

**Power Transmission – Course: Motor Vehicle Engineering 2. 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 clutch

1.1. Purpose and operating principle of the clutch

To drive a motor car, the output power of the combustion engine must be transmitted to the driving wheels. We distinguish four different kinds of drive:

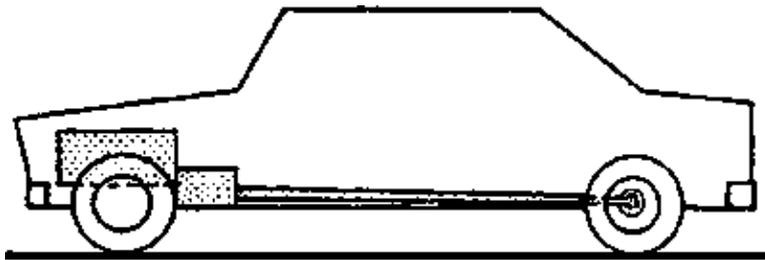


Figure 1/1 Rear-axle drive (front-mounted engine)

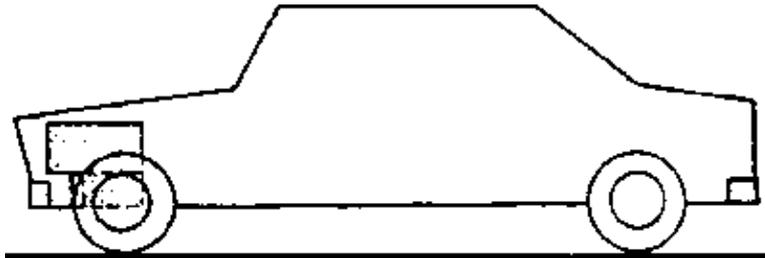


Figure 1/2 Front-axle drive (front-mounted engine)

The most common kind of drive is the rear-axle drive with the engine being front-mounted (Fig. 1/1). Fig. 1/2 shows a frontdriven car. Here, the engine is located in the front of the car, and the front wheels are driven.

Another kind of drive is the rear-axle drive with the engine being rear-mounted (Fig. 1/3).



Figure 1/3 Rear-axle drive (rear-mounted engine)

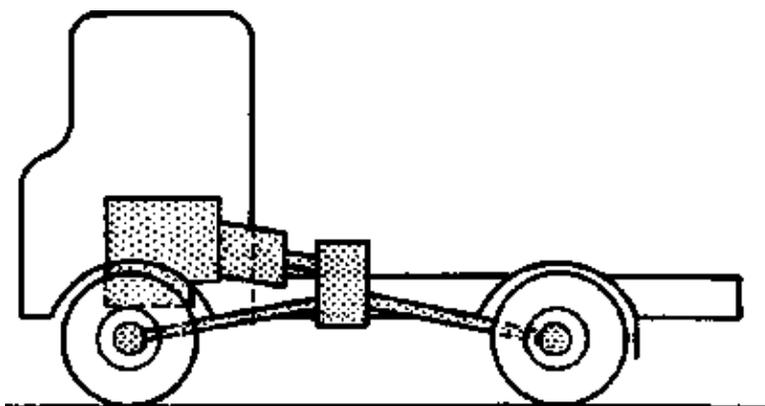


Figure 1/4 Four-wheel drive

The fourth kind of drive is the four-wheel drive (Fig. 1/4). It is used for cross-country vehicles, e.g. agricultural and military vehicles and those used in the building industry. With the four-wheel drive, all axles of the vehicle are driven by an additional transfer box. This increases the driving force and makes it easier for the vehicle to surmount obstacles and cope with heavy soils.

The power is transmitted from the engine through clutch – box – cardan shaft – final drive with differential gear to the wheels (Fig. 1/5).

The power of the engine is first transmitted through the clutch to the gearbox. Usually, the clutch is engaged. It can be disengaged by depressing a pedal, actuating a hand lever, or by electromagnetic operating elements. Disengaging the clutch interrupts the power transmission from the engine to the gearbox, permitting an easy shifting of the different gears.

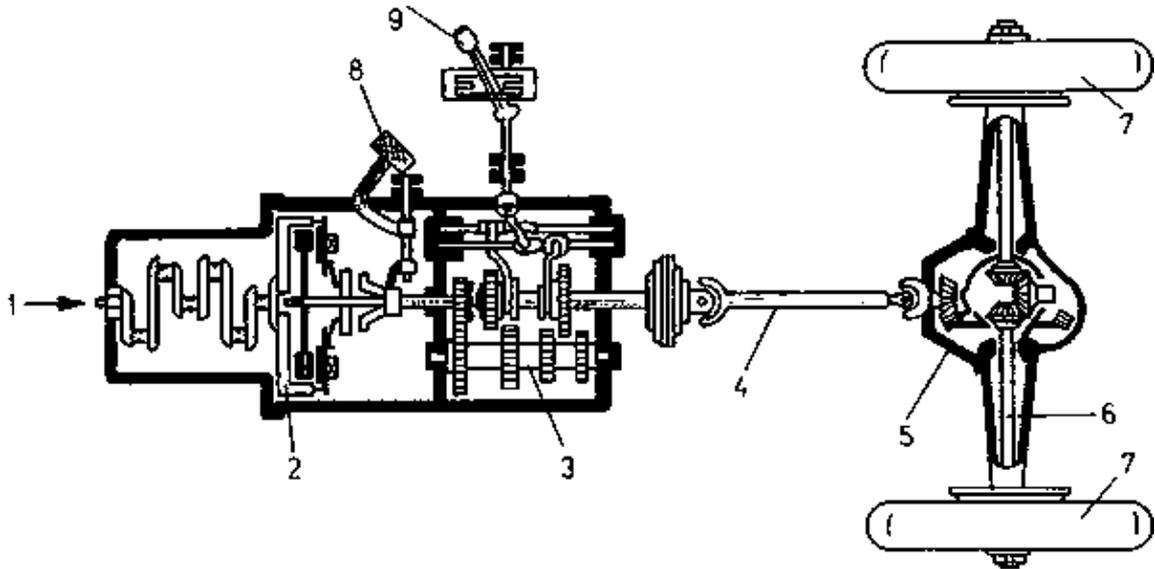


Figure 1/5 Power transmission

1 engine; 2 clutch; 3 gear-change; 4 cardan or propeller shaft; 5 differential unit; 6 axle; 7 wheels; 8 clutch pedal; 9 gear shifting lever

When starting the stationary vehicle, the clutch ensures that the speed of the gearbox is gradually adapted to that of the engine.

The clutch is attached to the engine's flywheel. The clutch bell, which is secured to the gearbox and connects it to the engine block, protects the clutch from damage and dirt.

Basically, there are three types of clutches:

1. Mechanical clutches
2. Hydraulic clutches
3. Electric clutches

1.2. The mechanical clutch

The mechanical friction clutch has remained the most common type of clutch until this day. The torque is transmitted by friction. As to their design, friction clutches are classified into cone clutches, single dry plate clutches, multiple dry disk clutches and multiple-disk clutches running in oil.

Because of their importance only dry clutches shall be dealt with in detail in this manual. Dry clutches are used in most vehicles. Fig. 1/6 is a cross section of a single dry plate clutch.

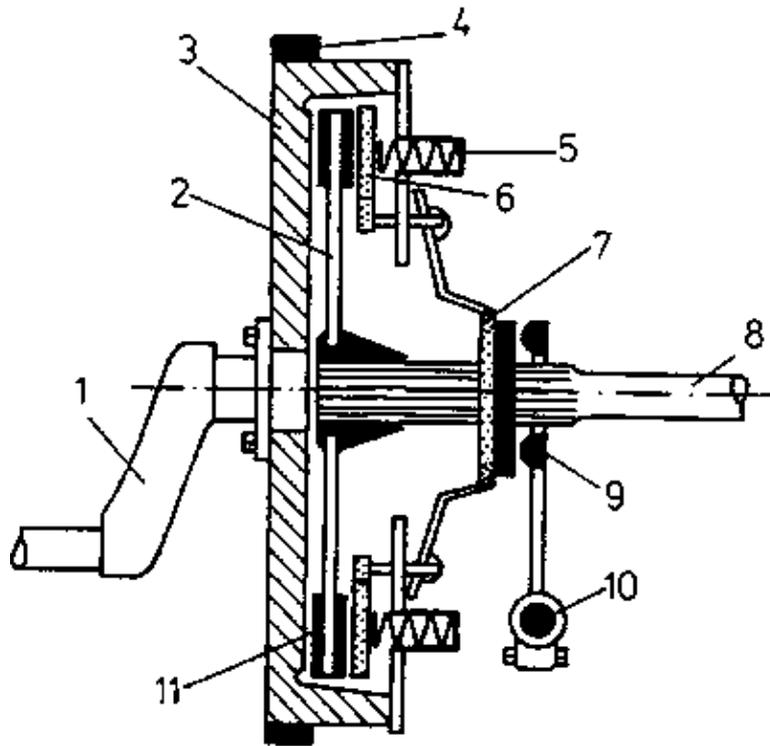


Figure 1/6 Single dry plate clutch

1 crankshaft; 2 catch plate; 3 flywheel; 4 starter rim gear; 5 pressure spring; 6 thrust plate; 7 thrust collar; 8 drive shaft; 9 release claw; 10 release shaft; 11 clutch facing

The principle underlying this design is that two disks are used to connect the engine to the drive. One of them is the engine's flywheel. The other is positioned on the drive shaft of the gear unit and can be shifted.

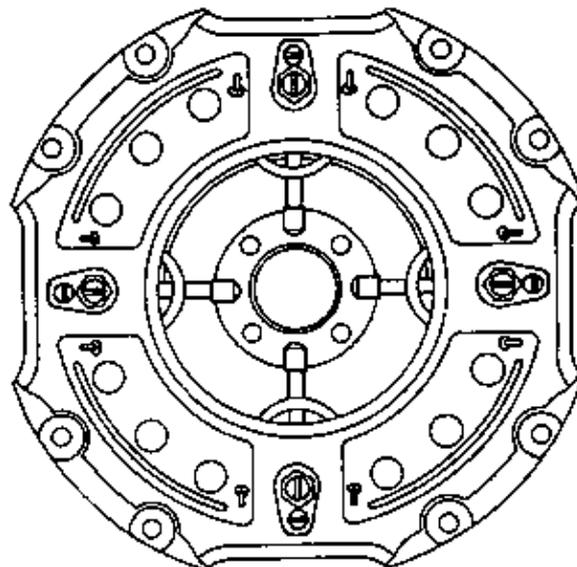


Figure 1/7 Ring spring clutch

The two disks are forced against each other by an automatic clutch fixed to the flywheel. A non-positive connection is made. The contact pressure is produced by ring springs, a central unit pressure spring in the center of the automatic clutch or by a plate spring (Figs. 1/7 and 1/8). Throwing in the clutch compresses the springs causing the contact pressure to be relieved. The catch plate is released, and the transmission of power is interrupted.

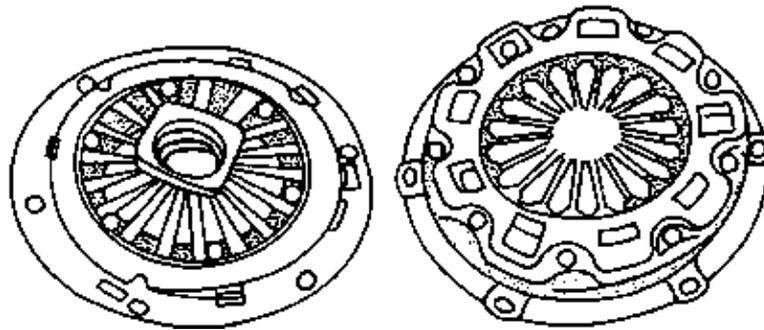


Figure 1/8 Belleville spring clutches

The clutch disk has slots dividing it into 12 to 16 sectors. Every other sector protrudes from the disk plane by some tenth of a mm parallel to it. This causes the disk to be compressed evenly, even if a moderate pressure is applied, ensuring an even wear of the friction facing.

