Chassis Unit – Course: Motor Vehicle Engineering 1. Textbook for Vocational Training

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Preface

This instruction manual is intended for all students of motor vehicle repair and maintenance.

It can be used as a basis for both theoretical lessons and practical training, and as such provides an essential link between theory and practice.

The manual is divided into three self–contained sections, each dealing with one of the main sub–assemblies of the vehicle: chassis, power transmission and combustion engine.

The instruction manual contains a clear and concise description of the design and function of each of the component parts of the motor vehicle, as well as information about the maintenance, servicing and repair of vehicles.

Numerous illustrations are intended to facilitate the student's understanding of the technical and engineering problems discussed. Test questions are included at the end of each chapter. These concentrate on points of particular importance to students of motor vehicle engineering and enable the individual student to assess his own progress.

1. The frame

1.1. Functions of the frame

The frame of a motor vehicle supports all the drive assemblies, i.e. the engine, gearbox and axles (front and rear).

In addition the suspension and steering systems and the shock absorbers are attached to it. The assembled components are collectively named the "chassis". The appropriate body is fixed to the chassis.

It is essential that the frame should not buckle on uneven road surfaces and that any distortions which may occur should not be transmitted to the body. The frame must therefore be torsion−resistant.

The frame of a motor vehicle is the load bearing part of the chassis which supports all forces (wheel forces) and weights. It should be as rigid as possible.

1.2. Frame types

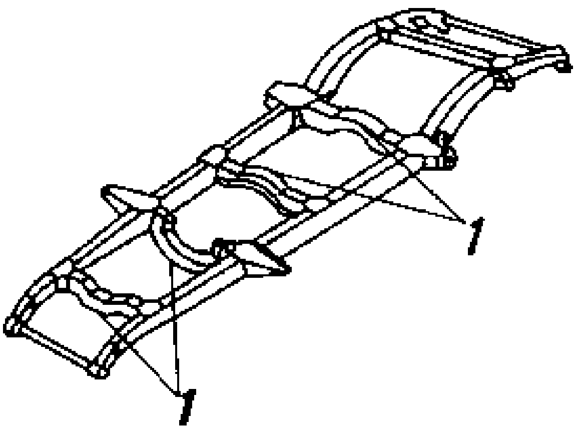
There are five different types of motor vehicle frame.

a) The box−type frame

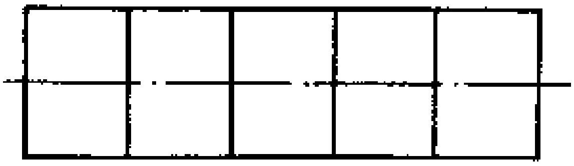
There are several types of box−frame which differ in the construction of their bracing. These can be seen in Figure 1/1. Cross bracing, diagonal bracing and triangular bracing can be used.

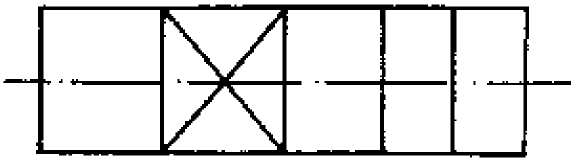
When deep−seated springs are used the frame is cranked in order to ensure correct axle freedom (see Figure 1/1).

Figure 1/1 Box−type frame

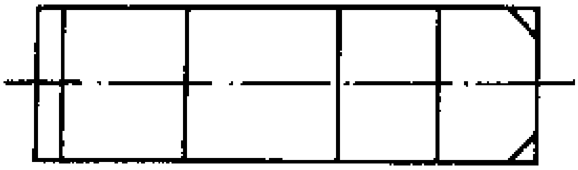


a) cranked box−type frame, 1 indicates cranked components,


b) box−type frame with cross bracing,



c) box−type frame with diagonal bracing,



d) box−type frame with triangular bracing

b) <u>The trapezoidal frame</u>

The trapezoidal frame is a symmetrical trapezoidal construction consisting of two side members with bracing. The frame is made from steel plate pressed into an open U profile. In order to ensure sufficient front wheel lock the frame tapers towards the front (Fig. 1/2).

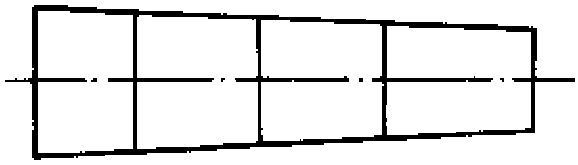


Figure 1/2 Trapezoidal frame

c) <u>The central member frame</u>

The central member frame (Fig. 1/3) has a single centrally positioned lengthwise member.

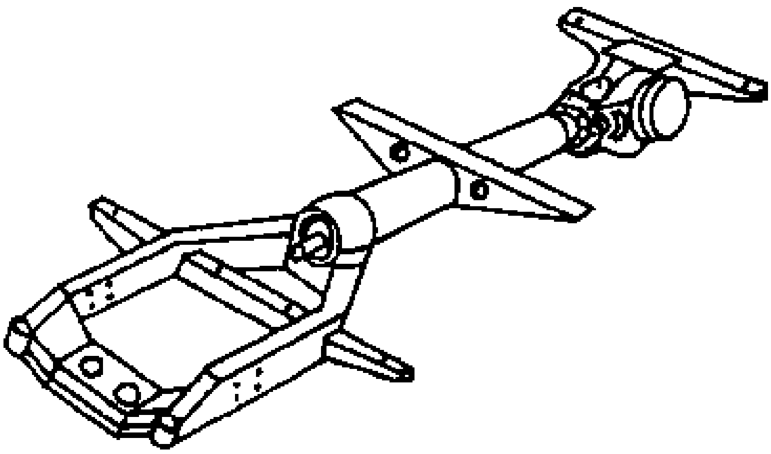


Figure 1/3 Central member frame

It is made from tubular or rectangular sections and is forked at the front end to take the motor and the gearbox. Attached to it are cross members of relatively small diameter which support the body. Due to its closed profile the frame is very torsion−resistant. The central member frame is used mainly in the manufacture of passenger vehicles. Pew lorries are fitted with this type of frame.

d) <u>The X−frame</u>

The X−frame consists of two side members made from tubular, oval or rectangular section. It is so designed, that the two side members curve towards each other and in the middle are only a few centimeters apart. When viewed from above the whole frame looks like an X. (Fig. 1/4) The closer the side members are to each other the stronger is the resistance against torsion. This type of frame is also typically very stable.

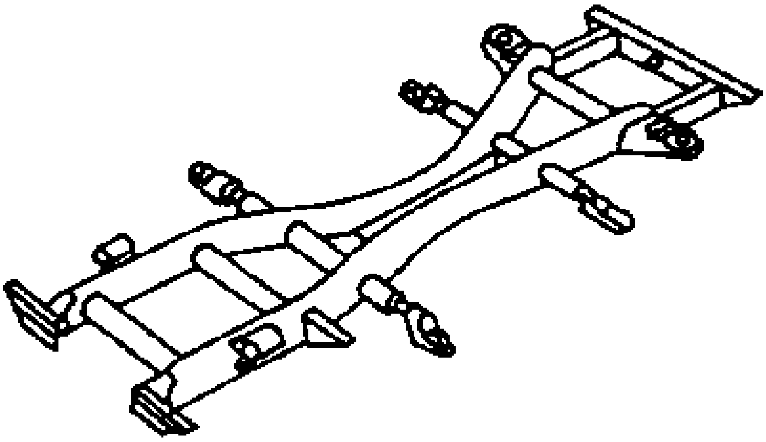


Figure 1/4 X−frame

e) The panel−type frame

The panel−type frame (Fig. 1/5) forms part of the car body and is considered a component thereof. During manufacture the frame and body are welded together, and this proves a disadvantage in comparison with other frame types because, if the frame has to be replaced the frame must cut away from the car body. An advantage of this frame type, however, is its light weight which means that it allows good fuel consumption.

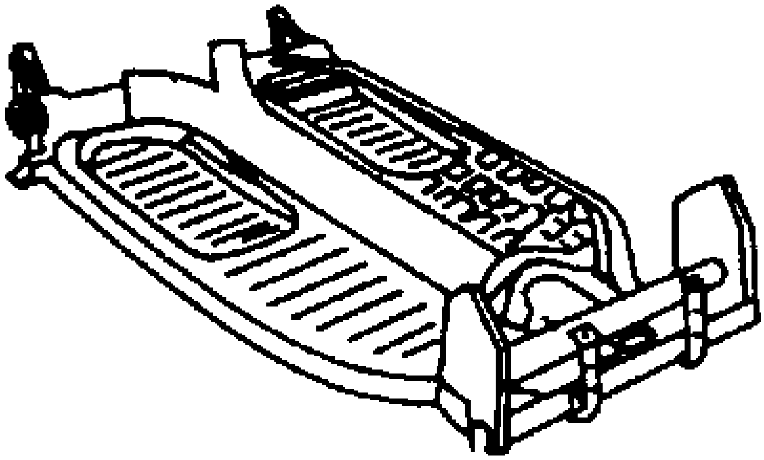


Figure 1/5 Panel−type frame

f) Integral body and frame

In the integral body and frame (Fig. 1/6) it is not an individual frame which supports the drive assemblies, but reinforced parts of the body itself. For this reason, this type of body can only properly fulfil its purpose if it is of light−weight construction. It must, however, also be buckle−, torsion− and vibration−resistant. Variations of this frame are the steel plate lattice−type and versions in which lengthwise, frame−like members, cross members and side members with bottom plates and side panels are integral parts of the body. Here small auxiliary frames can be used to support the engine and gearbox.

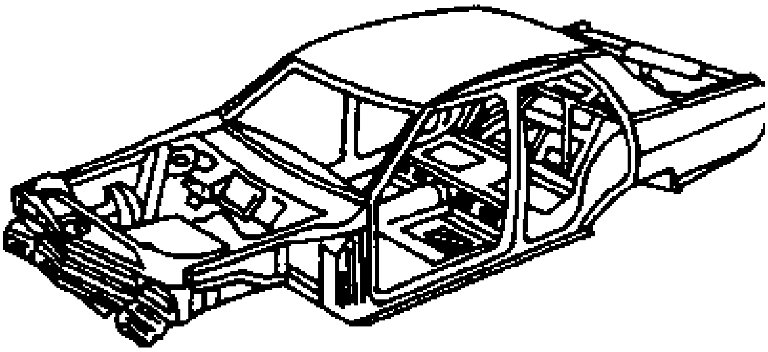


Figure 1/6 Integral body and frame

Motorcycle frames are not dealt with in this section as they represent a category of their own in frame construction.

1.3. Frame damage

Frame damage may be caused by wear or by accidents. The term wear covers both damage by environmental influences and by constant use.

Every motor vehicle frame is subject to wear, which can be accelerated by bad road and weather conditions.

Overloading is another cause of vehicle frame wear. It may be brought about by exceeding the maximum permissible payload and by driving too fast over bad road surfaces.

However frame damage is most frequently caused not by wear but by accidents. The frames are specifically designed to be strong enough to withstand the normal torsional strain.

Frame damage does not normally become noticable until it causes a change in roadholding or a deterioration in driving quality. If a frame is found to be buckled or broken it must be removed and measured. This measurement must be made with a special measuring device. The following are the commonest types of damage:

displaced front axle	distorted frame
displaced rear axle	displaced frame

Distorted and displaced frames can be straightened. Distortion, which may be caused by impact or buckling, will alter the structure of the frame. Displacement occurs when the two side members are shifted parallel to each other.

If a frame is broken it can be welded together, but the welded area must be reinforced with a gusset plate to prevent another break near the welded area. These repairs require a high level of technical knowledge and ability and must be carried out with great care.

Displacement of the front or rear axles can also be located by measuring, and thorough testing can ascertain whether or not they can be straightened. Before straightening, the leaf spring must be removed from the axle, and when the repair is complete the axle must be measured again.

If one of the axles is beyond repair the whole frame must be replaced.

In order to determine and eliminate frame deformations in time to repair them the frame must be measured periodically.

Measurements must be taken at the rearmost spring of the rear suspension and the foremost spring of the front suspension. Before measuring:

- The vehicle must be positioned on an even surface to obviate frame distortions which would distort the measuring results.
- The measuring points must be marked on the ground using a plummet.
- The marked points are to be measured diagonally by means of a string which must be taut throughout.

The lengths of the two diagonals are then compared to ensure that they are equal. If they are equal the frame is undamaged, however if they are not, the difference must be measured and the frame straightened. These measurements can only be taken on vehicles with frames.

The method for measuring frameless vehicles is different as they not have fixed measuring points as described above. When measuring integral frame and bodies and panel–type frames it is important to ensure that the wheels can run freely. Unbalanced wheels must be replaced with balanced ones. The vehicle should be driven onto a testing ramp and measured with the help of optical measuring equipment. A measuring rod can also be used. The front wheels must be aligned and a check made to see if the front and rear wheels on one side run on one track, or if toe−in and wheel camber show the same deviations. Then a perpendicular should be dropped at the middle of the steering stub and the diagonals measured.

1.4. Bodywork

The body of a vehicle is intended to accomodate persons or cargo. It can take many different forms with regard to both design and construction.

It is vital that the body should be of aerodynamic and lightweight design, and for this reason the principle of lightweight construction is followed in modern motor vehicle manufacture. Wind noise and boom should be obviated as far as possible.

Bodywork can be made from various materials: Wooden, lightweight metal, steel, composite (buses) and plastic−coated bodywork can be manufactured in varying styles. In contrast to the integral body or the panel−type frame it is of no significance whether or not the body is mounted to a frame, or forms a constructional unit with it. Today the motor vehicle industry is aiming to achieve a combination of minimum body weight and maximum pay load. The following section deals briefly with individual types of bodywork according to the materials used.

Wooden bodywork:

The term wooden bodywork includes all those components of the body which have a wooden skeleton, irrespective of the material used for the inner and outer panelling. Wooden bodywork is rarely used today because its manufacture is very complex and expensive.

Composite bodywork:

Composite bodies are those in which wood and metal are used for the skeleton (though not necessarily for the inner and outer panelling), and they occur in two different types, those made from steel sections and those with a framework construction.

The main characteristic of the first type is that hardwood elements are inserted into the steel sections of the skeleton onto which the inner panelling is mounted and which also serve to damp the vibrations which cause booming. The framework construction is used in particular for large bodies, e.g. for buses, and was adopted from the shipbuilding industry. In this design the number of joints subject to great stress and strain is reduced, but its most important advantage is the stability achieved by the use of bent frames.

All−steel bodywork:

This type of construction, in which the skeleton is made of thin−walled steel sections (from 2 mm thickness), produces rigid bodies. The are three types of all−steel bodywork, stressed−skin, cellular and sectional construction, all of which are lightweight.

In stressed−skin construction, rough−pressed components such as the front, side and rear panels are assembled and screwed or welded together to form a complete body.

In cellular construction, three cells are assembled to form a complete body. The advantage of this method of construction is that the individual cells − front, central and rear cells − can be economically replaced or repaired. The fact that the cells are manufactured separately makes it possible to produce a large number for different types of vehicles.

In sectional construction various pre−fabricated steel sections are welded together to form the skeleton. These can be removed and replaced with new ones after an accident, for example, or in case of corrosion. This method of construction also allows single section such as door sills and door posts to made and fitted manually. The outer panelling of the skeleton can be made of sheet steel or plastic.

Plastic−coated bodywork:

Plastic−coated bodies are substitutes for steel ones. Plastic materials have the following advantages over steel, they are:

1) thermally insulating
2) sound absorbing
3) non−booming
4) corrosion resistant
5) light weight

In this method of construction the skeleton consists of steel sections to which prefabricated plastic panels are mounted.

These panels can be replaced quickly and easily. The panels are sealed with weather strip putty and then the whole body is lacquered to protect it from the elements. The bodywork of lorry consists basically of the cab and a purpose designed rear body section. The main component of a passenger car or a bus is the passenger compartment. Lorries can also be manufactured with special purpose bodies.

The various types of bodywork are listed in Tab. 1.1. below.

Table 1.1.: List of the commonest forms of bodywork for lorries.

Platform truck with and without canvas cover	**box−type truck, open at top with collapsible side and rear walls**
Box−type truck	enclosed box with loading door
Tipper truck (two or three way)	enclosed platform, tippable on all sides
Estate car	body like saloon, space for transporting passengers and goods
Platform truck with hydraulic rear loading wall	rear loading wall, hydraulically raised
Tanker	for transporting liquids and powdered products
Crane or ladder truck	slewing lifting gear, mechanical ladders
Fire fighting vehicle	equipment: motor pump, hose reel, tools, seats for firemen
Road sweeper	equipment: spraying device, sweeping and suction devices
Workshop and repair	equipment: machine tools, welding equipment, hand tools, mobile workshop
Sales van	equipment: shop fittings, supply vehicle

In most cases frame and body are screwed together. Rubber spring packs (silent blocs) are located between the components of the body and the frame to prevent or suppress the transmission of vibrations to the frame. When components are in continuous use undamped vibrations can lead to structural fatigue and eventually to destruction of the component. Structural fatigue occurs when natural internal stress decreases.

Test questions:

1.1. What types of frames are you familiar with in motor vehicle engineering?

1.2. Name the main features which distinguish the various frame types.

1.3. Describe the design of a box−type frame.

1.4. Explain the difference between the terms 'panel−type frame' and 'integral frame and body'. Describe the design of these two types.

1.5. What do you understand by the term "wear"?

1.6. What causes "wear"?

1.7. What damage can be caused to the frame by wear and by accedints?

1.8. Outline the way in which a frame is measured.

1.9. What is the function of a vehicle frame?

1.10. What is the main demand made of the frame?

2. Springing and suspension

2.1. Springs and their functions

The purpose of spring components is achieved through their elasticity and therefore the materials and media used must be elastic, for example steel, rubber and air.

The principle of springing: If the equilibrium of an elastic body is disturbed, movements in different directions, called mechanical vibrations occur. The spring as an elastic system (mass and spring) is caused to vibrate by an impact and oscillates with ever decreasing amplitude of motion, until it returns to its original position. The period of vibration depends on the size of the swinging mass and the rigidity of the spring.

In a motor vehicle the springing is intended to damp the vibrations of the loosely coupled elastic system as quickly as possible after the impact.

This springing is required to vibrate slowly, and it is also regarded as favourable if the front and rear axle springing are of different rigidity. If a vehicle is to have good roadholding ability vibrations must be damped in order to prevent build−up. Vibrations are damped by the transformation of mechanical energy into thermal energy.

The most common types of spring are listed below:

− Steel springs

Leaf springs are simple and inexpensive to manufacture. A leaf spring pack is subjected to bending and can absorb thrust and lateral forces.

It is self−damping, but heavy and prone to spring friction. It is space consuming and must be serviced regularly. (Fig. 2/1)

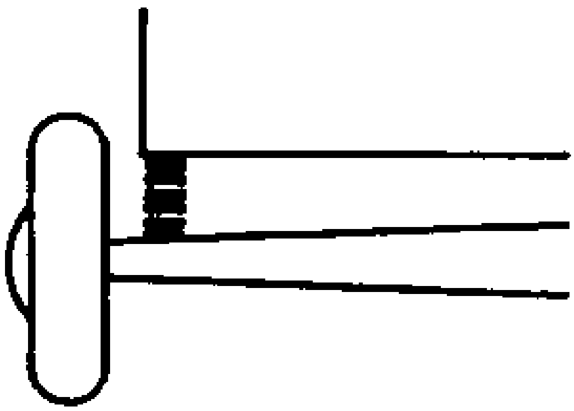


Figure 2/1 Leaf spring suspension

Use: cars; lorries; trailer vehicles; special purpose vehicles; rail−bound vehicles

Coil springs are simple to produce and allow a high performance whilst occupying a minimum of space. They are subjected to torsion, but cannot absorb thrust or lateral forces. Their self−damping is negligible but they do not require servicing. (Fig. 2/2)

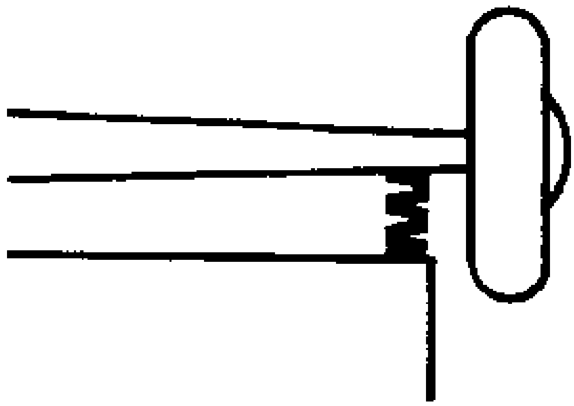


Figure 2/2Coil spring suspension

Use: cars; lorries; motor cycles; additional spring for trailers

Torsion bar springs are actuated by torsion and do not require servicing. They are lightweight and space−saving but made from high quality materials and expensive to produce. Damaging of the surface and overloading lead inevitably to the destruction of the torsion bar. With this type of spring damping is almost zero. (Fig. 2/3)

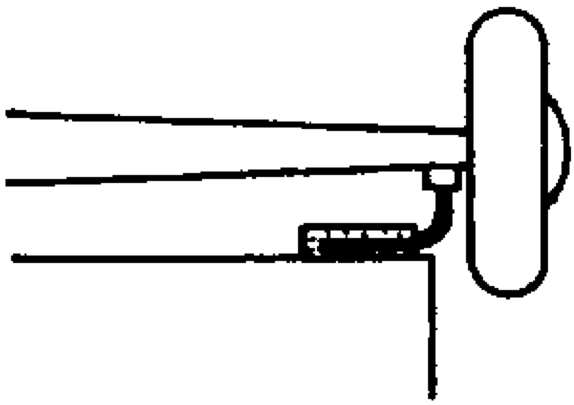


Figure 2/3 Torsion bar suspension

Use: cars; special purpose vehicles

− Rubber springs

Rubber springs have a progressive spring action and do not require servicing. There are three types of rubber springs: rubber torsion shear springs, rubber pack springs and hollow rubber springs. They are self−damping and relatively inexpensive to produce. Rubber springs do not perform well under changing loads and are sensitive to the sun, mechanical damage and lubricants.

Rubber torsion shear springs are actuated by torsion, rubber pack springs and hollow rubber springs to compression. (Fig. 2/4)

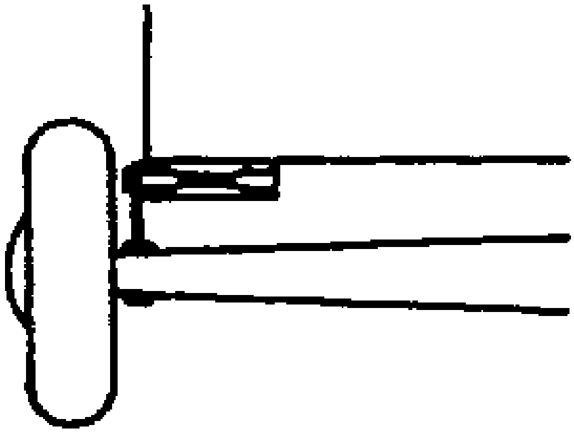


Figure 2/4 Rubber suspension

Use: cars; motor cycles as well as suspension of automotive units

– Air suspension

Air suspension is very efficient because it adjusts automatically to all load conditions, by means of a pneumatic control unit which is actuated by compression. In comparison with other types of suspension, the production of air suspension is very costly and it must be constantly serviced in order to avoid failure. Self–damping is negligible, it is spaceconsuming and very heavy. (Fig. 2/5)

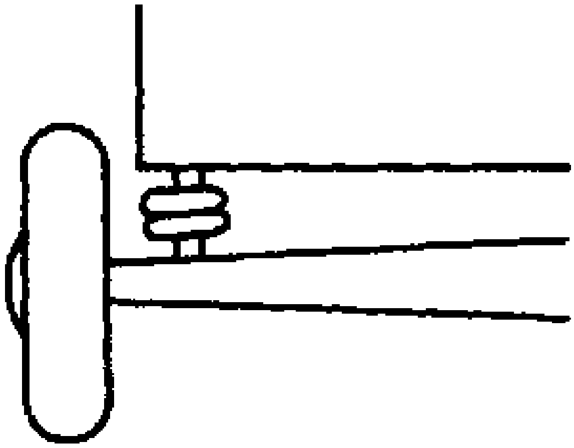


Figure 2/5 Air suspension

Use: predominantly in buses and heavy goods vehicles; cars

Design of leaf spring

A leaf spring pack consists of spring leaves of different lengths and different thicknesses. (Fig. 2/6)

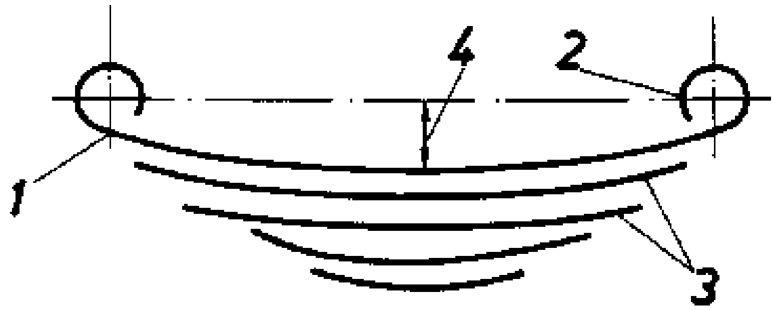


Figure 2/6 Construction of a leaf spring (cross section)

1 main leaf, 2 spring eye, 3 support leaves, 4 curvature of the spring leaves

If a leaf spring is loaded, sliding friction will occur between the leaves during springing, and this must be kept as low as possible. In order to achieve this, spring grease, a mixture of lubricating grease and graphite, is smeared between the individual leaves.

The leaf tips, which are subjected to the most friction, are further smoothed by longitudinal grinding.

Polyamide laminas can be inserted between the leaf tips so that they protrude beyond them, thus avoiding direct friction between them. (Fig. 2/7)

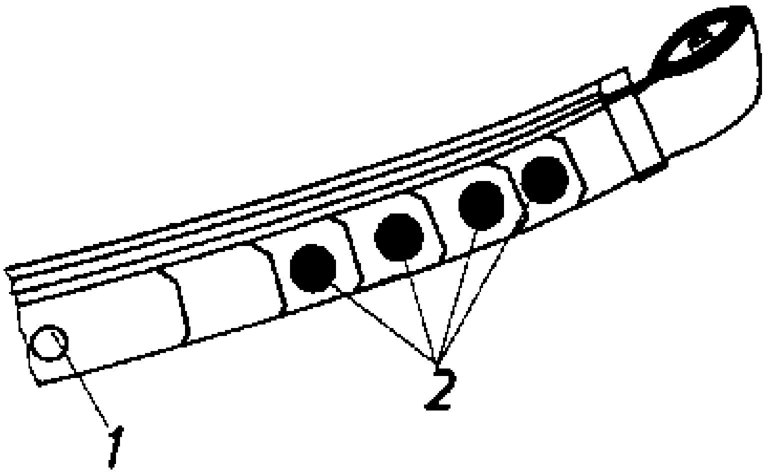


Figure 2/7 Construction of a leaf spring (leaf tips)

1 heart bolt, 2 polyamide laminas

This is intended to:

1. keep friction between the leaves constant, (this depends on the normal force and the friction coefficient)

2. keep the friction coefficient fairly constant irrespective of the lubrication of the leaves,

3. reduce spring noise,

4. protect the leaves from premature wear.

If a spring pack consists of single leaves of varying thicknesses, the thinner leaves must be curved more than the thicker ones, so that all leaves will be stressed equally under load.

If all the leaves are the same length, the thinner they are the smoother their effect, but the greater the number required for the same load capacity. This increases spring friction, which is favourable within certain limits, and improves damping.

All laminated leaf springs show spring friction. It is independant of the lubrication, the surface quality of the leaf springs, the curve of the leaves, the number of spring clamps, the thickness of the individual leaves and the thickness of the wear sections which develop at the leaf tips.

<u>Maintenance and repair of the leaf spring</u>

As we have already seen leaf springs require regular maintenance and servicing.

Wear sections on the leaves, loose spring clips and worn spring bolts, also called heart bolts, are often the causes of breaks in the leaves.

Regular inspection can:

1. prevent damage,
2. extend the service life of the spring,
3. increase the possible mileage of the vehicle,
4. protect the load.

Necessary maintenance work:

1. Spread a thin layer of graphite between the individual leaves to reduce sliding friction. This prevents water penetration which causes corrosion.

2. If a spring has to be lubricated, loosen the spring clamps and raise the vehicle so that the weight is taken off the axles and the springs. Then lubricate between the leaves with a grease gun.

3. At the same time check the wear sections and see if any of the spring leaves are broken.

4. Grease spring bushes and spring bolts regularly.

If a leaf spring shows fatigue it becomes weak and tensionless and must be removed. Such springs can be restored at a spring forge. There they are also examined for wear, and damaged spring leaves are replaced.

When repairing leaf springs ensure that the prescribed length and curve of the leaves are maintained.

When removing leaf springs ensure that the weight is taken off the axles and the springs. The frame must be supported by blocks.

Labour safety regulations must be followed at all times. The raised vehicle is to be secured by blocks to stop it rolling.

