International Research Journal of Education and Technology

Peer Reviewed Journal

ISSN 2581-7795

DESIGN AND OPTIMIZATION OF FRONT AXLE IN ELECTRIC UTILITY VEHICLE

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Abstract – *A front axle of the electric utility vehicle is a valuable asset while enhancing the performance, safety, and efficiency of the vehicle. As the utility applications of electric mobility solutions gain traction, there is increasing demand for lightweight and strong front axle designs that would be cost-efficient. This paper focuses on an overall view for the design and optimization of the front axles for EUVs while considering some vital aspects such as load bearing, weight, strength, and fitment with the vehicle suspension system. Optimization and other advanced computational methods are employed to address the load conditions that will further the axle design in relation to its geometry, material selection and overall structural stability. To achieve weight goals that will enhance energy efficiency and handling, alternative material such as aluminium alloys are proposed. The optimization step integrates fatigue studies and safety in the design – the goal is to achieve reliable and efficient structures. After which there can be comparisons based on load bearing ability, energy efficiencies, and ride comfort. The findings indicate that effective optimization of the proximal structures has a significant positive effect on the overall performance..*

***Key Words*: Strength and Durability, Lightweight Material, Front Axle, Electric Utility Vehicle, vehicle performance, Fusion.**

1.INTRODUCTION

The front axle is a vital part of a vehicle's drivetrain, electric utility vehicle (EUV) additionally included, and suspension systems. Positioned at the front of the vehicle, it serves as a structural support for the vehicle suspensions, steering controls, and wheel alignment by transmitting the load from the vehicle chassis to the wheels. Generally, in a conventional internal combustion engine (ICE) vehicle, the front axle would be subject to supporting the engine and transmission in the exertion of effort via the wheels. In contrast, in electric vehicles (EV), including EUVs, this front axle works with a lesser amount of energy, as shaped by changes in the configurations of drivetrains, such as the electric motor placement, which could either be in the front or the rear or possibly being integrated directly into the wheel hubs.

1.1 Construction and Operation

Front axle is made of I-section in the middle portion and circular or elliptical section at the ends. The special x-section of the axle makes it able to withstand bending loads due to weight of the vehicle and torque applied due to braking. On kind of front axle which consists of main beam, stub axle, and swivel pin, etc. The wheels are mounted on stub axles. The front axle has sufficiently rigidly and strength to transmit the weight of the vehicle from springs to the front wheels. The ends of the axle beam are shaped suitably assemble the stub axle. The ends of the beam are usually shaped either as yoke or plain surface with drilled hole in order to accommodate a swivel pin for connecting the stub axle assembly. A front axle beam is a suspension system, also called a solid axle, in which one set of wheels is connected laterally by a single beam or shaft. A front axle beam that does not transmit power is sometimes called a dead axle. Front axles are typically suspended either by leaf springs or coil springs.

1.2 Material Selection

Selection of materials consist of aluminum alloy for their strength, light, and durable other materials which are used for reducing vehicle weight and improving performance and durability of the vehicle.

Material properties

Material	Aluminum A365 T6
Density	2.670E-06 kg/mm^3
Young's modulus	72.40 GPa
Poisson ratio	0.33
Yield strength	165.00 MPa
Ultimate strength	234.00 MPa
Thermal conductivity	0.151 W/(mm C)
Thermal expansion	2.140E – 05 /C
Specific heat capacity	963.00 J/(Kg C)

1.2. OVERVIEW OF FRONT AXLE

International Research Journal of Education and Technology
Peer Reviewed Journal
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The front axle part is an important place in car suspension and steering, it is located at each side of the car respectively, used to support weight of car, maintain wheels rotating and attach the wheel to the car frame. It takes care of vehicle dynamics, handling, and safety. It is usually located in the front of the car and drives the left and right sides of the car to allow steering by the vehicle.

2. LITERATURE REVIEW

[1] M. J. López and F. R. Granados (2017), in their work on "Active Front Axles in Modern Automotive Engineering," pursued the application of active systems on the front axles. Different control systems for electronically and mechanically changing the performance of the axle with respect to road conditions in real time were reviewed. Such active axles were reported to change suspension parameters and improve torque distribution; these are finding applications even in luxury and high-performance vehicles.

[2] L. F. M. Rodrigues (2020), "Electric Axles for Electric Vehicles: Design and Integration" is a long discussion of the growing trend in the deployment of an electric front axle in electric vehicles. Rodrigues et al. observed that such axles not only provide an upgrade to the traditional and mechanical functions of axles but also supply electric motors and reduce the need for an independent drivetrain. The study had observed electric axles have an excellent combination of service, weight reduction, and space utilization, thereby making them suitable for an EV.

