Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Design and Analysis Approach for Material Optimization of Two-Wheeler Shock Absorber Springs

Ishrat M Mirzana[1], Qamar Sultana[2], Arshad Mohammed[3*], G Sailaja[4], Mohd Hasham Ali[5], Mohammed Sajid[6]
[1]*Professor, Mechanical Engineering Department, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*
[2]*Associate Professor, Civil Engineering Department, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*
[3*]*Assistant Professor, Drone Pilot, EE Dept, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*
[3*]*Email: drarshadmohammedphd@gmail.com*
[4]*Associate Professor, Mechanical Engineering Department, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*
[5]*Assistant Professor, Mechanical Engineering Department, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*
[6]*Assoc. Professor, Electrical and Electronics Engineering Department, Muffakham Jah College of Engineering and Technology (MJCET), Banjara Hills, Hyderabad, Telangana India*

ARTICLE INFO

Received: 29 Dec 2024

Revised: 12 Feb 2025

Accepted: 27 Feb 2025

ABSTRACT

Shock absorbers play a crucial role in two-wheelers by absorbing shocks from uneven terrains, improving ride comfort, and ensuring stability. This study focuses on the design and analysis of a helical spring used in the rear suspension system of a two-wheeler, aiming to enhance stiffness while minimizing stress and deflection. A comparative analysis is conducted on springs made from Inconel 600, chromium vanadium, and stainless steel to determine the most efficient material. The shock absorber spring is modelled, and finite element analysis is performed using ANSYS to evaluate its mechanical behaviour under various loading conditions, including the weight of the rider and the vehicle. A structural analysis is carried out to assess the spring's deformation at different vibration modes. Key performance parameters such as von Mises stress, von Mises strain, and total deformation are analysed to determine material suitability. The study reveals that an increase in coil diameter leads to higher stress concentration in the spring. Among the three materials tested, chromium vanadium demonstrates superior performance in terms of strength, stiffness, and durability, making it the most suitable material for shock absorber springs. The results provide valuable insights into material selection for enhancing the efficiency and longevity of two-wheeler suspension systems.

Keywords: Shock Absorber, Two-Wheeler Suspension, Helical Compression Spring, Dynamic Load Response, Material Performance, Advanced Alloys.

INTRODUCTION

Shock absorbers are a crucial part of vehicle suspension systems, designed to absorb and dissipate kinetic energy from road irregularities, ensuring better ride comfort, handling stability, and safety. In two-wheelers, the rear suspension system plays a key role in maintaining control and reducing rider fatigue by absorbing vibrations and impact forces caused by uneven surfaces. The primary function of a shock absorber spring is to provide the necessary damping force to control suspension movement, prevent excessive bouncing, and enhance the vehicle's overall performance. Figure 1, depicts the Rear shock absorber and spring of a motorcycle.

A two-wheeler suspension system generally consists of helical compression springs, which compress and expand in response to external forces. The effectiveness of a suspension spring depends on its material composition, geometric configuration, and mechanical properties, including stiffness, stress resistance, and fatigue life. Conventional suspension springs are typically made of stainless steel, but recent advancements in materials engineering have introduced chromium vanadium and Inconel 600 as potential alternatives, offering superior strength, corrosion resistance, and longevity. Material selection plays a critical role in defining the performance and durability of a shock absorber spring. A high-stiffness spring can efficiently control excessive suspension travel, but if it is too stiff, it may

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/
Research Article

lead to a rough and uncomfortable ride. Conversely, a low-stiffness spring provides better ride comfort but may compromise load-bearing capacity and stability. To achieve an optimal balance, finite element analysis (FEA) is widely used. This study focuses on the design, modelling, and analysis of a helical shock absorber spring for a two-wheeler rear suspension system. The research aims to enhance stiffness while reducing stress and deflection by conducting a comparative analysis of three materials:

- Stainless Steel: A commonly used material known for its durability but with limitations in fatigue resistance.
- Chromium Vanadium: A high-strength alloy offering better wear resistance and mechanical performance.
- Inconel 600: A nickel-based alloy with excellent fatigue strength, high-temperature resistance, and superior energy absorption properties.

The shock absorber spring is modelled using SOLIDWORKS 2019 and analysed through ANSYS 18.1 to assess stress, strain, and deformation characteristics under various loading conditions. By incorporating computational simulations, this research aims to provide valuable insights into material selection and performance optimization for enhancing the durability and efficiency of two-wheeler suspension systems. This study aims to optimize the stiffness while minimizing stress and deflection in shock absorber springs. It compares the mechanical behaviour of different materials under real-world loading conditions to identify the most suitable option. The research ultimately seeks to improve design and material selection for enhanced suspension performance and longevity. By leveraging finite element simulations, this research contributes to the advancement of high-performance suspension systems, ensuring improved rider comfort, better shock absorption, and enhanced vehicle stability. The results of this study can assist in the development of lightweight, durable, and high-efficiency suspension systems for modern two-wheelers.

