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MODELING AND FABRICATION OF DUAL AXIS STEERING MECHANISM

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Abstract
Most modern vehicles whether front-wheel drive, rear-wheel drive, or all-wheel drive, use a two-wheel steering system to control movement. Greater safety awareness has resulted in increased use of four-wheel steering vehicles, which are renowned for their performance and stability. The wheels of ordinary two-wheel steering vehicles do not aid in steering and instead follow the course of the front wheels. Four-wheel steering allows you to turn the wheels left or right according on the situation. The rear wheels can revolve in either the same or opposite directions as the front wheels. Dual-Axis system will be functioning in three different ways. Rotations are in phase, out of phase, or zero. This mechanism mainly focuses on the reduction of the turning radius in commercial vehicles. Previously this type of mechanism is only present in the high end sporting vehicles but this mechanism is useful for the commercial vehicles and it can perform better by almost 4% than compared to the current vehicles.

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

I. Introduction
Automobile handling has gotten more difficult as road traffic has risen. To improve vehicle handling, we should investigate alternative technologies or adjust the steering mechanism. Many drivers wish they could shrink their vehicle's turning radius or slide it sideways to avoid turning in congested places. The Four Wheel Three Mode software changes the rear wheels to match individual requirements. In contrast, four-wheel drive provides power to each of a vehicle's wheels. This technique allows the rear wheels to turn in the same direction as the front wheels. This improves automobile control, particularly when turning, parking, or entering tight spaces. This technology is commonly utilized in off-road vehicles including forklifts, construction and agricultural gear, and mining equipment. It's also useful in passenger cars, particularly SUVs. In-phase steering happens when the front and rear wheels turn in the same direction, causing the automobile to drift sideways. Some cars may have other setups like rear-wheel steering or a tiller. Tanks and tracked vehicles often employ differential steering, where tracks move at separate rates or in opposite directions to change direction of motion.

II. Literature Review
This Paper[Loganathan VN, et al [1] explores the design and fabrication of a dual-axis steering mechanism for vehicles, focusing on four-wheel steering systems. It delves into the advantages of four-wheel steering over traditional systems, the Ackerman condition for optimal steering angles, and key

components like rack and pinion, steering box, and power steering. The article discusses the principle of working for front and rear wheel steering mechanisms, emphasizing the need for improved handling and maneuverability in vehicles. Through detailed explanations and calculations, it provides insights into the practical implementation and benefits of a dual-axis steering.

This Paper by Kolekar et al [2] focuses on the topic of steering mechanisms in vehicles, with a specific emphasis on four-wheel steering systems. The paper provides insights into the benefits of four-wheel steering, such as enhanced control during cornering and parking, variable speed capabilities, and improved stability. It discusses various types of steering systems, including mechanical, electro/hydraulic, and electric steering. Ackerman's and Davis steering mechanisms are also explored, highlighting their importance in vehicle steering geometry. The survey references works by authors like Aniket Bhanudas Kolekar and Mr. Sumir Mulani, among others, to provide a comprehensive overview of steering technology in modern vehicles.

The authors Beomsu Bae et al] [3] discussed on a compact four-wheel steering robot platform and an adaptive steering control algorithm for manual operation. The platform is designed for research purposes with a focus on navigation and steering control. It features a unique horizontal independent steering system for precise control and maneuverability. The adaptive algorithm adjusts the steering configuration based on the desired steering angle, enhancing vehicle maneuverability. Experimental results validate the platform's accurate steering performance and the effectiveness of the adaptive steering algorithm. The study showcases the potential for developing versatile and efficient four-wheel steering robots for educational and research applications.

In this Paper by Deepaket al [4] utilizes PTC CREO 2.0 for design and ANSYS 14.5 for analysis, emphasizing the use of 1090 mild steel for the chassis. The vehicle features a space frame design to accommodate two passengers and includes a suspension system with double wishbone and swing arm components. The article delves into the calculation of turning radii using an all-wheel steering mechanism, showcasing the importance of innovative steering systems in enhancing vehicle maneuverability and efficiency.

The paper by Jadhav et al [5] study in the provided document delves into the design and simulation of the 4-wheel steering system, emphasizing the active role of rear wheels in steering compared to the standard 2-wheel steering system. It discusses how this system can compensate for understeer/oversteer issues, providing nearly neutral steering for drivers across various operating conditions. The paper also explores the development of a four-wheel steering system for RC vehicles, highlighting its stability and performance benefits during different driving maneuvers. The authors from AGPIT Solapur, India, present a detailed analysis using MATLAB software to compare the effectiveness of the 4-wheel steering system against the traditional 2-wheel steering setup.

In this paper Kuslits et al [6] "Modelling and control of a new differential steering concept" introduces a steer-by-wire concept using in-wheel motors for steering without a dedicated steering device. A planar vehicle model is presented to analyze the vehicle's behavior, with a state feedback linear controller for high-speed lateral dynamics and a PI angle controller for low-speed maneuvers. Simulation experiments show comparable steering performance to traditional cars.

This Paper by Singh Gautam et al [7] discusses the kinematic synthesis of a Modified Ackermann Steering Mechanism for automobiles by Er. Neeraj Singh Gautam and Prashant Awadhiya. The proposed mechanism aims to improve steering accuracy and response by utilizing a six-member design with seven precision points. A key difference from traditional mechanisms like the Ackermann Steering Mechanism is the increased precision and reduced structural error. By optimizing link dimensions and angles, the mechanism achieves a smaller turning radius compared to other designs like the Fahey Eight Member Mechanism and Pramanik Six Member Mechanism. The study emphasizes the importance of precision points in ensuring correct steering behavior and presents equations to guide the synthesis process effectively.

