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# Design and Analysis of Novel Human Mars Exploration Rover

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**Abstract:** This paper presents the design and analysis of a NASA human exploration rover, emphasizing the maintenance of strength, stiffness, and stability. The annual competition challenges college students to design, build, and race human-powered, collapsible vehicles over simulated lunar terrain. Key focus areas include manufacturability, cost reduction, and weight optimization. The selected optimal design is validated using conventional hand calculations.

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## 1. Introduction

The NASA Human Exploration Rover Challenge involves designing a human-powered vehicle capable of traversing simulated lunar terrain. This competition requires innovative engineering solutions to address challenges such as rough terrain, load-bearing capacity, and structural integrity. The design discussed in this paper features a triangular-supported, three-parallel-beam chassis with independent suspension and a four-wheel configuration, powered by human effort. This configuration ensures a balance between structural strength and manoeuvrability.

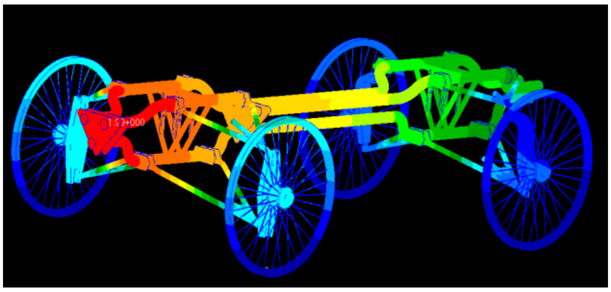

**Figure 1: Frame Design and Wheel Assembly**

The frame design is supported by three parallel beams in a triangular configuration, providing robust support and stability. The independent suspension system allows each wheel to respond to terrain variations independently, improving the rover's ability to navigate uneven surfaces.

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## 2. Design Constraints

The design constraints for the rover include collapsibility, ease of assembly and disassembly, and ergonomic considerations. The rover must fit into a 4x4 ft cube when collapsed, facilitating transportation and storage. Additionally, the design must accommodate both male and female drivers, requiring careful consideration of anthropometry and ergonomics to ensure comfort and efficiency.

## 3. Material Properties (Al-7075)

Al-7075 is chosen for its high strength-to-weight ratio and excellent mechanical properties, making it ideal for the rover's structural components. The material properties are as follows:

- Young's Modulus (E): 72,398.8 $N/mm^2$
- Poisson's Ratio: 0.33
- Density: 2810 $kg/m^3$
- Allowable Yield Stress: 448.18 $N/mm^2$
- Ultimate Tensile Stress (Ftu): 537.82 $N/mm^2$
- Shear Yield Stress (Fsy): 303.4 $N/mm^2$
- Factor of Safety: 2.5
- Allowable Working Stress: 179.27 $N/mm^2$.

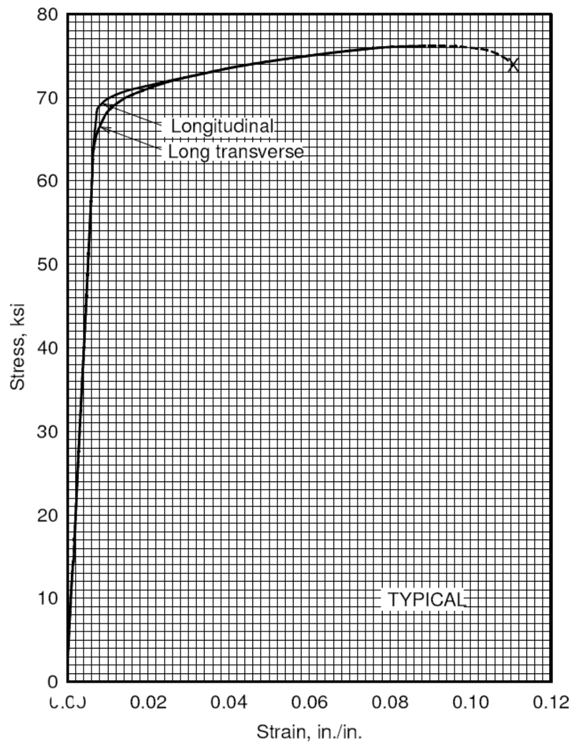


**Figure 2: Typical Tensile Stress-Strain Curve for Clad 7075-T6 Aluminum Alloy**

The stress-strain curve demonstrates the material's behavior under tensile load, providing essential data for design validation and analysis.

