Comparative Analysis of Suspension Springs For ATV

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***Abstract*— Coil springs in All-Terrain Vehicle (ATV) suspension systems are compared in this paper using four different materials: mild steel, high carbon steel, carbon fiber, and aluminum. Every material was assessed under the same loading circumstances using ANSYS's Finite Element Analysis (FEA). Total deformation, von Mises stress, strain distribution, and weight efficiency were among the performance metrics. The strongest and most load-bearing material, according to the results, is high carbon steel, which makes it perfect for harsh off-road situations. Carbon fiber, on the other hand, offers a considerable weight reduction with respectable structural integrity, exhibiting the best weight-to-performance ratio. Aluminum and mild steel performed moderately well, making them appropriate for certain uses with lower load requirements.**

The study outlines the material trade-offs between strength and weight and offers guidance for choosing coil spring materials according to performance requirements. Design suggestions to improve suspension longevity and efficiency in ATV systems are included in the paper's conclusion.

Keywords - Coil Spring, Suspension, All-Terrain Vehicles, FEA, Mild Steel, High Carbon Steel, Carbon Fiber, Aluminium.

I. Introduction

All-Terrain Vehicles (ATVs) need to be highly mobile, stable, and controlled in order to traverse rough and uneven terrain. The suspension system, which reduces shocks, keeps steady ground contact, and improves ride comfort, is a crucial part of these capabilities. A vital component of the suspension system, coil springs are essential for both shock absorption and general vehicle handling. Because steel is strong and long-lasting, it has historically been used to make these springs. However, alternative materials like composite materials and aluminum alloys have drawn attention in response to rising performance demands and a focus on weight reduction.

This study examines the mechanical properties of coil springs composed of aluminum, carbon fiber, mild steel, and high carbon steel. The study assesses these materials' performance and viability in ATV suspension applications under the same loading conditions using Finite Element Analysis (FEA) in ANSYS. Total deformation, von Mises stress, strain distribution, and weight efficiency are important evaluation metrics.

According to the findings, high carbon steel is perfect for applications requiring high performance because of its exceptional strength and load-bearing capacity. Carbon fiber, on the other hand, is a great option for applications where weight efficiency is a top priority because it offers substantial weight reduction despite having a lower strength. Aluminum and mild steel both perform moderately well; aluminum has the advantage of being lighter than high carbon steel, but at the expense of strength.

A thorough comparison of the material qualities for coil springs in ATV suspension systems is given by this study. The results provide useful information on how to choose materials to maximize suspension performance while balancing durability, strength, and weight to satisfy the unique requirements of ATV applications.

II. Materials and Methodology

II.I Material Properties

The materials selected for analysis and their mechanical properties are summarized below

Table 1. Suspension materials and their properties.

Material	Young's Modulus (GPa)	Density (g/cm^3)	Yeild Strength (MPa)
Mild Steel	200	7.85	250
High Carbon Steel	210	7.85	700
Carbon Fiber	150	1.60	600
Aluminium	70	2.70	310

II.II CAD Modelling and Meshing

A standard helical coil spring was designed in SolidWorks. The model parameters included:

- Outer Diameter: 65 mm
- Wire Diameter: 6 mm
- Free Length: 245 mm
- Number of Active Coils: 16

The 3D model was imported into ANSYS Workbench for meshing using tetrahedral elements, with a mesh size of 2 mm for high resolution.

Fig. 1 Suspension Spring CAD Model.

II.III. Boundary Conditions and Loading

-One end of the spring was fixed.
-A static vertical load of 1500 N was applied on the opposite face to simulate off-road conditions.

III. Results and Analysis.

III.I Total Deformation.

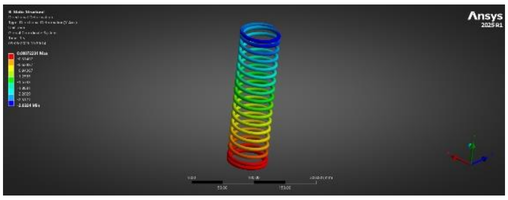

Fig. 2 Directional Deformation of Y-axis of mild Steel Spring.

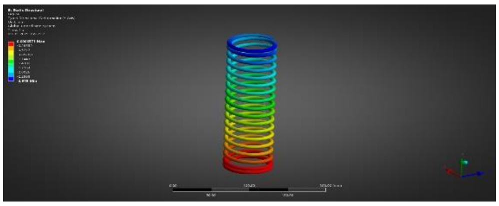

Fig. 3 Directional Deformation of Y-axis of High Carbon Steel Spring.

