

UNIT-IV

STEERING SYSTEM

INTRODUCTION

Any mode of transportation used by people must have some means of control. For the automobile, two primary control systems are at the driver's disposal: (1) the steering system, and (2) the braking system. This chapter will focus on the steering system. Most vehicles in service today have front-wheel steering, although a few vehicles have been marketed with four-wheel steering. Thus, the bulk of this chapter will discuss the front-wheel steering systems to include the following: a discussion of the steering mechanisms available, including power-assisted steering; the factors affecting wheel alignment; a simplified analysis of vehicle cornering dynamics; and the influences of front-wheel drive on steering response. The chapter concludes with a brief discussion of four-wheel steering and vehicle rollover behavior.

8.1. PURPOSE OF A STEERING SYSTEM

The steering system allows the driver to guide the car along the road and turn left or right as desired.

The system includes the following :

- (i) *The steering wheel* which the driver controls.
 - (ii) *The steering gear* which changes the rotary motion of the wheel into straight line motion, and
 - (iii) *The steering linkages* which transmit the steering gear movement to the front wheels.
- The steering system configuration depends on vehicle design (the drive train and suspension system used, whether it is a passenger car or a commercial vehicle etc.). At present, the rack-and-pinion type and the recirculating-ball types are in use.
 - Most steering systems were *manual* until a few year back. Then *power steering* became popular. It is now installed on almost all costly cars.

8.2. FUNCTIONS OF A STEERING SYSTEM

Following are the *functions* of a steering system :

1. The primary function of the steering system is *to achieve angular motion of the front wheels to negotiate a turn.*
2. To provide directional stability of the vehicle when going straight ahead.
3. To facilitate straight ahead recovery after completing a turn.
4. To minimise wear and tear of tyres.
5. To absorb a major part of the road shocks thereby preventing them to get transmitted to the hands of the driver.
6. To provide perfect rolling motion of the road wheels at all times.

8.3. REQUIREMENTS OF A GOOD STEERING SYSTEM

Following are the *requirements of a good steering system* :

1. Very accurate.
2. Easy to handle.
3. Provide directional stability.
4. Multiply the turning effort applied on the steering wheel by the driver.
5. Irreversible to a certain degree, so that the shocks of the road surface encountered by the wheels are not transmitted to driver's hands.

8.4. GENERAL ARRANGEMENT OF A STEERING SYSTEM

Fig. 8.1 shows the general arrangement of a steering system. The layout of steering system is shown in Fig. 8.2.

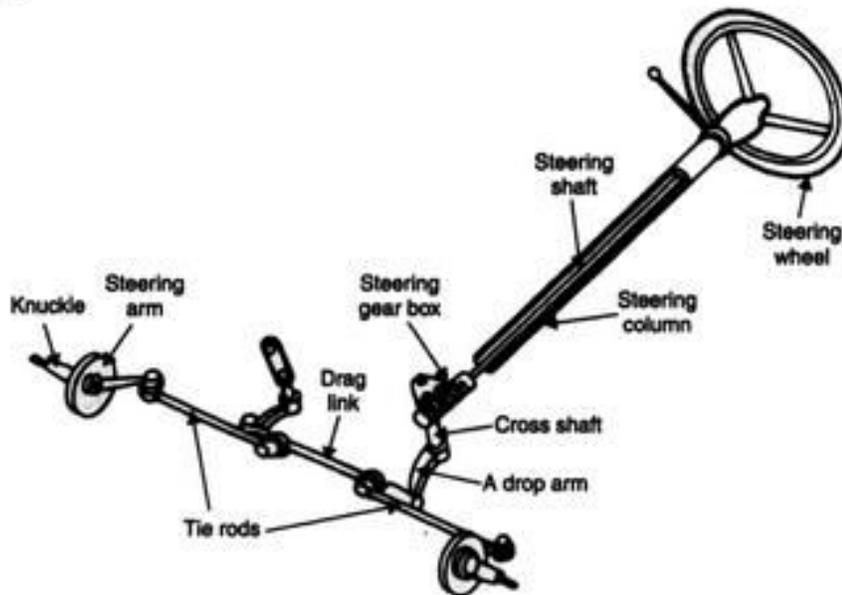


Fig. 8.1. General arrangement of a steering system.

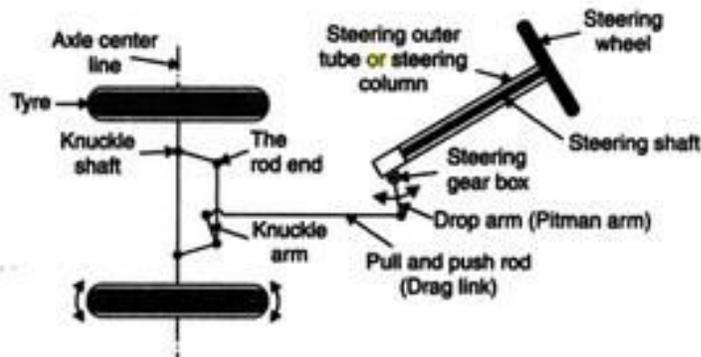


Fig. 8.2. Layout of steering system.

The main parts of a steering system are :

1. Steering wheel.
2. Steering column.
3. Steering shaft.
4. Steering gear box.
5. Steering drop arm (Pitman arm).
6. Pull and push rod (Drag link).
7. Knuckle arm.
8. Tie rod and tie rod end.

Working of steering mechanism :

- The *steering wheel* rotates the *steering column*. The *steering gear box* is fitted to the end of this column. Therefore, when the wheel is rotated, the *cross shaft* in the gear box oscillates. The cross shaft is connected to the *drop arm*. This arm is linked by means of a *drag link* to the *steering arms*. The steering arms on both wheels are connected by the *tie rods* to the drag link.
- When the steering wheel is operated, the knuckle moves to and fro, moving the wheels to the right **or** left. The ends of the tie rod and steering knuckle are connected to each other. One end of the drag link is connected to the tie rod. The other end is connected to the end of the drop arm. A ball and a socket joint gives the required movement to the joints between the tie rod, drag link and drop arm. When the vehicle is moving, the drop arm develops vibration. Shock springs are used in ball and socket system to absorb this vibration.

Brief description of steering parts :

1. Steering wheel :

- It is made of steel ring welded together on a hub with the help of two, three **or** four spokes. After welding ring with the spokes is ebonite moulded on it.
 - In certain vehicles centre hub has splines cut on it while in other cases a key groove is given to secure the steering shaft firmly in it.
- The steering wheels, in our country, have a *fixed position*. However, in foreign countries, these wheels in some vehicles can be *tilted and located in position* to suit the driver.
- Steering wheel is pulled out with the help of a *puller*.

2. Steering outer tube **or steering column :**

- This is a hollow steel pipe in which steering shaft is housed.
- One end of the pipe is fixed on steering box, the other end is usually held with the help of bracket under the instrument panel.

3. Steering shaft :

- The steering shaft is made out of good quality steel.
- One end is fixed in the steering wheel with the help of splines **or** key and kept tight by nut. The other end with worm is secured firmly in the steering box with the help of bearing placed both on top and bottom. Sometimes, instead of one shaft, two pieces of shafts are also used (in those cases where steering wheel and steering box are not in one line)

4. Steering gear box :

- Its function is to *convert rotary motion of wheel into to- and-fro motion of drop arm* so that the drag link tied up with drop arm can be pushed **or** pulled resulting into moving stub axle to right **or** left as desired by the driver.

5. Drop arm :

- It is forged out of good quality steel.
- Its one side is provided with splines which match the splines of sector shaft and held on sector shaft by nut. The other end has taper hole in which ball end is held tight with the help of nut.

