



Static structural analysis of 2-wheeler shock absorbers: A comparative study of Different materials

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Abstract

This study focuses on the design and static structural analysis of a 2-wheeler shock absorber using SolidWorks 2024 for 3D modeling and ANSYS 2024 R1 for structural analysis. The investigation aims to evaluate the mechanical performance of the shock absorber under various loading conditions. Three materials are considered for the spring and structural components: Structural Steel, Carbon Steel 1020, and Silicon Spring Steel. The design process includes detailed modeling of the shock absorber's key elements such as the spring, piston, and damping system. The static structural analysis examines key parameters including stress distribution, deformation, and factor of safety under typical load conditions encountered during vehicle operation. The findings provide valuable insights into material selection for enhanced shock absorber performance, ensuring improved ride comfort, durability, and safety in two-wheeler applications.

Keywords: 2-wheeler shock absorber, SolidWorks 2024, ANSYS 2024 R1

1.INTRODUCTION

A shock absorber or damper is a mechanical device designed to smooth out or damp shock impulse, and dissipate kinetic energy. Pneumatic and hydraulic shock absorbers commonly take the form of a cylinder with a sliding piston inside. The cylinder is filled with a fluid (such as hydraulic fluid) or air. This fluid-filled piston/cylinder combination is a dashpot. The shock absorbers duty is to absorb or dissipate energy. These are an important part of automobile suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in commuter railroads and rapid transit systems because they prevent railcars from damage station platforms.

2. LITARATURE REVIEW

K. Michalczyk [1] In their study to the model is also changed by changing the thickness of the spring. Structural analysis and modal analysis are done on the shock absorber by varying different spring materials. Spring materials are Spring Steel, Phosphor bronze, Beryllium

Copper and Titanium alloy. B. Pyttel, I. Brunner, et al. [2] the problems with motor cars was the large variation in sprung weight between lightly loaded and fully loaded, especially for the rear springs. When heavily loaded the springs could bottom out, and apart from fitting rubber 'bump stops', there were attempts to use heavy main springs with auxiliary springs to smooth the ride when lightly loaded, which were often called 'shock absorbers'. Touhid Zarrin-Ghalami, Ali Fatemi [3] presents the analytical proof of the presence of two inefficient areas in vehicle suspension oscillation cycle in linear shock absorber work. It derived on the basis of analysis of the dynamics equations for the linear single-support single-mass vibrating system with fixed elastic and damping characteristics at harmonic kinematic disturbance. Wei Li, Tatsuo Sakai, et al. [4] Preloaded liquid spring/damper based shock isolation systems are suitable for heavy load military applications. In this paper, mathematical models are developed for passive liquid spring shock absorbers. The preloading is achieved by mounting the load between two liquid spring/dampers. Dynamics of such shock absorbers involve coupled hydrodynamic and thermodynamic phenomena. Sid Ali Kaoua, Kamel Taibi, et al. [5] This paper displays a 3D geometric demonstrating of a twin helical spring and its limited component examination to contemplate the spring mechanical conduct under pliable hub stacking. The spiraled shape visual computerization is accomplished using Computer Aided Design (CAD) instruments, of which a limited component demonstrate is created. B. Pyttel, D. Schwerdt, et al. [6] The paper gives an outline of the current situation with look into on weakness quality and disappointment systems at high number of cycles ($N_f > 10^7$). Testing offices are recorded. A grouping of materials with run of the mill S-N bends and affecting elements like scores, remaining burdens and condition are given. Diverse disappointment instruments which happen particularly in the VHCF-locale like subsurface disappointment are clarified. Stefanie Stanzl-Tschegg [7] As far back as high-quality steels were found to flop beneath the conventional exhaustion constrain when stacked with more than 10^8 cycles, the examination of metals' and combinations' high cycle weariness properties has gotten expanded consideration.

3. METHODOLOGY

The shock absorber two-wheeler design is done in SolidWorks in order to develop the 3D models of major parts including the piston, spring, and damping system. In ANSYS 2024 R1, structural analysis is conducted in the static conditions, thus determining the stress distribution, deformation, and the safety factor in different load conditions. Shock absorber is experimented using three different materials structural steel, carbon steel 1020, and silicon spring steel under common loads of operation:

Shock Absorber Working principal:

The concept of a two-wheeler shock absorber is to absorb the impact of road irregularities in order to make the ride smoother. When the bumps hit the wheel, the shock absorber compresses converting the kinetic energy to heat either in the hydraulic fluid or gas. This process makes the compression process slow so that sudden jarring impacts are avoided. At rebound, the shock absorber regulates the restoration of the suspension back to the original extended position to avoid excessive bouncing. Damping in the shock absorber makes the movement controlled which enhances comfort, stability, handling by ensuring that tire contacts the road better.

Design of 2-wheeler shock absorber

The design of a 2-wheeler shock absorber using SolidWorks 2026 involves creating a detailed 3D model of the shock absorber, which includes key components such as the piston, spring, and damping system.