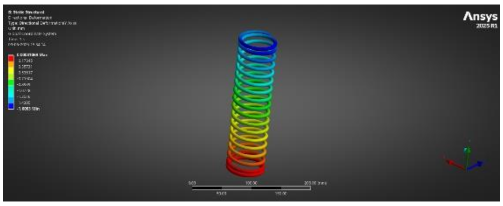

Fig. 4 Directional Deformation of Y-axis of Carbon fiber Spring.

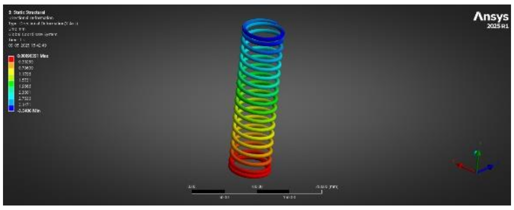

Fig. 5 Directional Deformation of Y-axis of Aluminium Spring.

Table 2. Total Deformation in materials.

Material	Total Deformation (mm)
Mild Steel	2.83
High Carbon Steel	2.50
Carbon Fiber	1.60
Aluminium	3.50

Carbon Fiber and High Carbon Steel exhibit lower deformation values, indicating superior stiffness and load absorption.

III.II Von Mises Stress.

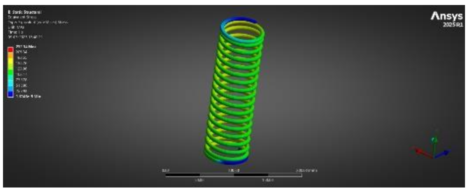

Fig. 6 Von Mises Stress axis of Mild Steel Spring.

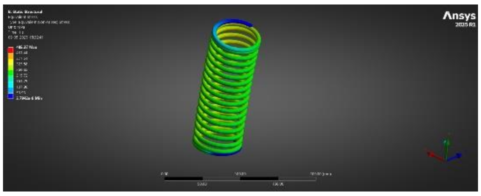

Fig. 7 Von Mises Stress axis of of High Carbon Steel Spring.

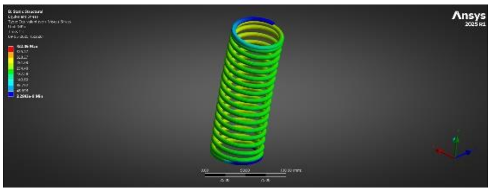

Fig. 8 Von Mises Stress axis of Carbon fiber Spring.

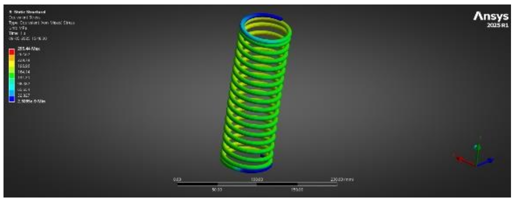

Fig. 9 Von Mises Stress axis of Aluminium Spring.

Table 3. Von Mises Stress in materials.

Material	Von Mises Stress (Mpa)
Mild Steel	232
High Carbon Steel	485
Carbon Fiber	422
Aluminium	295

While Mild Steel is close to its yield limit, High Carbon Steel demonstrates a wide safety margin under the same load.

III.III Strain Distribution.

Consistent mechanical behavior was indicated by the carbon fiber's uniform and minimal strain distribution. Localized strain regions in aluminum suggested possible weak points when subjected to dynamic loads.

III.IV Weight Comparison.

Table 4. materials weight.

Material	Relative weigth (kg)
Mild Steel	0.75
High Carbon Steel	0.75
Carbon Fiber	0.15
Aluminium	0.26

Carbon Fiber offers a dramatic reduction in weight without major compromise in performance.

IV Discussion

Because of its exceptional mechanical strength and low deformation under stress, high carbon steel is the best material for high-load ATV suspension applications. It is the best option for tough off-road situations where performance and durability are crucial because of its capacity to support heavy loads without sacrificing structural integrity.

Although much more costly, carbon fiber has a great strength-to-weight ratio. Because of this feature, it is especially beneficial for racing or performance-focused ATVs, where it is crucial to reduce weight without compromising mechanical efficiency. Despite not being as strong as high carbon steel, its lightweight design greatly enhances vehicle agility and fuel economy.
Even though aluminum is the lightest of the materials examined, it deforms and strains a lot when loaded. These disadvantages restrict its use in conventional coil spring designs unless its reduced strength is compensated for by structural reinforcement or hybrid composite configurations.