8.8. STEERING GEOMETRY

When a car is moving along a curve, all its wheels should *roll truly without any lateral slip*. This can be achieved if the axes of all four wheels intersect at one point. This point will be the centre about which the vehicle will be turning at that instant. Fig. 8.9, shows the steering geometry of the four wheels of a vehicle. The rear wheels rotate along two circles. The centres of both these circles are at O. The front wheels 1 and 2 have different axes. They rotate along two other circles with the same centre point. For correct functioning of any steering system, the centres of the wheels of the rear axles and of wheels 1, 2 should coincide.

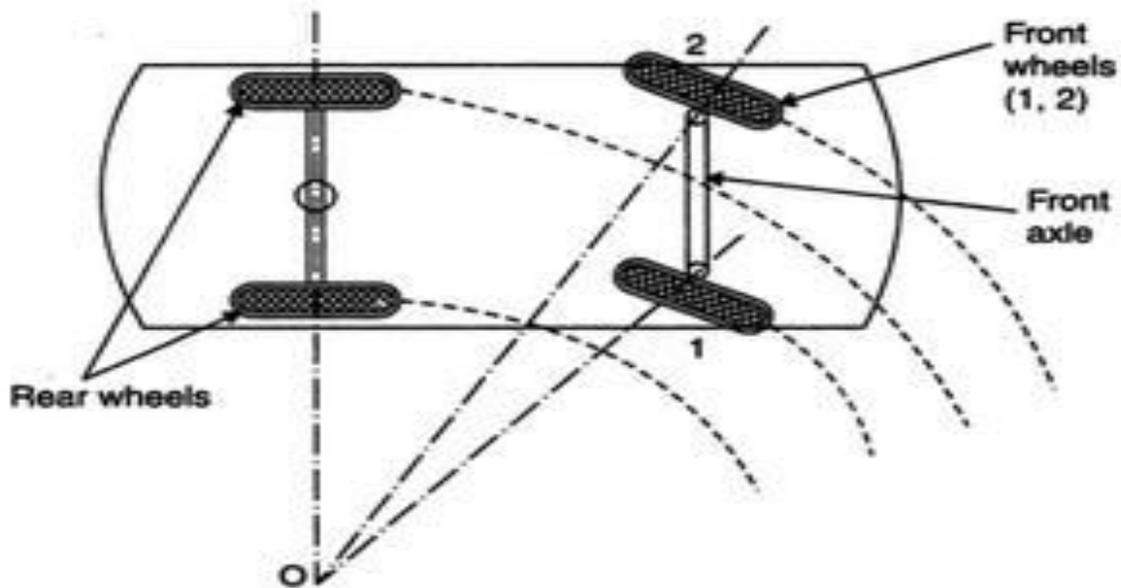


Fig. 8.9. Steering geometry.

8.10. STEERING MECHANISMS

8.10.1. Fundamental Equation for Correct Steering

The **steering gear mechanism** is used for changing the direction of two or more of the wheel axles with reference to the chassis, so as to move the automobile in any desired path. Usually the two back or rear wheels have a common axis, which is fixed in direction with reference to the chassis and the steering is done by means of front wheels.

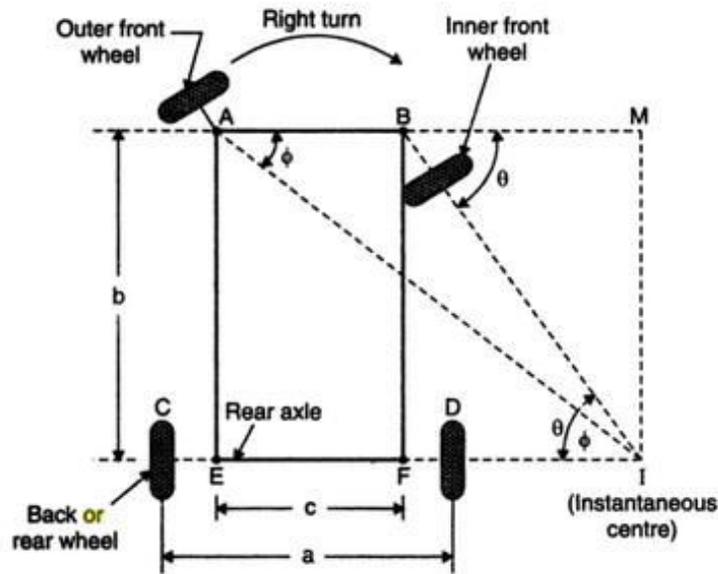


Fig. 8.15. Steering gear mechanism.

In automobiles, the front wheels are placed over the front axles, which are pivoted at the points A and B, as shown in Fig. 8.15. These points are fixed to the chassis. The back or rear wheels are placed over the back axle, at the two ends of the differential tube. When the vehicle takes a turn, the front wheels along with the respective axles turn about the respective pivoted points. The rear wheels remain straight and do not turn. Therefore, the steering is done by means of front wheels

only

In order to avoid skidding (*i.e.*, the slipping of the wheels tyres), the two front wheels must turn about the same instantaneous centre I which lies on the axis of the rear wheels. If the instantaneous centre of the two front wheels do not coincide with the instantaneous centre of the rear wheels, the skidding on the front or rear wheels will definitely take place, which will cause more wear and tear of the tyres.

Thus, the condition for the correct steering is that all the four wheels must turn about the same instantaneous centre. The axis of the inner wheel makes a larger turning angle θ than the angle ϕ subtended by the axis of outer wheel.

Let, a = Wheel track

b = Wheel base, and

c = Distance between the pivots A and B of the front axle.

Now, from $\triangle IBM$,
$$\cot \theta = \frac{BM}{IM}$$

and, from $\triangle IAM$,
$$\cot \phi = \frac{AM}{IM} = \frac{AB + BM}{IM} = \frac{AB}{IM} + \frac{BM}{IM} = \frac{c}{b} + \cot \theta \quad (\because IM = b)$$

$$\therefore \cot \phi - \cot \theta = \frac{c}{b} \quad \dots(8.1)$$

This is the fundamental equation for correct steering. If this condition is satisfied, there will be no skidding of wheels, when the vehicle takes a turn.

8.10.2. Types of Steering Gear Mechanisms

The steering gear mechanisms are of the following *two* types :

1. Davis steering gear

2. Ackermann steering gear.

- “*Davis steering gear*” has *sliding pairs*. Since sliding pair has more friction (than the turning pair), therefore this type of gear will wear out earlier and become inaccurate after sometime.
- “*Ackermann steering gear*” has *turning pairs*. This type of gear is not mathematically accurate except in three positions contrary to the Davis steering gear which is mathematically correct in all position. However, the Ackermann steering gear is *preferred to the Davis steering gear*.

The whole mechanism of the Ackermann steering gear is on the *back* of the front wheels, whereas in Davis steering gear, it is in *front* of the wheels.

1. Davis steering gear :

Refer to Fig. 8.16. It consists of a cross link *CD* sliding parallel to another link *AB* and is connected to the stub axles of the two front wheels by means of two similar bell crank levers *LAC* and *MBD* pivoted at *A* and *B*, respectively. The cross link *CD* slides in the bearing and carries pairs at its ends *C* and *D*. The slide blocks are pivoted on these pins and move with the turning of bell crank levers as the steering wheel is operated.

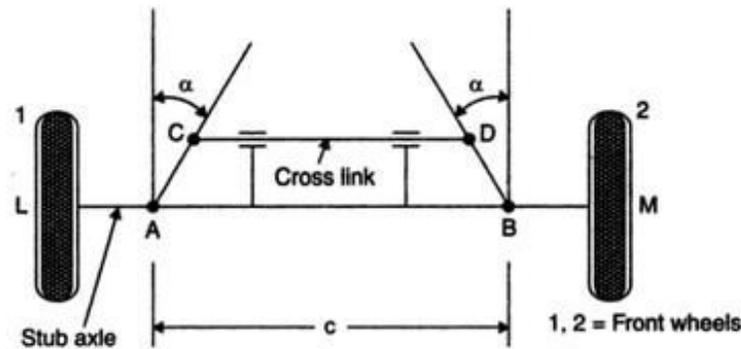


Fig. 8.16. Davis steering gear mechanism.

