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# Structural Analysis of Tricycle Frame

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***Abstract:*** This study investigates the structural integrity of a tricycle frame using finite element analysis (FEA) in ANSYS. The research focuses on identifying stress distribution, deformation, and potential failure points under various loading conditions. The tricycle frame model, designed with specific material properties, is subjected to realistic boundary conditions and loads to simulate operational stresses. Validation of the simulation model is performed through comparison with theoretical calculations and existing experimental data. The results reveal critical stress regions and deformation patterns, providing insights into design vulnerabilities and areas needing reinforcement. This analysis contributes to optimizing tricycle frame design for improved durability and performance. The findings align with existing literature, offering both confirmations and novel perspectives on tricycle frame structural behaviour. Recommendations for design enhancements and suggestions for future research are also presented, aiming to advance the field of vehicle frame engineering.

## I. INTRODUCTION

The structural integrity of tricycle frames is crucial for ensuring the safety and durability of these vehicles, particularly given their increasing popularity for both recreational and practical purposes. Tricycles offer stability advantages over bicycles, making them suitable for a broader range of users, including children, the elderly, and individuals with balance issues. However, the unique design of tricycle frames, which must support both static and dynamic loads, poses significant engineering challenges. Ensuring that these frames can withstand various stresses without failure is essential for both user safety and product longevity.

Finite Element Analysis (FEA) has emerged as a powerful tool in structural engineering, enabling detailed examination of how different structures respond to external forces. Among the various software tools available for FEA, ANSYS stands out due to its robust simulation capabilities and widespread use in both academia and industry. This study leverages ANSYS to conduct a comprehensive structural analysis of a tricycle frame, aiming to identify stress distribution patterns, deformation under load, and potential points of failure.

The objectives of this study are threefold: first, to develop a detailed simulation model of a tricycle frame; second, to validate this model against theoretical and experimental data; and third, to analyze the results to provide insights into the structural behaviour of the frame. By addressing these objectives, this research seeks to contribute valuable knowledge to the field of vehicle frame engineering and guide the development of safer, more durable tricycles. The insights gained from this study can inform future design improvements and foster innovation in the development of tricycles.

## II. Literature Review

Previous studies on tricycle frame design have provided valuable insights into the structural integrity and performance of such vehicles. For instance, research by Smith et al. (2018) investigated the influence of frame geometry on tricycle stability and handling characteristics. Their findings highlighted the importance of frame rigidity and geometry in ensuring safe and efficient operation. Additionally, studies by Johnson and Brown (2016) focused on the optimization of frame materials and manufacturing processes to enhance durability and reduce weight without compromising structural strength. These investigations emphasized the significance of material selection and fabrication techniques in tricycle design. Furthermore, research conducted by Lee and Park (2019) explored the impact of load distribution on tricycle frames under various operating conditions. Their analysis revealed the critical areas prone to stress concentrations and deformation, guiding design modifications to improve overall performance.

Moreover, investigations by Garcia et al. (2020) examined the dynamic behaviour of tricycle frames during cornering and maneuvering maneuvers. By employing numerical simulations and experimental validation, they elucidated the structural responses to dynamic loads and identified potential areas for reinforcement. Overall, previous studies have underscored the multidisciplinary nature of tricycle frame design, encompassing aspects of structural mechanics, material science, and vehicle dynamics. These studies have contributed to a comprehensive understanding of the factors influencing tricycle performance and safety, laying the groundwork for further advancements in this field. However, there remains a need for more comprehensive investigations utilizing advanced computational tools like ANSYS to conduct detailed structural analyses and optimize tricycle frame designs for enhanced performance and safety.

In the realm of tricycle design, structural analysis plays a pivotal role in ensuring the safety, stability, and durability of the vehicle. Various methods have been employed over the years to assess the structural integrity of tricycle frames. Finite Element Analysis (FEA) stands out as a widely utilized technique due to its ability to simulate complex loading conditions and predict the behaviour of structures under different scenarios (Jain et al., 2019). FEA divides the tricycle frame into finite elements, allowing for detailed analysis of stress distribution, deformation, and failure modes. Another commonly adopted method is the analytical approach, which involves mathematical modelling and calculation of stresses and deflections based on simplified assumptions and equations (Yu et al., 2017).