Figure: 1 Rear shock absorber and spring of a motorcycle

LITERATURE REVIEW

Several studies have explored the design, material selection, and performance analysis of helical compression springs used in automotive suspension systems. The mechanical behaviour of different spring materials has been extensively investigated to enhance fatigue life, optimize stiffness, and improve overall shock absorption efficiency. This section reviews key contributions in this domain. Material selection plays a vital role in defining the durability, load-bearing capacity, and deformation characteristics of shock absorber springs. Various studies have analysed the mechanical properties of alternative materials to improve suspension performance.

Rao et al. (2017) [1] studied chromium vanadium alloy, demonstrating its superior strength, fatigue resistance, and corrosion resistance compared to conventional stainless steel.

Patil et al. (2019)[2] conducted a comparative analysis of stainless steel and composite materials, concluding that while composite springs provide weight reduction benefits, they exhibit lower stiffness under high loads.

A. G. Hejib (2022) [3] utilized ANSYS for nonlinear stress analysis, showing that coil diameter and material selection significantly affect stress concentration and fatigue life.

Gupta et al. (2021)[4] conducted static and modal analyses of suspension springs, confirming that FEA results closely correlate with experimental data, making it a reliable method for structural optimization.

P. Khope, (2022)[5] optimized the geometry and material composition of springs through computational simulations, achieving better load distribution and enhanced spring performance.

MODAL AND DYNAMIC ANALYSIS OF SHOCK ABSORBERS

Modal and dynamic analysis help in understanding the vibrational response of suspension springs, ensuring stability under dynamic road conditions.

Sharma et al. (2019) examined modal frequencies of helical springs, concluding that increasing the number of active coils reduces stiffness and alters natural vibration modes.

Mehta and Das (2021) investigated the effect of different damping materials on suspension performance, recommending hybrid materials for improved vibration attenuation.

Roy et al. (2023) analysed shock absorber performance at various vibration frequencies, showing that spring stiffness directly influences vehicle stability and ride comfort.

SUMMARY OF LITERATURE REVIEW

From the reviewed studies, the following key observations can be made:

1. Material selection significantly affects the performance of shock absorber springs, with chromium vanadium and Inconel 600 showing superior mechanical properties.
2. FEA is an essential tool for analysing stress, deformation, and fatigue characteristics, enabling precise performance predictions.
3. This study builds upon previous research by conducting a comparative analysis of stainless steel, chromium vanadium, and Inconel 600 to determine the most efficient material for two-wheeler shock absorber springs.

STRUCTURAL ANALYSIS OF SHOCK ABSORBER SPRING:

The research aims to fill the process by assessing the performance of steel, Inconel 600, chromium vanadium, materials under varying load conditions, considering their deflections and changing their diameter of spring wire. Through simulation on Ansys, the study validates results and identifies that coil diameter affects spring stress. To identify the best suited material for compression spring for the given application. For this analysis three different materials are carried out which include stainless steel, Inconel 600, and Chromium vanadium.

To design and calculate the deflections of the spring for materials like steel, Inconel 600 and chromium vanadium, subjected to various loading conditions. In which the loads had been used for their variation of theoretical calculations and the analytical calculations. The loads to be used are (100kg to 200 kg) i.e., 1177N, 1373N, 1570N, 1740N, 1920N (the selection has been done as per the standards). To design and calculate the deflections of the spring for materials like steel, Inconel 600, Chromium vanadium, subjected to various loading conditions for changing the diameter of the spring wire to be used. [6][7][8]

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/ **Research Article**

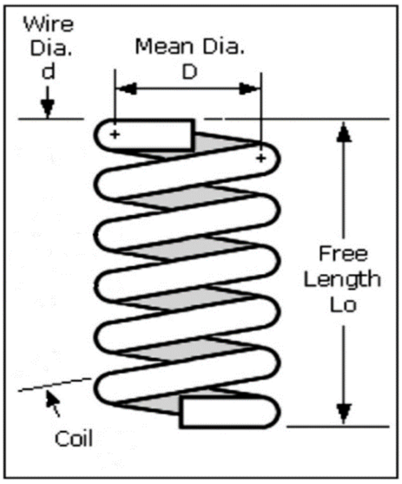

Figure 2, Design parameters of a helical spring.

For Steel Spring:

Considered Force (P) = 1177 N for design purpose,

Solid Height (Ls) = 225 mm

Wire diameter (d) = 7.5 mm,

Mean diameter (D) = 42.5 mm,

Sut (σ) = 1000 N/mm

Turns (n) = 17

Spring index,

(C) $=\frac{D}{d}=\frac{42.5}{7.5}=5.66$

The permissible stress is given by, τ=0.5, σ= 0.5 (1000) = 500 N/mm^2

$K=\frac{4c-1}{4c-4}+(\frac{0.615}{C})$

$=\frac{4\times5.66-1}{4\times5.66-4}+(\frac{0.615}{5.66})$

= 1.26

$\tau=\frac{K8PD}{\pi d^3}$

$=\frac{1.269\times8\times1177\times42.5}{\pi 7.5^3}$

= 383.16N/mm²

The Finite element Analysis is done and shown in the following figures, Figure number 3 to 12 for steel at the load of 1177 N,1373N,1570N,1766 N. The results are depicted in the table 1 and 2.