## 4. Finite Element Analysis (FEA) of Rover Assembly

Finite Element Analysis (FEA) is a crucial step in validating the rover's design. By simulating real-world conditions, FEA helps predict the rover's performance under various loading scenarios. The analysis was performed using commercial FE tools NASTRAN and PATRAN, focusing on strength analysis to identify maximum stress points and ensure the design's safety. The analysis involved defining the geometry, material properties, meshing the model, applying boundary conditions and loads, and interpreting the results to validate the design against calculated values.

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## 5. Meshed Model

Meshing is a critical component of FEA, affecting the accuracy and computational efficiency of the analysis. The model was meshed using 3D tet10 elements, which offer a good balance between accuracy and computational load.

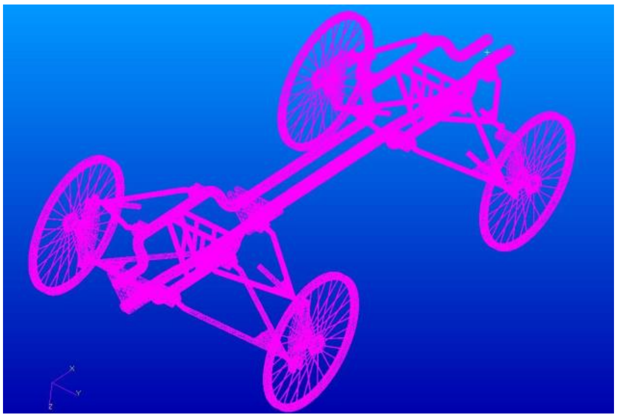


**Figure 4: Meshed Model of Mars Human Exploration Rover**

A finer mesh improves result accuracy but increases solution time. In this project, tet10 elements were chosen for their equivalency to hex8 elements, providing reliable results while maintaining computational efficiency.

## 6. Boundary Condition and Load Application

Accurate representation of boundary conditions and load applications is essential for realistic FEA simulations. In PATRAN, boundary conditions were applied to simulate the rover's operational environment, while connections between components were modeled using RBE2 elements. The shock absorber's effect was included using a spring constant to simulate its impact on the rover's performance.

