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Dynamic Investigation of Electric Vehicle Suspension System Using Solid Works and ANSYS Software

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Abstract: The suspension system affects ride comfort, handling, and safety. Optimizing suspension systems to improve rider experience and boost electric car and bike adoption is crucial as their popularity grows. ANSYS Finite Element Analysis (FEA) can analyze and optimize suspension designs for electric automobiles and bikes. FEA with ANSYS suspension system analysis and optimization is covered in this study. Electric vehicles' lower centre of gravity and variable load distribution make suspension analysis unusual, as the introduction states. Stress distribution, deformation, natural frequencies, and mode shapes analysis are described in FEA for suspension behavior. Performance, weight reduction, resource efficiency, quicker development cycles, and cost reductions are further highlighted by suspension design improvement. The paper examines multi-objective optimization, computational resource constraints, model complexity, and real-world variability as optimization difficulties. The effects of suspension system design and optimization on future electric cars and bikes are examined, highlighting the relevance of optimized suspensions in improving driving experiences and promoting electric vehicles as eco-friendly transportation solutions.
Keywords: Suspension system, Electric vehicle, Finite Element Analysis (FEA), ANSYS, Optimization, Ride comfort, Handling performance, Stress distribution, Deformation, Natural frequencies, Mode shapes.

I. INTRODUCTION

Electric vehicles (EVs) have become a potentially effective way to address the environmental issues with the conventional internal combustion engine vehicles. As the automobile sec to transitions towards sustainable mobility, the activity and safety of electric vehicles, have become paramount concerns. A critical component that significantly influences the ride comfort, handling, and overall safety is that an electric cares its suspension system. The suspension system is accountable for maintaining tire contact with the road, absorbing shocks from uneven surfaces, and providing stability during cornering and braking manoeuvres. Therefore, a thorough dynamic Assessment of the suspension system is crucial to ensure its optimal functionality and performance. In recent years, advances in CAD programs such as Solid Works have revolutionized the way engineers design and visualize complex mechanical systems. With its user-friendly interface and powerful modelling capabilities, Solid Works facilitates making something detailed 3D models of the suspension components, such as control arms, shock absorbers, springs, and bushings. These CAD models serve as the basis for subsequent simulation and analysis using ANSYS.

Before conducting the dynamic analysis, we need to establish the material properties and boundary conditions for the suspension components. Material properties, such as elastic modulus, Poisson's ratio, and density, will play a vital role in determining how the components respond to the applied loads. Additionally, the correct definition of boundary conditions, such as mounting points and constraints, ensures that the simulation replicates the actual operating conditions of the suspension system.

This study will consider a range of dynamic loading conditions to comprehensively evaluate the suspension system's performance. Static loads will help us understand how the system behaves under the vehicle's weight, while road irregularities will simulate the effect of bumps, potholes, and other surface imperfections. During cornering, lateral forces act on the suspension, and braking and acceleration introduce transient loads that affect the system's response. Analyzing these scenarios will provide us with a holistic understanding of the suspension system's capabilities and limitations.

The outcomes of this study will not only contribute to the design and optimization of the specific electric vehicle suspension system also provide insightful information for the broader automotive industry. The information from this research can be utilized to improve ride quality, stability, and safety of EVs, thereby accelerating the adoption of sustainable transportation solutions.

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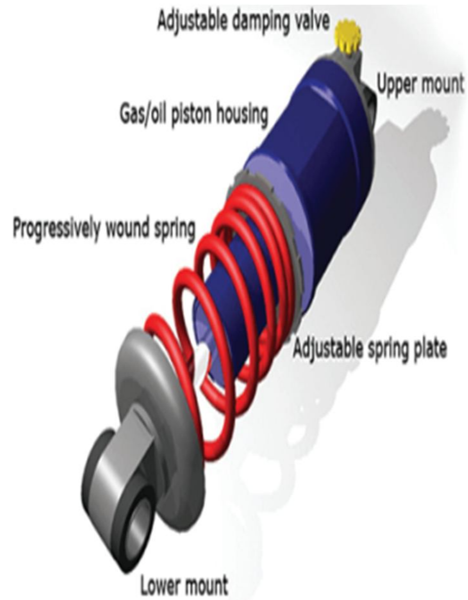

Figure 1 Shock Absorber and its Parts

II. LITERATURE REVIEW

The literature review gives a thorough description of existing research and studies related to the dynamic analysis of suspension systems for electric vehicles. This section aims to summarize key findings, methodologies, and advancements in the field, highlighting what's important about suspension system analysis in optimizing electric vehicle performance, safety, and comfort.

