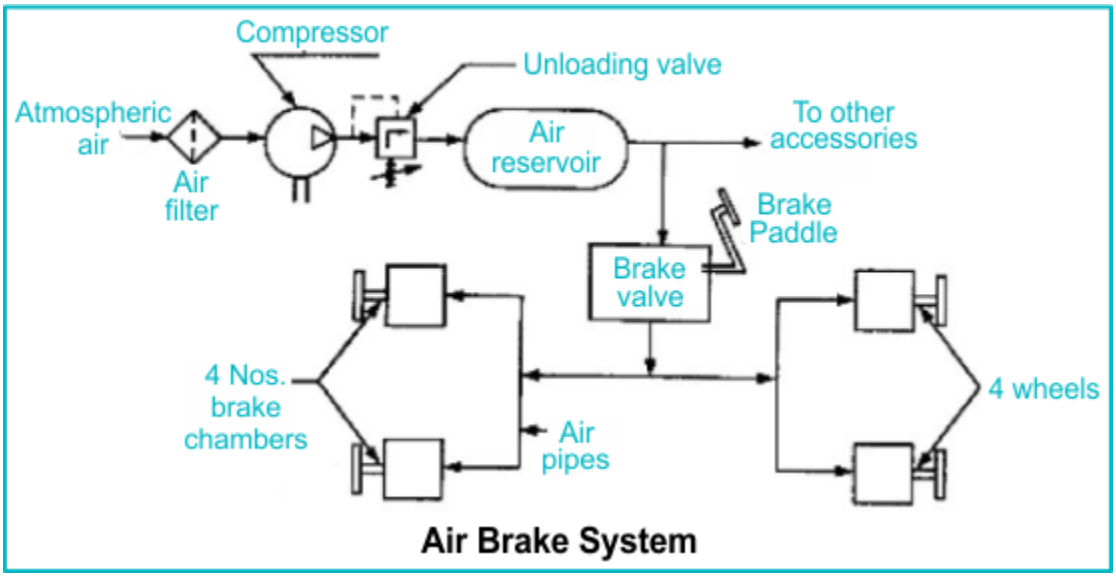


Figure 4.11 pneumatic braking system

3, Advantages:

- Consistent Performance: Provides consistent braking performance, especially in heavy-duty applications.
- Reduced Fade: Effective in minimizing brake fade during prolonged use.
- Powerful Braking: Well-suited for large and heavy vehicles.

4, Disadvantages:

- Complexity: Pneumatic systems are more complex than hydraulic or mechanical systems.
- Maintenance: Requires periodic checks for air leaks and system integrity.
- Initial Cost: Installation and maintenance costs can be higher compared to other braking systems.

5, Applications:

- Heavy-Duty Vehicles: Commonly used in trucks, buses, and other large commercial vehicles.
- Railway Systems: Pneumatic braking systems are employed in certain railway applications.

The pneumatic braking system is favored in heavy-duty applications where its reliability and consistent performance make it an ideal choice for ensuring safe and effective braking in large and powerful vehicles.

4.7 Vacuum assist braking system

A vacuum-assist braking system, commonly known as a vacuum booster or power brake system, is a braking system that utilizes engine vacuum to enhance the force applied by the driver on the brake pedal. This system is designed to reduce the amount of pedal effort needed for effective braking. Here's a brief overview:

1, Components:

- Brake Pedal: The driver's input device that initiates the braking process.
- Vacuum Booster: A cylindrical device located between the brake pedal and the master cylinder.

Function: Uses engine vacuum to amplify the force applied to the brake pedal by the driver, making braking easier.

- Master Cylinder: Converts the force from the brake pedal into hydraulic pressure.
  Function: Distributes brake fluid to the brake calipers or wheel cylinders.
- Brake Lines: Hydraulic tubes carrying brake fluid from the master cylinder to the brake calipers or wheel cylinders.
- Brake Calipers (Disc Brakes) or Wheel Cylinders (Drum Brakes):
- Hydraulic components that house pistons. In disc brakes, calipers squeeze brake pads against the brake disc, while in drum brakes, wheel cylinders press brake shoes against the brake drum.
- Brake Discs or Drums: Rotating components on the wheels against which the braking force is applied.

