Variable Steering Mechanism (Ackerman <> AntiAckerman)

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Abstract - The conventional Ackermann steering geometry poses challenges during high-speed turns, leading to tire scrubbing, increased drag, and potential understeer or oversteer tendencies. This geometry might fail to optimize tire contact patches, affecting vehicle handling on diverse corners of a race track. Fixed steering ratios further exacerbate the difficulty of achieving precise control during high-speed maneuver, potentially causing discomfort and reduced driver confidence. Addressing these challenges necessitates a dynamic steering system that intelligently adapts to varying driving conditions. Such a system must consider multiple variables, including vehicle speed, turning radius, and user input. The critical goal is to design a mechanism capable of dynamically adjusting steering geometry based on these factors. This adaptive system aims to optimize vehicle performance, ensuring a smoother and more responsive driving experience across diverse driving scenarios.The project titled "Variable Steering Mechanism" focuses on designing and implementing a system that allows the seamless transition between Ackerman and AntiAckerman steering geometries in an automobile. Ackerman steering is traditionally employed for smooth turns at low speeds, while Anti-Ackerman steering is preferred for stability at high speeds. The proposed mechanism aims to dynamically adjust the steering geometry based on driving conditions, optimizing vehicle performance and handling. This adaptive system seeks to enhance maneuverability, reduce tire wear, and improve overall safety by providing an intelligent and versatile solution for varying driving scenarios

1.INTRODUCTION

Imagine that you are driving your car at high speeds in a car race and suddenly you notice a sharp turn ahead. What will you do? If you try to reduce the speed you would not be able to quickly get back the same momentum and if you take a turn at the same speed, you may face an instability while driving. It would impact drivers' comfort and confidence. So, what's the solution to it? Here we come up with a solution to “Design and implement a variable steering mechanism” for a car, capable of transitioning smoothly between Ackermann and Anti-Ackerman geometries. The system should adapt to driving conditions, providing optimal steering angles for both low-speed maneuverability (Ackermann) and high-speed stability (Anti-Ackermann). The Ackermann steering system remains a fundamental and widely adopted design in vehicle engineering, offering advantages such as superior cornering stability, reduced tire wear, enhanced maneuverability, consistency across speed ranges, safety benefits, and engineering simplicity. Its widespread use in various vehicles underscores its importance in optimizing handling, safety, and tire longevity. On the other hand, the anti-Ackermann steering system, though less common, finds relevance in specific contexts. It is particularly suited for performance driving in motorsports like drifting, autocross, and track racing, where customized handling characteristics are crucial. Additionally, it has applications in specialized vehicles and serves as a platform for engineering experimentation. In the context of the presented mechanism, the goal is to develop a steering system that combines both Ackermann and anti-Ackermann characteristics, allowing drivers to customize their steering setup based on preferences and the driving environment. This innovation aims to provide versatility in steering geometry, addressing the distinct advantages of both systems and offering a solution that adapts to diverse driving styles and conditions. Consider factors such as vehicle speed, turning radius, and user input in developing a robust and efficient variable steering system transitioning from Ackermann to AntiAckerman geometry through a variable steering mechanism addresses various challenges associated with high-speed turning on race tracks.

1.1 Steering Mechanism

Steering mechanism in vehicles allows the driver to control the direction to travel by turning wheels. There are various types including rack and pinion, recirculating ball and electronic power steering each with its own advantages, strength and applications. It must also maintain straight ahead motion of vehicle while it encounters road bumps, pot holes etc. Also must operate with minimum effort during operating vehicle.

1.2 Problem Statement

a) In traditional Ackermann steering geometry, the inside wheel has a tighter turning radius than the outside wheel, causing tire scrubbing and increased drag during high-speed turns.

b) Ackermann geometry may contribute to understeer or oversteer tendencies during high-speed turns

c) Ackermann steering may not always ensure an optimal contact patch for the tires during high-speed turns.

d) Different corners on a race track may require varying steering behavior. Achieving precise control during high-speed turns can be challenging with fixed steering ratios

e) The driver may experience discomfort or reduced confidence in the vehicle's handling at high speeds. The challenge lies in designing a system that intelligently adapts to diverse driving conditions. This entails considering variables such as vehicle speed, turning radius, and user input. The mechanism should be capable of dynamically adjusting the steering geometry based on these factors, optimizing the vehicle's performance and ensuring a smooth driving experience.

