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# Implementation of Variable Turning Radius by Combining Ackermann and Reverse Ackermann Mechanism

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**Abstract:** The intention of the steering arrangement is to permit the driver to manipulate the association of the vehicle by curving the wheels. This is completed by a steering wheel, a steering column that transmits the rotation of the steering wheel to the steering gears, that rise the rotational power of the steering wheel so as to send larger torque to the steering linkage and the steering linkage that transmits the steering gear movement to the front wheels. The steering arrangement configuration depends on vehicle design (the drive train and suspension utilized, whether it is a traveller car or a commercial vehicle). At present the majorly utilized arrangement is the rack –and-pinion kind and the re-circulating–ball types.

**Key words:**

## INTRODUCTION

We know that the basic function of steering system is to turn the wheels in the desired direction. However, it is interesting to note that when the vehicle is turned, the front wheels do not point in the same direction.

For a proper steering system, each of the wheels must follow different turning circle and when a perpendicular is drawn from centre of each wheel; all the perpendiculars will meet at one single point, which is known as instantaneous center.

Considering the angular velocities of inner and outer rear wheels are different, the inner wheels should turn at a higher angle and [1] outer wheels should turn at a smaller angle while the vehicle is taking a turn in Ackermann condition. Considering slip angle to be zero.

**Factors Considering For Steering:**

- Factor pertaining to wheels
- Steering geometry
  - Camber
  - Kingpin inclination
  - Combined angle and scrub radius
  - Castor
  - Toe-in or toe-out
- Steering linkages
- Suspension system
- Directional stability
- Turning circle diameter
- Lock position
- Setback

**Ackermann Steering:** Ackermann steering [2]geometry is a geometric arrangement of linkages in the steering of a car or other vehicle designed to solve the problem of wheels on the inside and outside of a turn needing to trace out circles of different radius. It was invented by the German carriage builder Georg Lankensperger in Munich in 1817.The steering linkages are present in the back of the front axle comprising of a rack and pinion set-up.

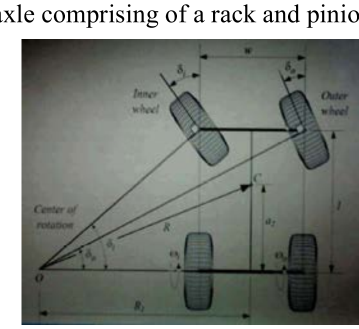


Fig. 1: Ackermann steering

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**Calculations:**
Let the dimensions of the vehicle be,

| | | |
|---|---|---|
| Wheelbase (L) | = | 1600 mm |
| Track width (W) | = | 1250 mm |
| Center of gravity (G) | = | 1000mm |
| Inner wheel angle (δ) | = | 30 δ |
| Over hung length (g) | = | 250mm |

Ackermann condition,

$\cot\delta o - \cot \delta i = W/L$

where,
δi - the steer angle of the inner wheel,
δo - the steer angle of the outer wheel.

The Inner and outer wheels angles are defined based on the turning center O.
$\cot\delta o - \cot 30 = 1250/1600$
The outer wheel angle,
δo =22δ.

The radius of rotation,

$R_1 = L \cot \delta i + W/2$

$= (1600/\tan 30) + 1250/2$
$= 3396$ mm.

The mean radius of rotation about O to centroid,

$R^2 = R_1^2 + G^2$
$= 3396^2 + 1000^2$
$R = 3540$ mm.

The ratio between the angular velocities of inner and outer wheel at rear axis,

$\omega_o/\omega_i = (R_1 + w/2)/(R_1 - w/2)$

$= (3396 + 1250/2)/(3396-1250/2)$
$= 1.451.$

From the above result we conclude that the outer wheel will rotate higher as 1.451 value of inner wheel at rear axis.

Space requirement,
$= R_{max} - R_{min}$
$R_{min} = L/\tan \delta_i$
$= 1600/\tan 30$
$R_{min} = 2771$mm.
$R_{max}^2 = (R_{min}+w)^2 + (L+g)^2$
$= (2771+1250)^2 + (1600+250)^2$
$R_{max} = 4426$mm.

Therefore the space requirement,
$= R_{max} - R_{min}$
$= 4426-2771$
$=1655$mm.

The corresponding angle of turn,
$\cot\delta = R/L$
$= 3540/1600$
$\delta = 26\ \delta$

Hence we conclude that for 30δ of the turn we need 1.655m of space to turn about the O and C.

**Limitations of Ackermann Steering:**

- Though the Ackermann steering is efficient and provides comfort to the driver, it is preferred for commercial and domestic vehicles.
- Since the radius of rotation of Ackermann steering is slightly high, the effectiveness of the steering at higher speeds is reduced.

**Reverse Ackermann Steering:** Reverse [3]Ackermann steering is employed in sports and race cars, where the wheels have to respond immediately as the steering wheel exhibits a slighter degree of turn and if the radius of rotation is reduced, the vehicle will exhibit a turn as soon as possible. The rack and pinion arrangement is placed in the front of the front axle which enables the outer wheel to exhibit a higher angle turn than the inner wheel while taking a turn[4]. This helps the vehicle to keep the point O in front of the vehicle within a shortest distance from it compared to the Ackermann steering.