A. *Importance Of Suspension System Analysis In Electric Vehicles*

Electric vehicles are unique from other types of vehicles. from conventional combustible internal combustion engines in several ways, including their weight distribution and power train characteristics. As EVs often have heavy battery packs positioned at different locations, the design and behavior of the suspension system play a crucial role in maintaining vehicle stability, ride comfort, and safety. Studies have shown that a well-designed suspension system can significantly improve EV handling, reduce energy consumption, and increase tire longevity, making suspension analysis an essential aspect of electric vehicle engineering.

B. *Modeling And Simulation Techniques*

Numerous researchers have utilized advanced modeling and simulation techniques to analyze suspension systems for electric vehicles. Finite Element Analysis (FEA) is a frequently used technique for assessing the structural integrity and dynamic the's actions the suspension components. FEA allows engineers to predict stress distributions, deformations, and performance characteristics under different loading conditions, leading to more informed design decisions.

C. *Multi-Body Dynamics Simulations*

Multi-body dynamics simulations are yet another widely utilized method tostudy the interaction between various suspension components and the overall vehicle behavior. This technique considers the effects of inertia, tire forces, and road inputs to model the suspension system's dynamic response accurately.

D. *Suspension Geometry And Kinematics*

The geometric layout and kinematics of a suspension system significantly influence the vehicle's handling and ride quality. Several Research has looked into the effects of different suspension geometries.

E. *Material Selection And Optimization*

Choosing appropriate materials for suspension components is essential to ensure durability and performance. Studies have explored the use of advanced materials, such as lightweight alloys, composites, and high-strength steels.

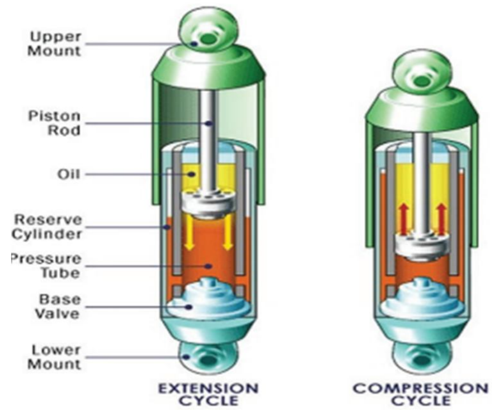

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Figure 2 Working Principle of a Shock Absorber

III. SUSPENSION SYSTEM DESIGN AND CAD MODELING

The suspension system of an electric vehicle (EV) is a critical component that influences ride comfort, handling, and safety. Designing an effective suspension system involves a complex interplay of various mechanical components, such as control arms, shock absorbers, springs, and bushings. This section focuses on the design of shock absorber as the main component of suspension system design process and how Computer-Aided Design (CAD) modeling using software like Solid Works plays a pivotal role in visualizing, optimizing, and refining the suspension components.

1) Suspension Design Considerations
2) Vehicle Weight
3) Ride Comfort
4) Handling and Stability
5) Durability
6) CAD Modelling using Solid Works
7) Geometry Creation
8) Material Selection

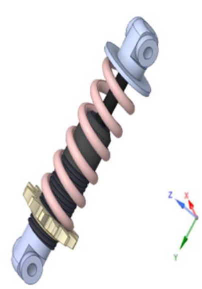

Figure 3 Assembled Model of Shock Absorber in SOLIDWORKS

IV. MATERIAL PROPERTIES AND BOUNDARY CONDITIONS

Material properties and boundary conditions are crucial aspects of dynamic analysis in suspension system design for electric vehicles. Selecting appropriate materials for suspension components and defining accurate boundary Conditions must be metto ensure the suspension system’s structural integrity and performance.

This section explores the significance of material properties and boundary conditions in suspension design, the process of material selection, and the impact of boundary conditions on simulation accuracy.

A. Material Properties In Suspension System Design

The selection of materials plays a crucial role in determining the behavior, durability, and weight of the suspension system. Various suspension components, including control arms, shock absorbers, springs, and bushings, necessitate specific mechanical properties of materials in order to achieve optimal performance.

