UNIT 4

Propeller Shaft and Rear Axle

Contents

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Learning objectives

1. To learn how the energy is transmitted to the rear wheel.
2. To learn how the engine energy is changed according to the rear wheel rotation.

4.0 Introduction

Propeller shaft is the most important part of transmission system of a vehicle. It is located in between the gear box and the differential unit. One end of the propeller shaft is connected to the gear box and the other end is connected with the differential unit, and transmits the engine power to the rear wheels. The two ends of propeller shaft are connected by the universal joints and hence the engine's power is transmitted to the rear wheels without any losses even with the difference in distances. For operating the propeller shaft based on various load conditions of vehicle, sliding joint is fitted in between the universal joint and propeller shaft. The propeller shaft withstands the full accelerating power comes from the gear box.

4.0.1 Propeller shaft

It is made of hardened steel and in tubular form. Two propeller shafts are used if the vehicle length is more. Bearing is fitted between the centre of two propeller shafts.

4.1 Material for the propeller shaft

Propeller shaft is generally made up of alloy steel. Moreover it is made up of spring steel material.

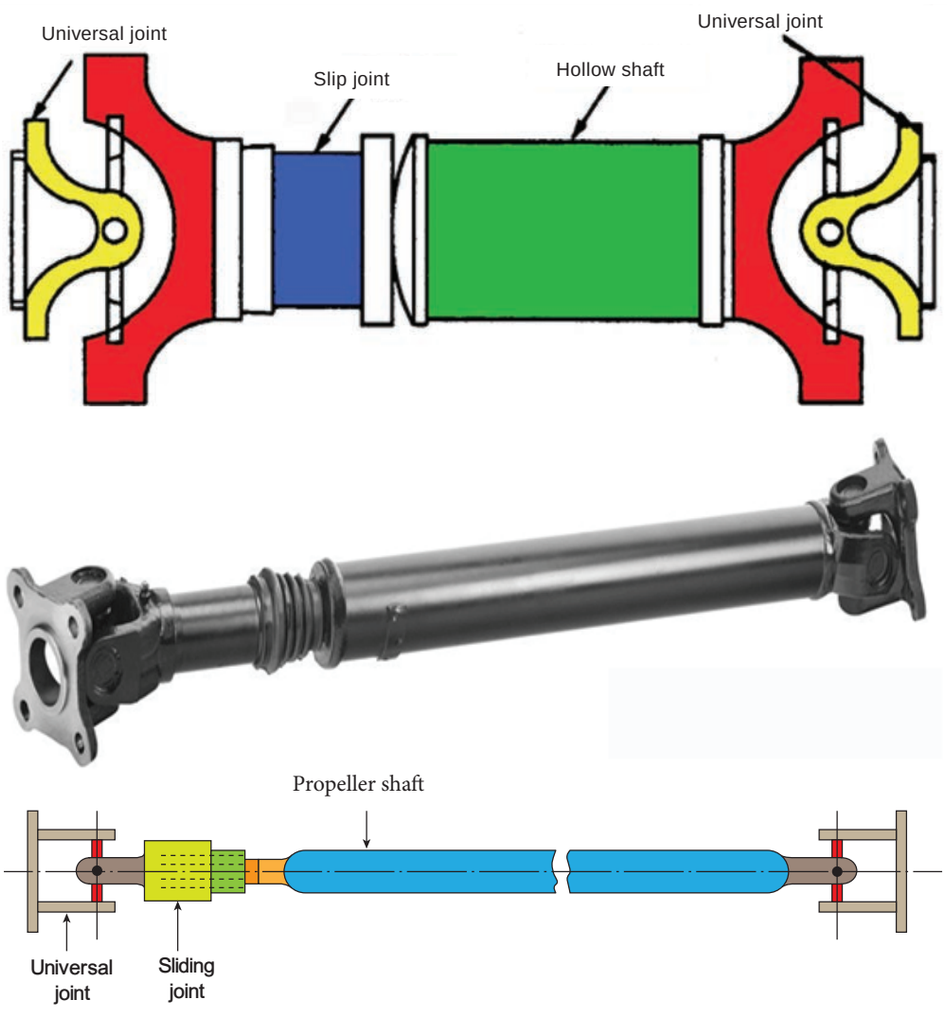


Figure 4.0.1 Propeller shaft

4.2 Functions of propeller shaft

- It transmits the engine's power from gear box to the differential unit smoothly.
- It transmits the rotational power from the gear box at different angles as per requirement.
- According to the load of the vehicle, the length of the propeller shaft varies and transmits the power through slip joints.
- When the vehicle is running, it completely withstands the vibration occurring in the transmission system.