<u>Helical springs</u>

Helical springs are actuated by compression; they are used on rigid axles and independently suspended wheels. (Figs. 2/8, 2/9)

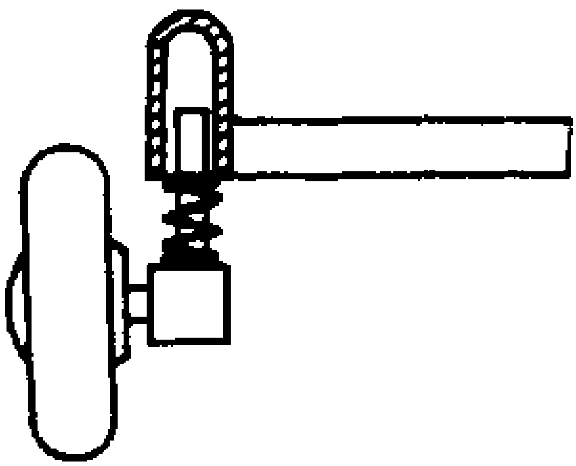


Figure 2/8 Coil spring suspension of a rigid axle

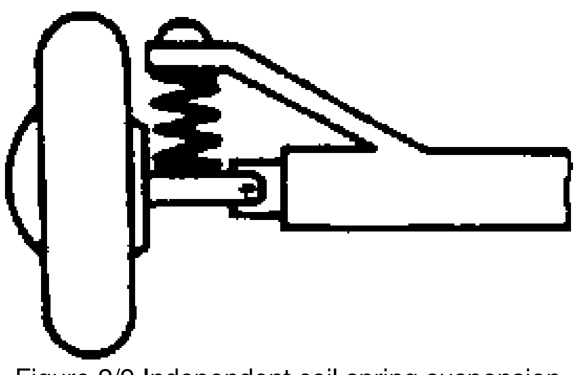


Figure 2/9 Independent coil spring suspension

Helical springs have the following advantages over leaf springs:

1. They require less room in the vehicle and are also considerably lighter.

2. As they have no external friction they do not need any special maintenance.
3. In comparison to leaf springs, helical springs have a smoother spring action and a better deflection.

Helical springs are not designed to take thrust forces and will buckle under them. These forces must be taken by other components such as the steering wheel and the drag links.

Long helical springs have only internal friction, i. a. friction occurs only within the material itself. For this reason, they cycle for longer than a leaf spring pack. Since these springs have negligible self−damping, they always have to be used with dampers.

As mentioned above, coil springs need no servicing. Damaged material surfaces and corrosion will lead to fatigue failure in the spring and must be avoided.

When a spring is mounted, care should be taken to ensure that it is at right angles to the axle.

Torsion bar springs

Torsion bar springs are actuated only by torsion (Fig. 2/10).

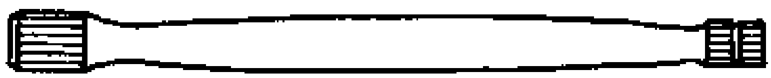


Figure 2/10 Torsion bar

Their main advantages are that they require little maintenance and are lightweight.

Torsion bar springs are made from high−quality special steel to give high fatigue strength and good cushioning properties. The surface of a torsion bar must be smooth; roughness or thost lines might cause fracture. The ends of the bar are upset and serrated. The torsion angle of a torsion bar is small and must be adjusted to the required deflection (Fig. 2/11).

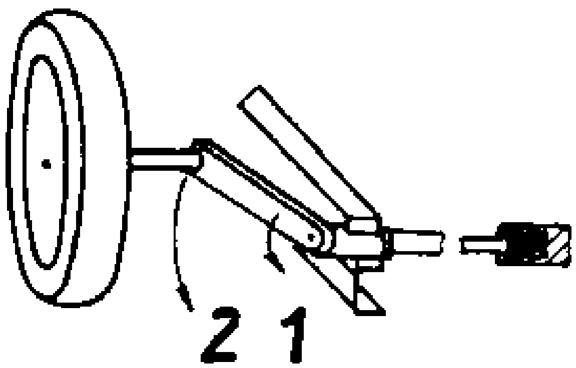


Figure 2/11 Lever action in torsion bar suspension

1 spring deflection, 2 spring deflection increased by lever action

Torsion bars have no external friction and the longer they are, the smoother their effect.

Torsion bars must not be subjected to bending. They are mounted in pipes which are fixed to the frame. When installed, torsion bars are fixed by means of a serration. They can be mounted at right angles or longitudinal to the direction of movement of the vehicle.

Torsion bars require no maintenance. During installation it is important to ensure that the torsion bars fit correctly into their mounts. Care must be taken to avoid damaging them during mounting and removal. They must be given a protective coating to protect them against corrosion. This coating must not be damaged or rust will form pits in the steel which will lead to the destruction of the torsion bar.

When replacing a torsion bar:

1. It should be marked 'left' or 'right'.

2. It must be removed from its mount with extreme care to avoid knocking it.

3. It should be laid on a wooden stand. It must not be put down vertically since there is the risk of it toppling over.

4. It is important that only acidless grease is used for assembly.

Rubber springs

The springs dealt with so far are based on the elasticity of the high quality steels used.

With rubber springs the elasticity of rubber is used as a means of suspension for motor vehicles and trailers. Rubber suspension is a progressive suspension, i.e. the spring becomes stiffer with increasing deflection.

Rubber suspension has one major advantage over steel, namely that due to internal friction a vibrating rubber spring returns to its initial position after only a few vibrations. For this reason, rubber is able to damp all types of vibration very well. The disadvantage of this system is that the deflection is minimal, and so a lever system must also be mounted to lengthen it. In this way, according to the principle of the lever, greater forces act on the rubber. Rubber springs require no maintenance and have a long service life, which is an advantage for the maintenance and upkeep of the car.

There are four different kinds of rubber springs used in motor vehicle engineering:

– rubber compression springs
– rubber torsion–shear springs
– rubber pack springs
– hollow rubber springs.

Rubber compression springs:

Rubber compression springs are used in lightweight motorcycles as frame–mounted rubber buffers for cushioning the front axle, and with steel springs for limiting spring deflection.

If spring deflection is too great, a rubber compression spring is used to take the load, thus preventing damage to the frame or the body (Fig. 2/12).

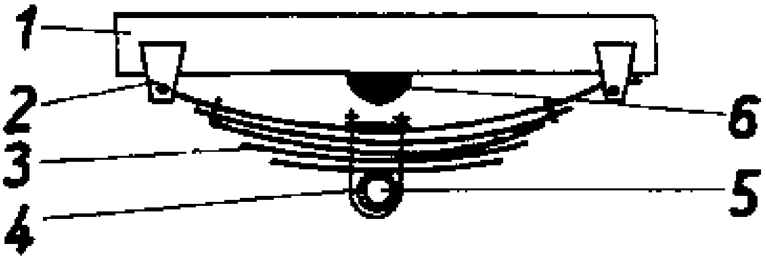


Figure 2/12 Use of a rubber compression spring

1 frame, 2 spring bracket, 3 leaf spring, 4 spring clamp, 5 axle, 6 rubber compression spring

Rubber torsion–shear springs:

A rubber torsion–shear spring consists of an inner and an outer metal bush. The space between these two bushes is filled with vulcanised rubber. The outer metal bush is pressed into a frame mount and thus firmly connected to the frame.

The control –arm which holds the wheel is fixed to the inner bush by means of a bolt. The wheel is cushioned by the elasticity of the rubber. This type of wheel suspension is ideal for light–weight constructions and does not require any maintenance (Fig. 2/13).

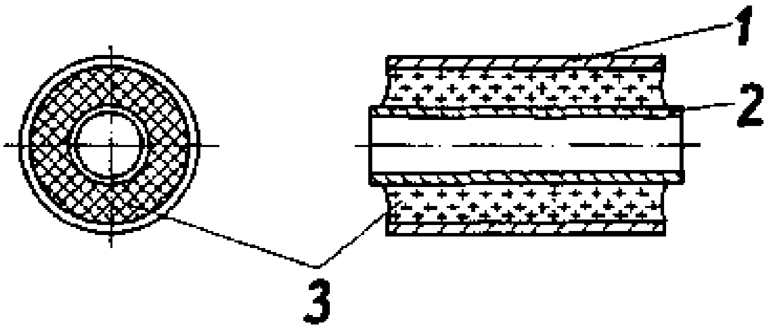


Figure 2/13 Rubber torsion−shear spring

1 outer metal bush, 2 inner metal bush, 3 layer of rubber

Rubber pack spring:

The rubber pack spring (silent bloc) is often used in heavy goods and rail vehicles and for suspending engines and gear boxes. It is an effective method of suspension as it can be subjected simultaneously to shear stress and compression (Fig. 2/14).

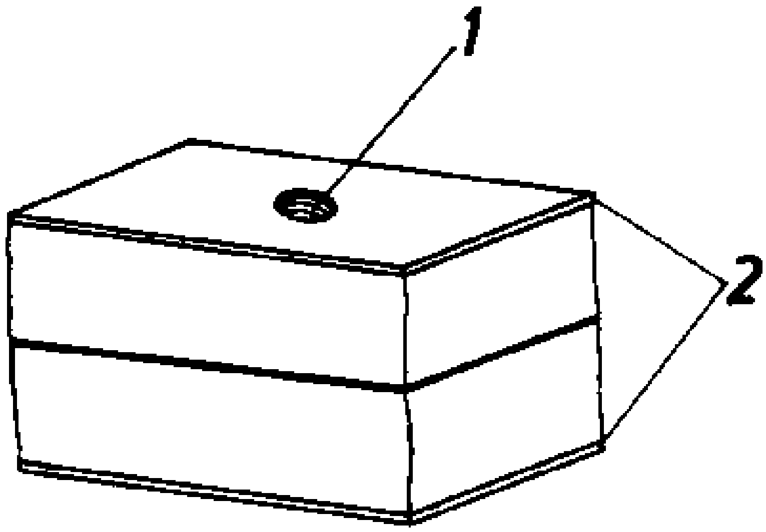


Figure 2/14 Rubber pack spring

1 internal thread, 2 bonded rubber pads

Hollow rubber springs:

Like the rubber compression spring, the hollow rubber spring is used as an additional spring. Its shape allows easy deformation and consequently a large deflection. (Fig. 2/15)

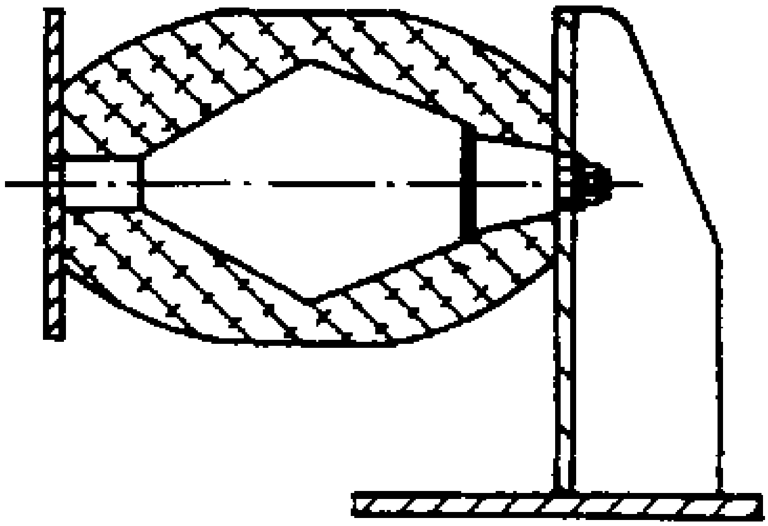


Figure 2/15 Hollow rubber spring

Rubber springs are used for damping low−amplitude vibrations which may occur, for example, at the engine supports, the leaf springs and spring bolts. The rubber is vulcanised to so−called vibration metal, and the springs produced in this way are called silent blocs.

Progressive rubber suspension requires no maintenance. If the spring is to be subjected to compression, sufficient clearance must be ensured. Rubber springs must be protected against constant heat as this will make the rubber brittle. Worn rubber components can easily be replaced according to the type of suspension.

<u>Air suspension</u>:

The fact that pneumatic tyres are used on vehicles shows that air is a good cushioning element. Air suspension is progressive. In this method of suspension the height of a vehicle can be kept constant by means of appropriate height controllers. There are two types of adjustable air suspension.

- pneumatically adjustable air suspension (Fig. 2/16)
- hydraulically adjustable air suspension (Fig. 2/17)

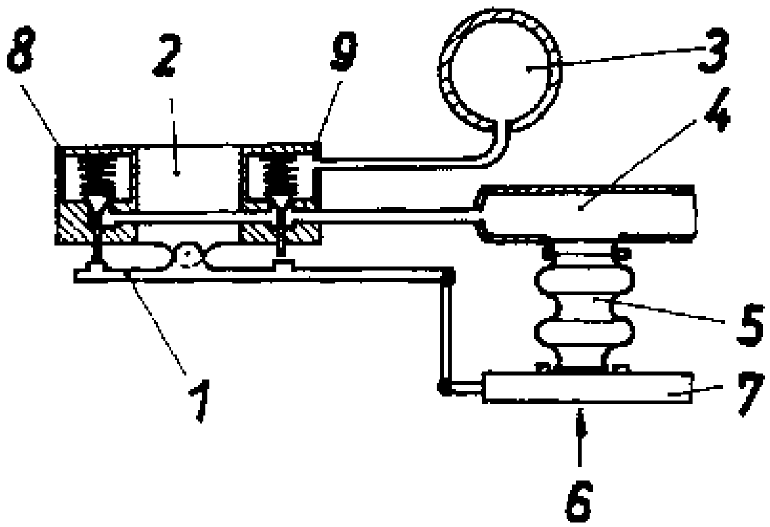


Figure 2/16 Pneumatically adjustable air suspension

1 control arm, 2 control valve, 3 compressed air cylinder, 4 air chamber (attached to the frame), 5 bellows, 6 wheel load, 7 component attached to the axle, 8 drain valve, 9 inlet valve

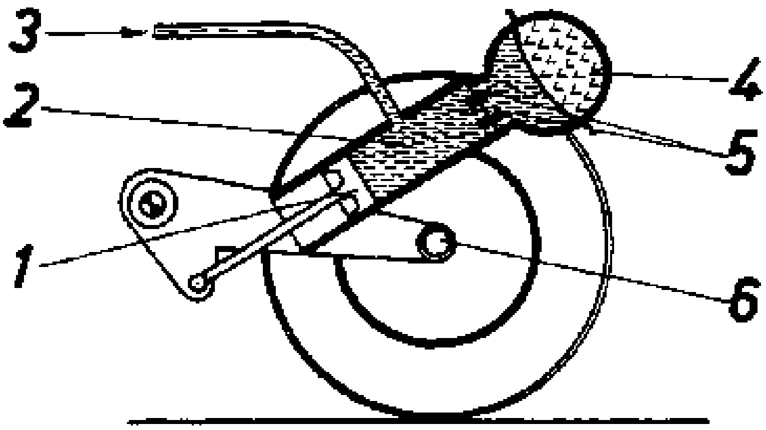


Figure 2/17 Hydraulically adjusted air suspension

1 control piston, 2 oil, 3 line from oil pump, 4 air cushion, 5 control valve, 6 wheel suspension

– Pneumatically adjustable air cushioning is used in vehicles where the ration of total utilised load−carrying capacity to the empty vehicles is large. The same height of the vehicle over the axle can be adjusted for different loads by controlling the air filling. Air chamber and rubber bellows form a storage volume. When the bellows expand, the control lever operates the drain valve. Normal height is reached by lowering. When the bellows are compressed, the control lever operates the admission valve, and the air flowing from the compressed−air reservoir returns the bellows to normal position.

There are three types of pneumatically adjustable air suspension which differ in the shape of the bellows. In lorries, semitrailer trucks and buses, cylindrical bellows are used (Fig. 2/18). In heavy trailers and semitrailers the so−called sandwich system, a ring bellows system, with long, oval rubber bellows, is used (Fig. 2/19).

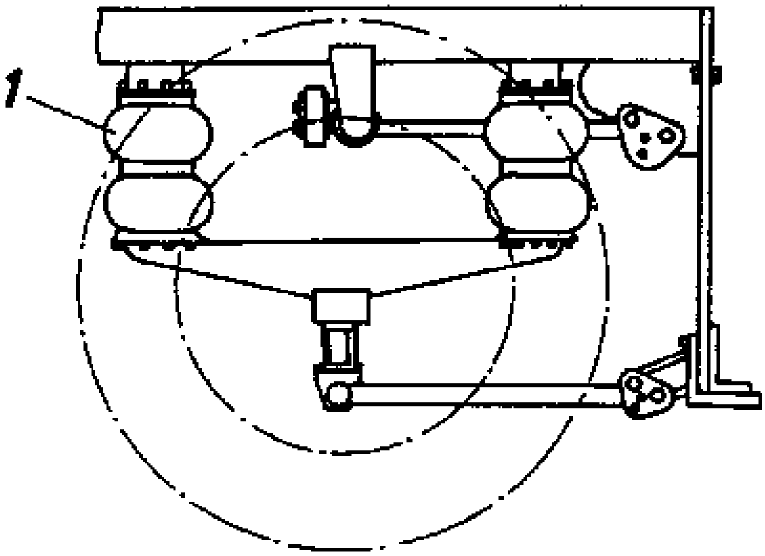


Figure 2/18 Pneumatically adjustable air suspension with cylindrical bellows

1 cylindrical bellows

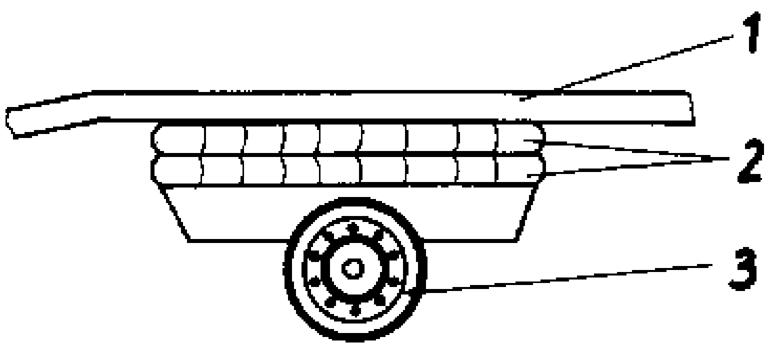


Figure 2/19 Pneumatically adjustable air suspension with ring bellows

1 frame, 2 ring bellows, 3 axle

Roller−type bellows have been developed for heavy passenger cars (Fig. 2/20).

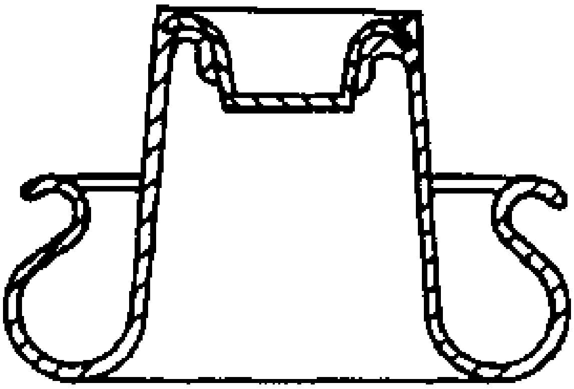


Figure 2/20 Pneumatically adjustable air suspension − roller−type bellows

− Vehicle in which the ratio of total utilised load capacity to empty vehicle weight is low, have hydraulically adjustable air suspension. Here the piston is held at the proper position not by controlling the air filling, but by controlling the oil volume between the piston and the air cushion. Oil foaming is prevented by a membrane between the oil volume and the air cushion. This method works on the principle that oil cannot be compressed.

2.2. Vibration dampers

Vibration dampers, also called shock absorbers, reduce vibrations and vibration times of spring elements and sprung masses in vehicles.

There are hydraulic single−action shock absorbers, double−action shock absorbers and telescopic shock absorbers.

The use of shock absorbers is determined by the vehicle's suspension system.

− Although they have a self−damping effect, leaf springs require shock absorbers.

In heavy lorries, leaf spring packs made of thick leaves are used so that a high self−damping effect is obtained, and shock absorbers are very seldom necessary.

− Since rubber springs are self−damping, they do not require shock absorbers. The damping effect results from rubber deformation. For this reason, rubber springs can themselves be used as shock absorbers.

− Torsion bar springs and coil springs have a very low self−damping effect. In order to reduce vibrations, single−action shock absorbers, double−action shock absorbers and telescopic shock absorbers are mounted in the vehicles.

− In case of oil hydraulic air suspension (Fig. 2/17), vibrations can be damped by a throttle in the pressure cylinder (control valves) of the spring element.

Hydraulic dampers are necessary for the other type of air cushioning.

Damping becomes stronger with progressive spring deflection and therefore shock absorbers can only be correctly built for specific loads. A shock absorber should meet the following requirements:

− They should always work correctly irrespective of variations in shock absorber oil temperatures, changing road conditions or changing vehicle loads.

− They should respond immediately to spring deflections to ensure fast damping of the vibrations.

– They should support progressive springing.

– The nearer they are to the wheel, the better they function. The principle of the lever is important here.

Below we deal with the shock absorbers already mentioned in more detail. Hydraulic dampers as described above are effective because liquids cannot be compressed. See Fig. 2/21.

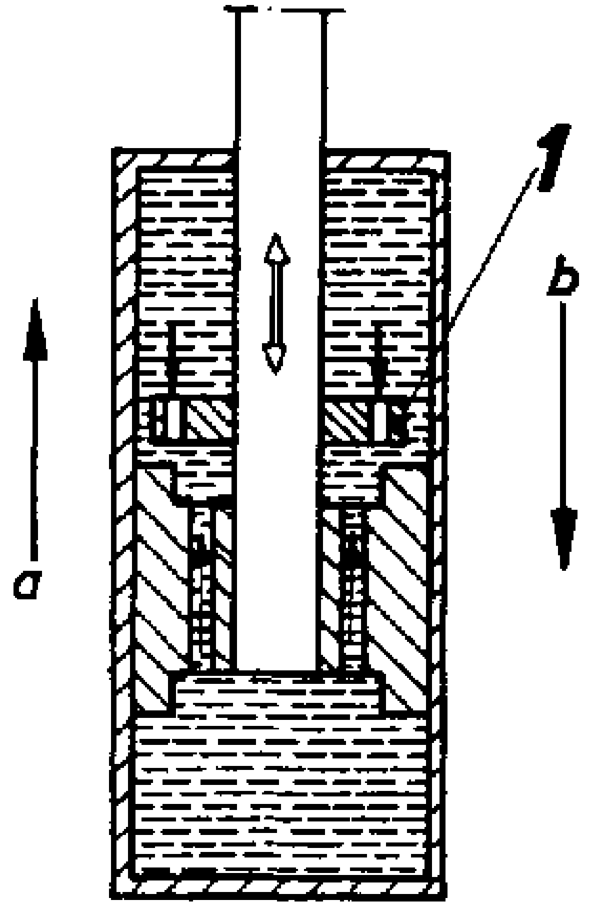


Figure 2/21 Hydraulic damper (principle)

1 compression disc (moveable on the rod) A compression, B expansion

A sealed casing is filled with oil which is pressed through a piston which divides the case into two chambers. The vibrations of the spring are transferred to the piston.

The piston has openings which can be enlarged and reduced by valves. Displacement causes fluid friction and thus vibrational energy is converted into heat energy.

All hydraulic shock absorbers use thin–bodies oils which must have special properties:

– Constant viscosity within the operating temperature range under normal conditions
– Sufficient and constant lubricating quality
– Free of acids and impurities
– Non–foaming

The damping force depends on the speed of the oil when pressed through the openings of the piston. The higher the speed the bigger the force, and therefore the damping, is required.

The driving speed, the vehicle load and the road conditions cause the springs to deflect. The vibrations have to be damped to given the vehicle good road holding qualities and, consequently, to guarantee safety on the road. Exact co–ordination of springs and shock absorbers prevent the driver and passengers from physical harm and protect the load and the vehicle.

Types of hydraulic shock absorbers

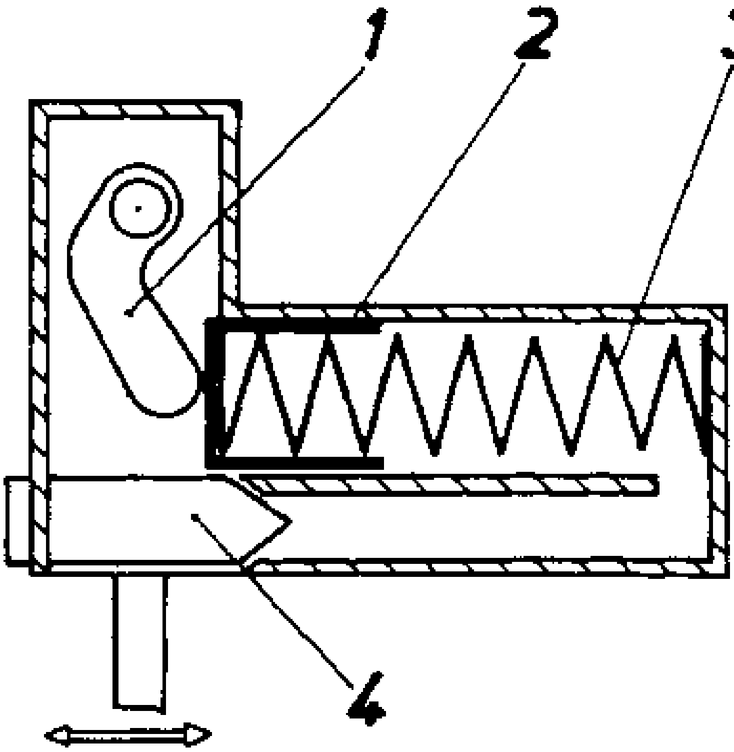


Figure 2/22 Single−action shock absorber

1 lever, 2 piston, 3 spring, 4 adjusting screw

Fig. 2/22 shows the single−action shock absorber. It only damps vibrations when the spring tension is released. The damping action can be adjusted by means of an adjusting screw. Piston and lever are held non−positively by the spring. The interaction of spring and oil causes damping. This shock absorber does require maintenance.

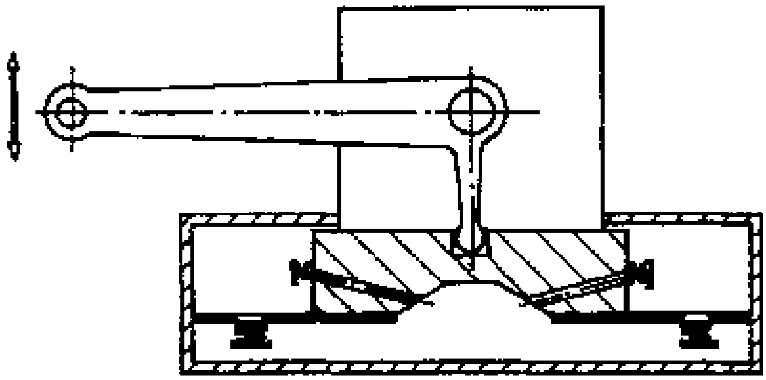


Figure 2/23 Double−action shock absorber

Fig. 2/23 shows how a double−action shock absorber works. As the name implies, it acts in two directions. When the spring deflects, the damping action is minimal; and when the tension reduces, the action increases. This shock absorber has high−pressure and low−pressure valves which can usually be adjusted. It requires maintenance. It is subjected to high pressures, and the damping path is short. It is subjected to intense heating. Damping losses are caused be the leverage.

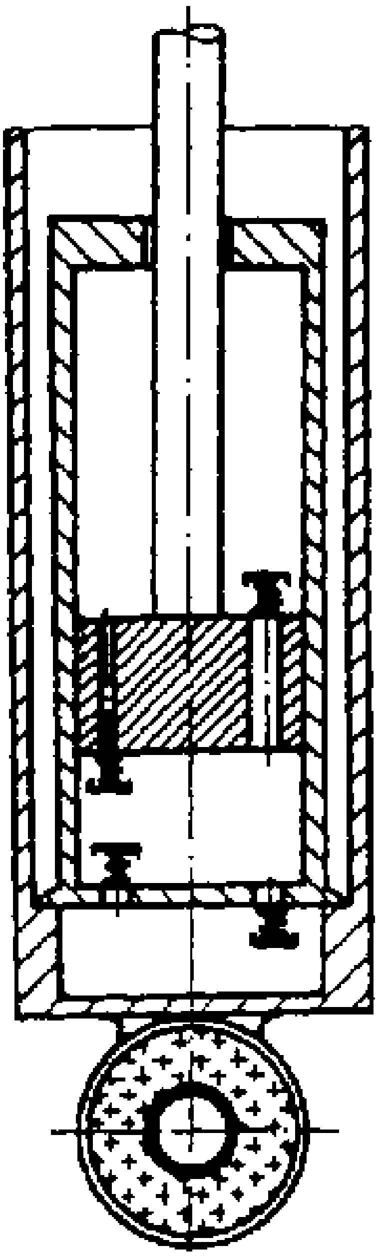


Figure 2/24 Telescopic shock absorber

Fig. 2/24 shows the telescopic shock absorber. It acts at right angles to the central axis and in two directions. The damping effect is minimal when the spring deflects, but it decreases considerably when it returns to its original position. During this time, the large boreholes in the piston are reduced in diameter by means of a diaphragm. This shock absorber requires little servicing and can be repaired very easily. It features long damping paths and low internal pressure. In this shock absorber, the oil is only moderately heated due to the low pressure. Wear is minimal. The design of the telescopic shock absorber permits easy installation.

Maintenance and repair of vibration dampers

Vibration dampers have to be checked regularly for correct mounting, oil content in the cylinder, and leaks at the screwing and the shock absorber shaft. These checks should be made after every 5,000 kilometres. In hydraulic single−action and double−action shock absorbers, the following operations are necessary in addition to topping up shock absorber oil:

− external cleaning of the shock absorber

− disconnecting of the leverage and inspection of the rubber torsion−shear springs (replace, if necessary)

− setting of the lever to its final position when filling with shock absorber oil and then moving it to and fro from one final position to the other to bleed the shock absorber

– draining of 3 to 10 mm^3 oil according to the manufacturer's instructions to enable the oil to expand when heated

– closing of the adjusting screw and reconnection of the leverage.

Fatigue in the high–pressure valve spring and wear of the shock absorber shaft are causes of decreased efficiency.

Wear of the shock absorber shaft increases the leverage play and seal play, causing oil losses which result in decreased efficiency.

In comparison to telescopic shock absorbers, the shock absorbers mentioned above have the following disadvantages:

– High pressures build up in them and accelerate wear.

– Due to ageing and the deposit of wear and abrasion particles, the shock absorber oil becomes viscous and should therefore be replaced after every 30.000 km. Before assembling the shock absorber, it should be cleaned with an oil–dissolving agent.