B. Key Material Properties To Consider Include

The elastic modulus is a measure of a material's inherent rigidity or ability to withstand deformation when subjected to external forces. Elements that are subjected to substantial stresses and need to retain their shape benefit from having higher elastic module.

C. Corrosion Resistance

Electric vehicles often operate in diverse environments, including regions with harsh weather conditions. Using materials that are highly resistant to corrosions critical for maintaining the suspension system's integrity over the vehicle's lifetime.

D. Material Selection Process

The material selection process involves identifying suitable materials based on their mechanical properties, cost, availability, and manufacturability. Engineers must also consider the environmental impact and sustainability of the chosen materials.

E. Boundary Conditions In Suspension Analysis

Boundary circumstances are constraints applied to the suspension system during finite element analysis (FEA). It is crucial to have accurate boundary conditions. to replicate real-world operating conditions and obtain reliable simulation results.

F. Sensitivity Analysis

Conducting sensitivity analysis is a crucial step in evaluating the impact of material attributes and boundary conditions on the behaviour of the suspension system. Parametric studies can be conducted by engineers through the manipulation of material properties and boundary conditions in order to get insights into their influence on various parameters such as stress distribution, deflection, and natural frequencies.

V. FEA ANALYSIS OF SHOCK ABSORBER USING ANSYS

The integration of computer-aided design (CAD) modeling and finite element analysis (FEA) is of paramount importance in establishing precise material characteristics and boundary conditions. Computer-aided design (CAD) models play a crucial role in finite element analysis (FEA) simulations by guaranteeing the precise representation of geometry and component interactions in the analysis. The initial stage of the analytical procedure involves the careful selection of suitable materials.

A. Selection Of Appropriate Material Properties For The Suspension Components

When building a suspension system for electric vehicles that is both high-performing and reliable, one of the most important aspects to consider is the selection of appropriate material qualities for the suspension components. Each component of the suspension system, including control arms, shock absorbers, springs, and bushings, must have particular mechanical qualities in order to be able to withstand the forces and loads that are applied to the vehicle while it is in use. In this section, we will investigate the factors that play a role in the selection of the material, as well as the primary material characteristics that are taken into consideration while designing the various suspension components.

B. Factors Influencing Material Selection:

Several factors influence the selection of materials for suspension components:

1) Mechanical Properties
2) Weight Reduction
3) Fatigue Resistance
4) Corrosion Resistance
5) Environmental Impact

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C. Definition Of Boundary Circumstances For Theanalysis, Including Mounting Points And Constraints

Boundary conditions play a crucial role in the dynamic analysis of suspension systems for electric vehicles. They are essential constraints applied to the suspension components during finite element analysis (FEA) to replicate real-world operating conditions accurately. This section discusses the key aspects of defining boundary conditions, including mounting points and constraints, in suspension analysis.

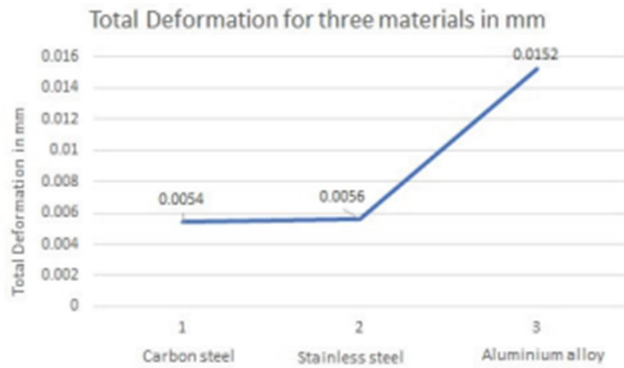

Figure 4 Total Deformation Graph for Different Materials

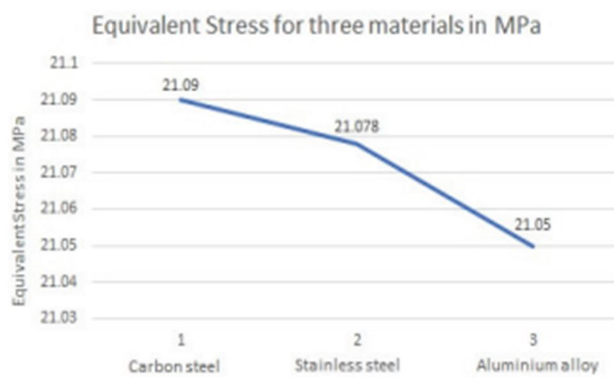

Figure 5 Equivalent Stress Graph for Different Materials

D. Constraints

Constraints in suspension analysis are used to restrict certain degrees of freedom for the suspension components. The constraints applied to the model depend on the type of suspension and the specific behaviour to be analysed.

