
UNIT 7 FRONT AXLE AND STEERING

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7.1 INTRODUCTION

In any motor cars and other four and six wheeler vehicles, steering is main component. Properly designed steering, works well and guides the vehicle to move in correct direction. Mainly steering is linked to the front axel with gear train mechanism. On the front axle, wheels are mounted, and with the help of steering wheel, the driver can turn the vehicle in right, left or straight directions.

The function of steering mechanism is clearly explained in this unit. In this unit, we also elaborated on the front axel and its types.

Principle of steering, steering geometry, steering gearbox and working of steering systems have been clearly explained.

Objectives

After studying this unit, you should be able to

- understand about front axle and steering,
- define function of front axle and steering,
- explain the principle of steering mechanism,
- describe the linking mechanism of front axle and steering wheel, and
- understand the steering geometry.

7.2 FRONT AXLE

Front wheels of the vehicle are mounted on front axles. Functions of front axle are listed below :

- (a) It supports the weight of front part of the vehicle.
- (b) It facilitates steering.
- (c) It absorbs shocks which are transmitted due to road surface irregularities.
- (d) It absorbs torque applied on it due to braking of vehicle.

Construction and Operation

Front axle is made of I-section in the middle portion and circular or elliptical section at the ends. The special x-section of the axle makes it able to withstand bending loads due to weight of the vehicle and torque applied due to braking. One kind of front axle is shown in Figure 7.1 which consists of main beam, stub axle, and swivel pin, etc. The wheels are mounted on stub axles.

Figure 7.1 : Front Axle

7.3 TYPES OF FRONT AXLES

There are two types of front axles :

- (a) Dead front axle, and
- (b) Live front axle.

Dead Front Axle

Dead axles are those axles, which do not rotate. These axles have sufficient rigidity and strength to take the weight. The ends of front axle are suitably designed to accommodate stub axles.

Live Front Axle

Live axles are used to transmit power from gear box to front wheels. Live front axles, although, front wheels. Live front axles, although, resemble rear axles but they are different at the ends where wheels are mounted. Maruti-800 has live front axle.

7.4 STUB AXLE

Stub axles are connected to the front axle by king pins. Front wheels are mounted on stub axles. The steering arrangement is connected to stub axles. Stub axle turns on king pins. King pins are fitted in the front axle beam eye and are located and locked there by a taper cotter pin. Stub axles are of four types :

- (a) Elliot
- (b) Reversed Elliot

- (c) Lamoine
- (d) Reversed lamoine

All are differ from each other in the manner in which they are connected to the front axle. Elliot type stub axle is shown in Figure 7.1.

7.5 STEERING

A good steering mechanism is must for a vehicle's stability at the time of turning. Steering of four wheeler is designed in a manner so that it will not permit lateral slip of front wheels during steering. There must be true rolling of wheels at the time of steering. The front wheels are mounted on front axles to allow their left and right swing for steering the vehicle. Steering is done by providing a suitable gearing and linkage between front wheels and steering wheel. A simplified diagram of a steering system has been shown in the Figure 7.2.

Figure 7.2 : Simple Driving of a Steering System

7.6 ACKERMAN'S PRINCIPLE OF STEERING

Ackerman's steering gear mechanism is based on Ackerman's principle of steering. The mechanism consists of a cross link BC connected to short axles AL and DM of front wheels through short arms AB and CD. These form the bell crank levers LAB and MDC. In case of straight motion of automobile the cross-link BC remains parallel to AD and short links AB and CD both make angle α from the horizontal axis of chasis.

(a) For Straight Motion

(b) For Right Turn

Figure 7.3 : Ackerman's Steering Mechanism (Principle)

Fundamental equation of steering is satisfied when the links AB and BC are proportioned suitably and angle α is selected suitably. The condition for correct steering is :

$$\cot \theta - \cot \phi = \frac{a}{l}$$

The angles θ and ϕ are shown in Figure 7.3(b) and distances 'a' and 'l' are shown in Figure 7.3(a). The value of $\frac{a}{l}$ lies between 0.4 and 0.5. It is generally taken near to average of two values, i.e. 0.455. The mechanism used for automatically adjusting the values of θ and ϕ for correct steering is known as Ackerman's steering gear mechanism. There are three values of angle ϕ for correct steering corresponding to three cases :

- (a) when vehicle is running straight,
- (b) when vehicle is turning to right, and
- (c) when vehicle is turning to left.