In case of oil leakage, the telescopic shock absorber should be removed and sent for repair to a workshop.

Telescopic shock absorbers may only be built in vertically or with a maximum angle of inclination of 45°.

2.3. Stabilizers and their construction

Stabilizers are necessary to reduce the tipping tendency and the lateral sway of vehicles. Hydraulic and torsion–bar stabilizers are used. The torsion–bar stabilizer (Fig. 2/25) is a mechanical lateral stabilizer mounted laterally or transversally to the vehicle axle; it connects the suspension of both wheels on one axle. If the body cants or an axle is lifted on one side, the stabilizer twists, raising the body by the force developing on the opposite side. Torsion–bar stabilizers are often used with coil springs. This stabilizer does not require any servicing, its production is inexpensive and its construction simple.

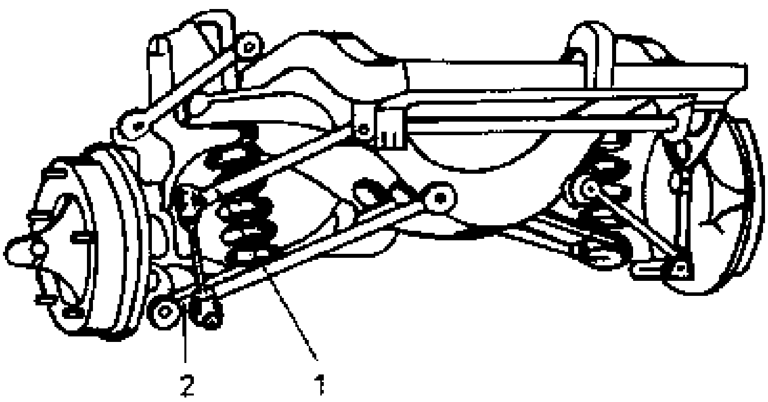


Figure 2/25 Torsion bar stabilizer

1 torsion bar stabilizer, 2 independent wheel suspension

Hydraulic stabilizers serve both for absorbing shocks and for lateral stabilization. Here double–action shock absorbers, connected to each other by pipes, are used. The pressure pipe of one shock absorber runs from its front pressure chamber to the rear pressure chamber of the other shock absorber, and vice versa, see Fig. 2/26.

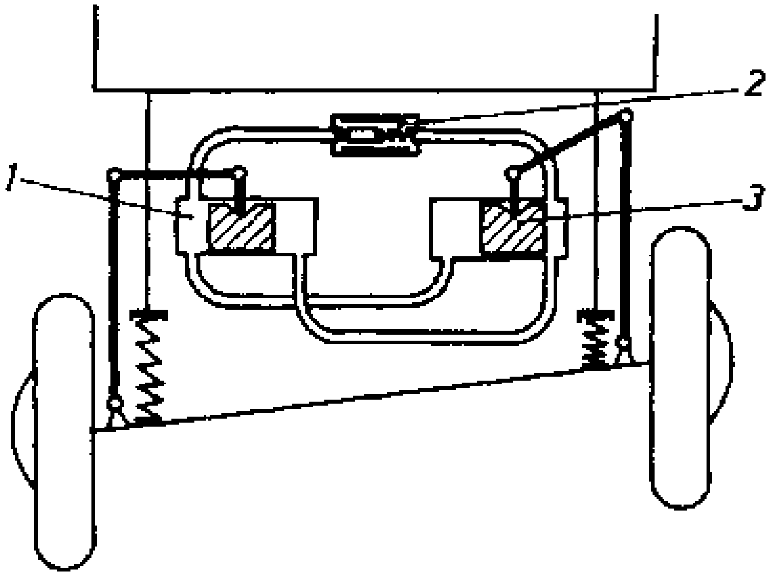


Figure 2/26 Hydraulic stabilizer

1 double−action shock absorber, left, 2 compensating valve, 3 double−action shock absorber, right

If both wheels of an axle are loaded simultaneously there is a pressure compensation in the pipe, i.e. the oil compensates at zero pressure. The tension reduction of the spring is damped. If only one side of the vehicle is loaded, the oil is pressed through the pipes to the other side and the body is raised.

The use of shock absorber oil in hydraulic stabilizer systems results in the following disadvantages:

− They require servicing.
− They are heavy.
− Due to the number of wear parts in the control valves they are particularly prone to wear.
− The construction of these systems is complex and expensive.

Hydraulic stabilizers are only used if the resulting improvement in the vehicle's road holding qualities are vitally necessary or economically justifiable.

Test questions:

2.1. What types of springs do you know?

2.2. Which materials and media may be used as springing elements?

2.3. What is a leaf spring pack subjected to?

2.4. Describe the terms 'coil spring' and 'torsion−bar spring'.

2.5. Where on a vehicle are rubber pack springs to be found?

2.6. What advantages has air suspension over other types of suspension?

2.7. Describe the design of a leaf spring pack.

2.8. What is the purpose of putting grease between the leaves of a leaf spring?

2.9. Why are polyamide laminas inserted in the tips of spring leaves?

2.10. Why must a leaf spring be regularly maintained?

2.11. Name the essential maintenance jobs on leaf springs.

2.12. What should be taken into consideration when repairing a leaf spring?

2.13. Describe the process of removing a leaf spring.

2.14. What is a coil spring subjected to?

2.15. What are the advantages of a coil spring over a leaf spring pack?

2.16. Why should coil springs always be fitted together with shock absorbers?

2.17. How is a coil spring maintained and repaired?

2.18. What are torsion−bar springs subjected to?

2.19. Why must the surface of a torsion bar be unmarked by machine tools?

2.20. What should be taken into consideration when mounting a torsion bar?

2.21. What spring material other than steel do you know?

2.22. What is understood by progressive springing?

2.23. What types of rubber springs do you know?

2.24. Describe the design of a rubber torsion shear spring.

2.25. What types of air suspension do you know?

2.26. Describe the construction of pneumatically adjustable air suspension.

2.27. What types of bellows are used in them?

2.28. Describe the design of hydraulically adjustable air suspension.

2.29. Explain the term 'vibration damper'.

2.30. What is the function of vibration dampers in vehicles?

2.31. Explain why rubber can also be used for vibration damping.

2.32. What is understood by a hydraulic shock absorber?

2.33. Describe the function of this type of vibration damper.

2.34. What requirements must be met by hydraulic shock absorbers?

2.35. Describe the design of a single−action shock absorber.

2.36. Describe the design and operating principle of a double−action shock absorber.

2.37. Describe the design and operating principle of a telescopic shock absorber.

3. Wheel suspension

This section deals with the various types of wheel suspension for vehicles. Wheel suspension is the connection of the wheels to the supporting vehicle frame and their guidance. The general function of a wheel suspension system is to connect the supporting vehicle frame to the wheels, to ensure wheel guidance and to transfer the weight of the vehicle onto the wheels.

The essential function of the wheel suspension is to properly transmit guiding forces acting on the wheel, such as thrust forces, brake forces and lateral forces, to the supporting vehicle frame. Each axle journal must be connected with the frame by a positive guidance during the up and down movements of the springs.

The wheel suspension of a vehicle is determined by three important factors:

- vehicle type
- intended purpose of the vehicle
- driving properties required for the specific vehicle type

Wheel suspension systems should meet the following requirements:

– Whatever the driving state – acceleration, constant speed, cornering or braking – and whatever the state of the road surface, all the wheels should always be in contact with the ground.

– They should allow only small transversal inclinations or vibrations, or none at all.

(Achieved by correct combination of front and rear wheel suspension)

– They should prevent changes of wheel camber and caster angle of the steered wheels during spring deflection.

– The wheel suspension system should not allow any change in the set wheel track as this will accelerate type wear and increase the danger of skidding, especially when the weight of the vehicle is distributed unevenly over the wheels.

– The wheel suspension system should be lightweight in order to keep the unsprung weight of the vehicle low.

– To increase road safety and the life of the suspension system, steering joints should not require maintenance.

The following parameters are dependent on wheel suspension:

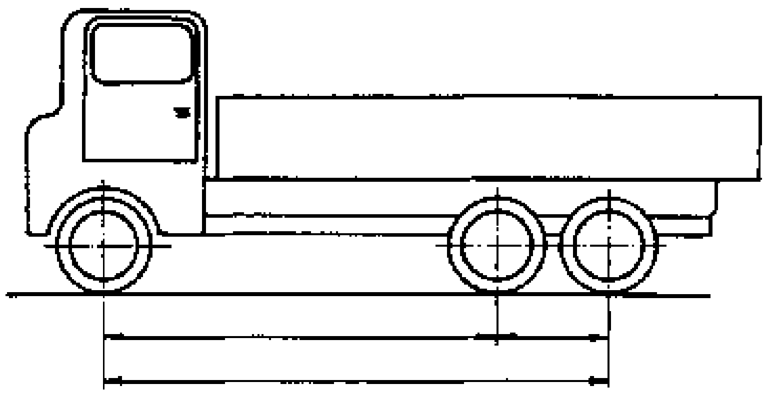


Figure 3/1 Wheel base

Wheel base (Fig. 3/1 – the distance between the mid–points of the front wheels and the rear wheels, measured in millimetres (mm).

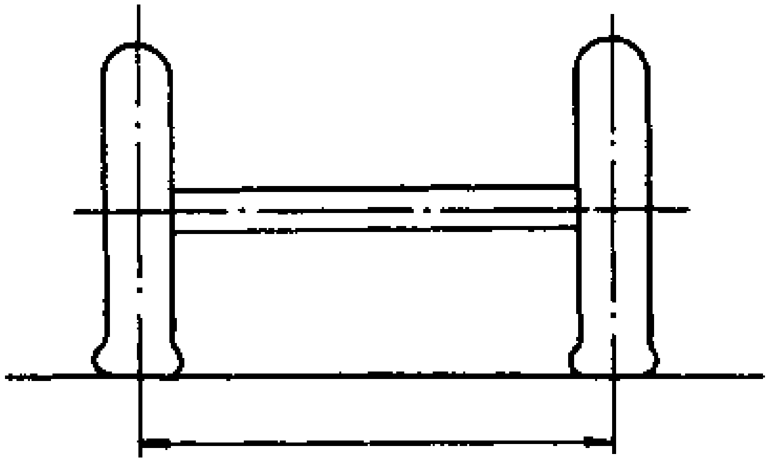


Figure 3/2 Track

Track (Fig. 3/2) – the distance between the mid–points of the two single wheels on one axle, measured in mm. In the case of twin wheels the distance is measured between the mid–points of twin wheels.

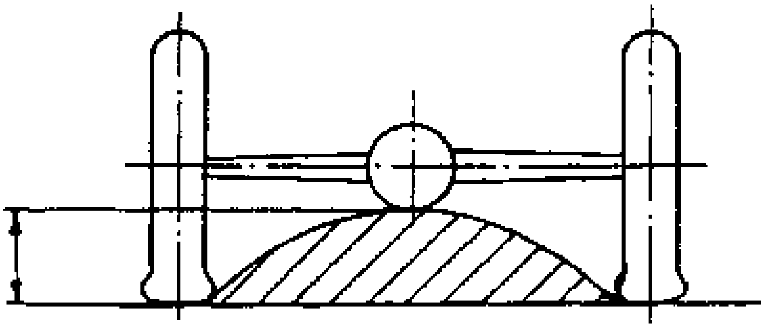


Figure 3/3 Ground clearance

Ground clearance (Fig. 3/3) – the shortest distance between the vehicle and the ground when the vehicle is fully loaded, measured in mm.

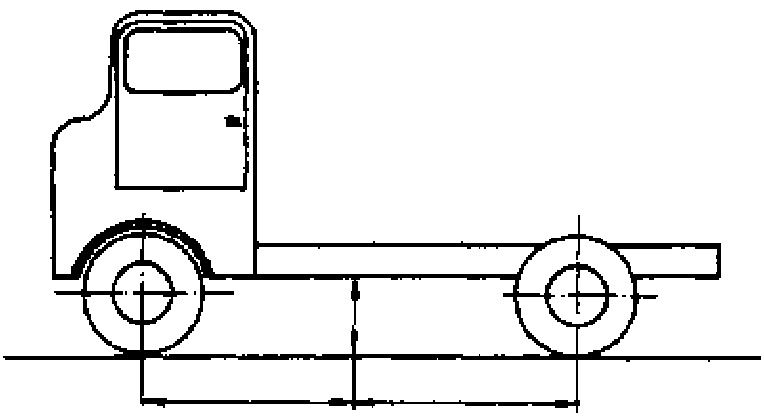


Figure 3/4 Height of the chassis above ground

Height of the chassis above ground (Fig. 3/4) –the distance between the upper edge of the chassis and the ground when the vehicle is fully loaded, measured in mm at the mid–point of the wheel base.

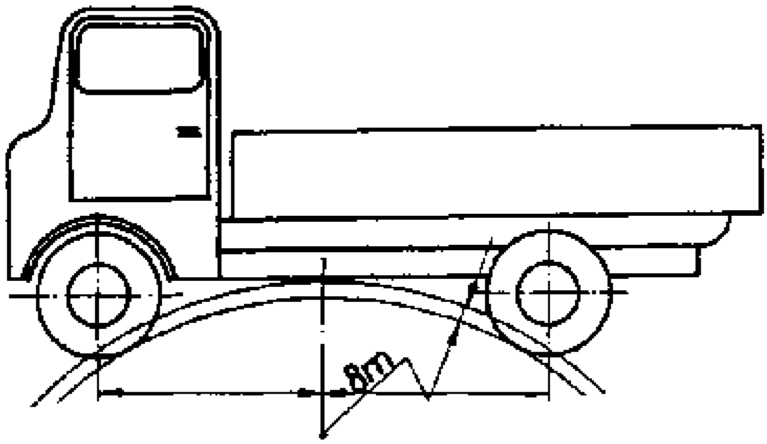


Figure 3/5 Ground clearance on a convex surface

Ground clearance on a convex surface (Fig. 3/5) – the shortest distance between the lower edge of the chassis of a fully loaded vehicle and the lateral surface or a cylinder, of 8 m radius for a lorry and 5 m radius for a car, whose axis is perpendicular to the longitudinal plane of symmetry of the vehicle, and on which the vehicle rests.

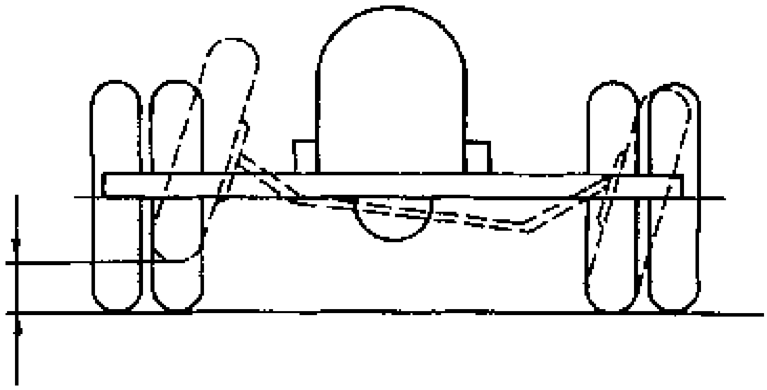


Figure 3/6 Lift

Lift (Fig. 3/6) – the height to which a front wheel may be lifted without the other wheels leaving their supporting surface, measured in mm.

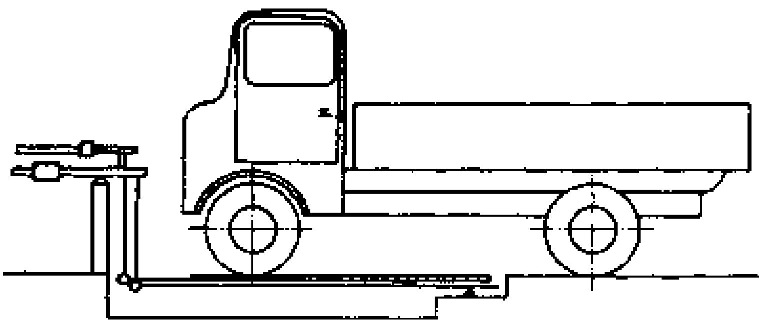


Figure 3/7 Maximum axle weight

Maximum axle weight (Fig. 3/7) – the total weight transferred from the wheels of one axle on to the road, measured in kilogrammes (kg). Two axles set between 1 metre and 2 metres apart are considered as a double axle.

The unsprung masses such as axles, brakes and wheels should be kept as small as possible. This can be favourably influenced by the type of wheel suspension.

The driving properties, especially steering stability, are influenced by the wheel suspension in connection with the springs of the vehicle and all other parts of the chassis.

3.1. Front and rear wheel suspension of driven and non-driven wheels

Vehicles can be driven the rear wheels or the front wheels or both, and so vehicle wheels can have different functions.

– They can be steered wheels. This applies to the front wheels in normal and rear–wheel drive vehicles. In vehicles with normal drive, the drive assembly is mounted in the front part of the vehicle and the force is transmitted to the rear axle by propeller shafts. In the case of rear–wheel drive vehicles, the drive assembly is mounted behind or directly on the rear axle.

– They can be driven wheels, as is the case with normal and rear–wheel drive vehicles.

– They can be both steered and driven wheels. This is the case with front–and four–wheel drive vehicles. In a front–wheel drive vehicle the drive assembly at the front or directly above the front axle. In a four–wheel drive vehicle all the wheels are driven be the drive assembly.

There are three different types of wheel suspension:

– rigid axle suspension
– independent suspension
– half–axle suspension

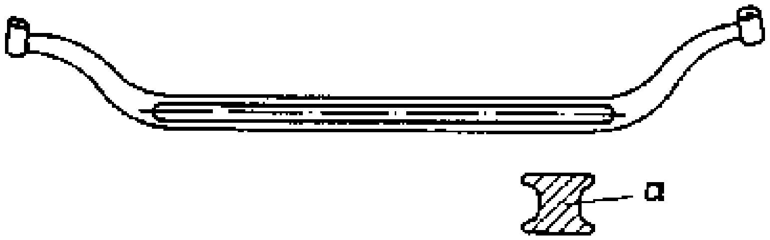


Figure 3/8 Rigid axle

A cross section of axle body

The term rigid axle suspension (Fig. 3/8) means that both the wheels on one axle have common suspension and common springing.

With this type of suspension the upward movement of one wheel is partially transmitted to the other. The track width cannot change but the wheel camber varies as the spring deflects.

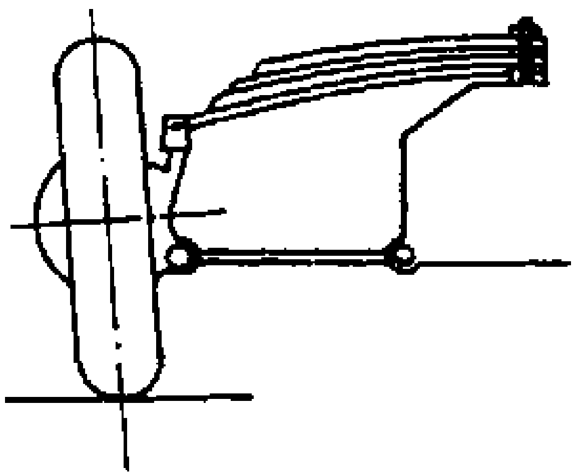


Figure 3/9 Independent suspension

With independent suspension (Fig. 3/9) the wheels are mounted independently, i.e. they are individually sprung, and spring deflections are restricted to one wheels only. Stabilizers are used, however, to achieve a balancing effect and thus the movement is transmitted to both wheels. Whether or not wheel track and camber change during deflection is dependent on the individual design of the suspension, especially on the design and arrangement of the guiding elements.

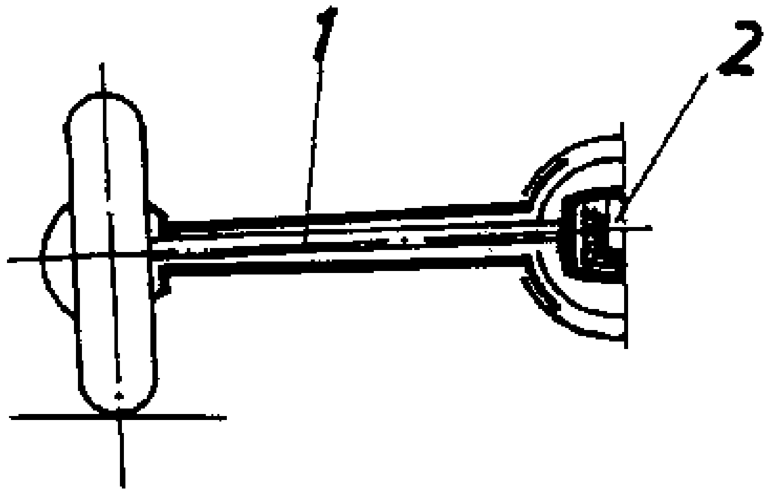


Figure 3/10 Half axle

1 Half axle, 2 differential

As the term half−axle (Fig. 3/10) suggests, the wheels are mounted separately to one half of the axle. The axle halves are connected to the differential unit in the centre of the chassis, and when the spring deflects they swing about this point. This type of wheel suspension is a combination of independent wheel and fixed wheel suspension.

Because of the wheel guiding forces, bending and torsional forces act on the wheel suspension elements. This means that these elements must be designed to withstand bending and torsion. Die−forged and rigid pressed sheet metal parts are used for this purpose.

Drop forgings and very rigidly designed pressure forged parts are used as these parts must be made of a tough and strong material. They are quenched and tempered.

There are quite different types of wheel suspension, and all kinds of springs can be used with them. The type of axle used depends on the purpose of the vehicle and the driving qualities required of it.

In modern vehicle construction, independent suspension is becoming ever more important, especially in the construction of passenger vehicles. In buses and lorries, however, rigid axles are still predominant. In some cars, independent suspension is used on the front wheels and a rigid axle for the rear wheels. Below the advantages of independent wheel suspension and half−axles over rigid axles are discussed:

– With independent suspension, the unsprung masses can be kept low.

– Road grip and, consequently, road safety are better.

– With this suspension, the centre of gravity is low and roadability is better which is especially important for racing cars.

– Different spring systems can be combined with these types of suspension in the vehicle.

– Wheel camber variations can be kept to a minimum during deflection.

– When the springs deflect, the wheel camber, toe−in and castor angle of the steered wheels do not change if the wheel guiding parts have been correctly designed (See section on steering).

Half axles have the following advantages over rigid axles:

– The unsprung masses are reduced as the drive mounted on the sprung chassis.

– The road grip of the wheels is better.

– They have a better stability on curves and a lower transversal inclination.

– Transmission of the wheel forces is better due to the greater distance between the swivel points (fixed points).

However, the rigid axle continues to prove its worth in motor engineering. It possesses some important advantages which should not go unmentioned.

– The rigid axle is simple in construction.
– It is simple and therefore fairly inexpensive to manufacture.
– This simplicity means that it is very reliable and requires little maintenance.

Rigid axles can be used for both front and rear axles, but these two types vary considerably.

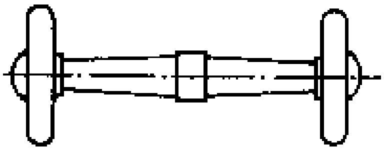
The rigid <u>front axle</u> is a continuous support with axle heads at either end which support the axle bolts for the steerable front wheels. The mounting surfaces for the springs are also found on this support. Fig. 3/11 shows the various types of axle.

Figure 3/11 Types of axle

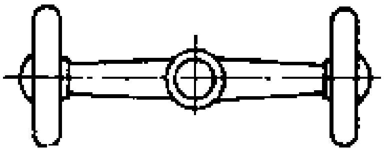
a...d rigid axles;

a) forked axle

b) stub axle

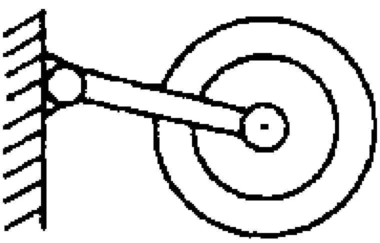


c) funnel axle

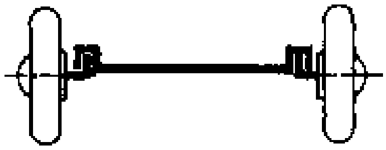


d) banjo axle

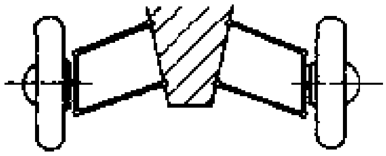
e) half axle as swing axle



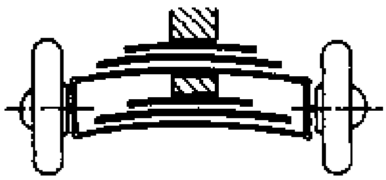
f) crank axle



g) guide axle (pivot axle)



h) wheel suspension by means of track control arms



i) wheel suspension by means of cross springs

In most cases the cross section of a rigid front axle is an I−beam section, but in smaller vehicles pipe−section axles are also common. They are manufactures from high−quality steel which must not be hot straightened after an accident because the heating process will cause the loss of the rigidity gained by quenching and tempering. The axle body is always cranked to ensure the lowest possible position of the frame.

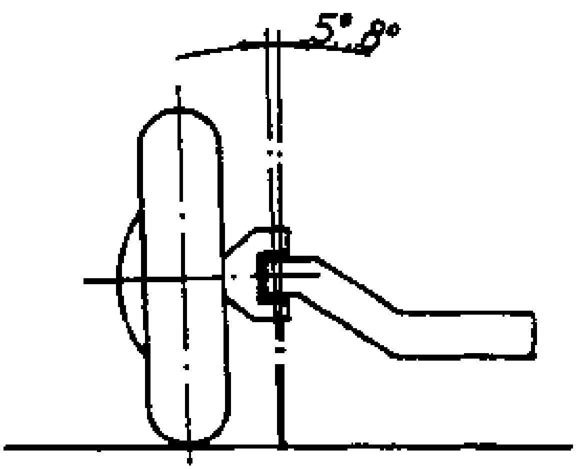


Figure 3/12 Position of the drive joint housing to the road

The axle heads are directed outwards in relation to the vertical to the road (Fig. 3/12) in such a way that an extension of the axle bolt in the axle head meets the ground (road) near to where the wheels touch the ground. This is to reduce the shocks to which the wheel is subjected while moving. The wheel position described here is called 'inclination'. Vehicles having no or minimum inclination only transmit each shock to which the front wheels are subjected, to the steering wheel. Such vehicles are difficult to drive and tend to 'drift', i.e. they are unstable, and the front wheels wobble. Rigid front axles are found nowadays only in lorries and buses.

To improve the driving comfort of a vehicle, more and more swing axles and independent wheel suspension systems are being used. Combinations of independent wheel suspension and rigid axles are also found. In this case, the front wheels are independently suspended while the rear axle is a rigid axle.

In independent wheel suspension systems a transversal leaf spring is often used to connect the two front wheels, and guidance is ensured by the steering arms. Coil springs and air suspension, shown in Figs. 2/17 and 2/25, are becoming increasingly more important. When using leaf springs track variations occur during spring deflection.

In the suspension shown in Fig. 3/9 even wheel camber may vary, this may, however, be kept within acceptable limits by constructional measures on the part of the manufacturer.

These variations do not occur with coil springs and air suspension.

With independent suspension, unsprung masses are kept low, i.e. they are restricted to the wheel drive, brake shoes, anchor plate and wheel.

Like front axles, the rear axles can be designed as rigid axles, swing axles and in the form of independently suspended wheels.

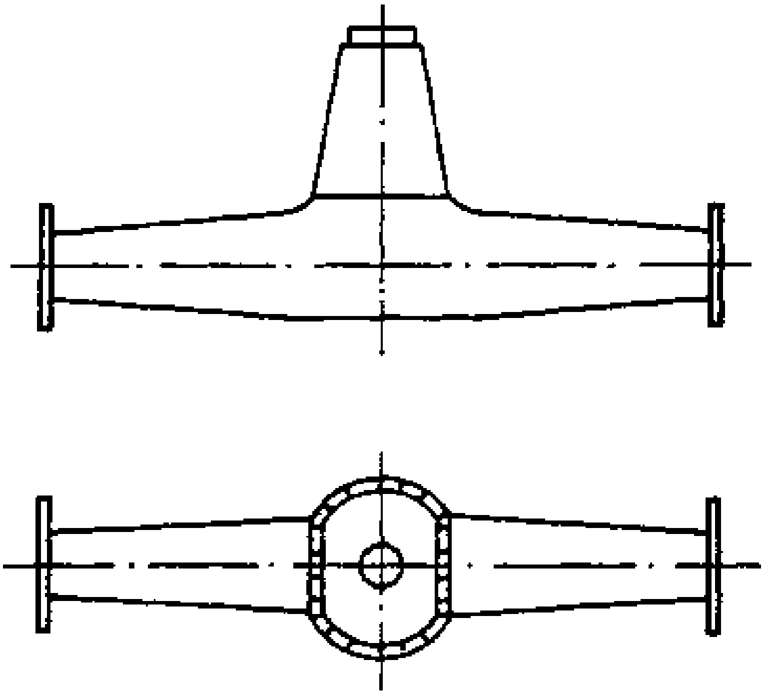


Figure 3/13 Funnel axle

The most common type of rear axle today is the rigid axle. It is used both in passenger cars and in lorries. Similar to the front axle, it is a continuous supporting axle body. Provided that the vehicle has rear axle drive, it serves to accomodate the power transmission components which are protected from outside damage by the construction of the axle body. It can be designed as a funnel axle or banjo axle (Figs. 3/13 and 3/14).

In case of a front wheel drive, the rear axle is a hollow body of square or pipe cross section. In rear wheel drive, the differential unit and the axle shafts, also called fully floating axles, are integrated in the axle body.