2. Objectives

The objective is to create a sophisticated variable steering mechanism for automobiles, allowing seamless transition between Ackermann and Anti-Ackerman steering geometries.

a) Transitioning to anti-Ackerman geometry through a variable steering mechanism can optimize the alignment of the wheels, reducing tire scrubbing and drag. This results in smoother turns and improved efficiency.

b) By dynamically adjusting the steering ratio towards anti-Ackermann, the variable steering mechanism can help mitigate understeer or oversteer, providing better stability and control throughout the turn.

c) Variable steering can modify the geometry to achieve an ideal tire contact patch, maximizing grip and traction. This is particularly crucial for maintaining control and performance during aggressive maneuvers.

d) A variable steering mechanism allows the driver or the vehicle's control system to adapt the steering geometry to the specific characteristics of each corner, optimizing performance and responsiveness.

3. Need Analysis

1. **Performance Optimization:** There is a pressing need to enhance vehicle performance during high-speed turns. The current Ackermann steering geometry causes tire scrubbing, increased drag, and compromised handling, leading to discomfort and reduced driver confidence.

2. **Handling Precision:** Achieving precise control on diverse corners of a race track is challenging due to fixed steering ratios. Variable steering behaviors are necessary to address this challenge and ensure optimal handling characteristics across different turning conditions.

3. **Tire Contact Optimization:** The existing steering geometry might not ensure an optimal contact patch for tires during high-speed turns. This inefficiency affects both tire wear and overall vehicle handling, emphasizing the need for an improved system.

4.**Adaptive System Requirement:** A dynamic steering mechanism capable of intelligently adapting to varying driving conditions is essential. This system should consider factors such as vehicle speed, turning radius, and user input to dynamically adjust steering geometry for optimal performance.

5.**User Experience Improvement:** Enhancing driver comfort and confidence at high speeds is imperative. A new steering system should aim to provide a smoother driving experience by addressing the limitations of the current Ackermann geometry

6. **Versatility in Steering Behaviour:** Different corners on a race track demand varying steering behaviours. The need is to develop a system that can adapt steering characteristics to suit these diverse driving scenarios effectively.

4.CALCULATIONS

Ackerman Calculations

The Given Data is from Formula student vehicle Car

Turning Radius	4000 mm
Wheel Base	1545 mm
Track Width Front	1000 mm
Track Width Rear	1100 mm

Table No.01

Turning Radius $=\frac{Wheelbase}{Sin(\delta r)}$

$4000 = \frac{1545}{Sin(\delta r)}$

$\delta r = Sin^{-1}\left(\frac{1545}{4000}\right)$

$\delta r = 22.77^{o}$ (Outer wheel Angle)

Ackerman $= tan^{-1}\left(\frac{Wheelbase}{\frac{Wheelbase}{tan(\delta r)} - Track\ Width\ Front}\right)$

Ackerman $= tan^{-1}\left(\frac{1545}{\frac{1545}{tan(22.7)} - 1000}\right) = 0.57438$

$tan^{-1}(0.57438)$

Ackerman = 29.2821

Ackerman% $= \frac{\delta_1}{Ackerman} * 100$

$\delta_1 = \frac{Ackerman\% * Ackerman}{100}$

$95\% * \frac{29.2821}{100} = 27.822^{o}$

$\delta_1 = 27.822^{o}$

Rack & Pinion Gear

Rack travel(either side) = 39 mm
Pinion (either side) = 90^{o}
Module = 1.5 mm

a) Rack Travel $= \frac{\pi\ Dpinion}{4}$
D pinion = 49.65 mm

b) Z pinion $= \frac{D\ pinion}{m}$
Z pinion = 33

c) Z rack = Z pinion
Z rack = 33

d) Tooth Depth(h) = 2.25m
h = 3.75 mm

e) Addendum (h_a) = 1.00m
h_a = 1.5 mm

f) Dedendum (h_f)= 1.25 mm
h_f = 1.875 mm

Steering Efforts

Total mass of car = 250 kg
Load transfer during braking = 27.5kg
Max wt on front end = 0.45*250+275 = 140 kg = 1373.5 N

The weight on the front axel is equal to net force transmitted by the rack to tie rods.