This paper by Pradhan et al [8] The article focuses on optimizing the kinematic design of a 6-bar rack and pinion Ackerman steering linkage for improved cornering performance in Formula Students

competition cars. Authors propose a method using a multi-objective genetic algorithm to minimize differences in slider displacements and deviations from true Ackerman geometry. The study aims to enhance steering performance by optimizing parameters like wheelbase, track width, tie rod, and tie-arm lengths. By synthesizing an optimal steering geometry, the research aims to reduce errors in steering and improve the vehicle's agility during cornering events in Formula Student competitions.
In this paper the authors Zhao et al [9] focuses on the design of rack-and-pinion steering linkages by Simionescu and Smith. It delves into the optimization of steering performance through geometric parameters and parametric design charts. The study highlights the importance of central outrigger and standard rack-and-pinion steering mechanisms in vehicle design, emphasizing their impact on steering accuracy and pressure angles. By employing an optimization-based synthesis method, the research aims to determine optimal domains for minimizing steering errors during the early stages of steering linkage design. Overall, the study provides valuable insights for automotive engineers in conceiving new steering mechanisms efficiently.
The paper Zhao et al [10] discusses the optimization and sensitivity analysis of planar rack-and-pinion steering linkages. The article explores the use of noncircular gears to meet Ackermann steering geometry requirements and emphasizes the importance of minimizing steering error in such mechanisms. The study includes numerical simulations and optimization methods to achieve precise solutions for steering mechanisms. Additionally, it highlights the significance of improving wear resistance in joints connected to specific links in the steering system design.
In the study by Zehetbauer et al [11] M titled "A minimal model to study self-excited vibrations of a tram wheel set in curves with small radius of curvature the authors meticulously examine the dynamics of tram wheel sets in challenging curves. They meticulously analyze the essential conditions for operating in the falling regime, emphasizing the critical relationship between angle of attack, curve radius, and vehicle speed. The authors delve into the occurrence of lateral periodic wheel set oscillations, potentially attributed to self-excitation, under specific curve conditions. By comparing results from a minimal lateral wheelset model with a detailed generic system model of a two-axle tram bogie, they highlight the significant influences on limit cycles. Through their focus on self-excited vibrations and stability analysis, the authors
The paper by Sleesongsom et al [12] titled "Multi-Objective, Reliability-Based Design Optimization of a Steering Linkage" by SuwinSleesongsom and Sujin Bureerat explores a novel technique for Reliability-Based Design Optimization (RBDO) in steering linkage design. The paper discusses the challenges of the double-loop nested problem in RBDO and introduces a single-loop approach called Multi-Objective, Reliability-Based Design Optimization (MORBDO). By combining a multi-objective evolutionary technique with worst-case scenario and fuzzy sets, the proposed MORBDO method simplifies the design process, providing more conservative and achievable results. The study validates the technique using optimization test problems and steering linkage design. The authors emphasize the efficiency and reliability of MORBDO compared to deterministic design methods, suggesting its potential application in optimizing aircraft mechanisms and structures in the future.
In this paper by Vanamala et al [13] presents a study on Four Wheel Steering Mechanism for automobiles by Uma Maheshwar Vanamala and Raja Rao Koganti from Osmania University. It explores the benefits of four-wheel steering systems compared to traditional two-wheel steering, emphasizing improved maneuverability and stability at varying speeds. The innovative design incorporates a mechanical steering system with components like a phase shifter box, connectors, couplers, and bevel gears to enable different steering modes based on driver preferences. The research delves into detailed engineering aspects such as torque calculations, material selection, and gear design to optimize the performance of the steering mechanism. The study aims to enhance vehicle control and response by integrating advanced steering technologies.
In this article by Adolphus et al [14] paper discusses the "Dual Mode Four Wheel Steering System" by Sanu Adolphus, Sooraj Abraham, Justin T Martin, Nikhil Sasikumaran Nair, and Liju Mathew Alexander. This system enhances vehicle maneuverability and stability by implementing a unique

steering mechanism where the rear wheels turn at specific ratios compared to the front wheels, based on speed. It aims to improve steering response, increase stability, and reduce the turning radius for better control. Key components include an Arduino circuit board, quadra coupler, and a DC motor. The survey also covers the concepts of four-wheel steering, rear wheel steering, and the design aspects of the prototype model.
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.
In this paper by Sundar et al [16], explores steering systems in automobiles, focusing on Ackerman and four-wheel steering. It discusses factors like vibration resistance and ease of assembly in steering system design. Four-wheel steering offers advantages over two-wheel steering, enhancing maneuverability and stability. The document emphasizes the importance of the differential mechanism in steering systems, particularly in electric vehicles and robots. By utilizing the differential mechanism and locking, various steering types can be achieved, including Ackerman steering. The paper suggests applying the differential mechanism to vehicles on challenging terrains for improved steering capabilities. Overall, the review highlights the potential for modifying steering system designs to enhance efficiency and performance, with four-wheel steering showing promise in advancing vehicle handling and safety.
In this paper authored by Singh et al [17] benefits of four-wheel steering systems in vehicles for better performance and safety. Traditional vehicles use two-wheel steering, but four-wheel steering is becoming popular due to its advantages. Four-wheel steering allows for optimal control during maneuvers at different speeds. At low speeds, the rear wheels steer in the opposite direction of the front wheels for sharper turns, while at higher speeds, they steer in the same direction for stability. The study focuses on reducing the turning radius and increasing stability using four-wheel steering systems. The research explores the combined movement of the control yoke angle and bevel gear revolutions to achieve rear wheel steering. Overall, four-wheel steering systems offer improved maneuverability, stability, and control in various driving conditions.
The paper by Patil et al [18] by covers the chassis and suspension system design using software tools like PTC CREO 2.0 and ANSYS 14.5. The study includes calculations for turning radius with all-wheel steering and finite elemental analysis for structural verification. Key components of the vehicle include the chassis, wishbone suspension system, and swing-arm. Materials like 1090 mild steel are used for the chassis, and design considerations focus on accommodating passengers, steering mechanisms, and motor attachments. The turning radius is calculated by considering the geometry of steering on both two-wheel and single-wheel sides. The analysis results show that the design is safe based on maximum equivalent stress values.
This study paper by Ackermann [19] delves into the concept of steering mechanisms, particularly focusing on the four-wheel steering (4WS) system. This system allows all four wheels to be turned using the steering, enhancing vehicle control during cornering and parking. It discusses different types of steering systems, outlining the requirements for effective steering, and exploring various steering mechanisms such as Ackerman's Steering Mechanism and Davis Steering Mechanism. Advantages of the 4WS system include improved vehicle control, superior cornering stability, enhanced steering responsiveness, and smaller turning radius for tight space maneuverability.
In this paper by Kim et al [20]article by Kim, Y., & Kim, Y, explores the benefits of implementing a four-wheel steering system in vehicles as opposed to the traditional two-wheel steering system. By

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utilizing four-wheel steering, vehicles can achieve higher efficiency and improved control. This system aims to decrease the turning radius, enhance stability, and provide better maneuverability, especially in tight spaces and during lane changes.