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

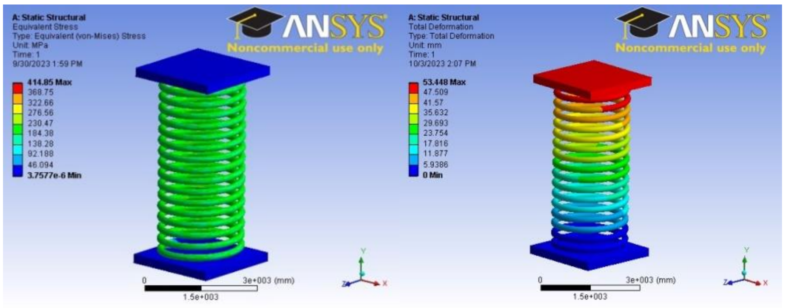

Figure 3, 4, shows von misses stress and deflection at load 1177 N for steel.

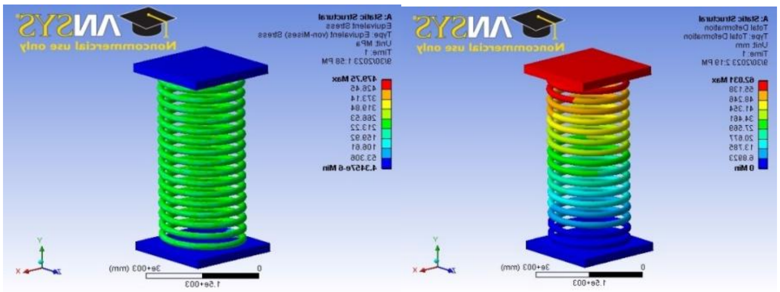

Figure: 5, 6, shows von misses stress and deflection at load 1373N for steel.

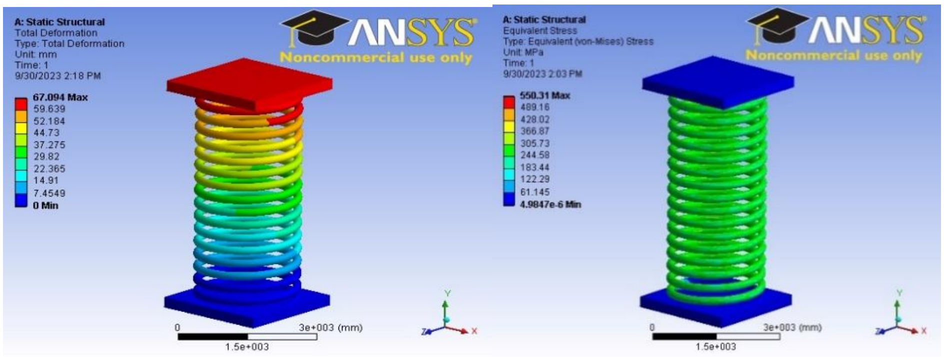

Figure: 7, 8, shows von misses stress and deflection at load 1570 N for steel.

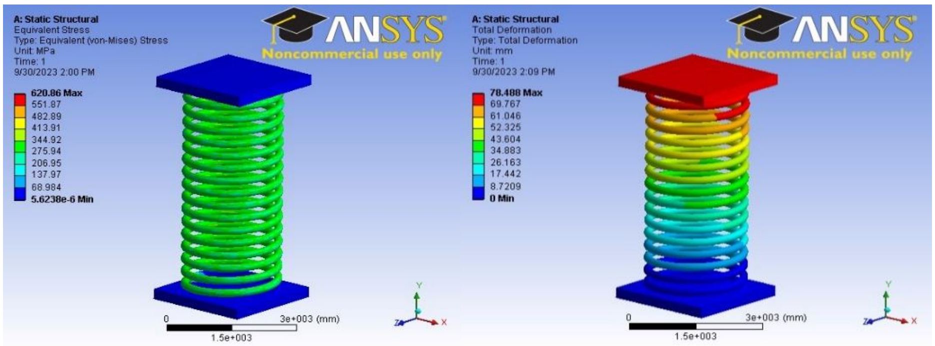

Figure:9,10, shows von misses stress and deflection at load 1766 N for steel.

