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Modeling and Fabrication of Dual Axis Steering Mechanism

Mr. N. Govind*[1], P. Sai Ashish[2]*, V. Satya Prasannam[3]*, R. Jashwanth[4]*, V. Charan Karthik[5]*, A. Ram Kumar[6]*.

[1]- Assistant Professor, GMR Institute of Technology, Rajam-532127
**[2,3,4,5,6]-Department of Mechanical Engineering, GMR Institute of Technology, Rajam-532127.*

ABSTRACT

Most contemporary cars, whether front-wheel drive, rear-wheel drive, or all-wheel drive, employ a two-wheel steering system to manage movement. Increased safety awareness has led to a greater usage of four-wheel steering vehicles, which are known for their performance and steadiness. The wheels of standard two-wheel steering vehicles do not assist in steering and instead follow the path of the front wheels. Four-wheel steering allows you to turn the wheels left or right, depending on the scenario. The rear wheels can rotate in the same or opposite direction as the front wheels. The Dual-Axis system will work in three distinct ways. Rotations are either in phase, out of phase, or zero. This mechanism primarily focuses on reducing the turning radius in commercial vehicles.

Keywords:- Dual Axis Steering, Ackerman Steering, Positive phase, Negative phase, Neutral phase, Turning Radius, Vehicle Stability.

Introduction

Automobile handling has become more challenging as road traffic has increased. To enhance vehicle handling, we should look at different technologies or modify the steering mechanism. Many drivers wish they could reduce their vehicle's turning radius or slide it sideways to avoid turning into busy areas. The Four Wheel Three Mode software adjusts the rear wheels to meet individual needs. In contrast, four-wheel drive powers all four wheels of a vehicle. This approach allows the rear wheels to rotate in the same direction as the front wheels. This enhances vehicle control, especially when turning, parking, or entering tight areas. This technology is often used in off-road vehicles like as forklifts, construction and agricultural machinery, and mining equipment. It's also beneficial in passenger vehicles, especially SUVs.

Literature Review

This paper [Loganathan VN et al [1] investigates the design and manufacture of a dual-axis steering mechanism for cars, with an emphasis on four-wheel steering systems. It discusses the benefits of four-wheel steering over traditional systems, the Ackerman condition for optimum steering angles, and major components such as rack and pinion, steering box, and power steering. The article describes the working concept of front and rear wheel steering systems, highlighting the importance of improving vehicle handling and maneuverability. It explains and calculates the practical application and advantages of dual-axis steering.

Kolekar et al [2] discuss steering mechanics in cars, with a focus on four-wheel steering systems. The study discusses the advantages of four-wheel steering, including superior control during turning and parking, variable speed capabilities, and increased stability. It covers a variety of steering methods, including mechanical, electro/hydraulic, and electric steering. Ackerman's and Davis steering mechanisms are also discussed, emphasizing their significance in vehicle steering geometry. The survey draws on the writings of writers such as Aniket Bhanudas Kolekar and Mr. Sumir Mulani, among others, to present a complete review of steering technology in current automobiles.

The authors, Beomsu Bae et al. [3], described a small four-wheel steering robot platform and an adaptive steering control algorithm for manual operation. The platform is intended for research purposes, with an emphasis on navigation and steering control. It has a distinctive horizontal independent steering mechanism for fine control and agility. The adaptive algorithm changes the steering arrangement based on the desired steering angle, increasing vehicle agility. The experimental findings support the platform's precise steering performance as well as the adaptive steering algorithm's efficacy. The study demonstrates the feasibility of constructing adaptable and efficient four-wheel steering robots for educational and research purposes.

Deepaket et al. [4] employ PTC CREO 2.0 for design and ANSYS 14.5 for analysis, with an emphasis on the utilization of 1090 mild steel in the chassis. The vehicle has a space frame design to seat two people and a suspension system with double wishbone and swing arm components. The paper digs into calculating turning radii using an all-wheel steering mechanism, demonstrating the significance of new steering systems in improving vehicle agility and efficiency.

