UNIT-V
SUSPENSION SYSTEM

INTRODUCTION

General Aspects :

The **suspension system** of *an automobile is one which separates the wheel / axle assembly from the body.* The *primary function* of the suspension system is to *isolate the vehicle structure from shocks and vibration due to irregularities of the road surface.*

Broadly speaking, suspension system consists of a *spring* and a *damper* (including also spring shackles, axles, wheels and stabilizer). The energy of road shock causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper, which is more commonly called a *shock absorber*.

— The suspension system of a motor vehicle is divided into the *rear-end* suspension and *front-end* suspension.

A good suspension system must have *springiness* and *damping*. Springiness is elastic resistance to a load. On application of sudden load the spring will compress/expand as the case may be without transmitting the same to the body. As the spring compression is complete it expands on rebound, and now damping becomes important since this will *absorb the work energy as heat energy and the continuous oscillations of the spring which normally would have taken place are absorbed*.

- The function of isolation of shocks and vibrations between the road and carriage is achieved by different elements at different sages as mentioned below :

(*i*) The first element/stage which takes the impact is the *tyre*. With pneumatic tyres, this is achieved by flexing and compression of pneumatic tyres at the contact point.

(*ii*) The second stage is between the axle/wheel system and the body. The elements incorporate *springs, dampers/shock absorbers, various linkages and tie bars. This part is called* **"suspension system".**

(*iii*) The last stage comprise the *seats* of the automobile which the passengers occupy. These are made of springs and foam/rubber cushions. They absorb all short amplitude high frequency vibrations which pass from the system to the passenger compartment.

— The *wheel and seats* usually overcome the high frequency and low amplitude vibrations.

— The *suspension system* tries to overcome the greater irregularities of the road which may impact all the wheels, both the wheels on one side, or one axle or only one wheel at a time, while transmitting minimum vibrations to the compartment of the passengers.

6.7. FUNCTIONS/OBJECTS OF A SUSPENSION SYSTEM

Following are the *functions / objects of suspension system* :

1. To prevent the road shocks from being transmitted to the vehicle frame.
2. To preserve the stability of the vehicle in pitching or rolling, while in motion.
3. To safeguard the occupants from road shocks.
4. To maintain proper steering geometry.
5. To provide good road holding while driving, cornering and braking.

6.8. REQUIREMENTS OF A SUSPENSION SYSTEM

The *requirements of a suspension system* are :

1. Low initial cost.
2. Minimum weight.
3. Minimum wheel hop.
4. Minimum tyre wear.
5. Minimum deflection consistent with required stability.
6. Compatibility with vehicle components—tyre, frame, wheel base, steering linkage.
7. Low maintenance and operating costs.

6.9. ELEMENTS OF A SUSPENSION SYSTEM

Fig. 6.17 shows the schematic form of a suspension system. The **sprung weight** is *the weight of passenger carriage whereas the* **unsprung weight** *is the weight of the wheel-axle system.*

The important *elements of a suspension system* are :

1. Springs.
2. Dampers (or shock absorbers).

- The *springs* provide spring effect to a large extent ; the tyre, however, provides the spring effect to a smaller extent.
- The *dampers* (or shock absorbers) provide the damping effect to a large extent. However in case of leaf springs, the friction between the leaves in motion does generate some damping effect. Dampers perform the following *two functions* :

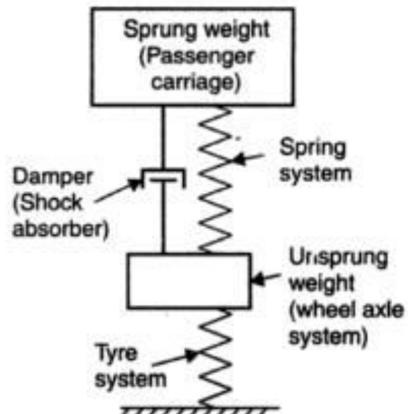


Fig. 6.17. Suspension system.

(*i*) They *reduce the tendency of the carriage unit to continue to "bounce"* [Fig. 6.18 (*a*)] *up and down* on its springs after the disturbance that caused the linear motion has ceased.

(*ii*) *They prevent excessive built up of amplitude of bounce* as a result of periodic excitation at a frequency identical to the natural frequency of vibration of the spring mass system.

Besides a simple bounce or vibration of the carriage unit as a whole, following two more types of vibration also exist :

(*i*) Rolling (*ii*) Pitching.

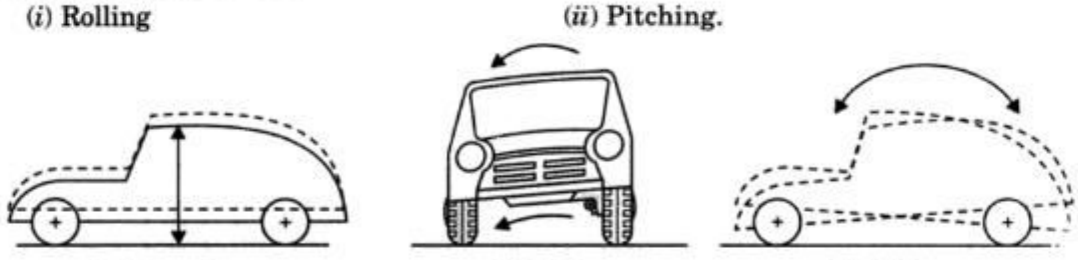

(*a*) Bouncing (*b*) Rolling (*c*) Pitching

Fig. 6.18. Basic suspension movements.

In **"rolling"**, [Fig. 6.18 (*b*)] *the carriage unit rolls about the longitudinal axis of the vehicle* while in **"pitching"**, *the carriage unit rolls about a transverse axis.*

- In rolling one side of the car goes down and the rear goes up and *vice versa*. The tendency to roll is checked by a *stabilizer*.
- *Pitching* [Fig. 6.18 (*c*)] is a more complex phenomenon and is affected by what is known as *"vibration coupling effect" i.e., interaction between front and rear suspension.* Since the picthing persists for a longer duration if the rear suspension has a lower natural frequency than the front suspension, therefore, the natural frequency of the rear suspension is normally made higher than that of the front.
- The pitching, in general, depends upon the following factors.

(*i*) The frequency of disturbances ;

(*ii*) Bumps over which the car rolls ;

(*iii*) Spacing of bumps ;

(*iv*) Speed of the vehicle ;

(*v*) Mass moment of inertia of the vehicle about the axis of pitch and its wheel base.

- *A combination of roll and pitch is called* ***diagonal pitch.***

  In order to control the above mentioned suspension movements, *antisway bars, stabilizers, pitch and roll control bars, mechanical levelling devices, hydroelastic systems etc. are employed.*

6.10. SPRINGS

The car body or frame supports the weight of the engine, the power train, and the passengers. The body or frame is supported by the *springs*. There is a spring at each wheel. The weight of the car frame, body and attached parts applies an initial compression to the springs. The springs compress further as the car wheels hit bumps or expand as the wheels drop into the holes in the road. The springs cannot do the complete job of absorbing road shocks. The tyres absorb some of the irregularities in the road. The springs in the car seats also help to absorb shock. However, little shock from road bumps and holes is felt by the passengers.

- Springs are resilient members and as such act as reservoirs of energy. *They store the energy due to the sudden force which comes when vehicle encounters a bump or a ditch. This energy is released subsequently and with the action of dampers, the energy is converted into heat and bounce is avoided.*
- Springs used for suspension system should *absorb road shocks quickly and return to the original position slowly.* Now let us examine this, a soft spring will oscillate too much *i.e.*, it will go up and down many times making a vehicle move along with it, while a stiff spring will not oscillate too much and will give a rough ride. As such a compromise is made by *using a soft spring with a shock absorber to control its up and down movement as well as to absorb the road shocks.*

Types of Springs :

The various types of automotive springs are :

1. *Leaf* (or *laminated*) *springs :*

(*i*) Full elliptic–Two semi-elliptic springs connected to form the shape of ellipse.

(*ii*) Three quarter elliptic–One semi-elliptic spring connected over a quarter elliptic spring.

(*iii*) Semi-elliptic–Forming the shape of half ellipse.

(*iv*) Quarter elliptic–Half of semi-elliptic spring.

(*v*) Transverse–Semi-elliptic type spring has the saddle above forming a bow and is fitted parallel to the wheel axle.

2. *Coil springs.*
3. *Torsion bars.*
4. *Air and gas springs.*
5. *Rubber springs.*

The main factors governing the choice of springs used are :

(*i*) Total weight of suspension system.

(*ii*) Total cost of installation.

(*iii*) Relative capacity for storing energy.

(*iv*) Guide linkage required.

(*v*) Location.

(*vi*) Fatigue life.

3. **Torsion bars :**

Torsion bar is simply a *rod acting in torsion and taking shear stresses only.* These bars are made of *heat-treated alloy spring steel.* The *amount of energy stored per unit weight of material is nearly the same as for coil springs.*

The torsion bar performs the spring's action by its resistance to twisting. The bar is mounted transversally in some of the vehicles, whereas in other constructions, it is employed lengthwise along the frame.

Fig. 6.22 shows a frame and axle.

— The axle is supported by a lower plate and another plate fixed to the frame. The lower plate is connected to a torsion bar. The end of the torsion bar is fitted to the chassis frame.

— When the wheel moves up or down, the torsion bar gets slightly twisted. In this position it absorbs the vibrations. When the wheel is coming down, the torsion bar reaches its original position. It absorbs vibrations and shocks. By this arrangement it acts like a spring and maintains the stability of the vehicle.

- As in coil springs, shot peening and anticorrosion treatment is also given to the torsion bar to improve fatigue life.

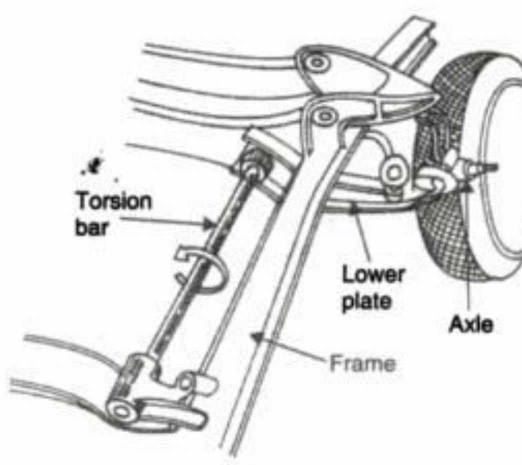


Fig. 6.22. Torsion bar.