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

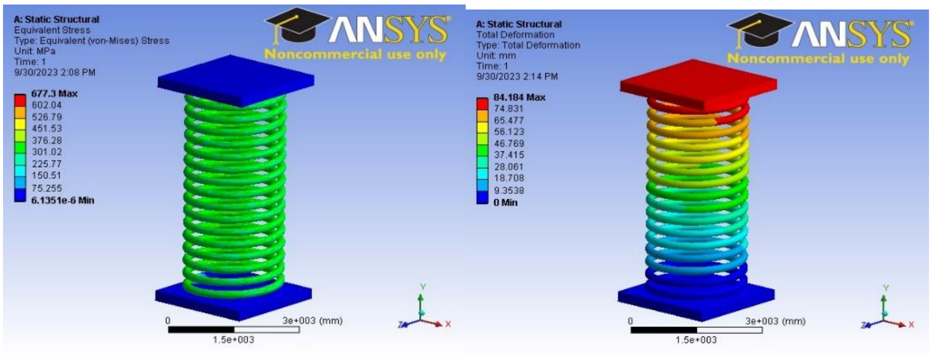

Figure: 11,12, shows von misses stress and deflection at load 1962N for steel.

Table 1: Variation of maximum theoretical and analytical deformation with variable loads

LOAD(N)	Theoretical Max. Deformation (mm)	Ansys Max. Deformation (mm)	Variation (%)
1177	49.15	53.43	8.7
1373	57.34	62.03	8.17
1570	65.57	67.09	2.31
1766	73.76	78.48	6.39
1962	81.94	84.18	2.73

Table 2: Analytical result of Stainless steel

LOAD(N)	**Max. stress(N/mm^2)**	**Deflection(mm)**
1177	414.83	53.43
1373	479.75	62.03
1570	550.31	67.09
1766	620.86	78.48
1962	677.30	84.18

For Inconel 600 spring:

Considered Force (P) = 1177 N for design purpose,

Solid Height (Ls) = 225 mm

Wire diameter (d) = 7.5 mm,

Mean diameter (D) = 42.5 mm,

Sut (σ) = 1000 N/mm

Turns (n) = 17

Spring index,

(C) $=\frac{D}{d}=\frac{42.5}{7.5}=5.66$

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

The permissible stress is given by,

τ=0.5, σ= 0.5 (1000) = 500 N/mm^2

$K=\frac{4c-1}{4c-4}+(\frac{0.615}{c})$

$=\frac{4\times5.66-1}{4\times5.66-4}+(\frac{0.615}{5.66})$ = 1.26

$\tau=\frac{K8PD}{\pi d^3}=\frac{1.269\times8\times1177\times42.5}{\pi 7.5^3}$= 383.16N/mm²

Deflection,

$=\frac{8PD^3N}{Gd^4}$

$=\frac{8\times1177\times42.5^3\times17}{75800\times7.5^4}$

=50.51 mm

Stiffness $=\frac{load}{deflection}=\frac{1177}{50.51}$ =23.30 N/mm.

The Finite element Analysis is done and shown in the following figures, Figure number 13 to 22 for Inconel at the load of 1177 N, 1373N, 1570N, 1766 N, 1962N. The results are depicted in the table 3 and 4. Here the load selection has been selected from 120 kg to 200kg as an average. So, 120*9.8=1177N, 140*9.8=1373, 160*9.8=1570N, 180*9.8=1766N and 200*9.8=1962N.[9][10]

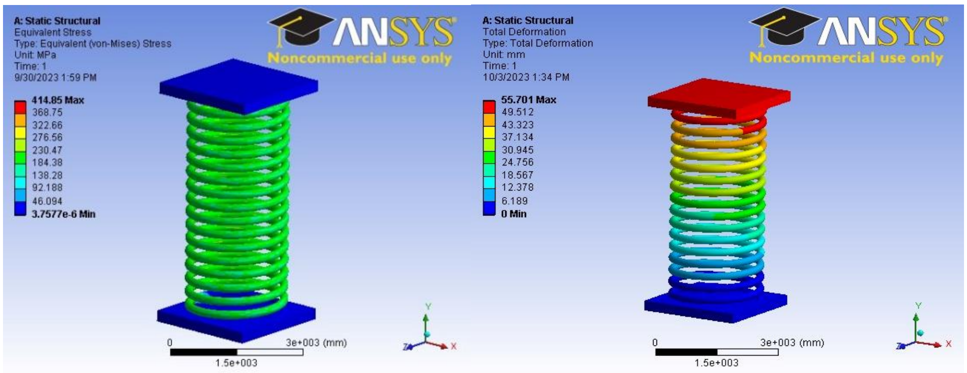

Figure 13, 14, shows von misses stress and deflection at load 1177 N for Inconel.