The work by Jadhav et al [5] in the attached document digs into the design and modeling of the 4-wheel steering system, stressing the active involvement of the rear wheels in steering as opposed to the typical 2-wheel steering system. It highlights how this system may adjust for understeer and oversteer difficulties, allowing drivers to steer virtually neutrally in a variety of operating scenarios. The article also looks at the creation of a four-wheel steering system for RC vehicles, emphasizing its stability and performance advantages throughout various driving maneuvers. The authors of AGPIT Solapur, India, offer a complete analysis using MATLAB software that compares the efficacy of the 4-wheel steering system to the typical 2-wheel steering arrangement.

In this study, Kuslits et al [6] "Modelling and control of a new differential steering concept" offer a steer-by-wire concept that uses in-wheel motors for steering instead of a specialized steering device. A planar vehicle model is offered to evaluate the vehicle's behavior, which includes a state feedback linear controller for high-speed lateral dynamics and a PI angle controller for low-speed maneuvers. Simulation investigations reveal that the steering performance is equivalent to that of regular autos.

Singh Gautam et al. [7] provide the kinematic synthesis of a Modified Ackermann Steering Mechanism for Automobiles by Er. Neeraj Singh Gautam and Prashant Awadhiya. The suggested system, which has six members and seven precision points, intends to increase steering accuracy and reactivity. A significant distinction from classic devices like the Ackermann Steering.

This study by Pradhan et al. [8]. The paper focuses on refining the kinematic design of a 6-bar rack and pinion Ackerman steering linkage for better cornering performance in Formula Student competitive vehicles. The authors present a technique that employs a multi-objective evolutionary algorithm to reduce variations in slider displacements and departures from real Ackerman geometry. The study seeks to improve steering performance by optimizing characteristics such as wheelbase, track width, tie rod, and tie-arm lengths. The project intends to eliminate steering mistakes and increase vehicle agility during cornering events in Formula Student races by developing an ideal steering geometry.

The authors of this study, Zhao et al [9], focus on Simionescu and Smith's design of rack-and-pinion steering linkages. It investigates the optimization of steering performance using geometric parameters and parametric design charts. The study emphasizes the significance of central outrigger and conventional rack-and-pinion steering systems in vehicle design, particularly their effect on steering accuracy and pressure angles. The study uses an optimization-based synthesis technique to identify ideal domains for decreasing steering mistakes in the early phases of steering linkage design. Overall, the study offers significant data for automobile engineers seeking to effectively design new steering systems.

Zhao et al. [10] investigate the optimization and sensitivity analysis of planar rack-and-pinion steering linkages. The study investigates the use of noncircular gears to fulfill Ackermann steering geometry criteria, emphasizing the significance of reducing steering error in such devices. Numerical simulations and optimization approaches are used in the study to get exact steering mechanism solutions. Furthermore, it emphasizes the need of enhancing wear resistance in joints associated to specific links in the steering system design.

Zehetbauer et al. [11] M's paper, "A minimal model to study self-excited vibrations of a tram wheel set in curves with small radius of curvature," examines the dynamics of tram wheel sets in hard curves. They methodically examine the necessary circumstances for operating in the falling regime, focusing on the vital link between angle of attack, curve radius, and vehicle speed. The authors investigate the occurrence of lateral periodic wheel set oscillations, which may be attributable to self-excitation, under specified curve circumstances.

Suwin Sleesongsom and Sujin Bureerat's study, "Multi-Objective, Reliability-Based Design Optimization of a Steering Linkage" [12], investigates a unique approach for Reliability-Based Design Optimization (RBDO) in steering linkage design. The study analyzes the complexities of RBDO's double-loop nested issue and presents a single-loop method known as Multi-Objective, Reliability-Based Design Optimization (MORBDO). The suggested MORBDO method streamlines the design process by integrating a multi-objective evolutionary strategy with worst-case scenarios and fuzzy sets, resulting in more conservative and feasible outcomes. The approach is validated by optimization test issues and steering linkage design.