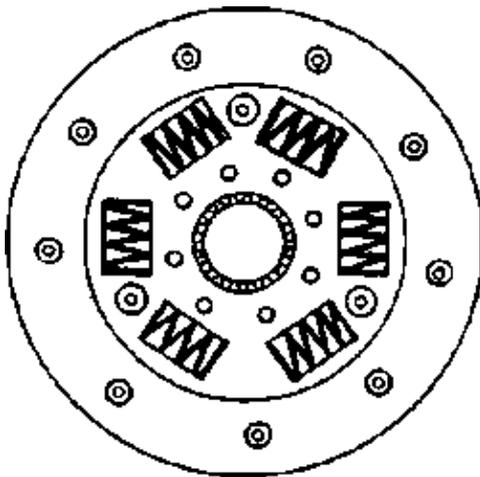


Figure 1/9 Torsional vibration damper with damping springs

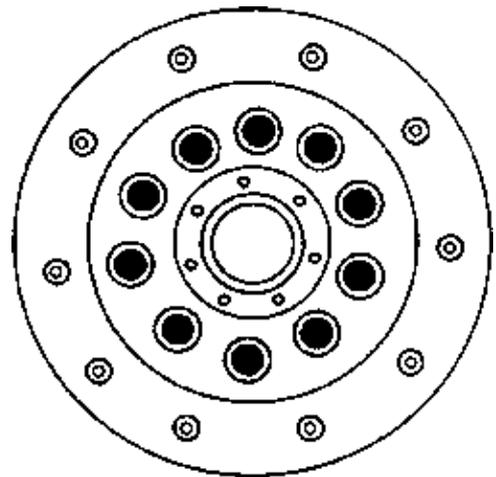


Figure 1/10 Torsional vibration damper with rubber elements

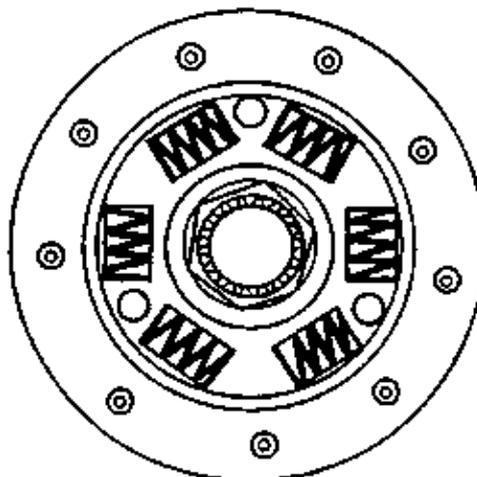


Figure 1/11 Torsional vibration damper with damping springs and adjustable internal friction

The clutch may be provided with dampers ensuring a smooth power transmission and preventing the friction facing from being subjected to excessive load during starting (Figs. 1/9 to 1/11). There are, however, also clutch disks without dampers. In this case, the friction facing is simply riveted to a flat steel plate. Friction facings are riveted to both sides of the clutch disk.

Like the brake lining, the friction facing consists of asbestos fibre cloth reinforced with brass wire, cotton fabric and compressed asbestos fibre compound. From this material, annular facings are made which are then fastened to the clutch disk by means of hollow aluminium or copper rivets, in the centre of the clutch disk there is the star member provided with internal tothing. It is riveted to the steel plate.

The internal tothing and the tothing of the gearbox drive shaft form a positive connection. The ring spring clutch is fitted with between 6 and 9 or more helical compression springs arranged annularly on the thrust plate. This enables a uniform pressure to be applied. In most cases, the springs are protected by sleeves. Central spring clutches have a strong helical spring positioned in the centre of the clutch cover. It produces the contact pressure and is provided with a thrust roller bearing.

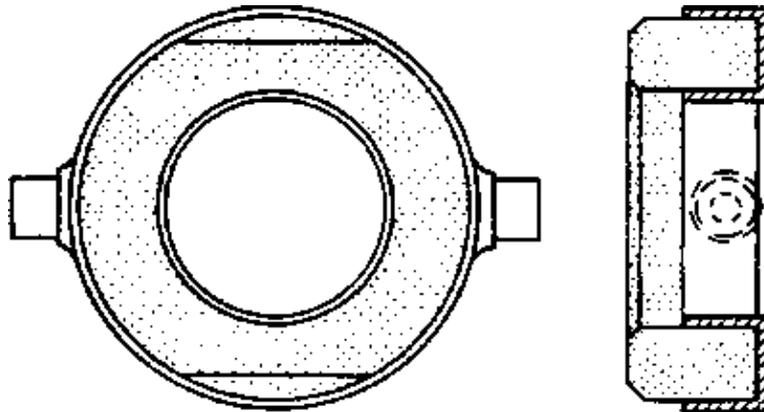


Figure 1/12 Clutch release bearing with graphite ring

With Belleville spring clutches (Fig. 1/8) the contact pressure is produced by the Belleville spring.

The clutch release bearing enables the clutch disk to move when throwing out the clutch.

Fig. 1/12 shows a clutch release bearing with graphite ring, whereas Fig. 1/13 illustrates a clutch release bearing with thrust roller bearing. They are fitted into the clutch release yoke (Fig. 1/14) and secured with clips. The bearings can be tilted in their seat. The release yoke is connected to the clutch shaft. The clutch shaft may be operated either by a hydraulic cylinder (similar to a wheel-braking cylinder) with brake fluid or by a linkage. The clutch thrust bearing exerts pressure on the release bearing. This compresses the springs thus interrupting the flow of power.

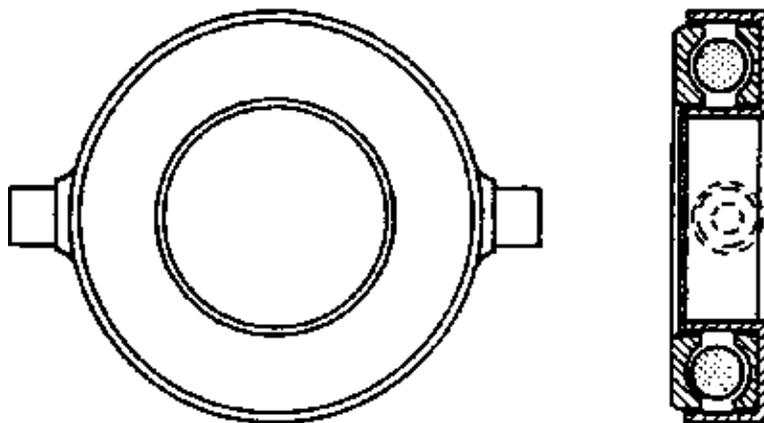


Figure 1/13 Clutch release bearing with thrust roller bearing

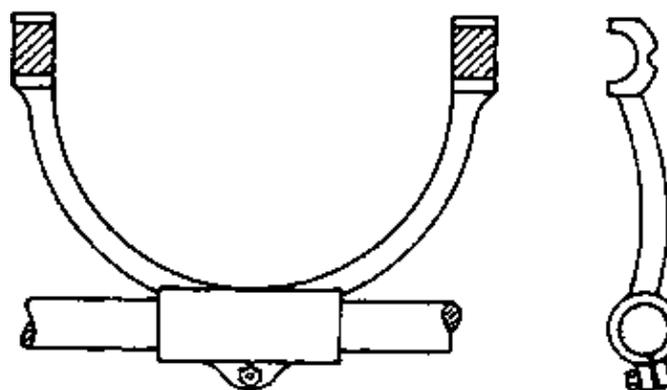


Figure 1/14 Clutch release yoke with clutch shaft

The release bearings are maintenance-free. The multiple dry disk clutch aims at enlarging the friction area. It is mainly used for heavy motor lorries. The operating principle is the same as that of the single dry plate clutch, however, several clutch disks faced on both sides and axially sliding on the drive shaft are used. A driving plate of cast steel is inserted between the clutch disks. It rotates positively with the flywheel as it is connected to it by grooves or bolts, but can be displaced in axial direction. The thrust springs force the thrust plate, the clutch disks and the driving disk as a whole package against the flywheel.

As already mentioned, the clutch remains engaged in its normal state. To prevent it from slipping, i.e. from being constantly under full spring pressure, there must always be a clearance of 2 to 3 mm between the release bearing and the slip ring. If there is a clearance, the clutch pedal moves easily the first 20 to 30 mm max. If there is no clearance, the clutch slips and gets hot resulting in excessive wear of the facing. If extreme heat develops the facing burns up. This is indicated by the smell. Another problem arises if the clutch clearance is too large. The pedal travel is then insufficient for the complete disengagement of the clutch, resulting in an overloading of the shifting mechanism, the gear-change box and the toothed gears. A noise can be heard when engaging a gear, or gears cannot be engaged at all. The clutch is readjusted by turning the adjustment screws located at the linkage or the clutch cylinder. If the clutch cannot be readjusted, the facing is too heavily worn. The clutch disk has to be replaced. When doing such a repair work, the condition of the flywheel and the thrust plate should be checked as well. If there is oil on the facing, the clutch may also tend to slip. If this occurs, the gaskets of the gearbox or the engine must be checked and replaced, if necessary, in order to ensure the proper functioning of the clutch.

1.3. The hydraulic clutch

The term “hydraulic clutch” denotes a clutch which utilizes the forces of gravity of a liquid for the transmission of power. The primary wheel is the driving part. The forces of gravity are produced here by acceleration, while in the secondary wheel, which is the driven part, they are generated by deceleration.

These clutches consist of two parts provided with radial ribs, i.e. the pump wheel and the turbine wheel. The pump wheel is connected to the crankshaft of the engine and takes the function of the flywheel. The two wheels face each other, forming a cavity which is divided into small chambers filled with a thinbodied oil. When the engine drives the pump wheel the centrifugal force causes the oil to flow towards the outer circumference thus making a circular motion in the cavity. The motion exerts a lateral pressure on the ribs of the turbine wheel (secondary wheel). As soon as the liquid pressure exceeds the resistance of the turbine wheel (which occurs at a certain engine speed), the turbine wheel is forced to rotate by the pump wheel (primary wheel).

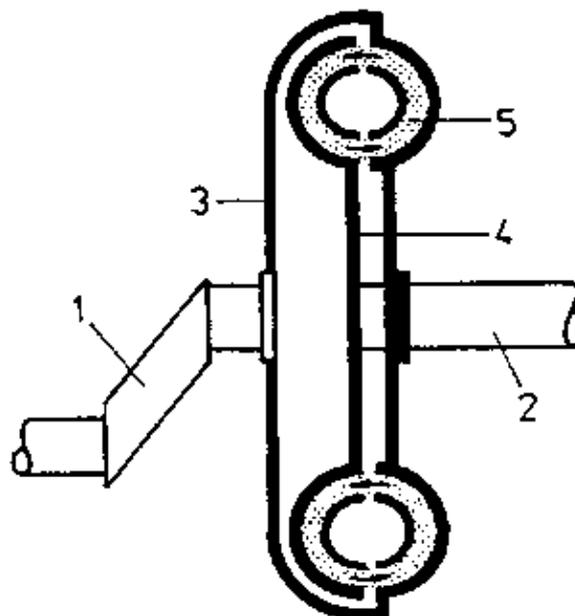


Figure 1/15 Hydraulic clutch

1 crankshaft; 2 gear shaft; 3 pump impeller; 4 turbine wheel; 5 radial ribs

Fig. 1/15 shows a hydraulic clutch. The power generated by the engine, i.e. the torque, is thus transmitted to the gearchange box. The output torque of the turbine wheel is always equal to the input torque of the pump wheel. This means that the efficiency of the output power is proportional to the input power. Power, in this case, means speed. The hydraulic clutch is particularly suitable as a starting clutch.

What is additionally needed is a separating clutch for changing the gears. In an automatic gear unit the separating clutch can be dispensed with.

Note:

Shift the lever to "idling" when working on mechanical gear unit, and to the zero position when working on automatic units.