When the wheel is running straight, the gear is said to be in its mid position. The short arms *AC* and *BD* are inclined at an angle $(90^\circ + \alpha)$ to their stub axles *AL* and *BM*, respectively.

The correct steering depends upon the suitable selection of cross-arm angle α , and is given by :

$$\tan \alpha = \frac{c}{2b}$$

where, c = Distance between the pivots of front axles, and
 b = Wheel base.

The range of $\frac{c}{b}$ is 0.4 to 0.5, hence α lies between 11.3° and 14.1° .

Note. Davis steering gear is *theoretically correct*, but due to presence of more sliding members, the wear will be increased which produces slackness between the sliding surfaces, thus *eliminating the original accuracy*. Hence this gear is *not in common use*.

2. Ackermann steering gear :

Refer to Fig. 8.17. It consists of a cross link CD connected to the short axles AL and BM of the two front wheels through the short arms AC and BD , forming bell crank lowers LAC and MBD , respectively.

When the wheel is running straight [Fig. 8.17 (a)], the cross-link CD is parallel to AB , the short arms AC and BD both make angle α to the horizontal axis of chassis. In order to satisfy the fundamental equation for correct steering, the links AC and BD are suitably proportioned and angle α is the suitably selected.

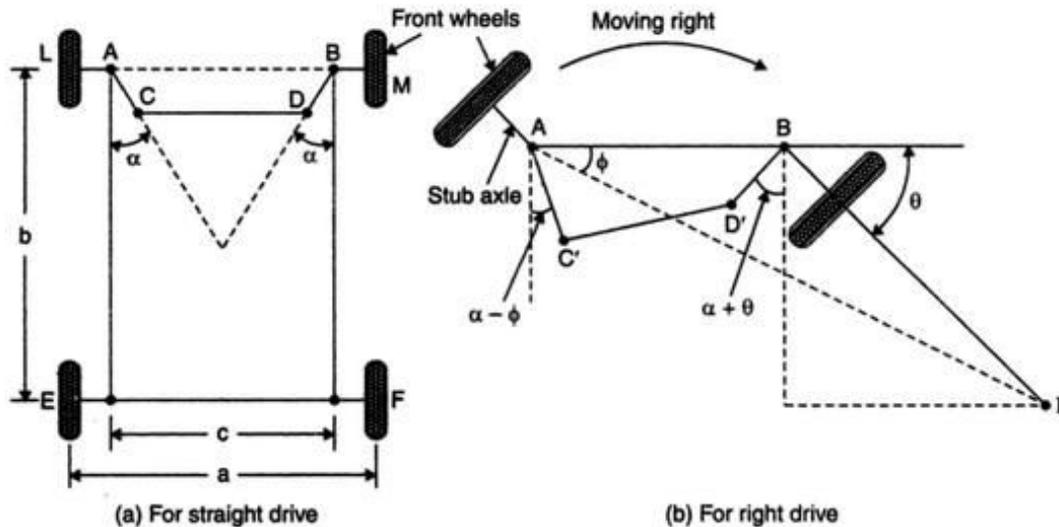


Fig. 8.17. Ackermann steering gear mechanism.

For correct steering, $\cot \phi - \cot \theta = \frac{c}{b}$

The angles ϕ and θ are shown in Fig. 8.17 (b).

The value of $\frac{c}{b}$ lies between 0.4 and 0.5, generally 0.455. The value of $\cot \phi - \cot \theta$ corresponds to the positions when steering is correct.

In fact there are *three* values of θ which give correct steering of the vehicle : *First*, while turning to 'right' ; *second*, while turning to left and *third* while it is running 'straight'.

The fundamental problem in steering is to enable the vehicle to traverse an arc such that all four wheels travel about the identical center point. In the days of horse-drawn carriages, this was accomplished with the fifth-wheel system depicted in Fig. 7.1.

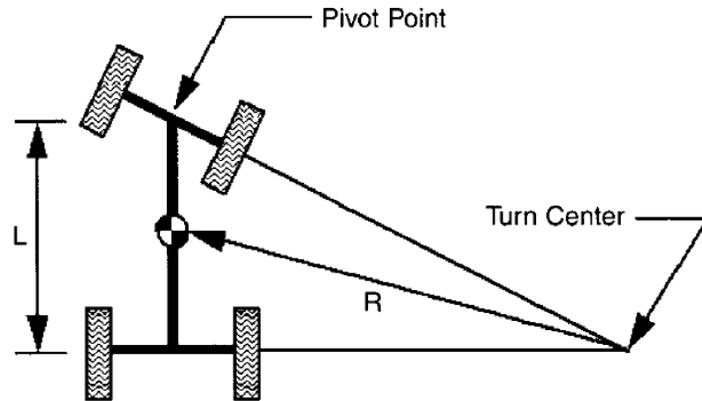


Figure 7.1. *Fifth-wheel steering.*

Although this system worked well for carriages, it soon proved unsuitable for automobiles. In addition to the high forces required of the driver to rotate the entire front axle, the system proved unstable, especially as vehicle speeds increased. The solution to this problem was developed by a German engineer named Lankensperger in 1817. Lankensperger had an inherent distrust of the German government, so he hired an agent in England to patent his idea. His chosen agent was a lawyer named Rudolph Ackerman. The lawyer secured the patent, but the system became known as the Ackerman system.

Figure 7.2 depicts the key features of this system. The end of each axle has a spindle that pivots around a kingpin. The linkages connecting the spindles form a trapezoid, with the base of the trapezoid formed by the rack and tie rods. The distance between the tie rod ends is less than the distance between the kingpins. The wheels are parallel to each other when they are in the straight-ahead position. However, when the wheels are turned, the inner wheel turns through a greater angle than the outer wheel. Figure 7.2 also shows that the layout is governed by the ratio of track (distance between the wheels) to wheelbase (distance between front and rear wheels). The Ackerman layout is accurate only in three positions: straight ahead, and at one position in each direction. The slight errors present in other positions are compensated for by the deflection of the pneumatic tires.

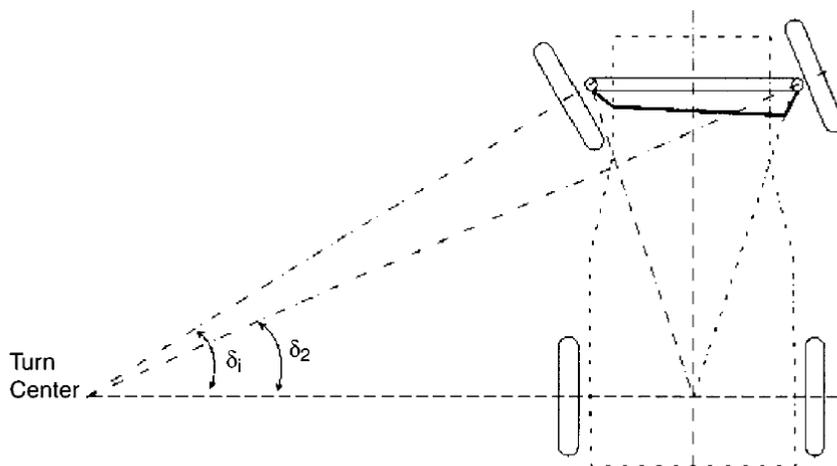


Figure 7.2. *Ackerman steering.*

For the purposes of this book, "steering mechanism" refers to those components required to realize the Ackerman system. Of course, all vehicles today use a steering wheel as the interface between the system and driver. (This has not always been the case. Early automobiles used a tiller.) The steering wheel rotates a column, and this column is the input to the steering mechanism.