- Torsion bars are *not very popular as suspension springs because their end fixings are more costly and provision has to be made for the adjustment of the ride height on the vehicle assembly line.* These are however used as *antiroll devices.*

6.11. DAMPERS (OR SHOCK ABSORBERS)

Dampers (or shock absorbers) *are used in the suspension system to check any continuous vibration which may follow the initial force on the system.*

Shock absorbers are necessary because springs do not "settle down" fast enough. After a spring has been compressed and released, it confines to *shorten and lengthen*, or *oscillate*, for a time. This is what happens if the spring at the wheel is not controlled. When the wheel hits a bump, the spring compresses. Then the spring expands after the wheel passes the bump. The expansion of the spring causes the car body and the frame to be thrown upward. But, having overexpanded, the spring shortens again. This action causes the wheel to move up and momentarily leave the road at the same time that the car body and frame drops down. The action is repeated until the oscillation gradually die out. Such spring action on car could produce a very bumpy and uncomfortable ride. It could also be dangerous, because a bouncing wheel makes the car difficult to control. Therefore, a dampening device is needed to control the spring oscillations. This device is called the *shock absorber*.

– In fact the name shock absorber is rather *misleading* since it is the spring and not the shock absorber that initially absorbs the shock. *The 'shock absorber' absorbs the energy of shock converted into vertical movement of the axle by providing damping and dissipating the same into heat.* Thus it *merely serves to control the amplitude and frequency of spring vibrations*. It cannot support weight and has *zero resistance*. Therefore, **'damper'** is a better term technically to describe the 'shock absorber'.

- In case of *"leaf spring suspension system"*, *the friction between the leaves provides the damping effect*. But because of the uncertainty of lubrication conditions, the amount of friction also varies and hence the damping characteristics do not remain constant. Therefore, additional damping is provided by means of *dampers* or shock absorbers.
- Frequently, the shock absorber housing is linked to the frame cross member and shock absorber arm is connected to the spring, axle or suspension control arm.

Modern cars mostly have *hydraulic dampers* which are of the following two types :

1. Telescopic dampers
2. Rocking lever dampers.

In these dampers hydraulic fluid is used as damping agent ; the *principle of operation* is as follows :

"When a piston forces the fluid in a cylinder to pass through some hole, a high resistance to the movement of the piston is developed, which provides the damping effect."

An additional advantage of hydraulic damper is that the damping is *proportional to the square of speed*. So for small vibrations the damping is also small, while for larger ones the damping becomes automatically more.

1. Telescopic dampers :

A telescopic damper or shock absorber (direct acting) is shown in Fig. 6.23. The cylinder is filled with a fluid prescribed by the manufacturer. There are valve openings in the piston. The valve openings are also at the bottom of the cylinder tube. There is a reservoir tube full of the fluid.

– When the wheels meet bumps and pot holes the shock absorber lengthens and shortens. When this happens, a piston inside a cylinder of shock absorber moves up or down.

When the shock absorber is compressed, the fluid in the cylinder passes upwards through the restricted valves of the piston. At the same time the fluid passes down through a small valve of the cylinder tube. By this arrangement the piston is able to move against the resistance of the fluid. Thus the shock on the vehicle is absorbed by the fluid.

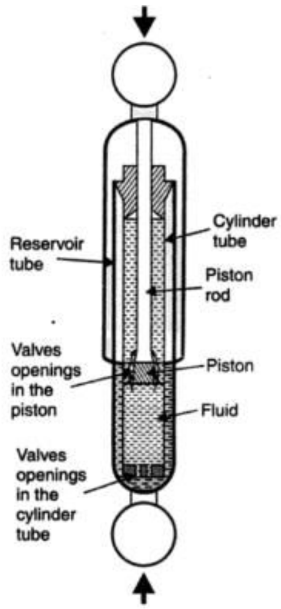


Fig. 6.23. Shock absorber under compression.

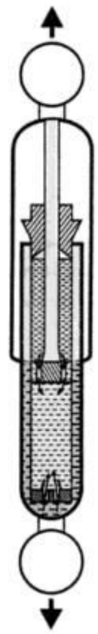


Fig. 6.24. Shock absorber under elongation.

– When the shock absorber is lengthening (Fig. 6.24), the liquid from the top portion of the piston is forced downward through the piston valves. At the same time the fluid from the reservoir tube enters through a valve at the bottom of the cylinder tube. By this arrangement the process of the shock absorber being lengthened is made very slow. This takes place after overcoming the resistance of the fluid.

Thus the shock absorber helps the springs of the axle from moving up and down at a very fast rate. It helps the oscillating springs of the car to settle down immediately.

Gas-filled shock absorber :

In this type of shock absorbers, *instead of only oil, a mixture of oil and gas is used for the damping effect.*

The main *advantages* of this type of shock absorber over the conventional type are as follows :

1. Because of the large piston, the specific pressures caused by damping are very much reduced, which has a positive effect on the valve components.
2. Provides longer life to tyres and other related components in the suspension (*e.g.*, springs bushes etc.)
3. It can tolerate heat to a greater degree ; this is an invaluable feature in tropical conditions.
4. The over-pressure in the working chamber produces an exact reaction of the valve components even at the lowest stroke and prevents the formation of bubbles (cavitation) at severe strain. This improves the rolling properties of the tyre and ensures a precise working of the shock absorber under any driving situation and road condition.
5. A large volume of oil is available for damping since a full diameter of the tube can be used as a working chamber.
6. It can be mounted in any position unlike the others which can be used only in a fixed 'top' position.
7. On bad roads, temperature and pressure of the gas increase and the body is lifted to a higher level. This increases ground clearance and reduces the risk of body damage.

2. **Rocking lever damper :**

Fig. 6.25 shows a rocking lever damper. Its working principle is same as that of the telescopic damper but has two pistons which move in a cylinder while the oil is displaced through a valve.

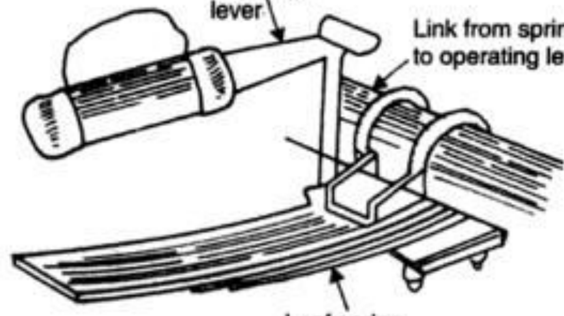


Fig. 6.25. Rocking lever damper/shock absorber.

The motion of the dual pistons takes place due to the motion of the wheels which is passed on to the pistons through the rocker levers.

Maintenance of damper/shock absorber :

When a shock absorber does not function properly it is better to remove it and replace it with a new one.

Sometimes an old *shock absorber can be properly serviced again, as per procedure given below* :

- Remove the shock absorber and dismantle its parts in a systematic manner.
- Clean these parts thoroughly.
- Fit new rubber gaskets.
- Then properly reassemble the parts.
- Pour in the fluid as recommended by the manufacturer for that particular shock absorber.

6.12. SUSPENSION SYSTEMS

6.12.1. Components of a Suspension System

A suspension system consists of the following *principle components* :

1. *Springs*. There neutralise the shocks from the road surface.

2. *Dampers* (*Shock absorbers*). They act to improve comfort by limiting the free oscillation of the springs.

3. *Stabilizer* (*Sway bar* or *antiroll bar*). It prevents lateral swaying of the car.

4. *A linkage system*. It acts to hold the above components in place and to control the longitudinal and lateral movements of the wheels.

Suspension may be *rigid axle suspension* or *independent suspension*.

6.12.2. Rigid Axle Front Suspension

A rigid axle suspension has the following *characteristics :*

1. It is durable enough for heavy-duty use.

2. The number of parts composing the suspension is small and the construction is simple ; therefore maintenance is simple.

3. While turning, there is a little tilting of the body.

4. Less tyre wear since there is little change in the alignment due to the up-and-down movement of the wheels.

5. Riding comfort is poor due to great unsprung weight.

6. Vibrations and oscillations occur rather easily since the movements of the left and right wheels mutually influence one another.

Fig. 6.26 shows a typical rigid axle front wheel suspension. This type of suspension was universally used before the introduction of independent front wheel suspension. It may use either two longitudinal leaf springs or transverse springs, usually in conjunction with shock absorbers. These assemblies are mounted similarly to rear leaf spring suspensions.

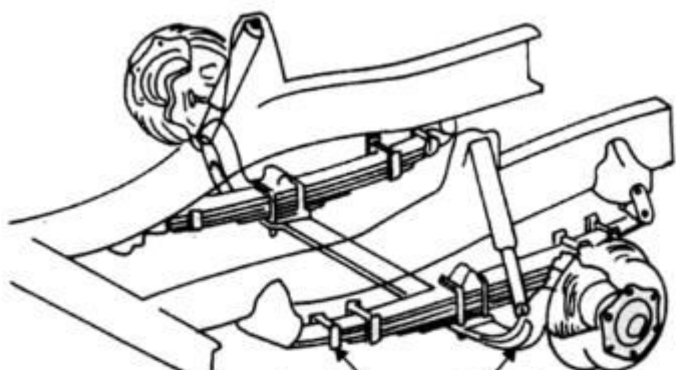


Fig. 6.26. Rigid axle front suspension.

6.12.3. Independent Suspension

"Independent suspension" *is a term used to describe any arrangement by which the wheels are connected to the carriage unit in a manner such that the rise and full of one wheel has no effect on the others.* Almost all the passenger cars now use the independent front suspension, in which the coil spring arrangement is the most common.

When a vehicle with rigid axle suspension encounters road irregularities, the axle tilts and the wheels no longer remain vertical. This causes the whole of the vehicle to tilt to one side. Such a state of affair is *not desirable.* Besides causing *rough ride,* it causes *'wheel wobble'.* The road adhesion is also decreased. In order to avoid this the *wheels are sprung independent of each other, so that tilting of one does not affect the other.*

Advantages :

The independent suspension claims the following advantages over the rigid axle type suspension.

1. In independent system since the wheels more or less travel with their planes perpendicular to the road surface, the *gyroscopic effects are reduced to a minimum.*

2. The engine and chassis frame can be placed relatively lower which means engine position can be moved forward resulting in more space for passengers.

3. Provides a greater degree of vertical/springing movement.

4. Diminished wheel wobble and steering tramp.

5. Provides scope for use of springs of greater resilience giving much better springing action than most rigid axle vehicles.

6. Reduced unsprung weight and hence improved ride and better road holding while cornering and braking.

7. The frame and body do not tilt but remain horizontal and the wheels vertical when the wheel encounters a road bump.

8. Variations in caster angle are reduced.

9. It uses coil springs which can be placed closer to the wheel. This is definite advantage *vis-a-vis* leaf springs for a wheel to be steered.

Disadvantages :

Apart from the distinct advantages which the independent suspension possesses, it has the following *disadvantages :*

1. High initial cost.

2. Owing to larger number of bearings greater maintenance is required.

3. More rigid sub-frame or chassis frame required.

4. Forces due to unbalanced wheels are more pronounced and transmitted easily to the steering wheel.

5. In the event of body roll, the wheel chambers tilt outwards in case of wishbone type and inwards in case of MacPherson strut type, due to which cornering power is reduced.