In this paper by Furkhan Abdul Khader [21] This article delves into the concept of a four-wheel steering system, also known as the Quadra steering system, for automobiles. It highlights the ability to steer both front and rear wheels based on speed and available turning space, aiming to enhance stability, handling, and control at higher speeds while providing ease during low-speed driving. Various steering mechanisms like Ackerman's and Davis steering mechanisms are explored in detail. Ackerman's steering geometry is designed to address the issue of inner and outer wheels needing to trace circles of different radii during turns. On the other hand, the Davis gear mechanism involves a cross link sliding parallel to another link and connected to the front wheels' stub axles. The article emphasizes how the four-wheel steering system offers superior cornering stability, improved responsiveness, smaller turning radius, and enhanced maneuverability compared to conventional two-wheel steering systems.

In this paper [22] delves into the analysis of rack and pinion steering mechanisms, particularly focusing on the stresses exerted on gear teeth when a load is applied through the rotation of the steering wheel. It compares the stress profiles of spur and helical gears to determine the preferable gear type. The study utilizes Solidworks software for modeling and Ansys for analysis. The research concludes that helical gears demonstrate lower maximum stresses compared to spur gears in this specific context. Rack and pinion steering mechanisms offer advantages in modern cars, providing a high level of feedback and direct steering feel. The document emphasizes the importance of understanding gear nomenclature, design considerations such as interference, and the modeling procedure for involute curves. Overall, the study sheds light on the mechanical intricacies of rack and pinion systems in steering mechanisms.

In this paper Mr. Krishna Bevinkatti [23] delves into the design of a cost-effective variable steering ratio mechanism with power assist for vehicles. Authored by Himanshu Singh, the study explores the concept of variable steering ratio, comparing steering mechanisms such as rack and pinion steering, recirculating ball type steering, Davis steering mechanism, and Ackermann steering mechanism. The research utilizes gears from Bajaj-Super and steering mechanism from Tata-Nano to construct the variable steering ratio mechanism. The results and discussions highlight the varying steering ratios achieved through gear engagement and emphasize the need for power assist to reduce steering effort. The study concludes that while the mechanism offers improved steering control, power assist is essential for practical application, with potential cost savings in rack and pinion manufacturing.

In this paper written by Wang et al [24] "NAVIGATING PRECISION: A COMPREHENSIVE EXAMINATION OF FSAE RACING CAR STEERING TRAPEZOID WITH ACKERMAN PRINCIPLE ANALYSIS" by Wang & Chen in the Klover Multidisciplinary Journal of Engineering investigates the steering trapezoid system of FSAE racing cars through an analysis of the Ackerman principle. The study likely explores how the Ackerman principle is utilized to enhance precision in steering, potentially shedding light on the design, functionality, and performance of steering mechanisms in FSAE racing cars. By delving into this aspect of racing car technology, the research may offer valuable insights for optimizing steering systems to improve overall performance and maneuverability in FSAE racing cars, contributing to advancements in the field of automotive engineering.

III. Methodology

Basic Geometry Involved

The car's inner and outer rear wheels do not move at the same rate as the entire vehicle. Steering is primarily concerned with pointing the wheels in the appropriate direction. Typically, many links, rods, pivots, and gears are required to accomplish this. The concept of caster angle involves employing a pivot point in front of each wheel to naturally center the steering in the direction of motion. To account for the fact that the steering linkages between the steering box and the wheels typically adhere to a version of Ackermann steering geometry, the degree of toe appropriate for driving straight lines is ineffective for turns as the inner wheel travels a path with a smaller radius than the outer wheel during a turn. The angle of the wheels to the vertical plane, together with the tires, impacts steering dynamics. Ariel Atom sports vehicles have a rack & pinion steering wheel. For high volume production, this is often put on the other side of the panel. The classic (non-assisted) steering box of an automobile allows for modifications to the braking and steering systems, as well as the frame's mounting system.

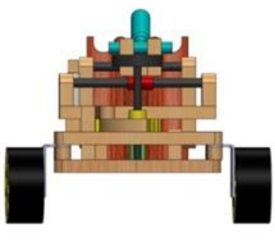
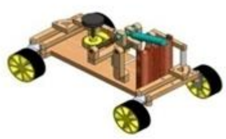
Design Considerations

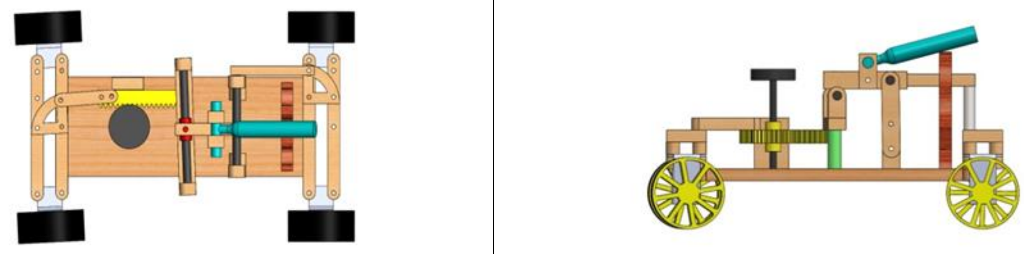
Several structural design considerations should be made for cost-effective and efficient manufacture. Many of these are applicable to alternative connecting techniques, and all apply to both subassemblies and the entire structure.

1. The gadget should be compatible with local manufacturing capabilities.
2. The attachment should use inexpensive materials and production processes.
3. It should be accessible and inexpensive to low-income populations and meet their fundamental requirement for mechanical power.
4. It should be easy to build, operate, maintain, and repair.
5. It should be as versatile as possible, supplying power to diverse agricultural equipment and small machines utilized in rural industries.
6. It should use locally accessible materials and expertise. Standard steel parts such as steel plates, iron rods, angle iron, and flat stock that are readily accessible should be utilized. Standard tools used in machine shops such as hacksaws, files, punches, taps & dies; medium duty welders; drill presses; small lathes, and milling machines should be suitable to create the parts needed for the dual-purpose bicycle.
7. It should employ standard parts whenever feasible.
8. The device should adjust readily. No permanent structural modifications should be done.
9. Excess weight should be minimized, as durability is a top priority.