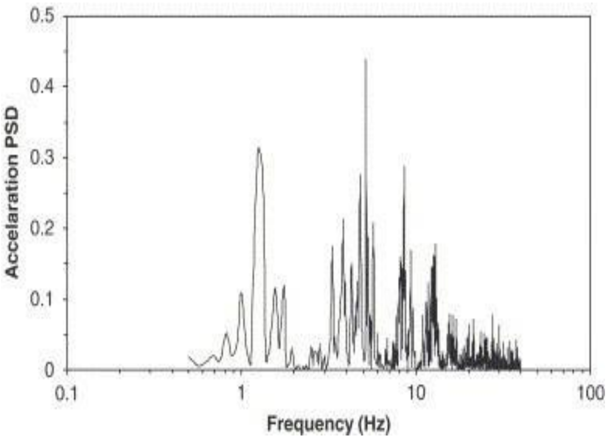



**Figure 5: Acceleron vs. Frequency**

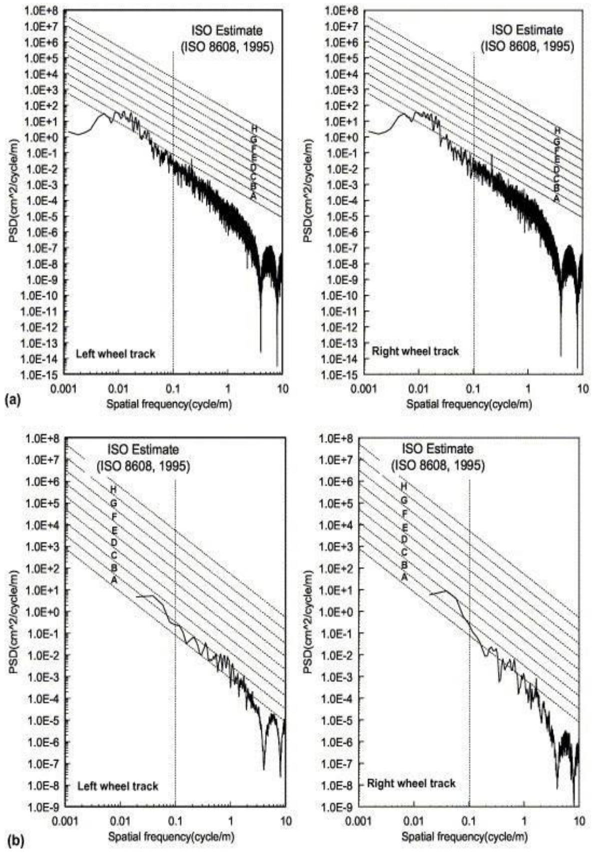



**Figure 6: PSD vs. Spatial Frequency Curve**

These figures illustrate the dynamic response of the rover under various conditions, providing insight into its performance and identifying areas for improvement.