6. Misalignment of steering geometry with the wear of components, thus requiring more frequent attention.

- In a car, the "*font axle*" is usually a *dead axle* (The dead axles do not contain differential and have no concern with the power transmission system of the automobile) although some cars do have front wheel drive. Therefore, *the independent suspension systems have been almost universally adopted* for the *front wheels*. The independent suspension system for the front wheels has to cope with the fact that they are to be *steered*.

"*Rear axle*" is usually a *live axle* (the rear axles are those axles which contain differential and through which rotary motion is transmitted to the wheels) with power being transmitted to the rear wheels. Thus independent suspension has not become popular for the rear wheels. Further rear wheels have to carry a lot of weight and while the weight on the front wheel remains more or less constant, in the case of rear wheels it makes a lot of difference when the car is running empty or when it is fully occupied. The suspension system has to cater to both these condition.

6.12.3.1. Front wheel (dead axle) independent suspension. The front suspension is more complicated than the rear suspension, *because the front wheels not only move up and down with respect to the car frame, but also swing at various angles to the car frame for steering.* In order to permit the front wheels to swing on one side or the other for steering, each wheel is supported on a spindle which is part of a steering knuckle. The steering knuckle is then supported through ball joints, by upper and lower control arms which are attached to the car frame.

Since the *front suspension* in a car has to bear a lot of forces particularly due to acceleration, braking and cornering, therefore, it must *adhere to the following conditions :*

(*i*) Not to allow the system to alter the tilt of the wheels to any serious degree.

(*ii*) Not to permit the various forces coming from road irregularities and cornering to deflect the car from its course of movement decided by the driver.

(*iii*) Not to allow the wheels to wobble, move any significant distance backwards or forwards or sideways.

The *following types of independent suspension systems are applicable to automobiles* :

1. Wishbone arm system.
2. Trailing link system.
3. Sliding pillar system.

1. **Wishbone arm system**

Fig. 6.27 shows the *double wish bone suspension system*. This is the *most popular type* of independent suspension system in which *coil springs are mostly used*. In European cars, torsion bars are quite popular in lieu of coil springs. In some automobiles, transverse leaf springs are used in this type of suspension. English car Humber contains transverse leaf spring in the front independent suspension system.

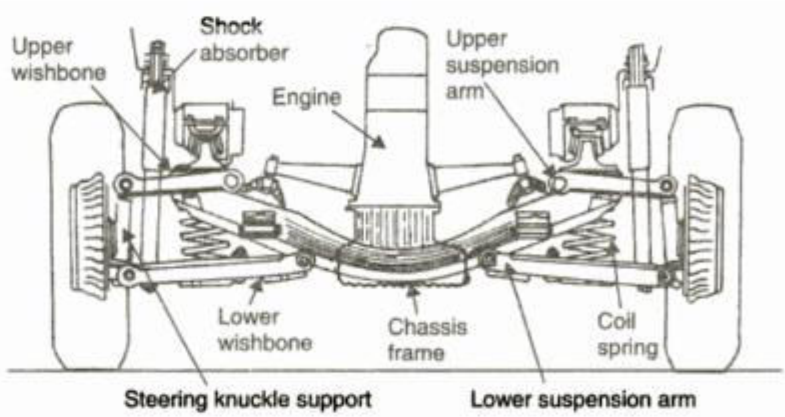


Fig. 6.27. Double wishbone suspension.

In this type of suspension, there are two suspension or control arms on each side of the vehicle. These arms are like the *two legs of chicken wishbone or letter V*. These wishbone arms are connected with chassis frame on the open end. One arm is *below* whereas other is *above* the frame. The closed ends of both upper and lower suspension arms are connected with the steering knuckle to support to which is attached steering knuckle by means of a king pin. A coil spring is placed between the frame and lower wishbone suspension arm. Mostly the open end of upper control arm is connected with the damper/shock absorber which is fitted at the frame. The upper and lower arms are connected in position, for the cradle.

When there is bump and the wheel tended to go up, the control arms move up and coil spring is compressed. Since the damper/shock absorber is fitted with the upper control arm, so it damps the vibrations set up in the coil spring due to road irregularities.

- The suspension using transverse leaf spring, consists of an upper wishbone, steering knuckle support and a transverse leaf spring. *The transverse spring serves two purposes of holding the lower end of steering knuckle support and of providing the spring action*. The basic construction is similar to regular wishbone design with the exception that no lower control arm is used.

— The wishbones may be *parallel and equal* or *unequal*. Early double wishbone suspension systems had both the link equal and parallel to each other ; they had the following *disadvantages* : (*i*) The wheels, on corners, lean outwards with the body resulting in undesirable steering effects ; (*ii*) Variation in track length resulted in adverse tyre wear. In order to avoid these undesirable effects in *modern automobile*, the two wishbones *were not only made unequal but also they were made non-parallel* (*usually the upper wishbone is made shorter so that the wheels do not remain upright but have a slight lean inwards*). In this arrangement the following *advantages* accrue : (*i*) The track length remains constant although a slight change in camber takes place which is better for tyre life ; (*ii*) Better cornering characteristics are obtained.

— In both the double wishbone suspension systems, when coil spring with telescopic damper is used they are usually installed *coaxially*. On some vehicles, the springs and dampers are *mounted separately*, so *that access could be gained more easily for servicing the damper*.

MacPherson strut assembly :

It is a single wishbone with a telescopic strut type system as shown in Fig. 6.28. The **MacPherson** system consists of a *telescopic strut*, *a single arm* and a *diagonal stay*. The strut is fixed to the body structure at the upper end through a flexible mounting and the lower part of the strut is connected at the bottom by a joint to the lower arm. The lower part of the strut also carries the stub axle, which in term carries the wheel. The steering motion is supplied to the lower part of the strut and it turns the whole strut. A coil and a hydraulic damper/shock absorber surround the upper part of the strut which takes care of the road irregularity shocks and vibrations.

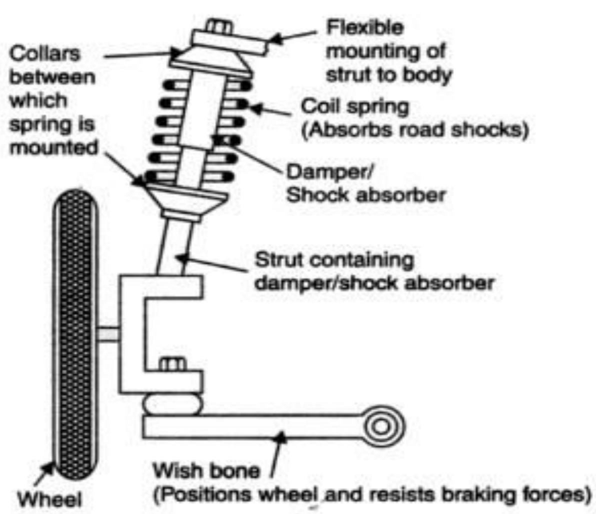


Fig. 6.28. MacPherson strut assembly.

Advantages of MacPherson system :

(*i*) Very easy maintenance.

(*ii*) Simple in mechanical construction.

(*iii*) Less variations in wheel camber.

(*iv*) Its light moving parts help the wheels to follow the road irregularities.

(*v*) Distinct advantages in case of transverse engines, since in that case there is no space or very little space for upper links to fit.

Disadvantages :

(*i*) During cornering and brake torque the radial loading comes on the piston due to the lateral forces.

(*ii*) In order to absorb the full suspension loads the body structure has to be really strong above the wheel arches where the struts are attached.

Maruti-800 suspension system :

Maruti-800 car incorporates the MacPherson type independent suspension system. It consists of *coil springs, front suspension struts, steering knuckles, a stabiliser bar and front suspension arms*. In this type of construction, shocks applied to wheels are distributed through steering knuckles from front suspension struts, coil springs, to front suspension arms and are absorbed.

- The spring rate of front coil spring and it's free length = 1.8 kg/mm and 336 mm respectively.
- The attenuation force of the suspension struts = 50 kg (extending side) and 24 kg (contracting side).
- The stroke of suspension struts = 135 mm.

2. **Trailing link system :** Refer to Fig. 6.29.

- These systems use parallelogram linkages lying beside the frame side members.
- Usually a horizontal coil spring is used in this type of suspension. During compression and rebound, the spring winds and unwinds like the balance spring in an ordinary watch.
- In some suspensions of this type, the torsion bar is fitted in lieu of horizontal coil spring.

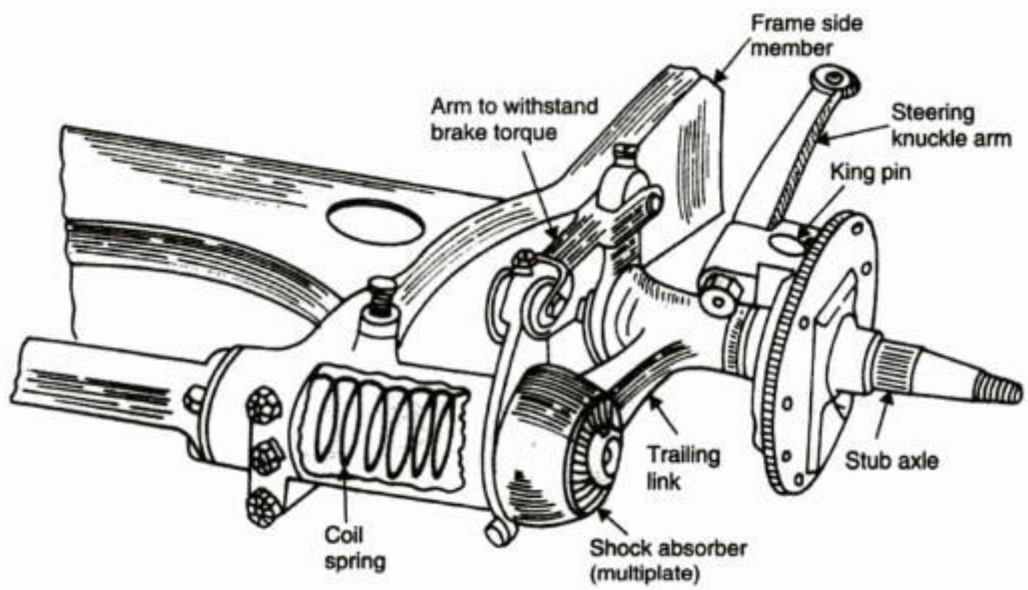


Fig. 6.29. Trailing link independent suspension.

3. **Sliding pillar type independent suspension.** Refer Fig. 6.30.

- This type of suspension was the first independent front end suspension ever used.
- In this system, the pillar or elongated king pin is attached to the wheel and slides up and down in the axle type beam affixed rigidly to the vehicle frame.