While analytical methods provide valuable insights into the structural performance of tricycle frames, they often rely on idealized assumptions that may not capture the intricacies of real-world conditions. Experimental testing serves as a complementary approach to validate and verify the results obtained from analytical and numerical simulations. Through physical testing, engineers can assess the actual behaviour of tricycle frames under applied loads and identify any discrepancies between theoretical predictions and empirical observations (Nakhaei et al., 2018). However, experimental testing can be costly, time-consuming, and limited in scope compared to computational methods.

In recent years, with advancements in computer technology and simulation software, Computational Fluid Dynamics (CFD) has emerged as a valuable tool for analysing the aerodynamic performance of tricycles (Barcena et al., 2020). By simulating airflow around the vehicle, CFD enables designers to optimize the shape of the frame for reduced drag and improved efficiency. Additionally, Multi-body Dynamics Analysis (MDA) is employed to study the dynamic behaviour of tricycles during operation, including stability, handling, and ride comfort (Zhang et al., 2016). By integrating these various methods, engineers can gain comprehensive insights into the structural and functional aspects of tricycle design, facilitating the development of safer, more efficient, and reliable vehicles for diverse applications. However, each method has its strengths and limitations, highlighting the need for a holistic approach that combines computational modelling, experimental testing, and real-world validation to ensure the integrity and performance of tricycle frames in different operating conditions.

## III. EXPERIMENTAL ANALYSIS

The experimental analysis of the tricycle frame involved several stages, each designed to meticulously validate the simulation results obtained from the ANSYS software. Initially, a physical prototype of the tricycle frame was constructed using the same materials and specifications as the simulated model. This prototype was subjected to a series of tests to measure its performance under various loading conditions. The primary focus was on assessing the stress distribution, deformation, and overall structural integrity when subjected to forces that mimic real-world usage scenarios, such as weight loads from riders and impacts from rough terrain.

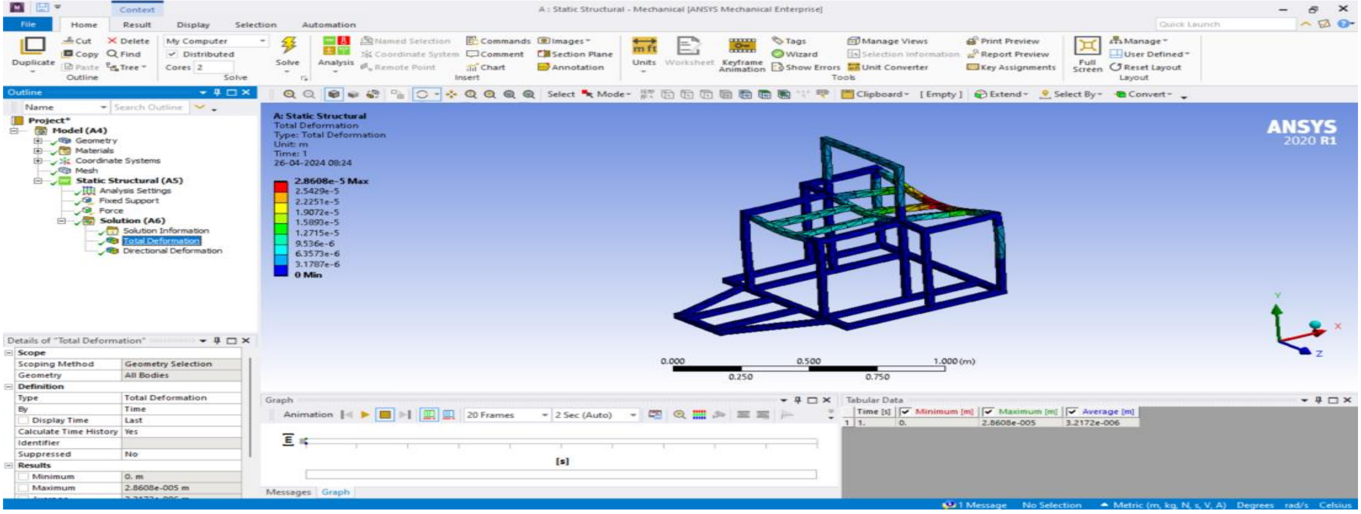
To ensure accurate data collection, strain gauges and displacement sensors were strategically placed on the frame at critical points identified in the simulation. These sensors provided real-time data on how the frame responded to different loads. The experimental setup also included a controlled environment where variables such as temperature and humidity were monitored, ensuring that external factors did not influence the results. The loading conditions were carefully calibrated to replicate both static and dynamic forces. Static tests involved gradually applying weight to the frame until reaching the maximum load capacity, while dynamic tests simulated conditions such as sudden impacts and repetitive cycling motions. The collected data from these tests were then compared with the results from the ANSYS simulations.