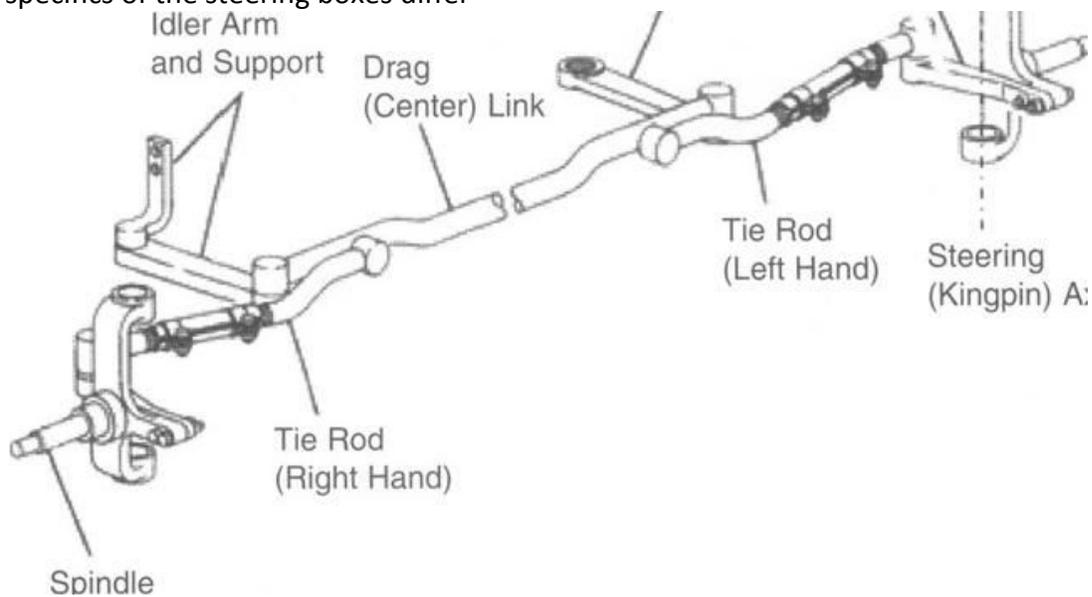
These mechanisms can be broadly grouped into two categories:

- (1) worm-type mechanisms, and
- (2) rack and pinion mechanisms

1. WORM SYSTEMS (STEERING GEARS)

A. STEERING SYSTEMS AND STEERING DYNAMICS

Figure 7.3 shows the steering linkages required by worm gear steering systems. The Pitman arm converts the rotational motion of the steering box output into side-to-side motion of the center link. The center link is tied to the steering arms by the tie rods, and the side-to-side motion causes the spindles to pivot around their respective steering axes (kingpins). To achieve Ackerman steering, the four-bar linkages must form a trapezoid instead of a parallelogram (refer to Fig. 7.2). Although all worm-type steering systems use linkages similar to these, the specifics of the steering boxes differ



Fig; 7.3

B. WORM AND SECTOR

Figure 7.4 depicts a worm and sector system. The shaft to the Pitman arm is connected to a gear that meshes with a worm gear on the steering column. Because the Pitman shaft gear needs to rotate through only approximately 70°, only a sector of the gear is actually used. The worm gear is assembled on tapered roller bearings to absorb some thrust load, and an adjusting nut is provided to regulate the amount of end-play in the worm.

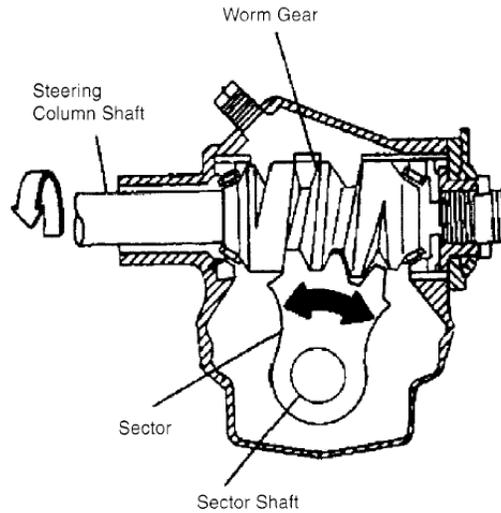


Figure 7.4. *Worm and sector steering gear.*
Adapted from TM 9-8000 (1985).

C.WORM AND ROLLER

The worm and roller system (Fig. 7.5) is very similar to the worm and sector system. In this case, roller is supported by ball bearings within the sector on the Pitman shaft. The bearings reduce sliding friction between the worm and sector. The worm also can be shaped similarly

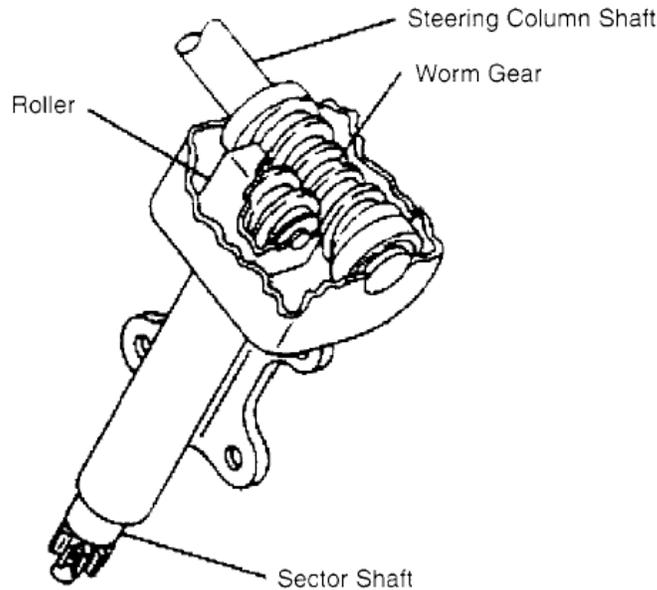


Figure 7.5. *Worm and roller steering gear.*
Adapted from TM 9-8000 (1985).

to an hourglass, that is, tapered from each end to the center. This provides better contact between the worm and the roller, as well as a variable steering ratio. When the wheels are at

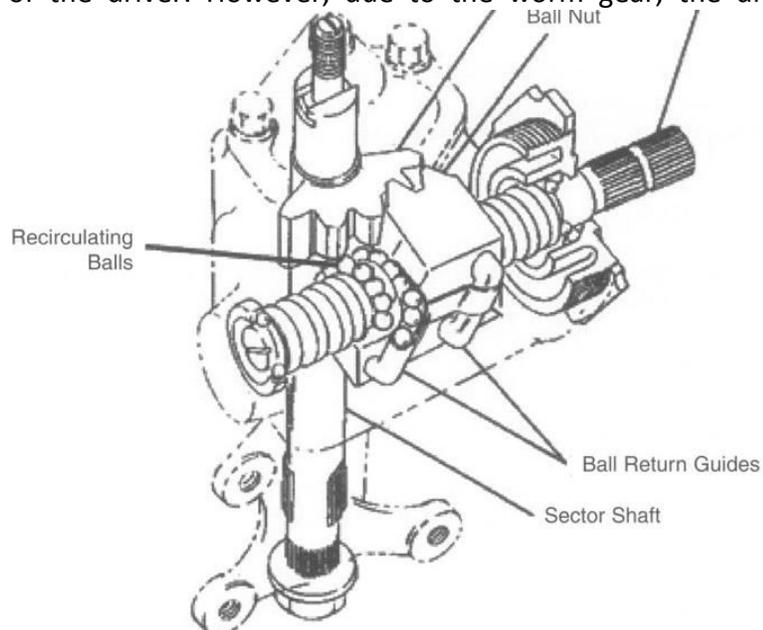
the center (straight-ahead) position, the steering reduction ratio is high to provide better control.