In addition to static loading conditions, suspension systems experience dynamic loading during vehicle operation. establishing suitable border conditions for dynamic loads, such as cornering, braking, and acceleration forces, to be important accurately assessing the suspension system's behavior under different driving scenarios.

E. Sensitivity Analysis

Engineers may do sensitivity analysis to comprehend the impact of boundary conditions on the behavior of suspension systems. Sensitivity analysis entails the manipulation of boundary conditions within permissible ranges to assess their influence on the outcomes of a simulation. This aids in the identification of crucial boundary conditions and their impact on the operation of suspension systems.

VI. DYNAMIC LOADING CONDITIONS

Dynamic loading conditions are an essential aspect of analyzing suspension systems for electric vehicles. Unlike static loads that act on the suspension components when the vehicle is at rest, dynamic loads simulate the real-world driving scenarios and maneuvers that the suspension system encounters during operation. This section explores the various dynamic loading conditions used in suspension analysis, including road irregularities, cornering, braking, and acceleration forces, and their significance in evaluating the performance and safety of electric vehicle suspensions.

Road irregularities, such as bumps, potholes, and undulations, pose significant challenges with relation to the suspension system.
As the vehicle travels over uneven road surfaces, the suspension components experience varying vertical forces and deflections. Road irregularities can induce high-frequency vibrations and dynamic loads, which impact ride comfort and vehicle stability. Simulating road irregularities in suspension analysis involves applying transient loads to the suspension system to mimic the vehicle's response to road disturbances. Engineers can use various road profiles and excitation inputs to assess the suspension's ability to absorb shocks and maintain tire contact with the road surface.
By analyzing dynamic loading conditions, engineers can optimize the suspension geometry, adjust damping characteristics, and fine-tune control algorithms to achieve desired vehicle handling and ride quality. Additionally, engineers can study the impact of different suspension configurations, such as double-wishbone, multi-link, or McPherson strut, on vehicle dynamics and choose the most suitable layout for specific driving scenarios.
While simulation provides valuable insights, real-world testing and validation are essential to verify the accuracy of the analysis and the suspension system's actual performance. Physical testing on test tracks or proving grounds allows engineers to confirm the behavior observed in simulations and make necessary adjustments to the suspension design.

VII. UTILIZING ANSYS FOR FINITE ELEMENT ANALYSIS (FEA)

Finite Element Analysis (FEA) is a powerful numerical simulation technique used to analyze and predict the behavior of complex engineering structures, such as suspension systems in electric vehicles. ANSYS, a widely used commercial software suite, provides a comprehensive set of tools for performing FEA simulations. This section explores the fundamentals of FEA using ANSYS, its applications in suspension analysis for electric vehicles, and the benefits it offers in optimizing suspension design and performance.
The comprehension of Finite Element Analysis (FEA):The analysis being conducted is a finite element analysis. A numerical technique that decomposes a complex structure into smaller, interrelated components known as finite elements. The mechanical behavior of these elements is described by mathematical formulae. Through the process of solving these equations, Finite Element Analysis (FEA) is able to compute the displacements, stresses, strains, and several other mechanical properties pertaining to the entirety of the structure. This procedure enables engineers to assess the reaction of the structure to different loads and boundary conditions, offering valuable insights into its performance and safety.

A. ANSYS: An Overview

ANSYS is a leading engineering simulation software package that provides a wide range of tools for structural analysis, fluid dynamics, electromagnetic simulations, and more. Within the realm of structural analysis, ANSYS offers capabilities for static, dynamic, thermal, and nonlinear simulations. The software employs the finite element method to solve complex engineering problems and has become a standard tool in industries such as automotive, aerospace, and mechanical engineering.

B. Challenges In FEA Using ANSYS

While FEA using ANSYS offers numerous advantages, it also presents some challenges:

1) Meshing Complexity: Generating an appropriate mesh for complex suspension geometries may require careful consideration and effort to strike a balance between accuracy and computational efficiency.
2) Convergence Issues: In some cases, FEA simulations may encounter convergence difficulties, particularly in nonlinear analyses or when modeling contact between components.
3) Material Characterization: Accurate material data is crucial for reliable simulations. Obtaining material properties and accurately characterizing material behavior can be challenging, particularly for advanced materials.