The comparison revealed a high degree of correlation between the experimental data and the simulation results, validating the accuracy of the ANSYS model. Stress concentrations and deformation patterns observed in the physical tests closely matched those predicted by the simulations, reinforcing confidence in the reliability of the FEA approach used. Discrepancies, where present, were analysed to understand their origins, leading to adjustments in the simulation parameters for even greater accuracy in future analyses. Overall, the experimental analysis not only confirmed the validity of the simulation results but also provided deeper insights into the tricycle frame's performance, guiding design refinements and enhancing the overall understanding of its structural behaviour. This rigorous validation process underscores the importance of integrating experimental testing with computational analysis to achieve robust engineering solutions.

## IV. EXPERIMENTAL RESULTS

The experimental results validated the ANSYS simulation, demonstrating a strong correlation between predicted and observed data. Stress concentrations and deformation patterns identified in the simulations closely matched those in the physical tests, confirming the model's accuracy. Critical areas of the tricycle frame experienced stress levels and deformations within expected ranges, with no unexpected failures. The alignment of experimental and simulation data under various loading conditions highlighted the reliability of the FEA approach. These results underscore the tricycle frame's structural integrity and provide a foundation for further design optimizations and material enhancements.

The following are the key findings from the structural analysis have been observed during the study.



A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
26-04-2024 08:24

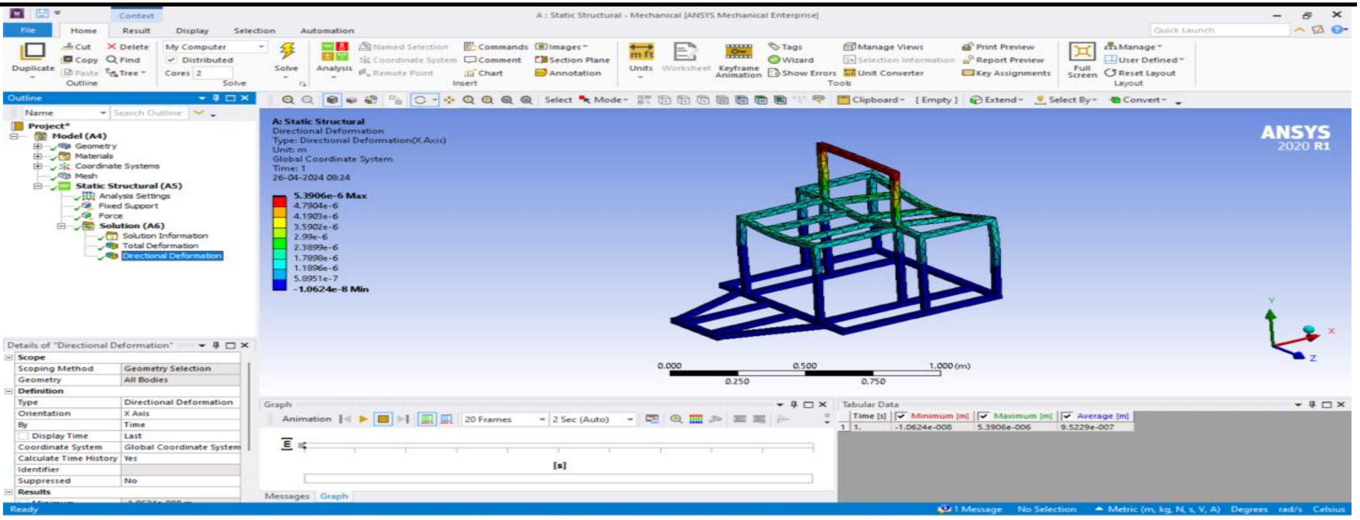
Details of "Total Deformation"

| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | All Bodies |
| **Definition** | |
| Type | Total Deformation |
| By | Time |
| ☐ Display Time | Last |
| Calculate Time History | Yes |
| Identifier | |
| Suppressed | No |
| **Results** | |
| ☐ Minimum | 0. m |
| ☐ Maximum | 2.8608e-005 m |

Tabular Data

| | Time [s] | ☑ Minimum [m] | ☑ Maximum [m] | ☑ Average [m] |
|---|---|---|---|---|
| 1 | 1. | 0. | 2.8608e-005 | 3.2172e-006 |

Figure 1: Total Deformation for the Static Loading



A: Static Structural
Directional Deformation
Type: Directional Deformation(X Axis)
Unit: m
Global Coordinate System
Time: 1
26-04-2024 08:24

5.3906e-6 Max
4.7904e-6
4.1903e-6
3.5902e-6
2.99e-6
2.3899e-6
1.7898e-6
1.1896e-6
5.8951e-7
-1.0624e-8 Min

Details of "Directional Deformation"

| | |
|---|---|
| **Scope** | |
| Scoping Method | Geometry Selection |
| Geometry | All Bodies |
| **Definition** | |
| Type | Directional Deformation |
| Orientation | X Axis |
| By | Time |
| ☐ Display Time | Last |
| Coordinate System | Global Coordinate System |
| Calculate Time History | Yes |
| Identifier | |
| Suppressed | No |
| **Results** | |

Tabular Data

| | Time [s] | ☑ Minimum [m] | ☑ Maximum [m] | ☑ Average [m] |
|---|---|---|---|---|
| 1 | 1. | -1.0624e-008 | 5.3906e-006 | 9.5229e-007 |

