Unit V- *Drive Lines*, Final Drive & Rear Axle

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❖Syllabus

- Effect of driving thrust and torque reaction, propeller shaft-universal joints, hooks and constant velocity U.J., Drive line arrangements – Hotchkiss drive & torque tube drive, Rear wheel drive & front wheel drive layouts.
- Purpose of final drive & drive ratio, Different types of final drives, need of differential, Constructional details of differential unit, Non-slip differential, Differential lock, Differential housing, Function of rear axle, Construction, Types of loads acting on rear axle, Axle types - semi-floating, full floating, three quarter floating, Axle shafts, Final drive lubrication.

Power Train components

Front wheel drive :

- Flywheel
- Clutch
- Gear box
- Transaxle
- Drive shaft
- Wheel

Rear wheel drive :

- Flywheel
- Clutch
- Gear box
- Universal joint / slip joint
- Propeller shaft
- Final drive
- Differential
- Rear axle
- Wheel

Four wheel drive :

- Flywheel
- Clutch
- Gear box
- Transfer case
- Universal joint & Slip joint
- Propeller shaft to front & rear
- Final drive
- Differential
- Front & Rear drive shaft
- Wheel

❖ FORCES AND TORQUES ON THE REAR AXLE:

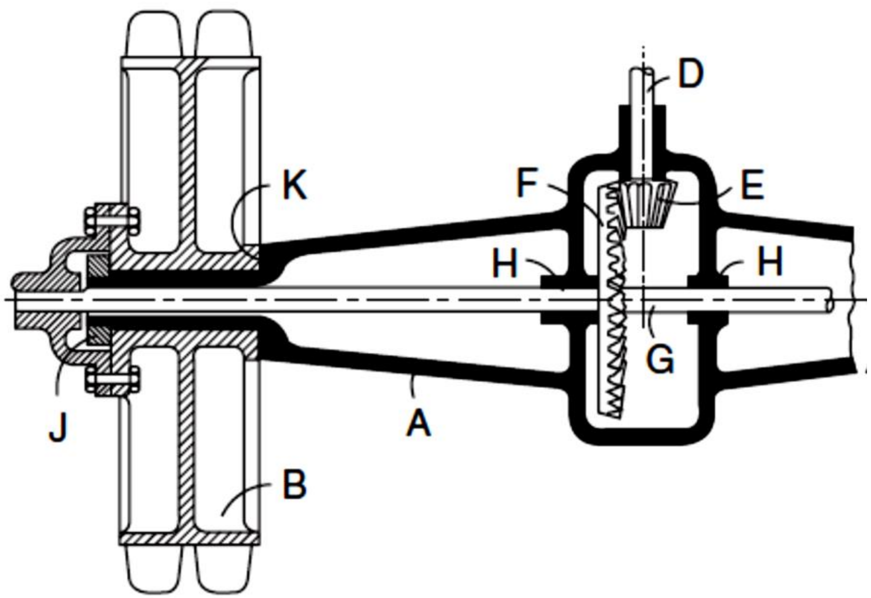
1. Weight of the Body
2. Torque Reaction
3. Driving thrust
4. Side thrust
5. Braking Torque

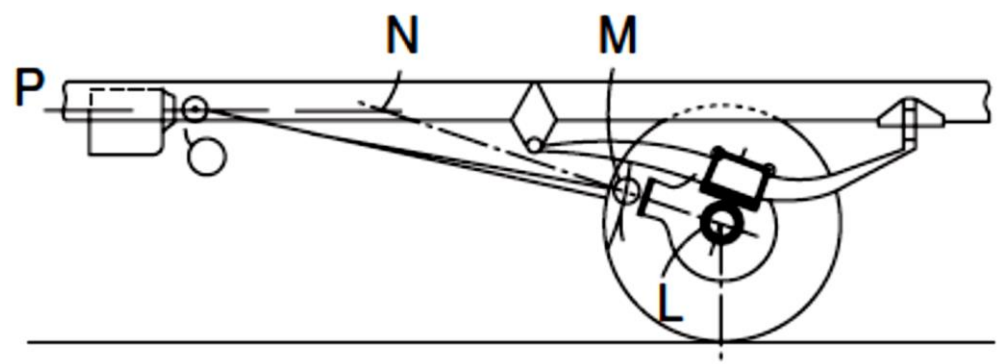
1. WEIGHT OF THE BODY:

- Rear axle behaves like a beam supported at the ends and loaded at two points.
- The load coming on the axle is due to the weight of the body being transmitted through the suspension springs.
- Weight causes shear force and bending on the wheels.

2. TORQUE REACTION:

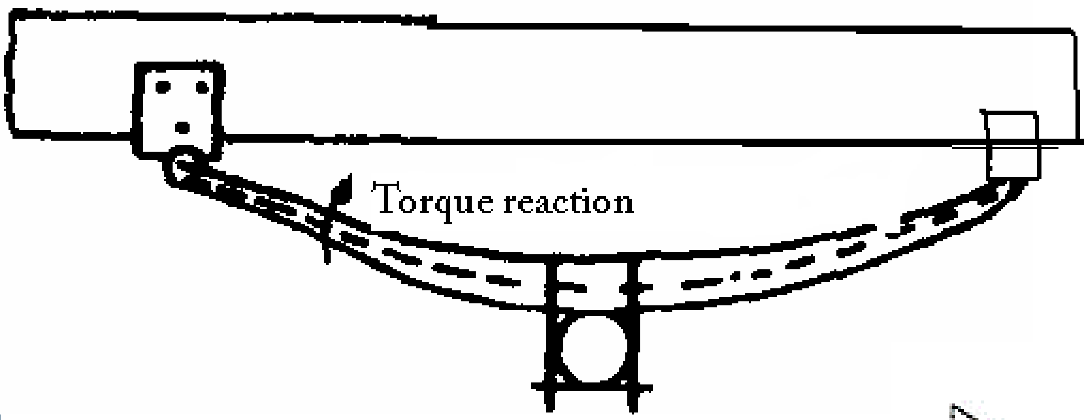
- From Fig 1, it can be seen that the propeller shaft applies the torque to the shaft D which is transmitted through the bevel gearing, is increased in the same ratio as the speed is reduced.

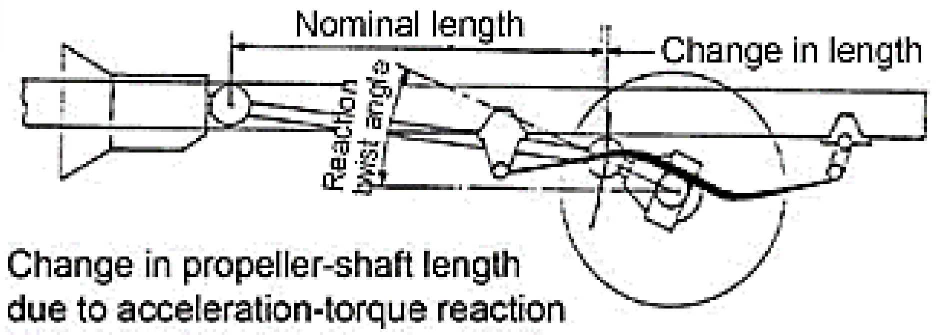


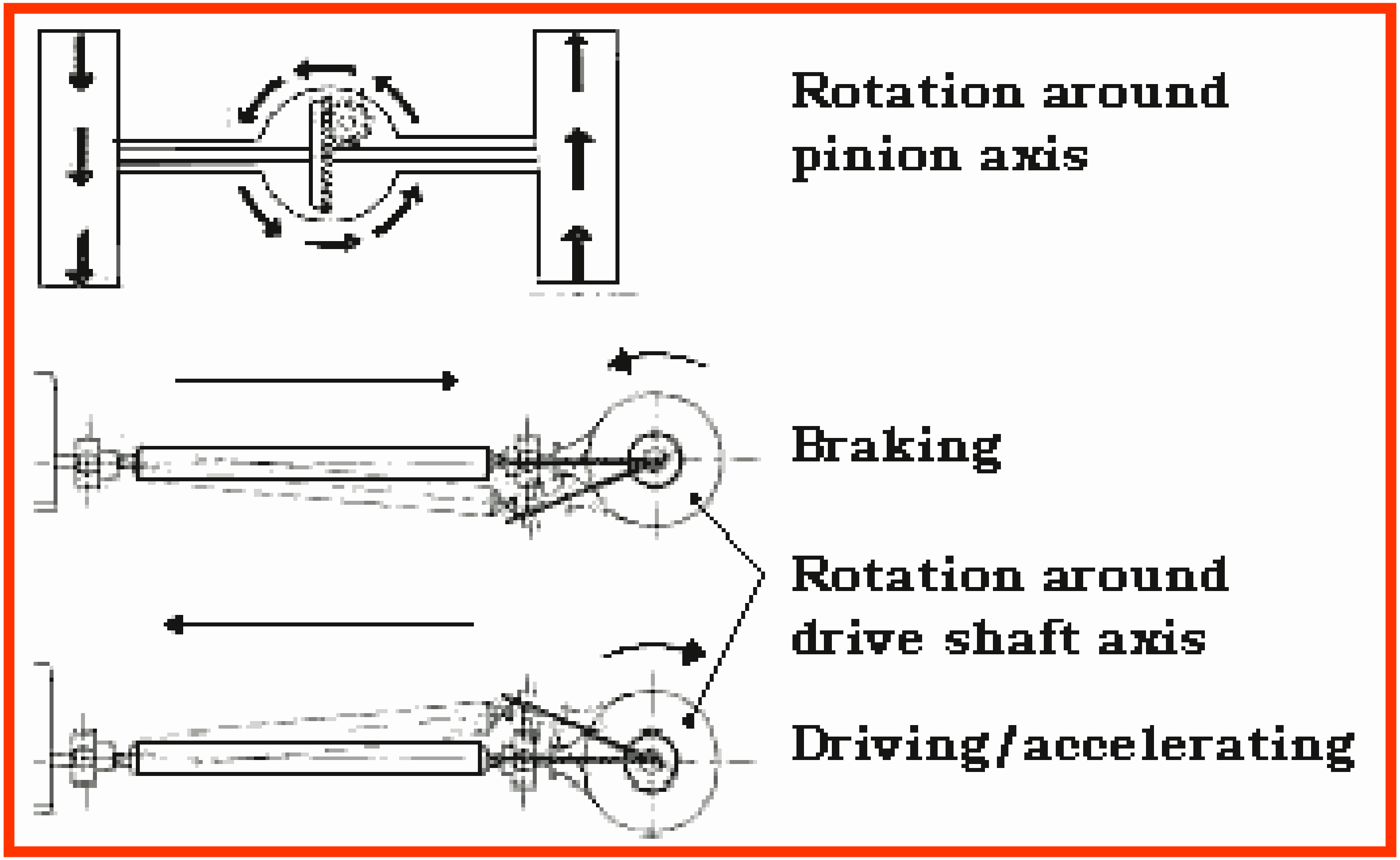


- The propeller shaft applies a torque to the differential crown pinion shaft.
- This torque is increased in the same ratio as the speed is reduced by the final drive (within the differential assembly) and is transmitted to the axle shafts which are connected to the road wheels.
- Now if the road wheels are fixed, then on turning the crown pinion shaft, the pinion will have to roll round the bevel wheel taking with it the axle casing.
- There is a tendency for the same action to occur when the road wheels are being driven by the pinion shaft.
- This phenomenon shown in figure is called torque reaction.
- The torque producing this action is the equal and opposite reaction to the driving torque which is applied to the road wheels

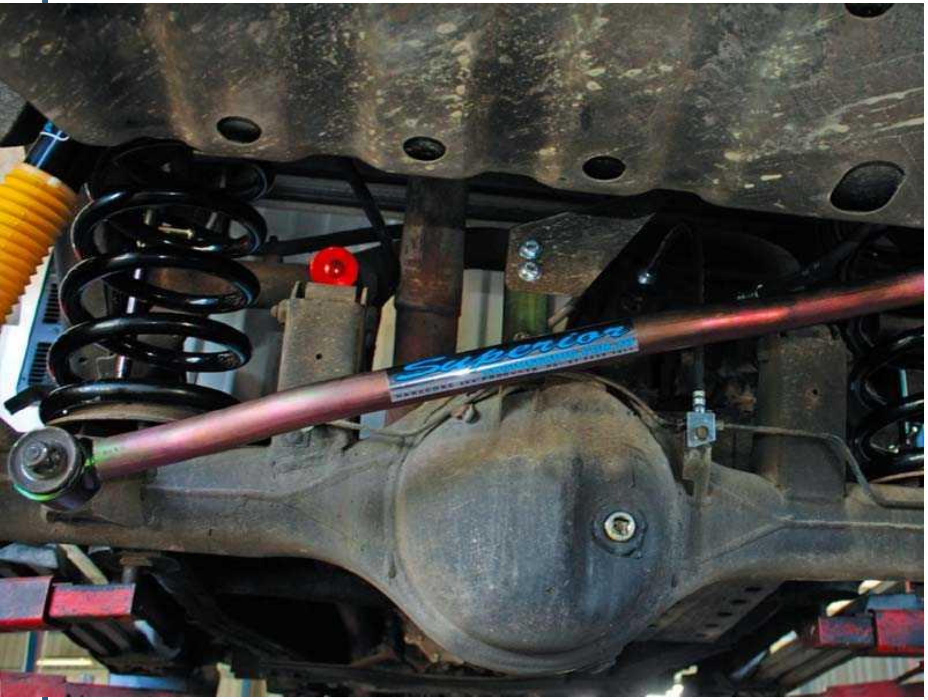
- Some means must be introduced to prevent the axle casing from rotating in the opposite direction.
- This may be simply the leaf springs themselves, or additional links – **torque-reaction (Panhard rods)** or **radius rods.**

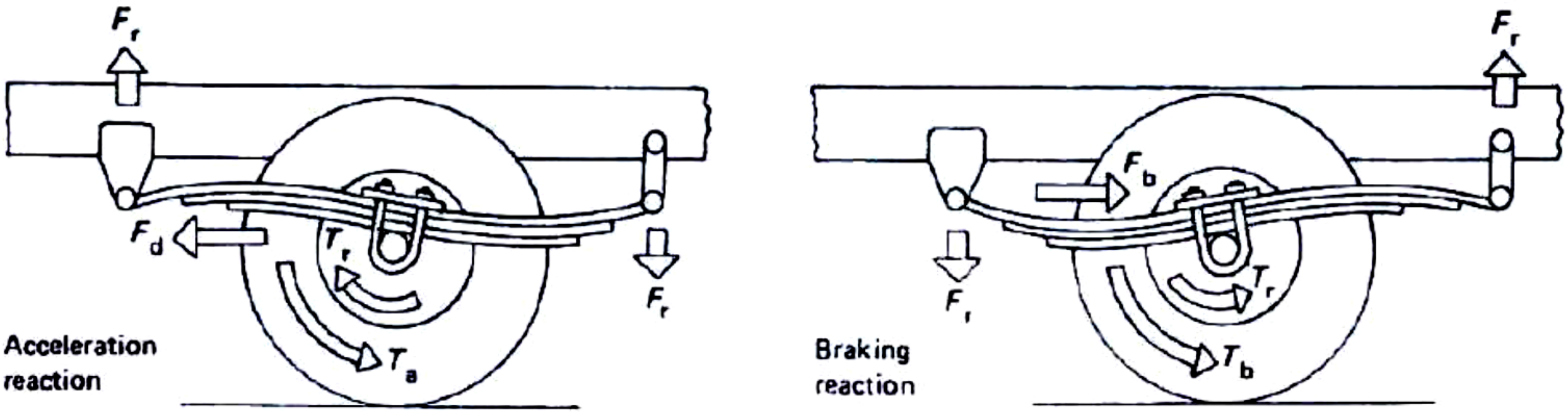





Rotation around pinion axis
Braking
Rotation around drive shaft axis
Driving/accelerating

❑Panhard Rod:





Acceleration and braking reaction forces acting on the spring shackles

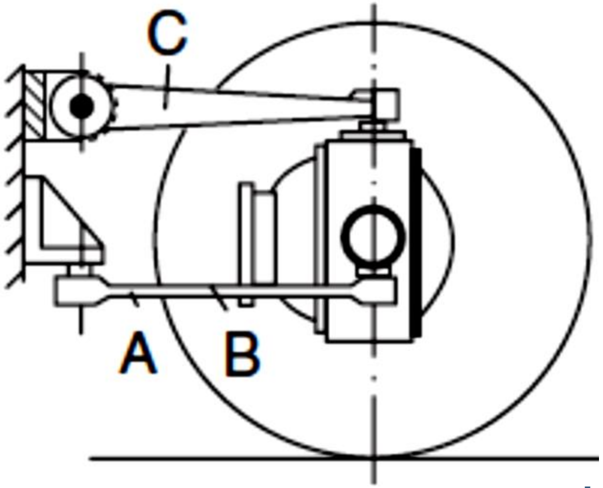
F_d – Driving force, F_r – Reaction force, F_b – Braking force,

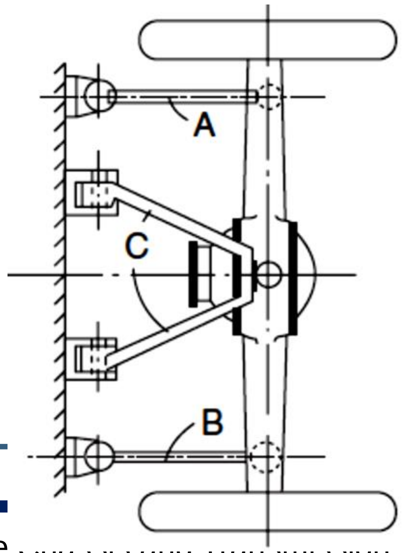
T_r – Reaction Torque, T_b – Braking torque, T_a – Acceleration Torque

3. DRIVING THRUST:

- The driving thrust, or tractive effort, of the road wheels is reacted by the vehicle structure, the reaction being the inertia of the mass of the vehicle if it is accelerating, or rolling resistance of the other axle plus the wind resistance if it is not – the rolling resistance of the tires of the driving axle involves of course purely local action and reaction.
- In effect, therefore, the driving axle has to push the carriage unit along, so it must be connected to the structure of the vehicle in such a way that this forward thrust can be transmitted from one to the other.
- This connection can be either the leaf springs or some other linkage for locating the axle relative to the carriage unit. The relevant members of this linkage are known as *thrust members*, or *radius rods*.

- The driving torque produced in the engine is primarily responsible for producing driving thrust in the rear road wheels. It has to be transferred from the rear axle housing to the chassis frame which can be accomplished through, either
  - (i) A strong rear springs,
  - (ii) A thrust-taking member such as radial rod.
- When springs are used to serve this purpose, they are made strong enough in addition to their springing action.