As the wheels are turned farther off-center, the ratio lowers. This gives better maneuverability during low-speed maneuvers such as parking.

D. RECIRCULATING BALL

Figure 7.6 shows the recirculating ball system, another form of worm and nut system. In this system, a nut is meshed onto the worm gear by means of a continuous row of ball bearings. As the worm turns, the nut moves up and down the worm threads. The ball bearings not only reduce the friction between the worm and nut, but they greatly reduce the wear because the balls continually recirculate through the system, thereby preventing any one area from bearing the brunt of the wear.

The primary advantage of all worm-type steering systems is reduced steering effort on the part of the driver. However, due to the worm gear, the driver receives no feedback from the



E. RECIRCULATING BALL STEERING GEAR.

wheels. For these reasons, worm-type steering systems are found primarily on large vehicles such as luxury cars, sport utility vehicles, pickup trucks, and commercial vehicles.

2. RACK AND PINION STEERING

The rack and pinion steering system is simpler, lighter, and generally cheaper than worm-type systems (Fig. 7.7). The steering column rotates a pinion gear that is meshed to a rack. The rack converts the rotary motion directly to side-to-side motion and is connected to the tie rods. The tie rods cause the wheels to pivot about the kingpins, thus turning the front wheels.

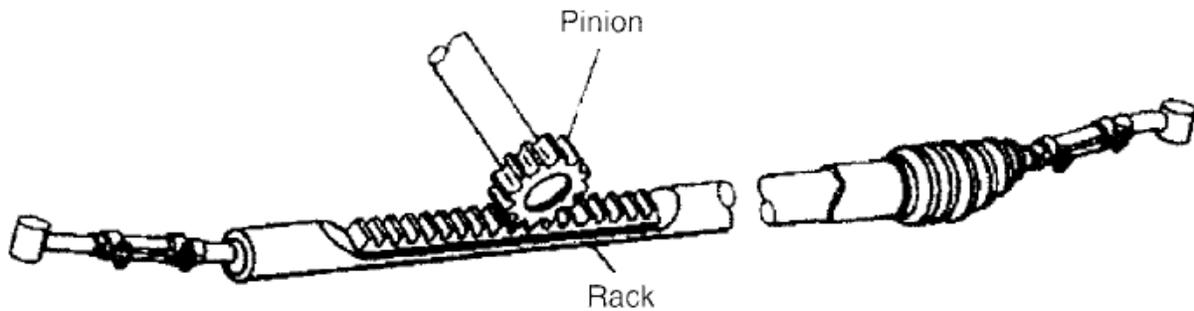


Figure 7.7. Rack and pinion steering gear.
Adapted from TM 9-8000 (1985).

Rack and pinion systems have the advantage of providing feedback to the driver. Furthermore, rack and pinion systems tend to be more responsive to driver input, and for this reason, rack and pinion steering is found on most small and sports cars.

POWER STEERING

Many vehicles incorporate a power steering system, the purpose of which is to reduce the driver's effort to turn the steering wheel. The system usually is hydraulically operated, with hydraulic pressure provided by a pump driven by a belt from the crankshaft. Figure 7.8 shows a drive system that is an older, V-belt type. These systems used multiple V-belts to drive the various accessories on the front of the engine. Most new vehicles use a single, ribbed belt (serpentine belt) to drive all of the accessories. The power steering pump contains an integral fluid reservoir, as well as the control and pressure regulating valves. The pump may be of the vane, tooth, or rotor type. Figure 7.9 shows one example of a vane-type pump. The pump receives fluid from the reservoir, and because it is belt driven by the crank, the pump operates whenever the engine is running. Figure 7.10 shows a typical control valve. When the wheels are in the straight-ahead position, the spool valve is centered. This allows fluid under pressure to bypass the system and return to the reservoir. When the driver turns

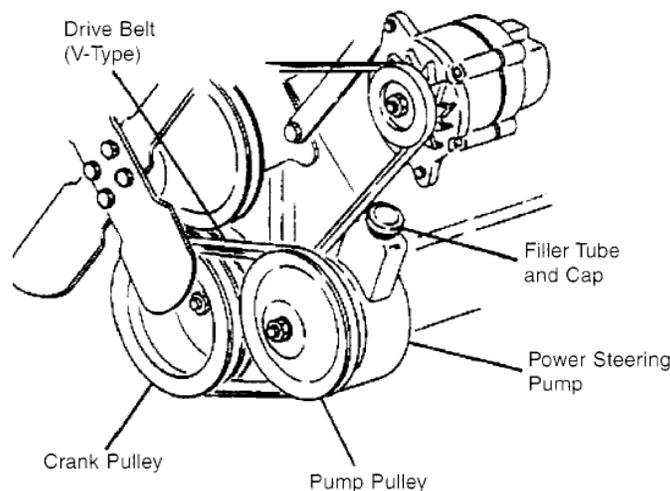


Figure 7.8. Power steering pump drive.
Adapted from TM 9-8000 (1985).

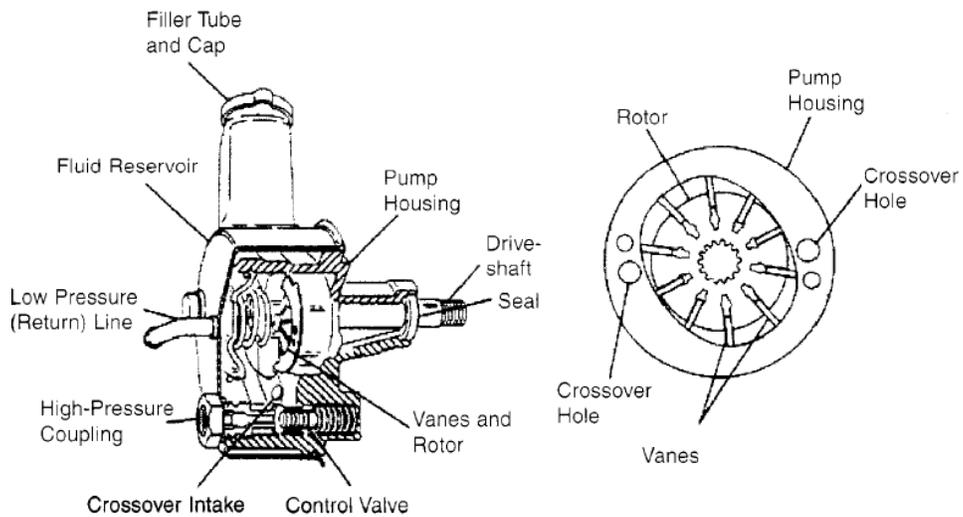
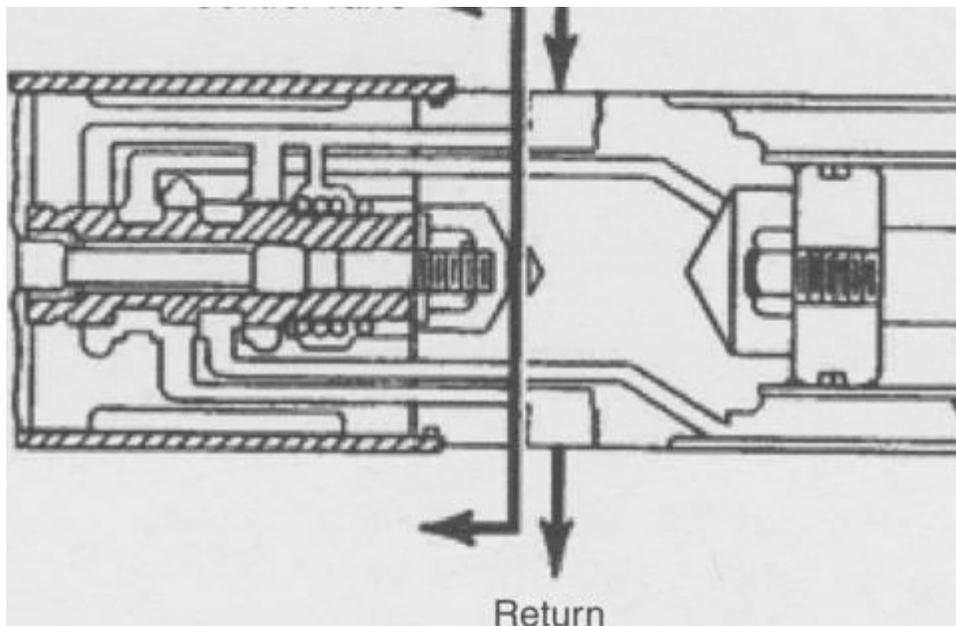