7.7 STEERING GEOMETRY

When a four wheeler (car) takes a turn, all its four wheels should roll without slipping laterally. This is possible only when the axes of four wheels intersect at one point. This point is the centre about which the vehicle turns at that instant. At this instant, rear rotate along two circles, where the centre of two circles is at 'O'. The front wheels have their different axes. These wheels also rotate along two other circles with same centre 'O'. Figure 7.4 shows the steering geometry of all the four wheels of the vehicle. For correct steering, the centre of the wheels of the rear axles and centre of front wheels must coincide.

Figure 7.4 : Steering Geometry of Four Wheels

7.8 CAMBER ANGLE

Camber angle is the angle between the vertical line and centre line of the tyre when viewed from the front of the vehicle. Camber angle is positive when this is outward. This happens when wheels are further apart at top than at bottom. On the contrary, camber angle is negative when angle is inward. This happens when wheels are further apart at bottom than at top. The camber, should not be more than 2° , because this causes uneven or more tyre wear on one side than on other side.

The front wheels are usually fitted with positive camber angle. This is done to prevent tilting of top of wheels inward due to excessive load or play in the king pin and wheel bearing. The load brings the wheels to vertical position.

Excessive camber is not good because it prevents proper wheel contact with the road. Unequal camber causes the vehicle in that direction in which camber is more. This disturbs the directional stability. Camber angle is shown in Figure 7.5.

Figure 7.5 : Camber Angle (Positive) and King Pin Inclination

7.9 KING PIN INCLINATION

It is the angle between king pin centre line and vertical line when seen from the front of the vehicle. It is also called steering axle inclination. King pin inclination and caster are used to improve directional stability in cars. Because of these provisions wheels tend to return to the straight ahead position after the vehicle completes any turn (due to steering left or right). This is also used to reduce steering effort when steering a stationary vehicle. In addition to this, it reduces tyre wear. This inclination varies from 4 to 8° in modern cars. The king pin inclination is shown in Figure 7.5. It should be equal on both sides, i.e. on both front wheels.

7.10 CASTER ANGLE

Caster angle is the tilt of king pin centre line towards front of back from the vertical line. It is the angle between the vertical line and king pin centre line in the p wheel plane when looked from side. It is shown in Figure 7.6.

Figure 7.6 : Caster Angle (Positive)

Caster angle is positive when top of the king pin is backward and negative when it is forward. The value of this angle in vehicles ranges from 2 to 8°. The caster angle provides directional stability to vehicle by making wheels to follow in the direction of movement of vehicle. The vehicle tends to roll out on turns when caster angle of both front wheels is positive. But it tends to back or lean in on turns when caster angles are negative. Positive caster angle increases the steering effort and tends to keep the wheels straight. Negative caster is provided in heavy duty vehicles to reduce steering effort.

7.11 TOE-IN AND TOE-OUT

The front wheels are slightly turned in at front side such that the distance between wheels at front (A) is little less than the distance at back (B), when seen from top. This difference in distance is called to-in. It is shown in Figure 7.7. The distance B is greater than A by 3 to 5 mm.

Figure 7.7 : Toe-in ($A < B$)

Purpose of Toe-in

- (a) To ensure that wheels are rolling parallel.
- (b) To stabilize steering and prevent slipping towards sides.
- (c) To prevent excessive tyre wear.
- (d) To offset the effect of small deflections in the wheel support system.

The wheels are set with to-in but they move parallel when car moves forward.

The difference in the angles between the two front wheels and frame of the car during turns is called toe-out. While taking the turn, the inside wheel makes larger angle than outer wheel to satisfy the condition of correct steering. The toe-out is shown in Figure 7.8.

Figure 7.8 : Toe-out at the Time of Turning of Vehicle

At turns, inner wheels makes an angle α which is more than angle β of outer wheel. Toe-out is set by maintaining proper relation between the steering knuckle arm, tie rods and pitman arm.

7.12 STEERING GEAR BOX

Steering gears are used to reduce the steering effort and convert rotary motion of steering wheel into straight line motion of linkage. Thus, steering gear provides mechanical advantage also to make steering easy. Steering gears are put inside the steering gear box. Steering gear box connects steering shaft and steering linkages.

Various types of steering gears used in different automobiles are listed below :

- (a) Worm and sector type,
- (b) Worm and worm wheel type,
- (c) Worm and roller type,

- (d) Rack and pinion type, and
- (e) Cam and roller type.