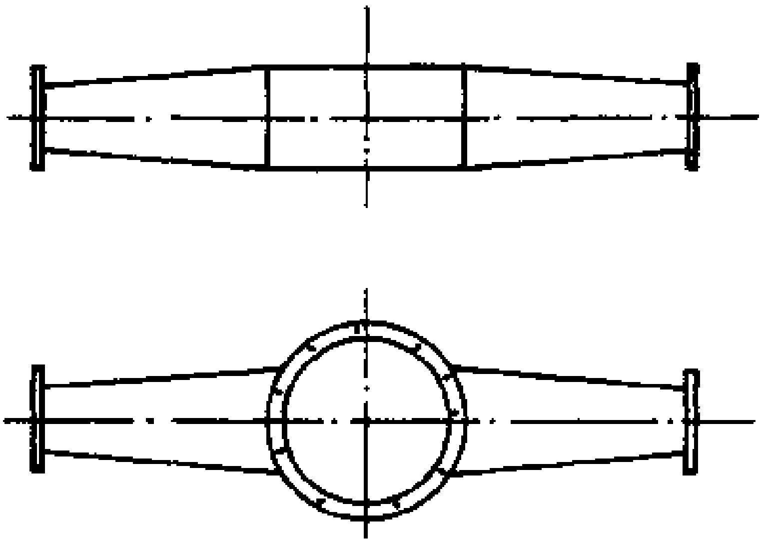


Figure 3/14 Banjo axle

The differential unit of a vehicle consists of the ring gear, bevel gear and planetary gears held by the differential housing. This differential gear unit has the function of compensating the rotation of the wheels on curves. On a curve, the inside wheel turns slower and covers a shorter distance than the outside wheel. The differential unit is used to compensate these different wheel speeds (Fig. 3/15).

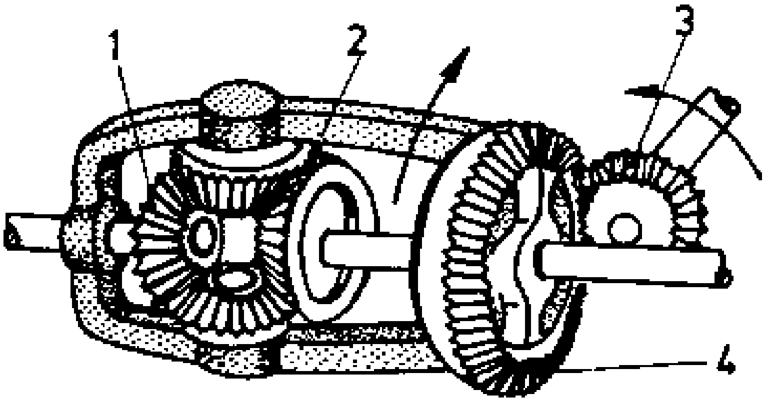


Figure 3/15 Differential gears

2 differential casing, 3 bevel gear, 4 crown wheel

Modern lorries have a second wheel drive transmission by means of spur gears (Fig. 3/16).

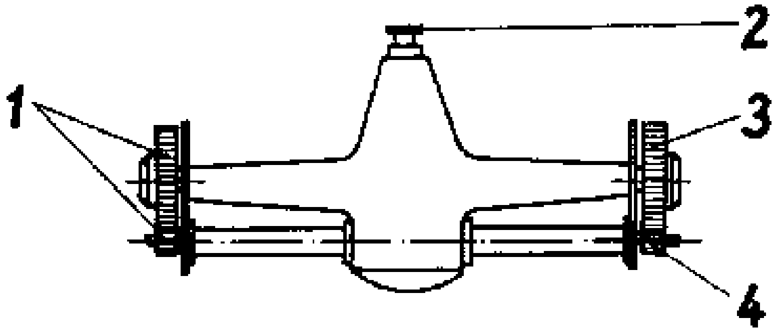


Figure 3/16 Second wheel drive transmission by spur gears

1 spur gears, 2 final drive, 3 driven gear, 4 driving gear

This additional transmission increases the force by which the wheels are driven, and keeps the driving power relatively low.

In lorries, axle bodies of cast steel are used for the rigid rear axle. In passenger cars light−metal or pressed sheet−steel parts are used. The axle bodies of rear−axle drives must be sealed as, after the assembly of all parts, they must be filled with oil for the drive to ensure lubrication of the rotating parts within the axle body. The amount and grade of oil to be used is specified by the manufacturer.

It is evident from the description of the rear axle that the unsprung masses are very heavy. This is due to the fact that the complete axle drive and the wheels are mounted onto the axle. To counteract this disadvantage, independent wheel suspension is made use of in vehicles with rigid rear−axle drive.

The purpose of independent wheel suspension in rear axle drives is to reduce the unsprung masses. The axle drive is fixed to the frame and the driving power is transmitted to the wheels by swing axles (see also Fig. 3/11) so that, besides the wheels, brakes, suspension elements and springs, the only shock−transmitting masses left are the swinging half−axles accomodated in the casing of the differential unit. They have to be supported on the frame for the transmission of the thrust. This design is used in vehicles with a central pipe frame. The two axle halves can be sprung by a transversal spring or by coil springs supported by the frame, and by lateral leaf springs in the case of double axles.

With front wheel drive, the rear axle has only a supporting function. The wheels can be held by wishbone suspensions or by simple suspension arms fixed to the frame. The rear axle is sprung by a transversal spring, a coil spring or a torsionbar spring.

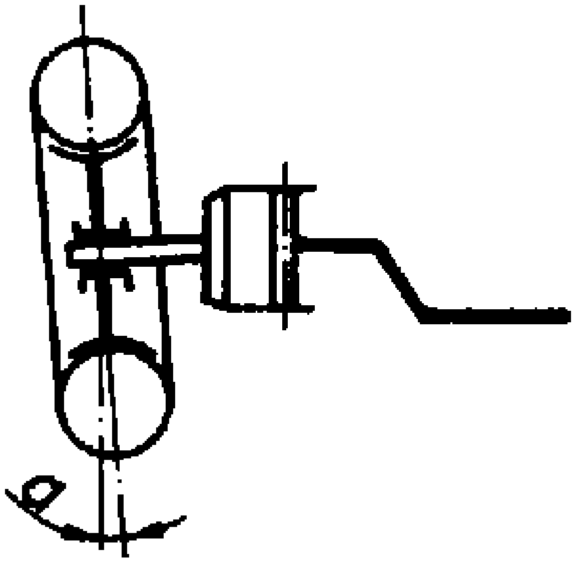
3.2. Wheel positions

This section deals with the position of the steered wheels of the front axle, which have to have specific relationships to the road. These are known as wheel camber, toe–in, castor angle and inclination.

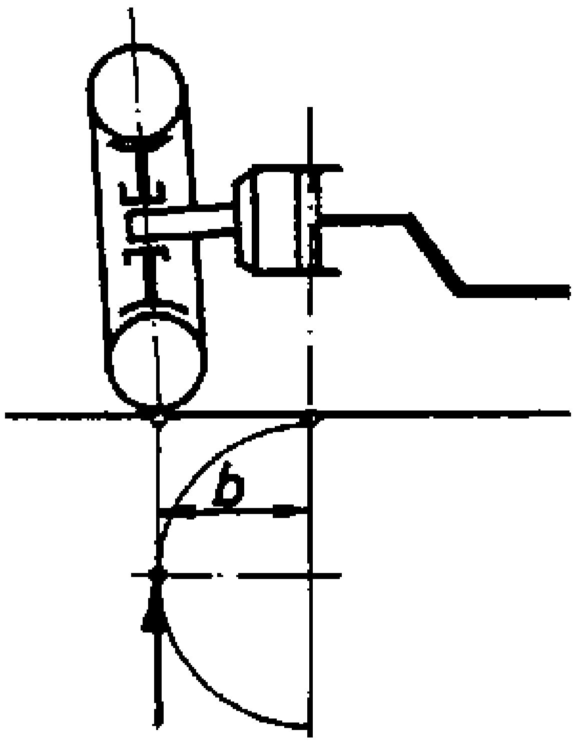
The various wheel positions serve to give the vehicle the following driving qualities:

- favourable driving properties
- perfect functioning of the steering system
- easy and safe steering under all conditions
- suppression of any steering vibrations

Figure 3/17 Wheel camber



a) camber angle 0,5° to 8°



b) steering roller radius

The wheel camber (Fig. 3/17a) is the inclination of the wheel plane in ° (degree) to the perpendicular raised from the point of wheel contact with the road.

The wheel camber prevents wobbling of the front steered wheels and causes the steering wheel to return automatically to the straight position after turning. If wheel camber is too great, tyre wear is accelerated, and wheel instability and torsional vibrations are caused, which lead in turn to wobbling of the steered wheels and unsafe driving. For this reason, the wheel camber should be as small as possible. However, a favourable steering roll radius should also be maintained. The purpose of a positive wheel camber is:

Because of the wheel camber the wheel tends to roll outwards like a cone but is forced to roll in a straight line by the wheel guidance. Wheel guidance means wheel suspension such as rigid axle or independent suspension. The wheels are positively guided, causing a force component which makes the wheels overrun the steering swivel pin. This results in an even loading of the wheel bearings, unloading of the axle stub nut and elimination of bearing play (Fig. 3/17b).

Toe−in is the distance by which the rear rim beads are farther away from each other than the front ones. This distance is measured on an even surface in the middle of the left and the right wheels of a vehicle with the wheels turned straight. The vehicle must be fully loaded (Fig. 3/18).

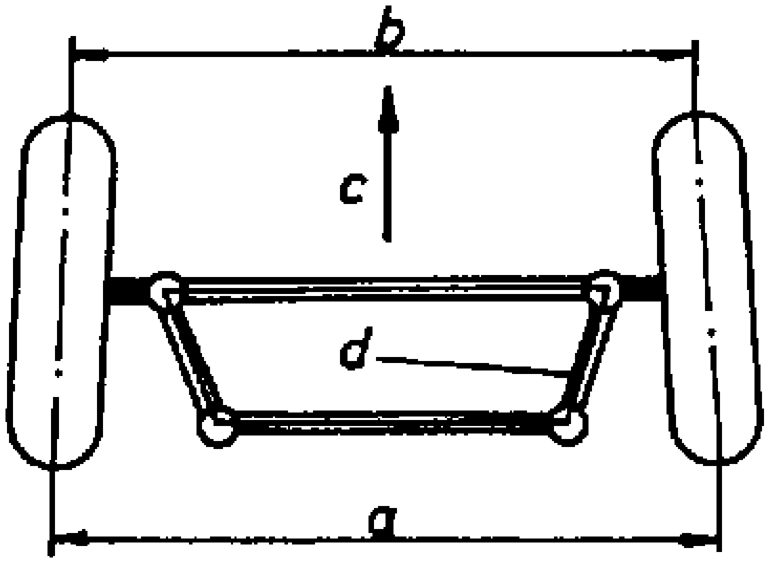


Figure 3/18 Toe−in

A rear track, B front track, C direction of travel, D steering trapezium

A graduated track meter is used for adjusting the toe−in at the tie rods connecting the left and the right part of the front axle.

The toe−in serves to reduce the tendency of the steered wheels to wobble, to reduce tyre wear and to make steering easier.

Another purpose of the toe−in is to set the wheels approximately parallel at high speeds by means of centrifugal force.

The inclination, as shown in Fig. 3/12, has an average value of between 5° and 8°. The inclination is measured with the vehicle fully loaded. Due to the inclination, shocks act on a short lever arm.

The castor angle is the extension of the perpendicular erected at the midpoint of the wheel compared to the midline of the steering swivel pin (Fig. 3/19).

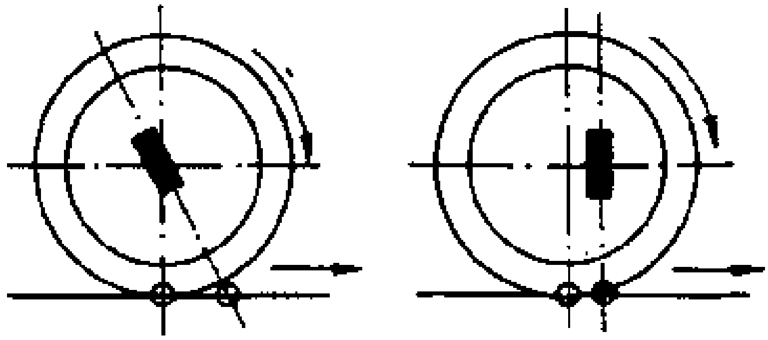


Figure 3/19 Castor angle

This distance is measured at the ground where the vehicle is positioned. It is intended to improve the steerability of the wheels, since pulled wheels are more stable compared to pushed wheels which are unsteady and tend to wobble. Because of the castor angle the wheels follow each steering movement well, do not wobble and straighten automatically.

3.3. Removal and fitting of axles

A vehicle is taken to a repair shop to have the front axle reconditioned.

In this example, a rigid front axle is to be completely reconditioned. In order to do this it is necessary to remove the axle from the vehicle. The vehicle is positioned in the repair bay, i.e. it has to be protected from rolling away by blocks. These blocks are placed at the wheels of the rear axle. How the wheel nuts are slackened. By means of an appropriate jack the vehicle can be lifted, the wheels can be unscrewed and removed. Supports are used to prevent the vehicle from tipping and to take the load off the jack.

Another jack is positioned under the axle in the middle of the axle body for support. After having finished these preparations the spring clips are loosened and the axle is separated from the springs. The steering track is loosened at the steering lever and has to be pressed out of the cone by means of a steering track remover. The shock absorbers also have to be removed from the axle body by loosening the screw connections. How the front axle is lying on the jack. Having lowered the jack, the axle can be removed from the vehicle and transported to the workshop where it is to be disassembled by means of a mobile jack. The individual parts then pass through a washing machine to be cleaned and are checked to see if they are re−usable.

Defective parts are discarded and are replaced by new or regerated ones during the assembly of the axle. The axle is re−fitted in reverse order. First the axle has to be fixed to the springs and straightened so that the vehicle does not move diagonally or break away from the track after repair. When removing the rear axle, the cardan shaft which transmits the power must also be removed. In order to avoid accidents care must be taken to ensure that the springs are always relieved during removal of the axles. When mounting the cardan shaft it is essential to ensure that it is put together in the same way as it was disassembled. The cardan shaft is balanced, and if two parts are incorrectly assembled an unbalance may occur and lead to the destruction of the transmission parts. When assembling the bevel gear at the rear axle, care must be taken to ensure that the clearance between the ring gear and the bevel gear is adjusted to guarantee effective and silent power transmission. The clearance can be adjusted by means of a dial gauge and is determined by the manufacturer. Since this clearance will increase in the course of time (due to wear) the distance can be corrected to a certain extent by the removal or insertion of thin spacer rings.

3.4. Repair tools and auxiliaries

Open ended wrenches, 12−point opening socket wrenches, wheel nut spanners and electrical and pneumatic tools with nut drivers of all wrench sizes are used for reconditioning axles.

Jacks, blocks and supports as well as transporters for handling components are used as auxiliary parts.

The axle testing gauge is used for measuring and checking inclination, wheel caber and castor.

The dial gauge is used for adjusting the clearance between the ring gear and the bevel gear as mentioned above.

The track meter, also mentioned above, is used for adjusting toe−in.

Test questions:

3.1. What do you understand by wheel suspension in a vehicle?

3.2. What is the main function of wheel suspension?

3.3. What factors determine the type of wheel suspension to be used on a vehicle?

3.4. What demands are made on the wheel suspension?

3.5. Explain the term wheel base.

3.6. What do you understand by wheel track and ground clearance?

3.7. What do you understand by the terms 'height of the chassis above ground' and 'ground clearance on a convex surface'?

3.8. Explain, with examples, the terms distortion and maximum weight.

3.9. What do you understand by a rigid axle?

3.10. Give a diagramatical explanation of independent suspension.

3.11. What do you understand by a half−axle?

3.12. What types of wheel suspension do you know?

3.13. Give the advantages of independent suspension.

3.14. Give the advantages of the half−axle.

3.15. What are the advantages of the rigid axle?

3.16. Describe the design of a rigid front axle.

3.17. What do you understand by resistance to rolling?

3.18. What different types of axle heads do you know?

3.19. Describe the construction of a differential unit.

3.20. What rear axle designs do you know?

3.21. What function does the differential unit fulfill in a driving axle?

3.22. Describe the structure of a differential unit.

3.23. What is the, function of the rear axle in front wheel drive? Give some examples of springing which could be used in such a case.

4. Steering

The steering system of a vehicle should, in every situation, cause the vehicle to travel in the direction required by the driver reliably and with the least possible effort. Along with wheel position and the brakes it is a very important component for ensuring road safety. Its design, and the load of the steered wheels, are determined according to the total weight and maximum speed of the vehicle, to give light and steady steering. In order to facilitate steering for drivers of heavy vehicles, power−assisted steering is fitted. This, however, also allows the driver to stop the vehicle by steering manually should the power−assisted system fail.

The steering system must be so designed that road surface and air currents do not cause the vehicle to change direction. The additional power−assisted steering can be operated hydraulically or pneumatically.

The joints of the steering system must not work loose due to gradual wear.

In order to ensure the vehicle's road safety, steering components must be replaced immediately wear or damage occurs.

4.1. Types of steering

Steering systems can be divided into two main groups:

- fifth−wheel steering
- axle pivot steering

Fifth−wheel steering is used in trailers, single track vehicles (motorcycles, mopeds and motor−assisted bicycles with kick starters) and special purpose vehicles. In this type of steering the whole axle is steered, and for this reason skidding is likely if bends are negotiated too quickly. Fifth−wheel steering allows the vehicle to negotiate tight bends or even to turn on the spot. The required sliding surfaces are provided by rings, discs bushes or ball bearings (Fig. 4/1).

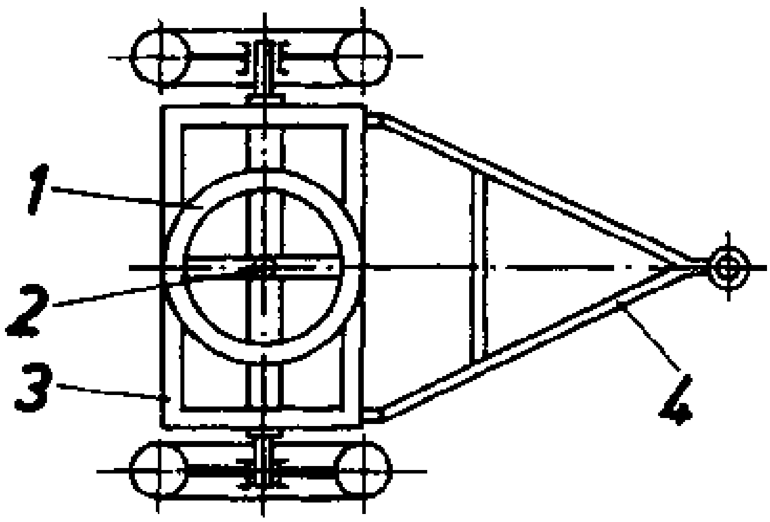


Figure 4/1 Fifth−wheel steering

1 slewing ring, 2 centre bolt, 3 swivelling bolster, 4 forked draw−bar

Axle pivot steering has a far more complicated structure. In this case an axle body (rigid axle, swing axle or independent suspension) is fixed to the frame via the springs. At the ends of the axle body there are swivelling steering stubs held by the steering swivel pin.

In contrast to fifth−wheel steering, a vehicle's ground clearance can be kept low with this type of steering design. The disadvantage is that a larger turning circle is required for this type of steering. The smallest turning circle can be determined when the steering angle of the wheels is as large as possible (Fig. 4/2).

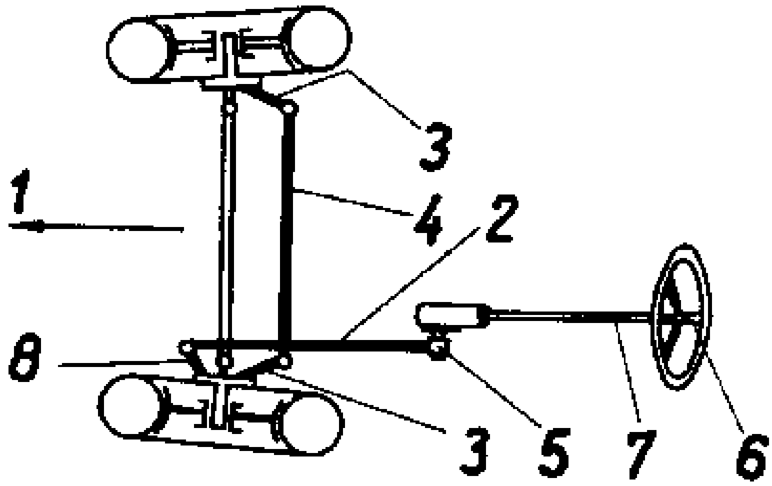


Figure 4/2 Axle−pivot steering

1 direction of travel, 2 drag link, 3 track rod arm, 4 track rod, 5 drop arm, 6 steering wheel, 7 steering column, 8 linkage lever

Axle pivot steering systems can be classified according to the structure of the steering gear. The most common types are listed below:

Peg−and−worm steering, worm steering, finger−type steering, cam and roller steering and rack−and−pinion steering.

It must be added that in fifth−wheel steering the whole axle, together with the swivelling holster, rotates around a pivot which is perpendicular to the axle. Thus good ground clearance is given for trailers and the tipping angle is increased.

For steering movement made by the driver, called the steering angle, is transmitted to the wheels in the following way:

The steering wheel is connected to the steering column by a cone with a disc spring or by toothed wheels, and is locked by a nut or a clamp.

At the lower end of the steering column is the steering worm (except in rack−and−pinion steering which has a gear wheel). The steering segment meshes with the steering worm or the gear wheel according to the design. The drop arm is mounted to the steering segment. These components are situated above the frame. The drag link beginning at the drop arm is connected with the steering stub, usually at the left−hand side of the vehicle (left−hand drive), by the connecting rod lever. There is another lever at the steering stub, which is called the track rod arm. Both steering stubs have a track rod arm which meshes with the track rod. In this way the steering trapezium is formed by the axle, the track rod arm and the track rod (Fig. 4/3).

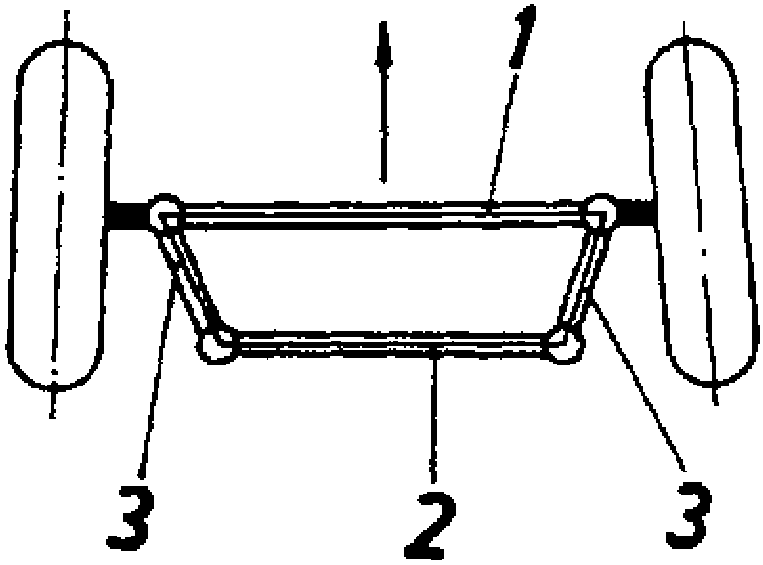


Figure 4/3 Steering trapezium

1 axle, 2 track rod, 3 track rod arm

As far as rack–and– pinion steering is concerned the track rods, which are split, are connected directly to the steering rack. All components of the steering system are secured by castle nuts and split pins. The following principle applies to the steering system and its components:

Screw connections have to be against loosening secured by castle nuts with split pins or by locking plates. Once removed, split pins and locking plates may not be used again. Welding of the steering system and of steering components is prohibited. Steering components may not be straightened by heating as this will cause them to loose the properties gained by their Initial heat treatment.

4.2. Construction and principle of steering systems

The most common type of steering is worm steering. It can be designed according to the special requirements of an individual vehicle to give almost self–retaining transmission of motion. The lesd angle of the worm is important for this self–retaining effect.

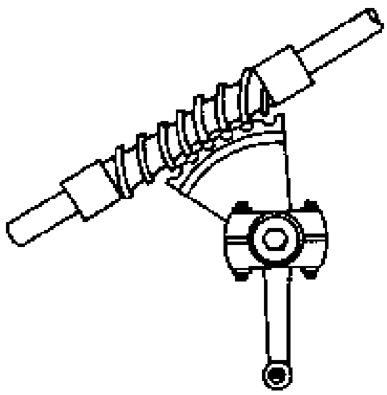


Figure 4/4 Worm steering system with gear segment

Worm steering (Fig. 4/4) has the advantage of being adjustable in three directions. The first is an axial direction at the thrust bearing of the steering shaft. This adjusts the height clearance. The second is the adjusting of the thrust bolt by means of which the centre of pressure can be changed.

The third possibility is the adjustment of the tooth play by means of an accentric cam.

In worm steering the straight direction of movement of the steering nut is transferred into the swivel motion of the steering shaft by means of slide rings or journal rings. The nut of the worm steering is babbitted. This steering system is not adjustable (Fig. 4/5).

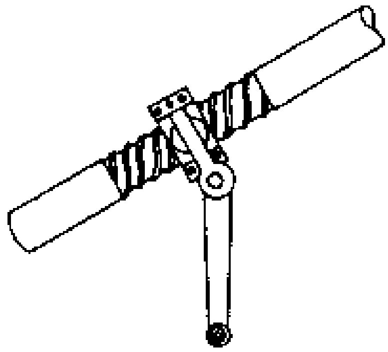


Figure 4/5 Worm steering system with slide rings and journal rings

In finger−type steering systems, a finger−type journal, in a ball and parallel−roller bearing, meshes with the worm. The ball and parallel−roller bearing is inside a lever which is firmly connected to the steering shaft. A rolling motion takes place between the worm and the finger. This gear is easy and the components wear only slightly. The worm threads are trapezoidal, and so the play between the worm and the finger can be adjusted. During adjustment the finger is pressed into the worm by means of an adjusting screw at the steering box. When adjusting the play, steering must always be in the centre position. If the steering is not centred the steering gear cannot be moved across the centre of the worm and it becomes jammed. The axial play is adjusted in the same way as for worm steering. With this steering system, lateral road shocks are hardly noticed and only a small force is required at the steering wheel. (Fig. 4/6) In the centre the lead angle of the worm is small, but it increases towards the ends. Therefore a bigger movement at the steering wheel is required for smaller steering locks, and smaller steering movement is required for bigger sheel locks.

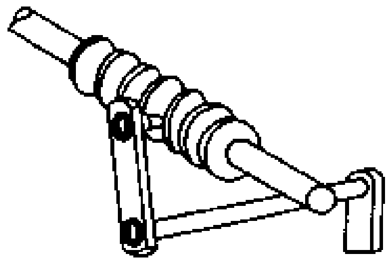


Figure 4/6 Finger−type steering system

In the cam−and−roller steering system a formed roller performs the task of the steering finger. The steering roller is in a ball bearing and has two roller teeth. When the steering wheel is turned these roller teeth describe an arc. Hence it follows that the worm is not cylindrical, but that its outer surface describes an arc.

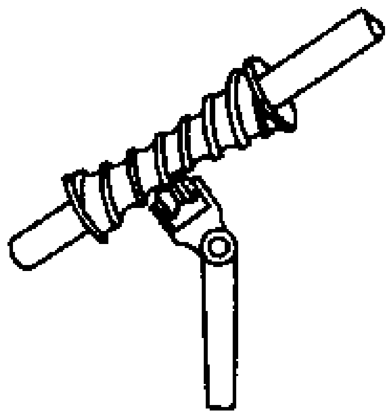
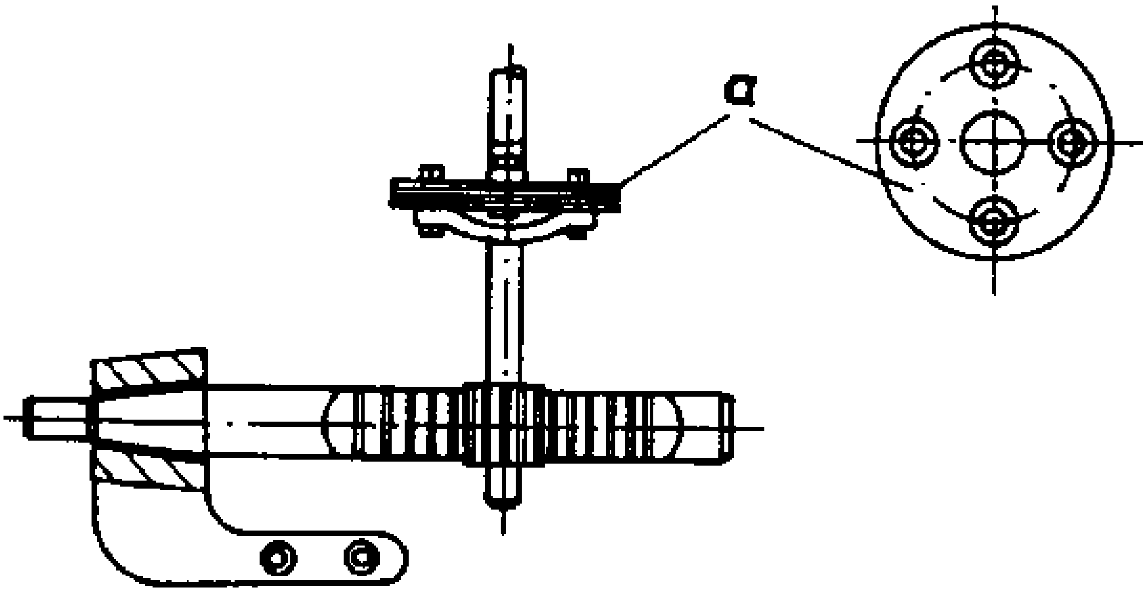


Figure 4/7 Cam−and−roller steering system

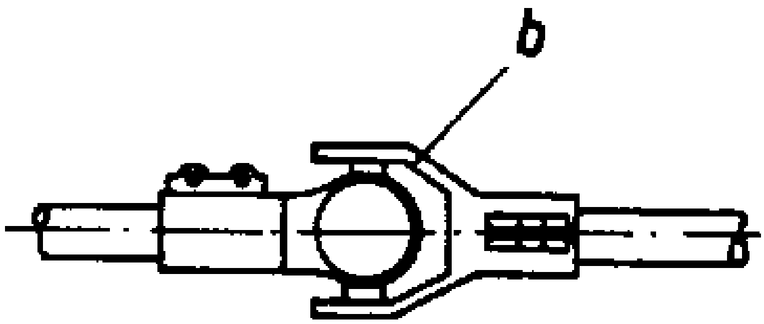
The diameter of the worm is smallest in the middle and it increases towards the ends. Due to the very large meshing surface between the steering worm and the steering roller efficient transmission is possible and wear on both parts is low. This type of steering is used particularly in heavy lorries. (Fig. 4/7)

Rack−and−pinion steering is simple in its structure. At the lower end of the steering shaft there is a pinion which meshes with a rack and moves it in two directions within the box. Rack−and−pinion steering is particularly suitable for vehicles with independent suspension since it is often used as a central component between split track rods. In this steering system the steering column is divided. It can be connected by fabric discs or by a universal coupling (Fig. 4/8). Such frame connections necessitate this divided support. Each steering gear has a play, determined at the steering wheel, which is normally the breadth of a hand. The play, which must be set exactly, is laid down by the steering gear manufacturer.