[3] D. W. Shaw and J. R. Dutton (2019) suggested new challenges for axle design in their writing "Challenges in Axle Design for Electric and Autonomous Vehicles," presenting the difficulties technology has presented to the automobile industry. Transitioning towards electric vehicles (EVs) and self-driving systems, Shaw and Dutton believed that traditional axle designs would require complete revamping. They believed that future front axles need to combine electric motors in the drive transmitting and sensors for self-driving. This requirement, combined with the ever-increasing drive towards sustainability, provides new initiatives for future axle designs that increase efficiency, integration, and performance.

3. METHODOLOGY

KEY ASPECTS OF FRONT AXLE DESIGN

1. MATERIAL SELECTION: choosing the right material for the front axle based on strength, weight and cost.
2. SIMULATION AND STRESS ANALYSIS: to simulate how the front axle respond to stress and load capacity. This ensures the durability and safety under real world conditions.
3. OPTIMIZATION: Reducing the weight is crucial for improving vehicle's weight distribution and performance, cost efficiency.
4. SAFETY CONSIDERATIONS: importance of the front axle to vehicle safety is paramount because it affects the handling, stability, and organizing of the vehicle. Proper design, manufacture, and maintenance of the front axle are deemed to be of paramount importance in assuring safety for the vehicle and its occupants.

4. MODELING AND SIMULATION

In this project, a 3D CAD model was developed using fusion 360, a comprehensive tool widely used in mechanical engineering for its precision and robust simulation capabilities. Fusion 360combines design and optimization functionalities, allowing us to create evaluate our mode within a single platform.

After the design phase, we completed the analysis directly in fusion 360. This streamlined approach enabled us to perform an in-depth simulation to understand the model performance under real world conditions.