Worm and Sector Type Steering Gear

In a worm and sector type steering gear a worm is provided at the end of steering shaft which meshes with a sector provided on a sector shaft. When the worm is rotated, the sector turns which moves the linkages for steering the vehicle. The sector shaft is also called pitman arm shaft, roller shaft or cross shaft. This is shown in Figure 7.9.

Figure 7.9 : Worm and Sector Steering Gear

Worm and Worm Wheel Type Steering Gear

In worm and worm wheel system, square threads are provided on the worm on the steering shaft. The worm meshes with the worm wheel which is mounted on a shaft. A drop arm is also mounted on the same shaft as shown in Figure 7.10. The rotation of steering shaft rotates the worm and worm wheel. This rotates drop arm by 60° to 90° . This moves the steering linkages. This type of gear box is used in tractors.

Figure 7.10 : Worm and Worm Wheel Steering Gear

A square shaft is generally used on which worm wheel is mounted.

Worm and Roller Type Steering Gear

In the worm and roller steering gear, a roller with two teeth is meshes with the teeth on roller. This type of system was popular in American passenger cars.

Rack and Pinion Steering Gear

A pinion is attached at the end of the steering shaft. A rack meshes with the pinion. The rotary movement of the steering moves the pinion which gives motion to the rack. The movement of the rack is responsible for turning the wheels through steering linkages.

7.13 STEERING LINKAGES

Steering linkages is connection of different links between steering gear box and front wheels. The rotation of steering wheel is transmitted to the steering gear from which it is transferred to the front wheels for turning them to left or right.

7.13.1 Steering Linkage for Conventional Rigid Axle Suspension

Steering linkage for a conventional rigid axle suspension has been shown in Figure 7.11. It is generally used in cars which have rigid front axle.

Figure 7.11 : Steering Linkage for a Rigid Axle Suspension

The steering knuckle arm is connected to pitman arm through a drag link (link rod). The right hand track rod arm is connected to left hand track rod arm through a track rod (or tie rod).

Working of Steering System

When steering wheel is rotated, the motion is transmitted to pitman arm through gear box. This motion is transmitted to drag link. Drag link transfers this movement to stub axle which rotates about king pin. This turns the right wheel. The left wheel is turned through the track rod and left hand track and arm.

7.13.2 Steering Linkage for Independent Front Suspension

If automobile is fitted with independent front suspensions then different type of steering linkages are used. In these linkages, the ball joints are fitted between steering linkage and steering arm which facilitates independent movement of the wheels. A simplified linkage is shown in Figure 7.12.

Figure 7.12 : Steering Linkage for Independent Front Suspension

7.14 LAYOUT OF A STEERING SYSTEM

Figure 7.13 shows a simplified layout of a steering system. A typical steering system consists of

- (a) Steering wheel,
- (b) Steering shaft,
- (c) Steering gear box,
- (d) Pitman arm,
- (e) Drag link,

- (f) Steering knuckle arm,
- (g) Tie rod, and
- (h) Track rod arm, etc.

Figure 7.13 : Layout of a Steering System

SAQ 1

- (a) Write the functions of steering in an automobile.
- (b) Name different types of steering gear boxes.
- (c) Describes worm and sector type steering gear box.
- (d) What is the function of steering linkage? Describe the working of steering linkage for rigid axle suspension.
- (e) Draw a line diagram of a steering linkage for independent front suspension type vehicle.

SAQ 2

- (a) Sketch a line diagram showing the layout of a steering system. List the main parts of which it consists.
- (b) Write the Ackerman's principle of steering. Show with the help of a diagram when vehicle takes a right turn.
- (c) Explain tow-in and toe-out with the help of suitable diagrams.
- (d) Explain the following terms with the help of diagrams :
 - (i) Caster,
 - (ii) Camber and
 - (iii) King pin inclination.

SAQ 3

- (a) What do you mean by steering geometry? Explain.
- (b) Write the functions of front axle.
- (c) What do you mean by :
 - (i) Line axle, and
 - (ii) Dead axle.

- (d) What is the function of stub axles? Describe their use and list different types.
- (e) Why the following provisions made in the vehicle :
 - (i) Toe-in,
 - (ii) Toe-out,
 - (iii) King pin inclination,
 - (iv) Camber angle, and
 - (v) Caster angle.

7.15 SUMMARY

7.16 KEY WORDS

7.17 ANSWERS TO SAQs

Refer the preceding text for all the Answers to SAQs.