Figure 7.9. *Vane-type power steering pump.*
Adapted from TM 9-8000 (1985).

the steering wheel, the spool valve is mechanically moved off-center. This allows fluid to be ported to the appropriate side of the cylinder unit and supplies the additional force to turn the wheels. The cylinder unit can be mounted on the steering column, in line with the rack, or integral to the recirculating ball gearbox. Figure 7.11 shows examples of each.



Power steering control valve (TM 9-8000, 1985).

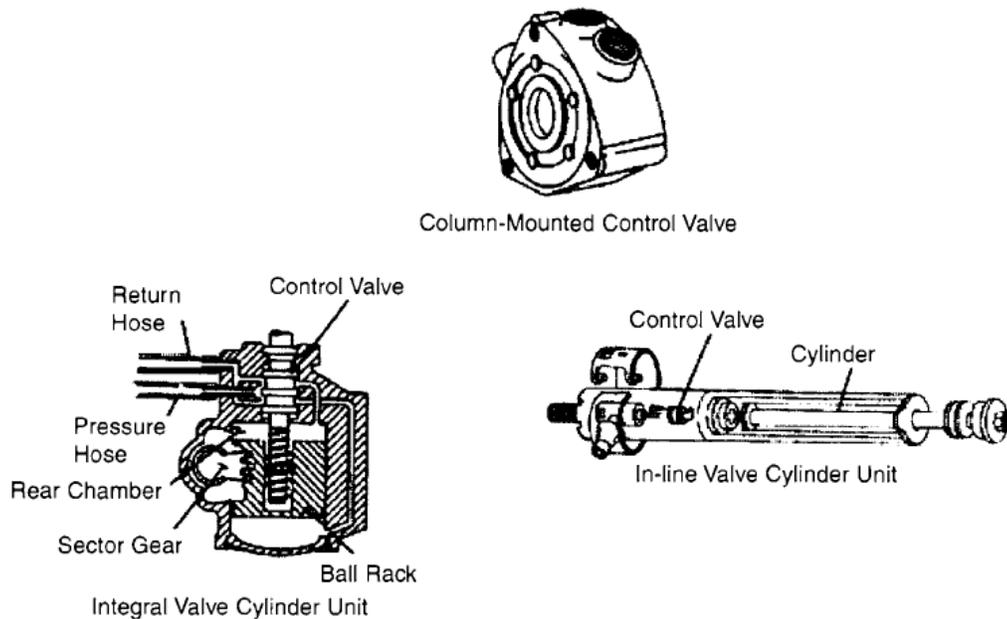


Figure 7.11. Control valve configurations (TM 9-8000, 1985).

WHEEL ALIGNMENT

In addition to allowing the vehicle to be turned, the steering system must be set up to allow the vehicle to track straight ahead without steering input from the driver. Thus, an important design factor for the vehicle is the wheel alignment. Four parameters are set by the designer, and these must be checked regularly to ensure they are within the original vehicle specifications.

The four parameters discussed here are as follows:

Automotive Engineering Fundamentals

1. Camber
2. Steering axis inclination (SAI)
3. Toe
4. Caster

1 Camber

Camber is the angle of the tire/wheel with respect to the vertical as viewed from the front of the vehicle, as shown in Fig. 7.17. Camber angles usually are very small, on the order of 1°; the camber angles shown in Fig. 7.17 are exaggerated. Positive camber is defined as the top of the wheel being tilted away from the vehicle, whereas negative camber tilts the top of the wheel toward the vehicle. Most vehicles use a small amount of positive camber, for reasons that will be discussed in the next section. However, some off-road vehicles and race cars have zero or slightly negative camber.

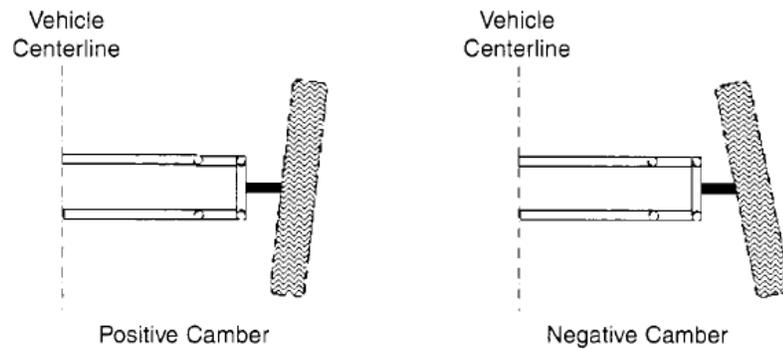


Figure 7.17. *Positive and negative camber (view from the front of the vehicle).*

2. STEERING AXIS INCLINATION (SAI)

Steering axis inclination (SAI) is the angle from the vertical defined by the centerline passing through the upper and lower ball joints. Usually, the upper ball joint is closer to the vehicle centerline than the lower, as shown in Fig. 7.18.