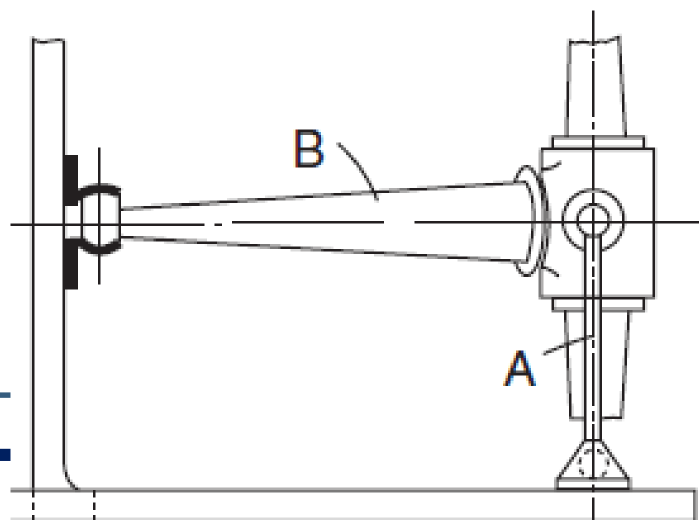


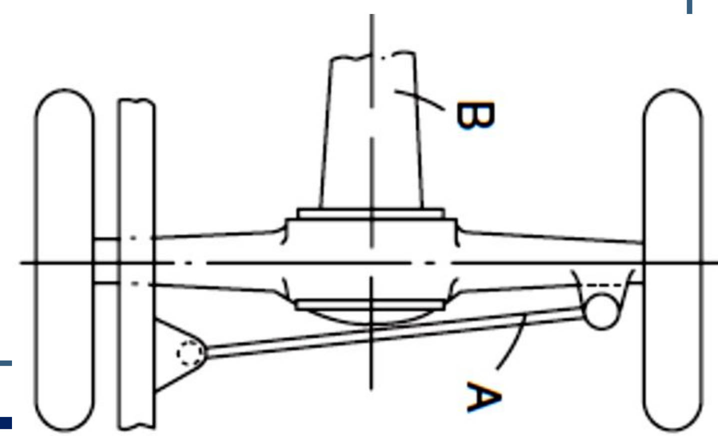
4. SIDE THRUST:

- The rear axle is invariably subjected to side thrust (or pull), when the rear wheels experience any side load. Such situation arises due to **cornering force** when the vehicle is negotiating a curve, or when the vehicle is moving over uneven ground.
- To combat the side thrust and to hold the axle in its desired position, the following provisions are generally made.

(i) Taper roller or ball-thrust bearings are used for rear wheel, and

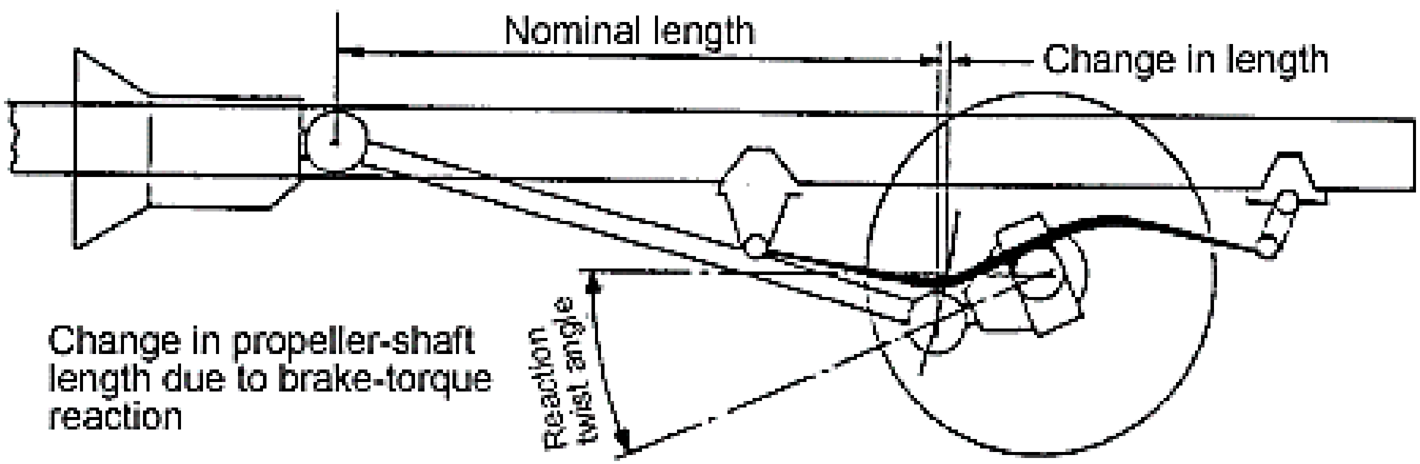
(ii) ‘Panhard rod’ is used between the axle casing and the frame.





5. BRAKING TORQUE:

- The axle casing experiences the 'brake torque' when the brakes are applied to the vehicle. The brake torque is produced in a direction opposite to the torque-reaction, since the braking effect is reverse of the driving effect.



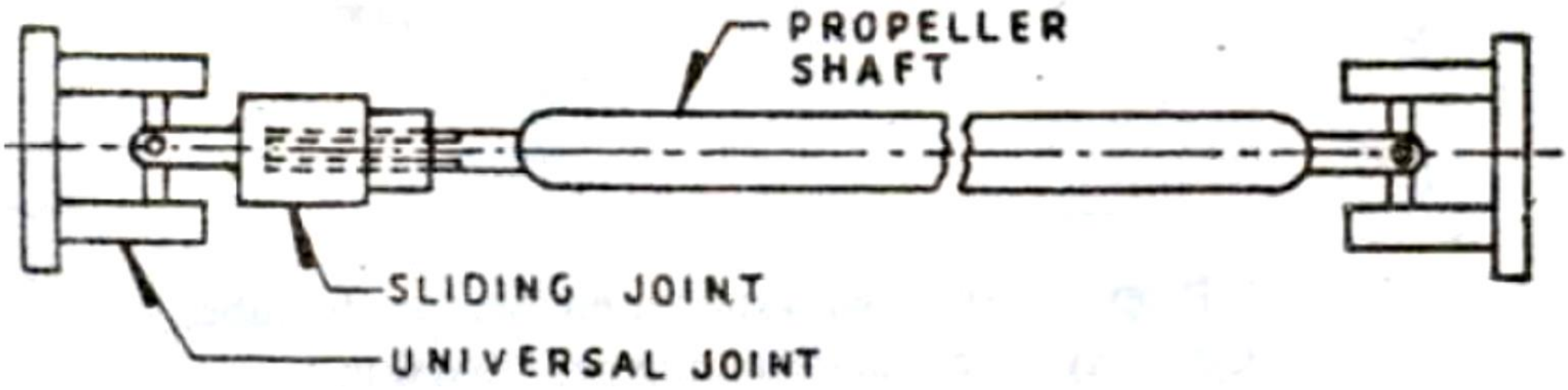
PROPELLER SHAFT:

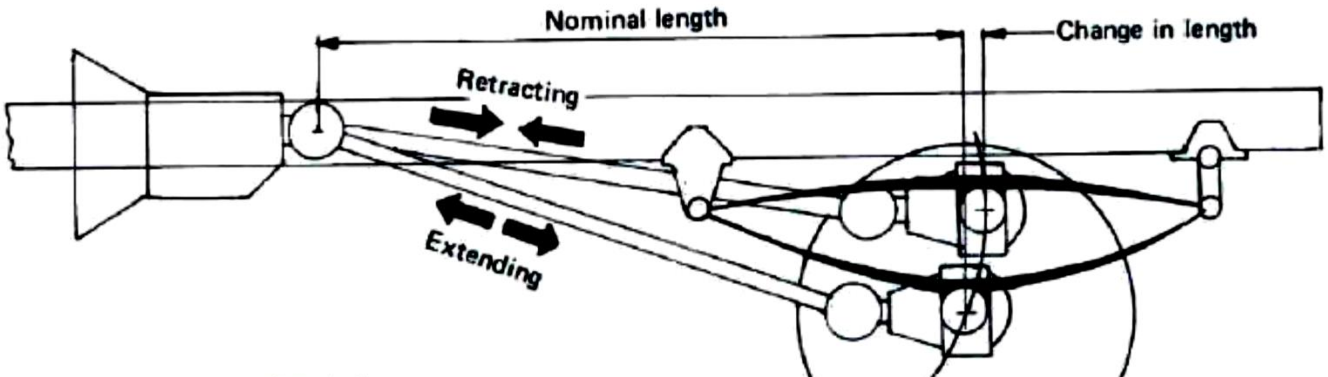
- The propeller shaft transfers the power drive from the out put shaft of the front body mounted gear box to the unsprung rear axle final drive, so providing the means of propelling the vehicle forward or in reverse.
- The propeller shaft consists of a **low carbon steel tube**, either formed from rolled steel sheet which is then butt welded along its seam or made from seamless drawn tubing.
- The hollow shaft ends are made a force fit over solid cylindrical recesses turned down on both universal joint yoke bosses supporting the shaft, or alternatively between one universal joint yoke boss and a sliding joint splined stub shaft.

- The ends of the tube are then butt welded to their respective yoke boss or stub shaft shoulder to make a rigid drive structure which is concentric to the input and output support shafts.
- The shaft is made hollow to apply its mass in the most effective position to resist twisting, longitudinal sagging and rotational whirl.

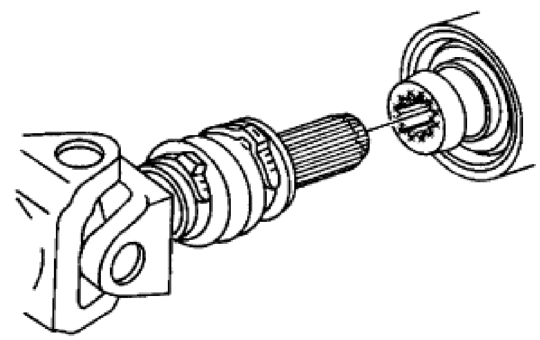
❖ Functions of a Propeller Shaft:

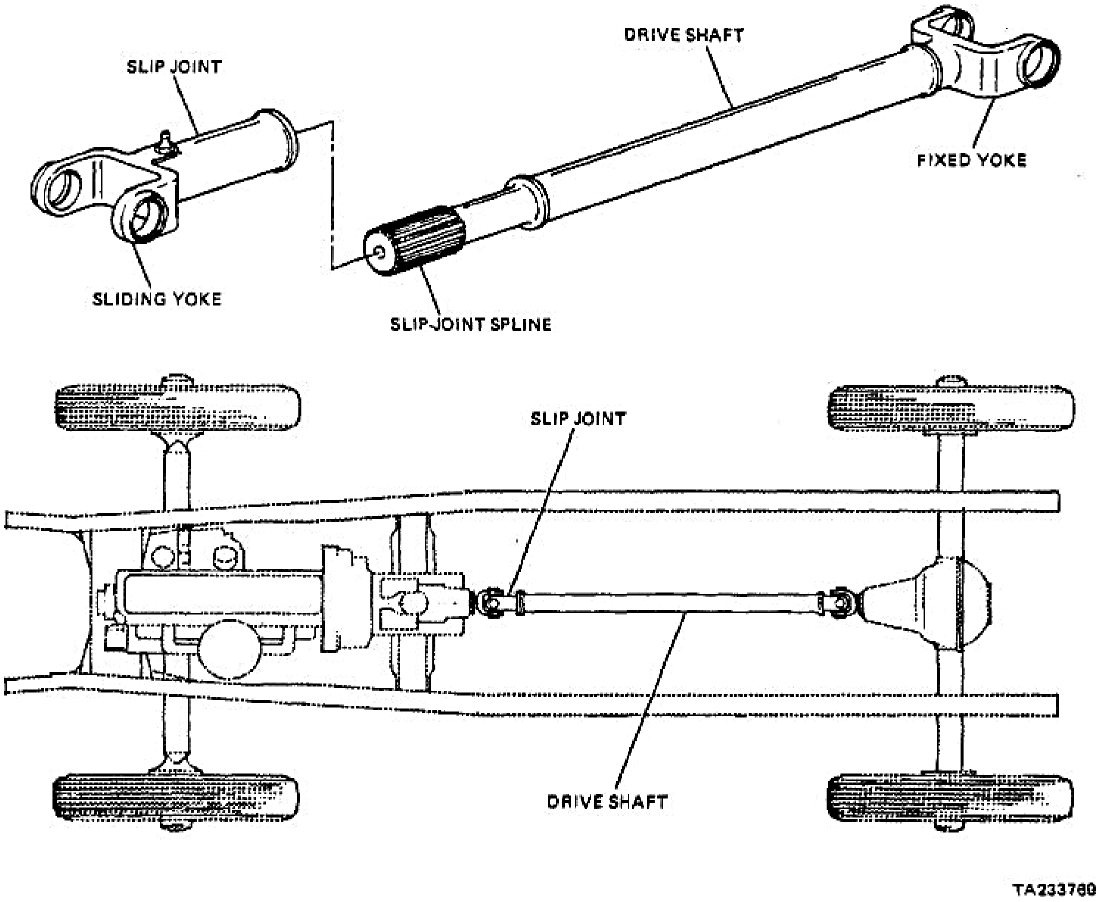
1. It transmits rotary motion of the gear box output shaft to the differential and then to the wheels through the axle shafts.
2. It transmits motion at an angle which is varying frequently.
3. It accommodates changes in length between gear box and rear axle.





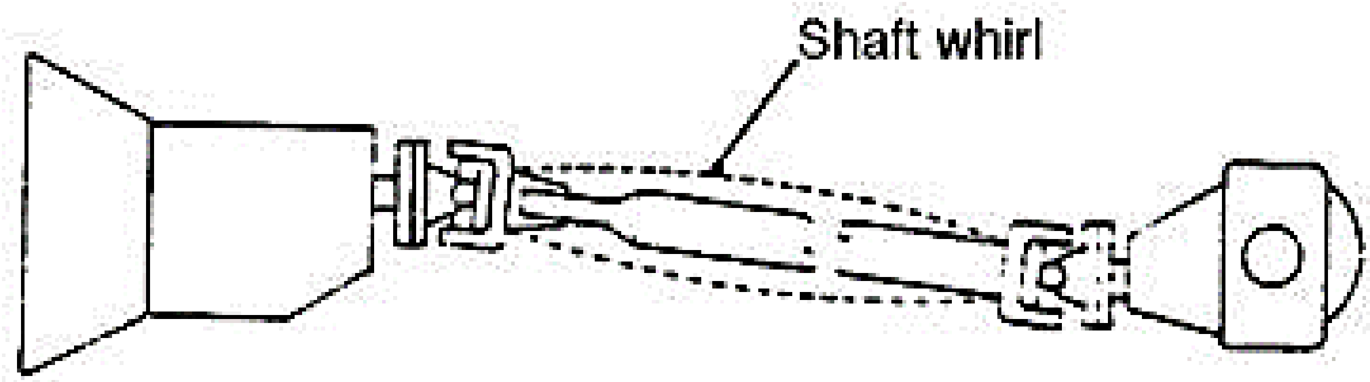
(b) Change in propeller-shaft length between bump and rebound




SLIP JOINT
DRIVE SHAFT
FIXED YOKE
SLIDING YOKE
SLIP-JOINT SPLINE
SLIP JOINT
DRIVE SHAFT
TA233789

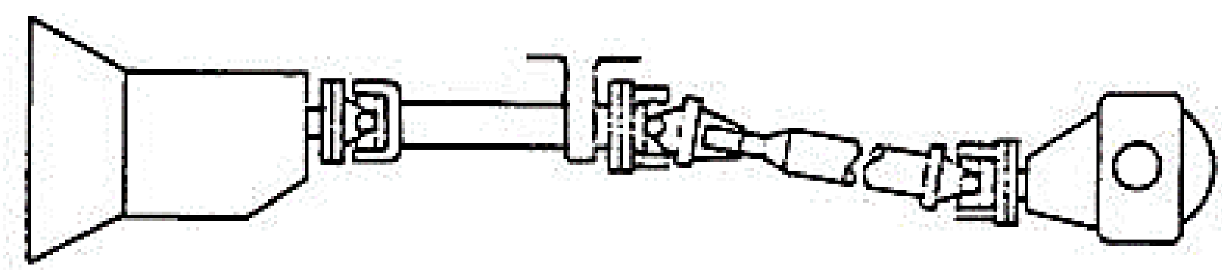
❖PROPELLER-SHAFT VIBRATION

- Due to the high speeds in top gear its R.P.M. is the same as the engine, the shaft must be balanced to avoid vibration
- Small cars and short vans and trucks are able to use a single propeller shaft with a slip-joint at the front end without experiencing any undue vibration. However, with vehicles of longer wheelbase, the longer propeller shaft required would tend to sag and under certain operating conditions would tend to whirl and then set up sympathetic resonant vibrations in the body of the vehicle - that is, cause the body to 'drum' or vibrate as the shaft whirls.



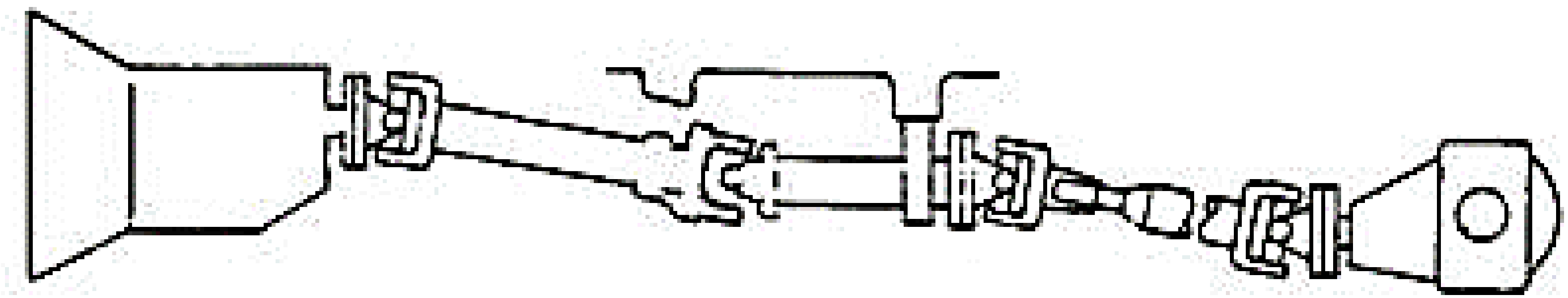
❖ DIVIDED PROPELLER SHAFTS

- Two-piece drive-lines, with two shafts and an intermediate support bearing are generally used on trucks with wheel bases from 3.4 to 4.8 m.
- The two-piece propeller shaft has three universal joints, and the primary propeller shaft is of the fixed-joints-and-tube-assembly type, but the secondary propeller shaft has a slip-joint at the support-bearing end to accommodate any elongation due to suspension movement. Usually the primary shaft is in line with the gearbox mainshaft axis, but the secondary propeller shaft is inclined slightly so that it intersects the rear-axle final-drive pinion shaft.



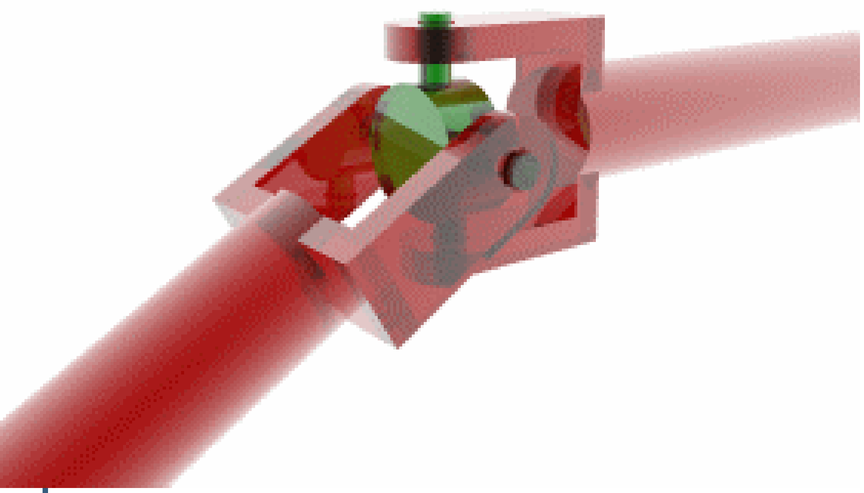
❖ DIVIDED PROPELLER SHAFTS

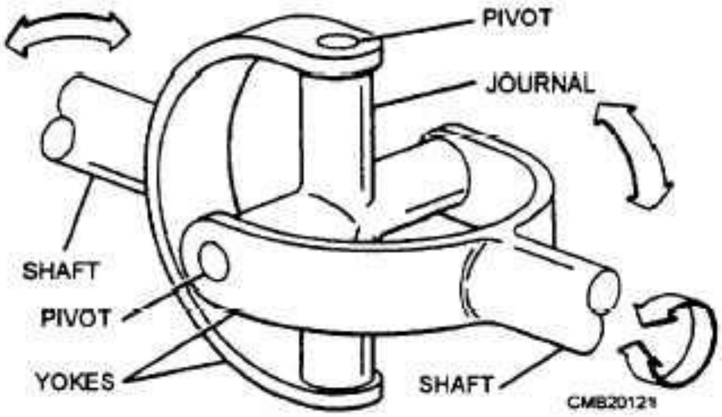
- For vehicles with wheelbases over 4.8 m, a three-piece drive-line with two intermediate support bearings may be necessary. There are four universal-joints, and it can be seen that the intermediate shaft lies parallel to the output shaft of the gearbox. Again only the rear propeller shaft incorporates a slip-joint to compensate for shaft length change.