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

Model validation

The study results obtained from the analysis of the Dual Axis Vehicle Steering Mechanism using SOLIDWORKS Simulation can have a significant impact on the design and performance of the steering mechanism in a dual-axis vehicle. Here are some ways in which the study results can influence the design and performance:

1. Stress Analysis The von Mises stress values obtained from the analysis provide insights into the distribution of stress within the steering mechanism components. High stress concentrations can indicate potential areas of failure or deformation. Design modifications can be made to reinforce these critical areas, improving the overall structural integrity and durability of the steering mechanism.

2. Displacement Analysis Understanding the displacement of various nodes in the steering mechanism helps in assessing how the components deform under applied loads. Excessive displacements can lead to misalignment or interference issues, affecting the functionality of the steering system. By optimizing the design based on displacement results, engineers can ensure proper operation and alignment of the components.

3. Reaction Forces and Moments Analyzing the reaction forces and moments provides valuable information on how external loads are distributed throughout the steering mechanism. By optimizing the design to handle these forces effectively, engineers can enhance the stability and performance of the dual-axis vehicle steering system.

4. Free Body Forces and Moments Understanding the internal forces and moments within the steering mechanism helps in evaluating the load-carrying capacity and structural behavior of the components. By considering free body forces and moments in the design process, engineers can optimize the geometry and material selection to minimize stress concentrations and improve overall performance.

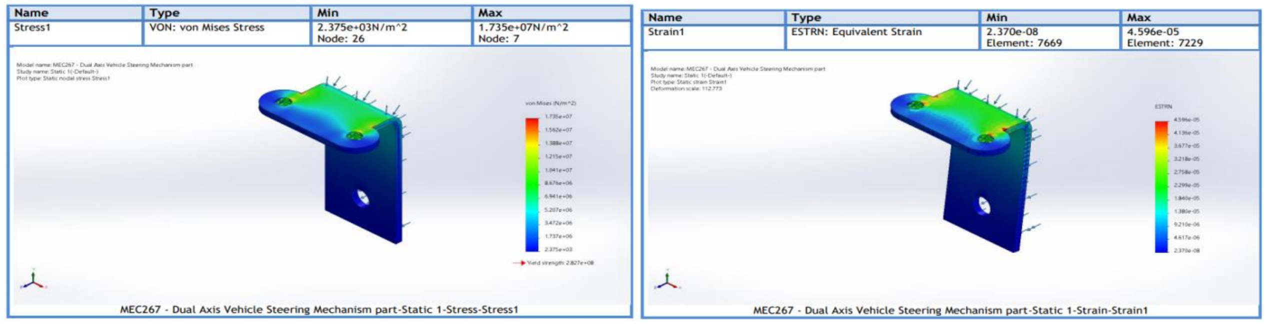
5. Design Optimization Based on the study results, design iterations can be performed to optimize the steering mechanism for improved performance, reliability, and efficiency. By making informed design decisions backed by simulation data, engineers can enhance the overall functionality and longevity of the dual-axis vehicle steering system.

6. Performance Validation The study results serve as a validation tool to ensure that the steering mechanism meets the performance requirements and safety standards. By comparing the simulation results with design specifications, engineers can verify the adequacy of the design and make necessary adjustments to enhance the performance of the steering system.

The study results from the analysis of the Dual Axis Vehicle Steering Mechanism play a crucial role in guiding design improvements, optimizing performance, and ensuring the reliability of the steering system in a dual-axis vehicle. By leveraging simulation data, engineers can make informed decisions to enhance the overall design and functionality of the steering mechanism.

IV. Results and discussions

Fig 2 Static Analysis of Wheel Mounting



Wheel mounting part

1. Properties
    - Mass: 0.0249694 kg
    - Volume: 3.17758e-06 m^3
    - Density: 7,858 kg/m^3
    - Weight: 0.2447 N
2. Study Properties
    - Study Name: Static 1
    - Analysis Type: Static
    - Mesh Type: Solid Mesh
    - Thermal Effect: On
    - Thermal Option: Include temperature loads
    - Zero Strain Temperature: 298 Kelvin
    - Solver Type: Automatic
    - Units:
    - Length/Displacement: mm
    - Temperature: Kelvin
    - Angular Velocity: Rad/sec
    - Pressure/Stress: N/m^2
4. Study Results
    - Stress Analysis:
    - Von Mises Stress:
    - Minimum: 2.375e+03 N/m^2
    - Maximum: 1.735e+07 N/m^2
    - Displacement Analysis:
    - Resultant Displacement:
    - Minimum: 0.000 mm
    - Maximum: 4.029 mm
5. Simulation Results:
    - Equivalent Strain:
    - Element 7669: 2.370e-08
    - Element 7229: 4.596e-05

These values and data points are crucial for understanding the behavior, performance, and structural integrity of the Dual Axis Vehicle Steering Mechanism under static loading conditions. The simulation results offer insights into stress distribution, displacement patterns, and overall response of the steering mechanism to applied loads, aiding in design optimization and performance enhancement.