Figure 4/8 Rack–and–pinion steering system



a) connected by fabric disc



b) connected by universal joint

In modern motor vehicle engineering the safety of the driver is of ever increasing importance, and for this reason so–called safety elements are built into the steering system in case of accident. This safety element is an energy absorbing steering column which is either telescopic or constructed partly from wire mesh and which collapses on impact with an obstacle. Another possibility is to provide the steering column with folding elements which perform the same task. Another safety measure is the safety steering wheel which also distorts on impact.

All linking components in the steering system of a vehicle are rotatable. This is achieved by the use of ball heads and ball cups which require no maintenance. The ball heads have limited freedom of movement (Fig. 4/9).

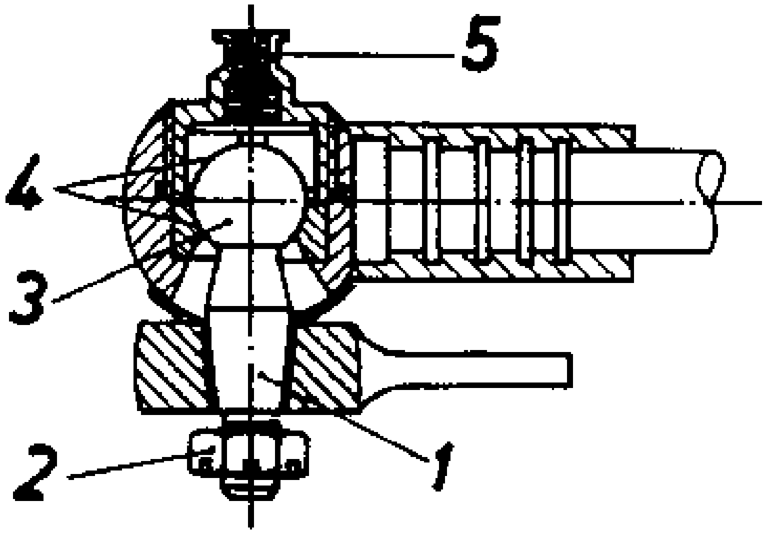


Figure 4/9 Ball head

1 cone, 2 castellated nut, 3 ball head, 4 ball socket, 5 lubricating nipple

At the ball heads there is a cone and a thread to connect the track rod and the rod arm at the steering stub.

Now we will deal with a type of steering gear, the principle of which is not new, but is which is widespread in the manufacture of commercial vehicles today. Fig. 4/10 illustrates the steering gear of the recirculating ball steering system. This recirculating ball steering system is used in the W 50 lorry and, compared with other mechanical steering gear systems, is very efficient. It can be more than 95 % effective. It is the most easy–running of all the steering systems described so far due to its rolling friction. This friction is caused by travelling in a closed circuit between the steering bolt and the steering unit.

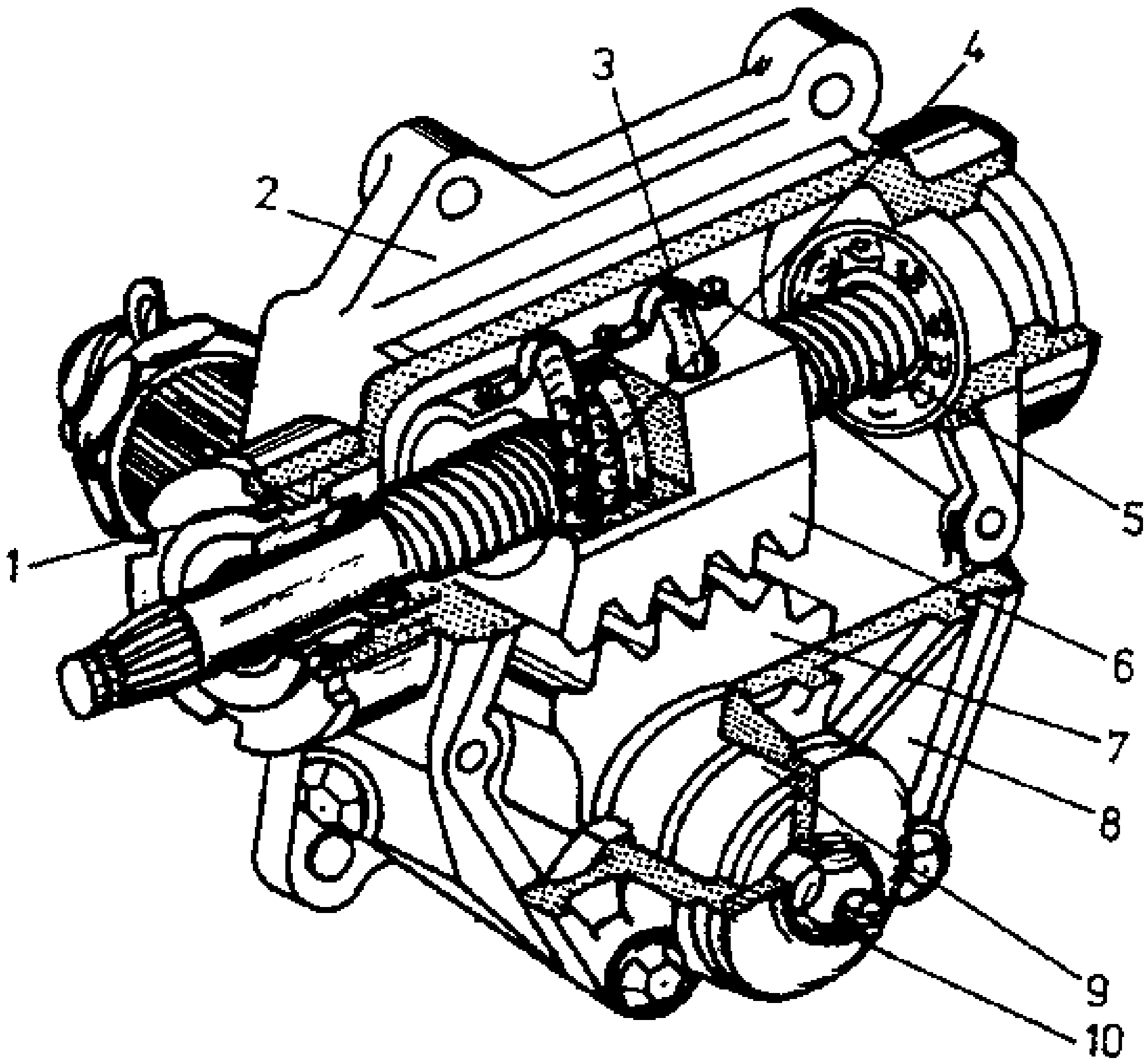


Figure 4/10 Recirculating ball steering system

1 threaded ring, 2 steering−gear housing, 3 small bulb tube, 4 balls, 5 steering bolt, 6 steering nut, 7 steering segment, 8 steering−gear case lid, 9 needle bearing, 10 adjusting screw

The balls travel through a small ball tube and form two endless ball chains. The practical value of this steering gear system is much greater than that of the finger−type steering system. The manufacturer gives, for example, 200.000 kilometres as the maximum service life for the type K 520 recirculating ball steering system. It requires no maintenance until, according to the maintenance schedule, the oil level must be checked.

4.3. Power−assisted steering systems

As already mentioned, power−assisted steering systems are used in heavy vehicles to facilitate steering for the driver. Power−assisted steering may be hydraulic, pneumatic or allhydraulic.

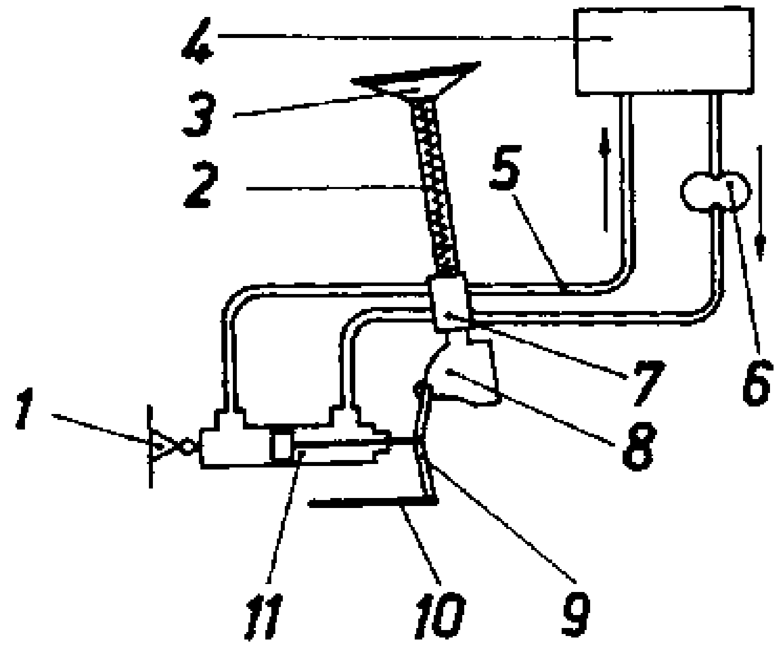


Figure 4/11 Hydromechanical steering system

1 frame, 2 steering spindle, 3 steering wheel, 4 oil tank, 5 return line, 6 gear pump, 7 control valve, 8 steering gear, 9 drop arm, 10 drag link, 11 double−action cylinder

Hydraulic power−assisted steering works by means of oil. This can be outside (hydromechanical steering Fig. 4/11), or inside, working directly on the steering worm (hydro−spindle steering system Fig. 4/12).

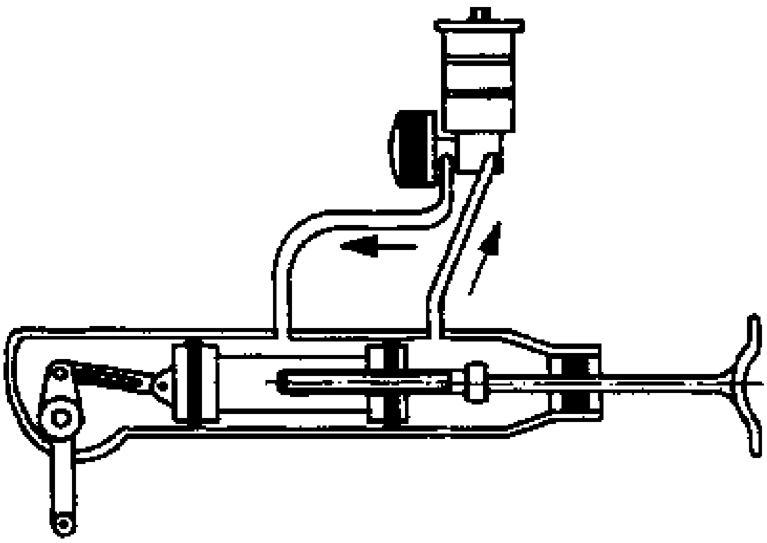


Figure 4/12 Hydro−spindle steering system

When the steering wheel is turned the additional force cuts in and facilitates steering.

Hydromechanical power−assisted steering works by means of a drag link on the drop arm. By means of a gear pump oil is forced through a system of lines and a control valve into a double action cylinder. The oil is forced into the appropriate chamber of the cylinder by the control valve which is connected to the steering column, and thus moves the piston in the same direction as the steering sheel. If the power−assisted steering system fails, it is possible to steer the vehicle mechanically like a normal steering system. Hydro−spindle and hydraulic cam−and−roller steering systems are very often combined.

Pneumatic power−assisted steering works on a similar principle to hydromechanical power−assisted steering. In this case when the drop arm is moved it operates a control valve which then opens the way to left or right side of the working piston.

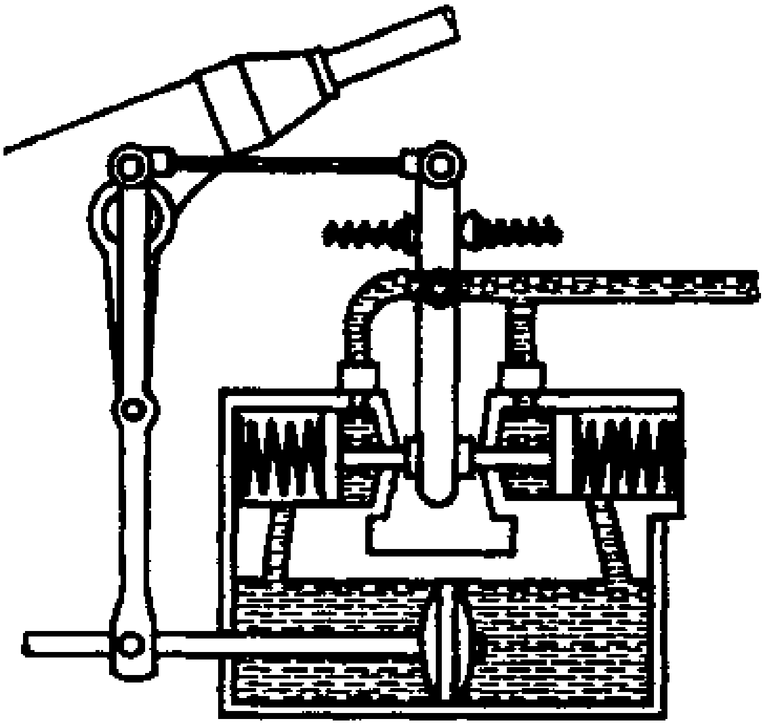


Figure 4/13 Pneumatic power–assisted steering system

The resulting force, which acts on the piston by means of compressed air, is transmitted by a linkage to the drop arm and facilitates steering. The compressed air is taken from the compressed air reservoirs in the vehicle's brake system (Fig. 4/13).

All–hydraulic power–assisted steering differs essentially from all the power–assisted steering systems mentioned above. It does not have a rigid connection between the drop arm and the steering wheel, i.e. there is no linkage in the form of a steering column.

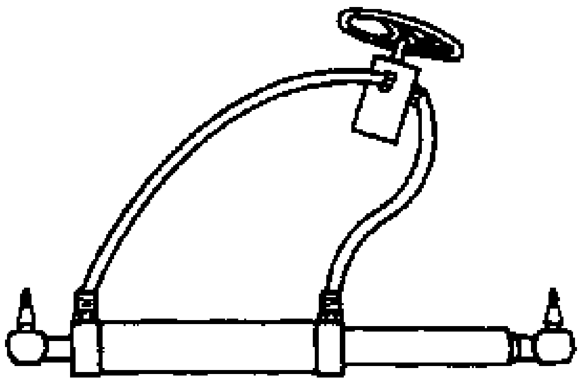


Figure 4/14 All–hydraulic power–assisted steering system

The steering wheel is coupled with a valve which transports the hydraulic oil in the same direction as the steering wheel. The oil is forced through the piping by means of a special hydro–pump. With this system very little effort is required, but should any part of the power–assisted system fail, the vehicle will be rendered unmanoeuvrable (Fig. 4/14).

4.4. Defects and wear of steering systems, and their elimination

As can be seen from the description of the individual steering gear types above, they are all subject to different degrees of wear. The surfaces of steering worms, and the moving parts which mesh with them, become hardened. Their supporting surfaces are formed of only a thin hard layer which is easily damaged by the application of force. Dents then develop causing irregular movement of the steering wheel. The roller bearing within the steering system may wear out, after which the steering motion can no longer be guaranteed. Due to wear, after a certain period of time it is no longer possible to readjust the steering. Then the components of the steering system have to be replaced to ensure safety again. Since different parts of the steering system are subject to different degrees of stress, they also wear at different rates. Wear is most obvious at the ball heads of the steering track rods, as these are subjected to the most stress due to the strain from the wheels. They wear out in the ball cup and track−keeping can no longer be guaranteed. The vehicle tries to break away. Wobbling and shocks at the steering wheel increase. The angle of play at the steering wheel should be about 15°. If it becomes too largy the steering system has to be readjusted. Prom time to time the toe−in has to be checked to keep wear of the front axle as low as possible.

Test questions:

4.1. Outline the purpose and the function of vehicle steering systems.

4.2. Describe the general structure of a steering system.

4.3. What do you understand by fifth−wheel steering?

4.4. Describe the structure of a stub axle steering system.

4.5. What types of steering gears do you know?

4.6. What measures must be taken while working on steering systems and their components?

4.7. Describe the structure and the mode of operation of a finger−type steering system.

4.8. Describe the structure of a rack−and−pinion steering system.

4.9. What are the functions of power−assisted steering systems?

4.10. Describe the structure and the mode of action of a pneumatic power−assisted steering system.

4.11. Describe the structure and the mode of action of a hydraulic power−assisted steering system.

4.12. What do you understand by an all−hydraulic power−assisted steering system and how does it work?

5. Wheels and tyres

Wheels and tyres are among the most stressed parts of the vehicle. They must absorb all the different forces which may occur between the road and the vehicle. Furthermore they must withstand the frictional heat which is generated by flexing of the tyres and friction between brake drum and brake lining during braking. The condition of the tyres ensures safe driving on all road and weather conditions.

The condition of the tyres and the fit of the wheels on the axles have a great influence on road safety.

Tyres are standardised and are marked uniformly throughout the world. Tyre dimensions are generally given in inches, but they may also be indicated in metric measurements. Normally, tyre sizes are given as two numbers, separated from by a dash or a letter.

Examples of tyre designations:

Designation	Explanation
4 1/2 J x 13	Wheel with well−base rim, tyre width 4 1/2 inches, J−type flange, rim diameter 13 inches
W 10 x 38	Wheel with wide base rim, tyre width 10 inches, rim diameter 38 inches
6.5 – 20	Wheel with tapered bead rim, tyre width 6.5 inches, rim diameter 20 inches
6.75 x 22.5	Wheel with 15° tapered rim, tyre width 6.75 inches, rim diameter 22.5 inches

5.1. Wheels and rims

Vehicle wheels have developed from wooden spoked wheels via cast wheels to the sheet metal disc wheel of today. This is the most commonly used wheel in motor vehicle engineering at the present time. The wheel must be able to resist and transmit all forces which act between the road and the vehicle. The following essential demands are made on the vehicle:

- adequate rim stability
- firm fit of the tyre on the rim
- firm and secure connection with the wheel hub
- good dissipation of frictional heat
- adequate space for accomodating the brake system

The following travelling comfort is demanded:

- vertical and lateral impact must be as small as possible
- unbalance at circumference must be kept low
- attractive design
- simple fitting of tyres to the rim and of wheel to the hub

Production should be based on the following:

- low production price
- long service life
- low weight of the rim and small mass moment of inertia

Wheels can be distinguished by the materials used for production and the design. Five of the most common types are listed below:

- wire–spoked wheels
- sheet metal wheels, double wall welded
- disc wheels
- cast light metal wheels
- cast steel wheels

The wheel of the vehicle consists of the wheel hub, spokes or disc and the rim, which can be of varying shapes. Rim shapes are shown in Fig. 5/1. Fig. 5/2. shows the most common types of rims used in lorries (commercial vehicles).

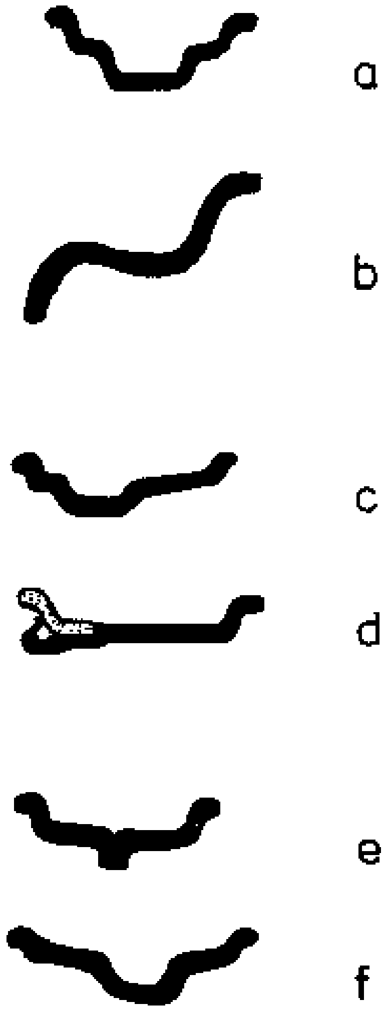


Figure 5/1 Wheel rim shapes

a) well−base rim, b) rump rim, c) asymmetrical rim, d) tapered bead seat rim, e) wide base rim, 15 tapered rim = f)

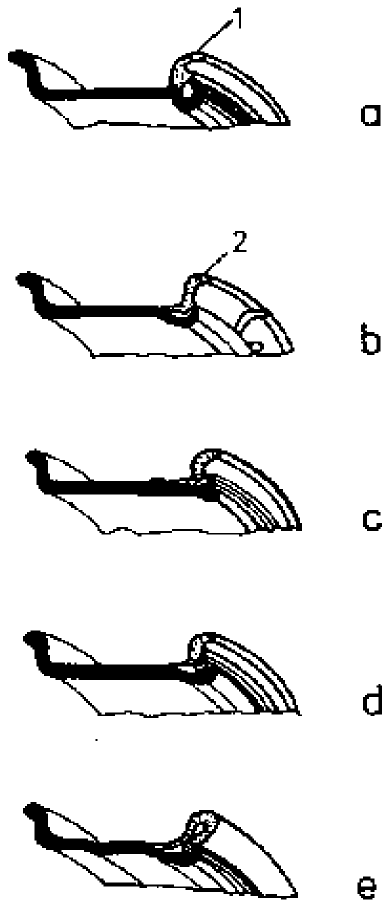


Figure 5/2 Rim types

a) flat base rim type 80 (with side ring 1), b) tapered bead seat rim type LS (with retaining ring 2), c) tapered bead seat rim type R 5 Firestone–Kronprinz system, d) tapered bead seat rim Lemmerz–system, e) tapered bead seat rim type AR

With regard to the rim base two types are distinguished:

– wide base rim
– well–base rim

The wide base rim is in sections to allow easy fitting and removal of the tyre. It can either be halved along its circumference, or divided by a detachable wheel ring with locking spring. If it is to be divided along the circumference the two rim halves are connected and held together by bolts. Tapered bead seat rims are similar to wide base rims. They are used for heavy lorries. Pitting the larger and stiffer tyres used for these vehicles makes the devision of the rim necessary, and so the rims are divided into two or three sections. There are different ways of dividing them. The centrally divided simples wheel and the triplex wheel are used. This triplex wheel is divided three times along its circumference, but each ring is a closed section.

The tapered bead seat rim has virtually replaced the wide base rim in motor vehicle engineering. Its advantage in comparison to the wide base is that the bead seat inclines 5° to the rim flange. The bead of the tyre is pressed onto the tapered bead seat rim by the tyre pressure. In this way the tapered bead seat rim and the flange prevent the bead from tipping. Fig. 5/3 shows a tyre fitted to a tapered bead seat rim.

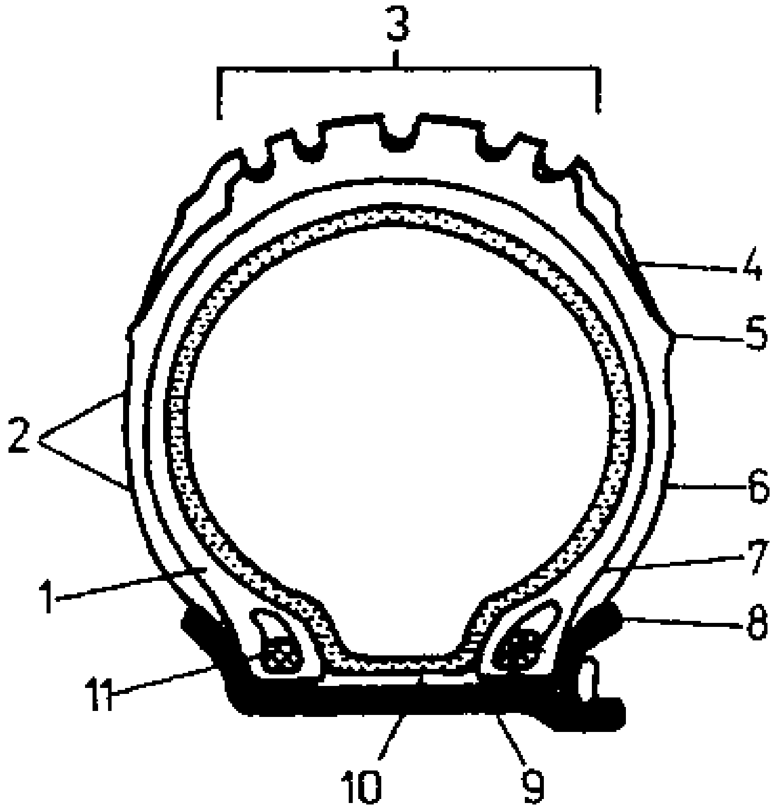


Figure 5/3 Tyre with tapered bead seat rim

1 fabric body, 2 flexing section, 3 tread, 4 shoulder, 5 tyre side wall, 6 side rubber, 7 bead, 8 rim flange, 9 tapered bead seat, 10 clincher, 11 bead core, 12 inner tube

For vehicles up to about 5 tonnes pay weight disc wheels are mainly used.

Steel wires, known as bead cores, run around the circumference of tyres. These steel wires are closed and not ductile. In the well–base rim this recess helps in fitting the tyre. The tyre and bead are pressed into the well–base at one side, and then pressed inwards or outwards across the rim flange on the opposite side. The tyre is always pressed into the well–base at the opposite side to the valve.

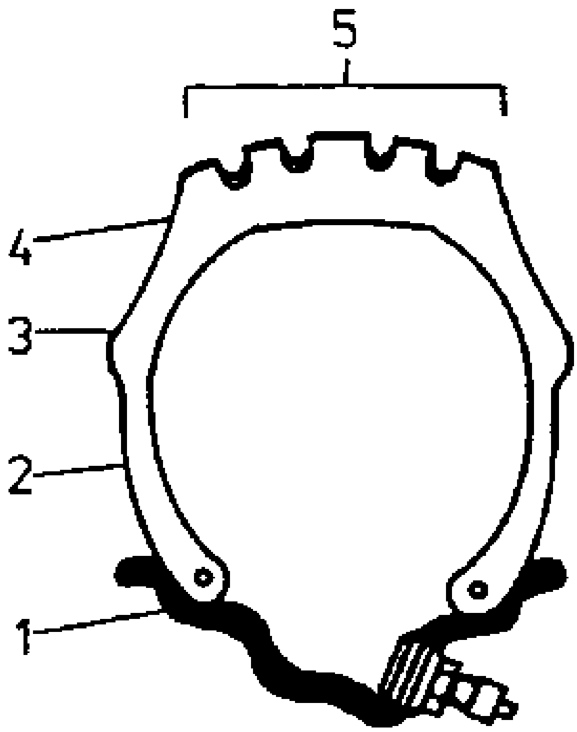


Figure 5/4 Tubeless tyre

1 rim flange, 2 side rubber, 3 tyre side wall, 4 shoulder, 5 tread

In passenger cars the wheel rim can have a 'hump' at the shoulder which prevents sudden air losses in tubeless tyres on tight bends and when air pressure is low. A tubeless tyre is shown in Fig. 5/4.

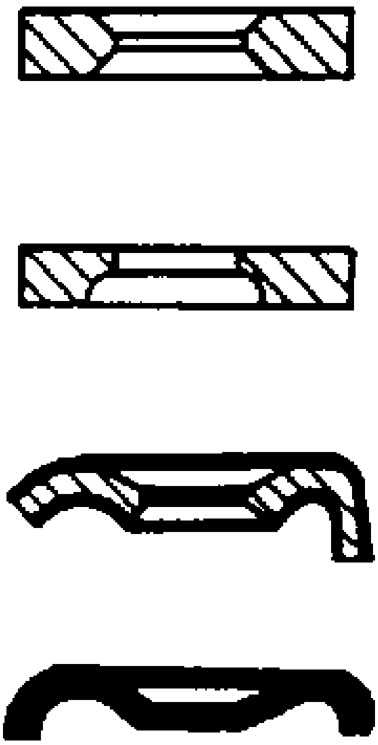


Figure 5/5 Types of rim mounting holes

Asymmetric rims are used in agricultural machines and construction machinery. These vehicles manly have rims with a broadened well−base. They are also called wide−base rims. In order to gain more space for the brakes the well−base is shifted asymmetrically to the outer rim flange. The 15 tapered rim is undivided, but has a particularly strongly inclined bead. The inclination is 15°. This type of rim is used in lorries. The rim is linked to the wheel hub by the wheel disc, but it is disconnectable. The rim diameter must always be larger than the wheel hub diameter. In the wheel disc there are clearance holes which are standardised. In Fig. 5/5 these clearance holes are shown.