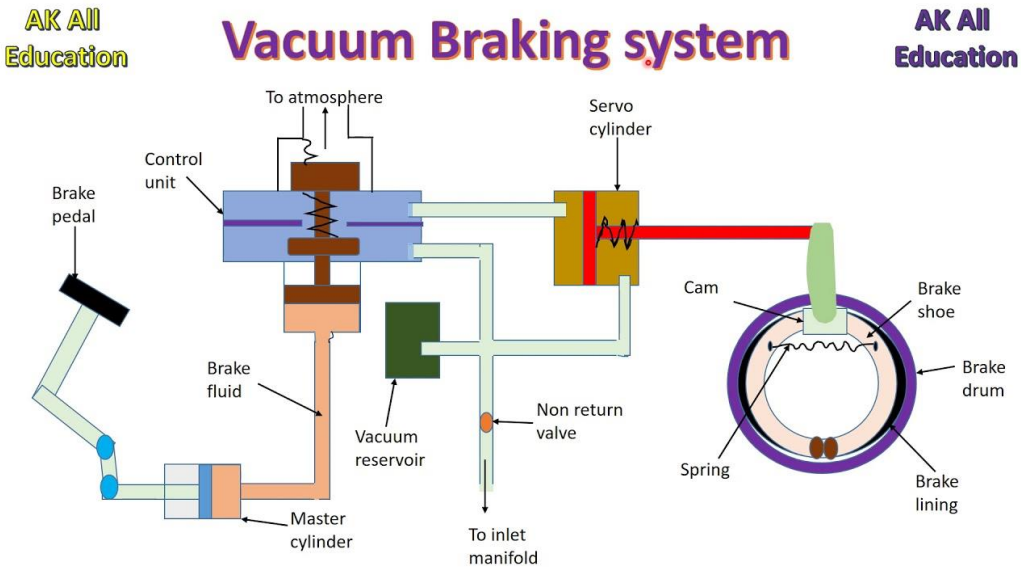


Figure 4.11vaccum assisted braking system

2, Operation:

- When the driver presses the brake pedal, the vacuum booster is activated.
- The vacuum booster uses engine vacuum to assist in applying additional force to the brake pedal.
- The increased force is transmitted to the master cylinder.
- The master cylinder converts this force into hydraulic pressure.
- The hydraulic pressure is transmitted through the brake lines to the brake calipers or wheel cylinders.
- In the brake calipers or wheel cylinders, the hydraulic pressure forces mechanical components to move, activating the brake shoes or pads.
- The brake shoes or pads generate friction against the rotating brake drums or discs, converting kinetic energy into heat and slowing down the wheels.

3, Advantages:

- Reduced Pedal Effort: Engine vacuum assistance reduces the amount of force the driver needs to apply to the brake pedal.
- Ease of Operation: Makes braking more comfortable and less fatiguing for the driver.

4, Disadvantages:

- Dependency on Engine Vacuum: If the engine stalls or there is a vacuum system failure, the braking performance may be compromised.
- Potential for Vacuum Leaks: Vacuum hoses or the booster itself may develop leaks, affecting braking efficiency.

Applications:

- Most Passenger Vehicles: Commonly found in a wide range of cars and light trucks.

The vacuum-assist braking system is a standard feature in many modern vehicles, providing a balance between effective braking performance and ease of operation for the driver.

4.8 Retarders

Retarders are systems used in vehicles to assist in slowing down or controlling speed, particularly in heavy-duty applications such as large trucks and buses. They work by providing additional resistance to the vehicle's motion, helping to reduce speed without relying solely on the traditional friction brakes.

Here are the main types of retarders:

- Exhaust Brake:

Description: The exhaust brake restricts the flow of exhaust gases, creating backpressure in the engine. This backpressure works against the engine's pistons, causing a reduction in speed.
Operation: When activated, the exhaust brake closes a valve in the exhaust system, creating resistance and slowing down the vehicle.

