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Comparison and Selection of Steering Geometry for 4-Wheel Efficycle

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Abstract

In this research paper, we have discussed different types of steering geometry such as Ackerman, anti-ackerman and Davis steering geometry. We have also discussed the advantages and disadvantages of all three types of geometry and implemented the best steering geometry for our four-wheel effic-ycle. We have done three iterations to determine the best Ackerman percentage, critical velocity and steering ratio.

Keywords: Steering Geometries, Ackermann Steering, Anti-Ackerman Steering, Davis Steering, critical velocity

1. Introduction

The steering system is a part of vehicle dynamics which helps to control the direction of the vehicle according to the driver's input. It influences the vehicle handling, control and cornering performance. There are multiple types of steering systems such as power steering, and mechanical steering but all of them are based on the geometry of the steering system. Geometry can be divided into three types that are Ackerman, Anti-Ackerman and Davis steering geometry.

Furthermore, we have discussed all three types of steering geometry and their advantages and disadvantages in the upcoming paragraph. This research paper can help other students to have a profound understanding of steering geometry and how they can opt for the most optimal geometry while designing their vehicle

2. Literature review

Engineers have done a lot of research to optimize all the steering geometry and further innovations are being done to improve the handling, and control of high-speed vehicles. In this review, we have discussed the advantages and disadvantages of Ackerman, Anti-Ackerman and Davis geometry respectively. [2, 3, 4]

2.1 *Methodology*

Ackermann geometry: In Ackerman geometry both front tyres while cornering have different radii. It is done to avoid sideways slippage as the wheels while turning form different circles with a common center point. It improves the grip of the wheels.

Advantages of Ackermann Geometry:

- To avoid the sideway slip of the wheel while cornering.
- Ackerman geometry is easy to understand and it makes designing the steering easy.
- It solves the problem of the wheels turning around a different radius.

Disadvantages of Ackermann Geometry:

- It is highly unstable at high speeds.
- Ackermann geometry causes uneven tyre wear.
- It is highly unstable at high speeds

The Davis steering mechanism consists of two arms or rods that connect the front wheels to the steering wheel. The arms are angled inward toward each other, and the steering wheel is attached to a pivot point where the arms meet. As the steering wheel is turned, the arms pivot around this point, causing the front wheels to turn at different angles. This mechanism ensures that the wheels turn at different angles reducing the slip and scrub and improving vehicle stability.

Advantages of Davis Geometry:

- It is stable at high speeds.
- It provides a smaller value of turning radius.
- Reduces Slip and Scrub.

Disadvantages of Davis Geometry:

- Causes more wear on the steering gear
- The friction produced is more due to sliding pairs

Anti-Ackermann geometry is a type of geometry designed for high-speed vehicles to reduce slip angles at front tyres during cornering. It is the opposite of Ackermann steering geometry as the outer wheel turns at a greater angle as compared to the inner wheel, therefore, covering less distance.

It is majorly used in Race cars where Traction and Vehicle stability are the main aspects to be considered rather than turning radius.

Advantages of Anti-Ackermann Geometry:

- Maximum traction is achieved.
- Reduces the value of slip angle at front tires providing stability

Disadvantages of Ackermann Geometry:

- Increases the value of the Turning radius.
- It makes the vehicle less manoeuvrable in congested corners.

3. Numerical analysis

4.1 Anti-Ackermann Steering Geometry Calculations
The turning angle for the outer wheel in Anti-Ackermann geometry can be expressed as:
tan(θ_outer) = L / (R + (t/2))
tan(θ_inner) = L / (R - (t/2))
where L = wheelbase, R = turning radius, t = track width.