4.3 Types of propeller shaft drive

The operation of propeller shaft is classified in to two types. They are

1. Hotchkiss Drive
2. Torque tube Drive

4.3.1 Hotchkiss drive

Construction

In this drive, the leaf springs are tightly fixed at the center of the axis of rear axle. The back end of the spring is attached with Shackle (movable). The front end is attached to the chassis frame with anchor pin (fixed). The two universal joints and a sliding joint were connected to the Propeller Shaft. The first universal joint is connected to the gear box shaft and second universal joint is attached with the bevel pinion shaft of the differential unit. The construction of the Hotchkiss Drive is shown in Figure 4.3.1.

Working Principle

When the vehicle goes forward with more loads, the front end of the propeller shaft elongates and the rear end of the leaf spring is pressed and the front part of the spring is elongated. This happens due to the front and backward movements of the universal joint and sliding joint located at the front end of the propeller shaft. Due to this the vehicle moves easily on the road.

This Hotchkiss drive is used in most of the vehicles. This type of drive makes the vehicle to move smoothly even on the roads with ups and down.

Advantages

1. Weight is less
2. Simple in construction
3. It does not make more noise.

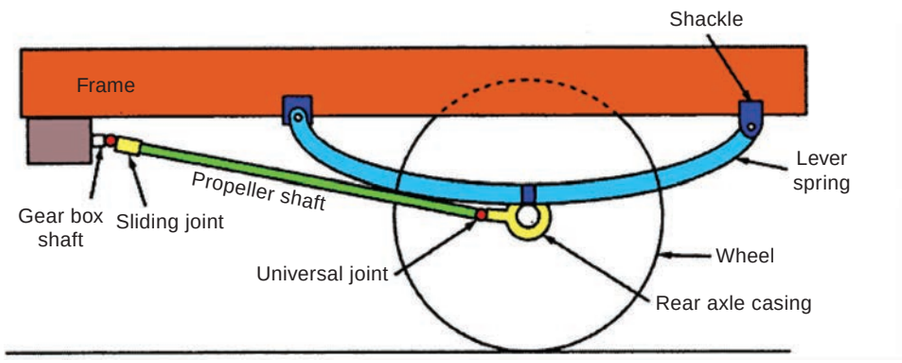


Figure 4.3.1 Hotchkiss drive

Disadvantages

1. Not protected well as the arrangement is in open outdoors.
2. Universal joints get damaged easily.

4.3.2 Torque tube drive

Construction

The propeller shaft of the vehicle is kept inside on another tube called as the torque tube which looks like a pipe. The construction of the Torque tube drive is shown in Figure 4.3.2.

The bearing which is connected to this allows the propeller shaft to rotate easily. Only one universal joint is fitted in this drive. The front part of the torque tube is like a cone and is connected at the back side of the gear box casing by using a ball and socket joint.

Working Principle

When the vehicle moves on the road, the torque and the drive thrust are transmitted to the chassis frame through axle casing. Since the ball and socket joint in the torque tube is supported by the roller bearing, the propeller shafts rotates easily. This torque tube drive is mostly used in cars and in heavy commercial vehicles.

Advantages

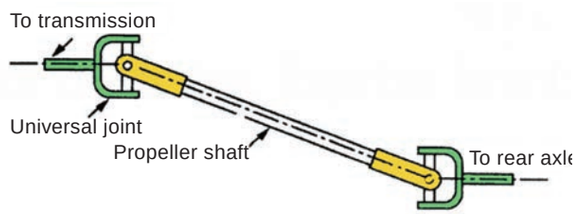
1. It's very safe to use.
2. It works for a long time.
3. Universal joint in this drive will not damage quickly

Disadvantages

1. Overweight.
2. It is not very strong.
3. It is not suitable for transmitting more power.

4.4 Parts of the propeller shaft

1. Universal joint
2. Sliding joint



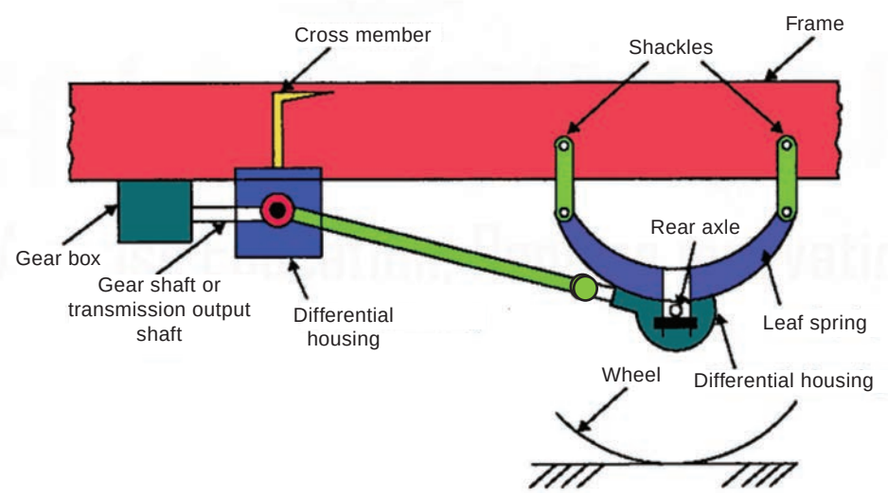


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Figure 4.3.2 Torque tube drive

4.5 Universal joint

This is connected at both ends of the propeller shaft. Since the propeller shaft is connected by the universal joint, it transmits the engine's power at different angles.