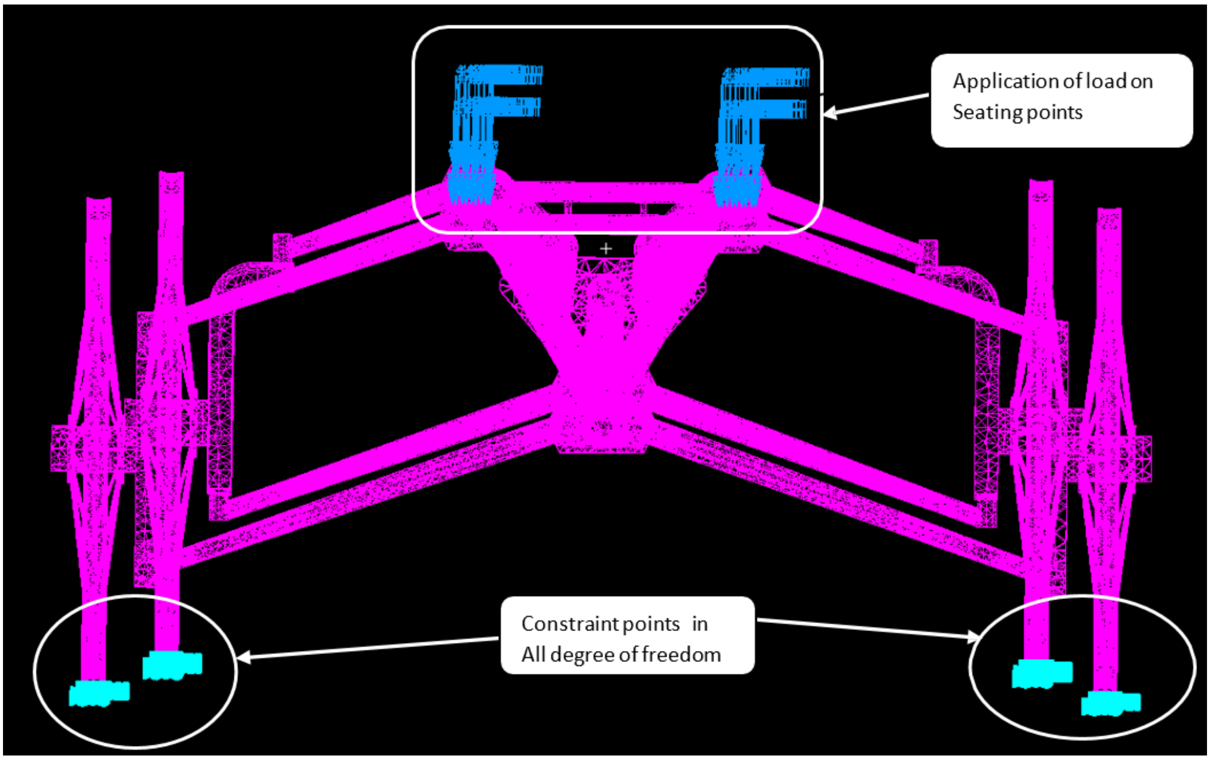
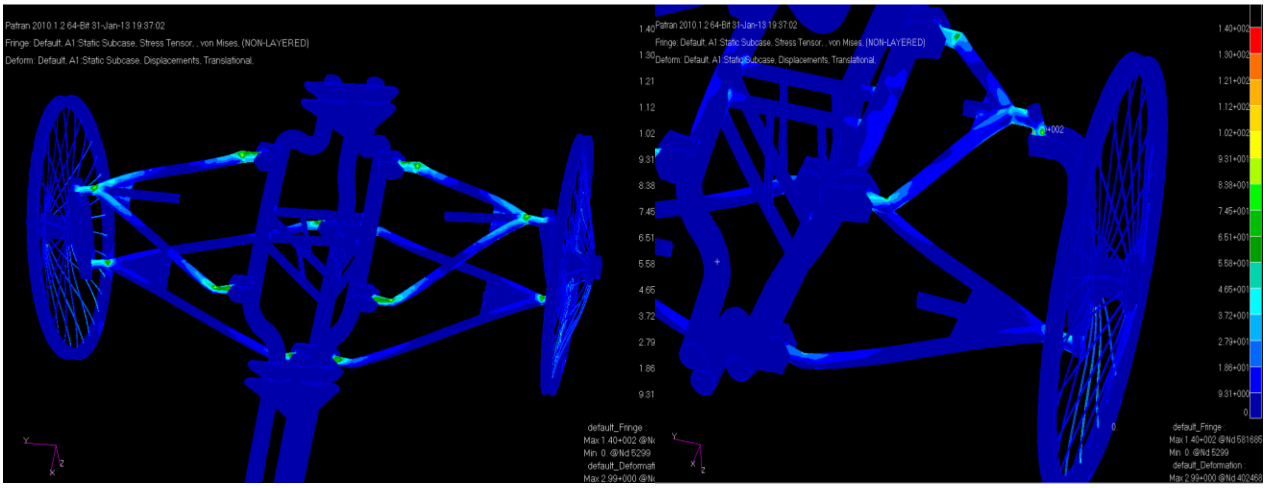



**Figure 7 Loading and Constraint Points**

## 7. FEA without Shock Absorber

Initial FEA was conducted without including shock absorbers to evaluate the baseline performance of the rover's design. The analysis focused on stress and displacement distribution across the chassis and suspension components.



**Figures 8-9: Stress Concentration and Displacement Plots (Without Shock Absorber)**

The results highlighted areas of high stress concentration and significant displacement, indicating potential points of failure and the need for design enhancements.

***Results:***

- Calculated Stress: 140 N/mm²
- Displacement: 2.99 mm

***Remarks:*** While the stress levels were below the allowable limit (179.27 N/mm²), the displacement was excessive, necessitating design modifications to improve structural stability and performance (ref.figure-10).