UNIVERSAL JOINTS:

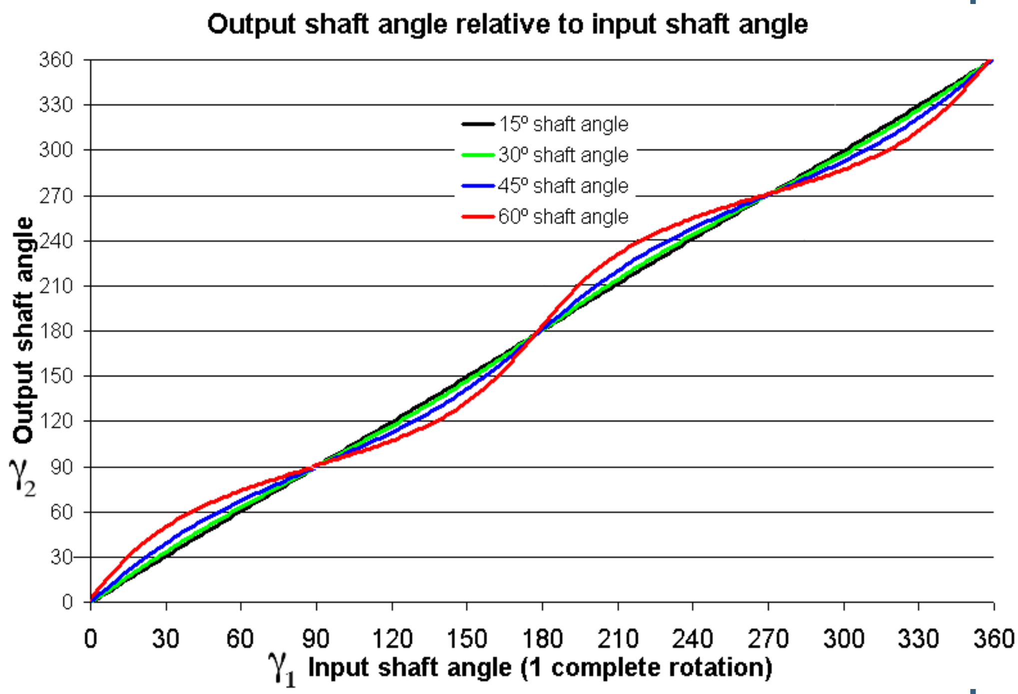
- The propeller shaft is provided with universal joints at its ends. The universal joint is a form of connection between two shafts, whose axes intersect and may assume different inclination at different times. This joint permit the rotation of one shaft about its axis by another shaft which rotates about its own axis.





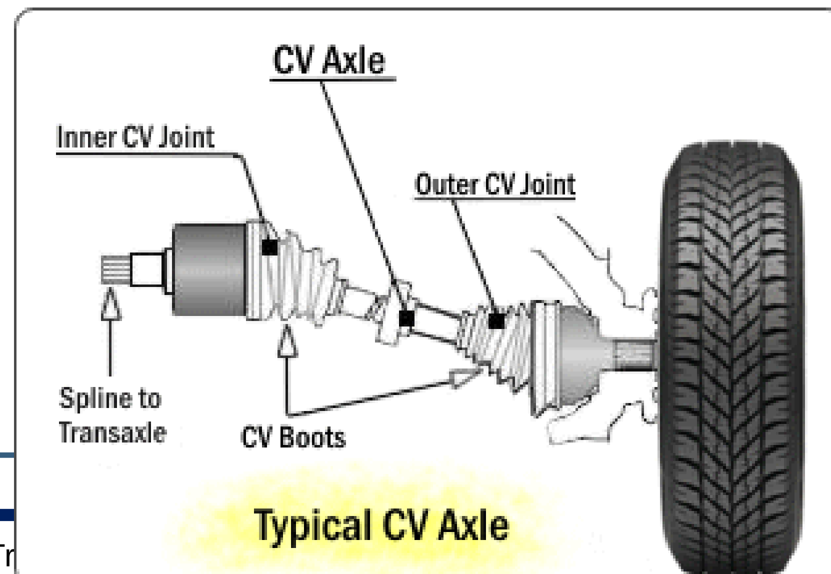
❑ *Why two universal joints at the ends of a propeller shaft?*

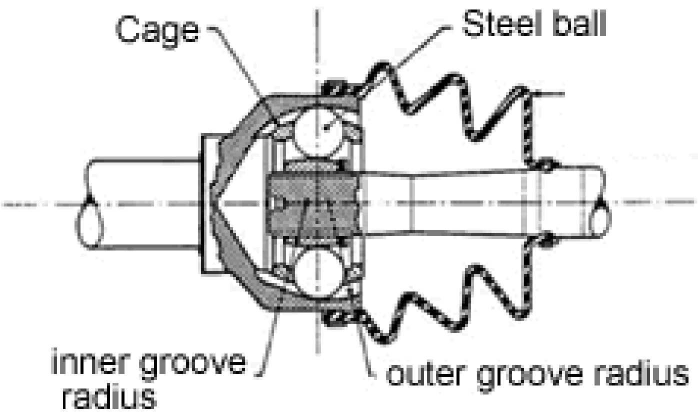
- The output shaft of a universal joint does not rotate with uniform speed within one revolution of the shaft when the input speed is uniform.
- The fluctuation in speed increases with increase in the angle between the shafts. This effect can be cancelled out by attaching one more u- joint whose input speed is fluctuating and output shat rotates with uniform speed.



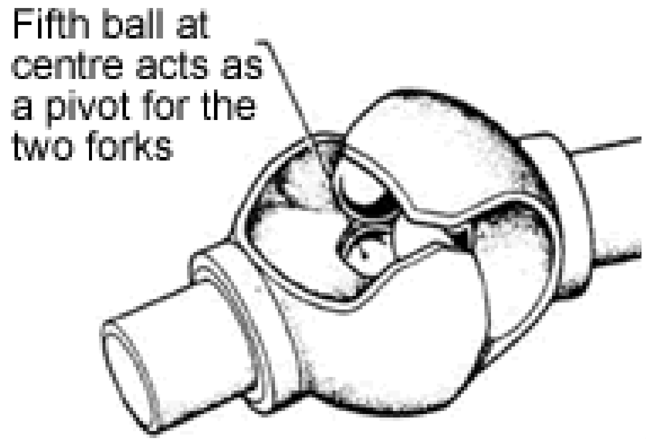
❖ CONSTANT VELOCITY UNIVERSAL JOINT

- Vehicles with front wheel drive require a special universal joint to maintain torque at the wheel whilst turning a corner. The joint is called a constant velocity joint.
- This joint does not have the disadvantage of the Hooke's type joint where two joints are necessary to maintain uniform velocity.
- In this joint a mechanism is incorporated between the "yokes" which automatically align itself when the angle is formed by the two shafts.
- The alignment may be obtained through the movement of steel balls in grooves or through the deflection of rubber components – these deflections neutralising the velocity variation.

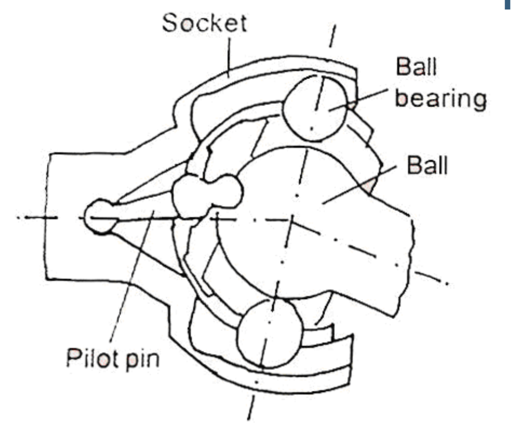




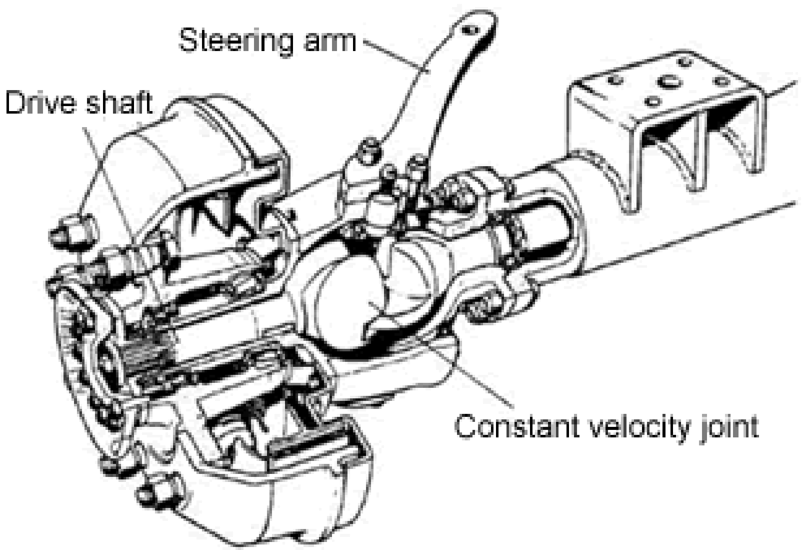
Birfield c.v. joint

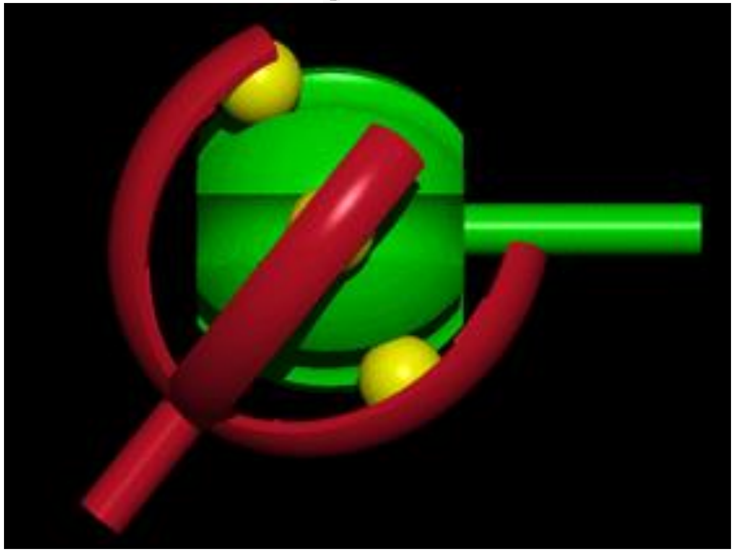


Weiss c.v. joint



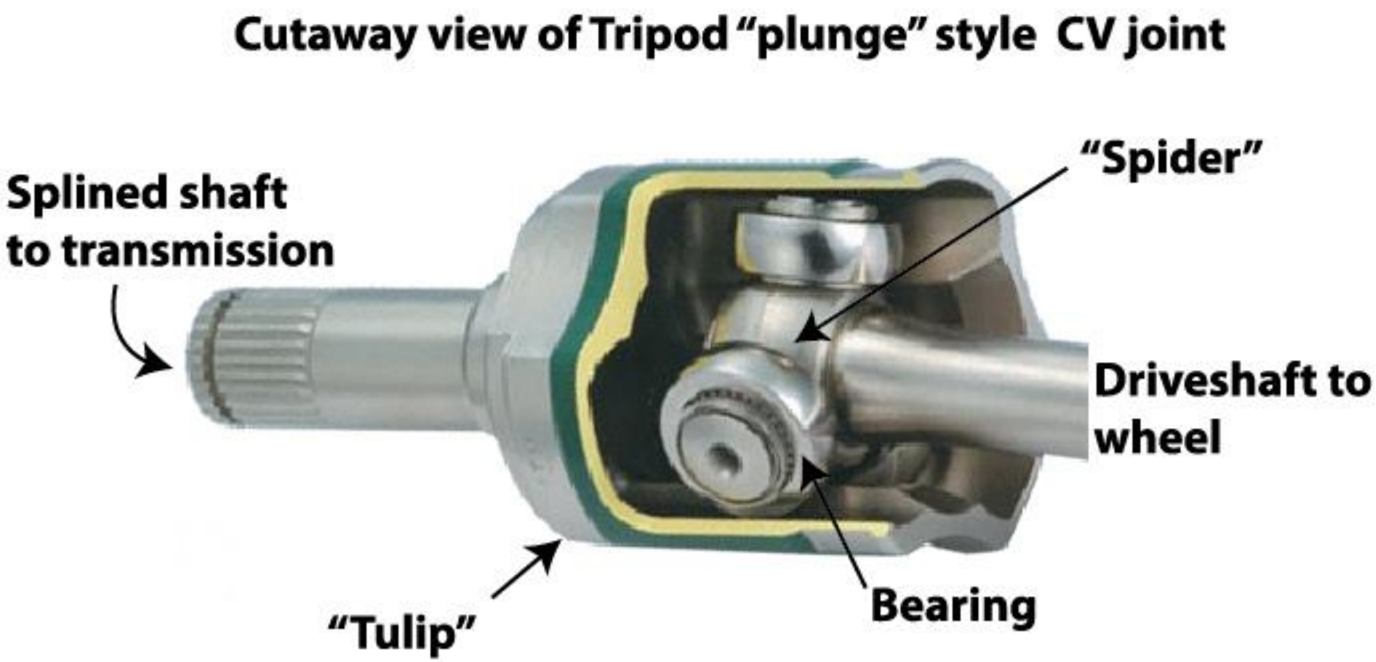
RZEPPA COSTANT-VELOCITY JOINT



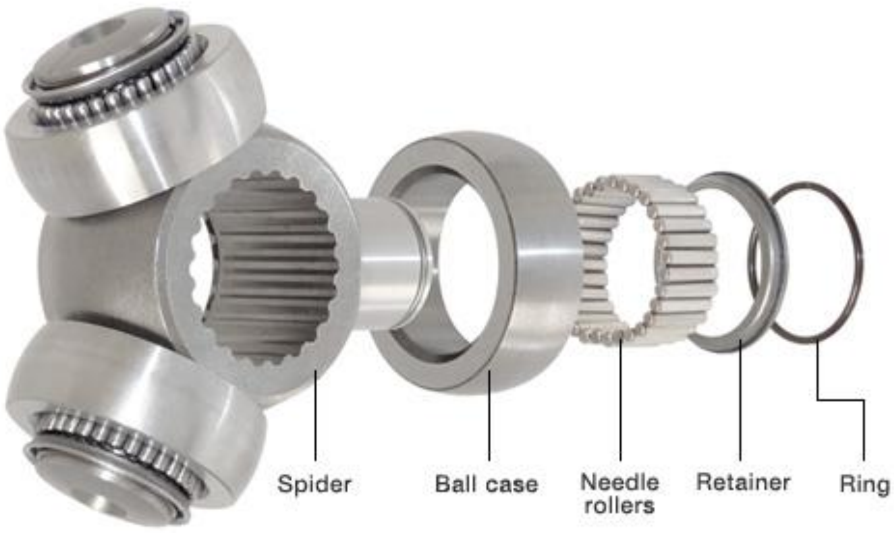


- The constant velocity universal joint does not suffer from the variation in the speed of the driven shaft. The speeds of the shafts connected by this joint are absolutely equal.
- A constant velocity universal joint consists of two yokes with oval races, four driving balls, a centre ball, a centre ball pin and retainer pin. The driving balls are freely mounted in the grooves. The centre ball is secured on the pin in one of the yokes. In this unit, the balls are the driving contact. They move laterally as the joint rotates.
- The movement of the balls permits the point of the driving contact between the two halves of the coupling to remain in a place which bisects the angle between the two shafts.
- By this arrangement, the fluctuation in speed of the driven shaft is avoided.

Tripod CV Joint:

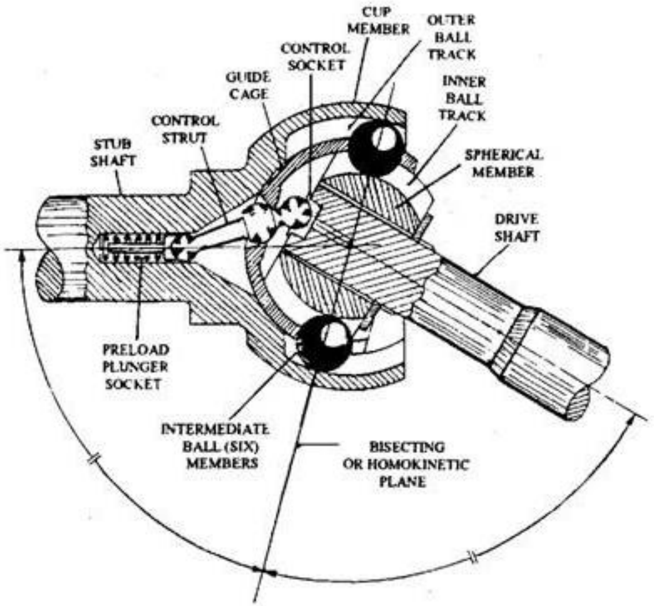


Spider Construction:

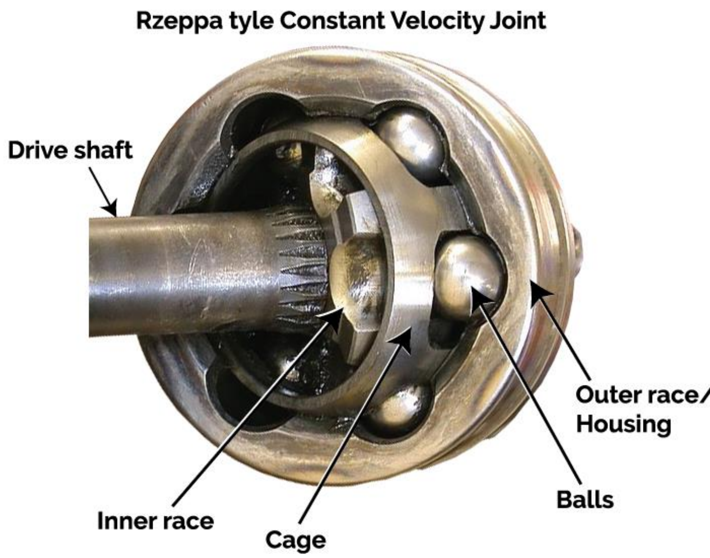


❑ Rzeppa Joint

- A Ford engineer, Alfred Hans Rzeppa (pronounced sheppa) invented one of the first practical constant velocity joints in 1926.
- This joint was able to transmit torque over a wide range of angles. An improved version of the joint was patented by Rzeppa in 1935.
- This version uses six balls as intermediate members, which are kept at all times in a plane bisecting the angle between the input and output shafts (Fig.).
- A controlled guide ball cage is incorporated, which maintains the balls in the bisecting plane (or the median plane) by means of a pivoting control strut, which swivels the cage at the correct angle.