- Engine Brake (Jake Brake):

Description: The engine brake, commonly known as a Jake Brake, alters the operation of the engine's exhaust valves to release compressed air in the cylinders. This released air creates resistance in the engine, leading to reduced speed.
Operation: When engaged, the engine brake momentarily opens the exhaust valves near the end of the compression stroke, allowing compressed air to escape, and this compression resistance aids in slowing down the vehicle.

- Hydraulic Retarder:

Description: A hydraulic retarder is a separate unit installed in the vehicle's drivetrain. It uses hydraulic fluid to create resistance and slow down the vehicle.
Operation: When activated, the hydraulic retarder generates resistance by forcing hydraulic fluid through a series of vanes or disks. The resulting drag on the drivetrain helps to control speed.

- Eddy Current Retarder:

Description: An eddy current retarder uses electromagnetic induction to create resistance and slow down the vehicle.
Operation: When activated, the retarder induces eddy currents in a rotating metal disk. The interaction of these currents with the magnetic field generates resistance, creating a braking effect.

Advantages of Retarders:

- Reduced Brake Wear: Retarders help reduce wear on traditional friction brakes, extending their lifespan.
- Improved Brake Performance: By supplementing traditional brakes, retarders contribute to more effective braking, especially in downhill or heavy-load situations.
- Enhanced Safety: Retarders contribute to improved vehicle control and stability during descents, reducing the risk of brake fade.

Disadvantages:

- Additional Complexity: Retarders add complexity to the vehicle's drivetrain system.
- Cost: Installation and maintenance of retarders can be expensive.
- Noise: Some types of retarders, such as engine brakes, can generate increased noise during operation.

Applications:

- Heavy-Duty Trucks: Commonly used in commercial trucks, especially those involved in long-haul transportation or hauling heavy loads.
- Buses: Often employed in buses to enhance safety and control during descents.
- Off-Road Vehicles: Utilized in certain off-road and industrial vehicles to improve braking efficiency.

Retarders are valuable components in the world of heavy-duty vehicles, providing an additional layer of control and safety in challenging driving conditions. Their application is particularly critical for vehicles operating on steep gradients or carrying substantial loads.

4.9 Anti-lock Braking System(ABS).

The Anti-Lock Braking System (ABS) is a safety feature designed to prevent wheel lockup during braking, offering enhanced vehicle control and reducing the risk of skidding.

Functions of ABS

- The anti-lock braking system (ABS) comes as a standard safety feature in all modern cars.
- This is where the anti-lock braking system (ABS) comes in.
- It prevents the wheels from locking up and helps them maintain grip with the road below.

Here's a brief overview:
Components:

- Wheel Speed Sensors: Monitor the speed of each wheel.
- Hydraulic Control Unit (HCU): Manages brake fluid pressure.
- Pump Motor: Assists in maintaining optimal brake pressure.
- Valves: Control the brake fluid flow to prevent wheel lockup.
- Electronic Control Unit (ECU): Processes data from wheel speed sensors and controls the HCU.

Operation:

- Wheel Speed Monitoring:
  ABS constantly monitors the speed of each wheel using wheel speed sensors.
- Detection of Wheel Lockup:

The system detects when a wheel is about to lock up during braking.

- Brake Pressure Modulation:
  The HCU modulates brake pressure by adjusting the valves in the brake lines.
- Pulsating Brakes:
  ABS causes the brakes to pulsate rapidly, preventing wheel lockup.
- Maintained Steering Control:
  By preventing lockup, ABS helps the driver maintain steering control during hard braking.