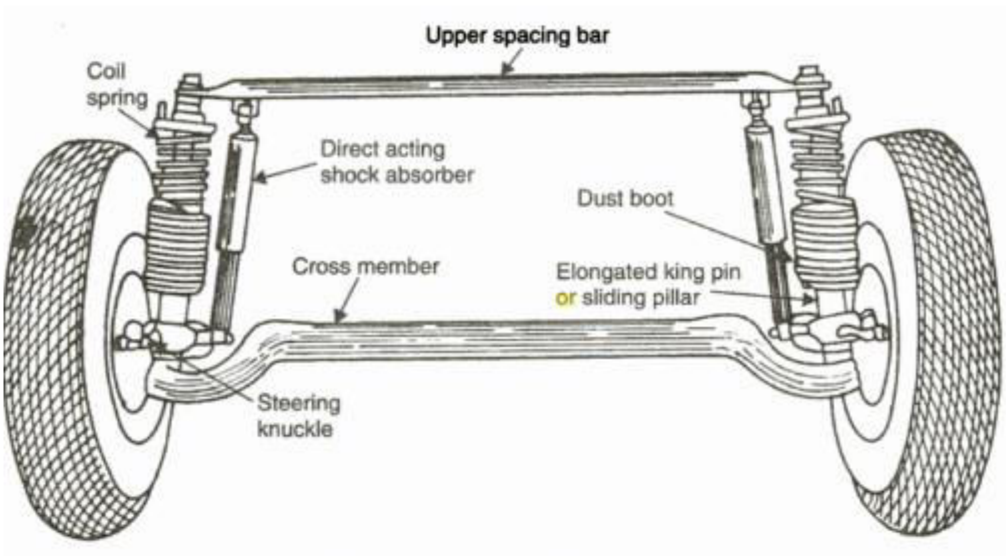
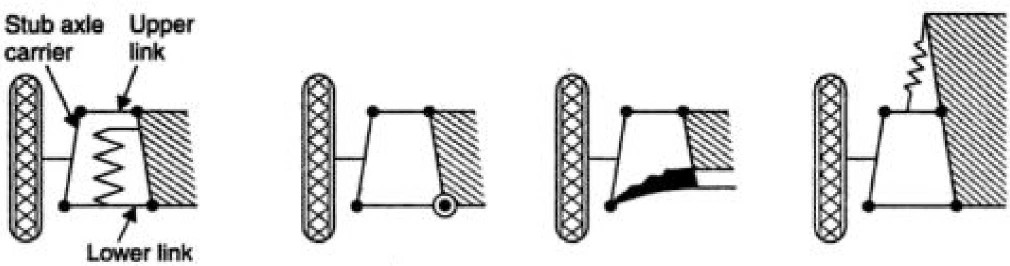


Fig. 6.30. Sliding pillar type of independent suspension.

Simplified diagrams of the independent front suspension :

Fig. 6.31 shows the simplified diagrams of the independent front suspensions using coil, torsion bar and leaf spring. Basically, the system is known as parallelogram type independent front suspension. It consists of upper and lower links connected by the stub axle carrier. In general, the lower link is larger than the upper and they may not be parallel. This arrangement maintains the track width as the wheels rise and fall and so minimize tyre wear caused by the wheel scrubbing sideways.



(*a*) Coil (*b*) Torsion bar (*c*) Leaf spring (*d*) Coil spring

Fig. 6.31. Parallelogram independent front suspensions.

- ***"Strut and link"*** *type suspension system* (Fig. 6.32) is particularly for integral body construction, because the loading points are widely spaced. The normal top link is replaced by a flexible mounting and a telescopic damper acts as a the king pin. This system, ***known as MacPherson system has little rolling action and absorbs shocks readily.***

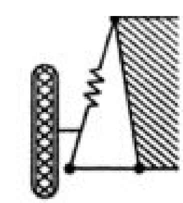


Fig. 6.32. Strut and link suspension system.

- *Trailing arm independent front suspension* (Fig. 6.33) maintains constant track and wheel altitude with a slight change in wheel base and caster angle. A coil spring is attached to the trailing arm which itself is attached to the shaft carrying the wheel hub. When the wheel moves up and down, it winds and unwinds the spring. In certain designs, a torsion bar has been used in place of the coil spring.

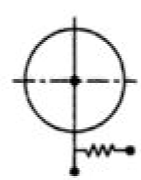


Fig. 6.33. Trailing arm

suspension system.

- In ***sliding type*** *suspension system* (Fig. 6.34). The stub axle can move up and down as well as rotate in the frame members. Track, wheel altitude and wheel base remains unchanged throughout the rise and fall of the wheel.
- In ***vertical guide*** *suspension system*, the king pin is attached directly to the cross member of the frame. It can slide up and down, thus compressing and expanding the springs.

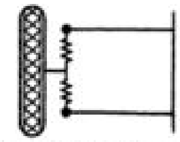


Fig. 6.34. Sliding type suspension system.

Torque rod :

- It is also known as *torque arm*. Its one end is rigidly fixed to the axle or axle housing, and the other end is attached to the frame by means of a pivoted mounting.
- It is used to *maintain correct alignment of the axle with the frame*. It also serves to remove all the stresses on the springs.

Stabilizer (or antiroll device) :

- A ***stabilizer*** or *a sway bar* (Fig. 6.35) is simply a bar of alloy steel with arms at each end connected to the lower wishbone of the independent suspension or axle. It is supported in bush bearings fixed to the frame, and is parallel to the cross member.
- It is necessarily used in all independent front end suspension. It *reduces the tendency of the vehicle to roll or tip on either side when taking a turn*. This tendency has been increased due to the use of softer springs and independent front end suspension.

– When both wheels deflect up or down by the same amount, the stabilizer bar simply turns in the bearings. When one wheel deflects, then only one end of the stabilizer moves, thus twisting the stabilizer bar which acts as a spring between the two sides of the independent suspension. In this way, the stabilizer reduces heeling or tipping of the vehicle on curves.

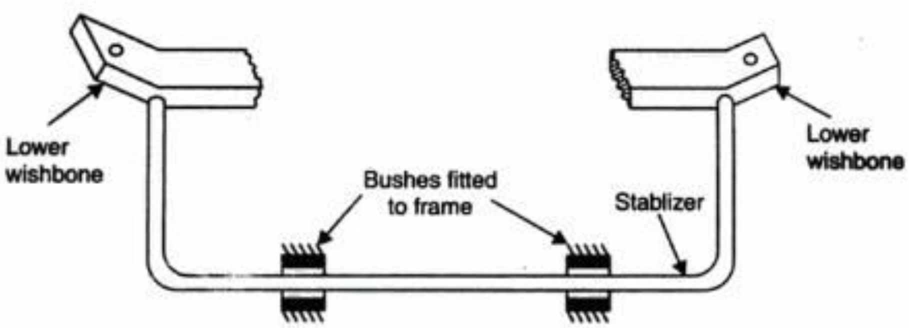


Fig. 6.35. Stabilizer.

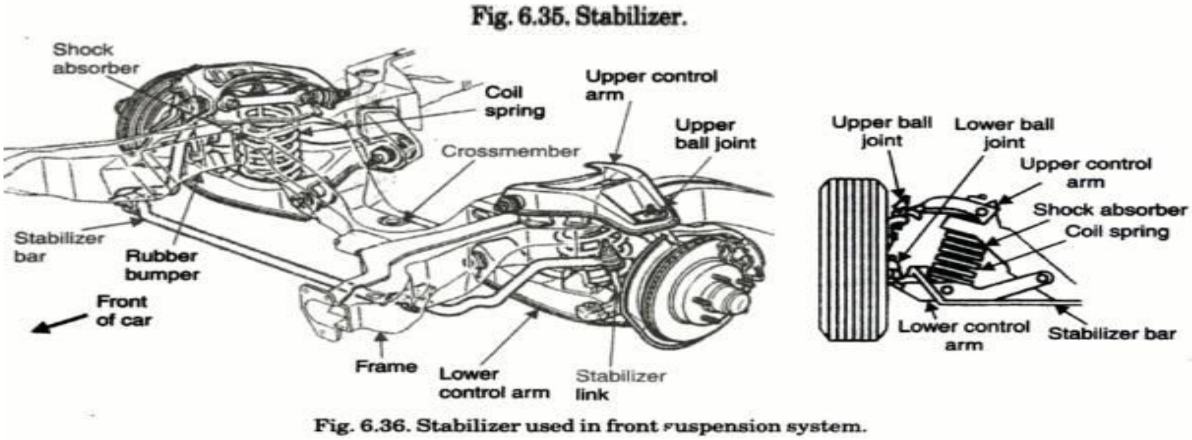


Fig. 6.36. Stabilizer used in front suspension system.

6.12.3.2. Rear wheel suspension system

Mostly rear axle is a live axle (except in front wheel drive cars). The rear axle even in case of four-wheel drive vehicles like jeeps mostly transmits the power. In case of heavy passenger vehicles or load carrying vehicles, the power is transmitted through the rear axle. A ***"live axle"*** *is one that either rotates or houses the shafts that rotate*, while a ***"dead axle"*** *simply carries at its ends the stub axles on which the wheels rotate*. A live axles performs the following *two functions* :

(*i*) It houses and supports the final drive, differential and shafts to the road wheel and reacts to the torques in both the input and output shafts.

(*ii*) It works as a beam that *carries* through the medium of springs and other suspension system, the weight of passenger compartment and its contents, and *transmits* these loads under dynamic conditions through the road wheels (rotating on its ends) to the ground.

The rear axle suspension system needs to be designed for overcoming the following forces :

(*i*) The weight of carriage unit (including contents).

(*ii*) Brake drag.

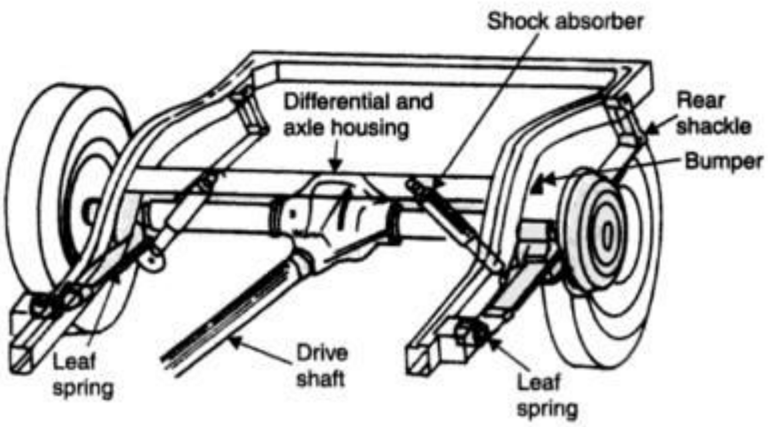
(*iii*) Torque reaction (both drive line and brakes).

(*iv*) Lateral forces.

(*v*) Driving thrust.