4.6 Slip joint

It is connected with the propeller shaft after the universal joint. It moves smoothly according to the movement of rear axle. Figure 4.6 shows the view of a slip joint used in automobiles.

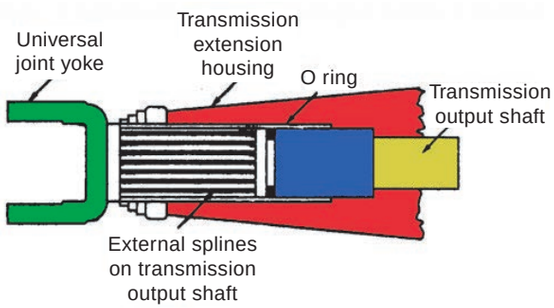


Figure 4.6 Slip joint used in automobile

4.7 Functions of universal joint

- It transmits the power from the gear box shaft to the propeller shaft through inclined direction.
- It helps to transmit the power without any loss when the vehicle is going on ups and downs of the roads.
- It withstands the vibrations occurring on the roads.
- It helps in varying the length of the propeller shaft.

4.8 Types of universal joint

1. Hooke's type
2. Pot type
3. Rubber coupling type
4. Ball type

4.8.1 Hooke's type

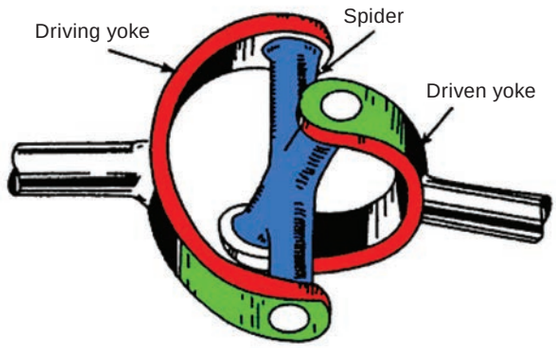


Figure 4.8.1 Hooke type universal joint

In this type of joint the spider is fixed in between the two yokes. In the spider, needle like bearings are present. These bearings are set at the bottom of the yoke on the slots made on the yoke for placing the bearings. Hence the bearings cannot come out of the yoke. One yoke is connected with the gear box and another one is connected with the propeller shaft. The spider rotates along with the driving yoke which is connected to the gear box. Thereby the drive yoke which is connected to the other side of the spider starts to rotate and transmits the power from gear box to propeller shaft smoothly. Figure 4.7 shows the hooke's join.

Advantages

1. It has high mechanical advantage.
2. It is simple in construction.
3. It transmits the power more effectively.
4. It works according to the weight of the vehicle.
5. It has long life.

6. It is mostly used in present day vehicles.
7. According to the up and down motion (18°) of propeller shaft the power is transmitted without any loss and vibrations.

4.8.2 Pot type universal joint

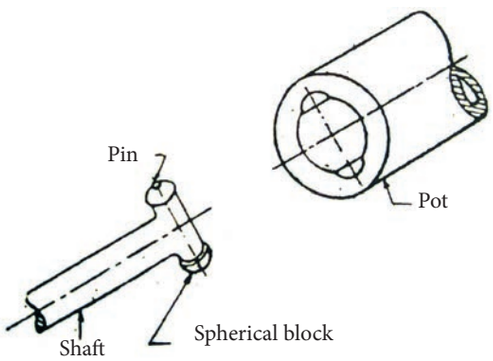


Figure 4.8.2 Pot type universal joint

One end of the shaft has T shape structure. Both the ends are joined with semi spheres using a pin. Cylinder like structure in the opposite is called pot type. Semi spheres in the T shaft are designed like moving part in the cylinder. So T shaft in the cylinder moves front and back and also in angles.

4.8.3 Rubber coupling type universal joint

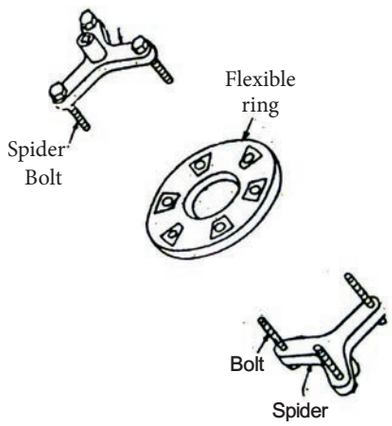
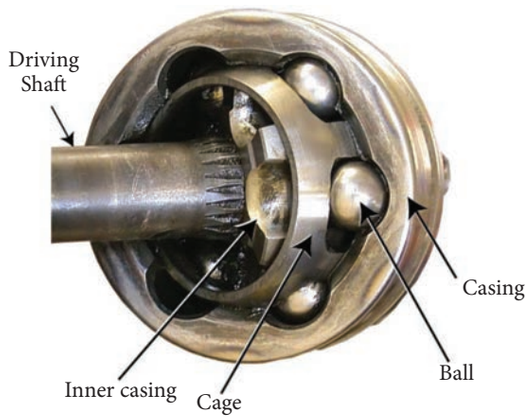