Test questions:

- 1.1. What do you understand by "transmission of power"?
- 1.2. Which kinds of drives do you know?
- 1.3. Explain the power train.
- 1.4. What is the function of a clutch?
- 1.5. What do you understand by "mechanical clutch"?
- 1.6. Describe the construction of a single dry plate clutch.
- 1.7. What is an automatic clutch?
- 1.8. What is a torsional vibration damper? What is its function?
- 1.9. Describe the construction of a clutch disk.
- 1.10. What do you have to check when a clutch slips?
- 1.11. Describe the construction of a hydraulic clutch.
- 1.12. Describe the operating principle of a hydraulic clutch.
- 1.13. What do you have to bear in mind when doing repair work on a motor vehicle with a hydraulic clutch?

2. Gear change boxes

2.1. Mechanical gearboxes

The engine of a motor vehicle generates sufficient power within a particular speed range only. Therefore, it should always run in the proper speed range for the different driving speeds or load conditions to prevent it from being overloaded. From this we can conclude that, while the engine power remains the same, a greater force should be available for the driving wheels. A motor vehicle may move the faster the less force is required for rotating the wheels. This is the reason why motor vehicles are equipped with gear-change boxes. Earlier these had three gears but today they are ever more stepped in order to allow engines of a low power to be used. Large and heavy vehicles today have as many as 8 to 10 gear steps. The gear unit is housed in a casing and generally forms an assembly including the clutch bell and the engine. The individual parts are screwed to each other. The gear unit can be operated either from a steering-column or floor-type gear shift. Steering-column gear change is mainly used in passenger cars. The power train is illustrated in Fig. 1/5.

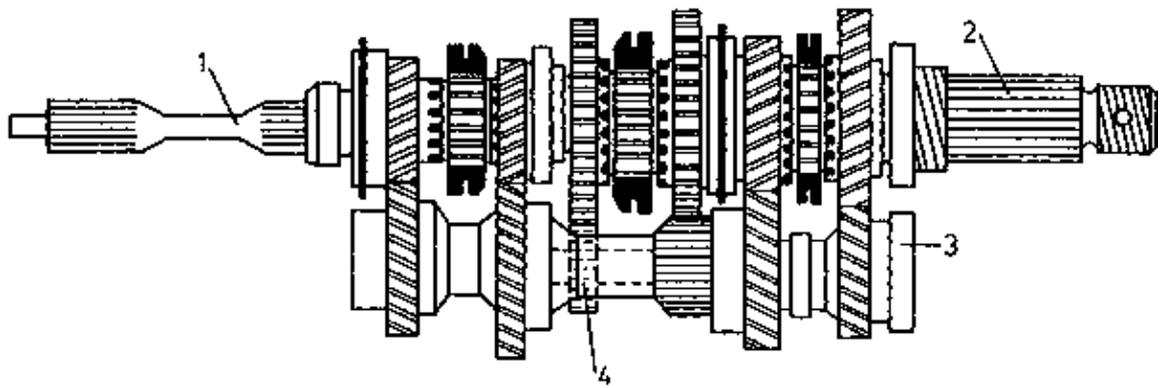


Figure 2/1 Gear box (for rear-axle drive)

1 drive shaft; 2 mainshaft; 3 countershaft; 4 reversing gears

In rear-axle driven vehicles the power is transmitted from the crankshaft via the clutch to the drive shaft, the countershaft and the main shaft (Fig. 2/1) from where it is transmitted via the propeller shaft to the final drive with the differential gear and on to the wheels by full-floating axle shafts. Fig. 2/2 shows a gearbox for a front-driven vehicle.

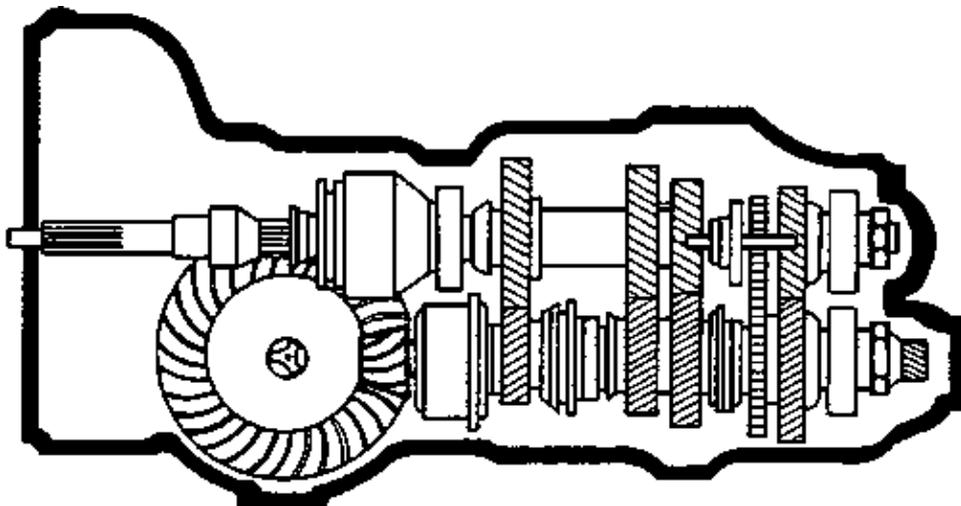
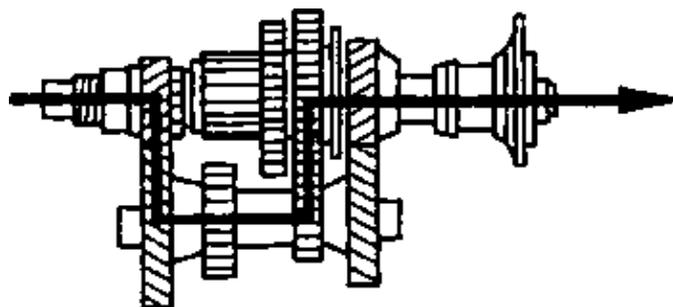


Figure 2/2 Gear-change box (for front-axle drive)

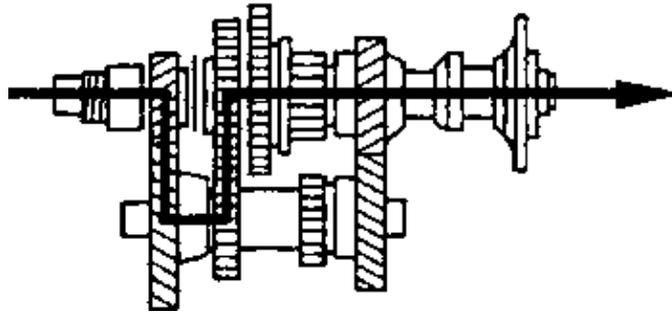
Intermediate gears permit the backward driving of the car. The gear unit should have a high wear resistance, run very smooth and be easily shiftable. The automotive industry still uses mainly the mechanical toothed gear unit. Its construction is simple and sturdy, and it features a high efficiency. Fig. 2/3 shows the power train in a mechanical four-speed gearbox for the individual gears. It is a two-shaft gear unit. The unit shown in Fig. 2/1 is a three-shaft unit with additional shaft and reversing gears.

The two-shaft gearbox is a sliding-mesh gear box. The driving gear of the countershaft and the third gear have helical teeth contributing essentially to the low noise of the gear unit.

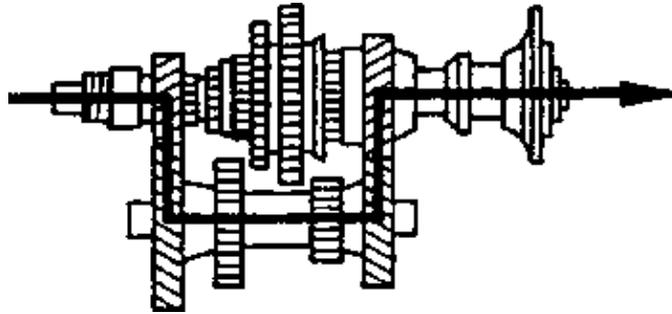
Figure 2/3 Power transmission in a four-speed gear-change box



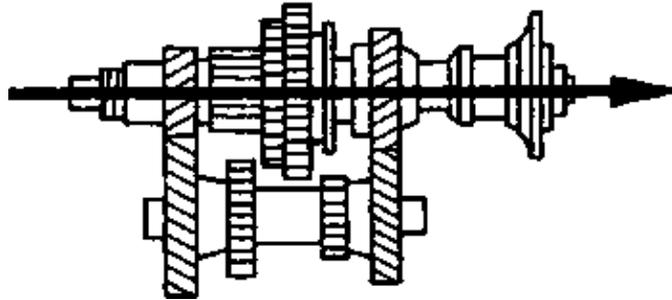
I. first gear;



II. second gear;



III. third gear;



IV. fourth gear

With straight-toothed gears a clicking noise is heard due to the clearance between the gears. For selecting the different gears the sliding gears are positioned axially on the grooved main shaft, the grooves causing them to rotate positively. The toothed gears of the countershaft are fixed on it (incorporated or pressed on). The gear shafts are held by antifriction bearings in the gearbox casing and run in oil.

Gears are changed (Fig. 2/4) in mechanical toothed gear units by shifting a lever connected to a ball-shaped assembly.

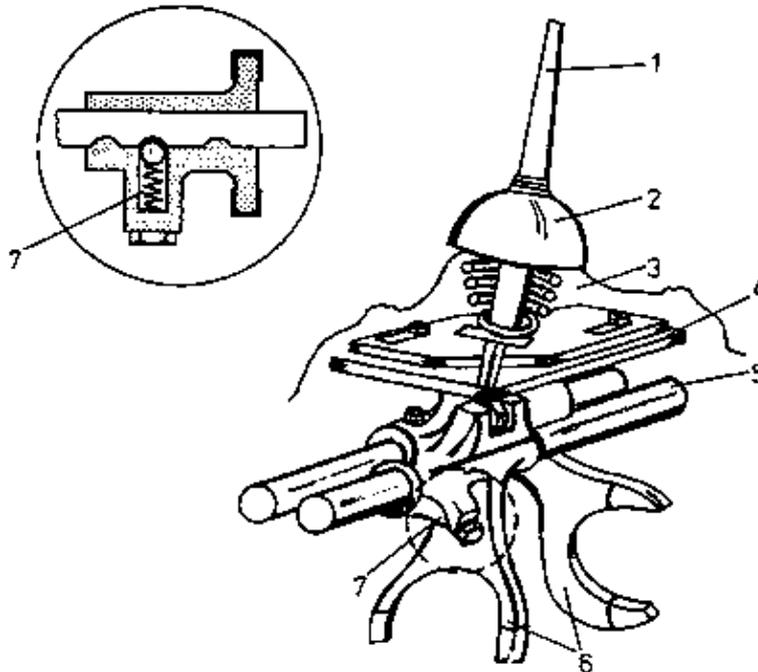


Figure 2/4 Gear changing mechanism

1 gear shifting lever; 2 joint; 3 shift arbor; 4 shift plate; 5 main shaft; 6 shifting fork; 7 shifting fork detent

The shift forks displace the gears as required for the desired speed. In most cases the shift forks are guided by shifter shafts. An interlock prevents the shifter shafts from moving uncontrolled. In addition, interlocks are incorporated to prevent simultaneous engaging of two gears.

The interlock consists of small balls which are forced against the shifter shaft by springs. The shifter shaft is provided with several depressions. The centre depression is for idling. To engage the reserve gear of a vehicle, another detent has to be overcome.

2.1.1. The sliding-mesh claw-clutch gearbox

The sliding-mesh claw-clutch gearbox (Fig, 2/1) provides for even greater noise reduction and easier gear shifting. All toothed gears, except the first and reserve gear, are helicaltoothed and in constant mesh. The gear shafts are carried in several roller bearings positioned in the casing. Rotary shaft seals are used to seal off the gear box casing. With this type of gear unit the gears are shifted by displaceable claw clutches which couple the gears to the main shaft. The claws are rugged and have a low circumferential speed as a result of their small diameter. They are also moved by shift forks.

The claws are of a robust design and not easily damaged even by wrong shifting.

2.1.2. The synchromesh gear unit

The shiftability of the sliding-mesh claw-clutch gearbox may be improved by synchronisation (synchronous = running at the same speed). It facilitates shifting and eliminates the shifting noise. This increases the life of the individual gears and the unit as a whole. A locking ring is provided to enable gear selection only after full synchronism between shaft and gear has been obtained.