Both rigid suspension and independent rear wheel suspension have been designed in several ways and some are specifically known by the names of the car models in which they are used. Some of these are discussed below :

1. **Leaf-spring rear-suspension system (Rigid suspension) :**



(*a*)

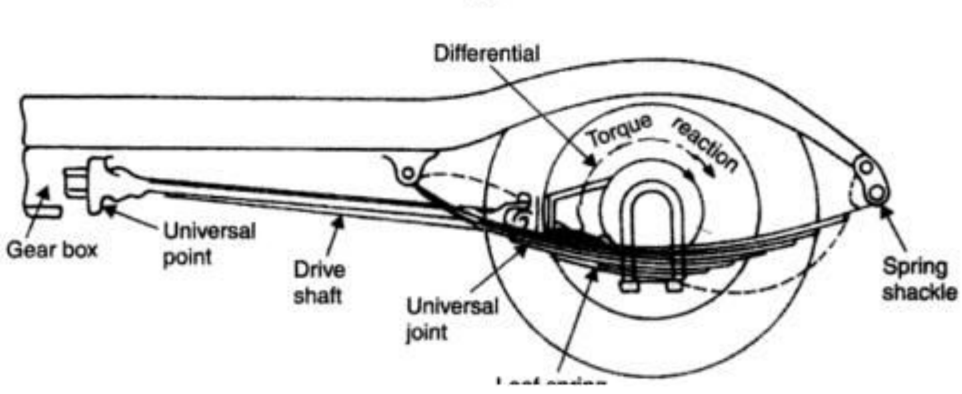


Fig. 6.37 shows rear rigid suspension using leaf springs (Hotch kiss drive). It employs two leaf springs located as far as possible on the axle. These springs not only absorb shocks but also position the axle and the axle moves up and down with it. Near the leaf springs are attached the dampers (*i.e.*, shock absorbers), one each to the two sides of the rear axle. The axle is usually fitted exactly at the mid point of the spring. However, in some cases it is fixed a bit ahead of the mid point to give a downward tilt as the axle rise when riding over bumps. This reduces the amount by which the propeller shaft lifts on a bump and in turn minimises the height of the propeller shaft tunnel and the amount it intrudes into body of the car. The leaf springs are fitted to the body with a *rubber bush in the front* while the *rear end* of the spring is fitted to the body through a *shackle with rubber brushes*. By doing so the increase or decrease in length of the spring, as it flexes up and down, is accommodated.

A leaf spring has a demerit that it *tends to distort when the axle tries to turn during acceleration or braking*. The following modifications have been made to overcome some of the shortcomings associated with Hotchkiss drive.

(*i*) *Linking the axle with the main structure*. This arrangement limits the fore and aft distortion of the springs.

Radius rods trailing from mountings on the structure help to position the axle.

(*ii*) *Use of transverse rod*. A transverse rod (also known as *Panhard rod*) is pivoted on the body structure at one end and on the axle at the other which assists in holding the axle in the position.

2. Independent rear suspension :

Though the rear wheels are not to be steered, yet there is a considerable difficulty in the rear wheel springing if the power has to be transmitted to the rear wheels. But even the rear wheel independent springing is coming into prominence because of its distinct advantages over the rigid axle type.

(*i*) ***Swinging half axle.*** The swinging half axle is the oldest arrangement in independent rear wheel suspension and is shown in Fig. 6.38 (*a*). Here the differential unit is carried by the car frame. The rear half axle is connected to a single universal joint. The wheel thus moves vertically while moving over a bump.

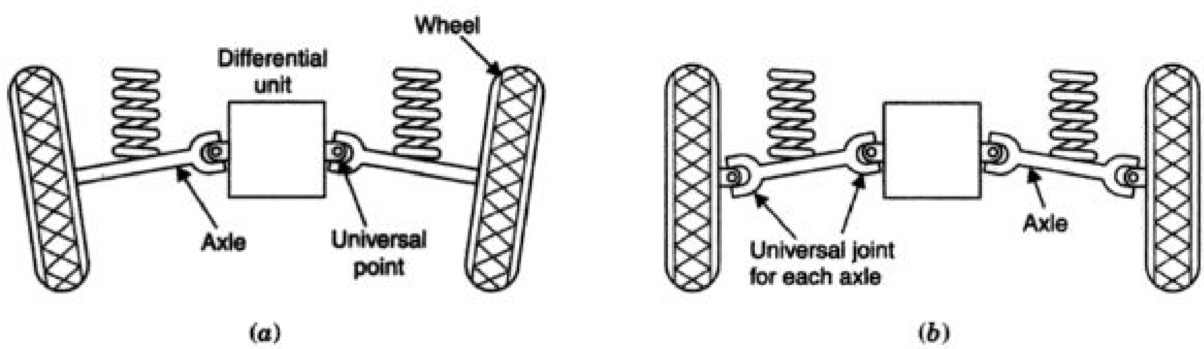


Fig. 6.38. Independent rear suspension.

In Fig. 6.38 (*b*), *two universal joints* have been used for each axle. The wheels move vertically up and down.

(*ii*) ***MacPherson strut.*** The MacPherson strut is used in rear suspension with half axles as discussed under front suspension.

(*iii*) ***Trailing arm design.*** In this type of design (Fig. 6.39) the trailing arms are pivoted at right angles to the centre line of the car. They link the main frame to the wheel carriers. This arrangement allows the wheels to move up and down.

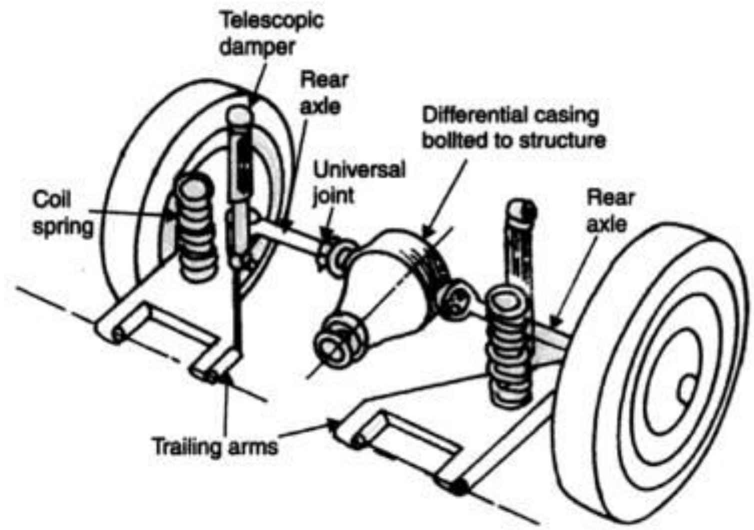


Fig. 6.39. Trailing arm.

BRAKING SYSTEM

INTRODUCTION

This chapter deals with the construction and operation of the various types of braking systems used in automotive vehicles.

Brakes are one of the most important control components of the vehicle. They contribute very much in the running and control of the vehicle. On the efficiency of brakes depends the lives and comfort not only of driver and passengers but other persons moving on the road. Furthermore it is a fact that owing to recent improvements in the braking mechanism it has been possible to have increased speeds of the modern cars on the road.

The braking system used *most frequently operates hydraulically, by pressure applied through a liquid*. These are the foot-operated brakes that the driver normally uses to slow or stop the car. They are called the "*service brakes*". In addition all cars have a *parking-brake system* which is mechanically operated by a *separate foot or hand lever*. On some trucks and buses, the braking system is operated by air pressure (*pneumatically*). This type of brake is an *air brake*. Many boat and camping trailers have *electric brakes*.

- *All the braking systems depend upon friction between moving parts and stationary parts for their stopping force.*
- ***Braking efficiency** is the ratio between the retarding force (or force of friction between the linings and the drum) and the weight of the vehicle*. It is expressed as percentage.

NECCESSITY OF BRAKING SYSTEM

In an automobile, if the pressure from accelerator pedal is removed, the ·ehicle tends to slow up because of wind resistance, drag of engine and road friction. These forces, of course, would stop the vehicle but in the present day traffic, this would be quite unpracticable and dangerous. *The braking system provides added friction to overcome motion and to slow up or to stop the vehicle. The momentum or kinetic energy developed by the vehicle when in motion is converted to heat energy by the friction of brake shoes and drums which is dissipated into the surrounding air.*

9.3. FUNCTIONS OF BRAKES

Brakes perform the following *functions* :

1. To stop the moving vehicle in the shortest possible time.

2. To help in controlling the speed of the vehicle and to reduce the speed at turnings and other crowded places.

3. To hold the vehicle in its stationary position, without the presence of the operator, after it has been brought to a stop.

— In a moving vehicle, the *friction* between brake drum and brake shoes (having lining riveted to it) slows down the rotation of wheel or stops the vehicle.

9.4. REQUIREMENTS OF A GOOD BRAKING SYSTEM

The *requirements of a good braking system* are as follows :

1. The brakes should stop the vehicle within a reasonable distance. The retardation shall be smooth and free from jerk or shudder.

2. The braking system should be very reliable to promote highest degree of safety on the road.

3. The braking system should not be affected by water, heat, road grit or dust etc.

4. Pedal effort applied by the driver should not be more so as not to strain the driver.

5. Brake should work equally good in all weathers.

6. The wear and tear of the material of the brake lining should be minimum for its longer life.

7. Due to the rubbing action of brake shoes alongwith lining against drum, large amount of heat is generated due to friction. The brake design system should be capable of dissipating this heat very quickly.

8. All the components and levers of the braking system should be strong enough to take the mechanical stresses and strains which are encountered during brake actuation.

9. No braking system can work at its best through worn out or incorrectly inflated tyres. Good, tyres are, therefore, a prime essential for efficient braking.

- The **capacity of a brake** depends upon the following *factors* :

(*i*) The unit pressure between the braking surfaces.

(*ii*) The coefficient of friction between the braking surfaces.

(*iii*) The peripheral velocity of the brake drum.

(*iv*) The projected area of the friction surfaces.

(*v*) The ability of the brake to dissipate heat equivalent to the energy being absorbed.

9.5. CLASSIFICATION OF BRAKES

Brakes may be *classified* as follows :

1. Mechanical brakes.
2. Hydraulic brakes.
3. Power brakes.

(*i*) Air brakes

(*ii*) Air-hydraulic brakes

(*iii*) Vacuum brakes

(*iv*) Electric brakes.

9.6. MECHANICAL BRAKES

9.6.1. Introduction

The *brakes which are operated mechanically by means of levers, linkages, pedals, cams, bell cranks, etc. are known as* **mechanical brakes.**

The external contracting brake which is usually hand brake in automobiles is mechanical brake. Automobiles contain *service brakes* operated mechanically.

Mechanical brakes were employed in olden days but now hydraulic and other types of braking system have taken its place.

9.6.2. Internal Expanding Mechanical Brake

Fig. 9.1 shows an *internal expanding brake (mechanical).*

Construction. It consists of two ***shoes*** S_1 and S_2. The outer surfaces of the shoes are lined with some ***friction material***, to increase the frictional coefficients and to prevent wearing away of the metal. Each shoe is pivoted at one end about a fixed ***fulcrum*** (O_1 and O_2) and made to contact a ***cam*** at the other end. When the cam rotates, the shoes are pushed outwards against the rim of the ***drum.*** The friction between the shoes and the drum produces the braking torque and consequently speed of the drum reduces. Brake shoe ***retracting spring*** which connects both the brake shoes at their loose end helps them in contracting after the brakes are released.