Mild steel is still a good choice for entry-level or low-budget ATVs because of its affordability and availability. However, when exposed to rough terrain, its lower stress tolerance and higher deformation can compromise suspension durability and performance. All things considered, the choice of materials should be in line with the intended ATV usage, cost limitations, and performance requirements.

V **Conclusion**

High carbon steel was found to be the most dependable material among those examined for ATV coil spring applications. It is perfect for rough, off-road conditions because of its high strength, low deformation, and exceptional durability under heavy static loads. Although carbon fiber has a considerable weight advantage and good strength, its costlier nature and brittleness under impact make it less useful for everyday applications. Even though aluminum was lightweight, it deformed excessively, which made it less appropriate in the absence of structural support. Despite being less expensive, mild steel lacks the requisite durability and strength. All things considered, high carbon steel offers the best mix of cost, performance, and dependability.

References

1. Sreenivasan, M., et al. "Finite Element Analysis of Coil Spring of a Motorcycle Suspension System Using Different Fibre Materials." *Materials Today: Proceedings*, vol. 33, 2020, pp. 1168–1174. https://doi.org/10.1016/j.matpr.2020.04.449.
2. Madheswaran, Dinesh Kumar, et al. "Finite Element Analysis of Coil Spring of a Motorcycle Suspension System Using Different Fibre Materials." *ResearchGate*, 2021. https://www.researchgate.net/publication/348231999.ResearchGate
3. "Static Structural Analysis of Industrial and Automobile Helical Springs Using Different Materials." *International Journal for Scientific Research & Development (IJSRD)*, vol. 9, no. 9, 2021. https://www.ijsrd.com/articles/IJSRDV9I90077.pdf
4. "Analysis of the Material Properties of Vehicle Suspension Coil Spring." *Scientific Research Publishing*, 2024. https://www.scirp.org/journal/paperinformation?paperid=129186.Yang, Zhi, et al. "Comparative study of interior permanent magnet, induction, and switched reluctance motor drives for EV and HEV applications." *IEEE Transactions on Transportation Electrification* 1.3 (2015): 245-254.
5. "Modeling and Stress Analysis of Aluminium Alloy Based Composite Materials." *ScienceDirect*, 2020. https://www.sciencedirect.com/science/article/abs/pii/S2214785320355826.
6. "Finite Element Analysis of Coil Spring by Using Carbon Fibre, Carbon Steel, and Epoxy Resin Materials." *ResearchGate*, 2023. https://www.researchgate.net/publication/368907779.
7. "Analysis and Experimental Validation for Behavior (Compression) of Helical Spring Used in Automobile." *International Journal of Innovative Engineering and Research Technology (IJIERT)*, 2016. https://repo.ijiert.org/index.php/ijiert/article/view/880/837.
8. Rajakumar, S., and M. Karthiyaraj. "Static structural analysis of helical compression spring materials." *International Journal of Engineering Development and Research* 9.1 (2021): 42-45.
9. Budan, D. Abdul, and T. S. Manjunatha. "Investigation on the feasibility of composite coil spring for automotive applications." *International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering* 4.10 (2010): 1035-1039.
10. Udhaya, A. R., B. Rajeswari, and T. Mugilan. "Static structural investigation of helical compression spring utilizing different materials for an automobile suspension system." *Materials Today: Proceedings* 80 (2023): 653-658.
11. Sequeira, Anil Antony, Ram Kishan Singh, and Ganesh K. Shetti. "Comparative analysis of helical steel springs with composite springs using finite element method." *Journal of Mechanical Engineering and Automation* 6.5A (2016): 63-70.
12. Kacar, Ilyas, and Vebil Yildirim. "Free vibration/buckling analyses of noncylindrical initially compressed helical composite springs." *Mechanics Based Design of Structures and Machines* 44.4 (2016): 340-353.
13. Patil, Sujit S., Subodh Karunasagar, and Shubham Shah. "Comparative study of helical compression suspension spring for different materials." *Asian Journal of Engineering and Applied Technology* 5.2 (2016): 22-28.

14. Tan, W. H., et al. "Structural analysis on the coil spring of motorcycle suspension system." *Journal of Physics: Conference Series*. Vol. 2051. No. 1. IOP Publishing, 2021.
15. Lavanya, N., P. Sampath Rao, and M. Pramod Reddy. "Design and analysis of a suspension coil spring for automotive vehicle." *international journal of engineering research and applications* 4.9 (2014): 151-157.
16. Alla, M. R., and M. Vidya Sagar. "Static and dynamic analysis of a two wheeler shock absorber using different materials for helical coil spring." *Shock* 6.03 (2019).