Figure 4.8.3 Rubber coupling type universal joint

In a round shaped rubber coupling there are six holes at an equal distance. This rubber coupling is placed between two spiders and fixed with bolt and nut. This rubber coupling is a flexible one to be with shaft. This can scope with only a small angle shake. It is also called as flexible ring type universal joint.

4.8.4 Ball type universal joint (Constant velocity type universal joint)



It is used to transmit the power approximately at 30° without vibration. Mostly used in front axle drive vehicles. It has input half shaft. One end of the shaft has splines in which inner spherical socket is fitted. Outer spherical socket is connected with the outer shaft. Grooves are cut between two sockets in which balls will move. When the input shaft rotates balls between the sockets will move and transmit the power smoothly.

4.9 Differential unit

When the vehicle moves straight on the road, the rear wheels run in the same way as the front wheels. The propeller shaft is connected to follow this. However, when the vehicle is negotiating a turn,

the outer wheels cover larger radius than the inner wheels. The outer wheels rotate more than the inner wheels. Hence the inner wheels have intermittent wear, less grip on the road and withstanding steering issues than outer wheels. The function of the differential unit is to provide different speeds for the inner and outer wheels whenever the vehicle is negotiating a turn.

Construction

Inside the differential casing sun gears are connected with the rear wheel axle. At the left side of the rear axle differential cage is fixed. For connecting two sun gears planets gears are used. At the end of the rear axle road wheels are connected. The construction of differential unit can be seen in Figure 4.9 and the pictorial view of a differential unit can be seen in Figure 4.9 (a).

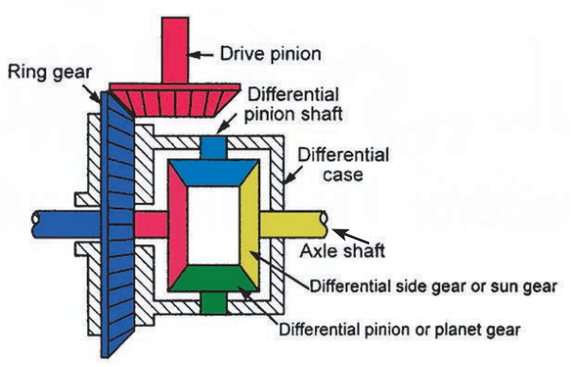


Figure 4.9 Construction of a differential unit

Working principle

When the differential cage rotates, the planet gears inside the differential casing also rotate along with it. Hence due to the rotation of planet gear, the sun gear which is connected to it also rotates and rotates the right side rear axle. Now due to the rotation of the differential cage, sun gears, planet gears, rear axle and rear wheels all rotate at the same speed. When the vehicle takes a turn on the road, the planet gear rotates and tends to rotate the outer wheel at high speed and hence the vehicle turns easily on the road.

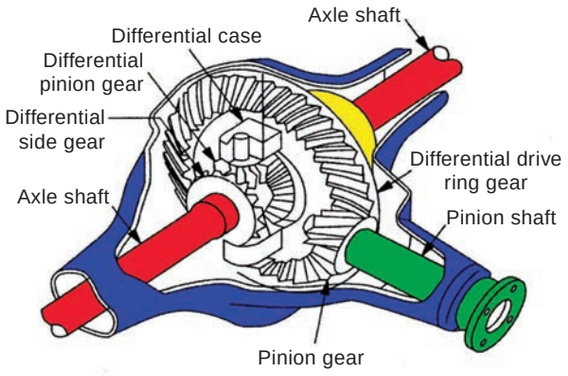


Figure 4.9 (a) Pictorial view of a Differential Unit

When the vehicle goes straight

The power passing from the engine through the clutch, gear box and propeller shaft rotates the pinion shaft of the differential unit. At that time the crown wheel which is connected to the pinion shaft also rotate along with the cage unit. In this condition the planet and sun gears in the differential unit rotate in the opposite direction which creates the brake and the entire unit rotates with full force. Hence the rear axle shaft which is connected to the sun gear rotates at high speed and transmits the power to rear wheels. In this condition the power is transferred at 90° angle and directs the vehicle in a straight direction.