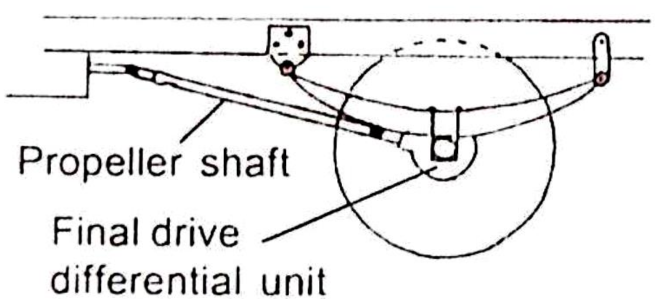


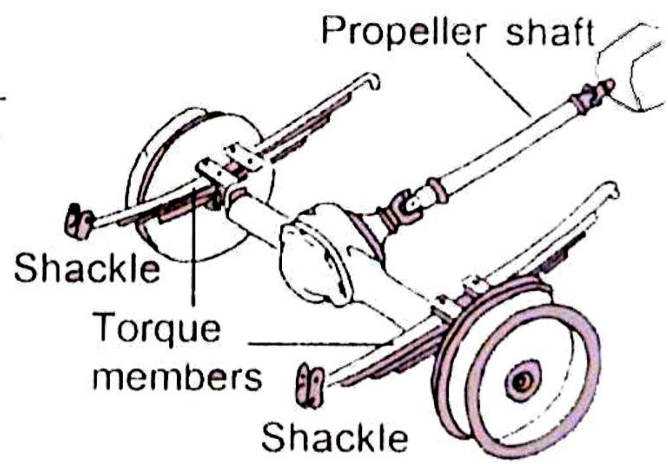
- This control strut is located in the centre of the enclosed end of the outer cup member.
- Both ball ends of the strut are positioned in a recess and socket formed in the adjacent ends of the driving and driven members of the joint respectively.
- A large spherical waist approximately midway along the strut aligns with a hole made in the centre of the cage.
- Any angular inclination of the two shafts at any instant deflects the strut, which in turn proportionally swivels the control ball cage at half the relative angular movement of both shafts.
- This method of cage control has a tendency to jam and, therefore, suffers from mechanical wear.

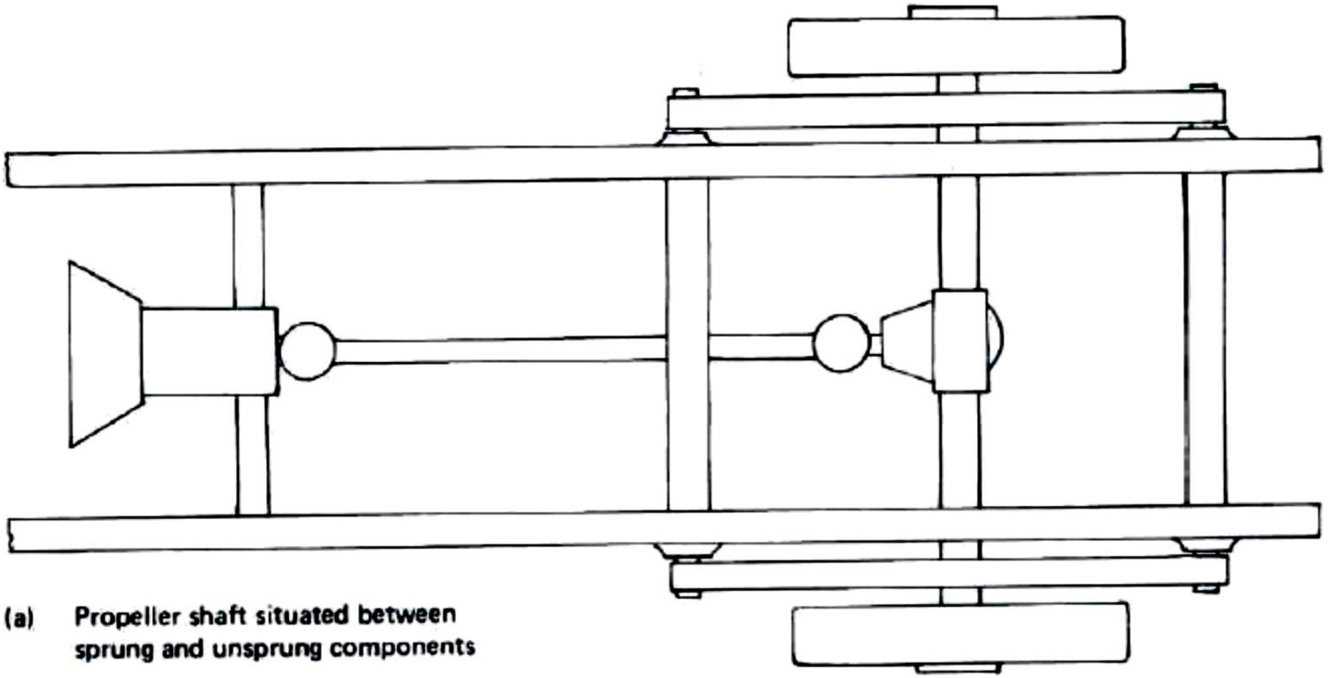


HOTCHKISS DRIVE:

- Two rear leaf springs, longitudinally mounted, are connected to the frame by a ‘fixed’ pivot at the front, and swinging shackles at the rear. At each end of the exposed or ‘open’ type propeller shaft is fitted a universal joint, with provision made for alteration in shaft length, which occurs when the springs are deflected.
- Torque reaction is resisted by clamping the axle to the springs by means of ‘U’ bolts. Under heavy driving conditions the springs will deflect up at the front and down at the rear, and vice versa during braking





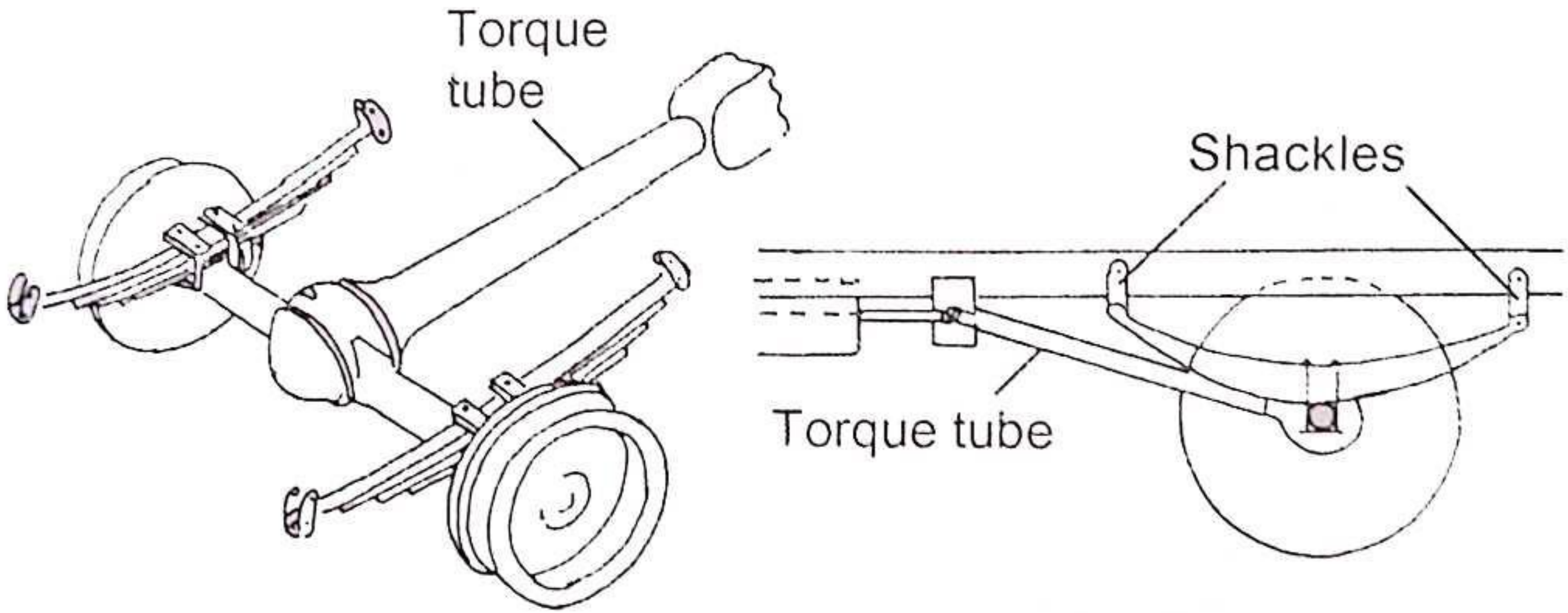


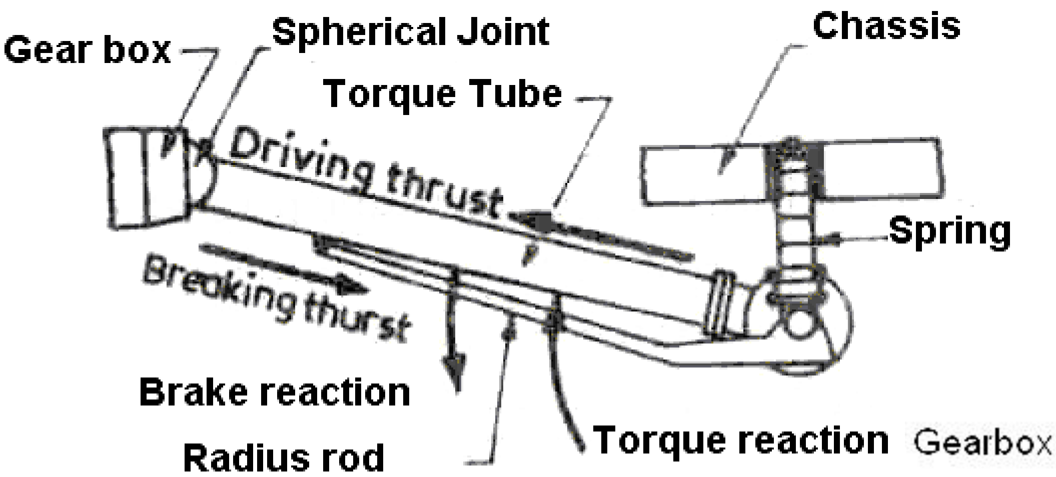
(a) Propeller shaft situated between sprung and unsprung components

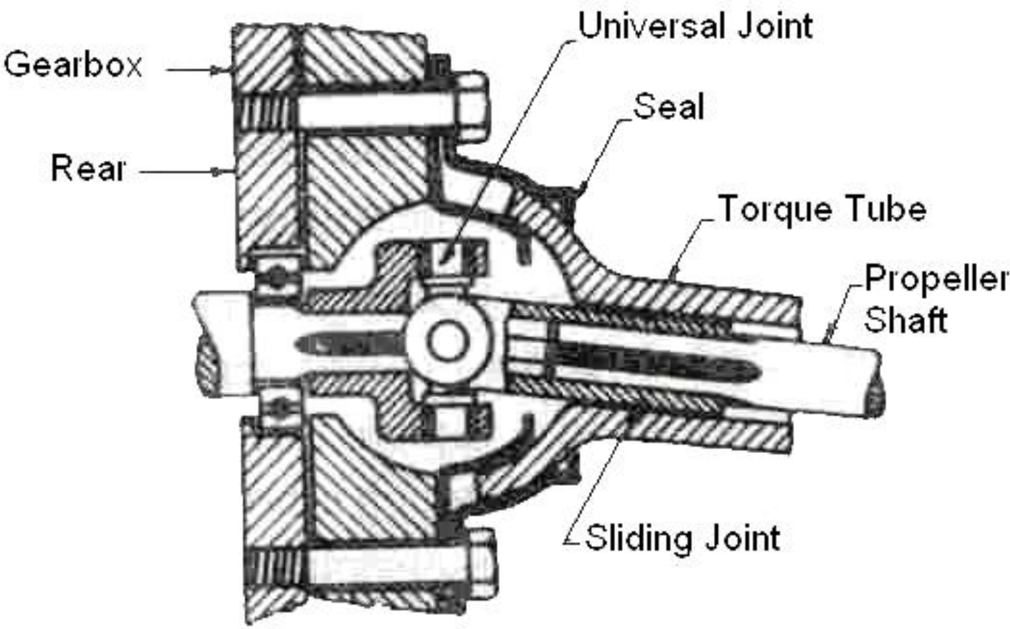
- The suspension springs are bolted rigidly to the rear axle casing. The front ends of the springs are pivoted on pins.
- These pins are carried in brackets bolted to the vehicle frame. The rear ends of the springs are connected to the frame by swinging links or shackles.
- This arrangement permits the deflection of the spring when the vehicle is accelerated or braked.
- The propeller shaft is provided with two universal joints one at each end and a sliding joint at one end. This arrangement permits the rear axle assembly to move up and down due to projections and depression on the road surface.

- Engine power is always transmitted from the gear box to the final drive in the differential through the propeller shaft. From the differential the driving torque is transmitted to the road wheels through the axle shafts. In this transmission system, the suspension springs also act as torque and thrust members.

TORQUE TUBE DRIVE:




Gear box
Spherical Joint
Torque Tube
Chassis
Driving thrust
Spring
Breaking thurst
Brake reaction
Radius rod
Torque reaction


Gearbox
Rear
Universal Joint
Seal
Torque Tube
Propeller Shaft
Sliding Joint

- There is a tubular member called torque tube which surrounds the propeller shaft and is bolted to the rear axle casing.
- The front end of this member is spherical in shape, the spherical end fits in a cup bolted to a cross member of the vehicle frame (or to the back of the gear box).
- The torque tube incorporates **bearings which support the propeller shaft**. The propeller shaft itself is usually made of hollow steel tubing which construction gives it a light weight and torsional strength.
- The suspension leaf springs are bolted to the spring seats that are provided on the axle casing. Each end of the springs is shackled to the frame.
- The tubular member will transmit the thrust from the axle to the frame and will also take the torque reaction.

- Often radius rods are used to assist the torque tube to take the twist and thrust of the vehicle drive.
- This construction, the centre line of the final drive bevel pinion shaft will always pass through the centre of the spherical cup.
- Now, if the propeller shaft is connected to the gear box shaft by a universal joint situated exactly at the centre of that cup, no other universal joint will be needed and no sliding joint will be necessary.
- This is because both pinion shaft and propeller shaft will move about the same centre, namely that of the spherical cup, when the axle moves up and down.

Purpose of Final Drive:

- The final drive unit has three functions to perform:

1. It gears down the speed of the propeller shaft to a suitable road wheel speed,
2. It divides the transmitted torque from the engine between the two driving wheels,
3. It turns the drive through a right angle, transferring it from the propeller shaft to the driving wheels.

- The propeller shaft in a conventional front-engine, rear-wheel drive car feeds the engine's torque into the final drive unit.
- The function of the final drive in this application is to turn the drive through a right angle and divide it into two equal parts which are then delivered to the rear wheels.
- A final drive is also needed in a front-wheel drive (FWD) car but with a transverse engine, as in the British Leyland Mini, there is naturally no need to turn the drive through a right angle.
- It must still split the drive into equal parts, however, for each driven wheel.

Drive Ratio:

Advantages:

1. Greater wheel torque in each gear.
2. Higher acceleration forces

Disadvantages:

1. Lower top speed for each gear.
2. Reduced fuel economy (Frictional Losses)
3. Increased Noise

FD	1st	2nd	3rd	4th	5th	6th	T+
4.1	45	68	95	121	144	173	0%
4.44	41	63	87	111	131	159	8.3%
4.57	40	61	85	108	128	155	11.5%
4.77	38	59	81	104	124	148	16.3%

Drive Ratio:

Final Drive Ratio	redline	1st	2nd	3rd	4th	5th	6th
3.07	6500	37.2	62.4	94.8	126.9	157.3	-
3.07	7000	40.1	67.2	102.1	136.6	169.4	-
3.15	6500	36.2	60.8	92.4	123.6	153.3	-
3.15	7000	39.0	65.5	99.5	133.1	165.1	-
3.23	6500	35.3	59.3	90.1	120.6	149.5	-
3.23	7000	38.1	63.9	97.0	129.8	161.0	-
3.38	6500	33.8	56.7	86.1	115.2	142.9	-
3.38	7000	36.4	61.1	92.7	124.1	153.9	-
3.46	6500	33.0	55.4	84.1	112.6	139.6	-
3.46	7000	35.5	59.6	90.5	121.2	150.3	-
3.64	6500	31.4	52.7	79.9	108.7	132.7	-
3.64	7000	33.8	56.7	86.1	117.1	142.9	-

Types of Final Drive

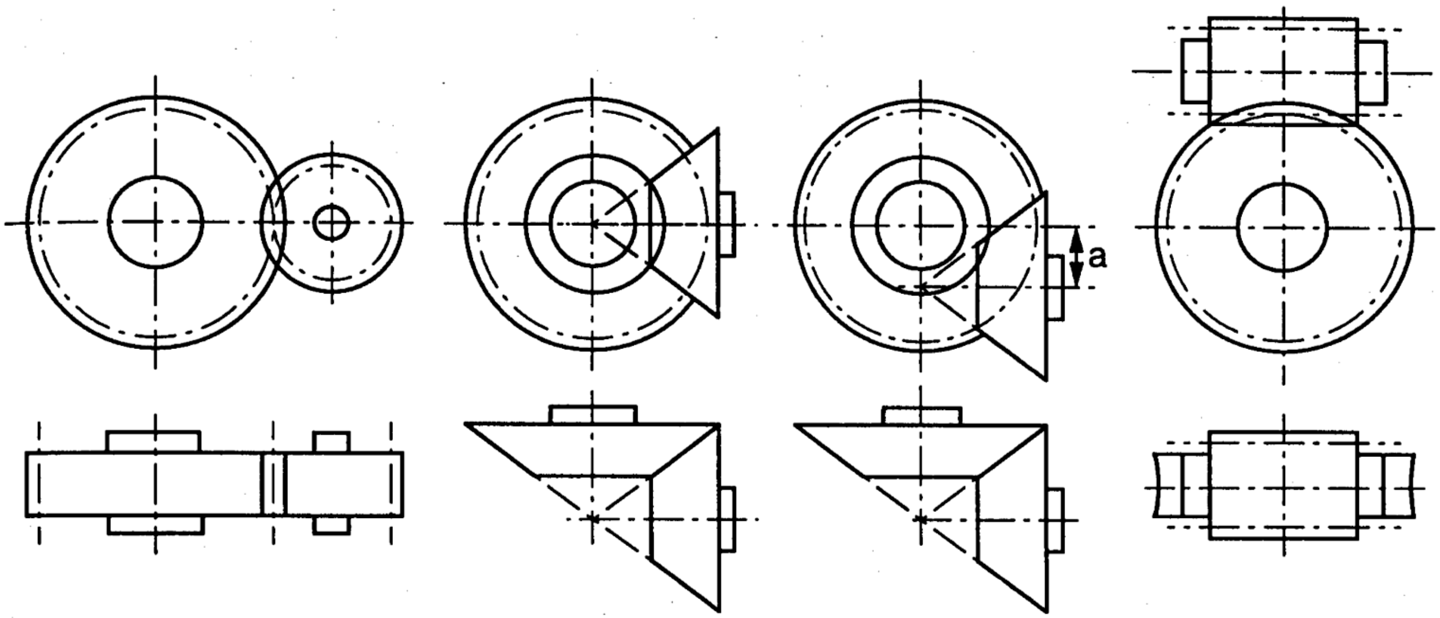
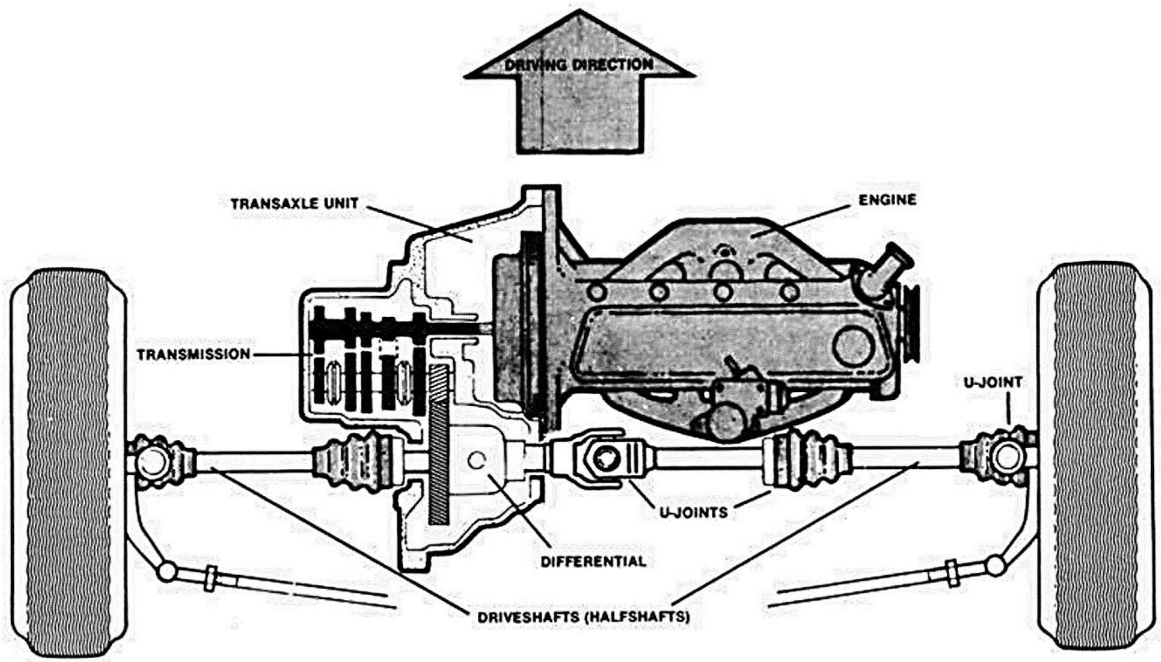