The gears of a gearbox are mainly subjected to surface wear and flexural stress. They are made of alloyed case hardened steel. The tooth profiles are hardened and ground. The following parts of the gear unit are particularly liable to wear:

- tooth profiles of the gears
- shift forks and claws of the sliding sleeves

- gear shaft bearings
- gear casing seals

Wear of the listed parts may give rise to various troubles in the gear unit:

Roaring of a gear unit is mainly due to gear errors or excessive wear of the teeth.

Toothed gears wear heavily when they are only partly in mesh. The surface load is then too high and teeth are broken. If the main shaft and the countershaft are not positioned parallel to each other in the gearbox casing, the gears will mesh only insufficiently, increasing wear and resulting in damage of the gear unit. Other errors include pitch errors, helix errors and profile errors. They have their cause in the manufacture of the toothed gears and cannot be eliminated by reworking the gears. Toothed gears showing such flaws have to be replaced.

If a gear unit runs with a knocking noise this is mostly due to broken or heavily damaged teeth or to distorted gear shafts. This fault can only be eliminated by replacing the defective parts. Other problems are poor shiftability of gears and the uncontrolled, the disengagement of gears. The causes may be found even in the clutch. If it is not properly thrown out, i.e. if the play is too large or the facing heavily worn, it is difficult to change gears. The seat of the sliding gears or the sliding claw may be too tight, The gears may not be in line. The play of the antifriction bearings may be too large, or the profiles of the shift forks may be worn down by continuous rubbing along the shift claw. The shift forks may also be distorted which may be caused by engaging a gear forcibly. Other gear troubles may be due to improper synchronisation, the causes being weak pressure springs, excessive clutch segment play or excessive wear of the keys and lock pins. The defective parts should be replaced to eliminate such faults.

Another source of trouble may be excessive wear of the sliding grooves, with the following causes being possible:

- The car is always started too quickly or is subject to heavy load by jerks and jolts. If worn gears have to be replaced, this should also be done with the grooved shaft,
- The gear unit blocks because the synchron segments are jammed. The film of oil between the segments is broken causing their surfaces to rub on each other until they get stuck. They can no longer be used and have to be replaced with new ones.
- With synchromesh gear units, care should be taken when shifting that the working point is not passed too quickly as this would increase wear of the toothed gears.

The working point is the point where the synchronizing clutch (Fig. 2/5) becomes effective and the detent springs are forced out of the sliding claw. This is seen in section A – A.

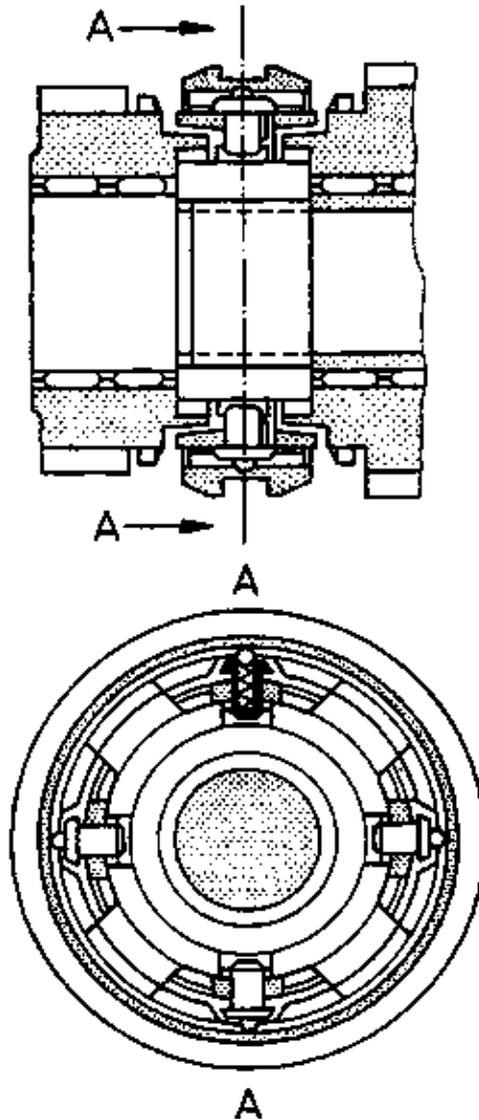


Figure 2/5 Synchronizing clutch A-A: section

The seals of mechanical gear-change boxes must be constantly checked for leakage to prevent gear oil from leaking. If, a leakage occurs, the oil level drops which leads to sticking of the gears, overheating of the antifriction bearings or burning of the rotary seals. A technical inspection should, therefore, include not only the oil level of the engine but also that of the gearbox and the other gear units such as the transfer box and differential unit.

2.1.3. The planetary gear unit

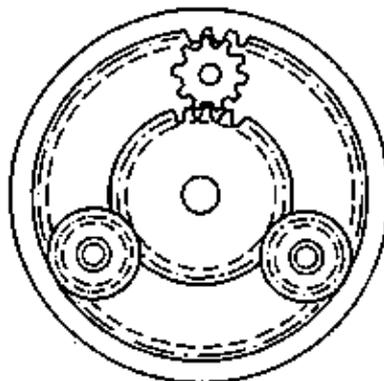


Figure 2/6 Planetary gear unit (cross section)

Another type of gearbox is the planetary gear unit, also called epicyclic gear (Fig. 2/6). The name has been derived from the planet pinions rotating around a sun gear. The planet pinions are fixed on a common holder and rotate in a ring gear. The planetary gear unit permits the selection of two speeds. For the first speed, the holder is moved and the ring gear remains stationary, the sun gear thus being turned at a particular speed.

For the second speed, the holder is moved and the sun gear remains stationary so that the planet pinions have to rotate around the sun gear. As a result, the ring gear rotates at another particular speed.

The planetary gear unit is often used for semi-automatic or automatic gear units. In this case, several gear units are usually mounted one after the other. The Wilson gear is an example of that.

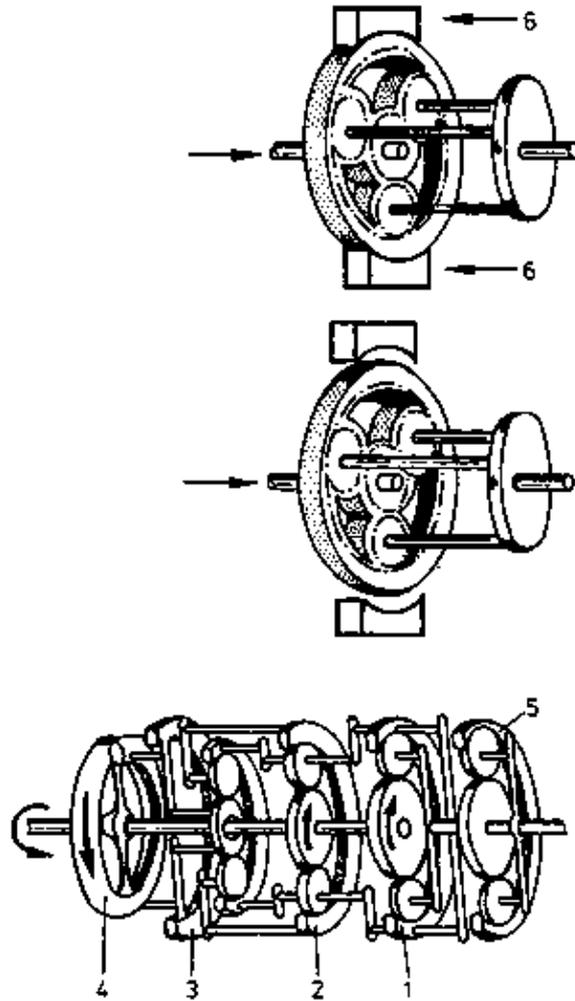


Figure 2/7 Planetary gear unit (longitudinal section)

1 first gear; 2 second gear; 3 third gear; 4 fourth gear; 5 reverse gear; 6 braked

As shown in Fig. 2/7, the Wilson (planetary) gear unit consists of several epicyclic units. The gears are preselected with a small lever in the driver's cabin and engaged by depressing a pedal. This pedal is used instead of the clutch pedal. The preselected gear is engaged by blocking the ring gear through a brake which is operated mechanically or electromagnetically. Only the ring gear of the selected gear is blocked.

2.2. The freewheel

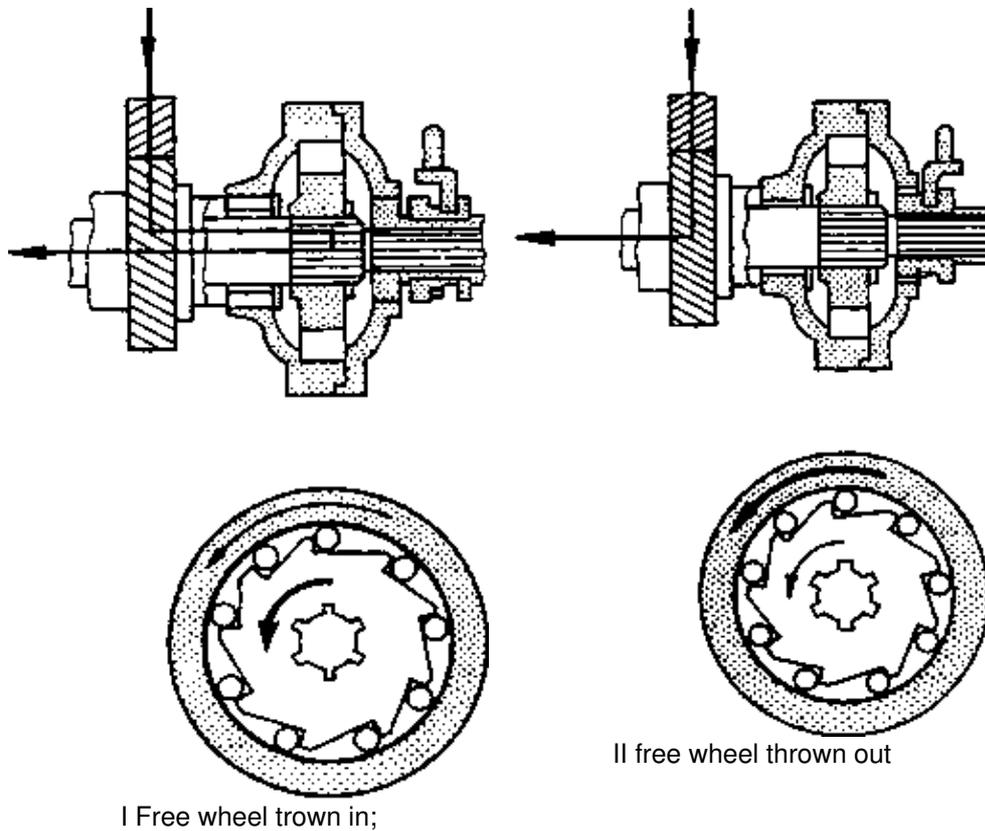
This paragraph deals once more with the mechanical gear-change box but with regard to the freewheel provided in some cases.

The freewheel (Fig. 2/8) is positioned between the drive shaft and the main shaft of the mechanical gear unit. Its function is to separate the drive from the driven wheels should they be forced to rotate faster than is possible by the power of the engine. This occurs when driving down hills. The car can thus utilize the natural drive. This saves fuel and spares the engine.

Operation of the freewheel:

The drive shaft of the gear unit is provided with a toothed star member. Loose rollers between the teeth in their bottom position when the vehicle is at rest or the star member rotates slowly. If the drive shaft is rotated, the rollers shift to their top position carrying the casing with them. The power is transmitted to the gear unit. If the freewheel is now blocked by a lever the rollers cannot return to the bottom position when the driven wheels rotate faster: the engine is made use of as an additional brake (the braking force is, however, very small with two-stroke engines).

Figure 2/8 Free wheel of a gearbox



2.3. The transfer box

Another mechanical gear unit shall be deal with in this paragraph: the auxiliary gearbox or transfer box.