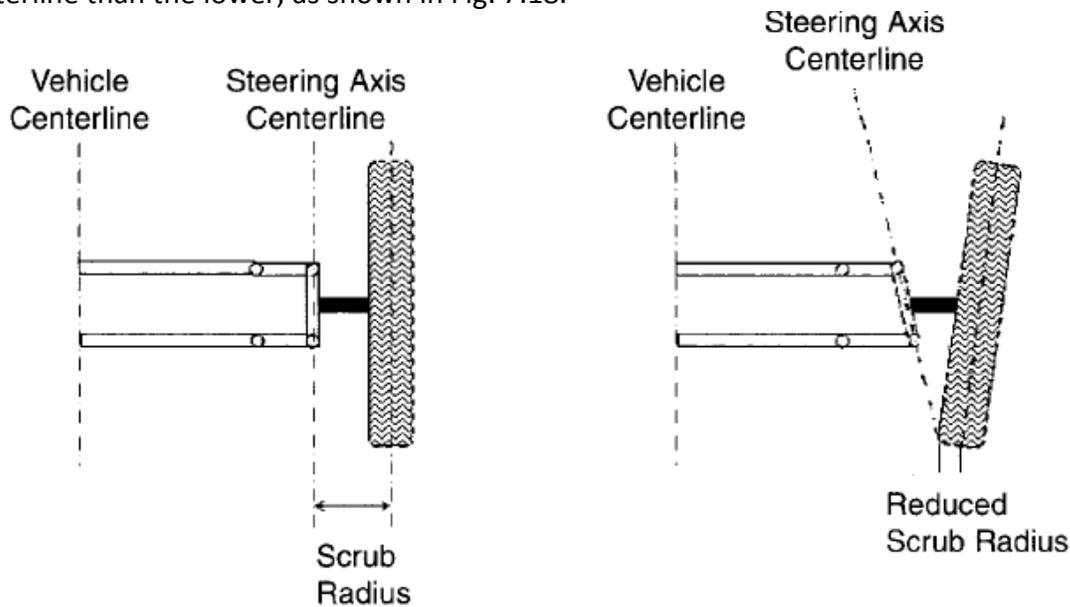


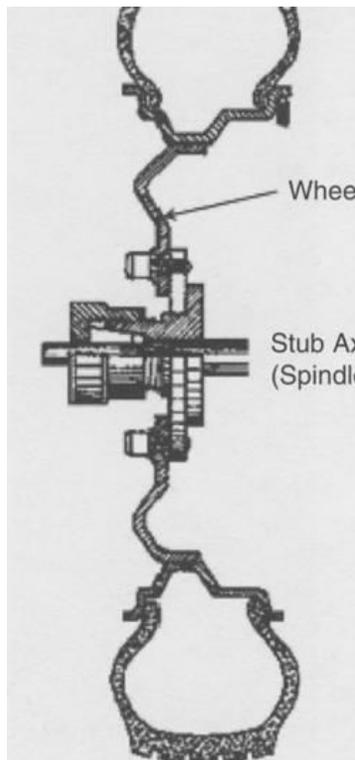
Figure 7.18. *Interaction of positive camber with steering axis inclination (SAI).*

Figure 7.18 also shows the advantage of combining positive camber with an inclined steering axis. If a vertical steering axis is combined with zero camber (left side of Fig. 7.18), any steering input requires the wheel to scrub in an arc around the steering axis. In addition to increasing driver effort, it causes increased tire wear. The combination of SAI and positive camber reduces the scrub radius (right side of Fig. 7.18). This reduces driver effort under low-speed turning conditions and minimizes tire wear. An additional benefit of this system is that the wheel arc is no longer parallel to the ground. Any turning of the wheel away from straight ahead causes it to arc toward the ground. Because the ground is not movable, this causes the front of the vehicle

to be raised. This is not the minimum potential energy position for the vehicle; thus, the weight of the vehicle tends to turn the wheel back to the straight ahead position. This phenomenon is very evident on most vehicles—merely turning the steering wheel to full lock while the vehicle is standing still will make the front end of the vehicle rise visibly. Although the stationary weight of the vehicle may not be sufficient to rotate the wheels back to the straight-ahead position, as soon as the vehicle begins to move, the wheels will return to the straight-ahead position without driver input. Caster angle also contributes to this self-aligning torque and will be discussed in Section 7.4.4. Note that the diagrams in the preceding figures have been simplified to facilitate discussion. In practice, the wheel is dished so that the scrub radius is further reduced, as illustrated in Fig. 7.19.

3 TOE

Toe is defined as the difference of the distance between the leading edge of the wheels and the distance between the trailing edge of the wheels when viewed from above. Toe-in means the front of the wheels are closer than the rear; toe-out implies the opposite. Figure 7.20 shows both cases.



Cross-sectional view of a wheel and tire assembly
Adapted from Automotive Engineering (1 982).

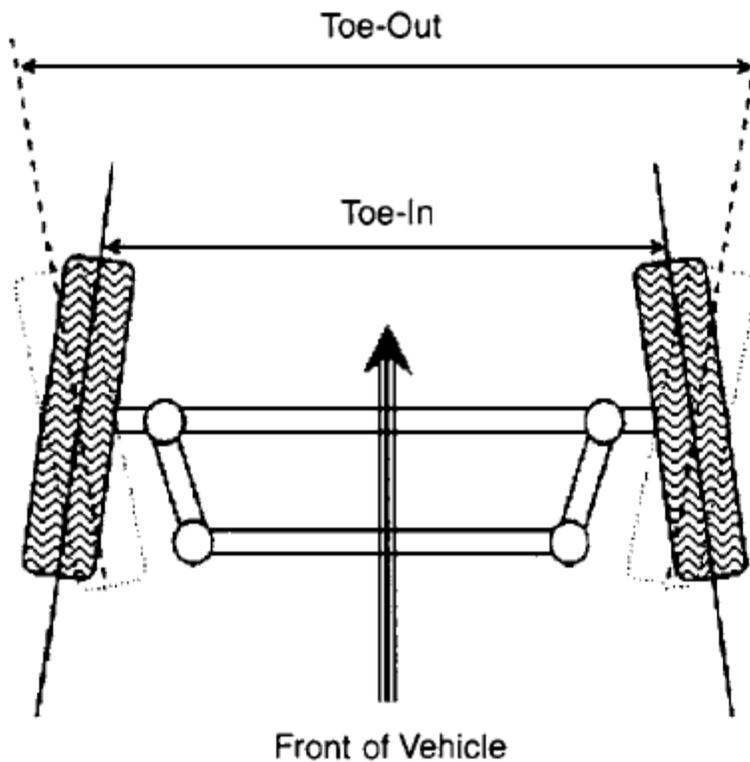


Figure 7.20. *Toe-in versus toe-out.*

For a rear-wheel-drive vehicle, the front wheels normally have a slight amount of toe-in. Figure 7.18 shows why this is true. When the vehicle begins to roll, rolling resistance produces a force through the tire contact patch perpendicular to the rolling axis. Due to the existence of the scrub radius, this force produces a torque around the steering axis that tends to cause the wheels to toe-out. The slight toe-in allows for this, and when rolling, the wheels align along the axis of the vehicle. Conversely, front-wheel-drive vehicles require slight toeout. In this case, the tractive force of the front wheels produces a moment about the steering axis that tends to toe the wheels inward. In this case, proper toe-out absorbs this motion and allows the wheels to parallel the direction of motion of the vehicle.

4. CASTER

Caster is the angle of the steering axis from the vertical as viewed from the side and is shown in Fig. 7.21. Positive caster is defined as the steering axis inclined toward the rear of the vehicle.

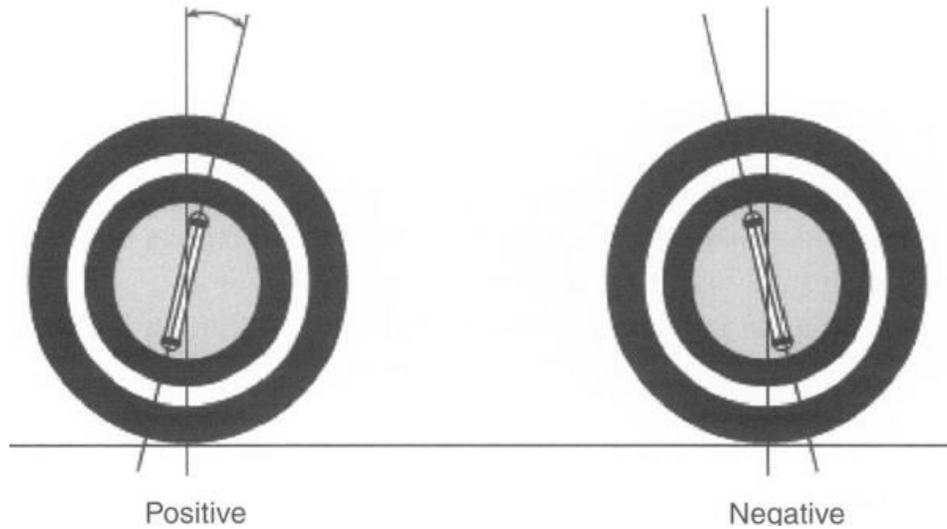


Figure 7.2 1. Caster angle.