Figure 6.53. Diagrammatic view of the formats for passenger car axle gearboxes

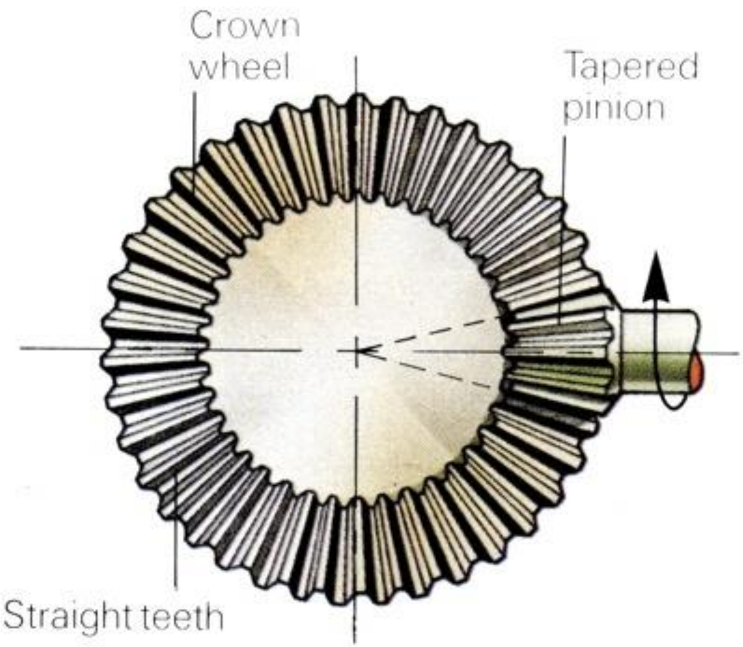
Types:

1. Spur Gear



2. Straight Bevel:

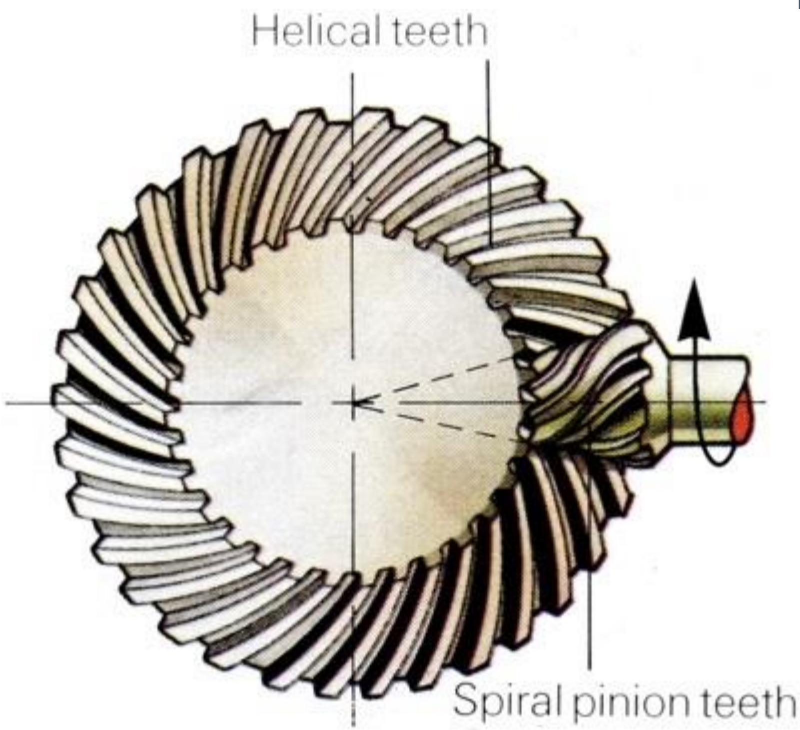
- The oldest crown wheel and pinion arrangements used straight-cut teeth because these were the easiest to make.
- However, straight-cut teeth mean that the drive is carried by one tooth at a time, which can lead to noise and vibration unless all the teeth are exactly evenly spaced and exactly the same shape.



Straight bevel

3. Spiral Bevel:

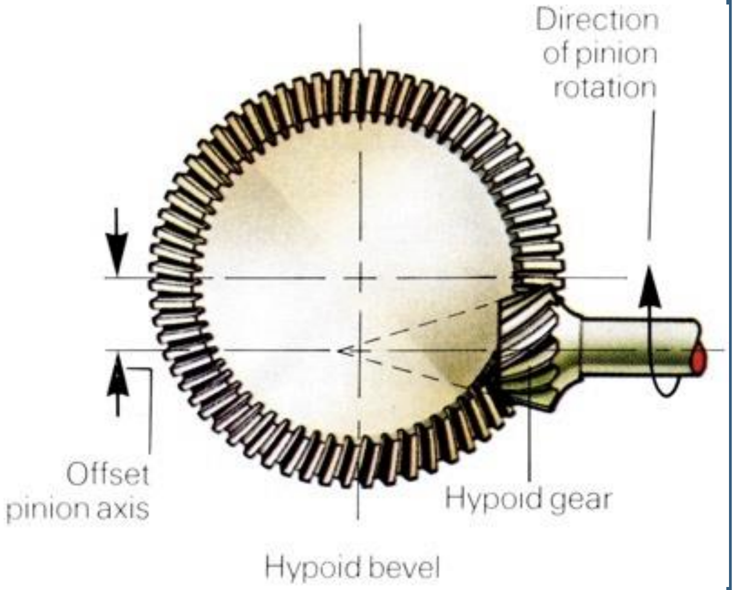
- With this tooth form, two or possibly even three pairs of teeth are in contact at the same time and smoother running results, together with more even wear.
- Costlier and difficult to manufacture.



Spiral bevel

4. Hypoid Bevel:

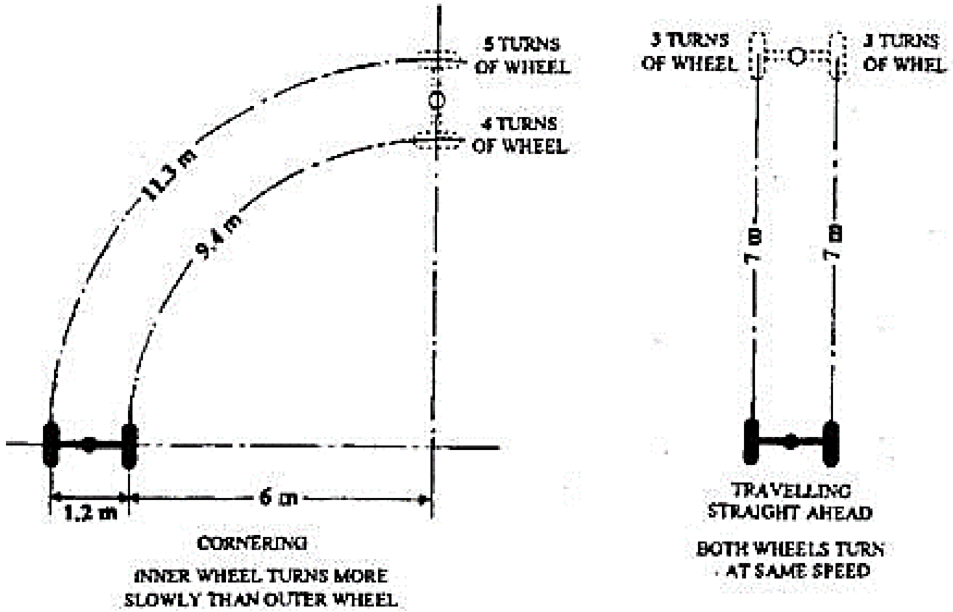
- To reduce the amount of space taken up in the passenger compartment by the transmission tunnel, the propeller shaft was lowered.
- In this way propeller shafts could be lowered by a very useful 150 mm (6ins) or more where they ran through the passenger compartment.



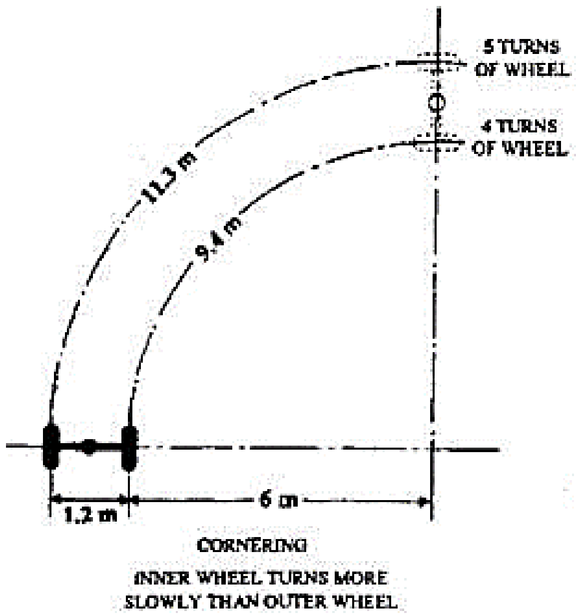
❖ **Need of Differential:**

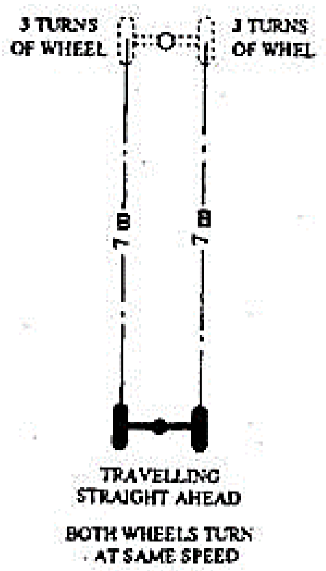
- In 1827, the watchmaker **Onésiphore Pequeur** of France invented the differential**.**
- It can be seen from the fig. that the outer wheel must travel a greater distance than the inner wheels during cornering of the vehicle.
- Hence, if the wheels are interconnected, the tyres have to ‘scrub’ over the road surface and tend to keep the vehicle moving straight ahead.
- These problems can be minimized by driving one wheel and allowing the other to run free.
- But this provides unbalanced driving thrust and unequal cornering speeds due to which the arrangement was not accepted. The problem was solved by the differential.

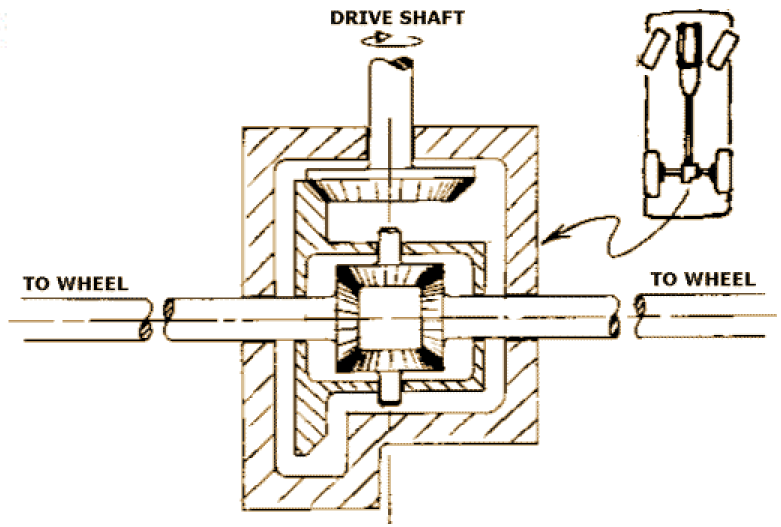
- This mechanism rotates the wheels at different speeds, while maintaining a drive to both wheels.



Example 1. The steering set of a, vehicle provides a turning-circle radius of 6.6 m with a wheel-track width of 1.2 m. The effective road wheel rolling diameter is 0.72 m. Calculate the number of revolutions made by the inner and outer wheels for one turning circle.







Example 1. The steering set of a, vehicle provides a turning-circle radius of 6.6 m with a wheel-track width of 1.2 m. The effective road wheel rolling diameter is 0.72 m. Calculate the number of revolutions made by the inner and outer wheels for one turning circle.

Solution.

Mean turning radius, $R_m = 6.6$ m.

Outer wheel turning radius $R_o = 6.6 + \frac{1.2}{2} = 7.2$ m.

Inner wheel turning radius, $R_i = 6.6 - \frac{1.2}{2} = 6$ m.

Rolling circumferences of road wheel $= \pi D = 0.72\,\pi$ m

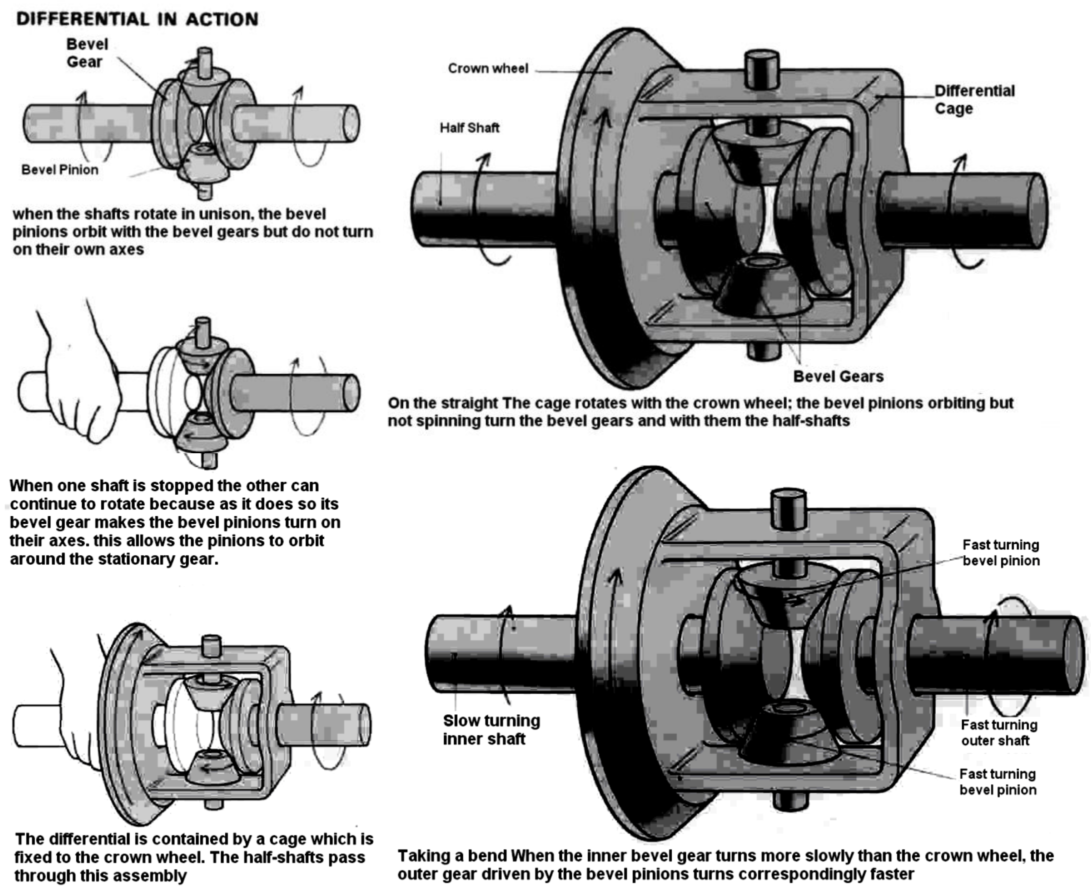
Distance travelled by outer wheel for one complete turning circle $= 2\pi R_o = 14.4\pi$ m.

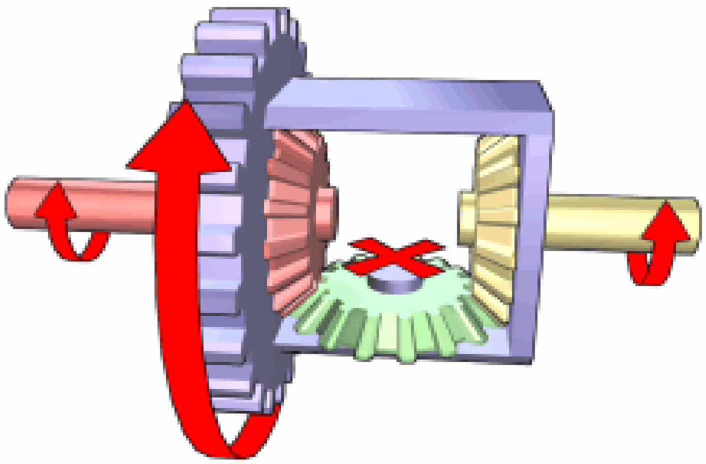
Distance travelled by inner wheel for one complete turning circle $= 2\pi R_i = 12\pi$ m.

Therefore, revolutions completed by outer wheels $= \frac{14.4\pi}{0.72\pi} = 20$ revolutions.

and revolutions completed by inner wheels $= \frac{12\pi}{0.72\pi} = 16.6$ revolutions.