When the vehicle is negotiating a turn

When the vehicle is in a position to take a turn on either right side or

left side, the driver rotates the steering wheel according to the turning direction, at that time the load is acting on the axle shaft of the wheel which is going to turn. Hence the sun gear which is connected to it is also subjected to the load and reduces the rotation. At the same time the planet gears which are connected on the top and bottom of it rotate at high speed and rotate the sun gear which is located on other side. Hence the outside wheel rotates at higher speed than the inner wheel and turns the vehicle for certain distance easily. In this case the speed lost by the inner wheel is gained by the outer wheel and hence the vehicle turns easily on either left or right side.

4.10 Connecting methods of bevel gears

Based on the arrangement of the teeth in the pinion gear, the connecting methods with crown wheel are classified in to four different types.

1. Straight bevel gears
2. Spiral bevel gears
3. Hypoid gears
4. Worm and worm wheel

4.10.1 Straight bevel gears

In this type the gear teeth are cut in straight and connected at the center of the pinion. To operate this more amount of energy is required. In addition, when it is in operation, it produces more noise and it wears quickly. Figure 4.10.1 shows the view of straight bevel gear.

Figure 4.10.1

4.10.2 Spiral bevel gears

In this type of gears the teeth are cut in the inclined position. Hence the teeth are very well in mesh with the other teeth and the energy is transferred very softly and uniformly. In this type the axis of the crown wheel and the pinion are arranged in the same axis. This gear works without any noise and lasts for a long time. Figure 4.10.2 shows the view of spiral bevel gear arrangement.

Figure 4.10.2 Spiral bevel gear

Advantages

1. It has a strong arrangement.
2. It is more efficient.
3. Silent and smooth in operation.

Disadvantages

1. Arranging the parts is very difficult.
2. It is more expensive.

4.10.3 Hypoid gears

In this type of gears the teeth are cut in spiral shape. In this arrangement the pinion gear is placed just below the center of the crown gear and hence the height of the chassis is reduced. Figure 4.10.3 shows the view of a hypoid gear arrangement.

Figure 4.10.3 Hypoid bevel gear

This type is mostly used in heavy vehicles. During its operation more heat is generated in it. Hence for reducing the heat generated, more amount of lubricating oil is required. It functions smoothly and works for long time.

Advantages

1. Safe to operate and it is less noisy in operation.
2. The height of chassis is less.
3. It can withstand maximum amount of rotational torque.

Disadvantages

1. It has low ground clearance.
2. Assembling and dismantling the parts is difficult. Repairing the parts is difficult.
3. It requires lubricating oil which must withstand high pressure.

Application

1. It is used mostly in the vehicles which are used for aged persons and patients.
2. It is used mostly in foreign cars.

4.10.4 Worm and worm wheel

In this type of gear in worm and worm wheel are used instead of pinion and crown wheel as shown in Figure 4.10.4. The worm in this arrangement is located as per the design either above or below the Worm Wheel. It is used mainly in heavy vehicles. It gives a smooth, superior and stable motion of operation. Worm is made of nickel and stabilized steel. Worm wheel is made up off phosphorous bronze material.

Figure 4.10.4 Worm and worm wheel arrangement

Advantages

1. Reduces the speed very quickly.
2. Transmission power is high.
3. Noiseless in operation.
4. By placing the worm at the upper side the ground clearance is increased.

Disadvantages

1. Assembling and repairing of parts is difficult.
2. It needs special lubricating oil.
3. It has very less ground clearance.
4. High cost and heavy weight.
5. It is suitable only for heavy vehicles.

4.11 Differential housing

Rear axle casing or housing is the one which has the differential unit and the half shaft within it. It helps in preventing formation of dust particles inside the axles. At the same time it provides the way for supplying the lubricating oil. The differential housing is generally classified in to two different types. They are,

1. Banjo type
2. Split type

4.11.1 Banjo type

As the complete structure of this casing looks like a banjo musical instrument, it is named as banjo type. Vacuum pipes are connected at both ends of it. At the middle the differential unit is placed. This type is generally used in all types of vehicles i.e. light and heavy vehicles. Figure 4.11.1 shows the view of the Banjo type differential housing

Advantages

1. Less weight
2. It withstands more weight.
3. Any repairs in this system can be done without dismantling in rear axle.

4.11.2 Split type

In this type, two vacuum tubes are connected with both sides of the differential casing by using bolts. In this type, if any fault occurs, the parts can be removed separately and repaired. Hence this type of housing is used in very few vehicles only. Figure 4.11.2 shows the split type differential housing