FIG 1: Front view

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FIG 2: Top view

International Research Journal of Education and Technology

Peer Reviewed Journal

ISSN 2581-7795

FIG 3: FRONT VIEW MESHING

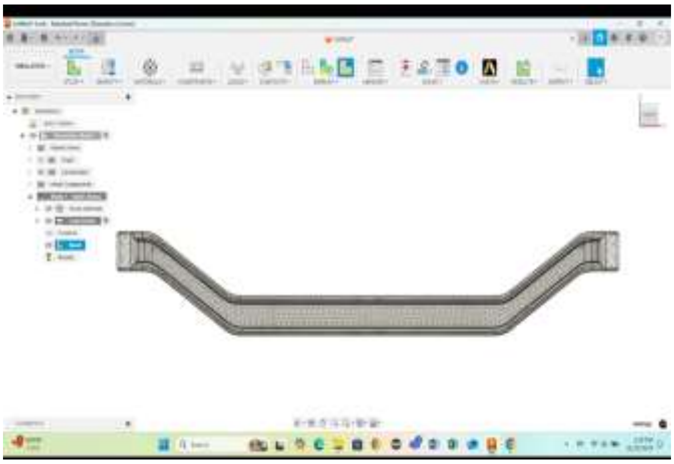

FIG 4: TOP VIEW MESHING

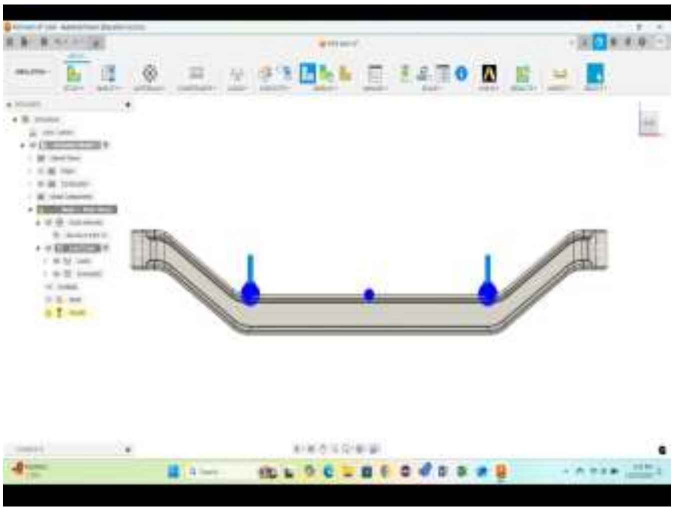

FIG 5: LOAD CAPACITY

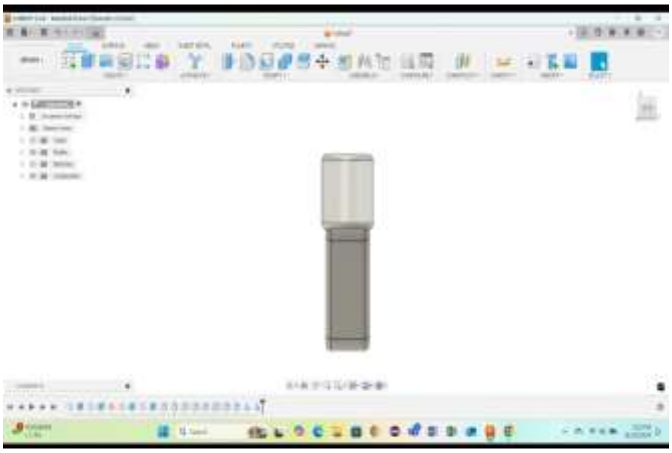

FIG 6

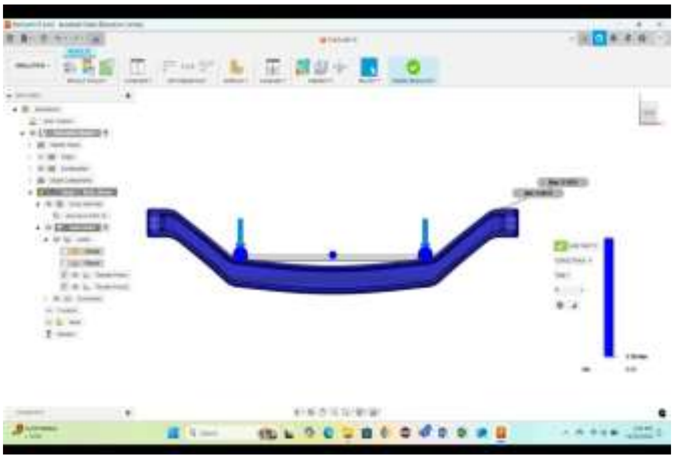

FIG 7: LOAD ANALYSIS

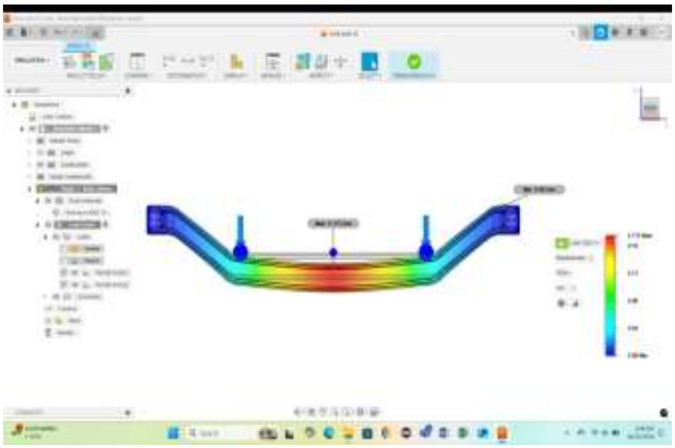

FIG 8: STATIC STRESS ANALYSIS

Fusion 360's integrated simulation capabilities, we streamlined the workflow by completing both the design and analysis phases within a single platform, eliminating the need for additional software. This efficient approach allowed us to assess the model's real-world performance under various conditions directly in Fusion 360.

The simulation process involved setting boundary conditions and applying realistic load scenarios to analyze stress distribution and load capacity throughout the model. This provided critical insights into areas of potential weakness or high-stress concentration, essential for ..

5.CALCULATIONS

Weight calculations

Total weight of axle = 9108.58 N

Weight of each spring seat=9108.58/2

=4554.29N

Vertical Deflection at spring pad

$$Y_c = w*a^2(3L-4a)/6EI \text{ (mm)}$$

Deflection at center of beam (max deflection)

$$Y_{max} = w*a\,(3L^2-4a^2)/24EI \text{ (mm)}$$

Axle load calculations

$$\text{Axle load} = \frac{\text{gross vehicle weight} \times \text{weight distribution}}{\text{Number of axles}}$$

6. CONCLUSIONS

This research project, titled "Design and Optimization of the Front Axle for Electric Utility Vehicles," offers powerful insights into the functional optimization of a key vehicle component to meet the specific requirements of electric utility vehicles. The project targets key challenges like lowering weight, improving structural integrity and making it cost-effective while optimising performance and longevity of the vehicle using advanced design and simulation tools like Fusion 360. The new optimized front-axle design will help make EVs more competitive.

ACKNOWLEDGEMENT

We sincerely thank our internal guide, Mr. N. Yadagiri, for his valuable advice and encouragement throughout this project. Our gratitude also extends to Dr. B. Vijaya Kumar, Professor and Head of the Mechanical Department, for his expert supervision and insightful suggestions. We appreciate Principal Dr. Koduganti Venkata Rao and the management for providing the necessary facilities. Additionally, we thank the Mechanical Engineering staff and lab technicians for their assistance.

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