Vanamala et al. [13] provide a research on Four Wheel Steering Mechanism for Automobiles by Uma Maheshwar Vanamala and Raja Rao Koganti of Osmania University. It investigates the advantages of four-wheel steering systems over typical two-wheel steering, focusing on enhanced maneuverability and stability at different speeds. The novel design includes a mechanical steering system with components such as a phase shifter box, connections, couplers, and bevel gears to allow for varied steering modes based on driver preferences. The study dives into specific technical factors such as torque calculations, material selection, and gear design in order to improve the steering mechanism's performance. The project seeks to improve vehicle control and reaction by using modern steering systems.

This article by Adolphus et al [14] describes the "Dual Mode Four Wheel Steering System" by Sanu Adolphus, Sooraj Abraham, Justin T Martin, Nikhil Sasikumaran Nair, and Liju Mathew Alexander. This method improves vehicle agility and stability by utilizing a novel steering mechanism in which the rear wheels revolve at specific ratios to the front wheels dependent on speed. Its goal is to improve steering reaction, boost stability, and minimize turning radius for more control. An Arduino circuit board, quadra coupler, and DC motor are all essential components. The poll includes discusses four-wheel steering and rear-wheel steering approaches, as well as the prototype model's design.

In this paper by Soni et al [15] has designed a four-wheel steering system using Maruti Suzuki 800 as a benchmark vehicle, highlighting its advantages and applications. Dilip S Choudhari has analyzed the working phases of a four-wheel steering system, comparing it with conventional systems. Arun Singh has provided a detailed description of a four-wheel steering system, discussing technical details, operational modes, and benefits. Amandeep has explored steering mechanisms in four-wheeled automobiles and conducted comparisons between different systems. Ahmed has investigated various steering mechanisms and introduced an improved Ackerman system for rear wheel applications. These authors have significantly enriched the understanding and research on four-wheel steering systems in the automotive sector.

Sundar et al. [16] investigate steering systems in autos, namely Ackerman and four-wheel steering. It tackles topics such as vibration resistance and simplicity of assembly in steering system design. Four-wheel steering has advantages over two-wheel steering, including increased maneuverability and stability. The publication underlines the significance of the differential mechanism in steering systems, especially in electric cars and robotics. The differential mechanism and locking may be used to produce many steering kinds, including Ackerman steering. The study proposes using the differential mechanism to automobiles on difficult terrains to increase steering performance. Overall, the analysis emphasizes the possibility for altering steering system designs to improve economy and performance, with four-wheel steering showing promise in terms of vehicle handling and safety.

Methodology

Basic Geometry Involved

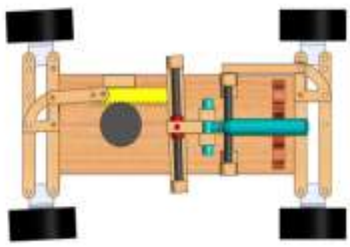
The car's inner and outer rear wheels do not travel at the same speed as the rest of the vehicle. Steering is largely concerned with directing the wheels in the proper direction. This often requires a large number of links, rods, pivots, and gears. The notion of caster angle entails using a pivot point in front of each wheel to naturally center the steering in the direction of travel. To account for the fact that the steering linkages between the steering box and the wheels typically follow a version of Ackermann steering geometry, the degree of toe appropriate for driving straight lines is ineffective for turns because the inner wheel travels a shorter radius than the outer wheel during a turn.

Development of 3D model

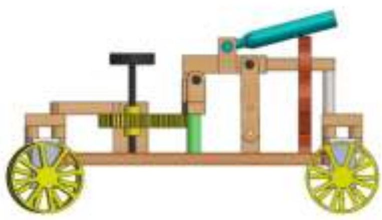
In this work, we used SolidWorks software to rigorously develop and evaluate a unique mechanism called the Dual Axis Steering Mechanism (DASM). Using SolidWorks' sophisticated capabilities, we methodically created the DASM's numerous components, assuring precision and functionality in all details. Comprehensive evaluations were then done to assess the mechanism's performance, structural integrity, and dynamic behavior. We investigated the DASM's efficacy and possible applications in a variety of engineering disciplines using rigorous simulations and testing. This project emphasizes the value of using advanced design and analysis tools like SolidWorks when developing and improving complex mechanical systems like the Dual Axis Steering Mechanism.The generated 3D views are as follows:

Front View

Isometric View



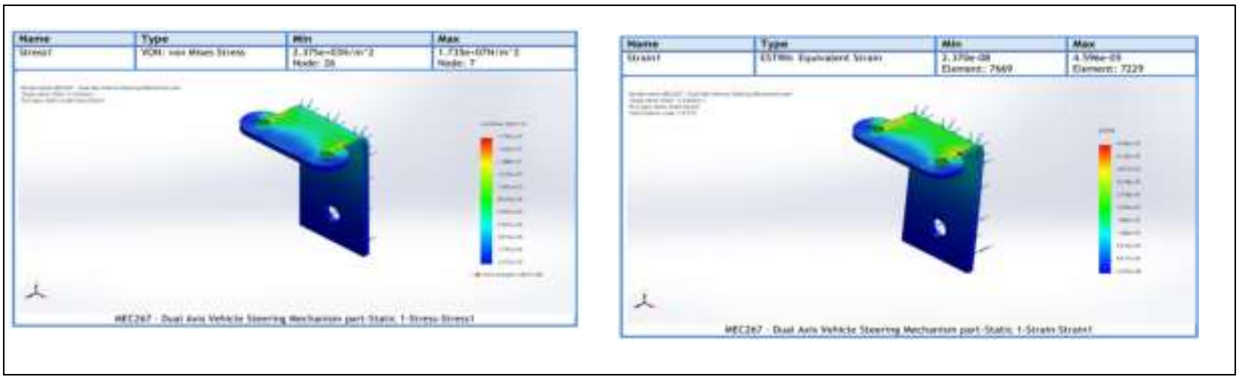
Top View



Side View

Fig 1 Projections of 3D Model

Results and discussions



These details provide a comprehensive overview of the simulation setup, material properties, loads, fixtures, and study results for the Dual Axis Vehicle Steering Mechanism part analyzed using SOLIDWORKS Simulation. The study results show minimal displacement and stress levels within acceptable limits, indicating a stable and reliable steering mechanism for dual-axis vehicles. Overall, the simulation demonstrates the effectiveness of the design and the suitability of the chosen materials in ensuring the functionality and safety of the steering system.

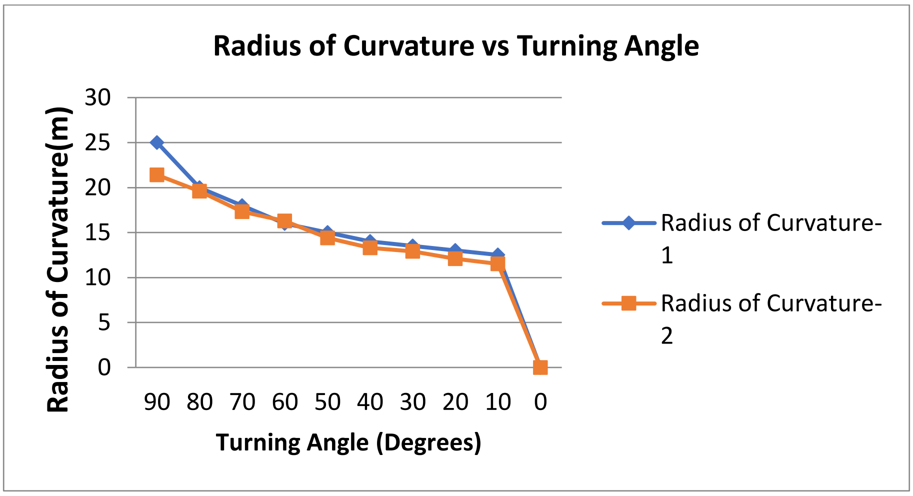


Figure 5.10 Radius of Curvature vs Turning Angle Graph

The graph titled "Radius of Curvature vs Turning Angle" displays a decreasing trend. It ranges from 0 to 100 degrees for turning angle and 0 to 30 for radius of curvature. The line graph connects red square data points, showing a consistent decrease in curvature radius with increasing angle, indicating an inverse relationship.