VIII. RESULTS AND ANALYSIS

In suspension utilizing Finite Element Analysis for analysis(FEA) with ANSYS, the simulation Results give important information on thebehavior and performance of the suspension system for electric vehicles. This section explores the results and analysis obtained from FEA simulations, including stress distribution, deformation, natural frequencies, ride comfort, handling characteristics, and other performance metrics. The interpretation of these results helps engineers optimize the suspension design, ensuring safety, comfort, and efficiency for electric vehicles.
The present study employed finite element analysis (FEA) through the utilization of ANSYS Workbench to examine the structural response of the component when subjected to static loading conditions. The primary objective of the analysis was to examine the overall deformation, equivalent stress, and distribution of elastic strain within the component.

A. Total Deformation

The investigation yielded a maximum overall deformation of 6.3648e-7 units. The term "total deformation" is used to describe the whole movement of a component under stresses. The low overall deformation here suggests that the component's structural integrity has been largely preserved, and that it will continue to show high levels of mechanical stability under the applied loads.

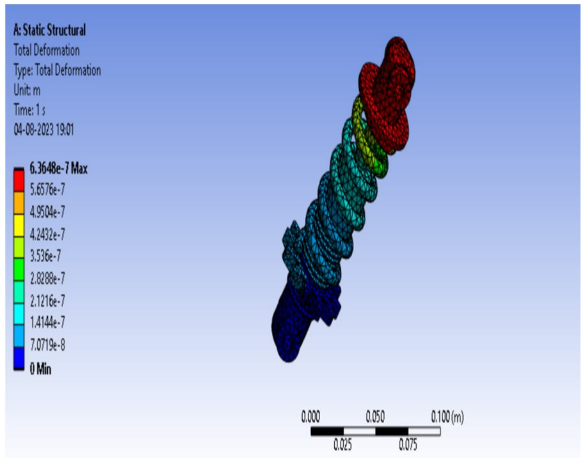

Figure 6 Total Deformation

B. Equivalent Stress

The direct stress as well as the influence of shear stress are taken into consideration in the calculation of the equivalent stress, which is an important quantity that shows the degree of stress in the component. According to the findings of the investigation, the highest equivalent stress was found to be 2.221e6 units. The amplitude of the equivalent stress is an important feature to consider when evaluating the structural integrity of the component since it assists in locating potential locations within the component that may be susceptible to yielding or failure.

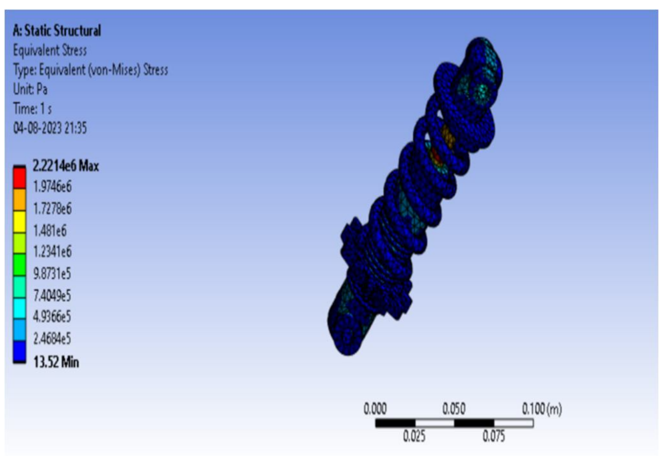

Figure 7 Equivalent Stress

C. Elastic Strain

The maximum elastic strain recorded in the analysis was found to be 1.13e-5 units. Elastic strain refers to the reversible deformation experienced by the material when subjected to external loads. Unlike plastic strain, elastic strain disappears once the load is removed, and the material returns to its original shape.

The low value of elastic strain observed in the component indicates that's it predominantly experiencing elastic deformation, which is desirable as it ensures that the component can maintain its shape and dimensions even after experiencing the applied loads. This behavior is essential in applications where precision and repeatability are crucial.