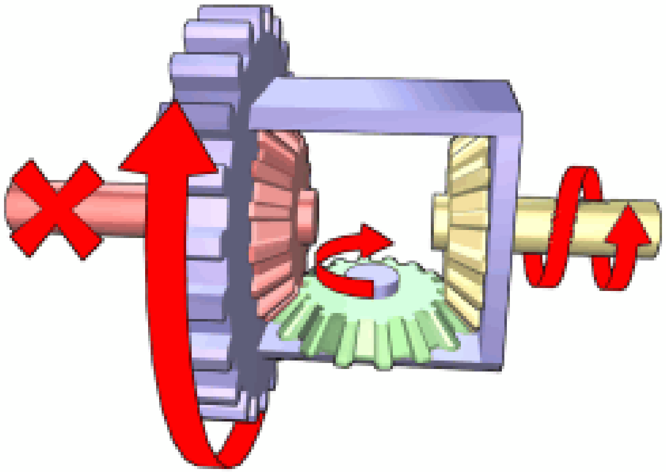
Differential:





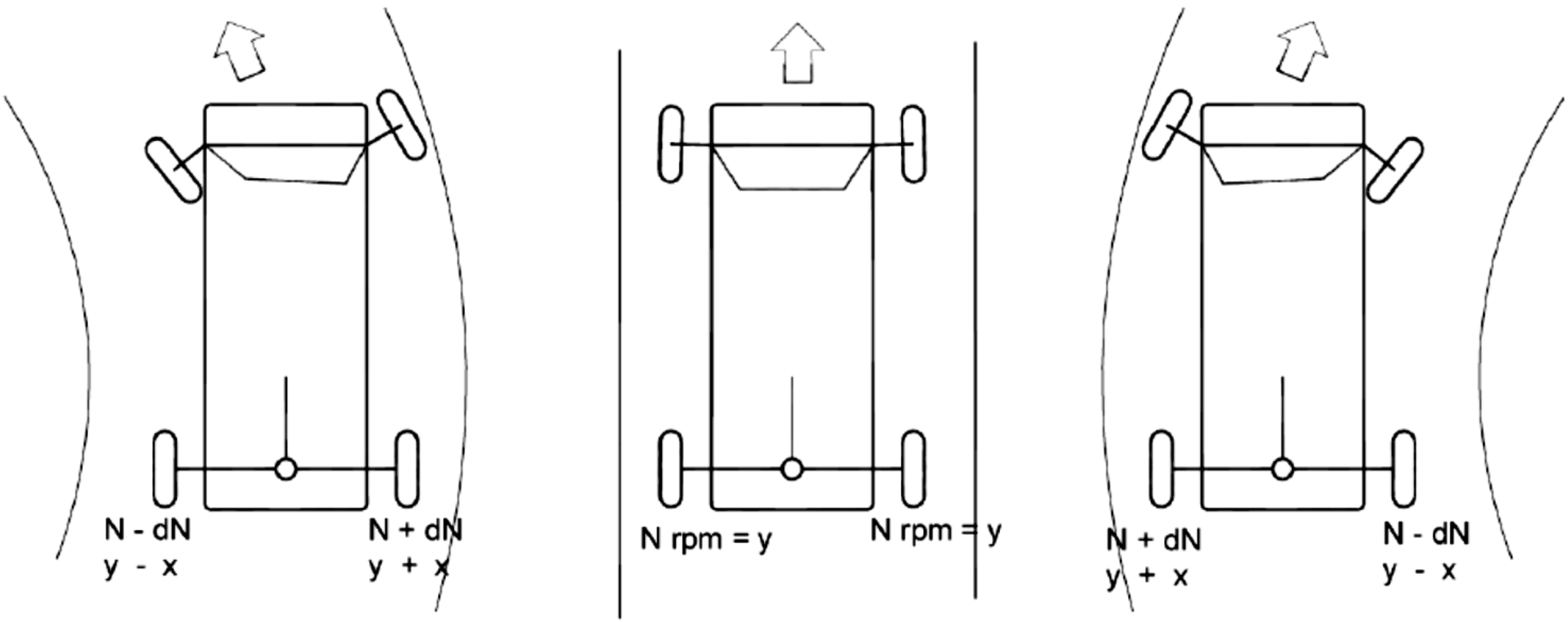
→ Input torque is applied to the ring gear (blue), which turns the entire carrier (blue), providing torque to both side gears (red and yellow), which in turn may drive the left and right wheels. If the resistance at both wheels is equal, the planet gear (green) does not rotate, and both wheels turn at the same rate.

If the left side gear (red) encounters resistance, ←
the planet gear (green) rotates about the left side gear,
in turn applying extra rotation to the right side gear (yellow)



Action	Arm 'B'	C (Tc)	E/F	D (T_D)
Fix the arm B and give +1 rev. to C	0	1	-	-1
Fix the arm B and give +1 rev. to C	0	+x	-	-x
Give +y rev. to atm B and +x rev. to C	y	y + x	-	y - x

$T_C = T_D = T_E = T_F$

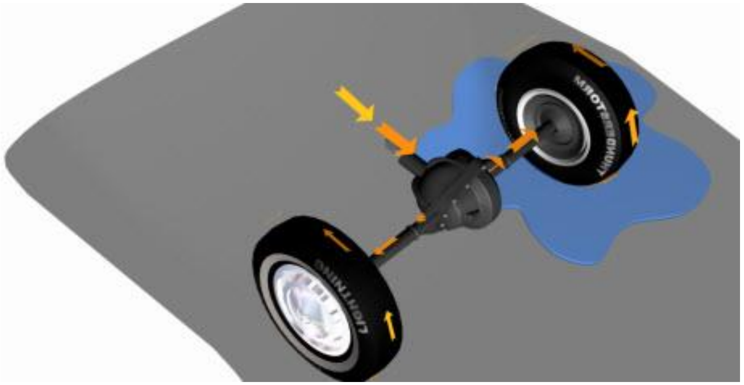

N - dN
y - x
N + dN
y + x
N rpm = y
N rpm = y
N + dN
y + x
N - dN
y - x

- Torque is supplied from the engine, via the transmission, to a drive shaft which runs to the final drive unit and contains the differential.
- A spiral bevel pinion gear takes its drive from the end of the propeller shaft, and is encased within the housing of the final drive unit.
- This meshes with the large spiral bevel *ring* gear, known as the crown wheel.
- The crown wheel gear is attached to the differential *carrier* or cage, which contains the 'sun' and 'planet' wheels or gears, which are a cluster of four opposed bevel gears in perpendicular plane.
- The two sun wheel gears are aligned on the same axis as the crown wheel gear, and drive the axle half shafts connected to the vehicle's driven wheels.
- The other two planet gears are aligned on a perpendicular axis which changes orientation with the ring gear's rotation
- As the differential carrier rotates, the changing axis orientation of the planet gears imparts the motion of the ring gear to the motion of the sun gears by pushing on them rather than turning against them but because the planet gears are not restricted from turning against each other, *within* that motion, the sun gears can counter-rotate relative to the ring gear and to each other under the same force

- The rotation of the crown wheel gear is always the average of the rotations of the side sun gears. This is why, if the driven road wheels are lifted clear of the ground with the engine off, and the drive shaft is held (say leaving the transmission 'in gear', preventing the ring gear from turning inside the differential), manually rotating one driven road wheel causes the opposite road wheel to rotate in the opposite direction by the same amount.
- When the vehicle is traveling in a straight line, there will be no differential movement of the planetary system of gears other than the minute movements necessary to compensate for slight differences in wheel diameter, undulations in the road (which make for a longer or shorter wheel path), etc.

Limitations of Open Differential:

- If one wheel begins to slip while the other maintains traction, the slipping wheel will receive most of the power
- This means that if one wheel is spinning on ice while the other is still in contact with the pavement, the OD only cause the slipping wheel to spin faster and very little power will reach the wheel with good traction
- Similarly, if one wheel is lifted off the ground, nearly all the power will go to the wheel that is off the ground. Such a loss of traction is sometimes called "diffing out"



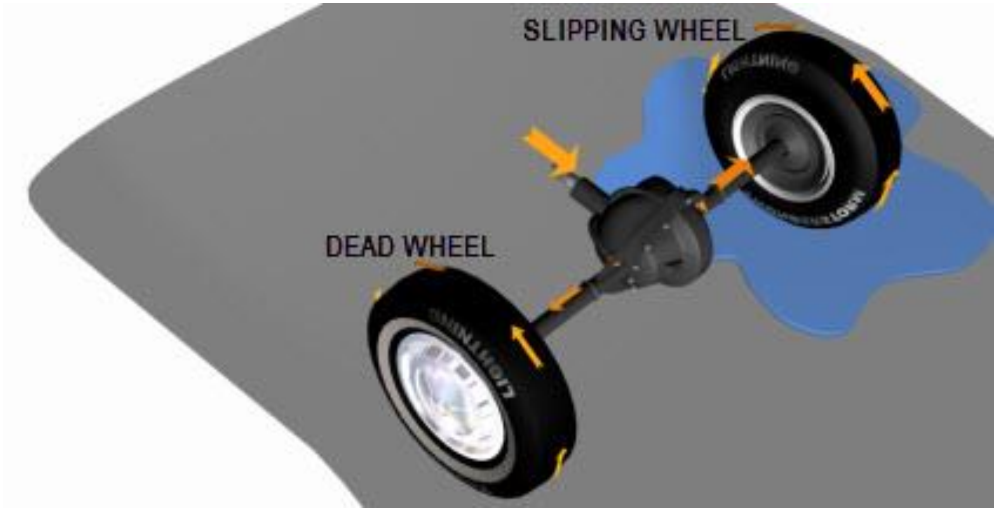
❖ Limited Slip Differential(LSD)

- Limited slip differentials *(LSD)* are used in automobile to overcome the traction difference problem of drive wheels.
- A **limited-slip differential** is a type of differential that allows its two output shafts to rotate at different speeds but limits the maximum difference between the two shafts

❑Problem with the Standard Differential

- Consider a situation where a vehicle fitted with a standard differential moves straight, and one drive wheel is on a surface with good traction and the other wheel is on a slippery track. In a standard differential the left and right axle rotations are completely independent. Since one wheel is on a slippery track, the standard differential will make that wheel spin in excessive speed, while the good traction wheel will remain almost dead. This means high power supply to the slippery wheel and low power flow to the good traction wheel. So the vehicle won’t be able to move.

One way to overcome this problem is to limit the independency or relative motion between the left and right axles. Limited slip differentials are introduced for this purpose. One of the most commonly used LSD technology is clutch-pack based.

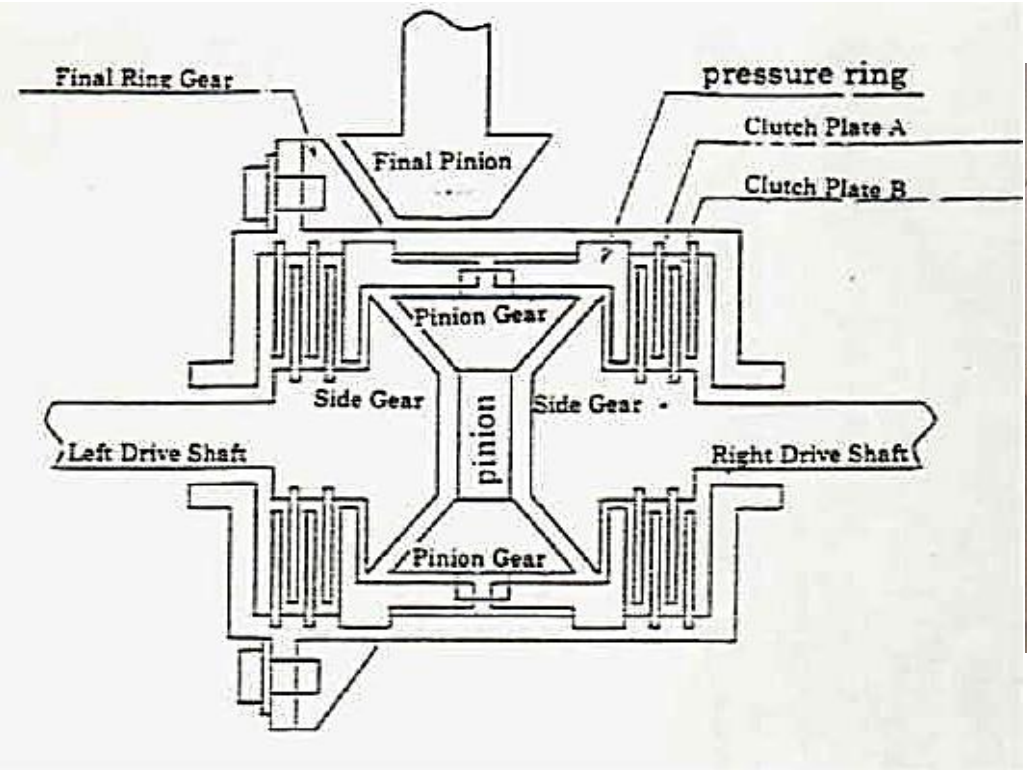


❖ Basics of limited slip differential

- The main advantage of a limited-slip differential is demonstrated by considering the case of an open differential in off-roading or snow situations where one wheel begins to slip or lose contact with the ground.
- In such a case with a standard differential, the slipping or non-contacting wheel will receive the majority of the power, while the contacting wheel will remain stationary with the ground.
- The torque transmitted will be equal at both wheels, and therefore, will not exceed the threshold of torque needed to move the wheel with traction.
- In this situation, a limited-slip differential prevents excessive power from being allocated to one wheel, and thereby keeping both wheels in powered rotation.

Constructional Features of LSD

- The basic components of a standard differential are shown below. It has got pinion gear, ring gear, case, spider gears and side gears.
- Apart from its basic components a Limited slip differential has got a series of friction and steel plates packed between the side gear and the casing.
- Friction discs are having internal teeth and they are locked with the splines of the side gear. So the friction discs and the side gear will always move together.


Final Ring Gear
Final Pinion
pressure ring
Clutch Plate A
Clutch Plate B
Pinion Gear
Side Gear
pinion
Side Gear
Left Drive Shaft
Right Drive Shaft
Pinion Gear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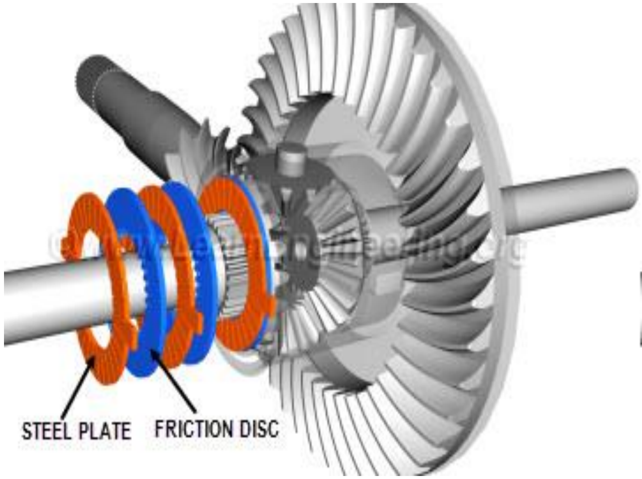
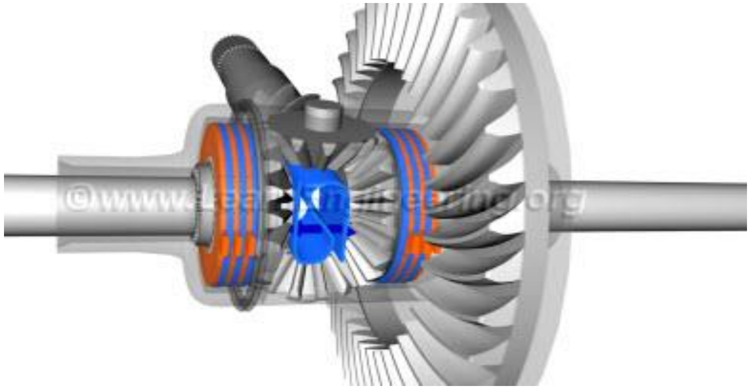
- Steels plates are having external tabs and are made to fit in the case groove. So they can rotate with the case.
- If any of the clutch pack assembly is well pressed, the frictional force within them will make it move as a single solid unit. Since steel plates are locked with the case and friction discs with the side gear, in a well pressed clutch pack casing and the clutch pack will move together. Or motion from the casing is directly passed to the corresponding axle.
- Space between the side gears is fitted with a pre-load spring. Pre load spring will always give a thrust force and will press clutch pack together.

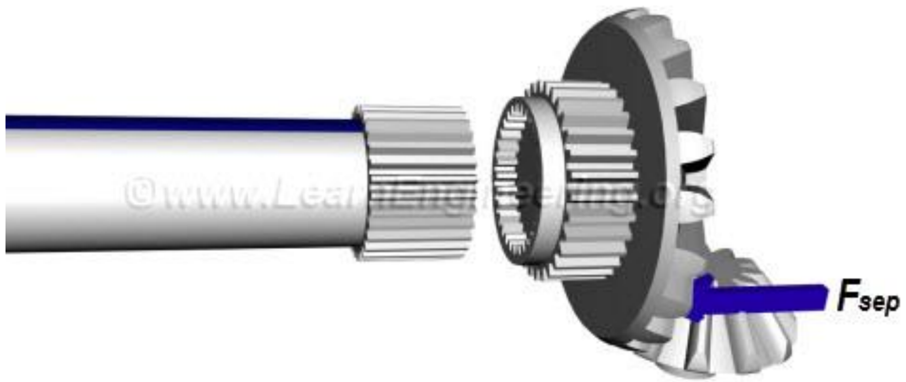




Separating action of Bevel gears

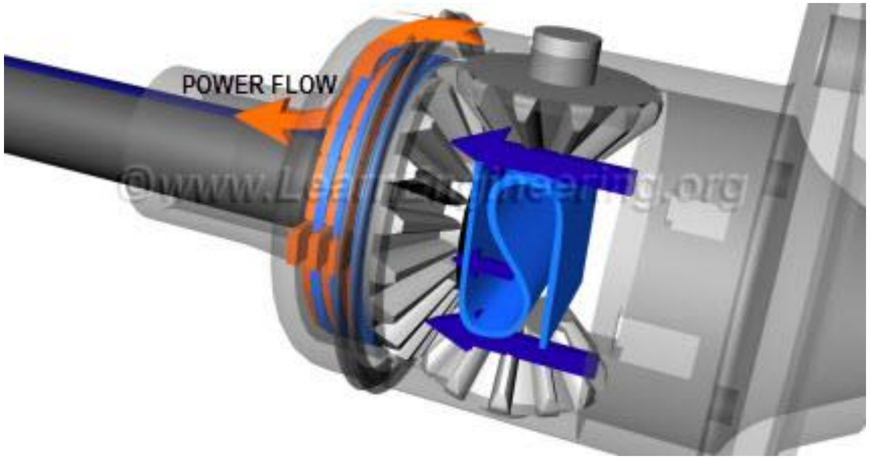
- When torque is transmitted through a bevel gear system axial forces are also induced apart from the tangential force. The axial force tries to separate out the gears.

- The side gear and axle are 2 separate units. The side gear has got a small allowance for axial movement.
- So during high torque transmission through spider-side gear arrangement, a high separating thrust force is also transmitted to the clutch pack.
- This force presses and locks the clutch pack assembly against wall of the casing.

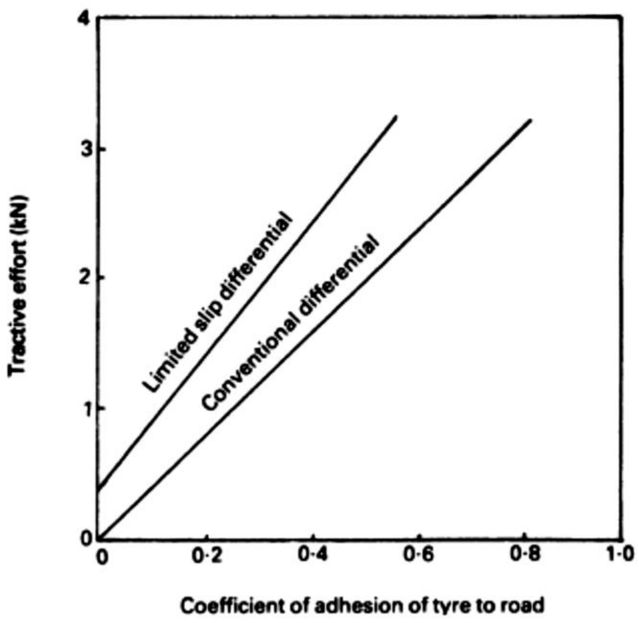


❖ Working of Limited Slip Differential

- Now back to the initial problem. Since one wheel is on a high traction surface, the torque transmitted to it will be higher.
- So the thrust force developed due to the bevel gear separation action also will be high at that side. Thus clutch pack at high traction wheel side will be pressed firmly and clutch pack will be locked.
- So power from the differential casing will flow directly to high traction axle via clutch pack assembly.