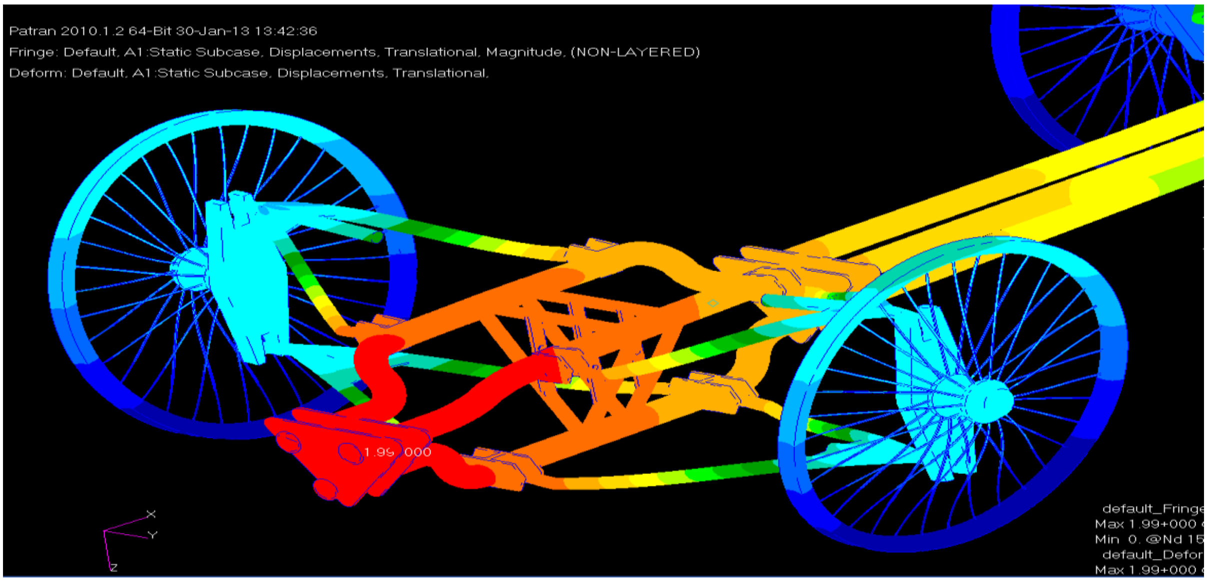



**Figure 10: Displacement Analysis**

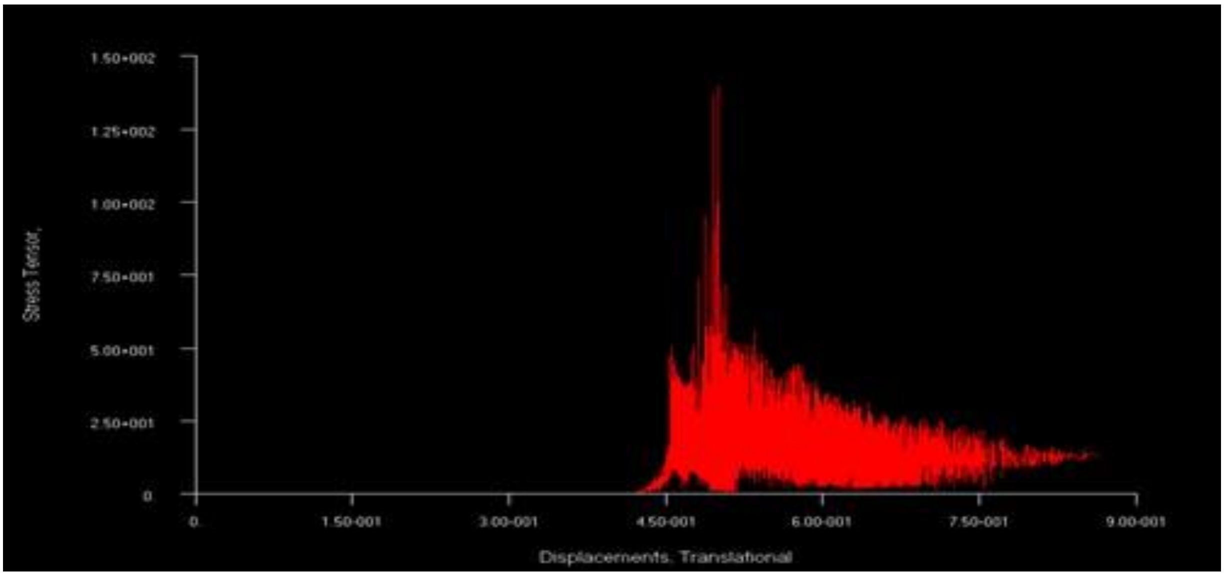



**Figure 11: Stress vs Displacement Graph**

## 8. FEA with Shock Absorber

To address the displacement issues identified in the initial analysis, shock absorbers were incorporated into the design. The subsequent FEA evaluated the impact of shock absorbers on stress and displacement distribution.