Rack And Pinion

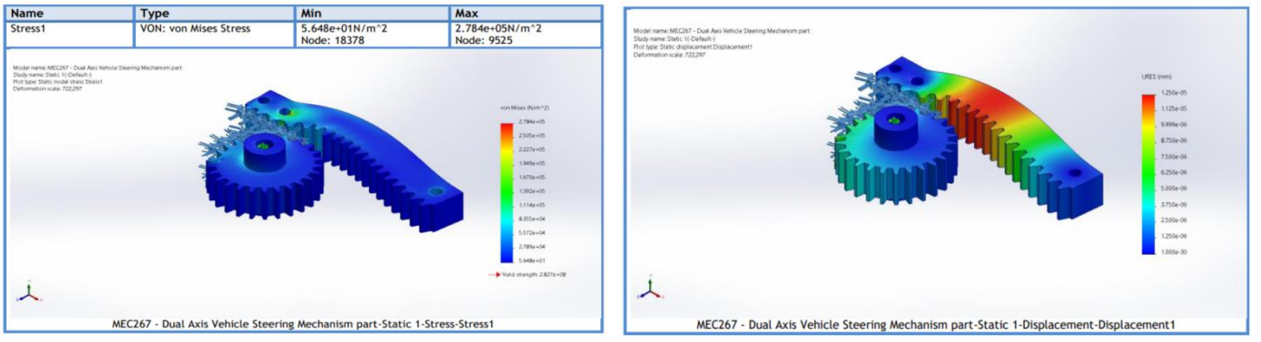


Fig 3 Static and Stress analysis of Rack and Pinion

1. Assumptions
   - The simulation model is named MEC267 - Dual Axis Vehicle Steering Mechanism part.
   - The model consists of two solid bodies: Plastic gear small-1-solid1 and Rack-1-solid1.
   - The properties of the solid bodies include mass, volume, density, and weight.
   - The material density used is 7,858 kg/m^3 for both solid bodies.
2. Material Properties
   - Material Name: 1023 Carbon Steel
   - Model Type: Linear Elastic Isotropic
   - Yield Strength: 2.82685e+08 N/m^2
   - Tensile Strength: 4.25e+08 N/m^2
   - Elastic Modulus: 2.05e+11 N/m^2
   - Poisson's Ratio: 0.29
   - Mass Density: 7,858 kg/m^3
   - Shear Modulus: 8e+10 N/m^2
   - Thermal Expansion Coefficient: 1.2e-05 /Kelvin
3. Study Properties
   - Study Name: Static 1
   - Analysis Type: Static
   - Mesh Type: Solid Mesh
   - Thermal Effect: On
   - Zero Strain Temperature: 298 Kelvin
   - Solver Type: Automatic
   - Compute Free Body Forces: On
   - Unit System: SI (MKS)
   - Length/Displacement: mm
   - Temperature: Kelvin
   - Angular Velocity: Rad/sec
   - Pressure/Stress: N/m^2
4. Mesh Information
   - Mesh Type: Solid Mesh
   - Mesher Used: Blended curvature-based mesh
   - Total Nodes: 21693
   - Total Elements: 13132

- Maximum Element Size: 0.119302 in
- Minimum Element Size: 0.0397669 in
- Maximum Aspect Ratio: 5.8182
- % of Elements with Aspect Ratio < 3: 93.5%
- % of Elements with Aspect Ratio > 10: 0%
- Time to Complete Mesh: 00:00:16

5.Study Results

- Stress1 (Von Mises Stress): Min = 5.648e+01 N/m^2, Max = 2.784e+05 N/m^2
- Displacement1 (Resultant Displacement): Min = 0.000e+00 mm, Max = 1.250e-05 mm

6. Resultant Forces

- Reaction Forces: X = -13.8537 N, Y = -8.05267e-05 N, Z = 7.99538 N, Resultant = 15.9954 N
- Free Body Forces: X = -3.67597e-05 N, Y = -5.81719e-05 N, Z = 0.000173133 N, Resultant = 0.000186307 N

These values and details provide a comprehensive overview of the simulation analysis conducted on the Dual Axis Vehicle Steering Mechanism part using SOLIDWORKS Simulation.

Slider Link

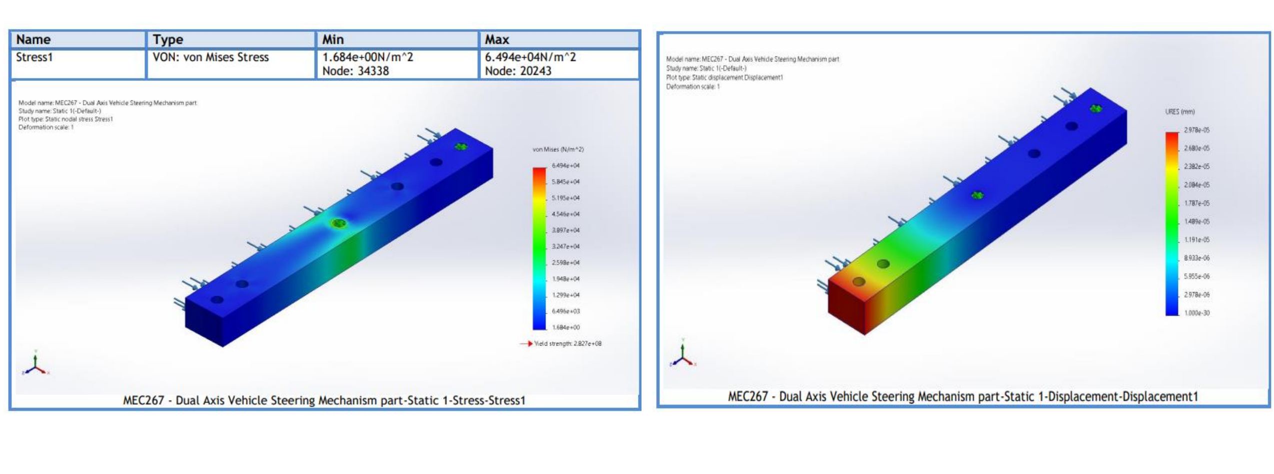


Fig 4 Static and Stress analysis of Slider Link

1.Assumptions

- The model name is "MEC267 - Dual Axis Vehicle Steering Mechanism part."
- The current configuration is set to Default.
- The solid body "Slider Link-1-solid1" has the following properties:
- Mass: 0.164976 kg
- Volume: 2.09946e-05 m^3
- Density: 7,858 kg/m^3
- Weight: 1.61676 N

2. Loads and Fixtures

- Fixture Details
- Fixture Name: Fixed-2
- Entities: 2 face(s)
- Type: Fixed Geometry
- Resultant Forces:
- Reaction Force (N): -0.999283 (X), -1.22236e-09 (Y), 0.0378582 (Z), Resultant: 1
- Reaction Moment (N.m): 0 (X, Y, Z)
- Load Details:

- Load Name: Force-5
- Entities: 1 face(s)
- Type: Apply normal force
- Value: 1 N

3. Study Properties

- Study Name: Static 1
- Analysis Type: Static
- Mesh Type: Solid Mesh
- Thermal Effect: On
- Thermal Option: Include temperature loads
- Zero Strain Temperature: 298 Kelvin
- Solver Type: Automatic
- Incompatible Bonding Options: Automatic
- Large Displacement: On
- Compute Free Body Forces: On
- Units:
- Unit System: SI (MKS)
- Length/Displacement: mm
- Temperature: Kelvin
- Angular Velocity: Rad/sec
- Pressure/Stress: N/m^2

4. Material Properties:

- Name: 1023 Carbon Steel Sheet (SS)
- Model Type: Linear Elastic Isotropic
- Default Failure Criterion: Max von Mises Stress
- Yield Strength: 2.82685e+08 N/m^2
- Tensile Strength: 4.25e+08 N/m^2
- Elastic Modulus: 2.05e+11 N/m^2
- Poisson's Ratio: 0.29
- Mass Density: 7,858 kg/m^3
- Shear Modulus: 8e+10 N/m^2
- Thermal Expansion Coefficient: 1.2e-05 /Kelvin

5. Study Results

- Stress Results:
- Name: Stress1
- Type: Von Mises Stress
- Min: 1.684e+00 N/m^2
- Max: 6.494e+04 N/m^2
- Displacement Results:
- Name: Displacement1
- Type: Resultant Displacement
- Min: 0.000e+00 mm
- Max: 2.978e-05 mm

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.