Normally, it is only used for special vehicles that are driven on difficult terrain or have to climb steep gradients. This gear unit often incorporates an additional low range of gears with a respective speed ratio. Gears are changed by levers located in the driver's cabin. Some designs of this gear unit feature a power take-off shaft for additional units such as a hydraulic pump for tilting the floor or the side wall of a truck or for driving agricultural machines. The transfer box is designed so that either all axles of a vehicle can be driven or only the rear axle. Generally, the transfer box is driven by a propeller shaft mounted behind the gearbox.

Fig. 2/9 shows the gears of a transfer box. It serves for an additional speed reduction.

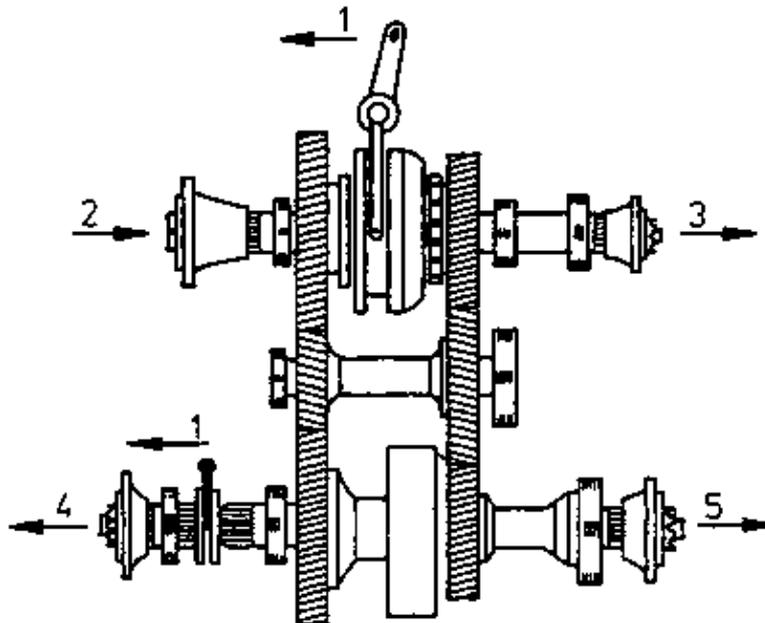


Figure 2/9 Transfer box

1 to shifting lever; 2 power from gear-change box; 3 driven side for accessory units; 4 drive for front axle; 5 drive for rear axle

The force of the driven wheels is increased but the speed reduced.

Any gear of the gearbox can be selected even-if the transfer box is engaged. If the engine is needed for operating an additional unit, the transmission of power to the axles of the vehicle may be interrupted by a shift claw. Only the additional unit is then driven by the engine, the vehicle remains stationary. The transfer box is equipped with helical gears to keep the noise within limits. It is used for derrick wagons and as drive unit for hydraulic pumps.

2.4. Fluid gear units

From the gear units described so far it was obvious that they were not infinitely variable. In this paragraph, the infinitely variable gear units shall be dealt with briefly.

According to their principle of operation they are classified into:

- infinitely variable mechanical gear units,
- hydraulic gear units,
- infinitely variable electric gear units.

In the following, especially the hydraulic gear unit shall be dealt with. As the name denotes, a hydraulic fluid is used, The hydraulic gear unit has been developed on the basis of the hydraulic clutch. It is used to drive heavy vehicles such as rail buses and heavy lorries but also larger passenger cars.

A turbine wheel incorporating three different blade rims is fitted on the drive shaft of the gear unit. Two other blade rims are positioned on the inside of the casing. They are used as fluid reciprocating blades. When the pump impeller begins to rotate, the centrifugal forces carry the fluid to the first system of the turbine wheel. The stationary blade rim in the casing reverses it, and it flows into the next blade rim. After the next change in the flow direction by the next stationary rim blade the fluid reaches the third system of the turbine wheel and is again in the centre. The process begins anew. With this system the clutch can be used to adjust the speed steplessly within a wide range.

Test questions:

2.1. What are the function of a gear-change box in a vehicle?

- 2.2. What is meant by “gear–change box”?
- 2.3. Describe the different power trains in a gear – change box.
- 2.4. What is the advantage of helical–toothed gears as compared to straight–toothed gears?
- 2.5. How are gears changed in mechanical gear–change boxes? Describe the construction and operating principle of the gear changing mechanism.
- 2.6. Describe the operating principle of a sliding–mesh gearbox.
- 2.7. Describe the construction and operating principle of a sliding–mesh claw–clutch gearbox.
- 2.8. What do you understand by “synchronisation” of a gear unit?
- 2.9. What is the advantage of synchronisation in mechanical gear–change boxes?
- 2.10. What types of wear in a gearbox do you know?
- 2.11. What is meant by “roaring” of a gearbox and how is it caused?
- 2.12. What do you understand by “knocking” of a gearbox? What are the causes?
- 2.13. What are the possible faults causing poor shiftability of a gearbox and disengaging of gears? How can they be eliminated?
- 2.14. Which causes for excessive wear of the sliding grooves do you know?
- 2.15. What is meant by “gearbox blocking”? How can you eliminate this fault?
- 2.16. What should be borne in mind when driving a car with a synchromesh gearbox?
- 2.17. Describe the construction and operating principle of a planetary gear unit.
- 2.18. Describe the construction and operation of a Wilson (planetary) gear.
- 2.19. Describe the construction and operating principle of the freewheel in a gear–change box.
- 2.20. What do you understand by a “transfer box”?
- 2.21. Give examples of the application of transfer boxes and describe the operation of such units.
- 2.22. Describe the construction and operating principle of a hydraulic gearbox.

3. Change of gears

As has been shown by the previous explanations multi–step gear units are operated by shift levers located in the driver’s cabin. They may be operated either via a linkage connected to the gearbox or by direct connection to the gearbox. In today’s vehicles two types of gear changing mechanisms predominate:

- steering–column gear shift
- floor–type gear shift

3.1. Steering-column gear shift

Steering-column gear shift is an indirect gear change. The shift lever is mounted on the steering column. It is connected to the short shift lever of the gearbox by reversing and slide members.

This type of gear changing mechanism has some negative aspects. The shifting path is long and therefore liable to trouble. Reversing members are required which are subject to constant wear. Exact shifting is then no longer ensured. The linkages are liable to corrosion. Screw joints and other securing elements are required.

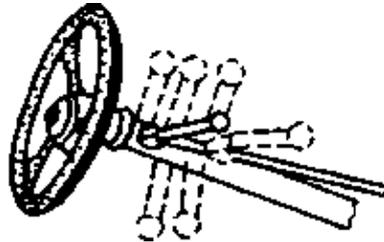


Figure 3/1 Steering-column gear shift

This gear changing mechanism can, however, not be completely eliminated from the automotive industry, since floor-type gear shifts cannot be used, for instance, in some front-driven vehicles.

Fig. 3/1 shows the steering-column gear changing mechanism.

3.2. Floor-type gear shift

Another common type of gear shift is the floor-type gear changing mechanism. In most cases it acts directly on the gearbox which is housed in a tunnel at the bottom of the vehicle. Larger vehicles with a centre-mounted or rear-mounted engine are provided with floor-type gear changing mechanisms. The shifting action is transmitted to the gearbox by reversing members and shift linkages (Fig. 3/2).

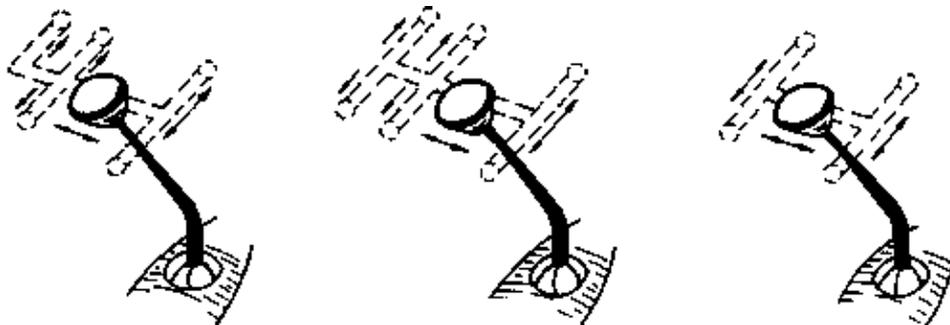


Figure 3/2 Floor-type gear shift

If there are shift linkages and reversing members, care should be taken to maintain them regularly to ensure proper gear shifting.

Test questions:

- 3.1. Describe the construction and operating principle of a steering-column gear change mechanism.
- 3.2. What do you understand by "floor-type gear shift"? How can it be designed?

4. Propeller shafts

The propeller shafts transmit the power of the engine from the gearbox to the driven axles. They are subject to heavy torsional stress since the force of the engine acts on one end, and on the other end the stationary masses or masses tending to come to a rest have to be moved. This stress increases gradually while starting

or accelerating the car. The propeller shaft have to satisfy the following requirements: minimum weight, maximum rigidity, high torsional strength and exact balance. If a propeller shaft is improperly balanced, it will generally vibrate during driving. The vibrations may damage the shaft and the adjacent parts. Fig. 4/1 shows the operating principle of a propeller shaft.

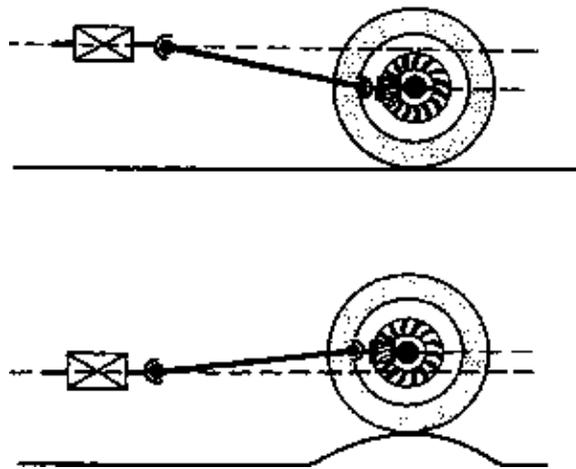


Figure 4/1 Operating principle of the cardan shaft

Propeller shafts are normally made of tubing to achieve high rigidity combined with low weight.

The tube tapers on both ends. Welded to one end is a universal joint and to the other end an internally and longitudinally toothed member.

Fig. 4/2 shows a propeller shaft of this type.

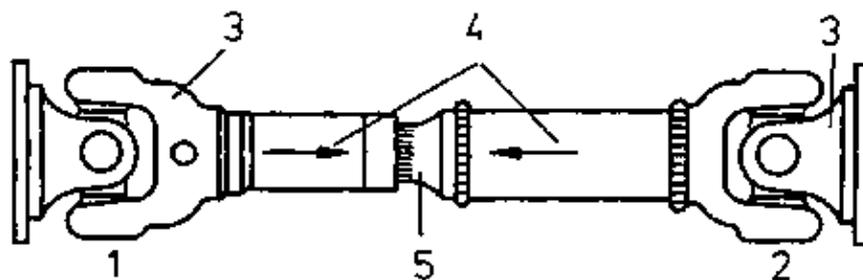


Figure 4/2 Cardan shaft or propeller shaft

1 first joint; 2 second joint; 3 fork positions; 4 marking arrows; 5 spline

4.1. The universal joint

The universal joints serve to balance chassis deflections and spring deflections of the driven axle. Each end of the shaft is there fore provided with universal joint (Fig. 4/3). Each universal joint consists of two yokes and a journal spider. The journals are ground because they rest in needle bearings which form end support bearings positioned in the yokes.

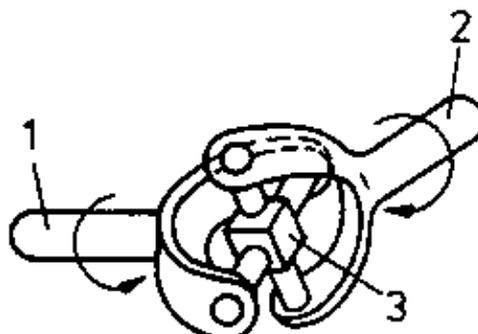


Figure 4/3 Universal joint

1 shaft I; 2 shaft II; 3 journal spider

All metallic bearing surfaces have to be protected against the ingress of dust. They must also be protected against moisture as it may cause the bearings to stick impairing proper functioning.