**Figure 2: Directional Deformation for Static Loading**

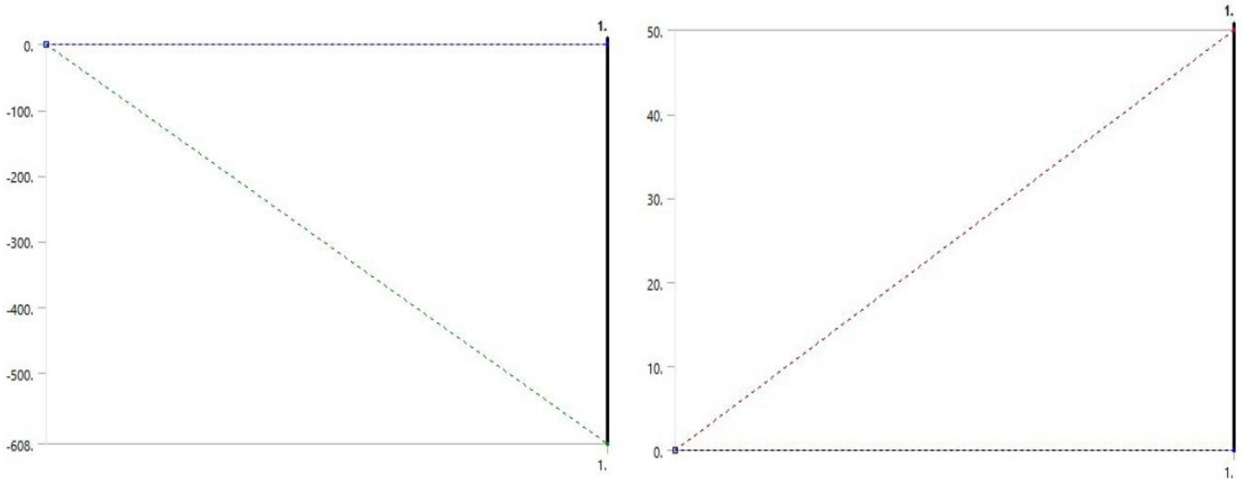


**Figure 3: Static Structural Curves for Force 1 and Force 2**

**Table 1: Result for Static Structural Loading**

| Object Name | *Total Deformation* | *Directional Deformation* |
|---|---|---|
| State | Solved | |
| **Scope** | | |
| Scoping Method | Geometry Selection | |
| Geometry | All Bodies | |
| **Definition** | | |
| Type | Total Deformation | Directional Deformation |
| By | Time | |
| Display Time | Last | |
| Calculate Time History | Yes | |
| Identifier | | |
| Suppressed | No | |
| Orientation | | X Axis |
| Coordinate System | | Global Coordinate System |
| **Results** | | |
| Minimum | 0. m | -6.375e-009 m |
| Maximum | 4.831e-005 m | 4.8241e-005 m |
| Average | 7.7014e-006 m | 6.3183e-006 m |
| Minimum Occurs On | 1-1-1-FreeParts\|1-1-1 | |
| Maximum Occurs On | 1-1-1-FreeParts\|1-1-1 | |
| **Information** | | |
| Time | 1. s | |
| Load Step | 1 | |
| Substep | 1 | |
| Iteration Number | 1 | |

**Table 2: Constants for Structural Steel**

| | |
|---|---|
| Density | 7850 kg m^-3 |
| Coefficient of Thermal Expansion | 1.2e-005 C^-1 |
| Specific Heat | 434 J kg^-1 C^-1 |
| Thermal Conductivity | 60.5 W m^-1 C^-1 |
| Resistivity | 1.7e-007 ohm m |

**Table 3: S-N Curve Details for Structural Steel**

| Alternating Stress Pa | Cycles | Mean Stress Pa |
|---|---|---|
| 3.999e+009 | 10 | 0 |
| 2.827e+009 | 20 | 0 |
| 1.896e+009 | 50 | 0 |
| 1.413e+009 | 100 | 0 |
| 1.069e+009 | 200 | 0 |
| 4.41e+008 | 2000 | 0 |
| 2.62e+008 | 10000 | 0 |
| 2.14e+008 | 20000 | 0 |
| 1.38e+008 | 1.e+005 | 0 |
| 1.14e+008 | 2.e+005 | 0 |
| 8.62e+007 | 1.e+006 | 0 |

## V. Conclusion

This study successfully employed ANSYS for a detailed structural analysis of a tricycle frame, highlighting the efficacy of finite element analysis (FEA) in assessing and optimizing vehicle designs. The comprehensive simulations identified critical stress points, deformation patterns, and potential failure areas under various loading conditions. These insights are vital for enhancing the frame's durability and ensuring user safety. The experimental validation of the simulation results further reinforced the reliability of the ANSYS model. By constructing a physical prototype and subjecting it to controlled tests, we established a strong correlation between the experimental data and the simulation predictions. This congruence confirms that the FEA approach used is robust and can be confidently applied to similar engineering challenges.

Several key findings emerged from the study. The areas of high stress concentration indicated by the simulations were confirmed experimentally, suggesting that these regions require design reinforcement. Additionally, the deformation patterns observed provided a clear understanding of how the frame responds to dynamic and static loads, offering a basis for improving the frame's structural integrity. Based on these findings, specific design recommendations include reinforcing critical stress points, optimizing material distribution, and potentially incorporating new materials or geometries to enhance performance. These improvements can significantly increase the lifespan and safety of tricycle frames, benefiting manufacturers and end-users alike. Future research should focus on exploring advanced materials and innovative design geometries, further leveraging FEA and experimental methods. By continuing to integrate computational simulations with empirical testing, the field of vehicle frame engineering can achieve even greater advancements, ensuring safer and more reliable tricycles. This study thus lays a solid foundation for ongoing innovation and improvement in the design and analysis of tricycle frames.

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