Net force in the rack = 1373.5 N

The force generated by a torque in the pinion
Pinion = Rack * Radius pinion = 34.094 Nm

This is the torque produce in the steering wheel by driver
The radius of steering wheel is 230 mm

$= \frac{Torque\ pinion}{Radius\ of\ Steering\ Wheel}$

$= \frac{34.094\ Nm}{230*10^{-3}} = 148.2347$

= 15.11 kgs

Steering Ratio

Steering ratio is defined as the ratio of angle turned by the steering wheel to that turned by the wheels of the car

Steering Ratio $= \frac{Steering\ Wheel}{\frac{\delta_r+\delta_1}{2}}$

Steering ratio = 3.60

C Factor
It is defined as rack travel per 360^{o}
C Factor = $\pi\ Dpinion$ = 155.98 mm

Anti Ackerman Calculations

The Given Data is from Formula student vehicle Car

Turning Radius	4000 mm
Wheel Base	1545 mm
Front Rack Width	1000 mm
Rear Rack Width	1100 mm

Table No .02

Inner wheel steering angle (θ_i) $= \frac{Wheel\ Base}{Turning\ Radius + \frac{Front\ Track\ Width}{2}}$

$\frac{1545}{4000+\frac{1000}{2}} = 0.3433$ Rad

$= 19.671^{o}$

Outer Wheel Steering Angle(θ_o) $= \frac{Wheelbase}{Turning\ Radius - \frac{Front\ Track\ Width}{2}}$

$\frac{1545}{4000-\frac{1000}{2}} = 0.4414$

= 25.291^o

Inner Turning Radius
$\frac{B}{Sin\theta_1} = \frac{1545}{Sin(19.671)}$
= 4589.760 mm

Outer Turning Radius
$\frac{B}{Sin\theta_0} = \frac{1545}{Sin(25.291)}$
= 3616.438

Forces on Tie Rod

Considering caster angle of 4° and a kingpin angle of 4° on the wheel the following values were obtained
Scrub patch due to kingpin axis on the ground contact = 42.41 mm.
Steering arm of length 60 mm was finalized after steering geometry iterations.
From Suspension geometry tie rod inclination (α) was found to be 15.7 degree
Mechanical Trail = 14.40 mm

Torque due to mechanical Trail
= Lateral Force * Mechanical Trail
= 1000*14.40 mm = 14400 Nmm

Torque due o scrub radius

Traction Force = 386.28*42.41
= 16381.28 Nmm

Total Torque = 14400+16381.28
= 30781.28

Now forces on tie rod = $\frac{Total\ Torque}{Steering\ Length.}$
=$\frac{3078.28}{60\ mm}$ = 513.021 N

Efforts Calculations,

From Suspension geometry tie rod inclination (α) was 15.7^o C

Forces on Rack = Forces on the Rod* Cos (α)
= 513.021* cos(15.7)
= 493.881 N

Torque on Pinion = Force on Rack * Pinion Radius
= 493.881 * 0.002475
= 12.22 N mm

considering torque on steering wheel equal to torque on pinion = 12.22 N mm

5. CONCLUSIONS

The Ackermann steering system remains a fundamental and widely adopted design in vehicle engineering, offering advantages such as superior cornering stability, reduced tire wear, enhanced maneuverability, consistency across speed ranges, safety benefits, and engineering simplicity. Its widespread use in various vehicles underscores its importance in optimizing handling, safety, and tire longevity.

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