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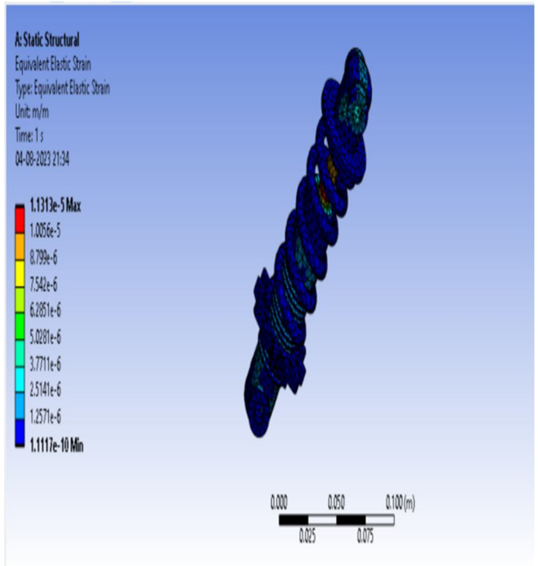

Figure 8 Elastic Strain

D. Comparison with Design Criteria

In order to evaluate the sufficiency of the component's design, the maximum values of total deformation, equivalent stress, and elastic strain were compared to preset design limitations and industry standards. If the maximum values of a component are significantly lower than the prescribed limits, it signifies that the component satisfies the design criteria and can be deemed as safe for its intended application.

In addition, the implementation of a sensitivity analysis can facilitate the identification of crucial parameters and enable the optimization of the design in order to attain enhanced performance or reduced costs.

IX. DISCUSSION

The results acquired from the finite element analysis using ANSYS Workbench provide valuable insights into the structural behavior of the component under static loading conditions. The discussion will focus on interpreting the findings, analyzing potential implications, and considering the limitations of the analysis.

A. Structural Integrity

The low maximum total deformation of 6.3648e-7 units indicates that the component is relatively rigid and can withstand the applied loads without significant deformation. This is a positive sign for the structural integrity of the component, as it suggests that there will be minimal changes in the component's shape and dimensions during operation. However, It's crucial to remember that total deformation should be assessed relative to the component's size and application requirements to ensure that even small deformations do not cause issues.

B. Stress Distribution

The maximum equivalent stress value of 2.221e6 MPa warrants attention, as it indicates the regions in the component where stress is most concentrated. High stress regions may lead to premature failure or plastic deformation of the material, potentially compromising the component's performance and safety. Further analysis should be conducted to identify stress concentration areas and consider design modifications or material changes to alleviate stress concentrations.

C. Material Behaviour

The maximum elastic strain of 1.13e-5 units suggests that the component mainly experiences elastic deformation under the applied loads. This behavior is desirable as it ensures that the component can return to its original shape when the load is removed, avoiding any permanent deformations that could impact its performance. However, it is crucial to consider the material's elastic limit and its ability to withstand repeated loading cycles to avoid fatigue-related failures.

D. Design Optimization

The results of the analysis present an opportunity for design optimization. By identifying stress concentration areas and areas experiencing higher deformations, engineers can modify the component's geometry or consider alternative materials to improve its performance and longevity. It is intended to design a component that not only meets safety requirements but also offers optimal efficiency and durability.

E. Limitations

It is essential to acknowledge the limitations of the current analysis. The assumptions made in the modeling process, such as material properties, boundary conditions, and geometric simplifications, may not fully represent the real-world scenario. Additionally, the static loading conditions considered in this study may not capture dynamic repercussions that could take place while actual operating conditions.

X. CONCLUSION

The suspension system holds a crucial role in the design of cars, particularly in the case of electric vehicles. With the increasing popularity of electric vehicles in the automotive sector, it has become imperative to optimize suspension systems in order to guarantee safety, enhance ride comfort, and improve handling performance. The utilization of Finite Element Analysis (FEA) through the ANSYS software platform has demonstrated its significance as a beneficial instrument for the examination and enhancement of suspension systems in the context of electric vehicles. This approach provides a thorough comprehension of the system's performance across diverse dynamic loading scenarios.

This article delved into the comprehensive examination and refinement of suspension system analysis and optimization through the utilization of Finite Element Analysis (FEA) with ANSYS software. The study commenced with an introductory section that highlighted the significance of suspension analysis in the context of electric vehicles. It underscored the necessity for improved ride comfort and handling, which are particularly crucial in light of the distinctive attributes exhibited by electric vehicles. Subsequently, we proceeded to explore the significance of Finite Element Analysis (FEA) in comprehending suspension dynamics, elucidating the capabilities of FEA simulations in facilitating the assessment of stress distribution, deformation, natural frequencies, and mode shapes analysis. Furthermore, we have emphasized the role of Finite Element Analysis (FEA) in assessing ride comfort, handling performance, and weight distribution in order to efficiently improve suspension systems.