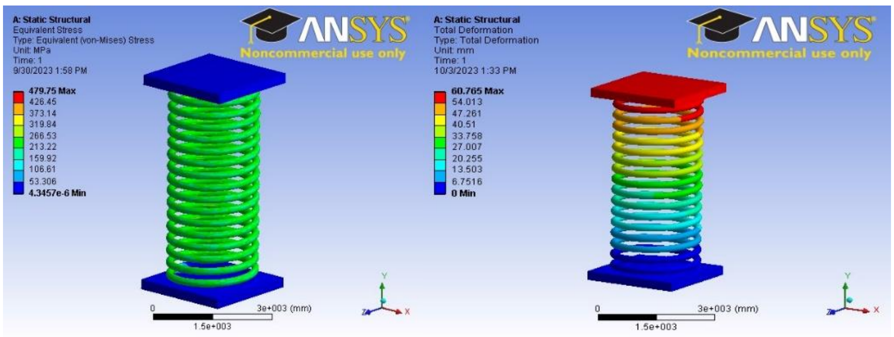

Figure 15, 16, shows von misses stress and deflection at load 1373 N for Inconel.

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

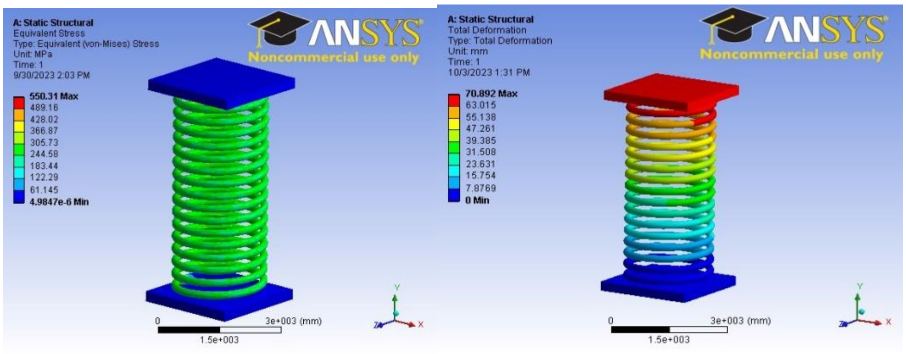

Figure 17, 18, shows von misses stress and deflection at load 1570 N for Inconel.

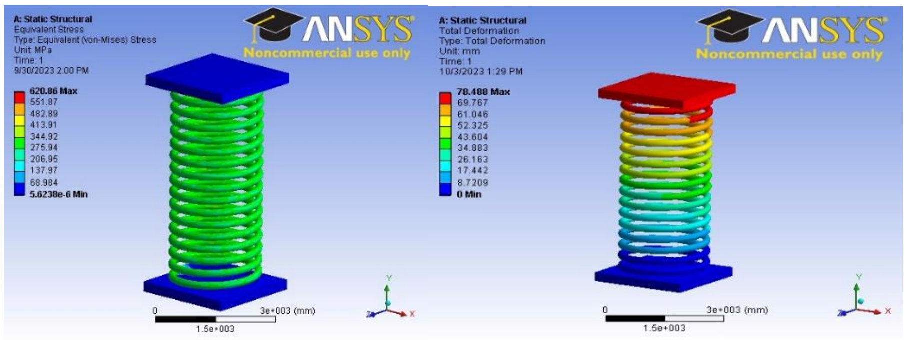

Figure 19, 20, shows von misses stress and deflection at load 1766 N for Inconel.

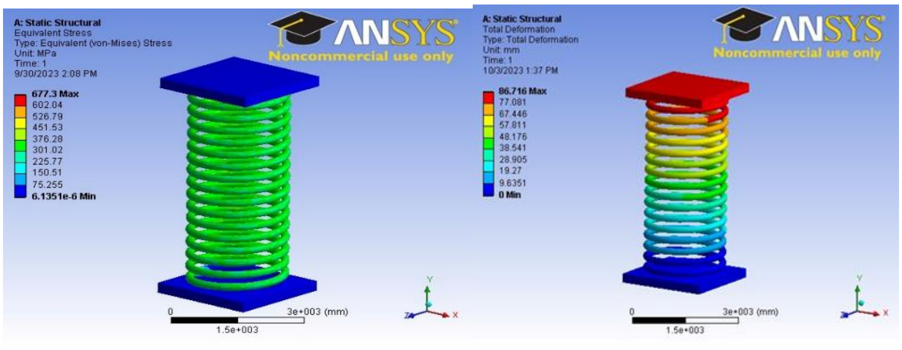

Figure 21, 22, shows von misses stress and deflection at load 1962N for Inconel.