When mounting the wheel at the wheel hub you must ensure that the wheel nuts correspond to the clearance holes so that the wheel fits firmly and safely.

Then wheel nuts can loosen when stressed and loaded. Centring of the wheel on the wheel hub can be done either by means of the wheel nuts or centring pins. Another method of centring is the use of a centre hole in the wheel disc. Holes and slots are made in the wheel disc to cool the brakes. The wheel nuts and the axle nuts can be covered by a hub cap.

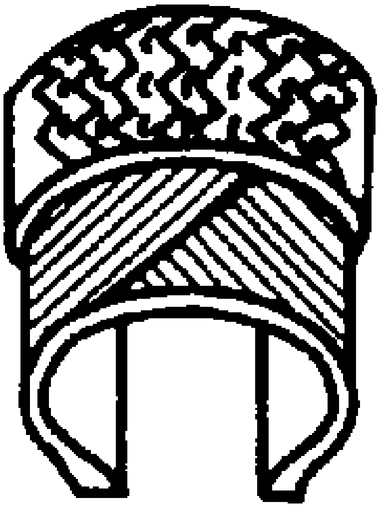
5.2. Tyres

The tyres of the vehicle are intended to moderate the effects of uneven road surfaces, to improve the driving qualities and to make high speeds possible by low ground friction. Today pneumatic types are used exclusively.

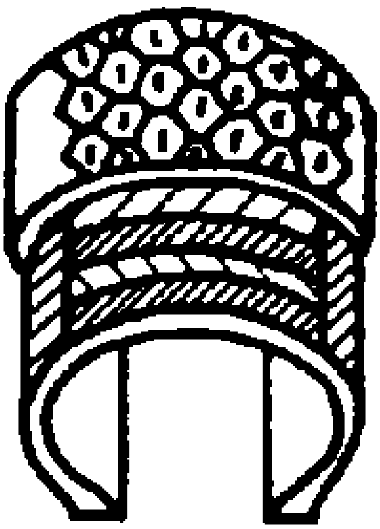
The rubber tyre tread is to guarantee that the tyres have a good road grip and protect the vehicle against skidding and side−slipping. To obtain a good road grip various tread patterns are available. The term 'tyre' includes the rim band, the tube and the tyre. The rim band is put between the rim and the tube to prevent friction between them. Such friction would lead to the premature destruction of the tube. The tyres used in modern vehicles are mostly low−pressure tyres. They are elastic and tend not to sink into the ground. The tread pattern should guarantee a good grip on the road. The lateral grooves on the tread help to prevent skidding, and the transversal grooves improve motion. Grip can be improved by narrow lateral and transversal grooves. Pneumatic tyres consist of several rubberised cord plies and the rubberised tread. These two section are connected by vulcanisation, i.e. heat treatment under pressure.

Figs. 5/6, 5/7 and 5/8 illustrate sections of the most common types of tyres. The plies in Fig. 5/7 are made of steel cord and lie on a textile cord radial carcass. By using steel cord in the belt the serviceability is further increased. Steel cord is also used in the belts of radial tyres.

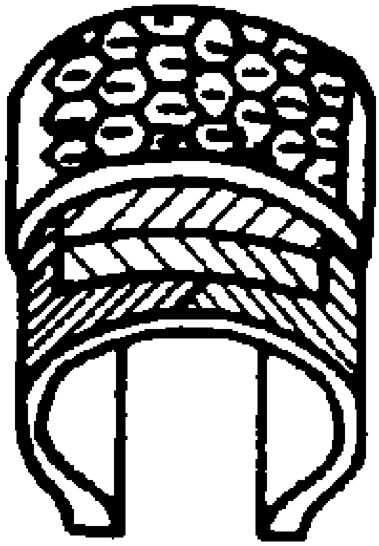
Figure 5/6 Types of tyres



a) conventional diagonal tyre with diagonal threads on the fabric body



b) radial tyre (braced−tread tyre) with radial threads



c) semi−radial tyre with diagonal threaded fabric body and surrounding belt

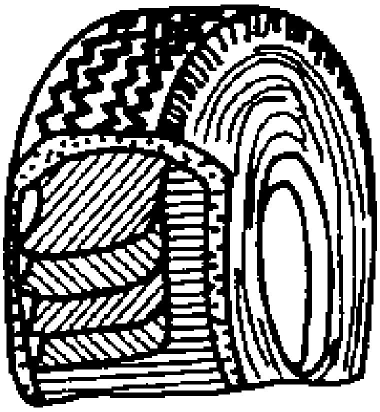


Figure 5/7 Radial tyre

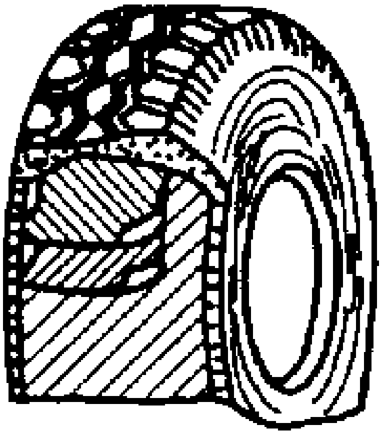


Figure 5/8 Semi−radial tyre

Designation of tyres

There are two types of tyres, high−pressure and low−pressure tyres. The difference is due to the different number of plies inside the carcass. In both types the tyre inflation pressure is between 0.07 and 0.28 p.s.i..

The inflation pressure necessary for the tyre is indicated by the manufacturer. The symbol between the two numbers (x for high−pressure, − for low−pressure) serve to make a distinction possible. The first number on the side wall of the type indicates its width, and the second number the rim diameter. Both dimensions are given in inches. The examples below illustrate these: 5.50 x 16; 6.50 − 19.

The table shows extracts from the technical data for various tyre sizes:

Designation	**dia. mm**	**Tyre width mm**	**Inflation pressure p.s.i.**	**Load−carrying capacity kg**	**Required rim**
Motorcyles					
2.50−19	625	65	0.13	160	2 x 19
3.25−19	667	85	0.13	210	2 1/2x 19
3.50−19	672	91	0.13	225	3 x 19
Cars					
4.50−16	645	118	0.14	300	3.00 Dx 16
5.50−16	695	147	0.14	450	3.50 Dx 16
6.00−l6e	720	158	0.15	550	4.00 Ex 16

Lorries					
7.25–20e	880	176	0.37	1200	6" – 20 L
6.00Tr–20	834	156	0.26	790	5" – 20 L
7.00Tr–20	874	174	0.30	1020	5" – 20 L

The above table serves as an example.

In addition to these two figures each tyre carries another figure which indicates type and use. As an example the identification letters of car tyres is given below. On lorries radial tyres are marked with an 'R' instead of a dash, for example: 8.25 R 20.

Designation	Example	Explanation
S or H instead of dash	5.90 S 13 5.90 H 13	Tyre suitable for high (S) or very high (H) speeds. Maximum speed depends on rim dia
SR instead of dash	165 SR 13	Radial tyre with maximum permissible speed of 180 km/h.
HR instead of dash	185 HR 13	Radial tyre suitable for more than 210 km/h.
VR instead of dash	165 VR 15	Radial tyre suitable for more than 210 km/h.

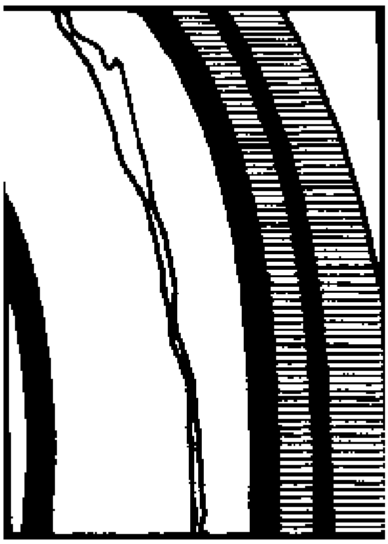
The permissible maximum speeds of other tyres cannot be seen from their designation. They are specified in the manufacturer's tyre catalogue. Further specifications found on tyres are:

4 PR = ply rating; this figure is not necessarily identical to the number of plies. It specifies the strength of the carcass. The word tubeless is self–explanatory.

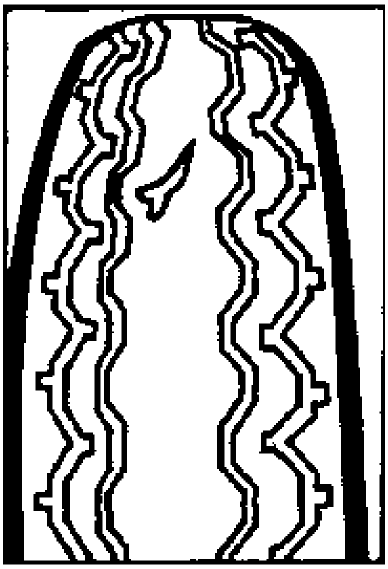
AS and AS–front are the specifications for tractoe tyres. AS for drive wheels and AS–front for non driven wheels; eg.

5.3. Tyre damage and defects

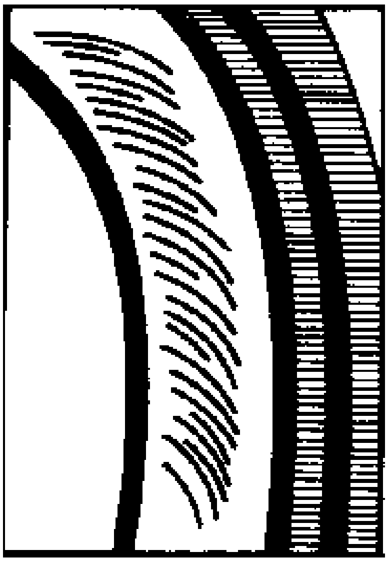
Figure 5/9 Tyre damage



a) due to overloading



b) due to excessive inflation pressure



c) due to insufficient inflation pressure

In Fig. 5/9 several types of tyre damage are shown. Tyre damage may develop due to non−compliance with the specifications given by the manufacturer, for example correct in inflation pressure or exceeding of the maximum permissible speed limit. Damage to a tyre side wall is shown in Fig. 5/9a. It develops due to overloading. This can be caused by overloading of the vehicle and exceeding the load−carrying capacity of the tyre.

The tyre damage in Fig 5/9b is due to excessive inflation pressure. The total weight of the vehicle and its load are supported by the tyres. For this reason, each tyre is given a specified inflation pressure, according to its size and intended load−carrying capacity, which must not be exceeded. If the inflation pressure is exceeded, the tread becomes damaged and the service life and mileage capacity are reduced.

In Fig. 5/9c the casing plies of the side walls have been damaged by insufficient inflation pressure. Due to the load, the tyre is compressed at the point where it comes into contact with the ground, and it starts to spring. If the inflation pressure is constantly too low, springing can lead to the destruction of the carcass. To increase the service life of the tyre it is necessary to check the inflation pressure regularly. If the vehicle is driven at a very high cruising speed, the tread becomes overheated. The rubber gets warm and peels away from the carcass. If a vehicle passes too quickly over sharp obstacles, punctures may occur, rendering the tyres unserviceable. If the wheel camber, toe−in and brakes are adjusted incorrectly, the tyres will rub and will wear quickly. Defective shock absorbers can be recognised by irregular wear of the tyre tread.

5.4. Rim damage and defects

The rim is subject to little wear. It occurs due to incorrect driving techniques and wheel nuts which are not correctly tightened after wheel changing. Incorrect driving techniques include the following:

Driving the vehicle at impermissible speed over raised edges, which can damage the rim edges.

Driving the vehicle at too great a speed over uneven road surfaces and potholes, which can damage the rims.

Incorrect fitting and removal of the tyre can damage the rim flanges and in turn also the tyres.

If the wheel nuts are not tightened correctly, the mounting holes in the wheel disc become deformed and the wheel no longer fits firmly to the wheel hub; this means that the road safety of the vehicle can no longer be ensured.

As the rims are constantly subjected to the influence of weather, corrosion may occur.

5.5. Influence of the condition of the tyre on road safety and petrol consumption

As explained above, the tyres of a vehicle are very important as improper maintenance and driving technique can have a considerable effect on their service life. The driver should consider the following points in order to increase the service life of the tyres:

– Lubricants and oils can damage rubber tyres, and must be removed from them immediately.

– It is possible that stones may become lodged between twin tyres – this will cause friction and so damage the tyres.

– The wheels of a vehicle must be examined regularly, as damage will lead to increasing tyre wear and petrol consumption.

The state of the tyres is of great importance for the road safety of the vehicle and for the service life of the tyres themselves. The <u>depth of tread</u> of a tyre should never be less than <u>1 mm</u>. If this should occur, the grip of the tyre on the road will be insufficient, and an accident may result. If the road is wet, the grooves in the tread will not be able to carry off enough water, a film of water will develop between the tyres and the road surface, preventing the vehicle from gripping the road correctly. It will start to 'drift' and will no longer be safe. This state is also called aquaplaning because the vehicle will leave the intended direction at the slightest steering movement. This may cause accidents and personal injury. If the tread depth is too small, the vehicle stopping distance is also affected. Since static friction is no longer completely ensured, the vehicle stopping distance is increased.

The diagram in Fig. 5/10 again illustrates the service life of the tyre in relation to inflation pressure.

With increasing age and mileage, the crown of the tyre becomes smaller and so the speed decreases. In order to reach the same speed as could be reached with new tyres, the performance of the engine has to be increased, and this can only be achieved by higher petrol consumption. If tyre inflation pressure falls below the value specified, the result will be the same as the effect of wear. Both examples demonstrate the fact that tyres influence petrol consumption. To ensure the efficiency of the vehicle the tyres should be checked regularly.

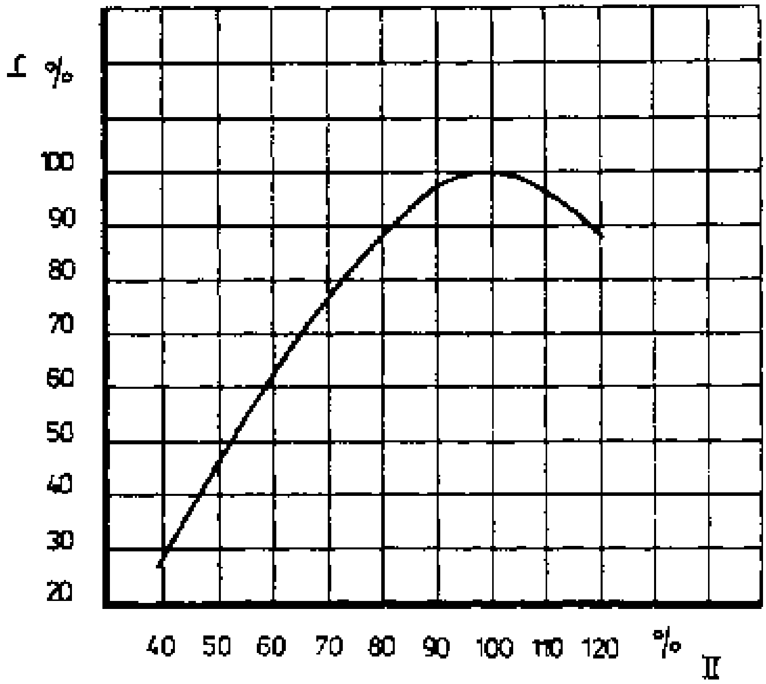


Figure 5/10 Importance of inflation pressure to tyre service life

I service life, II inflation pressure

A further increase in the service life of the tyres can be achieved by balancing the wheels. Due to their production, tyres and rims run unevenly. This unbalance has the following effects on road safety:

– Road grip is reduced by wheel wobble and vibrations.

– Steering of the front wheels is affected by wheel wobble.

– The centrifugal forces caused by the unbalance, which work outwards in constantly changing directions, cause excessive stress on the wheel bearings and steering components. Thus they shorten the service life of the components.

– Tyre wear is increased by improper run of the wheel.

Test questions:

5.1. Describe the design of a wheel.

5.2. What do you understand by a tubeless wheel and a wheel with a tube?

5.3. What rim forms do you know?

5.4. Describe a taperd bead seat rim.

5.5. Describe the fitting of a tyre to a well–base rim.

5.6. Explain the function of the wheels and the tyres.

5.7. What main demands are made on the wheels?

5.8. List the most common types of wheels.

5.9. What do you understand by a wide base rim? Give some examples.

5.10.What do you understand by a well–base rim?

5.11. What do you understand by the term 'tyres'?

5.12. What is the function of tyres on a vehicle?

5.13. What types of tyres do you know?

5.14. What types of tyre damage do you know? Give the reasons for them.

5.15. Name the factors which affect the service life of tyres.

5.16. What effect does the condition of the tyre have on the road safety and petrol consumption of a vehicle?

5.17. Give reasons for the necessity of balancing the wheels.

6. Brakes

6.1. Functions of the brakes

The brakes are an essential safety element of the vehicle. They are intended to reduce the speed of the vehicle (if necessary to bring it to a standstill) or to prevent the vehicle from rolling away.

The following brake systems are distinguished according to their function in the vehicle:

Service brake system	– to reduce the speed, if necessary to a standstill.
Auxiliary brake system	– an emergency brake in case of failure of the service brake system.
Parping brake system	– to prevent a parked vehicle from rolling away.
Retarder system	– to keep the speed of vehicles of more than 5 tonnes constant on long gradients. Also called the engine brake system.

6.2. Operating principle and types of brakes

Friction brakes are used exclusively in vehicles. A friction body is pressed axially or radially by a mechanism against a drum or disc. These are firmly connected to the wheels. The speed of the vehicle is reduced, if necessary to a standstill, by the developing friction. Kinetic energy is converted into heat energy, which depends on the speed to be reduced, the period of braking and the weight of the vehicle. In modern vehicles two types of braking systems are distinguished:

– drum brakes
– disc brakes

For a long time, drum brake systems were used on almost all vehicles. However, for some time disc brakes, which can also be combined with drum brakes, have been used more often. Both types of brakes can be operated mechanically, hydraulically–pneumatically. The brake is operated by the driver by foot or by hand. Manual brakes are used mostly in vehicles for disabled persons. These vehicles must be specially equipped for the purpose.

The following demands are made on the service brake:

– The shortest braking distance shall be achieved in the shortest possible time between actuating the brake and stopping the vehicle.

– To avoid premature blocking of one of the two axles, it is necessary to distribute the braking force according to the axle load displacement.

– The forces which have to be applied to operate the brake should be as low as possible. This can be achieved air pressure brake servo systems, vacuum brake servo systems, hydraulic pumps etc..

– In case of successive stop braking or continuous braking on long gradients, maximum deceleration should be maintained if possible.

The following demands are made on the brake system of a vehicle:

1. Vehicle must have two braking systems acting independently of each other, e.g. the service brake and the parking brake, or a braking system with two operating devices which work independently of each other, i.e. a main brake and another one which can be operated if the first fails.

2. The independent operating devices must have separate transmission systems on different braking surfaces, these can however be in or on the same drum.

3. If more than two wheels can be braked, common braking surfaces and common transmission systems (total or partial) can be used.

They must be constructed in such a way that if one component breaks at least two wheels, which are not on the same side, can be braked.

4. All braking surfaces must act on parts which are not disconnectable and which are connected positively with the wheels.

Brake linings

Materials such as asbestos and cotton combined with steel, aluminium or brass chips, are used predominantly as brake linings. These materials are impregnated with a binding agent and then dried out. The brake linings produced in this way are then glued or rivetted to the brake shoes. The rivets used for this purpose must be corrosion– and heat–proof to ensure full efficiency. These requirements also apply for the glue and the brake lining itself.

The brake lining should meet the following requirements:

– it must be able to withstand a contact pressure of about 1.2 N/mm^2
– the ends of the brake lining must be bevelled to avoid rattling and blocking of the brake shoe
– while operating the brake, the brake lining should lie completely on the brake shoe
– it must withstand temperatures of up to 400°C and wear little under normal service conditions.

As already mentioned, drum brakes are still one of the most common types of brakes used today. They are also called internal shoe brakes. Here the brake shoes are pressed against the drum, which is the most important component of the drum brake. There are different brake shoe arrangements in this brake type.

Simplex brake

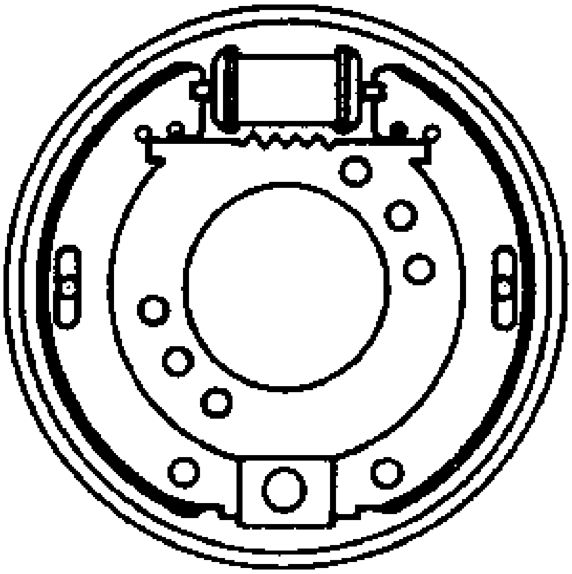


Figure 6/1 Simplex brake

The simplex brake is the most simple design among the drum brakes.

Two brake shoes work a brake anchor pin. They are pivoted on a shoe cap bolt. While braking, the front brake shoe (in direction of movement) is driven by the rotating drum and overruns the shoe cap bolt. This is also termed the leading or primary shoe, and the process is known as self−energisation. The second brake shoe is called the second or trailing shoe and is self−attenuating. The simplex brake (Fig. 6/1) is used mostly on rear wheels. When a vehicle is reversed, the functions of the primary and secondary shoes are reversed.

Duplex brake

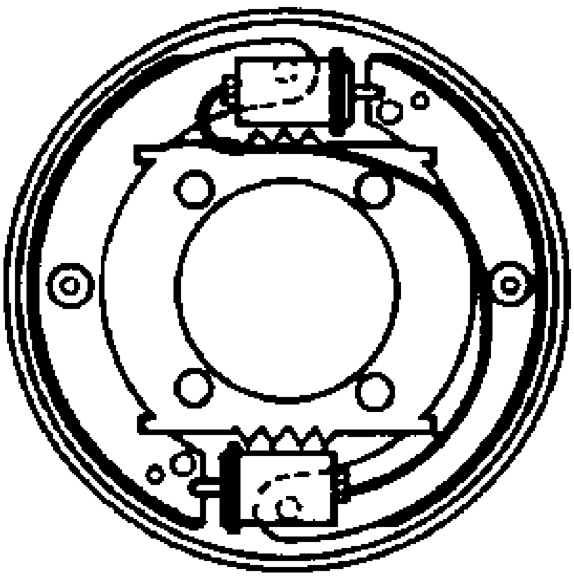


Figure 6/2 Duplex brake

The main characteristics of the duplex brake (Fig. 6/2) are its two wheel mounted brake cylinders. Each brake shoe is combined with such a wheel mounted brake cylinder. In this kind of brake, both brake shoes become primary shoes, and so self−energisation is increased. This type of brake is equipped with automatic adjustment.

Servo brake

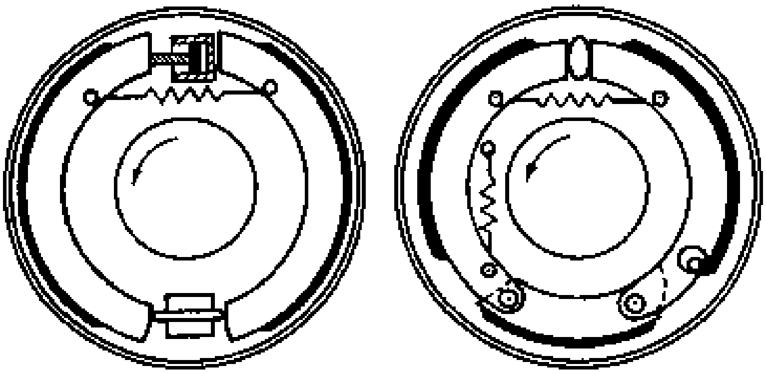


Figure 6/3 Servo brake

The servo brake (Fig. 6/3) consists of two or three brake shoes connected to one another at one pivoting point. When the brake is operated, the primary shoe puts the secondary shoe into operation via a spanner or a joint, and so the secondary shoe also becomes a leading shoe. This type of brake is also manufactured as a twin servo brake. This differs from the servo brake in that the brake cylinder operates bilaterally, i.e. both brake shoes spread at the same time. The disc brake is a more modern type of vehicle brake with a larger braking surface and therefore a better braking effect. Like drum brakes, the disc brake is a friction brake. Two types of disc brakes are distinguished, caliper−type disc brakes and internal−expanding clutch−type disc brakes.

Caliper−type disc brake

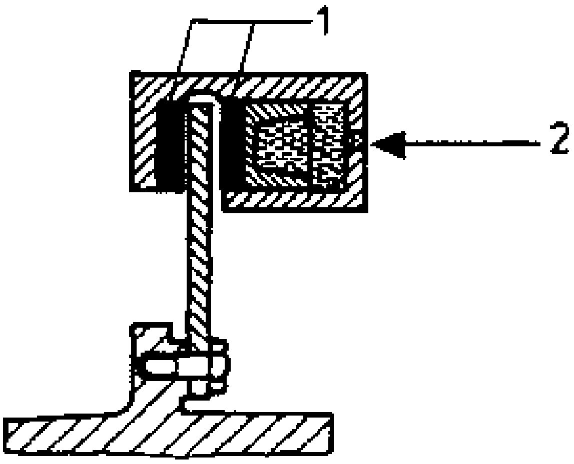


Figure 6/4 Floating caliper disc brake

1 friction lining
2 contact force

The brake anchor plate has two brake segments with brake linings. They act on both sides of the brake disc like tongs. They are set into motion by a brake cylinder which is operated by the brake fluid. There are two types of caliper−type disc brakes (Fig. 6/4) which can be distinguished by the form of the brake cylinder body. There are floating caliper disc brakes. In the floating caliper disc brake the brake cylinder anchor plate is movable. The hand brake system can be incorporated in the hydraulic actuator.

The fixed caliper disc brake has a fixed brake cylinder anchor plate and two pressure cylinders per caliper. For the hand brake either a special caliper or a drum brake can be used. (Fig. 6/5)

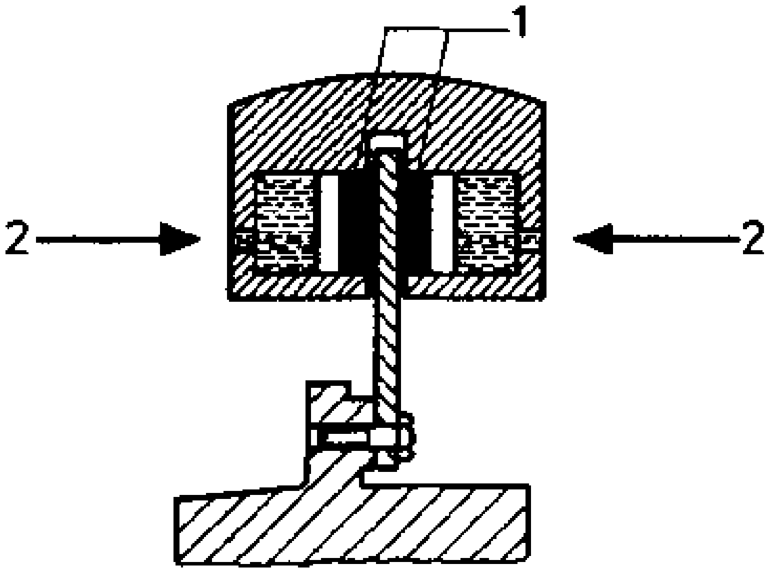


Figure 6/5 Fixed caliper disc brake

1 friction lining, 2 contact force

Internal–expanding clutch–type disc brake

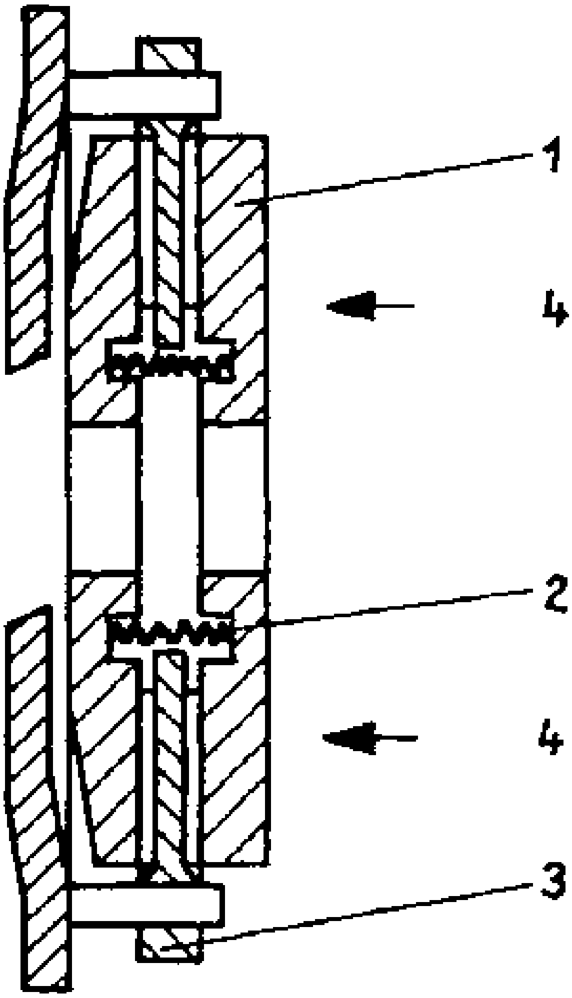


Figure 6/6 Internal expanding clutch–type disc brake

1 friction ring, 2 compression spring, 3 ring disc, 4 contact pressure

The internal–expanding clutch–type disc brake (Fig. 6/6) is used for lorries and tractors. Brake discs are pressed against a ring disc with a brake lining. With this type of brake, both pneumatic and hydraulic systems can be used. The lining is pressed by the pressure cylinder against the whole disc.