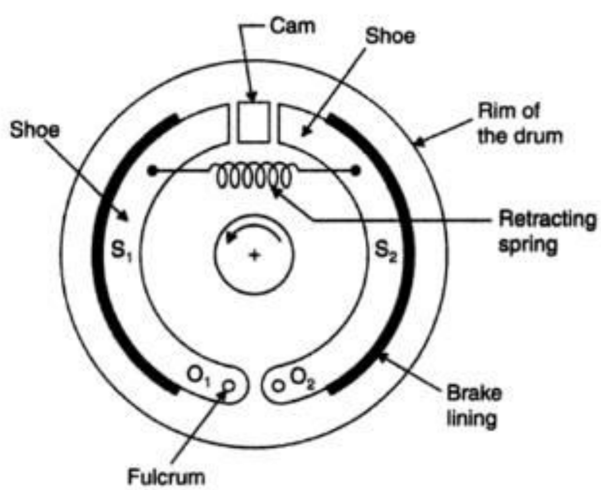


Fig. 9.1. Internal expanding brake.

Operation :

- When the brake pedal is *pressed down*, its motion is transmitted to the cam through various mechanical linkages. The motion of the cam tends to expand out the brake shoes. This inward motion of the brake shoes will try to slow down the motion of the rotating brake drum. Because the wheel is fixed to the brake drum, so automatically it will be held to move further.
- When brake pedal is *released*, the pedal will move up because of the tension of the return spring. A retracting spring draws the shoes away from the drum when the cam is moved to its initial position and hence the brake shoes are no longer in contact with the drum, which is now free to rotate.

9.6.3. Hand Brake (or Parking brake)

Hand brakes are usually the mechanical brakes. These brakes operate independently of the foot brakes. These are used for *parking on slopes and during emergency* and are also called "*secondary brakes*". Hand brake is generally located on the side of the driver's seat. On most of the vehicles hand brake applies only the rear brakes.

Fig 9.2 shows a schematic diagram of a typical hand brake.

In order to apply the brakes the ratched is released first by pressing the ratchet release handle, which causes the pawl to move up, disengaging the rotchet. Then the brake lever is pulled up, while further pulls the cable which in them operates the rear brakes mechanically through a linkage operating on the piston of the rear wheel cylinder, which is two halves. The ratchet release handle which had been pressed so far is released now, so that the pawl moves down the spring action and engages with the ratchet thus keeping the brakes applied.

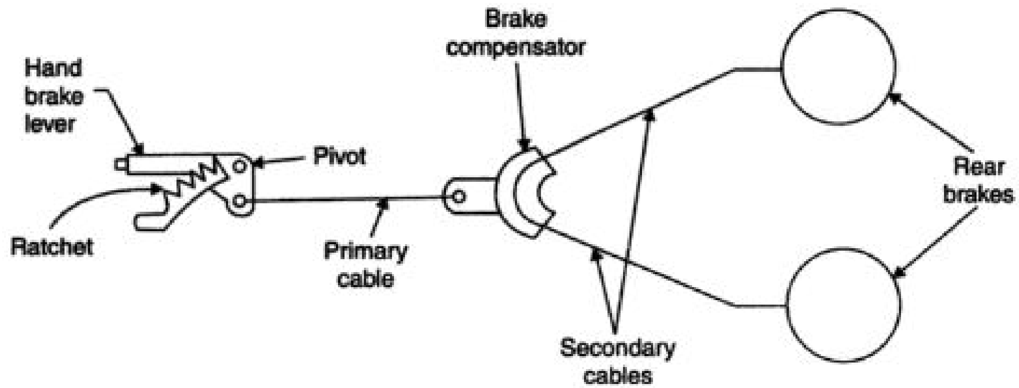


Fig. 9.2. Hand brake.

9.6.4. Disc Brakes

These brakes are different from drum brakes in that the drum is replaced by a circular plate and the brake shoes are replaced by a caliper which supports a pair of friction pads, one on each side of the disc. These pads are forced inward by the operating force and so retard the disc.

Fig. 9.3 shows a disc brake with fixed caliper.

Construction. A disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called *caliper*. The caliper is connected to some stationary part of the vehicle (such as stub axle or axle casing) and is cast in two parts, each containing a piston. In between the each piston and the disc, there is a friction pad held in position by retaining pins, spring plates etc. Passages are drilled in the caliper for the fluid to enter or leave each housing. These passages are also connected to one another for bleeding. Each cylinder contains a rubber sealing ring between the cylinder and the piston.

Working. On the application of brakes, hydraulically actuated pistons move the friction pads into contact with the disc, applying equal and opposite forces on the later. When the brakes are released, the rubber sealing rings act as return springs and retract the pistons and the friction pads away from the disc.

Special types of disc brakes include the *swinging caliper type* and the *sliding caliper type*.

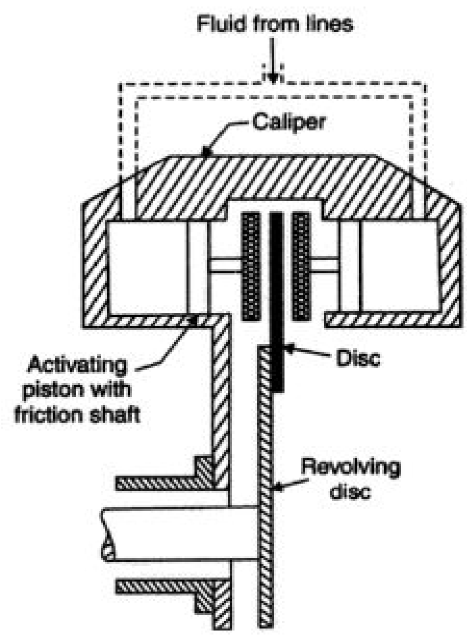


Fig. 9.3. Disc brake with fixed caliper.

The *advantages* and *disadvantages* of *disc brakes compared with drum brakes* are as follows :

Advantages :

(*i*) Lighter than drum brakes.

(*ii*) Better cooling (since the braking surface is exposed directly to air).

(*iii*) Offer better resistance to fade.

(*iv*) Uniform pressure distribution (since disc brakes have no self-servo effect).

(*v*) Brake pads can be easily replaced.

(*vi*) These brakes are self adjusting by design.

Disadvantages :

(*i*) Costlier than drum brakes.

(*ii*) For stopping the vehicle higher pedal pressure is required.

(*iii*) There is no servo action in these brakes.

(*iv*) It is difficult to install an adequate parking attachment.

- The *major drawback of a "mechanical brake system" is that it is very difficult to get simultaneous brake action on all the four wheels. Also lengths of various rods and cables vary and this causes unequal braking action.*

9.7. HYDRAULIC BRAKES

9.7.1. Introduction

Brakes which are operated by means of hydraulic pressure are known as **hydraulic brakes.**

In a *hydraulic system*, when the brakes are applied, the pressure in increased sufficiently in the system to produce equal and uniform backing action on all the four wheels. The hydraulic brakes function on the principle of *Pascal's law* which reads as follows :

"Pressure applied to a liquid is transmitted equally in all directions."

9.7.2. Hydraulic Braking System

The hydraulic braking system consists of *four wheel cylinders*, one at each of the four wheels of the vehicle as shown in Fig. 9.4. The system also consists of one *master cylinder*, which is connected

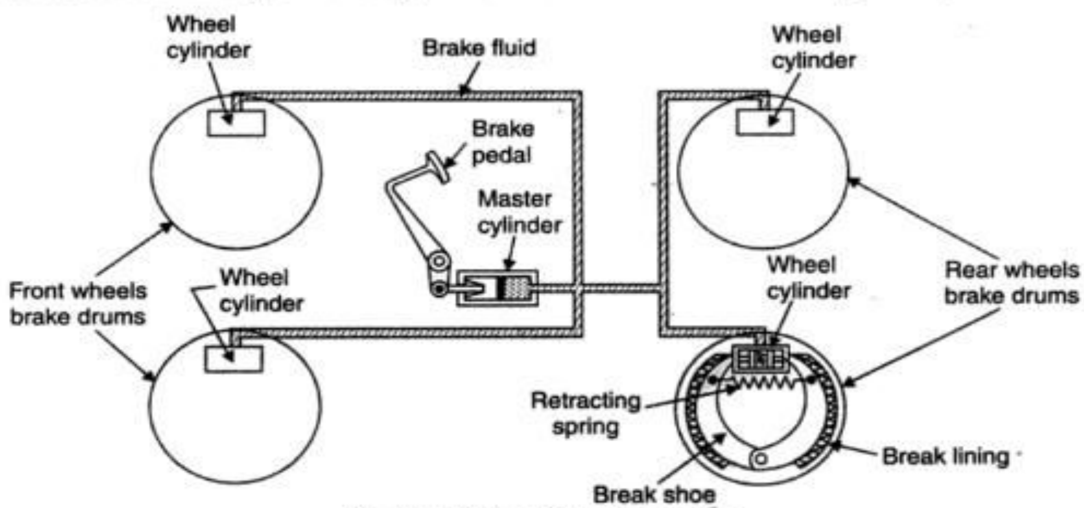


Fig. 9.4. Hydraulic brake system.

to the wheel cylinders by steel tubing. Each wheel cylinder contains *two pistons*, which will move out when the pressure will be applied through *brake fluid*. When the brakes are not in operation, the system is filled with brake fluid. Each wheel brake consists of a cylindrical brake drum which is mounted on the inner side of the wheel and revolves with it. There are *two brake shoes* mounted inside each of the brake drum but do not rotate with it.

When the brakes are to be applied, the driver presses down the brake pedal, the piston is forced into the master cylinder, thus increasing the pressure of the fluid in the master cylinder and in the entire hydraulic system. This pressure is conducted instantaneously to the wheel cylinders on each of the four brakes, where it forces the wheel cylinder pistons outwards. These pistons, in turn, force the brake shoes out against the brake drums. Thus the brakes are applied.

When the driver releases the brake pedal, the master cylinder piston returns to its original position due to the return spring pressure, and thus the fluid pressure in the entire system drops to its original low value, which allows retracting springs on wheel brakes to pull the brake shoes out of contact with the brake drums into their original positions. This causes the wheel cylinder pistons also to come back to their original inward position. Thus the brakes are released.

The hydraulic brake system contains two important components upon which the system is mostly dependent, these are :

1. Master cylinder
2. Wheel cylinder.

1. **Master cylinder :**

It is the *main cylinder* in the hydraulic brake system. It serves the following objects in the system.

(*i*) It builds up hydraulic pressure to operate the brakes.

(*ii*) It maintains a constant volume of fluid in the system owing to its reservoir.

(*iii*) It serves as a pump to bleed or force air out of the hydraulic system.

There are the following two types of master cylinders :

(*a*) *"Single master cylinder"* for all the front and rear wheel cylinders.

(*b*) *"Tandem master cylinder"* containing separate units for front and rear wheel cylinders.