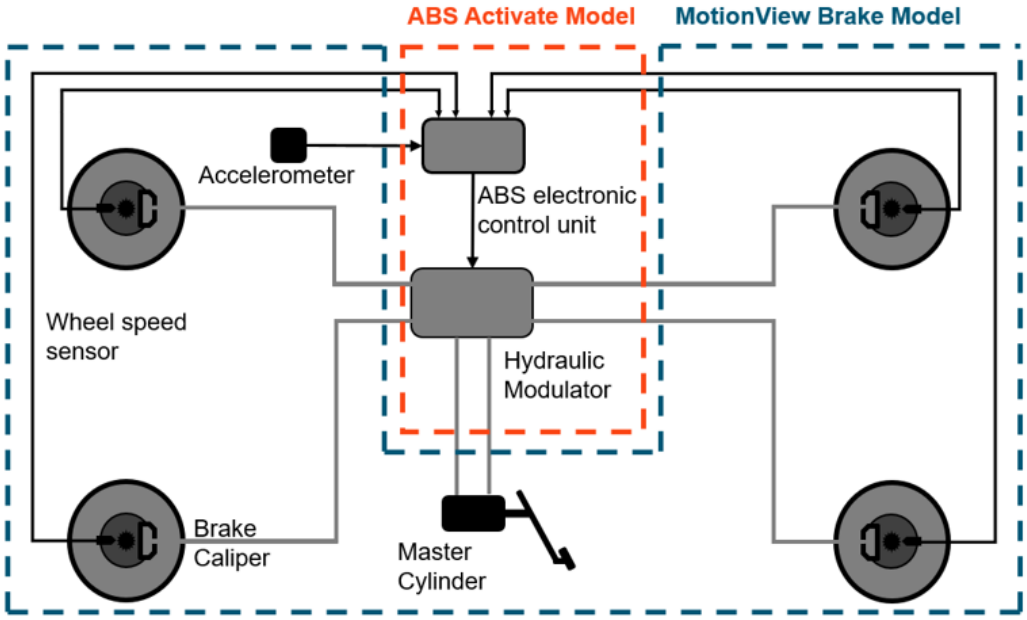


Figure 4.12 anti-lock braking system(ABS)

Advantages:

- Improved Steering Control: Prevents wheel lockup, allowing the driver to maintain control during braking.
- Shorter Stopping Distances: Reduces stopping distances, especially on slippery surfaces.
- Enhanced Stability: Contributes to vehicle stability and reduces the risk of skidding.
- Effective in Various Conditions: Works well on different road surfaces, including wet or icy conditions.

Disadvantages:

- Increased Complexity: Adds complexity to the braking system.
- Cost: Installation and maintenance can increase overall vehicle costs.
- Maintenance Dependence: Proper maintenance is crucial for effective ABS operation.

Applications:

- Passenger Cars: Standard feature in most modern cars.
- Commercial Vehicles: Common in trucks, buses, and commercial vehicles.
- Motorcycles: Increasingly integrated into motorcycle braking systems.

ABS has become a standard safety feature, significantly improving braking performance and vehicle control in diverse road conditions. Its implementation reflects a commitment to enhancing overall road safety and preventing accidents.

UNIT – V

Automobile Electrical System and Advances in Automobile Engineering

5.1 Battery

A battery is a device that stores and releases electrical energy through electrochemical reactions. It typically consists of one or more electrochemical cells, each composed of a positive electrode (cathode), a negative electrode (anode), and an electrolyte that allows ions to move between the electrodes. During discharge, chemical reactions within the battery generate electric current, and during charging, the process is reversed. Batteries serve as portable sources of power for a variety of electronic devices and applications.

The working principle of a battery involves electrochemical reactions that convert chemical energy into electrical energy. Here's a simplified explanation of how a battery works:

- Chemical Reactions:
- Electrolyte:
- Electron Flow:
- Ion Movement:
- Load Connection:
- Discharge and Recharge:

The overall process involves a continuous cycle of chemical reactions during discharge and recharge, allowing the battery to provide electrical energy over time.

Types of batteries

1. Primary Batteries (Disposable Batteries):

- Chemistry: Primary batteries are designed for single use and cannot be recharged. The chemical reactions that produce electrical energy in these batteries are typically not reversible.

Common Types:

- ✓ Alkaline batteries (e.g., AA, AAA)
- ✓ Zinc-carbon batteries
- ✓ Lithium batteries (e.g., CR2032)

Application:

Primary batteries are commonly used in low to moderate power consumption devices such as remote controls, flashlights, clocks, and other everyday household items.

Advantages:

- Convenient for portable, low-power devices.
- Generally, less expensive than rechargeable batteries.
- No need for a charging device.

Disadvantages:

- Once depleted, primary batteries must be replaced.
- Not environmentally friendly due to disposable nature.

2. Secondary Batteries (Rechargeable Batteries):

Chemistry: Secondary batteries are rechargeable, meaning the chemical reactions that produce electricity can be reversed by applying an external electrical current.