6.3. Mechanical braking system

Mechanical brakes are the oldest type of brakes. The force generated by foot or hand is transmitted to the brake shoes by means of a brake rods (Fig. 6/7) or a cable (Fig. 6/8).

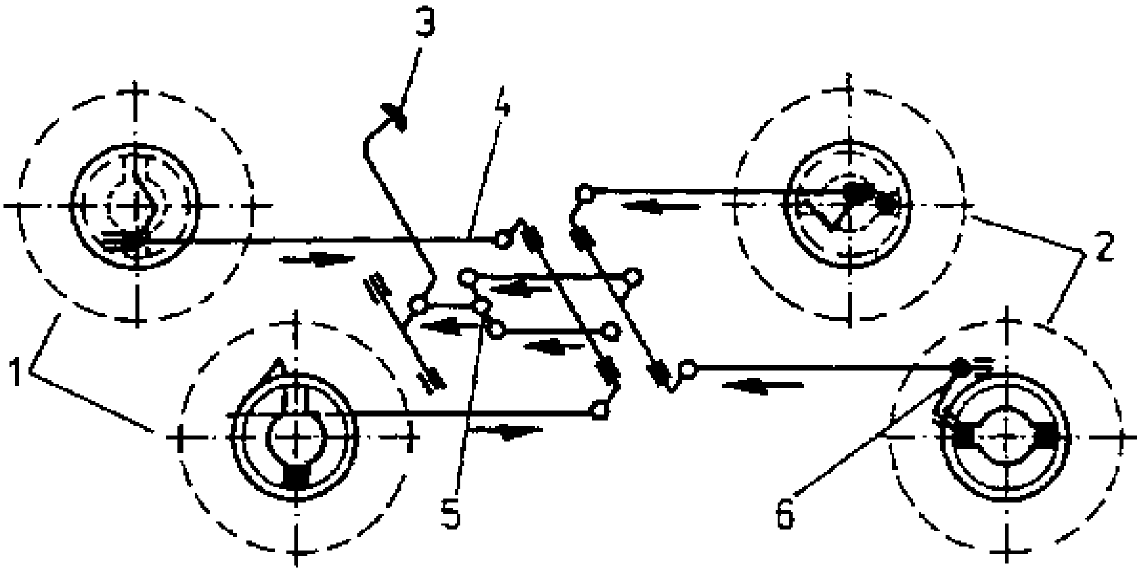


Figure 6/7 Mechanical brake with brake rods

1 front wheels, 2 rear wheels, 3 brake pedal, 4 brake rods, 5 brake compensator, 6 brake toggle lever

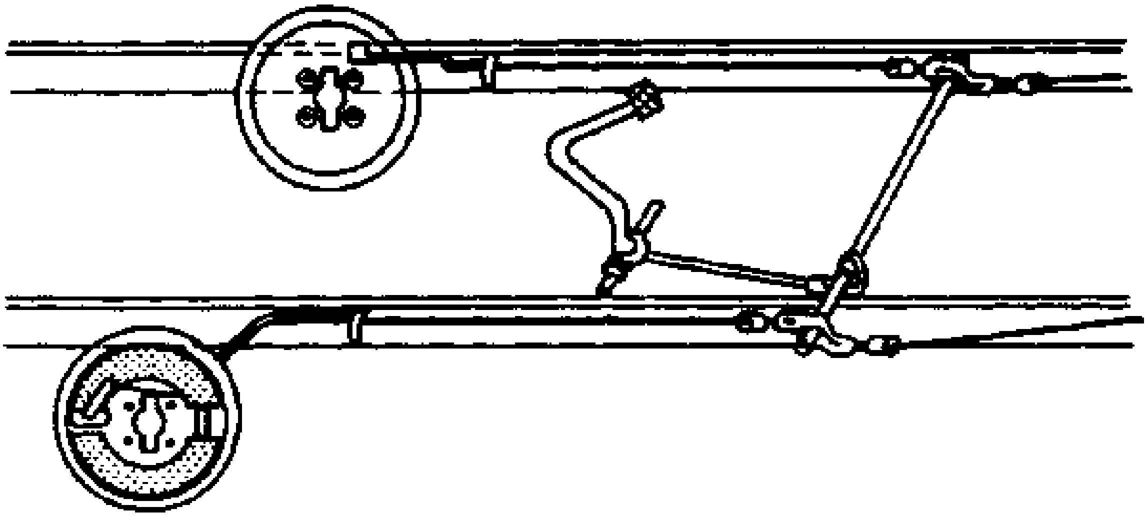


Figure 6/8 Mechanical brake with cable control

In modern vehicles the hand brake as a parking brake is a typical representative of the mechanical brake. The braking force is transmitted by a cable to the brake shoes. A skid sensor serves to distribute the braking force evenly on the front and rear axles. This sensor is also called a balance arm.

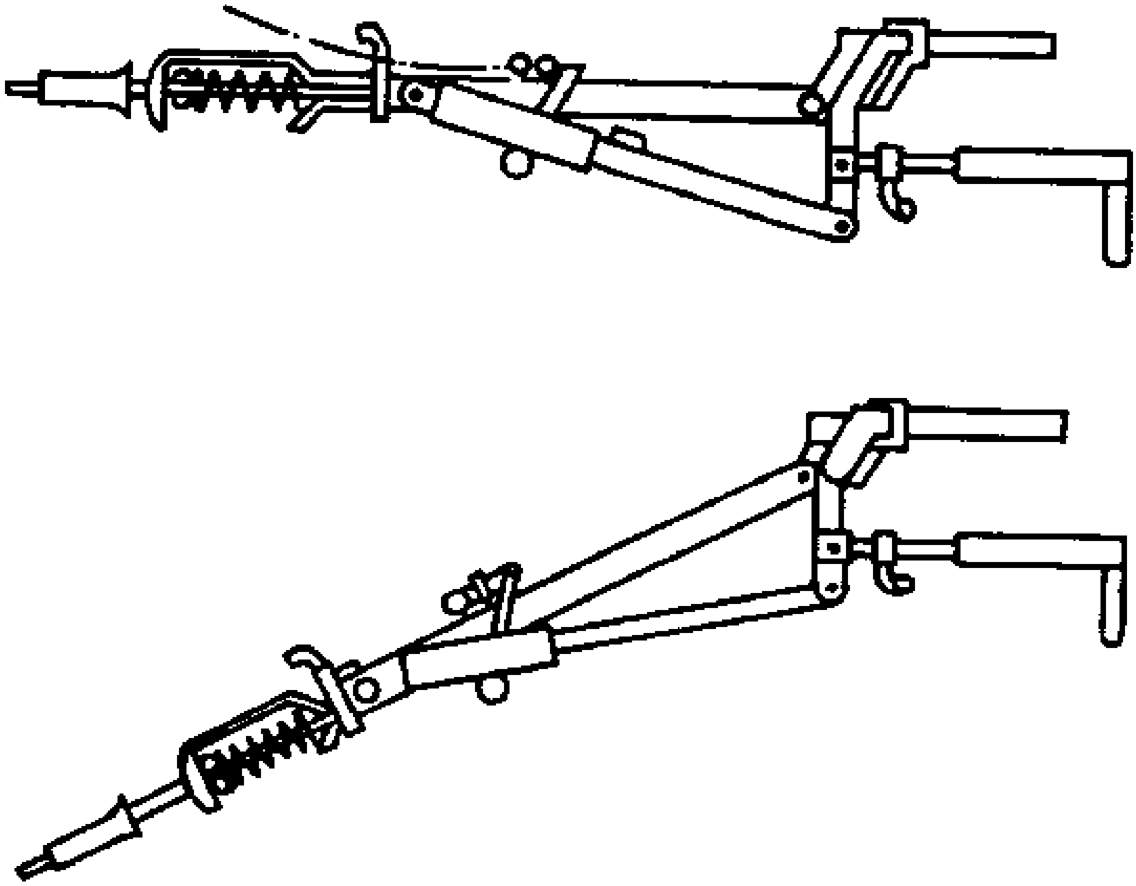


Figure 6/9 Over−run brake

The overrunning trailer brake shown in Fig. 6/9 is no longer widely used. When the brakes on a tractor unit are applied, the trailer runs up to it, the braking effect is transmitted to the brake shoes of the trailer wheels by a linkage in the tow bar and deceleration starts. This means that during emergency braking the trailer will move out of line with the tractor unit, causing a hazard to other traffic. Today this type of brake is only used in slow−moving vehicles. When the tow bar is lowered, this brake serves as a parking brake for the trailer.

6.4. Hydraulic braking systems

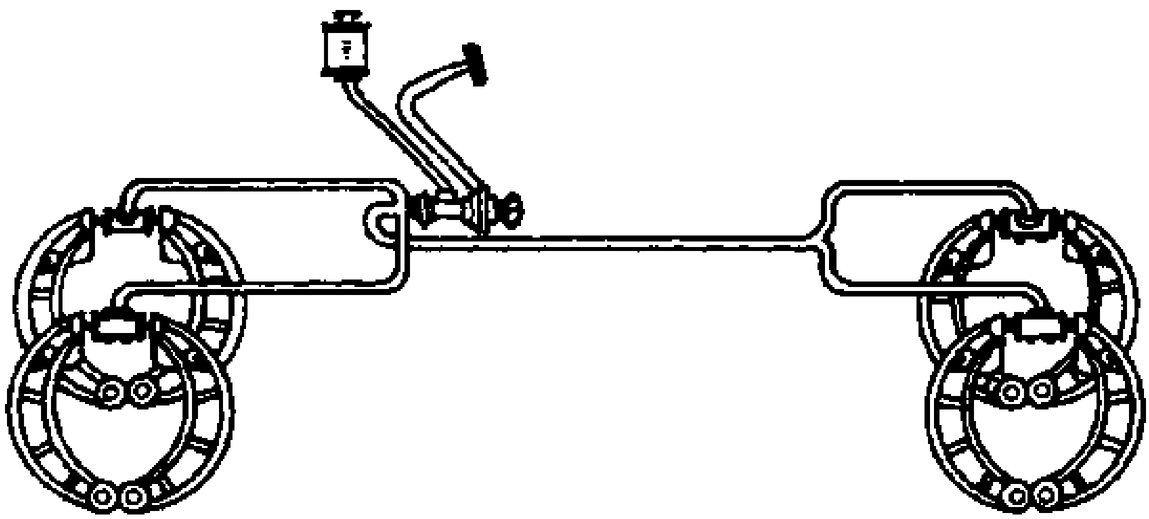


Figure 6/10 Hydraulic brake

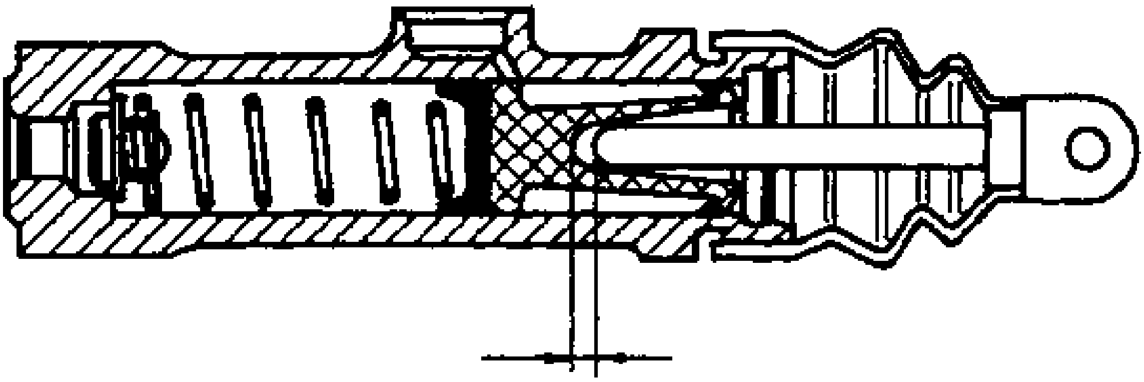


Figure 6/11 Main brake cylinder

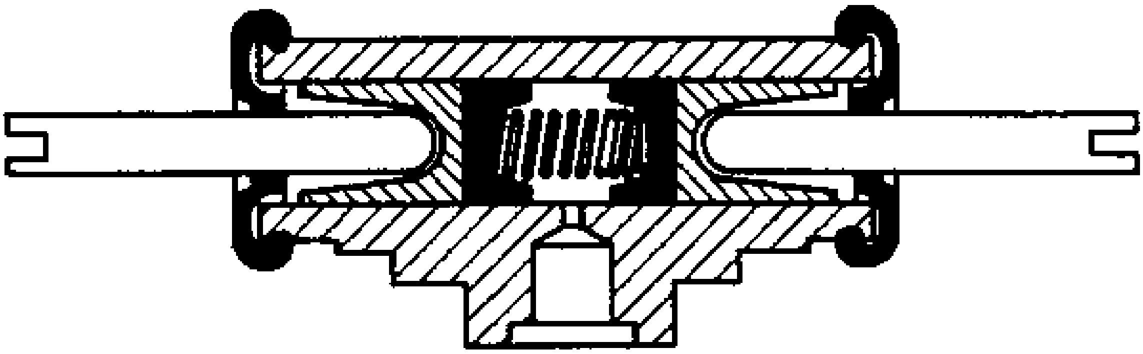


Figure 6/12 Wheel brake cylinder

With hydraulic brakes (Fig. 6/10) the braking force is transmitted by means of brake fluid. Joints, power−consuming sliding surfaces and balancing parts are not required. When operating the brake pedal, the brake fluid which is in the main brake cylinder with compensating reservoir (Fig. 6/11) is pressed into the brake lines. At the other end of the brake line are the wheel brake cylinders (Fig. 6/12) which produce the braking effect. Pascal's principle applies here. The principle states that when pressure is applied to any fluid, it is transmitted equally to all other parts of the fluid.

Hence it follows that the brake fluid ensures complete brake compensation. The brake lines are secured in rubber gaiters to prevent them being damaged by the frame. Where the brake lines pass the axle and the driven wheels, they are protected by rubber pressure hoses.

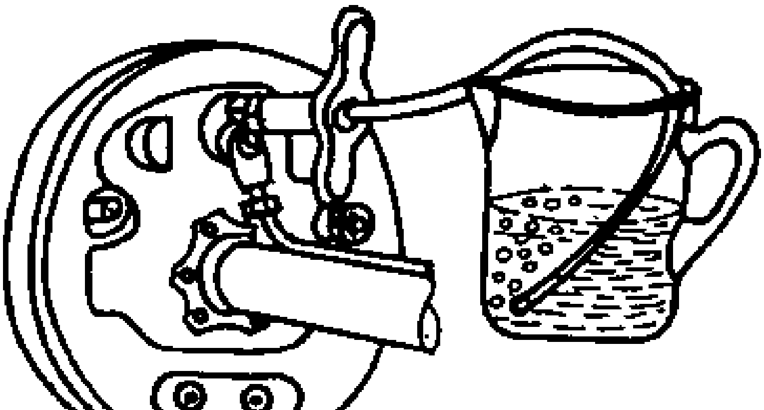


Figure 6/13 Bleeding the brake wheel cylinder

To ensure proper functioning, the brake system has to be bled. The process of bleeding a wheel brake cylinder is shown in Fig. 6/13.

Before bleeding, the fluid level in the compensating reservoir is to be checked, and during bleeding it must be constantly topped up. Bleeding is started at the point furthest from the main brake cylinder. The highest point should be bled last. The presence of air in the brake system becomes evident if the brakes need to be pumped in order to make them function correctly. Only after this pumping, which compresses the hydraulic brake system, the response time will be reduced. In extreme situations this may have grave consequences.

There are several bleeder screws at the brake calipers of the disc brake which have to be opened and closed according to the manufacturer's instructions while bleeding the system. To prevent any air from penetrating the bleeder screws during bleeding, a pipe is connected to them and put into a container filled with brake fluid. Then the brakes are pumped and the pressure is maintained. The bleeder screws are opened with a brake wrench and brake fluid and air may escape. This procedure has to be repeated at each bleeder screw until the brake can no longer be pumped. The brake pedal must be depressed until the bleeder screw has been closed. Having bled the whole system, the brakes must be tested to check that the individual wheels brake evenly. If necessary the brake shoes must be adjusted to ensure that the vehicle stays on track during braking. The vehicle will leave the track if the brakes on one side respond faster than those on the other side, or if a wheel locks.

Hydraulic brakes have to be flushed first with spirit and then with brake fluid to clean them. When repairing components of the brake system, the brake piston cups and brake cylinders are to be lubricated with brake grease before fitting. The wheel brake cylinders and the main brake cylinder as well as the brake lines have to be tested for leaks.

<u>Brake fluid</u>

Brake fluid is a synthetic fluid which transmits pressure during braking. It consists of a mixture of high−boiling alcohols, synthetic components such as glycols and their derivatives. This fluid is chemically indifferent to rubber and metal, and its properties change only slightly under temperature variations. This is vital since the brakes of a vehicle must work perfectly in the most varied temperature conditions. The brake fluid is non−ageing and non−corrosive. Its freezing point is approximately −65°C and its boiling point approximately 240°C to 290°C. Its disadvantage is that the brake fluid is hygroscopic, i.e. it tends to absorb water. This property makes it necessary for the fluid to be completely renewed after about two years, since the water will cause corrosion. High temperatures occur during braking and are transmitted to the brake fluid by the brake cylinders. If the water content is too high, bubbles will develop which have a negative effect on braking.

If a loss of brake fluid is noticed in the brake system, it is important to ensure that brake fluid of the appropriate classification is used for refilling. Not all brake fluids may be mixed.

If brake fluid comes into contact with paintwork of the vehicle, it must be removed immediately with water to avoid damage to the paintwork. The brake fluid causes the paint to become soft and flake off, thus allowing corrosion to occur.

6.5. Pneumatic braking system

With pneumatic brake systems, air at different pressures serves as the means of transmission of the braking force. Vacuum servo brakes, compressed air brakes and combined brake systems are all pneumatic brakes.

With <u>vacuum servo brakes</u> an additional force is generated by the vacuum in the engine induction line. This is used to support the action of the mechanical or hydraulic brakes. A vacuum brake booster is connected to the mechanical transmission elements in this system.

The compressed air brake system (Figs. 6/14 and 6/15) is fed by means of a piston compressor. It is driven by the engine of the vehicle and generates the operating pressure for the brake system. This operating pressure is limited to between 71 and114 p.s.i. by a pressure regulator incorporated in the system. If this pressure is reached the piston compressor is switched to idle running. This means that air pressure produced thereafter is blown off into the open air via a relief valve, if maximum pressure has been reached in the reservoirs. These reservoirs have a capacity of between 40 and 80 litres. There are two reservoirs to ensure that sufficient air is available for the brake to be operated frequently, and so that the engine does not have to idle for a long time in order to reach the operating pressure. When a pressure of 43 p.s.i. is reached, the vehicle is ready to drive. The pressure can be read at a pressure gauge in the driver's cab. This gauge shows the air pressure in the system and the brake pressure. The brake system of a vehicle consists of the piston compressor, the tyre inflator, the pressure regulator upstream of the first reservoir, the relief valve of the main reservoir, the brake pedal, the engine brake valve and the trailer brake valve as well as the wheel brake cylinders and the transmission lines which are connected to a double pressure gauge. There is another valve at the reservoirs to remove the condensed water from the system. The relief valve of the main reservoir does not open until the operating pressure is reached in the first reservoir. Both reservoirs are connected with the tractor unit brake valve. When operating the brake pedal, the feed line to the wheel brake cylinders is opened, the compressed air flows in and the braking effect is produced. At the same time the trailer brake valve is operated by a linkage and the trailer brakes are actuated by means of a feed line. The tractor unit and the trailer are connected by a coupling head and a pressure hose. When operating the brake, a vacuum develops in the trailer control valve which is coupled with a load sensitive brake pressure regulator. This causes the air to flow from the reservoir into the brake lines, and so braking is effected via the brake lines. After braking, the air used is discharges to atmosphere. The brake pressure regulator has to be set to the load of the trailer before starting. This must be done so that the trailer brakes before the tractor unit in order to avoid overrunning.

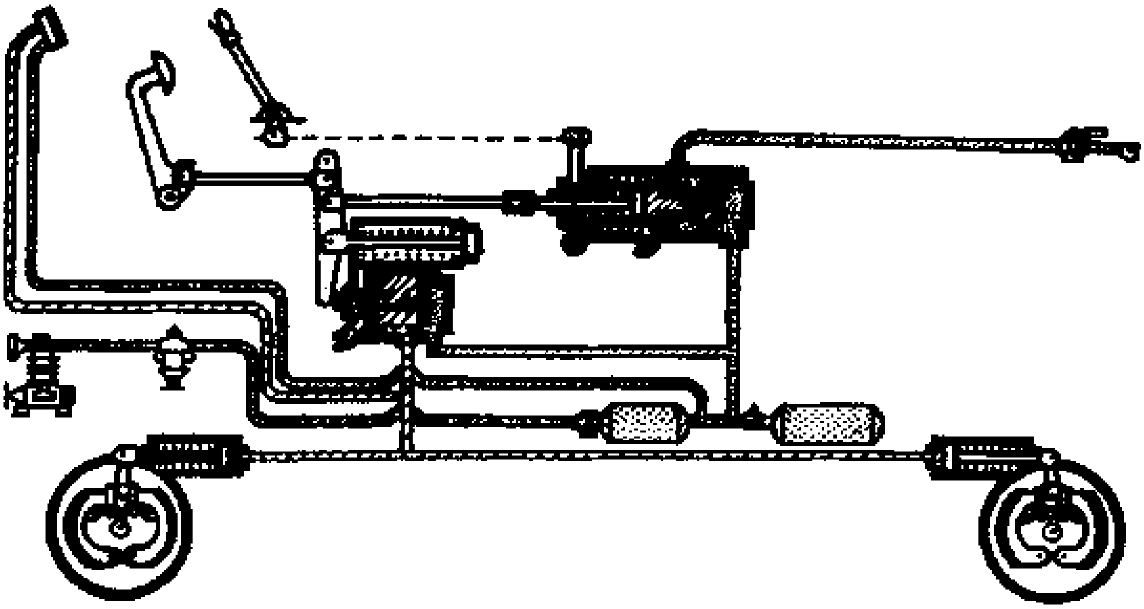


Figure 6/14 Pneumatic brake for motorised vehicles

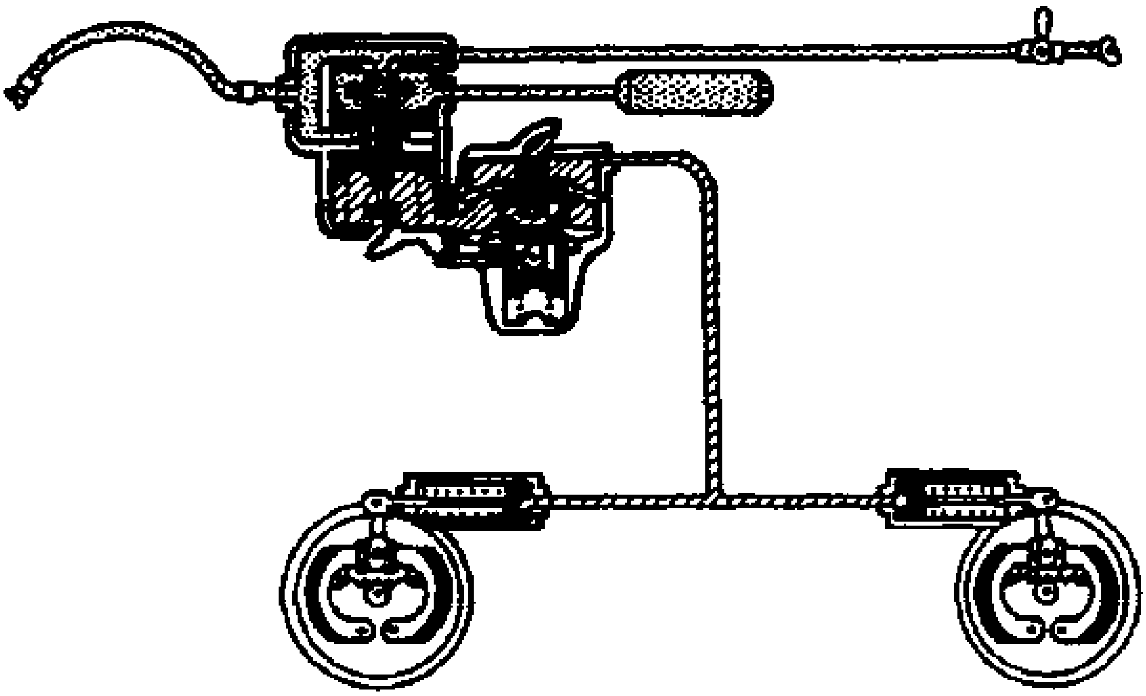


Figure 6/15 Pneumatic brake for trailers

The brake valves and the pressure regulators must not be adjusted or repaired by unauthorised persons if safety and service−ability are to be guaranteed.

Valves and pressure regulators have technical data determined by the manufacturer which must be adhered to. Repairs must be carried out in special workshops. Only the mechanical transmission components of the brake system may be adjusted. The pipes are made of seamless drawn tubular steel and are screwed together. They are cold bent with a bending tool. After repair the brake system is checked for leaks. This is done by putting the system under pressure and by covering the joints with a mixture of water and foaming agent. The presence of air bubbles shows the location of any leaks, and these can then be eliminated by retightening the joint concerned or by replacing the whole component. After repair the system must be checked for leaks again.

To avoid accidents it is important to ensure that any air pressure is released before starting work on the brake system.

If the tractor unit is moved or driven without the trailer, the shut−off valve has to be closed before the brake hose is removed from the coupling so that the compressed air cannot escape. The coupling line must also be at zero pressure. The trailer will brake automatically after uncoupling, and in order to move it the shut−off valve has to be set to release. Damage due to dirt is one of the main causes of defects in pneumatic brake systems. It is therefore necessary to periodically check and clean the air filter in the air compressor. After cleaning with a cleaning fluid (Not petrol!) and blowing out, the filter is slightly moistened with oil to bind most of the dirt particles together.

If the required operating pressure is not reached, the valves and the piston rings in the air compressor have to be checked, and replaced if necessary.

Other defects, which can be located by the escape of air when the compressor is at a standstill, can be traced back to leaking joints, valves, diaphragms or power pistons. These defects can be eliminated by cleaning the components, by tightening screws or by replacing defective parts.

6.6. Combined brake system

Combined brake systems are used when mechanical or hydraulic brakes are not strong enough but when the use of pneumatic brakes is not warranted. The have a pneumatic actuating system but their operating principle is hydraulic. The actuating system comprises, as shown in Fig. 6/16, a piston compressor, a pressure regulator, an anti−freeze pump, an air reservoir, a brake booster valve, an engine brake valve, a spring accumulator, a shut−off valve and the coupling head for the trailer. The brake booster is coupled to the hydraulic main brake cylinder. It is a dual−circuit brake cylinder which works on brake fluid which transmits the braking force to the wheel brake cylinders. In motor vehicle engineering, single− and dual−circuit brake systems are used. With the single−circuit system power transmission to all four wheel brake cylinders is via a single−chamber main brake cylinder. If one link in this chain fails, the brake system ceases to be serviceable. As it is not possible to drive without brakes, the vehicle cannot be used in traffic until it has been repaired. Due to the malfunction the brake fluid escapes and the system is no longer closed. Due to this disadvantage of the single−circuit brake system, modern motor vehicle engineering is turning increasingly to the dual−circuit system.