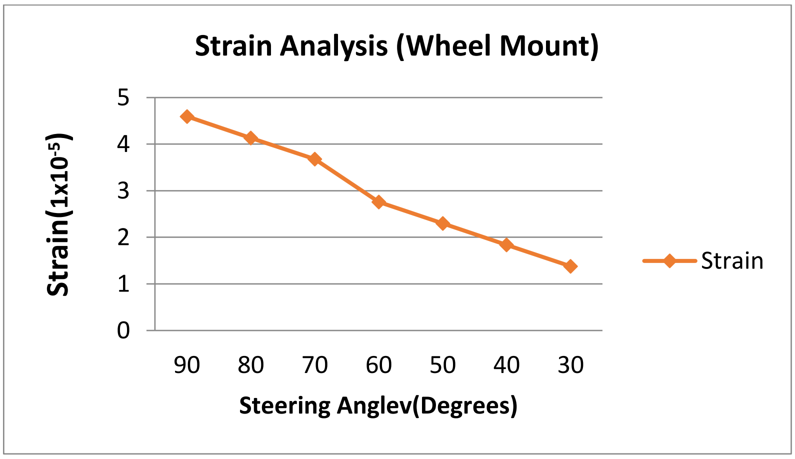


Figure 5.12 Strain Analysis (Wheel mount) Graph

The graph titled "Strain Analysis (Wheel Mount)" shows the correlation between steering wheel angle and strain. It ranges from 0 to 90 degrees and 0 to 5 for strain. The line graph, with diamond data points, indicates a negative linear relationship. The graph is clean, with clear labels and a red line on a white background.

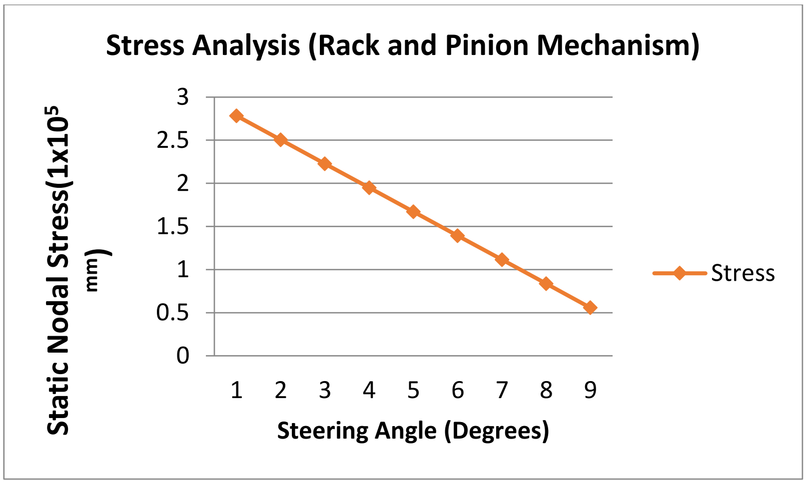


Figure 5.16 Stress Analysis (Rack and Pinion Mechanism) Graph

The graph illustrates stress variation in a rack and pinion mechanism with steering angle. Stress levels decrease linearly from around 2.5 kPa at 1 degree to slightly above 0.5 kPa at 9 degrees. This suggests stress reduction with wider steering angles. The data points form a consistent downward trend, indicating a clear relationship between angle and stress.

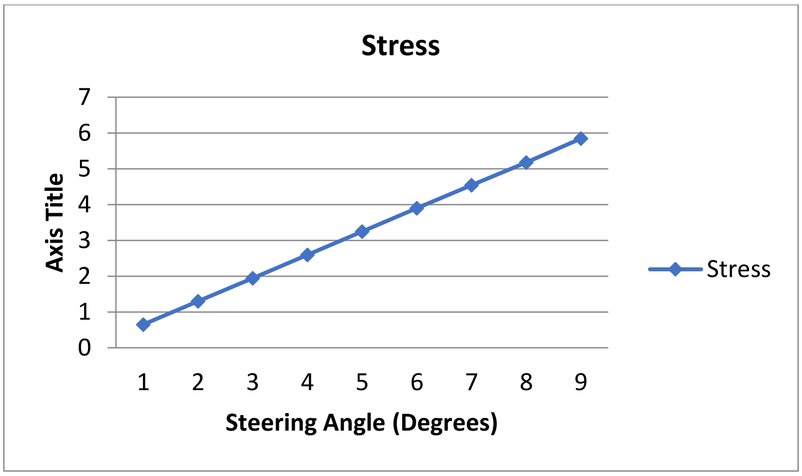


Figure 5.17 Stress Analysis (linkage) Graph

The image displays a graph titled "Stress Analysis (Linkage)" showing stress levels (y-axis) against steering angle (x-axis). Stress decreases from around 6 at 0 degrees to 1 at 80 degrees. The data points form a decreasing trend, indicating stress reduction as the steering angle increases in the linkage mechanism.