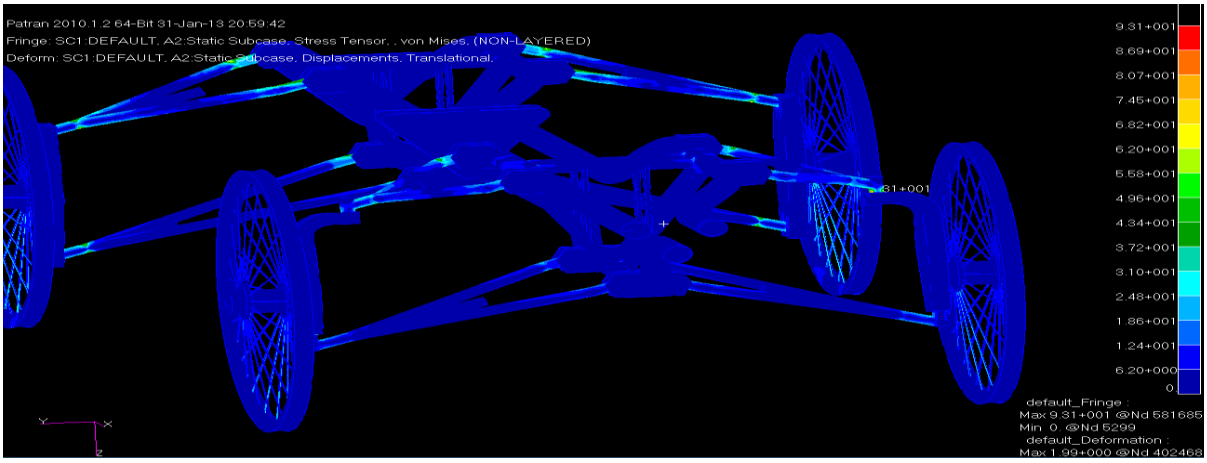



**Figure 12 Stress analysis (with shock absorber)**

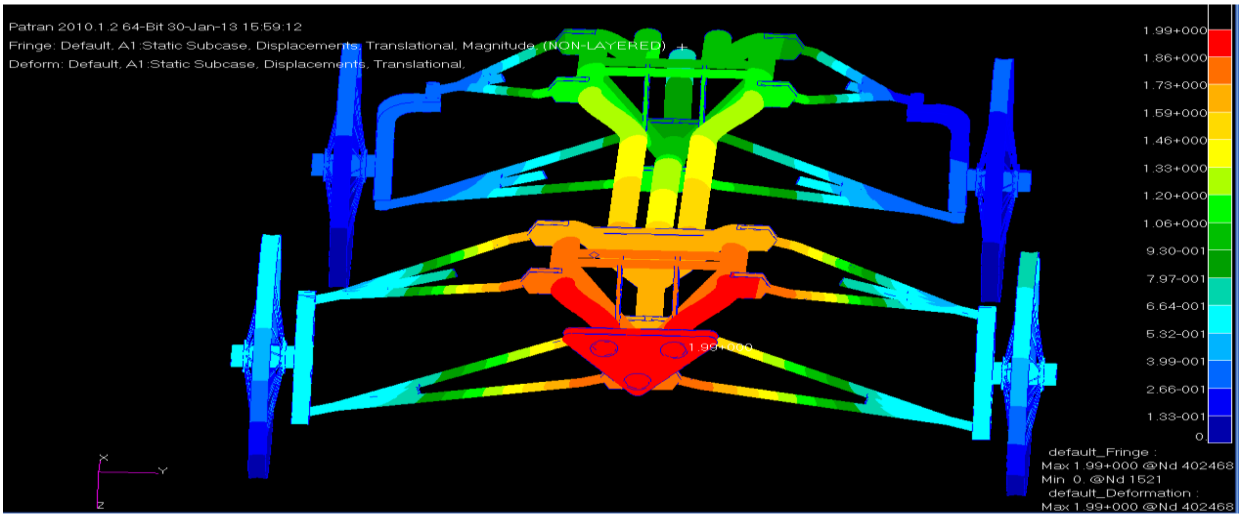


Figure 13: Displacement analysis (with shock absorber)

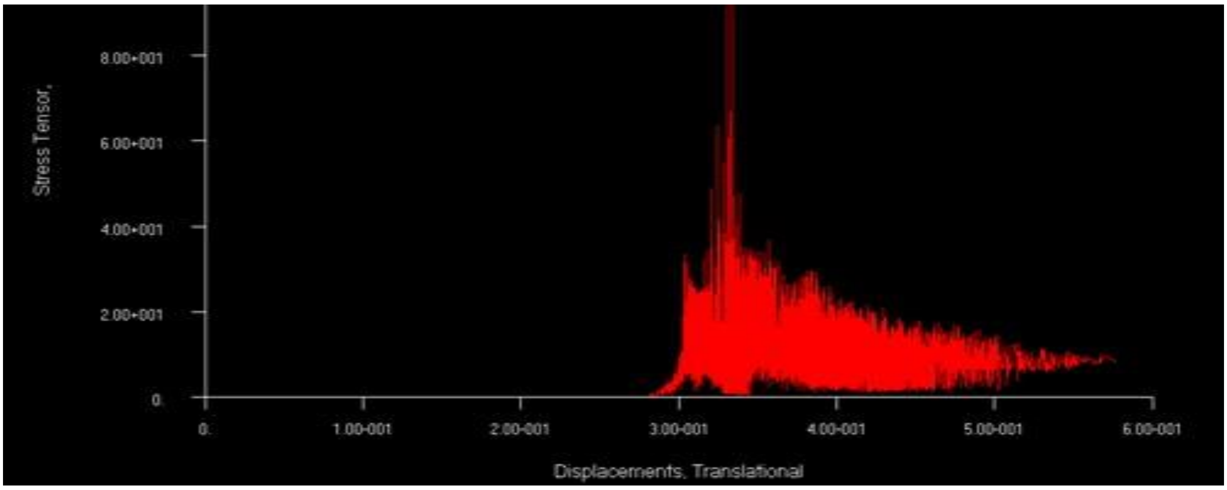


Figure 14: Stress Vs Displacement Graph

The inclusion of shock absorbers significantly reduced displacement by absorbing and dissipating energy transferred to the wheels, enhancing the rover's overall performance.

***Results:***

- Calculated Stress: 93.1 N/mm²
- Displacement: 1.99 mm

***Remarks:*** The stress levels were well within the allowable limits, and the displacement was effectively controlled, demonstrating the benefits of incorporating shock absorbers into the design.

## 9. Conclusion

The design and analysis of the NASA human exploration rover demonstrate that the current structure is conservative, with reported stresses well below allowable limits. Incorporating shock absorbers effectively reduces unwanted wheel displacement by absorbing excess energy, enhancing the rover's performance and stability.

## 10. Acknowledgements

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## 12. Conflict of Interest

The author declare no competing conflict of interest.

## 13. Funding

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