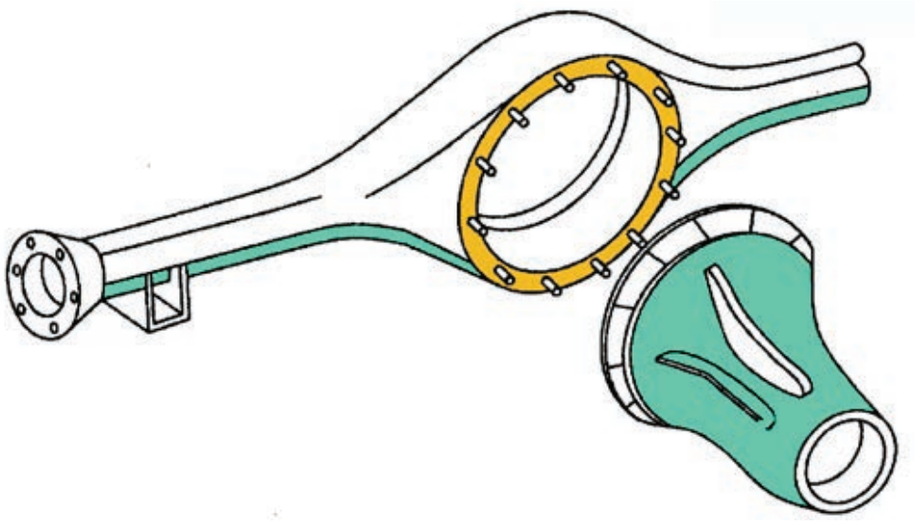


Figure 4.11.1 Banjo type differential housing

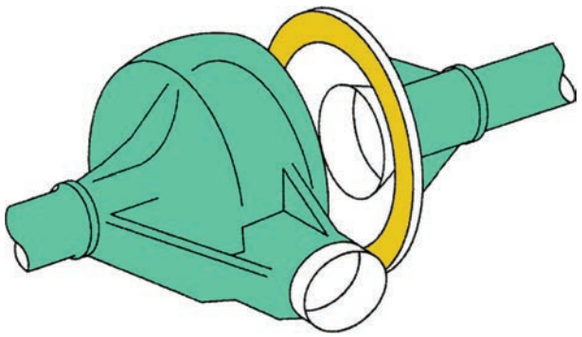


Figure 4.11.2 Split type differential housing

DO YOU KNOW?

In 1892, Rudolf Diesel a German engineer invented a "New Rational Combustion Engine" which lead him to building the first Diesel Engine in 1897.

4.12 Rear axle

The engine's power comes from the differential is transmitted through the rigid shaft called as the rear axle. It is made as two parts such as left side and right side in the vehicle and used. The axle's inner edge is connected with the sun gear by the splines and outer edge is connected to the wheel hub. This axle withstands the weight, vibrations and torque of the vehicles.

Purpose

1. To withstand rear side weight of the vehicle.
2. To transmit the engine power to rear wheels.
3. To act as axle needle for the wheels.
4. It acts as housing for the final drive, differential and half shafts.

Forces acting on the rear axle

The following forces act on the rear axle

1. Torque reaction
2. Driving torque or driving thrust
3. Side thrust
4. Weight of the body

1. Torque reaction

When the torque is transmitted from the propeller shaft through the differential, the bevel pinion is started to rotate over the crown wheel, at the time an opposite force is developed against the direction of differential housing. This force is equal to driving torque and operates in the opposite direction. This force produces a bending moment on the propeller shaft.

2. Driving torque

It is the torque transferred from the engine to the axle casing. The force created due to this on the rear axle is transferred to the body through chassis frame. Radius rods in the chassis are used to transmit this drive torque to the body.

3. Side thrust

This refers to the thrust developed between the axles in the longitudinal direction. This thrust is caused by the force of air acting on sideways. By connecting panhard rods on the chassis frame the side thrust could be minimized.

4. Weight of the body

The total weight of the goods and passengers of the vehicle acting on the axle are called as unsprung mass. They act on the axle through the springs. The total weight of the vehicle develops a shear force and bending moment on the axle. For reducing these forces powerful springs must be used.

4.13 Types of rear axle

The rear axle can be classified in to three different types according to the construction of rear axle shaft and wheel hub connections, They are

1. Semi-floating axle
2. Full-floating axle
3. Three quarter floating axle

4.13.1 Semi- floating axle

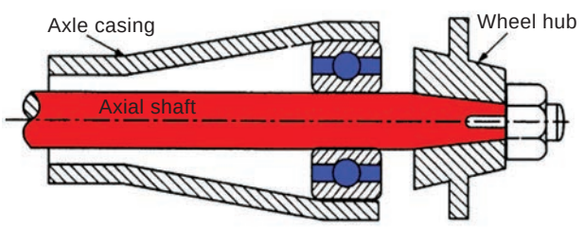


Figure 4.13.1 Semi-floating axle

In this type of axle a bearing is placed in-between the axle shaft and the axle casing. The outer axle shaft is coupled with the wheel hub by using locknut and the key. The axle shaft withstands the vehicle weight, driving thrust and transmits the power to the wheels. It is simple and cheaper compared to other types. This type is used in vehicles such as fiat 100 and standard-20. Figure 4.13.1 shows the view of a semi floating rear axle.