The implications of suspension system design and optimization on the future of electric vehicles were also considered. As the automotive industry transitions towards electrification, optimized suspension systems become pivotal in enhancing driving experiences and promoting widespread adoption of electric vehicles. The improvements in ride comfort, handling, and energy efficiency through suspension.

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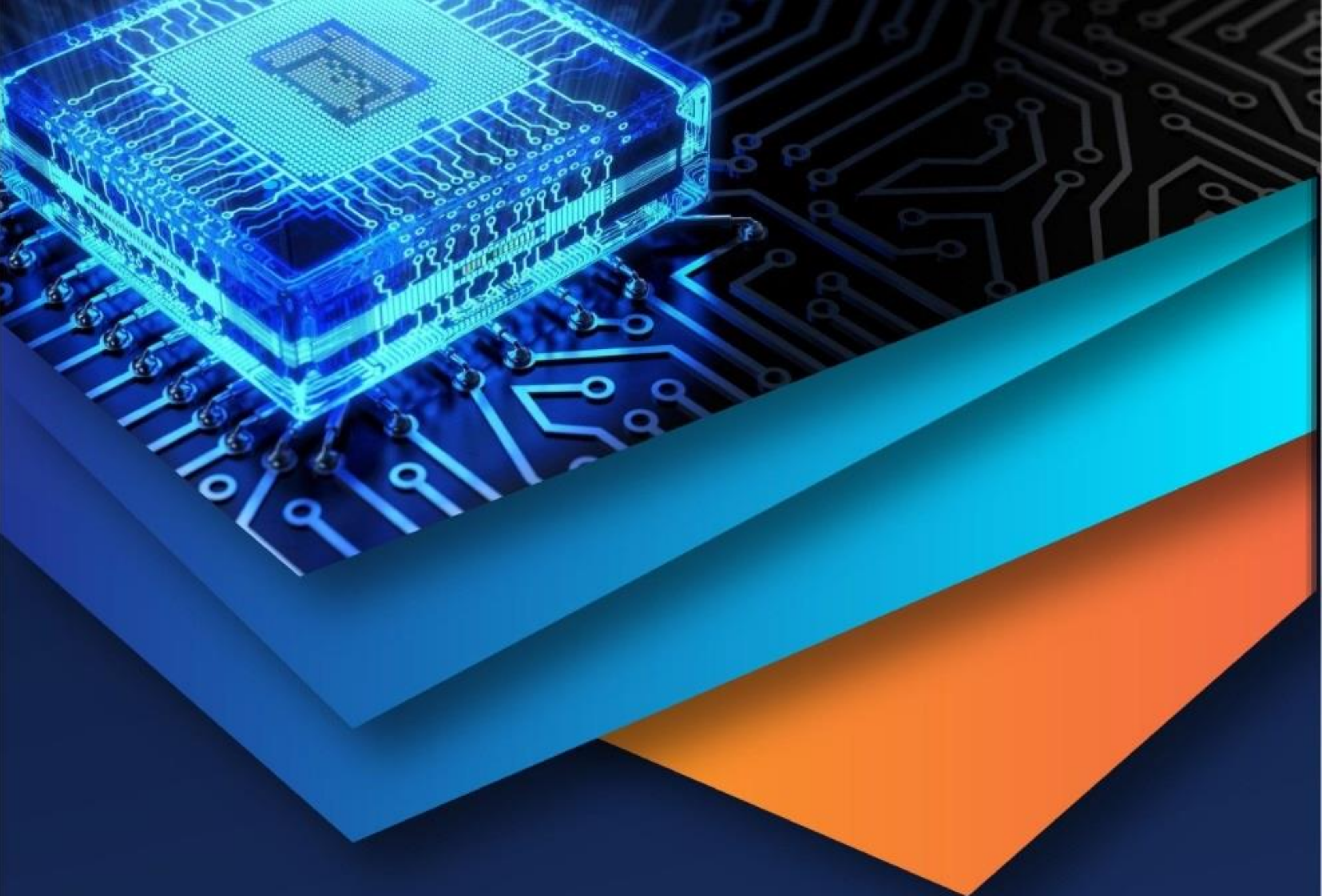

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