(*a*) ***Single master cylinder :***

Construction :

The master cylinder (Fig. 9.5), named as the heart of the hydraulic brake systems, consists of two main chambers : (*i*) The *"fluid reservoir"* (which contains the fluid to supply

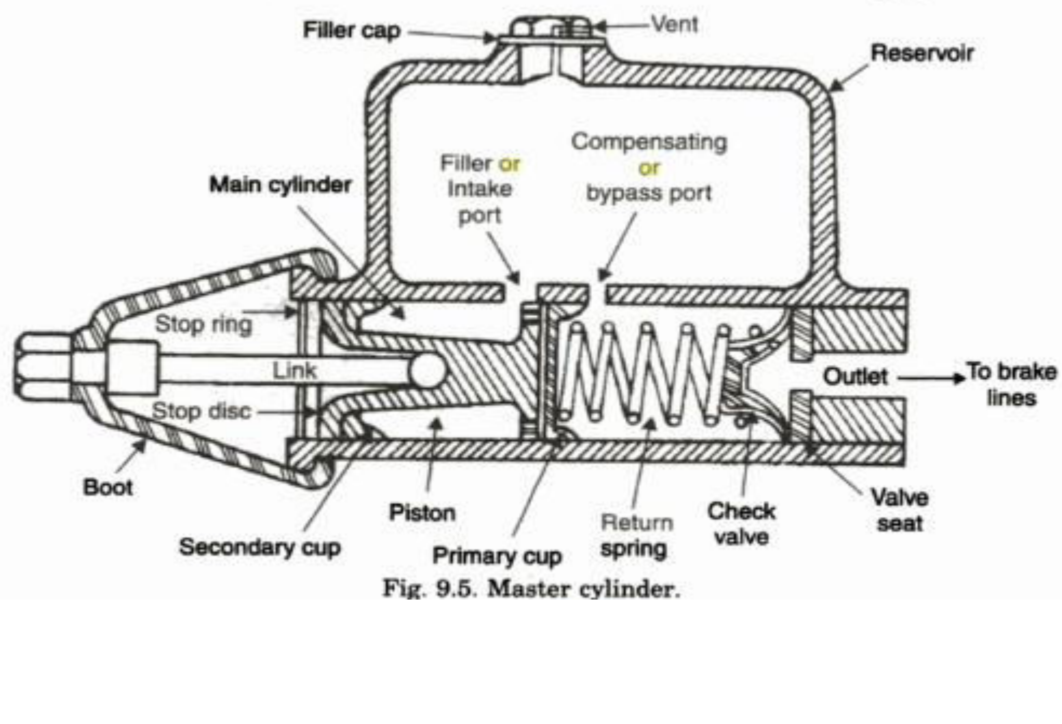


Fig. 9.5. Master cylinder.

to the brake system), and (*ii*) the "*compression chamber*" (in which piston operates). The reservoir supplies fluid to the brake system through two ports. The larger port is called the *filler or intake port* and is connected to the hollow portion of the piston (there are a number of holes in the piston on the primary or high pressure seal side) between the primary and secondary cups which act as piston seals. The smaller port is called the *compensating, bypass or relief port* which connects the reservoir *directly* with the cylinder and lines when the piston is in the *released position*. The reservoir is vented to the atmosphere so that atmospheric pressure causes the flow through the filler port. The vent is placed in the filler cap. The "*boot*" covers the push rod and the end of the cylinder to keep it free from foreign matter. Towards the brake lines side of the compression chamber, there is a fluid "*check valve*" with a rubber cup inside. It serves to retain the residual pressure in the brake lines even when the brakes are released.

Working :

- When the brake pedal is ***pressed*** piston of the master cylinder moves forward to force the liquid under pressure into the system. The relief port is sealed out of the system. The liquid pressure is conducted to the wheel cylinders, where it forces the wheel cylinder pistons outwards. These pistons force the brakes shoes out against the brake drums and the brakes are applied.
- As soon as the brake pedal is ***released,*** the *return spring* quickly forces the master cylinder piston back against the piston stop. Since the fluid in the lines returns rather slowly, a vacuum tends to form in the cylinder in front of the piston. This causes the primary cup to collapse/deflect to allow the liquid to flow from the reservoir through the filler port past the piston to fill the vacuum.
- When the pedal is in "*off position*", the liquid may flow from the reservoir through the relief port in the master cylinder, supply lines, and wheel cylinders to make up for any fluid that may be lost or to compensate for shrinkage cooling of the liquid. In this way, a complete column of liquid is always maintained between the master cylinder piston and wheel cylinder pistons.

In some makes of master cylinders a bleeder screw is also provided to bleed air out of the master cylinder.

(*b*) ***Tandem master cylinder :***

A simple master cylinder is mostly used in all small and medium type of vehicles. However, in some vehicles, the tandem master cylinder is used.

A "*tandem master cylinder*" is *the master cylinder with two separate cylinders and reservoirs in the same master cylinder assembly, one operating front brakes and the other cylinder operating rear brakes*. This master cylinder avoids the possibility of all the brakes of a vehicle being put out of order by a leak or fracture in the pipe line leading to one wheel cylinder.

It *ensures reliability with not much extra cost*. In this arrangement separate lines go to different sections of the brake system, say, the rear and the front brakes and it so arranged that if the front brake lines are damaged, the rear brakes will be still effective. Similarly if rear brake line is defective, at least front brakes will be applied.

Fig. 9.6 shows a single line diagram of a tandem master cylinder. Two pistons have been shown which are in line with each other. If line A fails, the piston A bottoms against the end of the cylinder while the piston B continues to develop pressure in the line B thus applying brakes to one set of wheels. If the line B fails piston B comes up against piston A, thus building up pressure in line A.

Fig. 9.7 shows the sectional view of a tandem master cylinder. As shown in diagram, the master cylinder contains two pistons, the rear being operated directly by the brake pedal. The space between the pistons is connected to the front brakes while the connection to rear brakes is made at the front end opposite to operating link.

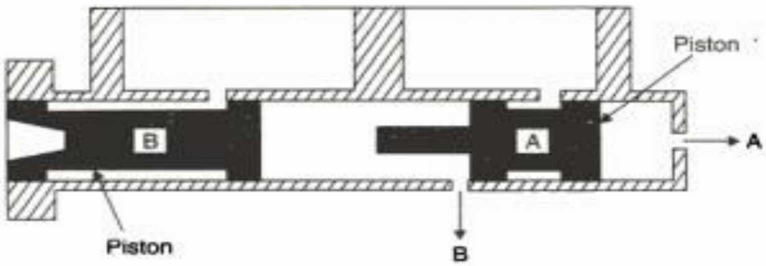


Fig. 9.6. Simple line diagram of tandem master cylinder.

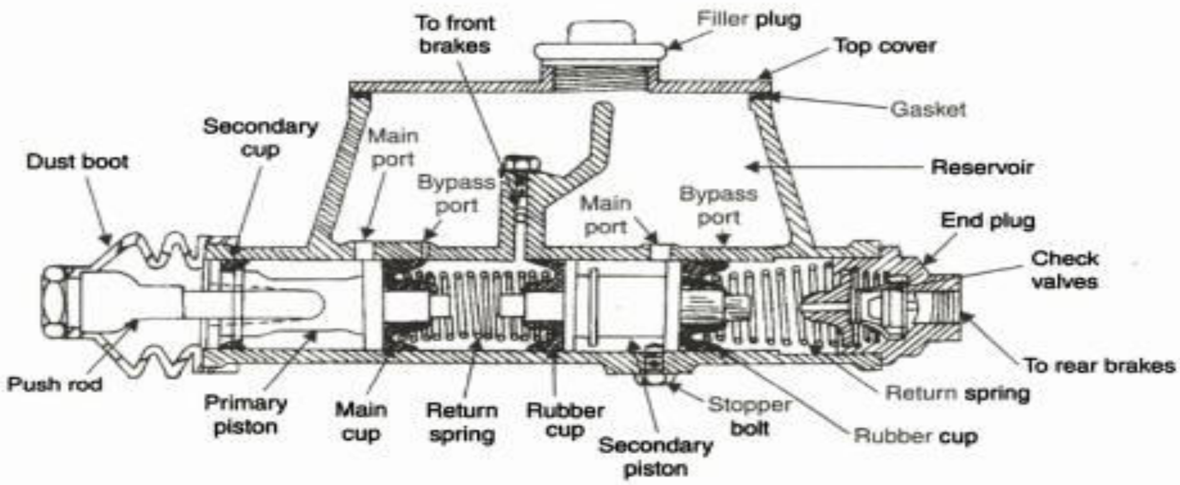


Fig. 9.7. Tandem master cylinder (Sectional view).

Depressing the brake pedal moves the rear piston inward developing pressure in the operating cylinder for front brakes. Since the front piston is free to move along the cylinder, so it also moves ahead developing an equal pressure in the operating cylinder for rear brakes. The return motion of the front piston is limited by the stopper screw.

2. **Wheel cylinder (or Slave cylinder) :**

Refer to Fig. 9.8. A wheel cylinder consists of a *cylinder*, *two pistons*, *two rubber cups* and a *spring*. The fluid presses against pistons. The pistons move outward in the cylinder. When the pistons

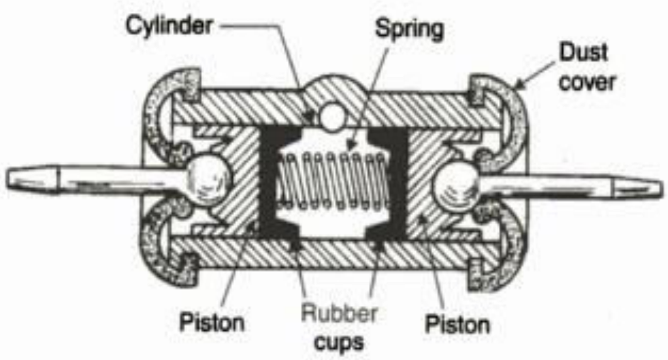


Fig. 9.8. Wheel cylinder.

come closer, the liquid is forced into the master cylinder. The spring between the two pistons holds the rubber cups in position.

- The copper-coated, tin-plated annealed steel tubing and flexible hoses are used to connect the master cylinder to the wheel cylinders. The hoses are used to connect the lines to the front wheel cylinder to permit the front wheel to be turned. Rear wheel cylinders are generally connected directly to a line fastened to the rear axle housing. The brake lines are attached directly or by means of brackets to the frame or axle housings.

9.7.3. Advantages and Disadvantages of Hydraulic Brakes

Advantages :

1. Equal braking effort to all the four wheels (since fluid exerts equal pressure every where in the circuit).
2. The system is simple in construction.
3. Less rate of wear (due to absence of joints compared to mechanical brakes).
4. The system is mostly self-lubricating.
5. Increased braking effort.
6. High mechanical advantage.
7. Flexibility in brake lines.
8. The hydraulic brakes can also provide differential braking action between the front and rear brakes by using the wheel cylinder of different size for the front and rear wheels.

Disadvantages :

1. Even slight leakage of air into the braking system makes it useless.
2. The brake shoes are liable to get ruined if the brake fluid leaks out.
3. This system is suitable only for applying brakes *intermittently*. For parking purpose separate mechanical linkage has to be employed.