4.13.2 Full floating axle

In this type, one bearing is placed at the differential housing and the two tapper roller bearings are placed between the axle housing and wheel hub. Moreover the axle shaft is kept inside the axle housing and at its other end wheel hub is fitted by using a flange. The axle casing bears the whole weight of the vehicle and axle shaft transmits only the driving torque to the wheels. This type of axle is used in Ashok Leyland tarus, Tata 1612, 1312, Eicher 10.80, 10.90 Mondraj vehicles. Figure 4.13.2 shows the full floating rear axle.

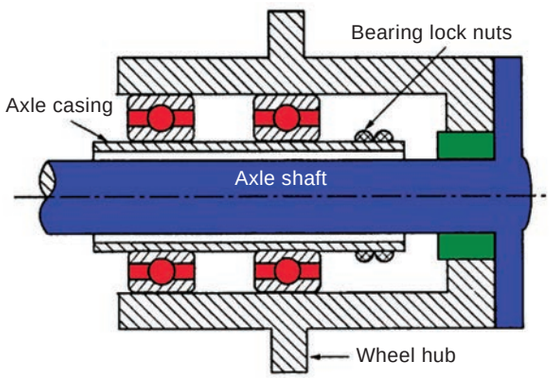


Figure 4.13.2 Full floating axle

Advantages

1. As the axle shaft transmits the power only to wheels the power output is higher.
2. Without removing the wheel and hub the axle can be removed.
3. If the axle shaft is broken, the power transmission only will be stopped.

4.13.3 Three quarter floating axle

In this type, one bearing is at the differential side and another bearing is placed in between the axle housing and wheel hub. The axle shaft is connected tightly with lock nut and key with the wheel hub. The axle shaft receives both driving torque and end thrust completely and bears one fourth of the vehicle's weight. The remaining weight of the vehicle is carried out by the axle housing. It is mostly used in the ambassador and Jeep like vehicles.

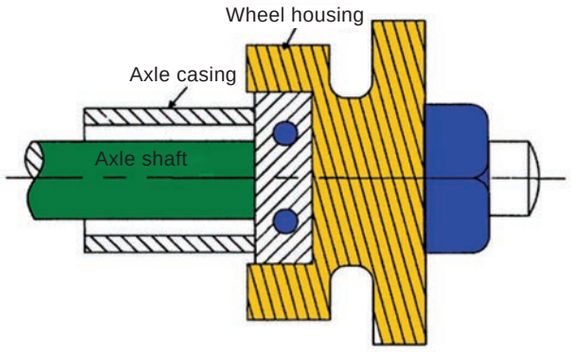
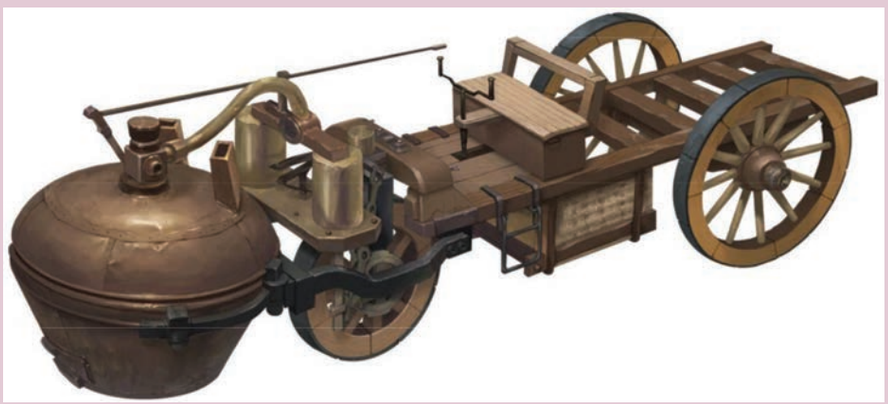


Figure 4.13.3 Three quarter floating axle

DO YOU KNOW?

In 1769 Nicolas-Joseph Cugnot of France arguably invented the first full-scale, self-propelled mechanical vehicle or automobile. It was a steam-powered tricycle.



4.14 Propeller shaft-Trouble shooting

Improper rotation of the propeller shaft

S.No	Causes	Remedies
1.	There will be bend or twist on the shaft.	Need to rectify the run out by using the dial tester.
2.	The Propeller shaft may be unbalanced.	Need to inspect the shaft to bring it to its correct position.
3.	Wear occurred in splines, bearings and slip joints.	Inspect and replace the worn out parts.

More noise from propeller shaft assembly

S.No	Causes	Remedies
1.	The shaft might be bent or twisted	Inspect the shaft and fix it.
2.	Absence of lubricating oil in the propeller shaft unit .	Lubricate the shaft unit using the lubricating oil.
3.	Deposition of dust particles inside the bearings.	Need to clean it.
4.	Worn out of the splines.	Inspect and replace with a new one.