Table 3: Variation of maximum theoretical and analytical deformation with variable loads

LOAD(N)	Theoretical Max. Deformation (mm)	Ansys Max. Deformation (mm)	Variation (%)
1177	50.51	55.16	9.2
1373	58.92	60.76	3.12
1570	67.38	70.89	5.2
1766	75.79	78.48	3.54
1962	84.20	86.71	2.98

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

Table 4: Analytical Results of Inconel 600

LOAD(N)	Max. stress(N/mm^2)	Deflection(mm)
1177	414.83	55.16
1373	479.75	60.76
1570	550.31	70.89
1766	620.86	78.48
1962	677.30	86.71

For Chromium Vanadium spring:

Considered Force (P) = 1177 N for design purpose,

Solid Height (Ls) = 225 mm

Wire diameter (d) = 7.5 mm,

Mean diameter (D) = 42.5 mm,

$Sut\ (\sigma)$ = 1000 N/mm

Turns (n) = 17

Spring index,

(C) $=\frac{D}{d}=\frac{42.5}{7.5}$=5.66

The permissible stress is given by,

τ=0.5 σ = 0.5 (1000) = 500 N/mm^2

K=$\frac{4c-1}{4c-4}+(\frac{0.615}{c})$

=$\frac{4\times5.66-1}{4\times5.66-4}+(\frac{0.615}{5.66})$ = 1.26

τ=$\frac{K8PD}{\pi d^3}=\frac{1.269\times8\times1177\times42.5}{\pi 7.5^3}$ = 383.16 N/mm²

Deflection,=$\frac{8PD^3N}{Gd^4}=\frac{8\times1177\times42.5^3\times17}{87500\times7.5^4}$=44.38 mm

Stiffness,=$\frac{load}{deflection}=\frac{1177}{44.38}$ =26.52 N/mm

The Finite element Analysis is done and shown in the following figures, Figure number 23 to 32 for Chromium vanadium at the load of 1177 N,1373N,1570N,1766 N. The results are depicted in the table 5 and 6.[11][12]

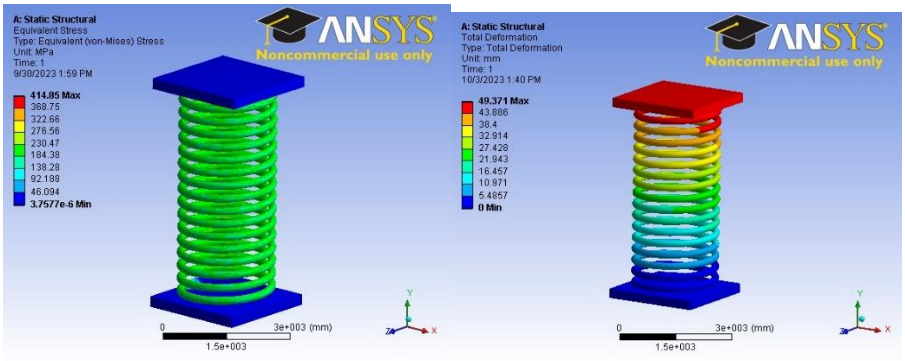

Figure 23, 24, shows von misses stress and deflection at load 1177 N for Chromium

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

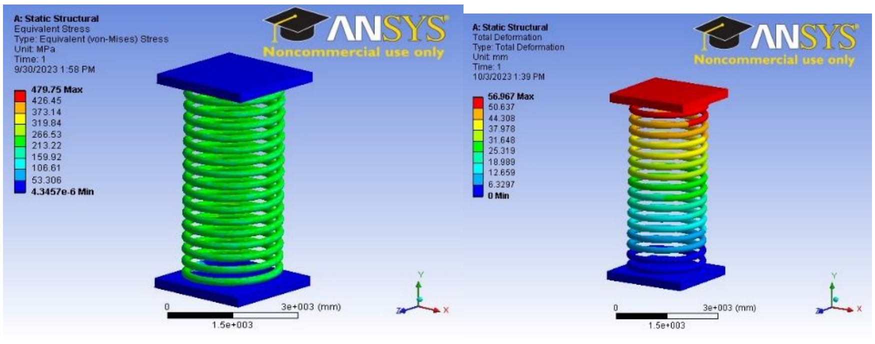

Figure 25, 26, shows von misses stress and deflection at load 1373 N for Chromium

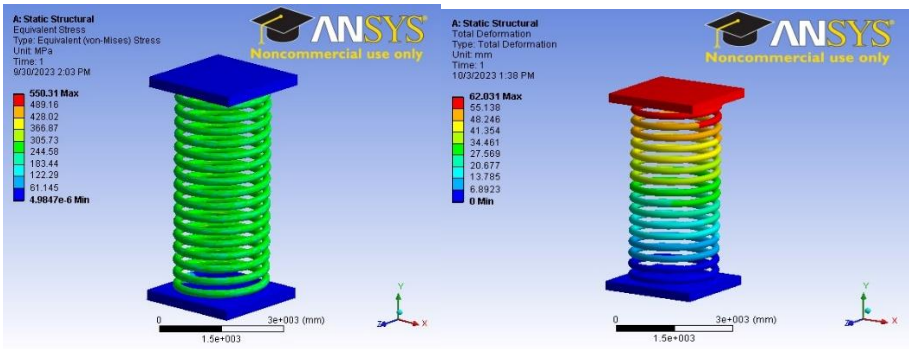

Figure 27, 28, shows von misses stress and deflection at load 1570 N for Chromium.