PNEUMATIC BRAKES OR AIR BRAKES

In air brakes, the brake shoe operating cam is operated by means of air pressure which is developed by an air compressor driven by the engine. There are separate brake chambers for the separate brake shoe operating cams. The brake chambers are connected with the air reservoir by means of pipe line. A brake valve operated by the foot pedal, controls the pressure of air which affects the brake chambers. Fig. 9.11 shows the general arrangement (simple line diagram) of an air brake system. Fig. 9.12 shows the layout of an air brake system for bus or truck.

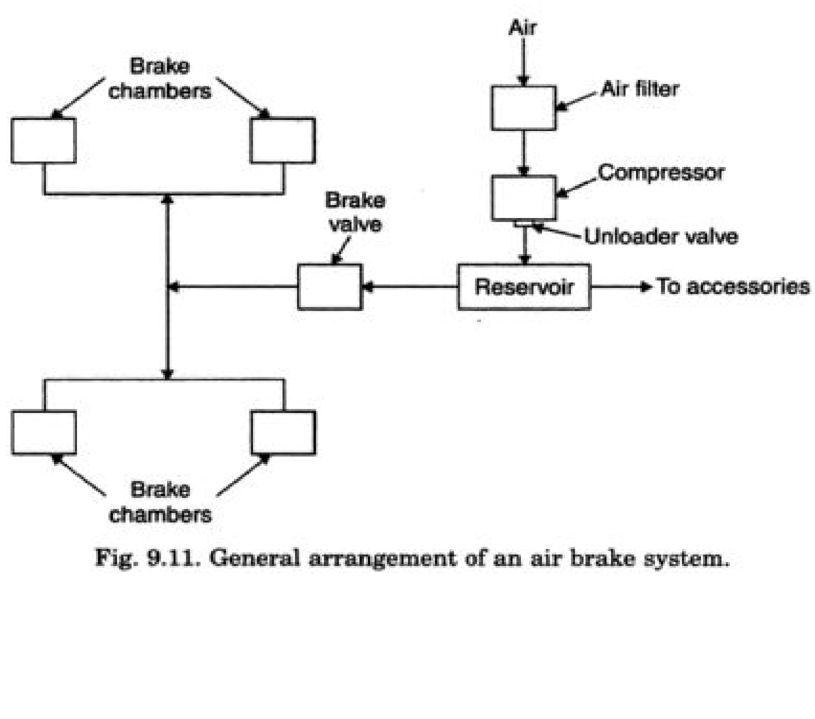


Fig. 9.11. General arrangement of an air brake system.

When the foot pedal is pressed down, air pressure acts on the diaphragm of brake chamber. The diaphragm is linked with the brake shoe operating camshaft. The diaphragm is pushed outward in the brake chamber causing movement of brake shoe operating cam. The brake shoe expands outwards and hold the moving brake drums as they come into its contact. The brakes are thus *applied*.

As soon as the pressure is released from the brake pedal, it comes back with the help of return spring. This results in closing of brake valve and release of pressure inside the brake chamber. The brake shoe operating cam moves in the reverse direction as a result of pressure release on the brake chamber. The brake shoe contracts inward with the help of retracting spring, releasing the brake drum of the binding effect. The brakes are thus *released*.

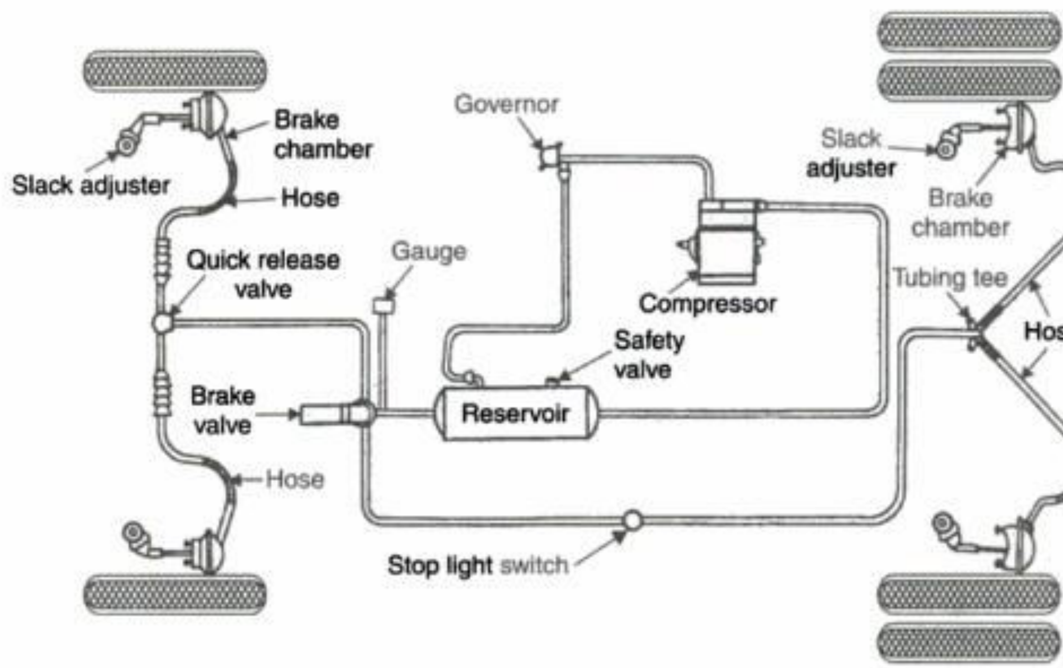


Fig. 9.12. Layout of an air brake system for bus or truck.

Main parts of an air brake :

Following are the main parts of an air brake :

(*i*) Air compressor.
(*ii*) Unloader valve.
(*iii*) Reservoir.
(*iv*) Brake valve.
(*v*) Brake chamber.
(*vi*) Quick release valve.
(*vii*) Relay valve.
(*viii*) Warning signal.

(*i*) ***Air compressor :***

- It builds up air pressure in reservoir.
- A piston type air compressor is commonly employed in the brake system. When piston moves downwards air is drawn into the cylinder through intake valve. When the piston moves upward, the intake valve is closed and outlet valve is opened by the air pressure and the air is forced out into the reservoir.

(*ii*) ***Unloader valve :***

- This valve is mounted in the air pressure system between the compressor and the reservoir to control the pressure of air in the reservoir. It relieves the compressor of its pumping load once the unloader cut-out pressure is obtained and seals the reservoir when the compressor has built up a pressure depending upon the setting of the adjusting screw which is normally 7.4 bar. The unloader then diverts the air delivered by the compressor to the atmosphere thus allowing the compressor to run right whilst the reservoir contains an adequate supply of air.
- It consists mainly of a *governor valve, an unloader plunger and a non-return valve.*

(*iii*) ***Reservoir :***

- *It stores compressed air at the specified pressure for brake application.*
- It is made of sheet steel and a *safety valve* is provided at the top of the reservoir to regulate the air pressure. A *drain plug* is also provided at the bottom for periodic draining of the reservoir, without which the lubricating oil from the compressor and moisture in the air would form emulsion which would damage the other brake units (*e.g.*, brake valve, brake chambers etc.).

(*iv*) ***Brake valve :***

- It is the control valve which is operated by the brake pedal. It controls the intensity of braking in an air pressure system.
- It is located between the reservoir and air lines leading to individual brake chambers.

(*v*) ***Brake chamber :***

- The brake chambers convert the energy of the compressed air into mechanical force and motion necessary to operate the vehicle brakes.
- A brake chamber consists of a housing which encloses a movable diaphragm connected by a rod linked to the brake shoe operating camshaft. The chamber is divided into two parts by the diaphragm, the side opposite to the rod being air tight. Air pressure acts in the air tight portion of the chamber which causes deflection of diaphragm and application of brakes.

(*vi*) ***Quick release valve :***

- It is employed in the front brake lines to accelerate the release of air from the brake chambers.
- It directly releases pressure to the atmosphere rather than through the brake valve.

(*vii*) ***Relay valve :***

- The relay valve speeds up the application and release of air from the brake chambers.
- It supplies air to the brake chambers directly from the reservoir for quick application of the brake. It also exhausts compressed air from the rear brake chambers directly to the atmosphere rather than through the brake valve.

(*viii*) ***Warning signal :***

It is a warning light or buzzer which warns low pressure in the circuit.

9.8.1.2. Advantages and disadvantages of air brakes

Advantages :

Air brakes entail the following *advantages* :

1. Much more powerful than the ordinary mechanical or hydraulic brakes (that is why these are exclusively used in *heavy vehicles*).

2. Simplified chassis design.

3. The compressed air from reservoir, apart from braking, can be used for tyre inflation, windscreen wipers, horns etc.

Disadvantages :

1. Involve relatively more parts.

2. The air compressor uses a certain amount of the engine power.

9.8.4. Vacuum Brakes

Any mechanism which adds to the driver's effort in applying the brakes is called a ***servo mechanism*** (It may be mentioned that servo is also used in place of power cylinders), although that effort remains a considerable part of the total braking effort required.

Initially mechanical servos were used, but after the introduction of vacuum operated servos these have becomes obsolete.

In the vacuum brakes the *suction from the engine inlet manifold is utilised for brake application.*

There are *two types* of vacuum brakes, both incorporating a piston or a diaphragm operating in a cylinder and provided with suitable linkage for brake application. A small vacuum reservoir is also there to provide enough vacuum for several brake applications even after the engine has stopped.

First type. In this system both sides of the piston are *exposed to atmosphere* when brakes are in the released position. For applying brakes, engine vacuum is applied on one side of the piston, subjecting the same to differential pressure and thus operating the linkage. This system is called "*atmospheric suspended*" system.

Second type. In this case both sides of the piston are *subjected to engine vacuum* in the brakes released position. To apply brakes, one side is exposed to atmosphere which provides the desired force on the piston. This system is called "*vacuum suspended*" system. This system is preferred over the first system since this is comparatively *more rapid in action.* These days *vacuum suspended brakes are predominantly used.*

In ***"vacuum suspended servo"*** the air is first exhausted from both sides of the piston in a large cylinder and during the application of brake, the air then admitted from the atmosphere to one side of the piston. The amount of air entering the cylinder is controlled by the driver. The piston of the cylinder moves under the pressure differential which in turn moves the hydraulic piston thus forcing the fluid into brake pipes into the wheel cylinders. The vacuum (about 0.35 bar) is obtained from the inlet manifold of the engine. In this system a vacuum reserve tank is fitted between servo and engine. The tank and servo are protected with the help of non-return valves in order to enable them to hold some vacuum in case of failure of other components. The *tank provides reserve of some vacuum which can be utilised for making number of stops in quick succession.*

- Till now engine vacuum was the only source of power for vacuum-assist brakes on cars. However, with the use of smaller engines and provision of emission controls, some vehicles do not have sufficient vacuum to operate the power brakes. In such cases, *separate vacuum pumps are* used.