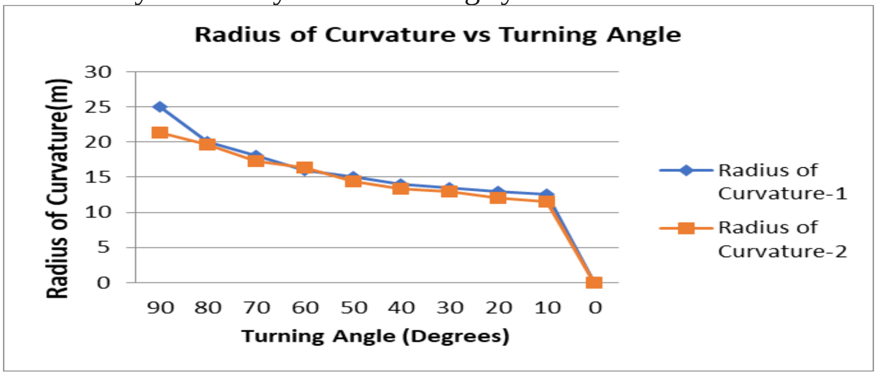


Figure 5 Radius of Curvature vs Turning Angle Graph

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.

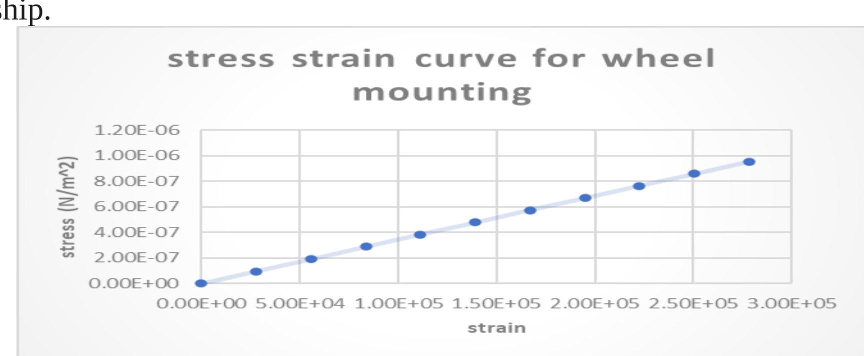


Figure 6 Stress Strain Curve for Wheel Mounting Graph

Fig shows the stress vs strain variation which is applied on vehicular wheel mounting for a load of 5N. It is observed that the type of stress applied is von Mises stress in which the minimum value is 2.375 x 10^3 N/m^2 and the maximum value is 1.735 x 10^7 N/m^2. Also, the equivalent strain is formed when the load is applied in which the minimum value is observed as 2.370 x 10^{-8} and the maximum value is 4.596 x 10^{-5}.

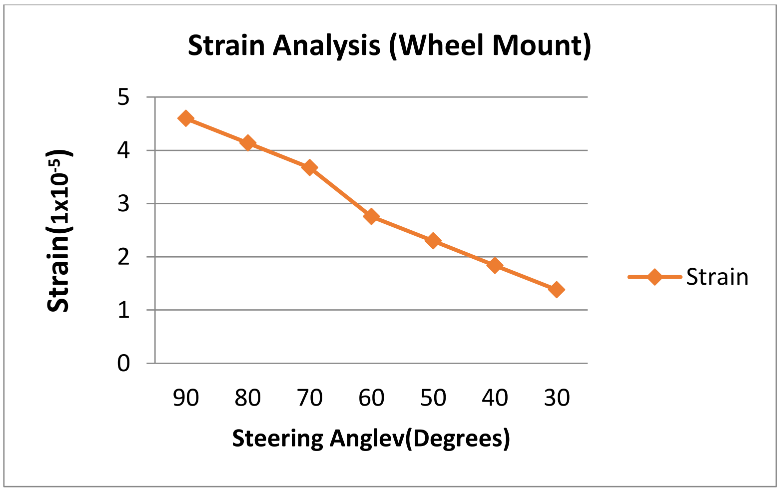


Figure 7 Strain Analysis (Wheel mount) Graph

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.

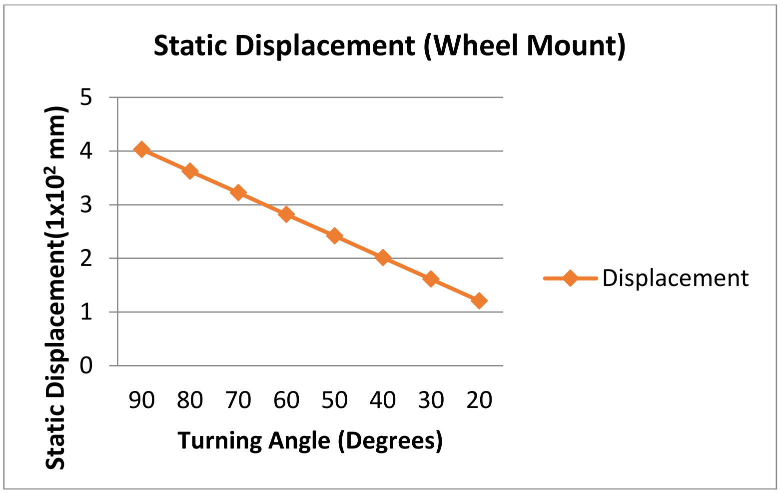


Figure 8 Static Displacement (Wheel Mount) Graph

The graph in the image depicts "Static Displacement (Wheel Mount)" with the x-axis labeled as "Turning Angle (Degrees)" ranging from 0 to 90 degrees. The y-axis is labeled as "Static Displacement (mm)" ranging from 0 to 4.5. It shows a pattern of increasing static displacement as the turning angle increases.