4.2. The longitudinal propeller shaft

The propeller shaft must have a length-changing means. Longitudinal propeller shafts are provided with a spline. Often, this is protected against moisture and dust by a rubber sleeve. It must always be lubricated when making inspections. The lubricant is forced into a grease nipple in the short part of the spline using a grease gun (caution: excessive lubricant may hamper the movement of the spline). Fig. 4/2 shows a longitudinal propeller shaft with spline. The arrows on the shaft must be in line as the shaft is balanced in this position.

When assembling propeller shafts care should be taken that the universal joints coincide in position. If the shafts are improperly installed, heavy vibrations will occur which may destroy the shaft.

The non-enclosed longitudinal propeller shafts are mounted in the direction of the vehicle. If the distance between gearbox and rear axle is too long, the shaft should be supported by centre bearings to limit vibrations. Propeller shafts running at high speeds (mainly in passenger cars) should not be interrupted, if possible. In modern vehicles with rear-axle drive the gearbox is displaced or extended so that a short propeller shaft can be used and vibrations are reduced. Vibrations are also reduced by incorporating the spline into the gearbox.

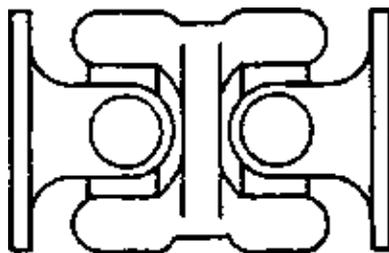


Figure 4/4 Double universal joint

If the transfer box is connected by a flange, a double universal joint (Fig. 4/4) may be incorporated between the gearbox and the transfer box. It is used to connect the two gear units and to balance the movements of the Silentbloc type rubber-metal connections.

4.3. The transverse propeller shaft

Besides the longitudinal shafts, transverse propeller shafts are known. They are designed to be installed at right angles to the longitudinal axis of the vehicle. Like the longitudinal propeller shafts, they are used to drive the wheels. They are found in front-driven vehicles and vehicles with single-wheel suspension. The propeller shafts of a front-driven vehicle must be suitable for a deflection angle 45 to compensate for the steering angle and the resulting spring angle. Here the uniform circumferential speed of the wheels with a large steering angle is important. Generally, constant velocity joints are used for drives of this type. If a constant velocity joint is a universal joint, then it must be a double joint (Fig. 4/5).

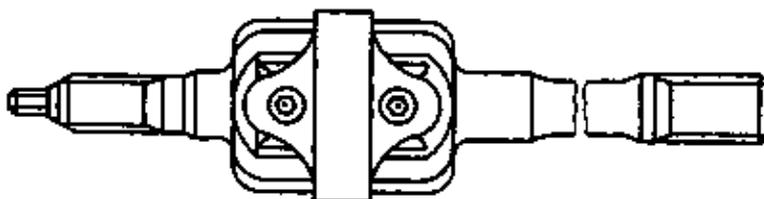


Figure 4/5 Constant velocity joint

The double universal joint incorporates a pilot device. If the bearings of the joint are near to the gearbox, the pilot device can be dispensed with. If the driven wheels are suspended singly, an additional joint is necessary.

This joint can operate with two slide members or one tripod member (Fig. 4/6) which are (is) carried in slide bearings in the gearbox and can compensate the movements of the single-wheel suspensions.

Transverse propeller shafts belong to the springless masses of a vehicle. Therefore, they should be of low weight. Transverse propeller shafts normally have two joints. The connection between them may be loose or rigid. If the joints or the connection pieces are equipped with flexible members then torsionally elastic connection is obtained which permits a shock-absorbing power transmission.

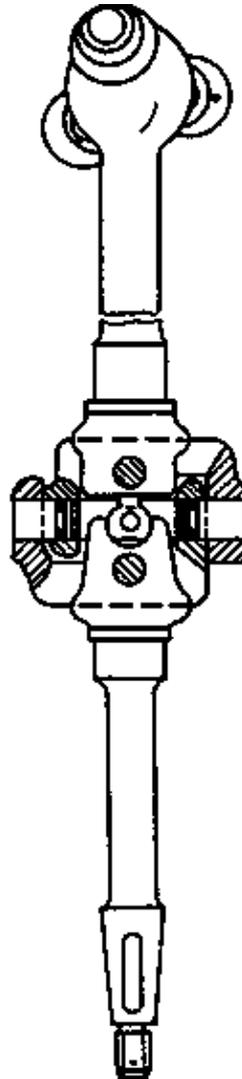


Figure 4/6 Double universal joint with 2 slide members and tripod member

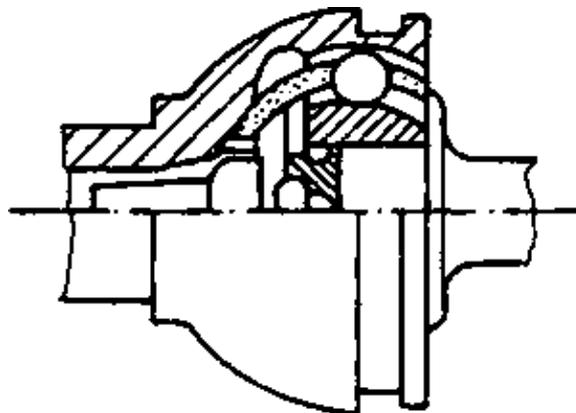


Figure 4/7 Ball joint

Transverse propeller shafts may not only be provided with universal joints but also with ball joints. They enable a high mobility to be obtained (Fig. 4/7). They consist of hardened steel balls rolling on a circular surface. Since the relative movements are balanced by the balls in any position, no non-uniform rotation may

occur. Therefore, these joints are also referred to as “ideal” constant velocity joints.

These joints permit large deflection angles (about 38°). Since they are very small they are often used in front-driven vehicles. As compared to other joints their manufacture is difficult.

One of the most simple types of joints is the flexible disk joint (Fig. 4/8). It transmits torques elastically and accommodates vibrations. The angular mobility of this joint is ensured by flexible fabric disks or rope sheaves. Such joints have only a very small deflection angle of approximately 3°.

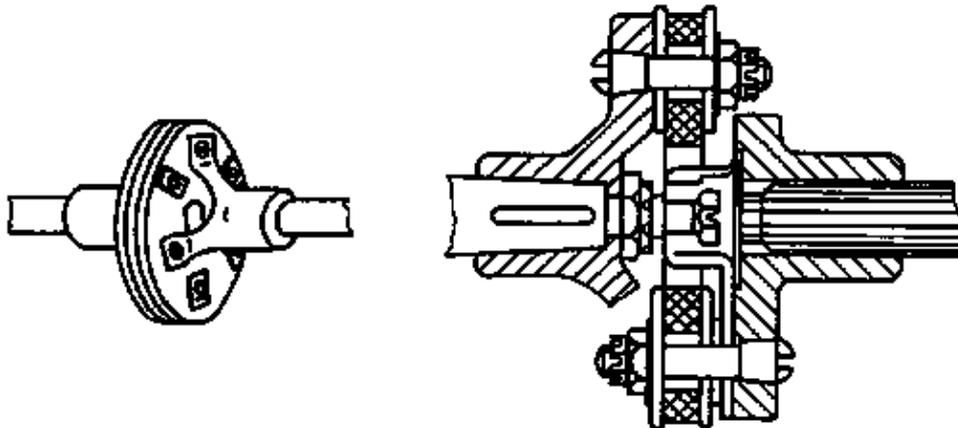


Figure 4/8 Flexible disk joint

Fig. 4/8 shows how the two shafts are connected to the joint. The shafts have “flange arms” positioned at angles of 120° to each other. These arms are connected to the disk joint by fit bolts which are also used to centre the disk. With this type of joint the countershaft is offset by 60°.

The following table shows a comparison of the advantages and disadvantages of metal joints and rubber fabric joints:

	Metal joints	Rubber fabric joints
Power transmission	for maximum loads	used for minor and medium loads
Permissible angle variation	30° (special joint 50°)	limited to about 8°
Maintenance	routine lubrication required	no lubrication required

If the favourable properties of both types of joints were to be made use of, the two types would have to be incorporated in one propeller shaft train.

4.4. Maintenance and repair of propeller shafts

Despite its important function in the transmission of power, the propeller shaft is still frequently considered to be of minor importance. As a result, maintenance and care is neglected. The propeller shafts can, however, only withstand their high loads when they are regularly maintained. Otherwise, the bearing play will increase prematurely resulting in early wear of the driving parts. If the propeller shaft breaks, the braking effect of the engine is no longer present so that the road safety of the vehicle is impaired.

The flange connections should be regularly checked for tightness. This includes that no flange bolts are missing. The bolts must comply with the hole diameter since they are not only stressed in tension but also in shear during movement.

The universal joints should be regularly checked for proper lubrication. The check may be made with a grease gun. If grease emerges from a bearing, then it is sufficiently greased.

With enclosed universal joints it should be seen to that the rubber sleeves protecting the joint from dirt, water and moisture are leakproof.

Flexible disk joints should be protected from oil and grease since these destroy the rubber member, thus making the joint inoperative.

Wear of the catches or the grooved members causes vibration of the propeller shaft, resulting in drumming.

The engaging splines must be mounted carefully so as not to damage the seals on the profiled ends of the propeller shaft. Before installing propeller shafts or splines remember to grease them, since the grease film ensures easy movement. Furthermore, propeller shafts may only be stressed within their angle of deflection.

When installing propeller shafts it is important that the yokes on the shaft ends be at the same level. They must be fully aligned as misalignment causes unbalance. If there are so-called propeller shaft trains in a vehicle, i.e. several propeller shafts are installed one after the other, the specified claw position must be maintained. When installing the shafts it should be seen to easily and do not jam that the splines move. Forces are generated by heavily moving splines that may result in an overloading of the gear unit bearings and even destroy them in case of extended service.

Test questions:

- 4.1. What are the functions of propeller shafts in a vehicle?
- 4.2. To what stresses are propeller shafts exposed?
- 4.3. Why must propeller shafts be balanced? What should be borne in mind when reinstalling them?
- 4.4. Describe the construction of a longitudinal propeller shaft.
- 4.5. What is the function of universal joints of a propeller shaft?
- 4.6. Why are propeller shafts mounted in centre bearings in some types of vehicles?
- 4.7. Which types of propeller shafts do you know besides the longitudinal propeller shaft?
- 4.8. Describe the construction of the trans-verse propeller shaft with double joint.
- 4.9. Describe the construction of a ball joint.
- 4.10. Describe the construction of a flexible disk joint.
- 4.11. Why is it necessary to maintain the propeller shafts of a vehicle regularly?
- 4.12. What should be borne in mind when installing propeller shafts?
- 4.13. Why is it necessary to protect flexible disk joints from oil and grease?
- 4.14. Describe the installation of a propeller shaft in a vehicle with rear-axle drive.

5. Final drives

The final drive forms the connection between the propeller shaft and the differential unit.

Normally, final drive and differential unit are housed in one casing and screwed to each other. They run in an oil bath.

Principally, two types of final drive are distinguished:

- bevel-gear drive and
- worm-gear drive

In most cases the propeller shaft is positioned in the direction of travel and the driving gears are positioned at right angles to it. From this can be concluded that the direction of force action has to be turned by 90. This is implemented by the final drive. To increase the torque, the final drive is provided with a transmission gear. For passenger cars, the gear ratio is between 4 to 1 and 6 to 1 and for lorries between 5 to 1 and 10 to 1. The gear ratio of a vehicle is composed of that of the gearbox and that of the final drive.