4.2 Davis Steering Geometry Calculations
In Davis steering, the steering arms are inclined, and the relation can be derived as:
tan(θ) = L / (R ± (t/2))
where the plus sign applies for the inner wheel and minus for the outer wheel.
This mechanism ensures that both wheels trace different circles with a common center, reducing slip and scrub.

$$L_{wheelbase} = 1.27\ m$$
$$W_{track\ width} = 0.93\ m$$

$Considering\ turning\ radius = R$

$To\ find\ the\ perfect\ Ackermann\ geometry\ for\ our\ vehicle\ we\ performed\ various\ iterations\ by\ varying\ the\ values\ of\ the\ turning\ radius\ (under\ 4m\ as\ per\ the\ figure\ of\ 8\ test).$

$We\ performed\ three\ iterations\ for\ which\ the\ results\ are\ as\ mentioned\ below:$

$$For\ R = 2\ m$$
$$Inner\ angle = 39.658^0 \quad Outer\ angle = 27.216^0$$
$$Ackermann\ \% = 99.58\%$$
$$For\ R = 2.5\ m$$

$$Inner\ angle\ = 32.005^0\quad Outer\ angle\ = 23.122^0 \tag{1}$$

$$Ackermann\ \%\ =\ 100.175\% \tag{2}$$

$$For\ R\ =\ 3m$$
$$Inner\ angle\ =\ 26.6^0\quad Outer\ angle\ =\ 20.10^0$$
$$Ackermann\ \%\ =\ 100.21\%$$

$As\ for\ turning\ radius\ of$ 2. 5$m\ we\ were\ getting$ 100. 175% $Ackermann\ \%\ in\ reference\ to$ 100% $or\ perfect\ Ackermann\ percentage.$

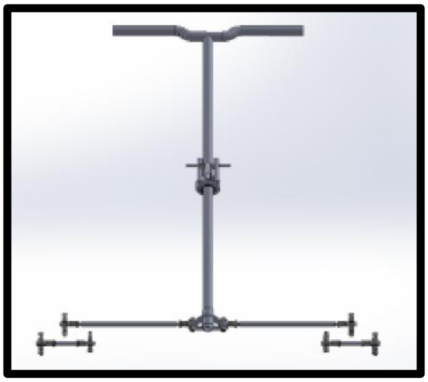
$$Critical\ Velocity\ =\ \sqrt{\mu g r}$$

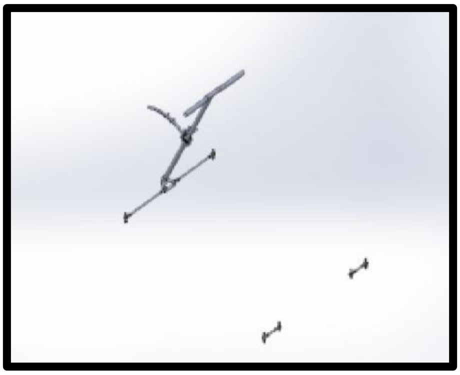
$$\mu\ =\ 1.2$$
$$g\ =\ 9.8\ m/s$$
$$R\ =\ 2.5\ m$$

$$So\ critical\ velocity\ =\ 5.42\ m/s$$

$Steering\ ratio(S.R)\ refers\ to\ the\ ratio\ between\ the\ turn\ of\ the\ steering\ wheel\ and\ the\ turn\ of\ the\ wheels.$

$$S.R\ =\frac{Lock\ to\ lock\ angle\ of\ steering\ handle}{Inside\ angle + Outside\ angle} =\ 1.08 \tag{3}$$





4. Results

On studying and researching three types of steering geometries, the Geometry that suits the best for our vehicle best is Ackermann Geometry based on factors such as ease of manufacturing and basic mathematical Calculations and as the speed of the vehicle is low, this geometry suits the best. The numerical calculations we have done provide all the desired results.

The turning radius calculated is $2.5\,m$ with inner and outer angles as 32.005^0 & 23.122^0 respectively. The steering ratio calculated is 1.08

5. Conclusion

The implementation of the idea of comparing different steering geometries based on their applications, advantages & disadvantages has been successful in selecting the steering geometry of our vehicle. Through a thorough evaluation of different steering geometries' behaviour, this research aims to contribute to the development of a simple and efficient steering system to achieve maximum vehicle handling.

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