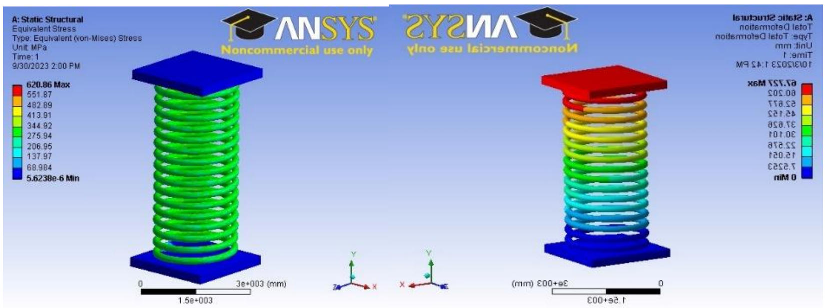

Figure: 29, 30, shows von misses stress and deflection at load 1766 N for Chromium.

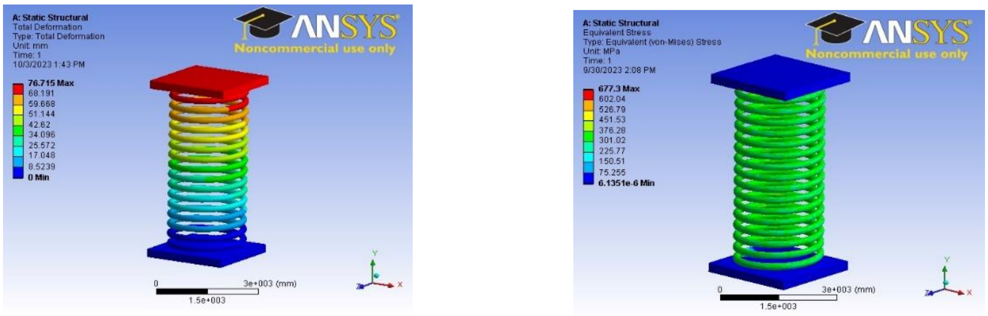

Figure: 31, 32, shows von misses stress and deflection at load 1962N for Chromium.

Table 5: Variation of maximum theoretical and analytical deformation with variable loads

LOAD(N)	Theoretical Max. Deformation (mm)	Ansys Max. Deformation (mm)	Variation (%)

1177	44.38	49.37	11.24
1373	51.77	56.96	10
1570	58.37	62.03	6.27
1766	65.65	67.72	3.15
1962	72.94	76.71	5.16

Table 6: Analytical results of Chromium vanadium

LOAD(N)	Max. stress(N/mm^2)	Deflection(mm)
1177	414.83	49.37
1373	479.75	56.96
1570	550.31	62.03
1766	620.86	67.72
1962	677.30	76.71

RESULTS AND DISCUSSION

The performance of stainless steel, Inconel 600, and chromium vanadium as shock absorber spring materials was evaluated based on deformation and stress distribution under applied loads starting from 1177N (120 Kg*9.8) and ending at 1962N (200Kg*9.8). The analysis was conducted using both theoretical calculations and finite element analysis (FEA).[13][14][15]

Deformation Analysis

The deformation analysis for all three materials under varying loads reveals distinct performance characteristics. Stainless Steel exhibits a theoretical deformation of 49.15 mm and an analytical deformation of 53.44 mm at 1177N, increasing to 81.94 mm and 84.18 mm, respectively, at 1962N. Inconel 600 shows slightly higher deformation, with theoretical and analytical values of 50.51 mm and 55.16 mm at 1177N, and 84.20 mm and 86.71 mm at 1962N. Among the three, Chromium Vanadium demonstrates the least deformation, with a theoretical value of 44.38 mm at 1177N and an analytical deformation of 76.74 mm at 1962N, indicating superior stiffness and load-bearing capacity. These results suggest that chromium vanadium has the lowest deformation under both loading conditions, making it the most efficient material for maintaining structural integrity and minimizing excessive deflection in shock absorber springs.

Stress Analysis

The maximum von Mises stress values for each material were analysed under different loading conditions. At 1177N, the maximum stress recorded was 414.83 N/mm², while at 1962N, it increased to 677.30 N/mm², indicating a significant rise in stress with higher loads.

The stress values indicate that all three materials experience significant stress under high loads, but chromium vanadium, due to its higher stiffness and strength, exhibits better mechanical performance with lower deformation while sustaining comparable stress levels. The comparative study reveals that chromium vanadium is the most suitable material for shock absorber springs due to its higher stiffness, lower deformation, and strong load-bearing capability. Although Inconel 600 provides good fatigue resistance, it exhibits slightly higher deformations under load. Stainless steel, while widely used, demonstrates the highest deformation, making it less effective for applications requiring enhanced durability and performance. These findings indicate that material selection plays a crucial role in optimizing suspension system efficiency, where chromium vanadium stands out as the best-performing material. Future research can explore advanced composite materials and manufacturing techniques to further improve shock absorber durability, energy absorption, and ride comfort.