Common Types:

- Lithium-ion batteries (e.g., laptop batteries, electric vehicle batteries)
- Nickel-cadmium (NiCd) batteries
- Nickel-metal hydride (NiMH) batteries

Application:

- Rechargeable batteries are used in devices with higher power requirements, such as smartphones, laptops, cameras, power tools, and electric vehicles.

Advantages:

- Can be recharged and reused multiple times.
- More cost-effective in the long run.
- Generally better for the environment due to reduced waste.

Disadvantages:

- Typically, more expensive upfront.
- Require a compatible charging device.
- Self-discharge rate may be higher than primary batteries.

components in battery

A battery is a complex electrochemical device composed of several key components that work together to generate and store electrical energy.

Here are the main components of a typical battery:

Anode:

- The anode is the negative electrode of the battery.
- It releases electrons during the chemical reaction that occurs during discharging.

Cathode:

- The cathode is the positive electrode of the battery.
- It accepts electrons during the discharging process.

Electrolyte:

- The electrolyte is a chemical substance (liquid or gel) that facilitates the movement of ions between the anode and cathode.
- It allows the flow of electrons within the battery, completing the electrochemical circuit.

Separator:

- The separator is a physical barrier that prevents direct contact between the anode and cathode.
- It ensures that electrons flow through the external circuit and ions move through the electrolyte.

Collector:

- Collectors are conductive materials connected to the anode and cathode, allowing the flow of electrons to and from the external circuit.

Terminal:

- Terminals are the external connections of the battery that allow it to be connected to an electrical circuit.
- The positive terminal is connected to the cathode, and the negative terminal is connected to the anode.

Current Collector:

- Current collectors are metallic foils or grids that collect current from the active materials in the electrodes.
- In lithium-ion batteries, for example, current collectors are typically made of copper for the anode and aluminum for the cathode.

Case or Housing:

- The case or housing encloses the internal components of the battery, protecting them from external factors and providing structural support.

Vent:

- Some batteries have a vent to release excess pressure and prevent the build-up of gases during extreme conditions.

Thermal Management System (Optional):

- In some advanced batteries, especially those used in electric vehicles, a thermal management system may be included to regulate the temperature and prevent overheating.

Current Pathways:

- These are pathways within the battery that allow the flow of electrons and ions during discharge and recharge cycles.

Different types of batteries may have variations in these components, and advanced battery technologies may incorporate additional features for safety, efficiency, and performance. The specific materials used in the anode, cathode, and electrolyte also vary depending on the type of battery chemistry, such as lithium-ion, lead-acid, nickel-metal hydride, etc.

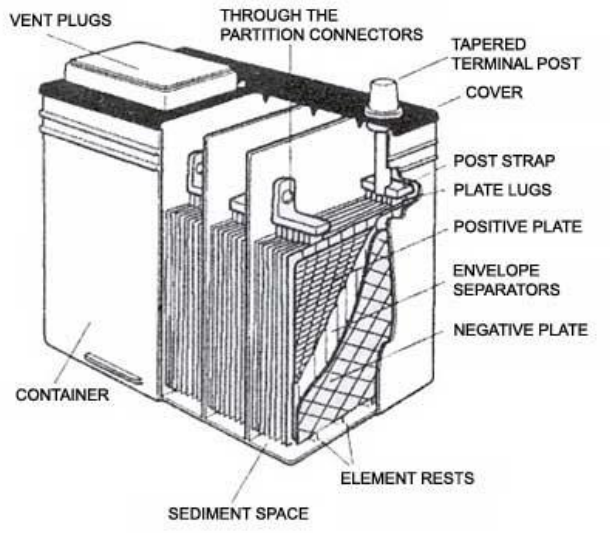


Figure 5.1 components in a battery

5.2 General electrical circuits

5.3 Active Suspension System (ASS)

5.4 Electronic Brake Distribution (EBD)

5.5 Electronic Stability Program(ESP)

5.6 Traction Control System (TCS)

5.7 Global Positioning System (GPS)

5.8 Hybrid vehicle

5.9 Fuel Cell.