With positive caster, the tire contact patch is aft of the intersection of the steering axis and the ground. This is a desirable feature for stability, as illustrated by Fig. 7.22. When the wheel is turned, the cornering force acts perpendicular to the wheel axis and through the contact patch. This creates a torque about the steering axis that acts to center the wheel. Obviously, negative caster results in the opposite effect, and the wheel would tend to continue turning about the steering axis. The most common example of positive caster is a shopping cart. The wheels are free to turn around the steering axis, and when the cart is pushed straight ahead, the wheels self-align to the straight-ahead position.

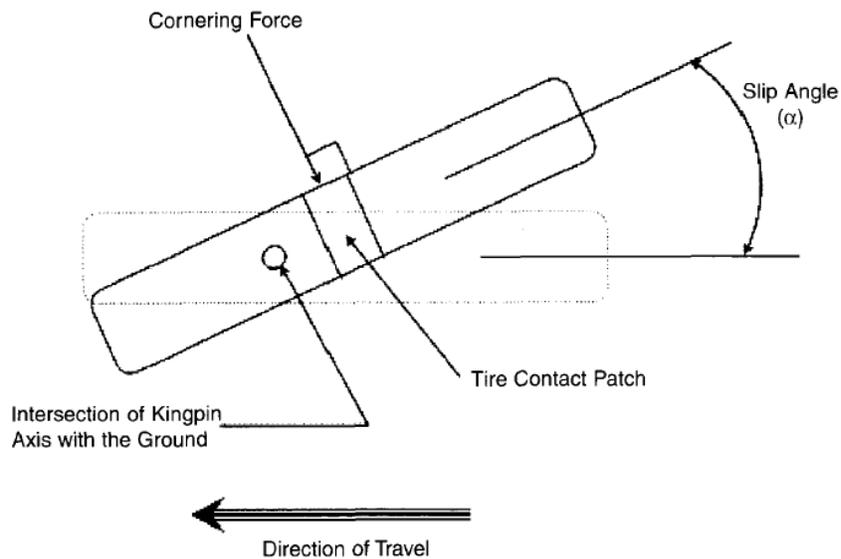


Figure 7.22. Self-aligning torque generated by positive caster.

Checking of wheel alignment :

Before checking the wheel alignment, king-pin inclination, camber and caster angles and toe-in need to be checked.

The king-pin inclination and the camber angle are fixed in those vehicles which have axle beam. But the caster angle is adjustable by a caster plate. In those vehicles having independent suspension system, these angles are adjusted by a shim between the lower and upper arm brackets or by eccentric clamping bolts of the arm.

- The camber, caster king-pin inclination are checked by a particular type of gauge. This gauge consists of two parts : Level and angle gauge and turn table.
- For checking toe-in several gauges are available.
 - Optical gauge of Dunlop Tyre Company gives very accurate reading.
 - *Telescopic gauge* is commonly used in workshops. It consists of two pipes which can slide one inside the other. At the end of each pipe there is a rod which can be adjusted at any position on the pipe. Each rod has an adjustable pointer. To check the toe-in touch the pointers of the gauge with the front wheels and note the reading on the pipe. Similarly, touch the pointers of the gauge with the rear portion of the front wheels and note the reading. *The difference between the two readings is the toe-in.*

8.12. STEERING LINKAGES

Steering linkage is a connection of various links between the steering gear box and the front wheels. It depends upon the type of the vehicle, whether it is a car which has independent front suspension or a commercial vehicle having generally a rigid axle type front suspension.

The steering linkage transfers the side-to-side or front-to-rear movement of the pitman arm into the left-to-right movement at the wheels.

Conventional steering linkage :

Fig. 8.19 shows a steering linkage for a conventional rigid axle suspension. It is commonly used in cars provided with rigid front axle.

- The *drop arm* (or Pitman arm) is rigidly connected to cross-shaft of the steering gear at its upper end, which its lower end is connected to the *link rod* through a ball joint. To the other end of the link rod is connected the link rod arm through a ball joint. Attached rigidly to the other end of the link rod arm is the *stub axle* on which the road wheel is mounted.

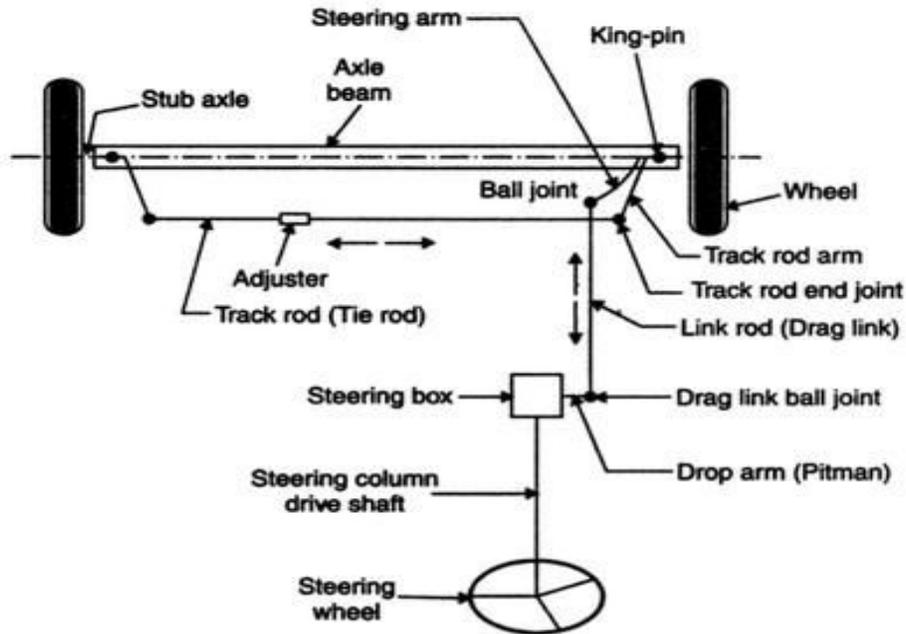


Fig. 8.19. Steering linkage for a conventional rigid axle suspension.

- Each stub axle has a forged track rod arm rigidly bolted to the wheel axis. The other ends of the track rod arms are connected to the track rod by means of ball joints. An adjuster is also provided in the track rod to change its length for adjusting wheel align-

Working. When the steering wheel is turned, the swinging action of the drop arm imparts a near linear movement to the link rod. This movement is transmitted through the link rod arm to the stub axle so as to turn the later about its pivot, which may be a king-pin or ball joints. The other wheel is steered through the track rod. Thus only one wheel is positively steered.

Steering linkages for independent front suspension :

Some steer linkages for independent front suspension are shown in Fig. 8.20. In these linkages, the ball joints are fitted between the linkage and the steering arms to allow for the independent movement of the wheels.

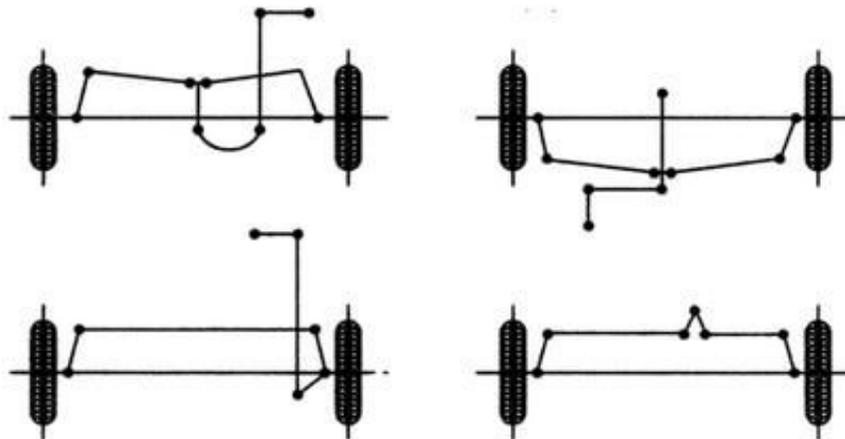


Fig. 8.20. Various types of steering linkages.