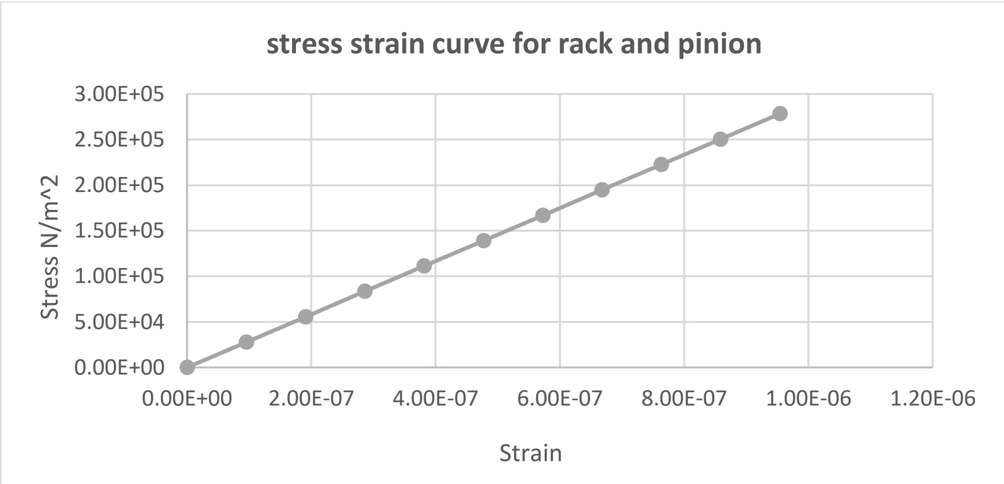


Figure 9 Stress Strain Curve for Rack and Pinion Graph

Fig shows the stress vs strain variation which is applied on vehicular wheel mounting for a load of 5N. It is observed that the type of stress applied is von Mises stress in which the minimum value is 5.648 x $10^1 N/m^2$ and the maximum value is 2.784 x $10^5 N/m^2$. Also, the equivalent strain is formed when the load is applied in which the minimum value is observed as 3.091 x 10^{-10} and the maximum value is 9.543 x 10^{-07}.

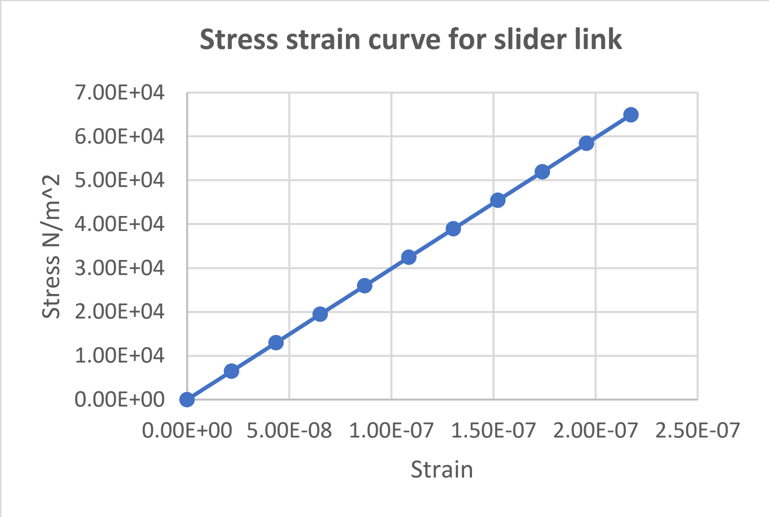


Figure 10 Stress Strain Curve for Slider Link Graph

Fig shows the stress vs strain variation which is applied on vehicular wheel mounting for a load of 5NAlso, the equivalent strain is formed when the load is applied in which the minimum value is observed as 2.125 x 10^{-11} and the maximum value is 2.174 x 10^{-7}.

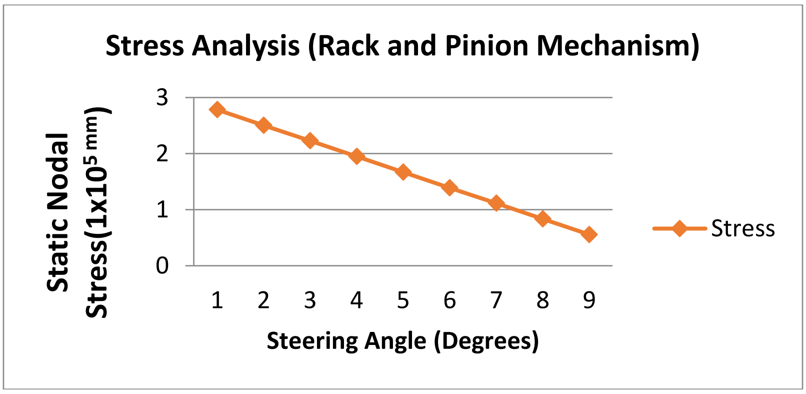


Figure 11 Stress Analysis (Rack and Pinion Mechanism) Graph

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.

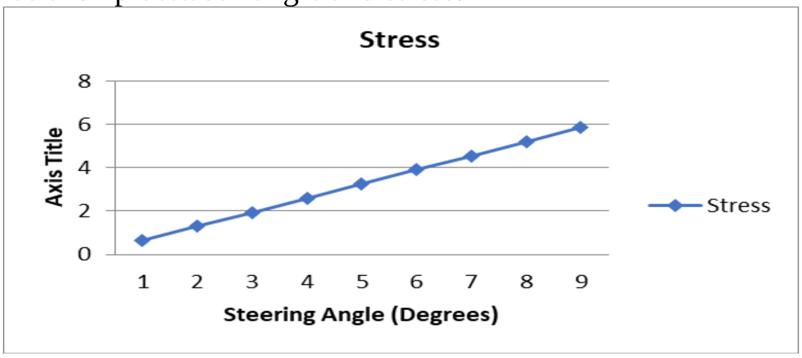


Figure 12 Stress Analysis (linkage) Graph

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

We calculated the turning circle radius of each wheel and the automobile before validating it. We use our draft to determine the inner lock angle (θif) of the front wheels. By Ackerman Mechanism :
$Sin(\alpha + \delta_{if}) = Y+X/R$
Where, α = Ackerman Angle
δ_{if} = Inside Lock Angle
Y = Arm Base
X = Linear Displacement of rack for one gyration
R = Ackerman Arm Radius
$Sin(13.640 + \delta_{if}) = 1.415+3.1/6$
$\delta_{if} = 35.160$
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,
$\delta_{if} = 35.160$
$\tan \delta_{if} = c_1 / R_1 - t_w/2$……………………………(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)
$Tan\ \delta_{of} = 3.09/(5.15+0.762)$
$\delta_{of} = Tan^{-1}[3.09/(5.15+0.762)]$