5.1. The bevel-gear drive

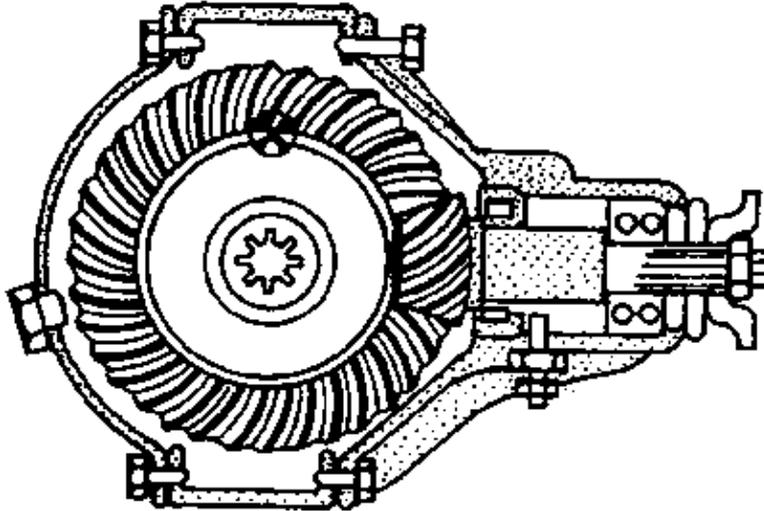


Figure 5/1 Bevel-gear drive

In the bevel-gear drive (Fig. 5/1) the driving pinion engages with a ring gear. There are two types of bevel gear drive. In the standard design, the central axis of the driving bevel gear connected to the propeller shaft is exactly at the same level as the central axis of the driven ring gear (as shown in Fig. 5/1). The bevel gears of the final drive are provided with a special tothing.

This type of tothing ensures a quieter running of the final drive to be achieved in comparison with straight tothing.

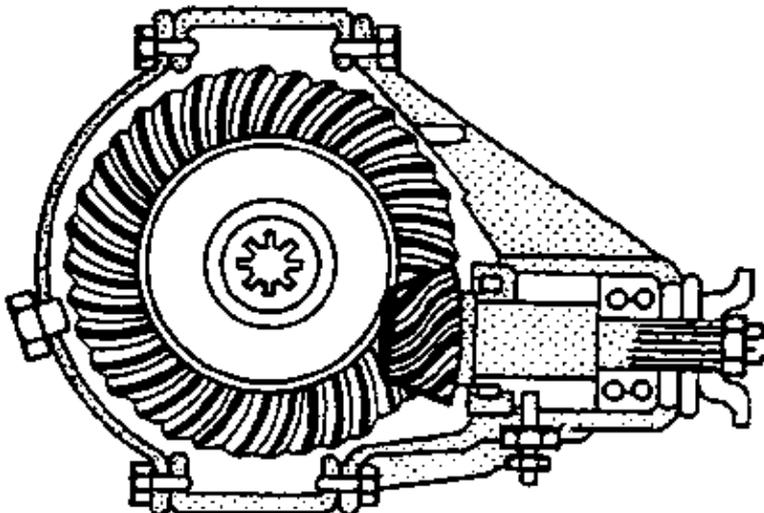


Figure 5/2 Hypoid-gear drive

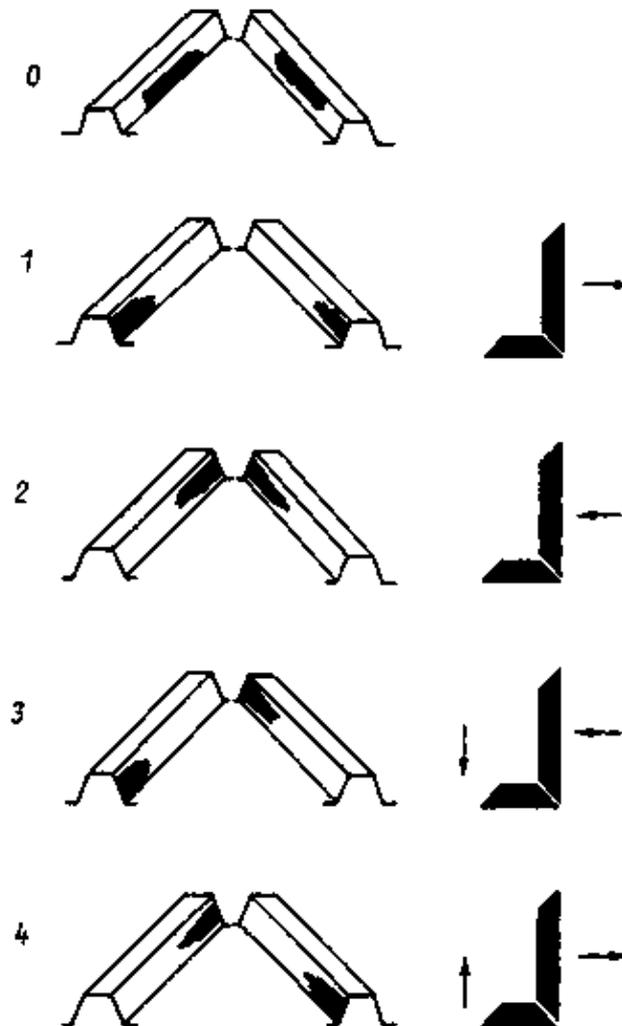
The hypoid-gear drive (Fig. 5/2) is the second type of bevel-gear drive.

The bevel gear and the ring gear have a hypoidtooth system where the angle of the teeth differs from that of a normal bevel gear drive.

This permits the driving pinion to be mounted off the ring gear centre. Owing to this, the body of the vehicle or the propeller shaft tunnel in the body may be of a lower design.

The hypoid-gear drive is subjected to considerable lateral pressures. This calls for a special lubricant. The hypoid oil used is very viscous, and unlike other lubricants it accommodates the high lateral forces acting on the tooth profiles and prevents the grease film from being broken.

For quiet running it is necessary for the bevel gears of the final drive to mesh properly. This means that the reference circles of the tooth profiles of the two bevel gears must come into contact. This can be seen from the tooth bearings (Fig. 5/3). To obtain a tooth bearing, marking ink is to be applied on both gears. Then the gears are rolled in mesh in two directions since you can reserve a car. Through this procedure the bearing faces are marked. The gears can then be adjusted. Note that the teeth may not contact each other at the smallest diameter.



1 to 4 wrong engagement correct

Figure 5/3 Tooth bearings, 0 engagement

Explanation of the tooth bearings illustrated in Fig. 5/3:

0 This bearing shows the proper mesh of the bevel gears.

1 Wrong mesh: The ring gear must be moved slightly out of mesh.

2 Wrong mesh: The ring gear must be moved slightly into mesh.

3 Wrong mesh: The ring gear must be moved slightly into mesh, and the driving pinion must be moved slightly out of mesh.

4 Wrong mesh: The driving pinion must be moved slightly into mesh, and the ring gear must be moved slightly out of mesh.

A readjustment of the two bevel gears can be made as follows:

- Adjusting washers may be inserted between the shaft flanges and bearing bushes or fitted to the front faces of the bevel gears.
- Shims are inserted between the fitting surfaces of bearing faces and casing parts.
- The whole bearing assembly can be shifted by a thread.

The shims and adjusting washers are very thin and sensitive.

Fig. 5/4 shows the support of the ring gear. This support counteracts sudden shocks resulting from wrong gear changing, blocking of the engine and other external forces. In such situations enormous forces occur causing the ring gear to deflect considerably, resulting in the teeth of the ring gear and the bevel gear to be subjected to considerable stress

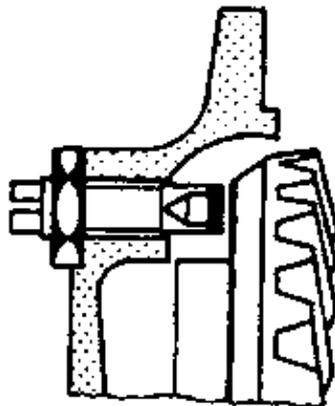


Figure 5/4 Crown wheel support

The ring gear is supported by an adjustable thrust bolt. The gap between the support and the rear face of the ring gear must be adjusted to 0.1 mm. To prevent the drive pinion from being distorted, the ring gear in lorries is in most cases carried in bearings on two sides.

5.2. The worm-gear drive

Final drive by means of a worm and a worm gear is mainly used for heavy lorries. The advantage is that high gear ratios can be implemented in a comparatively small space. Another advantage is the low noise level. The unit can drive two rear axles without a transfer box being required.

Figs. 5/5 and 5/6 show two possible types of worm-gear units. The construction depends on the intended use of the vehicle.

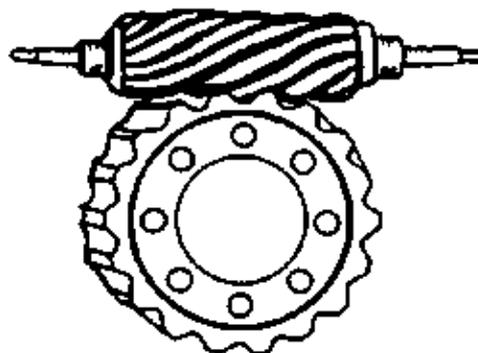
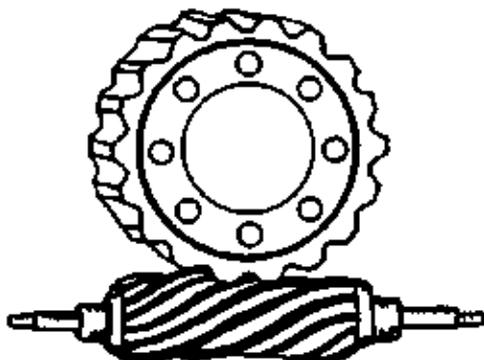


Figure 5/5 Worm drive with bottom-mounted worm Figure 5/6 Worm drive – with overhead worm

If the worm is bottom-mounted, the vehicle's centre of gravity is low. If the worm is mounted overhead, a higher ground clearance is obtained. Such a worm-gear unit is also used for driving the tachometer shaft.

5.3. Other types of drive

In order to achieve for the bevel-gear drive the gear ratios possible for the worm-gear drive, bevel-gear unit and spur gear pair are combined. Fig. 5/7 shows such a combination. The IFA W 50 lorry is provided with such an assembly. The ring gear is connected to a spur pinion which drives a spur gear. This, in turn, is connected to the axle shafts and drives the wheels.

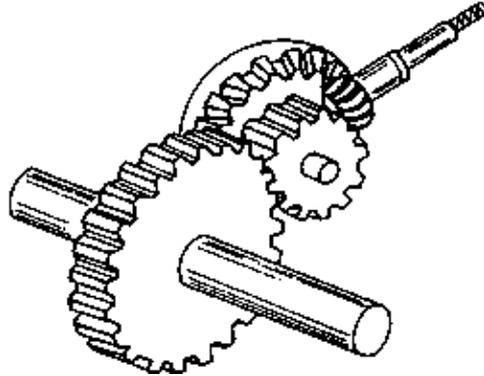


Figure 5/7 Combination of bevel-gear drive and spur gear pair

Another type of final drive is by the spicyclic spur gear unit. Here, differential spur gears are connected to the ring gear and positioned so that they mesh with it in pairs.

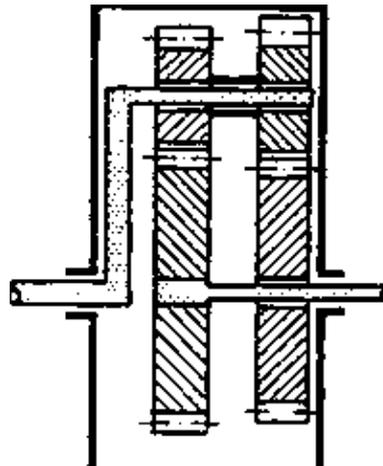


Figure 5/8 Epicyclic spur gears on parallel axes

Fig. 5/8 shows an epicyclic spur gear unit. The differential | pinions rotate in the stationary casing. Epicyclic spur gear units of this type are often used for automatic gear units.

Test questions:

- 5.1. Which types of drives do you know?
- 5.2. Describe the construction of a bevel-gear drive.
- 5.3. What do you understand by “hypoid-gear drive”?
- 5.4. Explain the proper adjustment of the bevel gears by using the tooth bearing diagrams.
- 5.5. What is the function of the ring gear support?
- 5.6. What do you understand by “worm-gear drive”?
- 5.7. Why are worm-gear drives with bottom-mounted and overhead worm used?
- 5.8. What is an epicyclic spur gear unit?