Over noise coming from differential unit

S.No	Causes	Remedies
1.	Insufficient amount of lubricating oil in the differential casing.	Need to pour required amount of lubricating oil in casing.
2.	Because of the usage of low grade lubricating oil.	Need to use good quality lubricating oil.
3.	There may be broken teeth in the pinion and bevel gears in the differential unit.	Find and replace with a new one.
4.	Insufficient gap between the gear mating points.	Need to correct with sufficient gap between the gear mating points
5.	Bearings might be broken in the differential unit.	Replace with new bearings.
6.	Cage unit might be slightly loosened with the crown wheel.	Connect them tightly.
7.	Washers might be broken or worn out in the differential unit.	Need to change with new washers.
8.	The spider or gears may have worn out or broken in the differential unit.	Need to change with a new one.
9.	The gears teeth may not be connected properly in the differential unit.	With the help of marking point make the connection between gear teeth and fix it.

Comparisons between Hotchkiss drive and Torque tube drive

S.No	Hotchkiss	Torque tube drive
1	Two universal joints are used.	Only one universal joint is used.
2	Slip joint is required.	No slip joint is present.
3	Propeller shaft is mounted in open space.	Propeller shaft is closed and placed in the torque tube.
4	Propeller shaft will bend and change its length.	No such changes occur.
5	The power and brake force are on both sides.	The force will be acting on only one side.

4.15 Maintenance of the Propeller shaft

- Lubrication must be provided periodically at the slip joints in the propeller shaft by using the grease
- Lubrication must be provided for the universal joins by using grease
- After cleaning the bearings they must be lubricated with grease.
- Bearing cup, spider, circlip and seal must be tested and lubricated

Student Activity

1. Visit any automobile depot nearby you and study the repair work of the heavy vehicles, working of propeller shaft and its types and submit a detailed report of your visit.
2. Visit nearby depot and study the construction of the heavy vehicle differential unit and its working and submit the report
3. Study the faults occurring in the differential unit by visiting a nearby depot and submit your inspection report.

Glossary

1.	Propeller Shaft	–	சுழல் தண்டு
2.	Rear Axle	–	பின் இருசு
3.	Bearing	–	உருளைத் தாங்கி
4.	Universal Joint	–	பலகோண (அச்சு) இணைப்பு
5.	Differential Unit	–	மாறபட்ட வேக வழங்கி
6.	Synchromesh	–	ஒத்து இயங்கு
7.	Driving Gear	–	இயக்கும் பற்சக்கரம்
8.	Driven Gear	–	இயக்கப்படும் பற்சக்கரம்
9.	Half Shaft	–	அரைத் தண்டு
10.	Sliding Mesh	–	நகர்ந்து இணைதல்

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Evaluation

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PART - A

One mark questions

Choose the correct answer

1. The front end of the propeller shaft is connected with
   a) Engine
   b) Clutch
   c) Gear Box
   d) Differential

2. The component which transmits the engine's power from the gear box to the differential is called as
   a) Clutch
   b) Rear Axle
   c) Clutch shaft
   d) Propeller shaft

3. The component which corrects the length of the propeller shaft is
   a) Clutch
   b) Gear Box
   c) Slip Joint
   d) Universal Joint

4. The component which transfers the rotational power from the gear box at certain angle is
   a) Clutch
   b) Propeller shaft
   c) Differential
   d) Rear Axle

5. In a vehicle the part which protects the leaf spring is

a) Differential
b) Shackle
c) Bolt
d) Gage

6. In the universal joint the part which connects the two yokes is
   a) Spider
   b) Driving yoke
   c) Driven Yoke
   d) Engine shaft

7. When the vehicle is taking a turn on the road, the component which helps to rotate the inner wheel at lower speed than the outer wheel is called as
   a) Differential
   b) Universal Joint
   c) Propeller shaft
   d) Rear Axle

8. The part which transmits the rotational power from the propeller shaft to the rear axle is called as
   a) Propeller shaft
   b) Engine
   c) Differential
   d) Clutch

9. In the power transmission system the part which transmits the power at 90^0 angle is called as
   a) Engine
   b) Differential
   c) Gear Box
   d) Wheel

10. The type of rear axle which bears the whole weight of the vehicle is called as
    a) Semi floating axle
    b) Full floating axle
    c) Quarter floating axle
    d) Three quarter floating axle

PART - B

Three mark questions

1. What are the functions of the propeller shaft?
2. What are the types of universal joint?
3. How does the shackle work?
4. What are the types of propeller shaft?
5. Write the functions of the differential
6. Write the classification of the differential
7. What are the types of differential casing?
8. Write the classification of the rear axles?

PART - C

Five mark questions

1. Write advantages and drawbacks of the Hotchkiss Drive
2. Describe the faults and rectification methods of the Differential
3. Explain the construction and working of any one universal joint with a suitable diagram

PART - D

Ten mark questions

1. Explain the construction and working of a differential Unit with a suitable diagram
2. Describe the common faults occurring in the propeller shaft and rectification methods in detail.
3. Explain the construction of any one rear axle with a suitable sketch