Journal of Information Systems Engineering and Management
2025, 10(44s)
e-ISSN: 2468-4376
https://www.jisem-journal.com/

Research Article

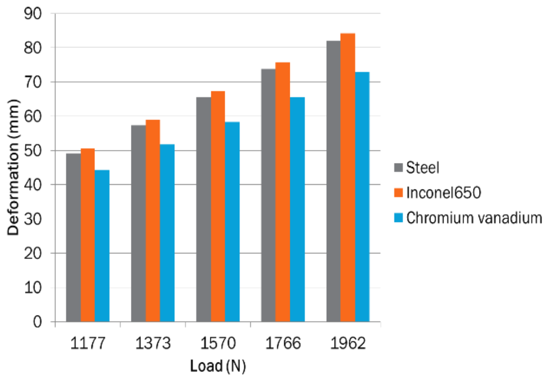

Figure:33, graph shows that the three different materials are stainless steel, Inconel 600, chromium vanadium, with different loading conditions.

CONCLUSIONS:

This study focused on the design, modelling, and static analysis of a helical compression spring for a 150cc two-wheeler shock absorber. The spring was modelled in SOLIDWORKS and analysed using ANSYS to evaluate stress distribution and deformation under loads ranging from 1177N to 1962N. Results showed that maximum stress occurs on the inner coil for all materials. Among Spring Steel, Chromium Vanadium, and Inconel 600, Chromium Vanadium exhibited the least deformation (49.37 mm at 1177N), indicating superior stiffness and strength. This makes it the preferred choice for shock absorber springs. Also the factor of safety of the considered material Chromium Vanadium is 1.45, which is well within the limit i.e., FOS is > 1. Future research can explore advanced materials for enhanced suspension performance.

REFERENCES

[1] Rao, S. S. (2019). *Vibration of continuous systems*. John Wiley & Sons.
[2] Patel, D. P. & Patel, K. S. “Performance evaluation of helical compression spring for automobile suspension system,” *J. Mater. Sci. Eng.*, vol. 4, no. 1, pp. 17–25, 2016.
[3] Hejib, A. G., "Analysis of Helical Compression Spring Used in Two Wheeler Suspension System," *Int. J. Sci. Res. Eng. Trends*, vol. 8, no. 1, pp. 359–361, 2022
[4] Gupta, K. M. (2014). Engineering materials: research, applications and advances.
[5] Khope, P. B., Shelare, S. D., & Gunjal, S. S. (2022). Design and Analysis of Two Wheeler Suspension Helical Compression Spring. *Optimization of Industrial Systems*, 265-278.
[6] Islam, T., Uddin, M. W., & Uddin, R. (2024). Finite element analysis of motorcycle suspension system stability using different materials. *Journal of Engineering Research*.
[7] Liu, W., Janbaz, S., Dykstra, D., Ennis, B., & Coulais, C. (2023). Leveraging yield buckling to achieve ideal shock absorbers. *arXiv preprint arXiv:2310.04748*.
[8] Schickhofer, L., & Antonopoulos, C. G. (2024). Cause–effect relationship between model parameters and damping performance of hydraulic shock absorbers. *International Journal of Non-Linear Mechanics*, *159*, 104627.
[9] Imoro, I., Nkrumah, J. K., Ziblim, B., & Mohammed, A. H. (2023). Analysis of the material properties of vehicle suspension coil spring. *World Journal of Engineering and Technology*, *11*(4), 827-858.
[10] Khope, P. B., Shelare, S. D., & Gunjal, S. S. (2022). Design and Analysis of Two Wheeler Suspension Helical Compression Spring. *Optimization of Industrial Systems*, 265-278.
[11] "Analysis of Helical Spring, a Review," *Int. Res. J. Mod. Eng. Technol. Sci.*, vol. 6, no. 12, pp. 2694–2700, 2024.
[12] "Static & Dynamic Analysis of Open Coil Helical Spring Used in Two Wheeler Suspension," *Int. Res. J. Eng. Technol.*, vol. 11, no. 4, pp. 528–535, 2024.
[13] Chougule, P. S., & J. S. Giri., 2018. "Analysis of Shock Absorber Springs with Different Materials." *International Journal of Mechanical Engineering and Robotics Research* 7 (5): 447–453.

[14] Patel, D. P., & K. S. Patel., 2016. "Performance Evaluation of Helical Compression Spring for Automobile Suspension System." *Journal of Materials Science and Engineering* 4 (1): 17–25.

[15] Srinivasan, V., & R. Ramakrishnan., 2020. "Comparative Analysis of Different Spring Materials for Automotive Suspension Systems." *International Journal of Automotive Engineering* 9 (2): 212–220.