Calculation of turning circle radius

The calculation for finding the turning circle radius depending on the steering wheel angle and the displacement caused by it can be found by using the following equations:

$\mathrm{Sin}(\alpha + \delta_{if}) = Y+X/R$

Where, α = Ackerman Angle

δ_{if} = Inside Lock Angle

Y = Arm Base

X = Linear Displacement of rack for one gyration

R = Ackerman Arm Radius

$\mathrm{Sin}\,(13.640 + \delta_{if}) = 1.415+3.1/6$

δ_{if} =35.160

Calculating the center of gravity with respect to the rear axle results in the inner lock angle of the front wheel.

We understand that,

$R_2=a_2+R_{12}$………………………………(1)

Where, R = 5.394 m (Turning radius of the vehicle)

A_2 = Distance of CG from rear axle

R_1 = Distance between instantaneous centre and the axis of

the vehicle

To find a_2

$W_f = W*a_2/L$………………………..(2)

Where, W_f = Load on front axle (On basis weight

distribution)

W = Total weight of car

L = Wheelbase

Therefore,

A_2=1.60m

Substituting the value of a_2 in the above equation

R_1=5.15m

To find position of instantaneous Center from both the

axis

From our standard calculations of 2 Wheel Steering,

δ_{if} = 35.160

tan $\delta_{if} = c_1 /R_1 – t_w/2$…………………………….(3)

Where, t_w = Front track width

δ_{if} = Inside Lock angle of front wheel

Therefore,

Tan 35.160 = C_1 / 5.15*0.762

C_1 = 3.09m

$C_1 + C_2 = R$ …….….…………………….. (4)

Where, C_1 = Distance of instantaneous centre from front

axle axis

C_2 = Distance of instantaneous centre from rear axle axis

Therefore, C_2 = 5.394 – 3.09 C2 = 2.304m

Therefore, from equation (3) and (4)

C_1 = 3.09m C_2 = 2.304m

To find the remaining lock angles

to find δ_{of} = outer angles of front wheel

Tan $\delta_{of}=[C_1/(R_1+t_w/2)]$……….(5)

Tan δ_{of}=3.09/(5.15+0.762)

δ_{of} = Tan^{-1}[3.09/(5.15+0.762)]

δ_{of} = 27.590

to find δ_{ir} = inner angles of rear wheel

tan δ_{ir} =[C_1/(R_1-t_w/2)]……….(6)

tan δ_{ir} =2.304/(5.15+0.762)

δ ir =tan-1[2.304/(5.15+0.762)]

δ ir =27.700

to find δ or = outer angle of rear wheel

tan δ or =[C2/(R1+tw/2)]……….(7)

tan δ or =3.09/(5.15+0.762)

δ or =tan-1[2.304/(5.15+0.762)]

δ or =21.290

Conclusion

Finally, the Dual Axis Steering Mechanism reduces the turning radius by 4% more than the current mechanism, improving maneuverability in congested urban areas and tight spaces, as well as improving operational efficiency for commercial vehicles, allowing heavy and long commercial vehicles to turn more easily on narrow roads.Furthermore, the mechanism may give better control during maneuvers, and the increased stability leads to safer and more predictable driving experiences in any tough driving situations. Overall, the Dual Axis Steering Mechanism improves not only the performance of commercial vehicles, but also the driving experience for operators by increasing the vehicle's stability while taking a turn at high speeds and managing the vehicle by preventing drifting and rolling. As the automotive industry evolves, innovations such as the Dual Axis Steering Mechanism are critical to fostering innovation while also enhancing the efficiency and safety of commercial vehicle operations.

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