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

V.Conclusion

In conclusion, the implementation of Dual Axis Steering in vehicles presents a significant advancement in automotive technology, offering enhanced performance, stability, and maneuverability. By allowing the rear wheels to turn in coordination with the front wheels, this system reduces the turning radius, improves control during maneuvers, and enhances overall driving experience. The versatility of Dual Axis Steering extends its benefits to various vehicle types, including commercial vehicles, off-road vehicles, and passenger cars, catering to a wide range of driving needs. Through the use of advanced design tools like SolidWorks, the development and evaluation of Dual Axis Steering mechanisms can be conducted with precision and efficiency, ensuring structural integrity and optimal functionality. As safety awareness increases and demands for improved vehicle handling grow, the adoption of four-wheel steering systems like Dual Axis Steering is poised to revolutionize the automotive industry, offering drivers a more dynamic and responsive drive experience while maintaining stability and control in diverse driving conditions.

References

[1]. Loganathan VN, Abhijit M, Bharath G, Gowtham S, Dharoon V. (2023). Design and Fabrication of Dual-Axis Steering Mechanism. International Journal of Creative Research Thoughts (IJCRT), Volume 11, Issue 4, April 2023.
[2]. Kolekar, A. B., Mulani, S., Nerkar, A., & Borchate, S. (2017). Review on Steering Mechanism. IJSART, 3(4), 1155-1160.
[3]. Bae, B., & Lee, D.-H. (2023). Design of a Four-Wheel Steering Mobile Robot Platform and Adaptive Steering Control for Manual Operation. Electronics, 12, 3511.
[4]. Deepak, P., Reddy, S. V., Ramya, N., Goud, M. B., & Shekar, K. C. (2014). Design and Analysis of Three Wheeled Dual-Steering Vehicle. International Journal of Engineering Research & Technology, 3(4), 352-361.
[5]. Jadhav, V., Deshmukh, R., & Dongri, A. (2019). Design and simulation of 4-wheel steering system. International Journal Of Innovations in Engineering Research And Technology, 2394-3696.
[6]. Kuslits, M., & Bestle, D. (2018). Modelling and control of a new differential steering concept. Vehicle System Dynamics, 1–23.
[7]. Singh Gautam, E. N., & Awadhiya, P. (2007). Kinematic Synthesis of a Modified Ackermann Steering Mechanism for Automobiles. SAE Technical Paper Series.
[8]. Pradhan, D., Ganguly, K., Swain, B., & Roy, H. (2020). Optimal kinematic synthesis of 6 bar rack and pinion Ackerman steering linkage. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 235(6), 1660–1669.
[9]. Zhao, J. S., Liu, X., Feng, Z. J., & Dai, J. S. (2013). Design of an Ackermann-type steering mechanism. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 227(11), 2549-2562.

[10]. Zhao, J. S., Liu, X., Feng, Z. J., & Dai, J. S. (2013). Design of an Ackermann-type steering mechanism. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 227(11), 2549-2562.
[11]. Zehetbauer, F., Edelmann, J., & Plöchl, M. (2023). A minimal model to study self-excited vibrations of a tram wheelset in curves with small radius of curvature. Vehicle System Dynamics, 61(11), 2867-2887.
[12]. Sleesongsom, S., & Bureerat, S. (2020). Multi-objective, reliability-based design optimization of a steering linkage. Applied Sciences, 10(17), 5748.
[13]. Vanamala, U. M., & Koganti, R. R. (2013). An Innovative Design Concept of Four Wheel Steering Mechanism for an Automobile. In (2013-01-2845). SAE International Journal
[14]. Adolphus, S., Abraham, S., Martin, J. T., Nair, N. S., & Alexander, L. M. (2016). Dual Mode Four Wheel Steering System. International Journal for Innovative Research in Science & Technology, 2(12), 81-87.
[15]. Soni, A., & Nagpal, S. (2021). Study of Four-Wheel Steering Systems' Viability in Future Automobiles. International Journal of Engineering and Advanced Technology (IJEAST), 4, 265-270.
[16]. Sundar, S., Sudarsanan, T., & Krishnan, R. (n.d.). Review of Design and Fabrication of Four Wheel Steering System [Review of Design and Fabrication of Four Wheel Steering System]. Academia.edu
[17]. Singh, A., Kumar, A., Chaudhary, R., & Singh, R. C. (2014, February 01). Study of 4 Wheel Steering Systems to Reduce Turning Radius and Increase Stability. In Proceedings of the International Conference on Advance Research and Innovation (ICARI 2014) [Conference Proceedings]. Available from ResearchGate.net
[18]. Patil, S. S., & Patil, R. S. (n.d.). Design and Analysis of Three Wheeled Dual-Steering Vehicle. International Journal of Engineering Research & Technology (IJERT).
[19]. Ackermann, J. (1995). The steering geometry. *SAE Technical Paper Series* (No. 952421).
[20]. Kim, Y., & Kim, Y. (2015). Benefits of four-wheel steering for vehicle stability during high-speed lane changes. *Vehicle System Dynamics*, 53(11), 1627-1644. DOI: 10.1080/08944934.2015.1022282
[21]. ANALYSIS OF RACK AND PINION OF DAVIS STEERING MECHANISM (2018) Furkhan Abdul Khader 1, Shaik Sharosh2 1,2,3,4Student(BE) , Mechanical Eng. Dept., Muffakham Jah College of Engineering and Technology, India,
[22]. ANALYSIS OF RACK AND PINION OF DAVIS STEERING MECHANISM. Journal of Emerging Technologies and Innovative Research [JETIR].
[23]. Four wheel steering system for Automobile (2015)Mr. Krishna Bevinkatti Undergraduate Student / Dept. Of Mechanical Engg./VVPIET, Solapur University, Maharashtra India
[24]. Wang, L. J., & Chen, X. Y. (2024). NAVIGATING PRECISION: A COMPREHENSIVE EXAMINATION OF FSAE RACING CAR STEERING TRAPEZOID WITH ACKERMAN PRINCIPLE ANALYSIS. Klover Multidisciplinary Journal of Engineering, 12(1), 7-17.