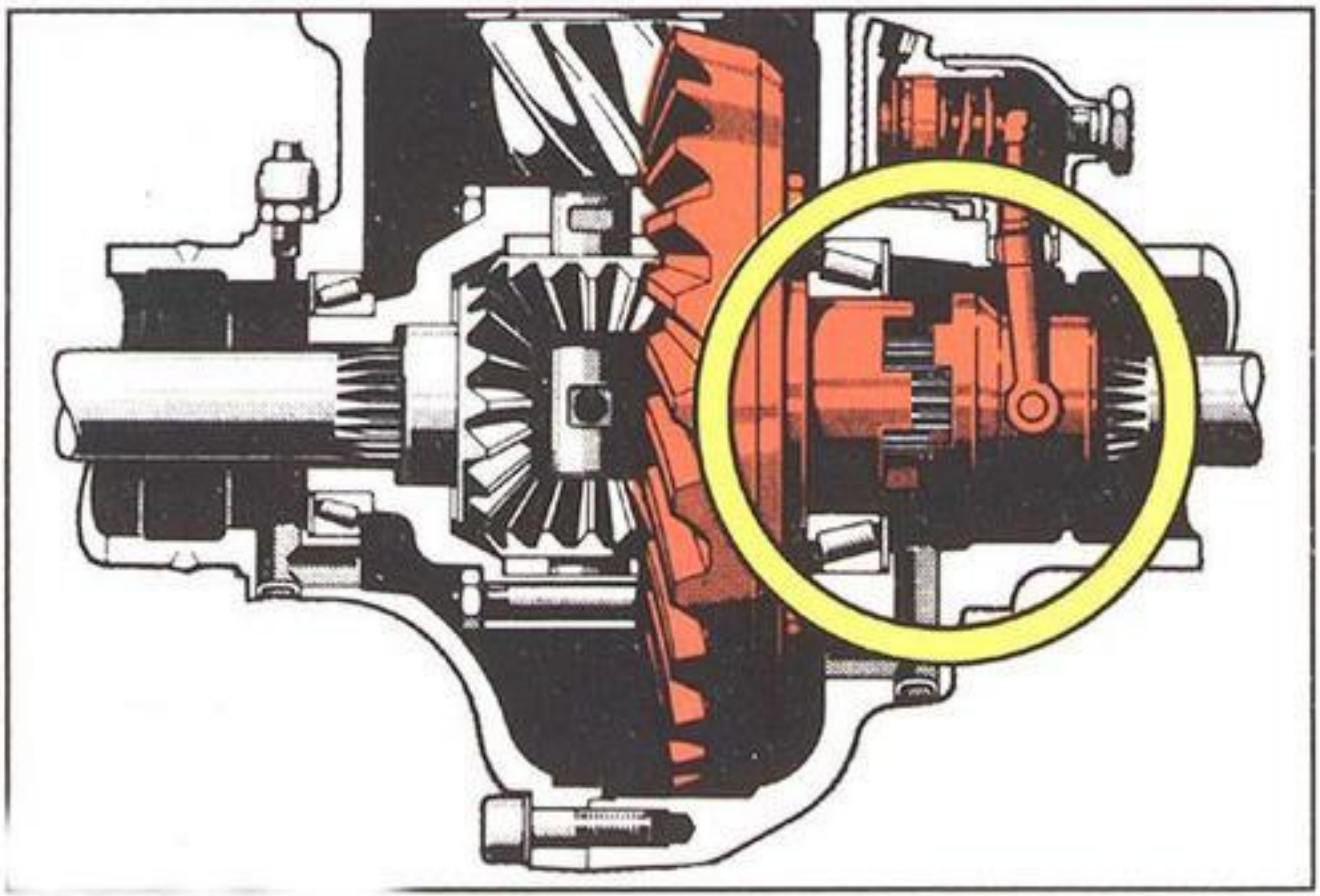


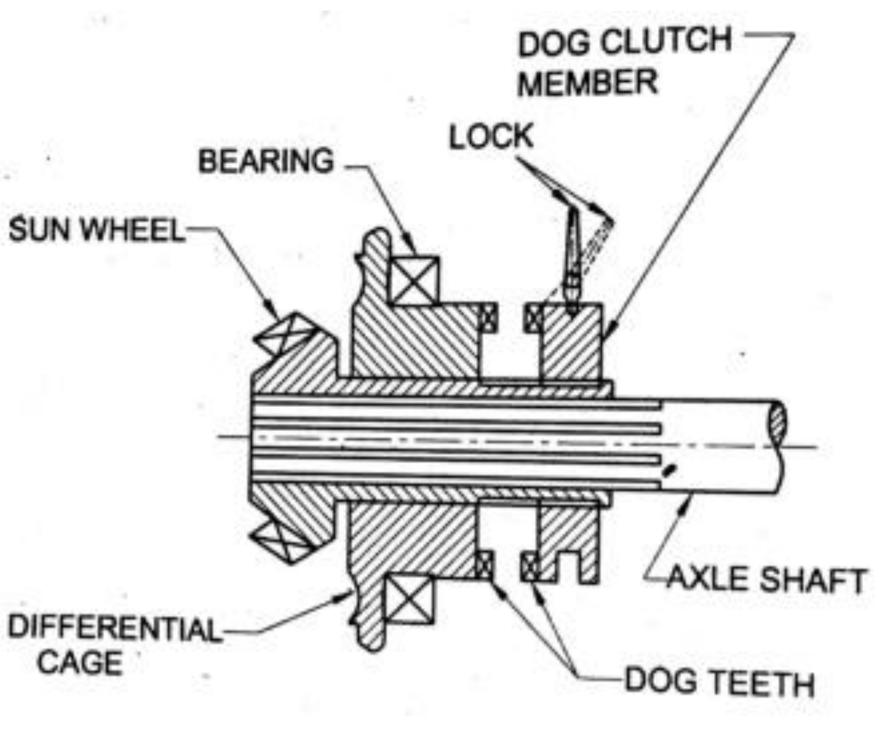
- On the other hand clutch pack on the low traction wheel side is not engaged yet, so power flow will be limited to that side. So the vehicle will be able to overcome the traction difference problem.
- However while taking a turn the LSD can act like a normal differential. In this case thrust force developed due to bevel gear separation action won't be that high. So the plates in clutch pack will easily overcome frictional resistance and will be able to slip against each other. Thus the right and left wheel can have different speed just like an open differential.



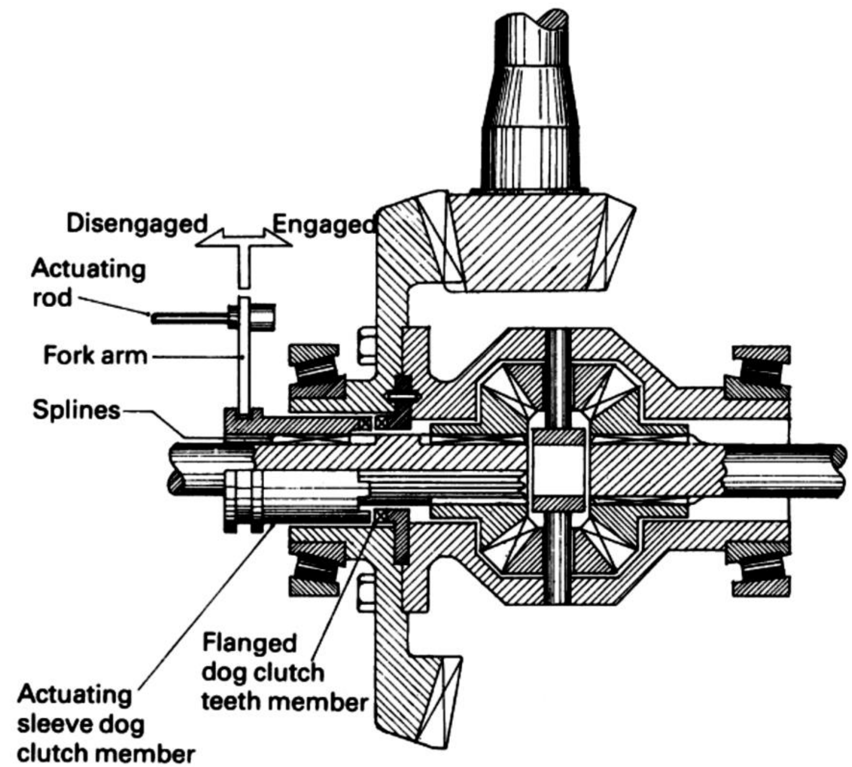
Locking Differential:

- A **locking differential**, **differential lock**, **diff lock** or **locker** is a variation on the standard automotive differential.
- A locking differential may provide increased traction compared to a standard, or "open" differential by restricting each of the two wheels on an axle to the same rotational speed without regard to available traction or differences in resistance seen at each wheel.
- A locking differential is designed to overcome the main limitation of a standard open differential by essentially "locking" both wheels on an axle together as if on a common shaft. This forces both wheels to turn in unison, regardless of the traction (or lack thereof) available to either wheel individually.



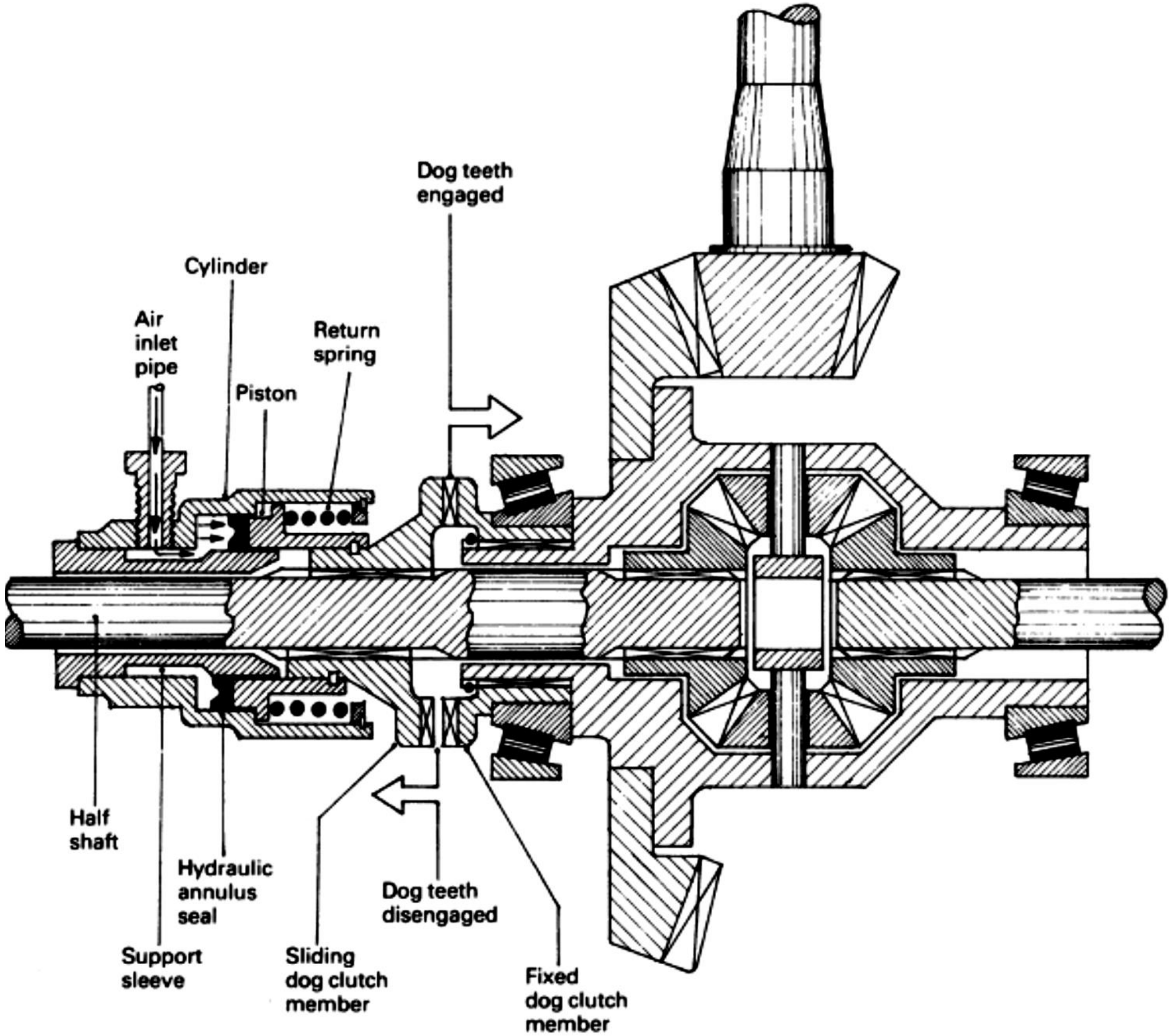


LOCKING DIFFERENTIAL



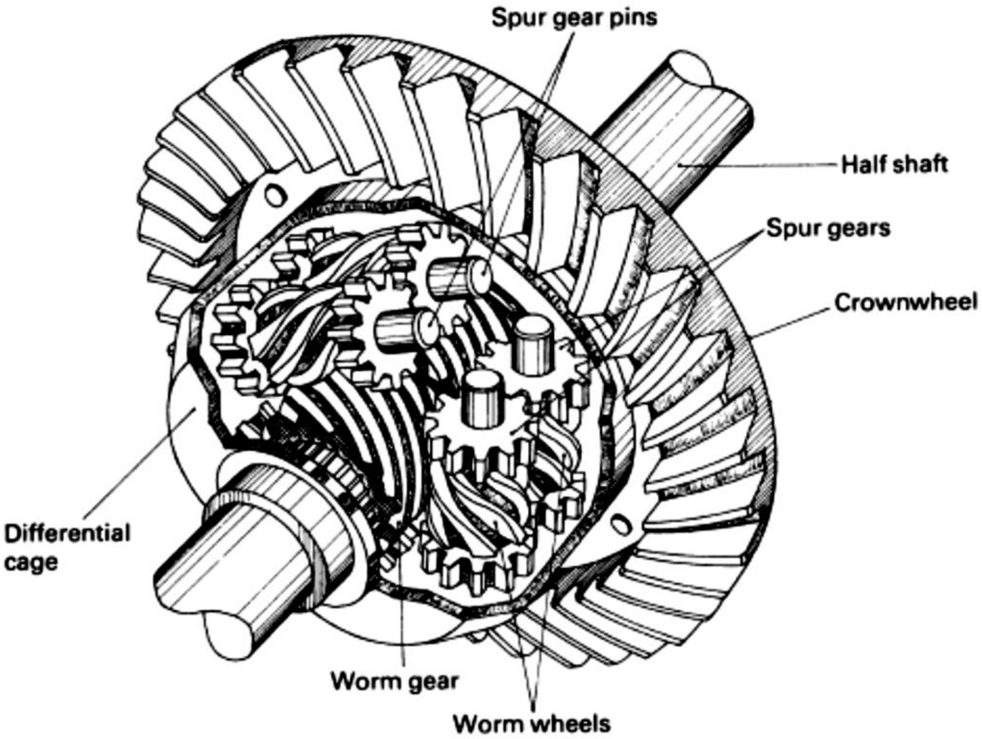
Manually Operated Differential Locking Mechanism

Differential Lock with Air Control Mechanism



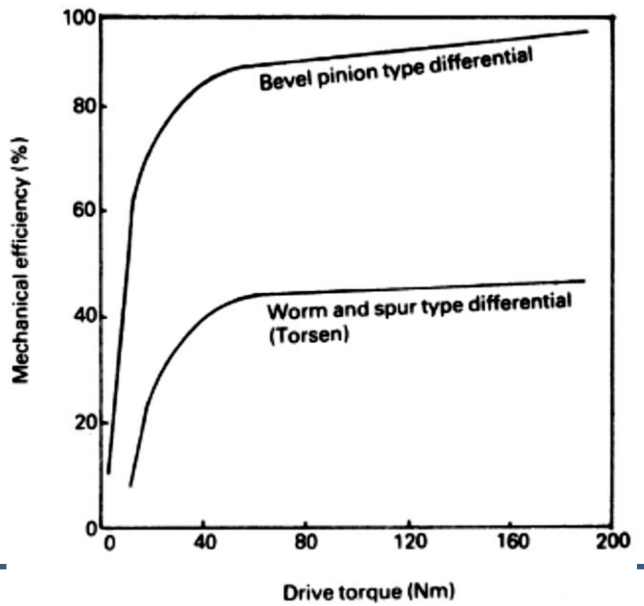
❖ Torsen Differential

- **Torsen** Torque-Sensing
(full name **Torsen traction**)
is a type of limited-slip differential
used in automobiles
- It was invented by American
Vernon Gleasman and manufactured
by the Gleason Corporation



❑ Torsen differentials can be used in one or more positions on a motor vehicle:

- **Center** — used to allocate appropriate torque distribution between front and rear axles on an all-wheel drive vehicle.
- **Rear** — used to apportion appropriate torque distribution between left and right sides in rear axles. This may be on either a rear-wheel drive or four-wheel drive vehicle.
- **Front** — used to apportion appropriate torque distribution between left and right sides in front axles. This may be on either a front-wheel drive or four-wheel drive vehicle.
- A four-wheel-drive vehicle, for example, may use either one, two, or three Torsen differentials.



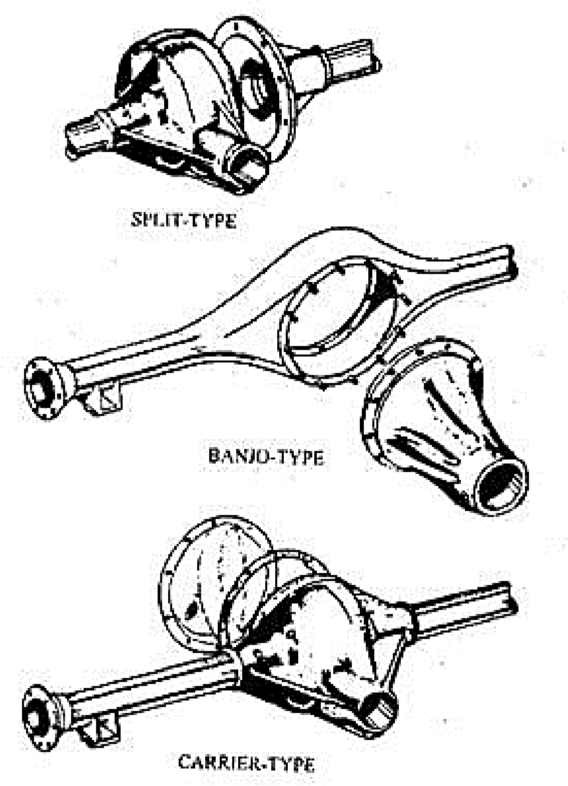
❖ Rear Axle:

- Rear Axles are structural members on which Rear wheels are mounted on bearings.
- The weight of the body of the automobile and load due to the occupants is transmitted through springs to the axle casing.
- The vehicle with non-independent rear suspension uses either a dead axle or a live axle.
- The dead axle only supports the weight of the vehicle, but the live axle besides fulfilling this task, contains a gear and shaft mechanism to drive the road wheels.
- The arrangements for supporting the road-wheels on live axles and providing the driving traction use an axle-hub mounted on to the axle-casing and supported by ball or roller-bearing.
- The two main components installed inside the axle of a rear-wheel drive vehicle are the final drive and differential.