6. The differential unit

The differential unit is firmly connected to a ring gear. On both sides of the differential casing, drive shafts for the wheels are introduced. In the casing they are connected to bevel gears either by internal toothings of the bevel gears or a tulip-shaped drive member in mesh with a tripod member or slide members. (Only rarely are the bevel gears fastened to the drive shaft.) A differential “star” comprising two or four pivoted bevel gears is seated between these two bevel gears (Fig. 6/1).

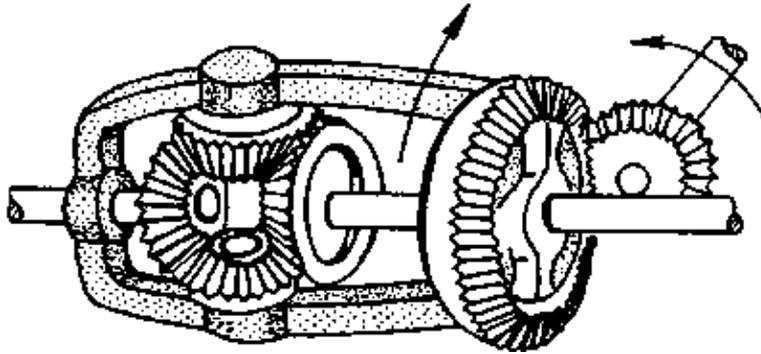


Figure 6/1 Differential gear unit

Operating principle of the differential unit:

The propeller shaft causes the drive pinion to rotate which, in turn, drives the ring gear carrying along the differential casing fixed to it. This causes the two drive shafts to rotate which, in turn, drive the wheels.

When the vehicle goes straight ahead, the driven wheels turn at equal speed. The differential gears do not rotate but serve only as a coupling between the rotating differential casing which makes a circular movement, i.e. they rotate together with the differential casing. When the vehicle goes through a corner, the differential casing continues to rotate at the same speed. Since the inner wheel has to travel a shorter distance than the outer wheel, its speed is reduced as compared to the differential casing, with the differential gears rotating around their axes rolling on the bevel gear lagging behind. Through this, the shaft of the outer wheel is driven, increasing the wheel's speed as compared to the differential casing.

We can draw the following conclusion from this: The slower the inner wheel rotates the faster the outer wheel must rotate.

If one of the two driving wheels encounters a stationary obstacle and, therefore, can no longer rotate, the other wheel must take over its speed. This means that the latter rotates at double speed while the former remains stationary. This can be observed when one wheel sinks into soft ground and has no adhesion. It is then held up, while the other is still able to move freely. In this situation the vehicle cannot be driven away under its own power.

These problems are excluded in modern lorries moving mainly over difficult terrain in that they are provided with a differential lock.

The purpose of the differential lock is to establish a rigid connection between the two axle halves. The differential lock is generally operated by the driver from his cabin. It eliminates the disadvantages of a differential unit.

In the following, the function of the differential lock is described briefly: A claw clutch is attached to a drive shaft which can be positively connected to the differential casing by actuating a lever. If the clutch is engaged, the shaft and the associated drive shaft pinion are no longer capable of turning relative to the final drive casing.

The differential gears can no longer rotate. Like the propeller shaft toothing they act as a catch for the bevel gear of the other drive shaft. Thus, the vehicle can be driven away under its own power.

It is important to release the differential lock as soon as the vehicle reaches solid ground once again. Otherwise the gearbox components would be excessively stressed on a nonskid road and in bends, the tyres

would wear quickly and steering would be impeded.

Differential locks may be designed similar to previously described freewheel. The differential units are then selflocking. As soon as the speed of one of the driving wheels becomes excessive, this unit is locked automatically as a result of the centrifugal forces and returns automatically to its normal “unlocked” position when the driving wheels run at equal speed.

Test questions:

- 6.1. What do you understand by “differential unit”?
- 6.2. Describe the construction of a differential unit.
- 6.3. Describe the operating principle of the differential unit when the vehicle goes straight ahead.
- 6.4. Describe the operating principle of the differential unit when the vehicle goes through corners.
- 6.5. Why are differential locks used in vehicles?
- 6.6. Describe the operating principle of the differential lock.
- 6.7. What do you understand by a “self-locking differential unit”?

7. Lubrication

Each gear unit in a vehicle must be lubricated in order to run properly. Additive-treated and non-additive-treated oils are used for lubrication. The additives improve the lubricating quality, resistance to ageing and corrosion, the foaming behaviour and the viscosity-temperature relation. They are used to reduce mechanical wear. They form a film with a low shear resistance on the tooth profiles that is continuously worn and renewed thus preventing seizing of the tooth profiles. The viscosity of additive-treated oils is lower than that of non-treated oils. This is of great advantage during the running of the vehicle since it reduces mechanical losses in the power train, facilitates changing of gears and results in an improved heat removal. Additive-treated gear oils have a wide operating temperature range. They can be employed at temperatures between -20°C and $+100^{\circ}\text{C}$.

Gear oils are used for all types of gear units found in vehicles and for antifriction bearings exposed to high stresses. They are employed to lubricate gearboxes, transfer boxes, differential gear units, steering gear units and final drives.

An oil renewal should generally be carried out between 20,000 km and 30,000 km (max.). After a repair of a gear unit fresh gear oil should always be used, since abraded metal particles settle in the oil during operation.

As mentioned above, hypoid oil is a gear oil with a very high additive content; it is used for highly stressed gear units.

Application of oil

Viscosity plays a decisive role for the application of a gear oil. It influences the oil flow, the thickness of the oil film to be built up on the components to be lubricated, the mechanical efficiency of the gear unit, the thermal behaviour and the power losses due to friction. Furthermore, it depends on the viscosity whether a gear oil can be used for full fluid-film lubrication. For proper running of the gear units it is necessary that operation conditions, design and viscosity be matches to each other. This increase also the service life of the gear unit components.

If a gear unit features a low circumferential speed and a high ambient temperature, the lubricating oil should have a high viscosity. If, however, a high circumferential speed and a low ambient temperature occur, the viscosity of the gear oil may be low.

If a gear unit is exposed to alternating or discontinuous loads, a high–viscosity oil should be used. If low–viscosity gear oil is used, special care should be taken that the connections to the gearbox are leakproof since proper lubrication is no longer ensured when the thin oil escapes. Therefore, the oil level should be checked regularly in gear units with low–viscosity oil. This is done with a dip–stick or by opening an inspection plug where the oil flows out when the filling is sufficient.

Gear oils are divided into SAE viscosity classes.

Because of the convenient identification of lubricating oils – gear oils or engine oils –viscosity grades are indicated worldwide in SAE.

The tabel below lists the viscosity classes: The most common viscosity classes are between 75 and 250 and are specified for –17.8°C and +98,9°C in the table. Viscosity is given in sq.mm/s.

SAE viscosity class	Viscosity in sq.mm/s (cSt)			
	at –17,8 °C		at +98,9 °C	
	minimum	maximum	minimum	maximum
75	–	3,257	4,18	–
80	8,257	21,716	4,18	–
90	–	–	14,24	25,0
140	–	–	25,0	42,7
250	–	–	42,7	–

Advantages of additive–treated gear oils

Additive–treated gear oils provide an outstanding protection against seizing of gear unit parts and wear due to friction. They have a high thermal and ageing stability. Gear oils have a good viscosity–temperature behaviour, protect against corrosion and feature a favourable foaming behaviour.

Disadvantages of additive–treates gear oils

Since high–viscosity oils are also additive–treated oils, only their disadvantages shall be listed.

They are generally used for full fluid–film lubrication. This means that the respective gear unit component dips into the oil–bath during its rotation. This type of lubrication is also called oil–bath lubrication or dip–feed lubrication. It re– suits in a considerable loss of power, leading to high temperatures accelerating the ageing of the oil.

At low outdoor temperatures the oil is very hard and the teeth have to free themselves at first. Thus full lubrication is not ensured from the start. This results in increased wear of the tooth profiles. In the case of dip–feed lubrication gear parts which do not run directly in the oil–bath and do not dip into it may wear prematurely because the oil is not sufficiently whirled around since it–is cold. At low outdoor temperatures the delivery rate of the oil pump in a forced lubrication system may be insufficient, also resulting in increased wear.

In gearboxes, mechanical troubles may occur which even make it impossible to move the vehicle. In such a case, the gearbox should be warmed up using a suitable heat source to thin the oil.

Gear grease

Another type of lubrication is by gear greases. They are used wherever lubrication with gear oil is impossible or does not seem appropriate (for example, when the gear oil drips down or is spun off thus being not available for lubrication).

Greases are oils thickened by additives. They are used for the following applications:

- for antifriction bearings and stuffing boxes that come into contact with water (pump greases);
- for lubrication points which have to be protected against foreign matter (foreign matter being dust or dirt particles or water; the grease film protects the adjacent parts)
- for lubrication points requiring very little grease (these lubrication points are understood as being permanently lubricated, e.g. universal joints, springs, pedal shafts, etc.)
- for slowly rotating bearings and those with high surface pressures.

As applies to the lubrication with gear oil, some aspects are of major importance to the selection of greases.

The design of the bearings – plain bearings or antifriction bearings – must be taken into account. Furthermore, speed, bearing load and bearing temperature have to be considered.

Test questions:

- 7.1. What do you understand by “lubrication”?
- 7.2. What should be the properties of a lubricant intended for use in vehicles?
- 7.3. What do you understand by “additive–treated oils”?
- 7.4. What are the advantages of additive–treated oils in comparison with non–treated ones?
- 7.5. When should the gear oil be renewed?
- 7.6. Why may only fresh gear oil be used after gear units have been repaired?
- 7.7. What do you have to take into account when using oils?
- 7.8. What do you understand by “viscosity” of an oil?
- 7.9. Name the disadvantages of high–viscosity oils?
- 7.10. Which other lubricants, except oils, do you know?
- 7.11. What are the functions of these lubricants? Give some examples.
- 7.12. Where are these lubricants used in a vehicle?

8. General instructions for repairing gear units:

After the gear unit to be repaired has been removed, its outer surface should be cleaned. The unit is then disassembled. The individual components must also be thoroughly cleaned so that they can be checked for reusability. Reusable parts are laid aside for reassembly. Non–reusable parts are checked to find out whether reconditioning is possible or whether they have to be scrapped.

Parts to be scrapped have to be replaced with new ones. Before reassembly the sealing faces of the gearbox casing should be checked for smoothness, because they may have been damaged by careless disassembly. When disassembling a casing, wedges such as screw drivers should never be forced between sealing faces as this would damage them.

All abraded particle must be removed from the casing. Then the sealing faces are smoothed on a surface planing plate covered with abrasive fabric. At the same time, the casing can be checked for distortion of the sealing faces. After smoothing the casing must be cleaned again since abraded material will have deposited on it.

Now assembly can be started. An oil film should be applied to the gear shafts, especially the bearings. The lips of the rotary shaft seals must be coated with oil to prevent them from running dry and being burned. An oil film should also be applied to the toothed gears so that the gear shafts rotate more easily and do not abrade due to dry running while they are being checked for serviceability.

When gaskets are placed on the sealing faces between the casing halves these faces must also be coated with oil before applying the gaskets so as to achieve leakproofness. If no gaskets are used, the seal faces are coated with sealing compound which has the same effect as a paper seal.

After the casing halves have been assembled, the screws are put in place and screwed in finger-tight. When all screws are inserted, they are tightened crosswise so as to prevent the casing halves from being distorted, which would again result in leakages or seizing of gear shafts. For tightening the screws, dynamometric keys with a plug-on cocket should be used so as not to stress the screws beyond their tensile strength. If this occurs considerable efforts are required to reestablish the initial condition of the casing.

The repaired gear unit is then checked for proper functioning. The gears are engaged and the gear shaft rotated simultaneously. If the gear unit functions properly, the specified amount of gear oil can be filled in. The gear unit is then reinstalled into the power train.

The basis concept of disassembling and reassembling gear units remains the same even if units are concerned the casings of which cannot be dismantled into halves.