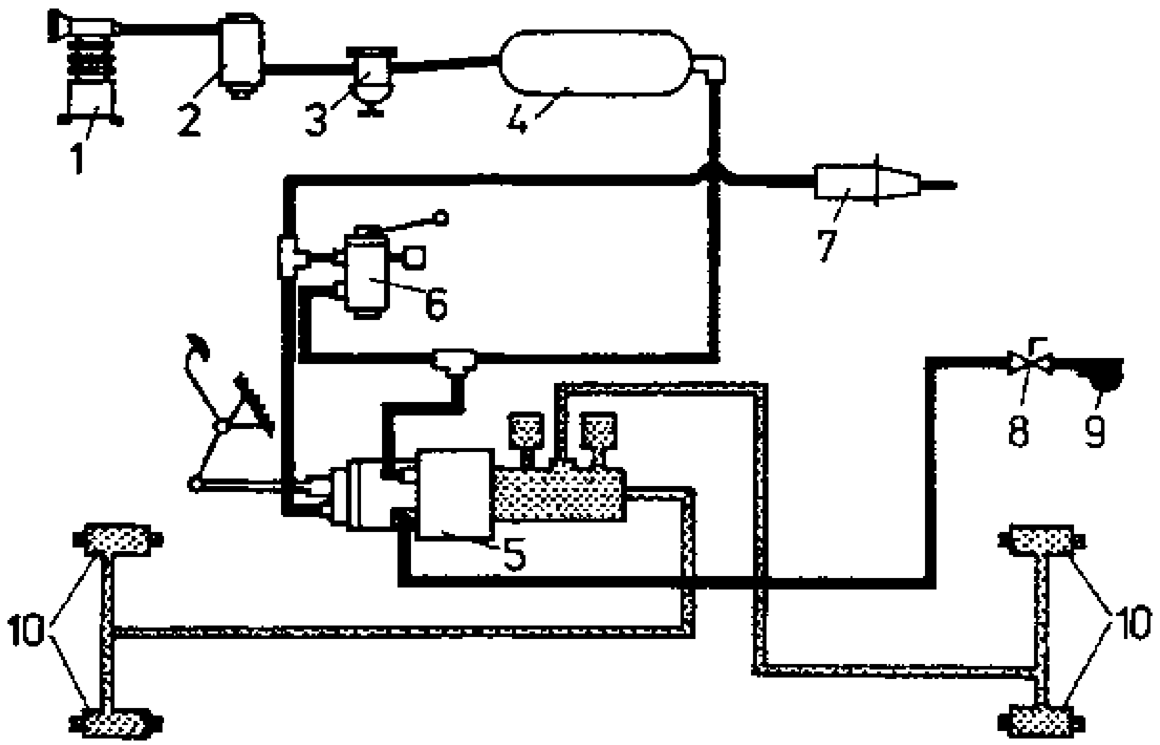


Figure 6/16 Combination brake

1 reciprocating compressor, 2 pressure regulator, 3 antifreeze pump, 4 air brake reservoir, 5 servo brake valve, 6 engine brake valve, 7 spring accumulator, 8 shut−off valve, 9 coupling head for trailer brake unit, 10 hydraulic wheel brake cylinder

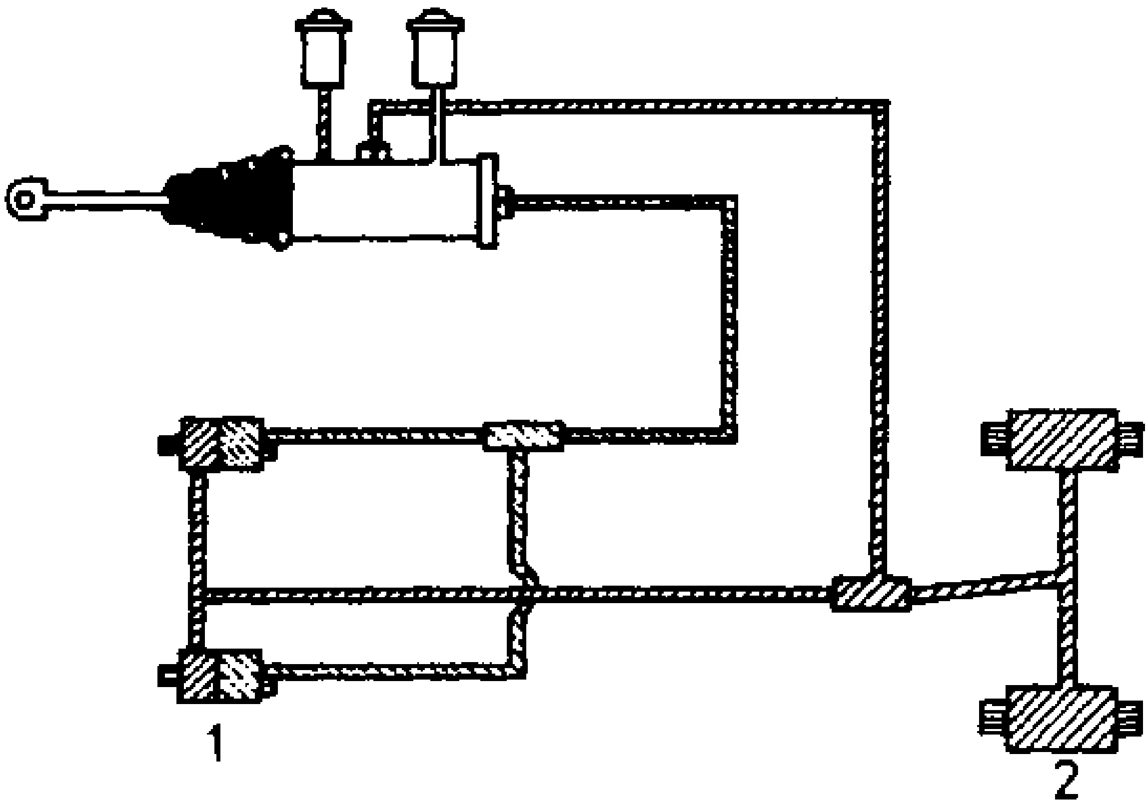


Figure 6/17 'Non−genuine' dual−circuit braking system

1 twin−chamber brake cylinder, 2 single−chamber brake cylinder

There are genuine and non−genuine dual−circuit brake systems. A 'non−genuine' dual−circuit brake system is one in which the front and rear axles are separately connected in two individual brake circuits. A genuine dual−circuit brake system is one in which all the wheel brake cylinders are dual−chamber drake cylinders. In Fig. 6/17 the wheel brake cylinders of a front axle are illustrated as dual−chamber brake cylinders. In a genuine dual−circuit brake system, if one of the brake circuits fails, the vehicle is still completely serviceable as the second brake circuit then comes into action.

6.7. Brake system of the IFA W 50

The W 50 lorry has a pneumatically−assisted hydraulic brake system. The drum brakes, which have a bilaterally acting wheel brake cylinder, produce a duo−servo−effect. This system, shown in Fig. 6/16, is a dual−circuit brake system. It requires some additional components in its structure, such as the brake booster and the spring accumulator. The piston compressor is the vital component for effective breaking, it produces the air pressure required for braking which is accumulated in the reservoir. When the foot pedal is operated, the linkage works directly on the brake booster which is in turn linked to the main brake cylinder. The main brake cylinder is a hydraulic dual−circuit brake system. The wheel brake cylinders are actuated by means of the brake fluid and so the braking begins. If the pneumatically assisted system fails, braking of the vehicle is still possible but more difficult, and the vehicle must be driven very slowly.

The individual components of the brake system:

Brake booster

When operating the brake pedal a piston is moved by a linkage in such away that the compressed air assists the function of the piston itself. This increased force is transmitted to the main brake cylinder via the piston rod. In this way the brake booster serves to assist the force of the driver's foot, and the energy expended is reduced.

Main brake cylinder

In the IFA W 50 lorry the main brake cylinder is divided into two independent brake circuits. Each brake cylinder has a brake cylinder element and a compensating reservoir. The piston rod coming from the brake booster operated the piston in the first brake circuit, which in turn transmits pressure to the brake fluid. Due to this, the second cylinder is moved and transmits pressure to the brake fluid of the second brake circuit. Both cylinders are kept at a distance determined by the manufacturer by a compression spring.

If one of the two brake circuits fails due to a defect, the other will continue working. The compensating reservoir and the main brake cylinder, shown in Fig. 6/11 as a single−circuit brake cylinder, are connected by a feed line. There must be a play of one millimetre between the piston in the brake cylinder and the piston rod. The foot valve in the main brake cylinder produces a slight overpressure which keeps lost motion to a minimum. If it becomes too high, adjustment is necessary. The level of the brake fluid in the compensating reservoirs must be checked regularly to prevent failure of the whole brake system. The pressure of the brake fluid is transmitted to the wheel brake cylinders by the brake line.

Wheel brake cylinder

In the wheel brake cylinders there are two pistons (Fig. 6/12) which are sealed by rubber gaiters. The space between the two pistons is occupied by a compression spring and the brake fluid. The compression spring maintains the distance between the two pistons. It also ensures that the inlet opening is not closed by the pistons. In the pistons there are push rods which operate the brake shoes. The wheel brake cylinders are protected against dirt penetration by a rubber gaiter, which also holds the push rods horizontal. When the brake is released, the push rods are pressed back into the wheel brake cylinders by the brake shoes which are tensioned by a spring.

Hand brake valve

Each vehicle must be fitted with a parking brake. It can be a mechanical, or as is the case with the IFA W 50 lorry, a compressed air brake. This type of parking brake is shown in Fig. 6/18. When operating the hand brake lever the push rod is shifted so that the outlet is opened, and there is a gradual pressure drop in the spring. This type of parking brake is also called a spring brake. The pressure drop in the brake lines causes the brake to be fully applied. In comparison to all mechanically operated parking brakes, this type has the advantage that it comes into effect immediately on operation. With most ratchet brakes, the wheel brake lever must be operated several times before it is locked. Therefore in emergencies this brake can be used immediately, even if both brake circuits fail. A compression spring and a release mechanism return the brake to the release position.

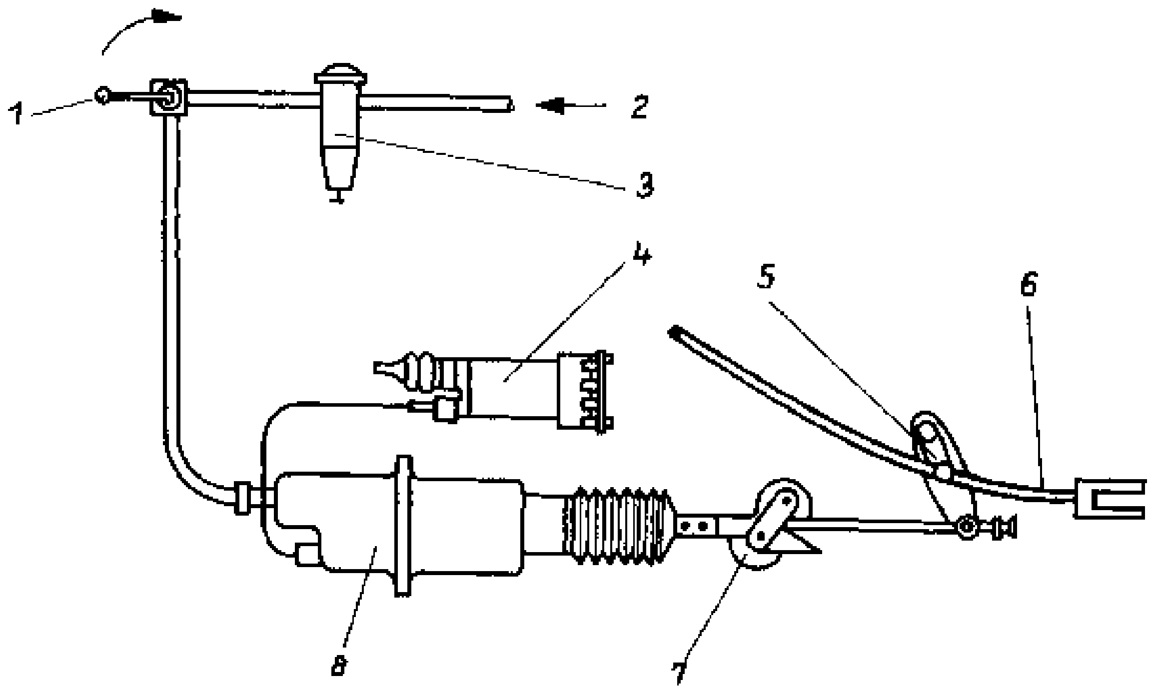


Figure 6/18 Parking brake

1 hand brake valve, 2 air supply, 3 pressure regulator, 4 servo brake valve, 5 frace compensator, 6 hand brake cable, 7 release, 8 spring accumulator

Engine brake

Vehicles over 5.5 tonnes total weight must have an engine brake system. It is fitted in the exhaust manifold of the engine as is shown in Fig. 6/15. The engine brake can be actuated either hydraulically or mechanically.

The engine brake is actuated by operating a bleed valve or by retracting the accelerator pedal. The compressed air flows via the engine brake valve into the clutch release cylinder, thus closing a flap in the exhaust system. At the same time the fuel feed is reduced. The burnt exhaust gases accumulate is this chamber and the vehicle is decelerated by the compressor effect of the engine. The vehicle can also be brought to a standstill. The purpose of the engine brake is to avoid overloading of the brake system on long gradients.

Trailers with compressed air brake systems are coupled to the IFA W 50 lorry.

Faults and rectifications

From time to time every brake system is subject to faults, some of which are dealt with below.

The most common fault found in the IFA W 50 lorry is that it pulls either to the left or the right during braking. The cause of this fault can lie in the presence of oil or grease on the brake shoes, in uneven wear of the brake linings or misshapen brake drums. In most cases it is advisable to replace the faulty or unserviceable parts. If the brake shoes need to be fitted with new linings, both wheels on one axle must be repaired at the same time to prevent the brakes from pulling to the side.

Defective wheel brake cylinders or hand brake cables which have been greased too much can be the cause of oil or grease on the brake shoes. Worn brake linings and connections may cause the foot pedal travel to be too great. When the brake linings have been worn down to 50 % of their original thickness, they must be replaced. If re−adjustment of the brakes is possible, proceed as follows:

Lift the axle so that the wheels can be moved freely by hand, i.e. so that they no longer have any road grip. Then remove the locking pins. Using a large screwdriver, turn the eccentric wheel to the right to lock the brake, so turning the gear back by three teeth.

Move the wheel in the direction of travel, and if the brake has been adjusted correctly a slight rubbing noise should be heard. When the work is completed, the locking pin can be replaced. Proceed in the same way for the other wheel. Ensure that the wheels are running in parallel.

When work on one axle is complete, lower the vehicle and adjust the other axle in the same way. As the hand brake cannot be used, ensure that brake blocks are placed in front of the wheels on the ground to stop the vehicle from rolling away.

Air in the brake system can cause the brake pedal travel to be too great. With the IFA W 50 lorry bleeding is started at the main brake cylinder. The reservoir must be topped up. Place a ring spanner on the bleeder screw and then attach a tightly fitting hose to it. Put the end of the hose into a half–filled bottle of brake fluid, to stop air from re–entering the brake system. Two people are required for bleeding a hydraulic brake system, one to open and close the bleeder screw and the other to operate the brake pedal. They must communicate orally. As mentioned above, the brake system is to be pumped, i.e. the air in the brake system is compressed. When the person pumping the brakes feels some resistance, pressure has built up and the bleeder screw should be opened. As soon as the foot pedal reaches the floor, the bleeder valve must be closed. Then release the brake and repeat the process until bubbles no longer appear in the bottle. When the main brake cylinder has been bled at both its bleeder screws, the same process is carried out at the wheel brake cylinders. During bleeding the level of the brake fluid in the bottle must be constantly checked and topped up. Before bleeding, the brake system must be visually checked for leaks, and the connecting hose to the wheels must be examined for cracks and fractures.

If the play between the piston rod and the piston in the main brake cylinder is too small, the brakes will become warm. This can be rectified by adjusting the play.

If the brake rattles, it means that the brake lining is worn out and must be replaced. Rattling can also occur if the brake linings are not sufficiently bevelled, in which case the ends of the linings must be rebevelled. If the lateral play is very great, or if the brake pedal sticks, this is a sign that the bush is worn and must be replaced. When the return spring becomes slack it must be replaced.

A fast pressure drop in the brake system means that the connections or the units are defective. When a defective part is located, for example the brake booster or the spring accumulator, it must be replaced. It must not be repaired, because after repair its serviceability has to be checked on special machines. Whilst they are fitted to the vehicle this is not possible and so their correct functioning cannot be guaranteed.

<u>Test questions</u>:

6.1. What types of drum brakes do you know?

6.2. What are the tasks of brakes on a vehicle?

6.3. Describe the design of a simplex brake.

6.4. What do you understand by a duplex brake?

6.5. Describe the design and the operating principle of a servo brake.

6.6. Describe the design and the operating principle of a disc brake.

6.7. What types of disc brakes do you know?

6.8. What do you understand by mechanical brakes and for what purpose are they used in modern vehicles?

6.9. Describe the design of a hydraulic brake system.

6.10. What advantages does the hydraulic brake system have over the mechanical brake system?

6.11. Describe the basic principle of bleeding a hydraulic brake system.

6.12. Why must brake systems be bled?

6.13. What is brake fluid and of what does it consist?

6.14. What properties does brake fluid have and how must it be handled?

6.15. Why must only brake fluids of the same classification be used for topping up?

6.16. Describe the design of a compressed air brake system by means of an example.

6.17. What can be adjusted in such a system?

6.18. What functions do the pressure controller and the relief valve perform?

6.19. How can a brake system be checked for leaks?

6.20. Why can the piping of a brake system only be bent when cold?

6.20. What failures do you know and how can they be rectified?

6.21. Describe the design of a combined brake system.

6.22. What do you understand by a single−circuit brake system and what is its disadvantage?

6.23. What do you understand by a genuine and a 'non−genuine' dual−circuit brake system? Give examples of their advantages and disadvantages.

6.24. Describe the design of the brake system of the IFA W 50.

6.25. Explain the operating principle of the spring accumulator brake.

6.26. Describe the bleeding of a hydraulic brake.

6.27. What can be the causes of unserviceable brakes?

6.28. How can a worn bush be detected?

6.29. Why can the pneumatic units of the brake system be repaired only in authorised workshops?

7. Types, functions and uses of lifting gear

Two types of lifting gear are used for vehicle repairs:

1. mechanical lifting gear
2. hydraulic lifting gear

Mechanical lifting gear can be manual or mechanised. They are suitable only for certain load capacities. Before using a lifting unit, check whether it is suitable for load concerned. The following lifting units are used for vehicle repairs:

block and pulley	(manual)
scissor−type jack	(manual)
autohoists	(mechanised)
column−type car lift	(mechanised)
pit hoist	(mechanised)
assembly hoist	(manual and mechanised)

The block and tackle (Fig. 7/1) has a wide variety of uses. It can for example be used for dismantling, lifting and fitting bodies. It is seldom fixed in one place, but usually mobile. It works on the basis of an endless chain which must be operated manually. By means of this chain it can be moved up and down. The transmission ratio of the block and tackle facilitates the lifting of large loads. The transmission ratio is the transmission of a force or motion from a small to a large wheel or vice versa. With transmission from a small sheel to a large wheel, the speed is reduced or the lifting force is kept small. The part to be lifted is fixed to the hook of the block and tackle by steel cables or special assessories (balance beam, crane hook).

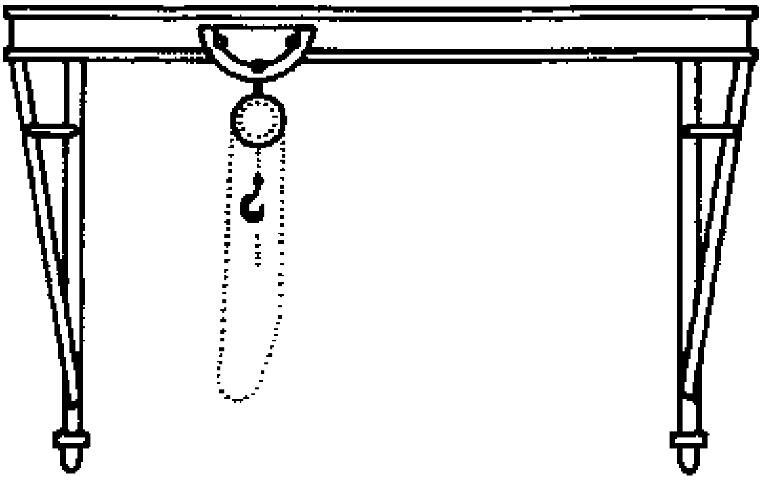


Figure 7/1 Block and tackle (mobile)

When working with this lifting device it is important to ensure that the part to be lifted is safely secured and correctly suspended, in order to avoid accidents.

The block and tackle is mobile even when loaded.

The scissor−type jack (Fig. 7/2) is raised or lowered by a spindle which is moved by a crank. It is generally used for changing wheels on cars or as a support for facilitating the fitting of screws. The scissor−type jack has a relatively low load capacity and therefore is rarely used in repairs to lorries.

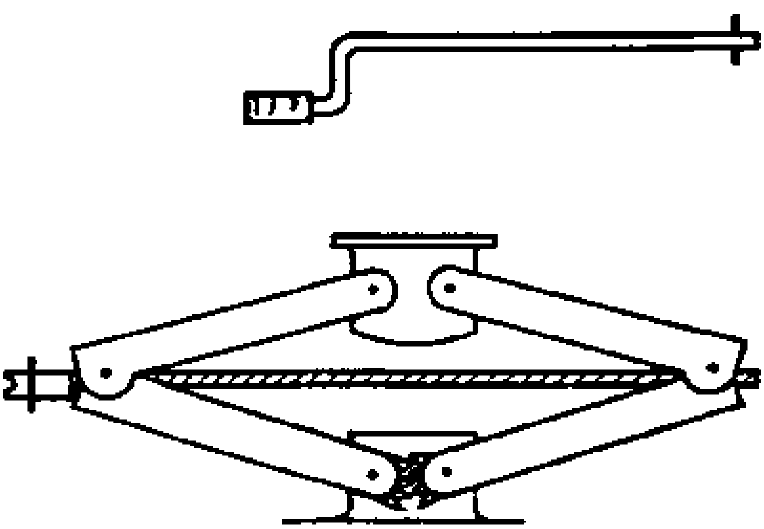


Figure 7/2 Scissor−type jack

The autohoists (Figs. 7/6 and 7/7) and the column−type car lifts (Fig. 7/8) are used to lift the vehicle from ground level to working height. They are motorised. Once they have reached the desired working height, they must be secured to stop them falling down. The difference between the autohoist and the column−type car lift is that on the autohoist the vehicle stands on its wheels, and when work is being carried out on the brakes it must be raised further. With the column−type car lift the vehicle rests on small areas of the frame and no parts of the lifting gear hinder repair work.

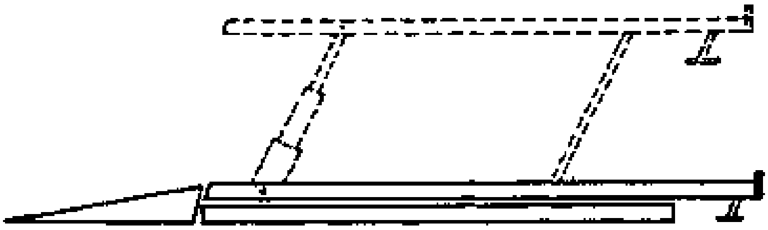


Figure 7/6 Auto−hoist for lorries

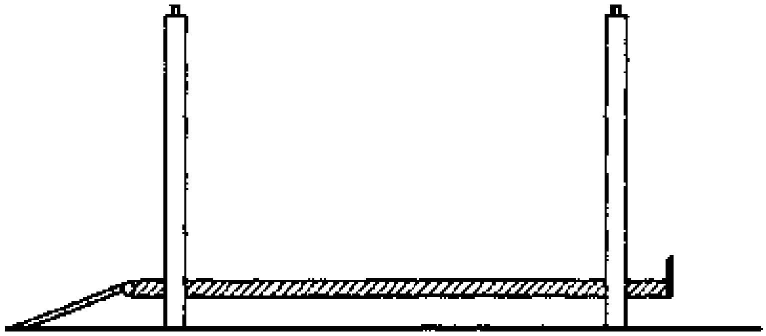


Figure 7/7 Auto−hoist for cars

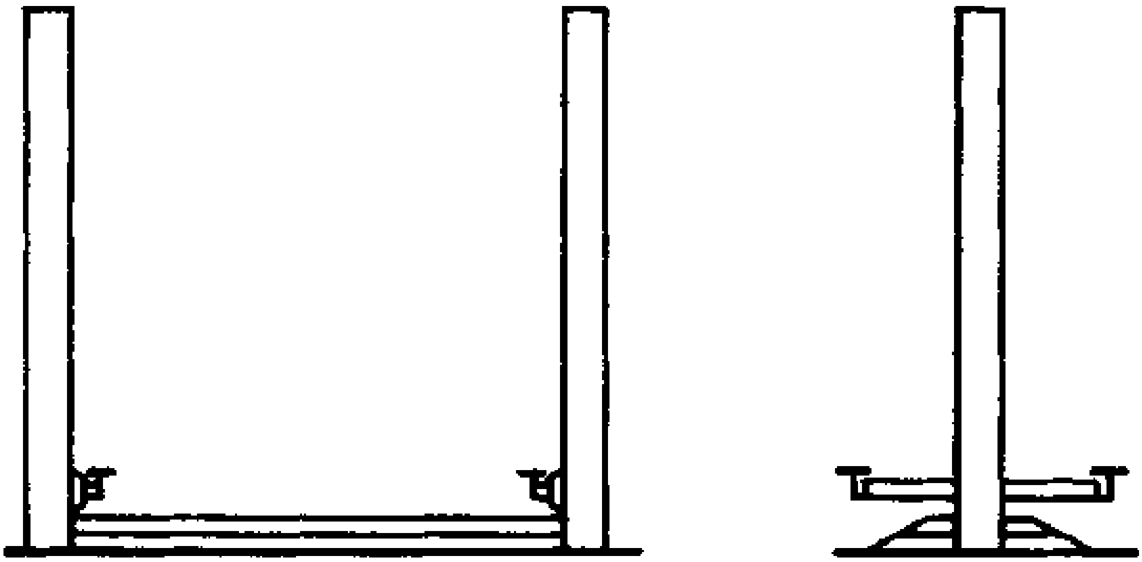
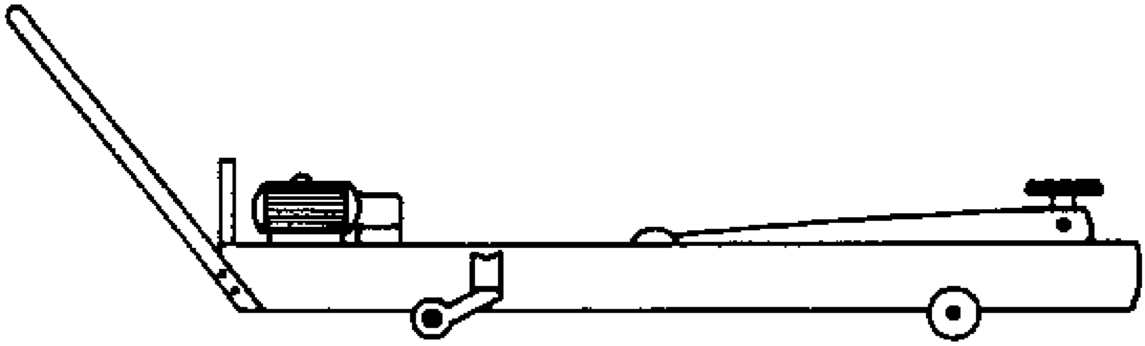


Figure 7/8 Column−typ car lift

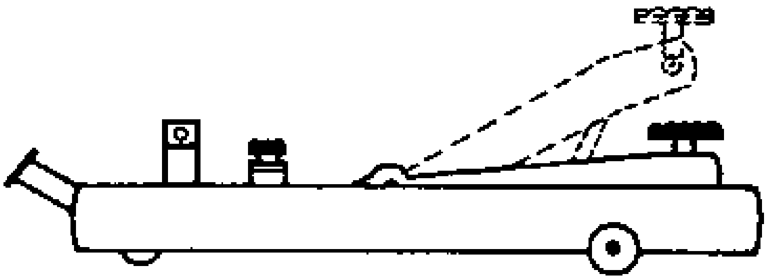
In this way the mechanic's work is made easier. There are autohoists for both cars and lorries; column−type car lifts, however, are made only for cars because they have a limited load capacity. Both of these lifting devices are stationary. Autohoists can be operated hydraulically.

Assembly hoists (Fig. 7/3) can be found in every workshops and are used to remove individual parts from the vehicle, for example axles or gear boxes. Electrically driven assembly hoists are driven by a spindle and the hydraulic hoists by a pump piston and brake fluid. They have a limited load capacity. Pit hoists (Fig. 7/4) are installed in inspection pits. The assembly trestle (Fig. 7/5) is used to secure raised vehicles.

Figure 7/3 Assembly hoist



a) electrical



b) hydraulic

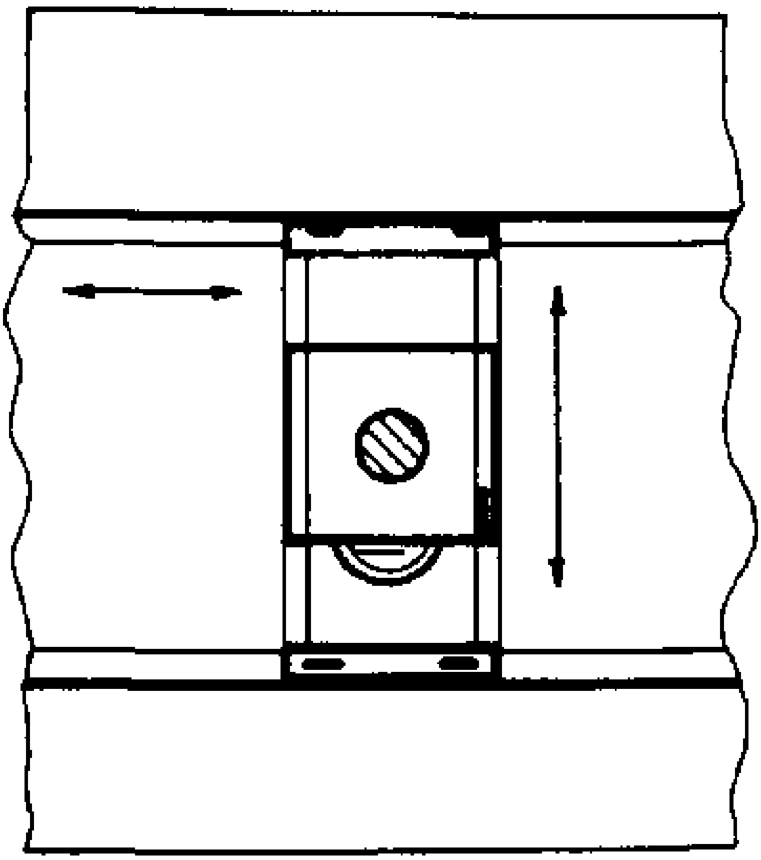


Figure 7/4 Pit hoist

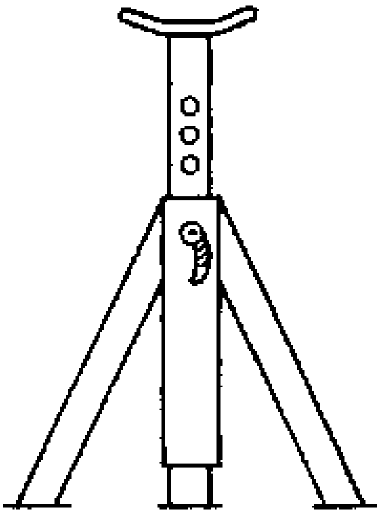


Figure 7/5 Assembly trestle