Classification of rear axle:

1. According to the design of axle:

1. Banjo axle
2. Split axle
3. Salisbury or integral carrier type

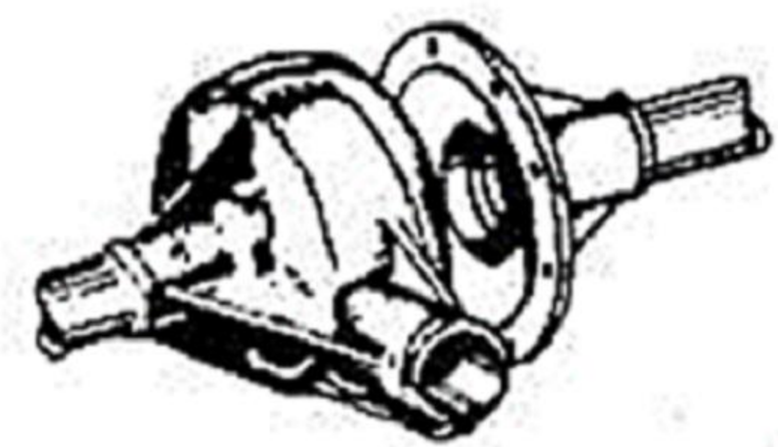


2. According to the method of supporting:

1. Semi Floating Axle
2. Three Quarter Floating Axle
3. Fully Floating Axle

1. Split Type Casing:

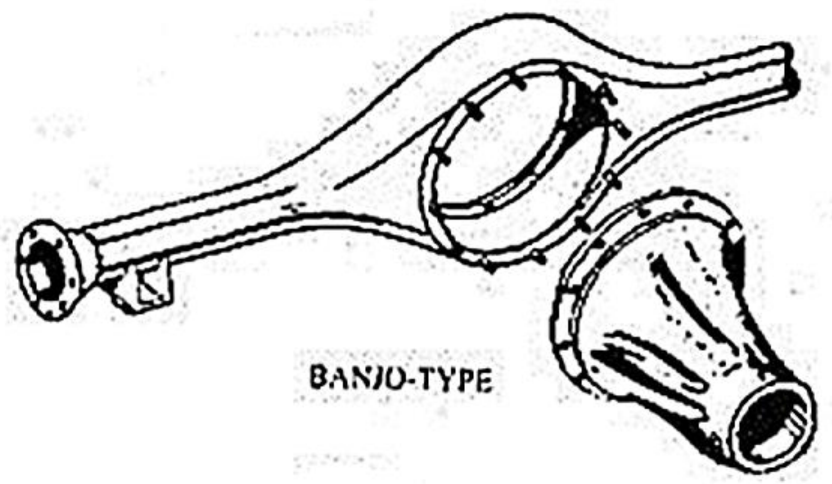
- In this type, the axle casing is made in two halves and then bolted together for assembly.
- This type has a major disadvantage that in case of any fault, the whole of the rear axle has to removed as a unit and then disassembled.
- This type is no longer produced or used.



SPLIT-TYPE

2. Banjo Type:

- The tubular axle section of this casing is built up of steel pressings, which is welded together and suitably strengthened to withstand the bending load.
- The centre of this casing with the axle tube on one side resembles a banjo.
- The final drive assembly is mounted in detachable malleable iron housing and is secured by a ring of bolts to the axle casing.
- The axle shafts are slid into this assembly from the road wheel end of the casing. On some banjo axles a domed plate is bolted to the rear face of the casing.
- Removal of this plate provides access to the final drive gears and in cases where the axle shaft is secured to the differential, this enables the axle shaft to be unlocked from the sun gear (side gear).


BANJO-TYPE

3. Carrier Type

- This is similar in construction to the banjo type except that in this the carrier.
- i.e, the differential housing, has permanent housing tubes pressed and welded in its sides.
- According to S.A.E nomenclature, it is called the unitized carrier housing.
- This type of housing is most widely used these days in case of rear drive cars.


CARRIER-TYPE

1. Semi-floating Axle

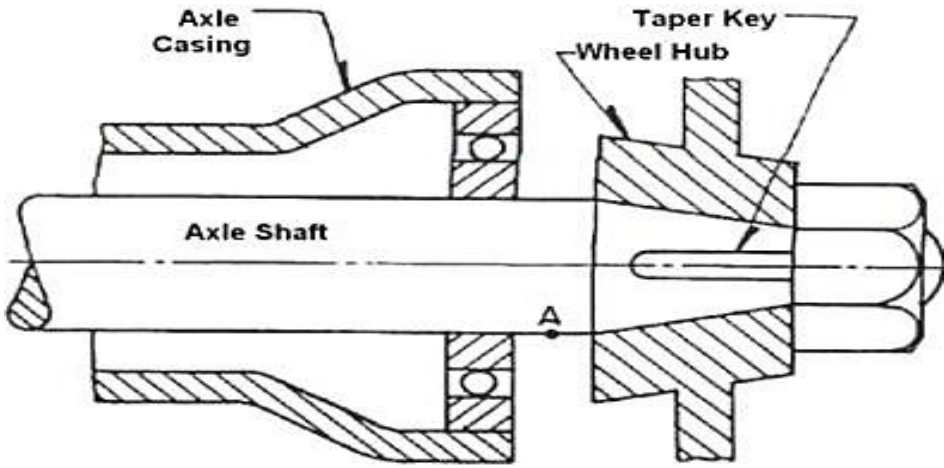
- The wheel hub is connected directly to the rear axle.
- All the loads are taken by the rear axle (Shearing, Bending, End thrust, Driving torque and brake torque).

Advantages

- The semi floating axle is the simplest and cheapest and they are widely used in cars.

Disadvantages

- The axle has to be designed for carrying higher loads i.e. they are of higher diameter for the same torque transmitted by other types of axle supporting.



2. Full floating axle

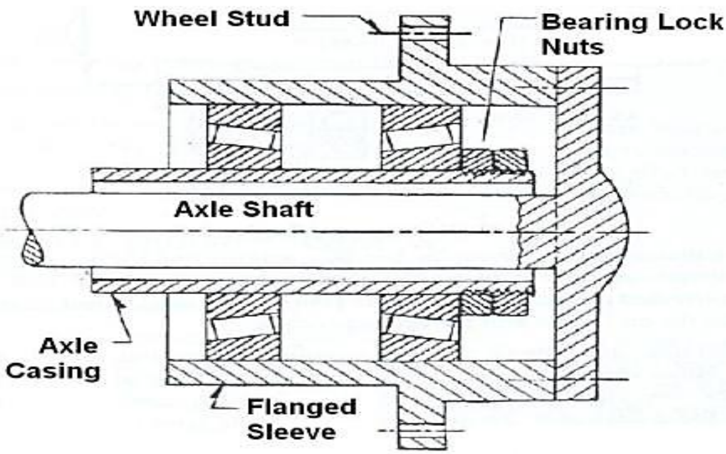
- The wheels hubs are mounted directly onto the axle casing and are supported by two taper roller bearings.
- The load on the axle is very less. It need to take only the drive torque.

Advantages

- These are very robust type and are used for heavy vehicles.
- Axle shaft carry only the drive torque so their failure does not affect the vehicle wheels.
- Vehicle can be towed with the broken axle shaft.
- Axle shaft can be replaced by without jacking.

Disadvantage

- Costliest type of axle supporting.



3. Three quarter floating axle

- The bearing is mounted between the axle and the axle casing.
- The axle shaft has to take drive torque and the end loads.
- The axle casing will take Bending an shearing forces.

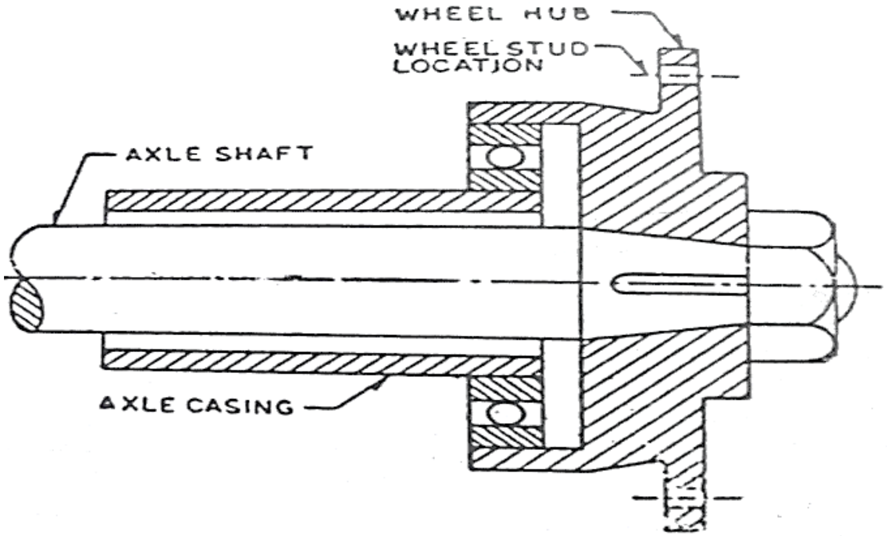
Advantages

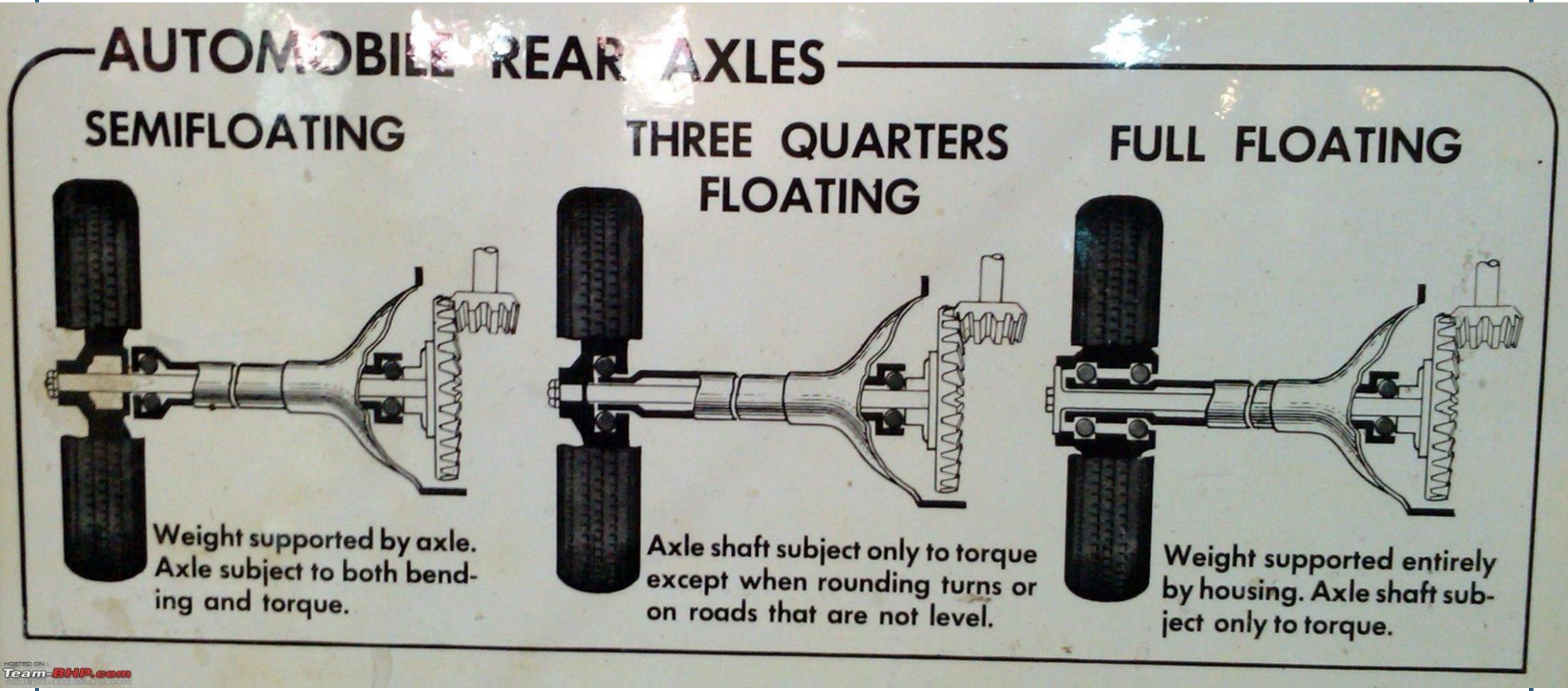
- At one time this axle type was commonly used for cars and light commercial vehicles.

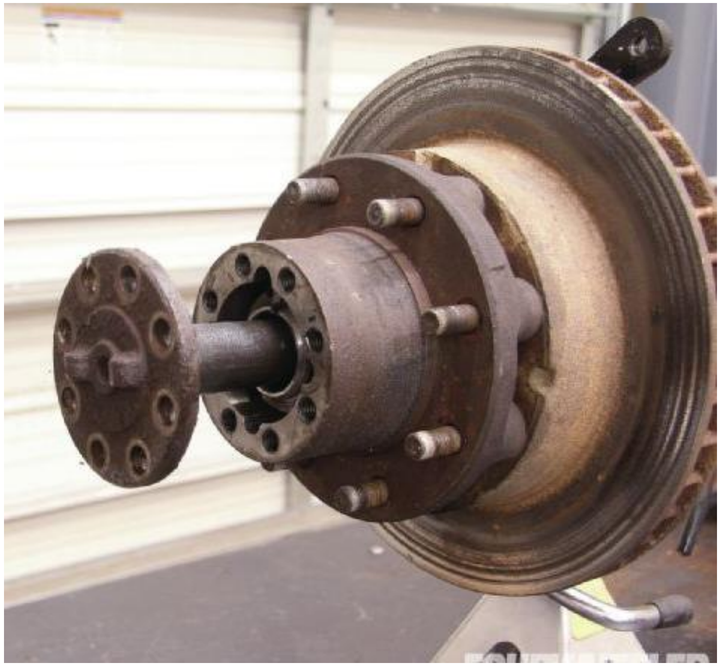
Disadvantages

- These axles are no longer preferred

instead semi floating axles are used.




AUTOMOBILE REAR AXLES
SEMIFLOATING
THREE QUARTERS FLOATING
FULL FLOATING
Weight supported by axle. Axle subject to both bending and torque.
Axle shaft subject only to torque except when rounding turns or on roads that are not level.
Weight supported entirely by housing. Axle shaft subject only to torque.
Team-BHP.com



❖ Axle Shafts

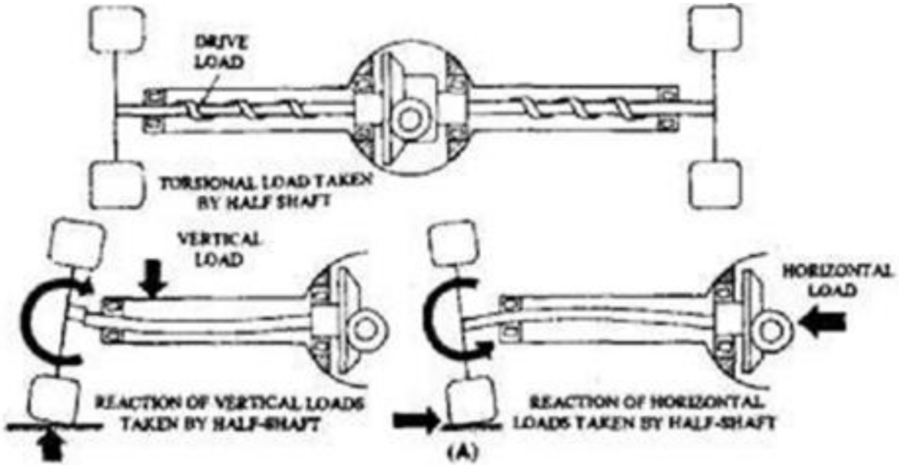
- The axle shaft transmits the drive from the differential sun wheel to the rear hub. The various types of shafts may be compared based on the stresses they resist. A simple automobile shaft has to withstand;

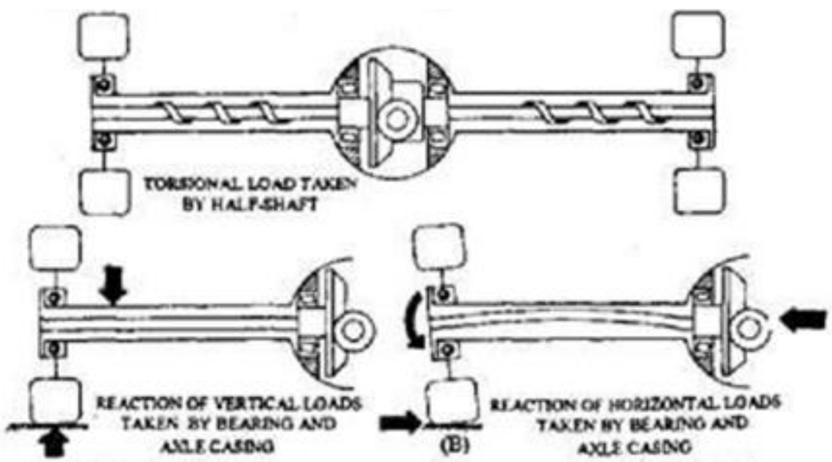
(i) Torsional stress due to driving and braking torque,

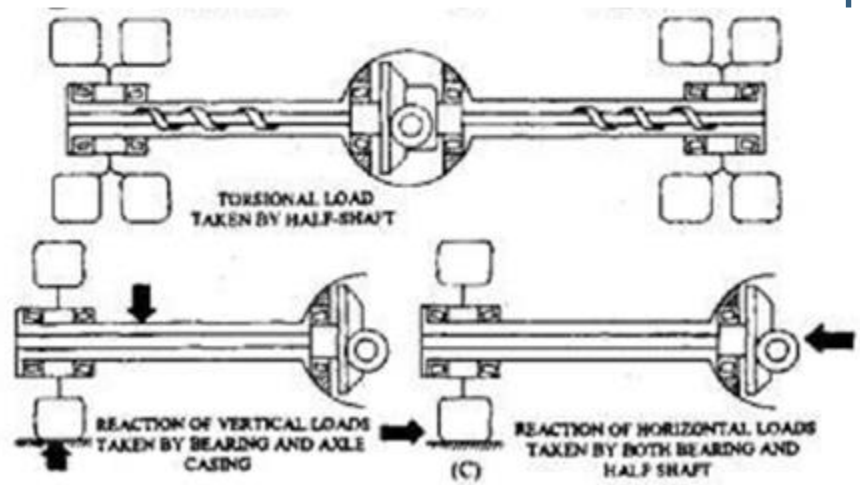
(ii) Shear and bending stresses due to the weight of the vehicle, and

(iii)Tensile and compressive stresses due to cornering forces.

(iv)Driving Torque


DRIVE LOAD
TORSIONAL LOAD TAKEN BY HALF SHAFT
VERTICAL LOAD
HORIZONTAL LOAD
REACTION OF VERTICAL LOADS TAKEN BY HALF-SHAFT
REACTION OF HORIZONTAL LOADS TAKEN BY HALF-SHAFT
(A)


TORSIONAL LOAD TAKEN BY HALF-SHAFT
REACTION OF VERTICAL LOADS TAKEN BY BEARING AND AXLE CASING
REACTION OF HORIZONTAL LOADS TAKEN BY BEARING AND AXLE CASING
(B)


TORSIONAL LOAD TAKEN BY HALF-SHAFT
REACTION OF VERTICAL LOADS TAKEN BY BEARING AND AXLE CASING
REACTION OF HORIZONTAL LOADS TAKEN BY BOTH BEARING AND HALF SHAFT
(C)