**Need for Reverse Ackermann Steering:** The Ackermann steering is efficient and widely used in the commercial and domestic vehicles and if it is implemented in the high speed vehicles it is found to have the following constraints:

- Understeer – this occurs when the car steers less than (under) the amount commanded by the driver.
- Radius of rotation– the Ackermann steering exhibits a larger radius of rotation.
- Response time is less

The above problems can be solved by using reverse Ackermann system.

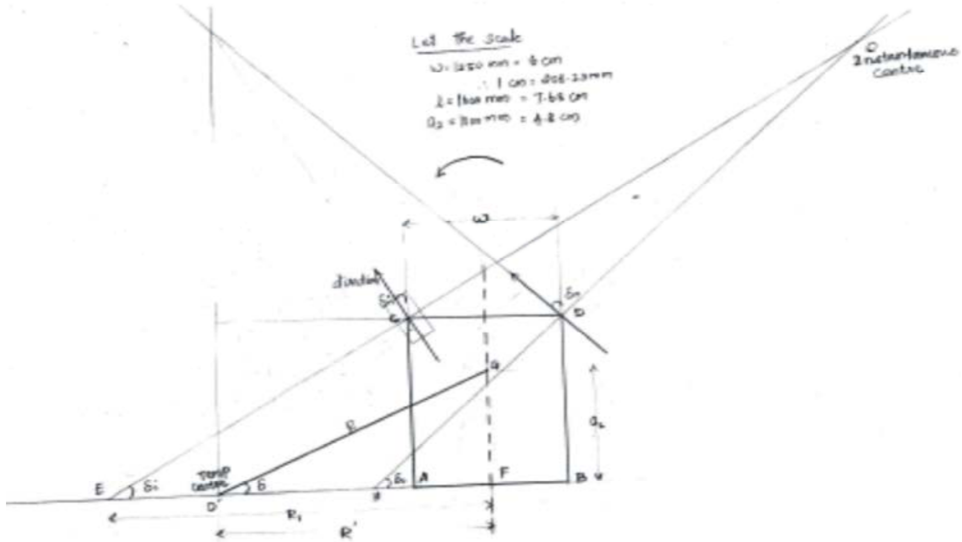

Fig. 2: Reverse Ackermann steering

Reverse Ackermann steering is completely the reverse of Ackermann steering system where the outer wheel of the vehicle will make a high angular turn than the inner wheel. A light modification is done on the front steering links. The steering links present in the back of the front axle is shifted to the front of the axle.After the links are shifted, if the pinion is directly coupled with the rack, there is a contradiction between the steering rotation and the rack movement (i.e the rack will move opposite to steered direction,this leads the vehicle to turn right, if the steering wheel rotates in left).A intermediate gear called an idlegear is introduced between the pinion and the rack which changes the pinion`s rotation before it is meshed with the rack.

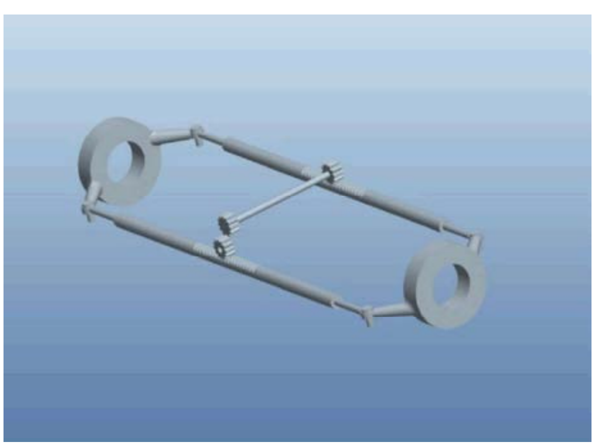

Fig. 2: Design of the mechanism

**Design of Angle of Turn**

Cot - Cot = W/L

Let it be,

W = 1250mm

L = 1600mm

= 30

Cot 30 – Cot = 1250/1600

= 46

Compare the diagram of reverse Ackermann steering geometry,

From the triangle AEC,

tan = AC/AE

AE = l/tan = 1600/tan 30

AE = 2771 mm

By graphical analysis method,

$R_1$ = EF = AE + W/2

= 2771 + 1250/2 mm

$R_1$ = 3396 mm

But the instantaneous center is placed away from the vehicle and in opposite direction to the motion of the vehicle.

From the diagram,

R` = 2166mm

$R^2 = R^{`2} + a_2^2$

= 2166^2 + 1000^2

R = 2386mm.

$\tan = a_2/R`$
$= 1000 / 2166$
$= 24.7$ (approx 25)

This value is low as compared to the Ackermann steering. We can use it for high speed driving such as race cars.

## CONCLUSION

According to the reverse Ackermann mechanism, the instantaneous point is in far away from vehicle and placed opposite to the vehicle movement direction.If we turn the vehicle in left, the vehicle must turn about the instantaneous center which is in opposite side to the motion. The vehicle will have a tendency to turn about instantaneous centre by completing the left turn earlier as possible. The vehicle creates a temporary turning center to turn left about the center the vehicle. This distance in which the turn is made is lesser than the Ackermann steering (refer calculations).

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