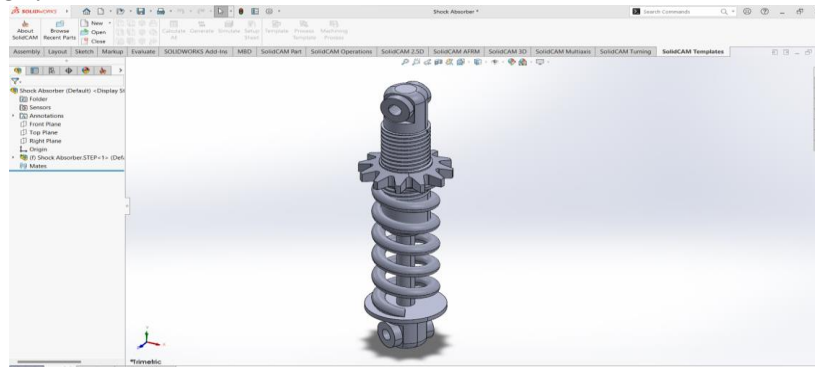


Figure 1: Design model

Table 1, Shock Absorbor Material properties

Material Parameters	Structural Steel	Carbon Steel 1020	Silicon Steel	Spring
Density (g/cm ³)	7.85	7.87	7.8	
Melting Point (°C)	1370–1530	1450–1500	1400–1450	
Tensile Strength (MPa)	400-550	400-500	900-1100	
Yield Strength (MPa)	250-350	250	500-800	
Poisson's Ratio	0.29	0.29	0.29	
Thermal Conductivity (W/m·K)	45	50	45-50	

4. RESULTS AND DISCUSSIONS

Static structural analysis is a method used in engineering to determine the effects of static (non-moving) loads on a structure or mechanical component. This type of analysis is crucial in ensuring that the structure or component can withstand the applied loads without failing. The analysis focuses on aspects like stress, strain, deformation, and factor of safety

Case -1 Structural steel at 300 KG.

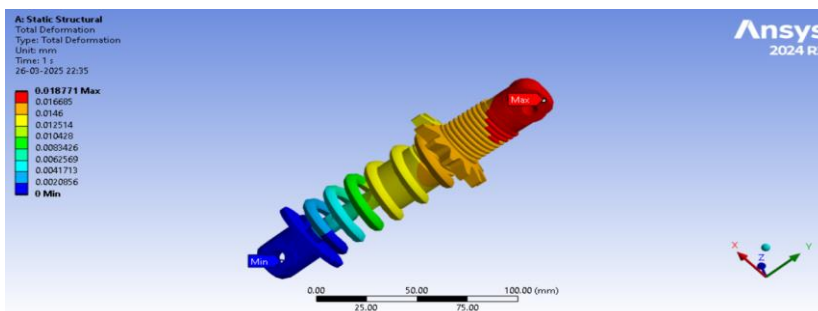


Figure 2: Total deformation

The image shows the total deformation of a shock absorber made of structural steel under a load of 300 kg. The maximum total deformation is 0.018771 mm, as indicated in the legend. The location of the maximum total deformation is shown by the red region on the shock absorber.

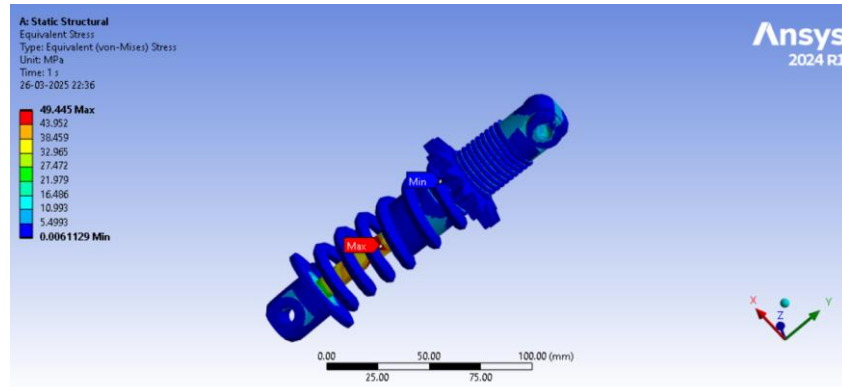


Figure 3: Equivalent stress

The image shows the equivalent stress distribution in a shock absorber subjected to a load of 300 kg. The maximum equivalent stress is 44.43 MPa, as indicated in the legend.

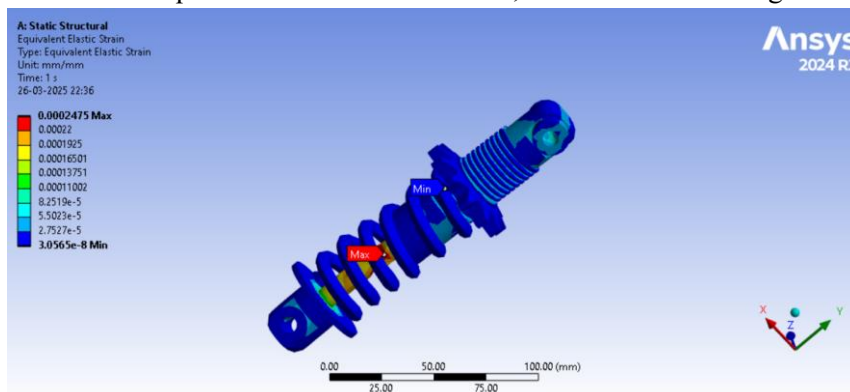


Figure 4: Equivalent strain

The image shows the equivalent strain distribution in a shock absorber subjected to a load of 300 kg. The maximum equivalent strain is 0.0002475 mm/mm, as indicated in the legend. The location of the maximum equivalent strain is shown by the red region on the shock absorber.

Structural steel Shock absorber at 450 KG.

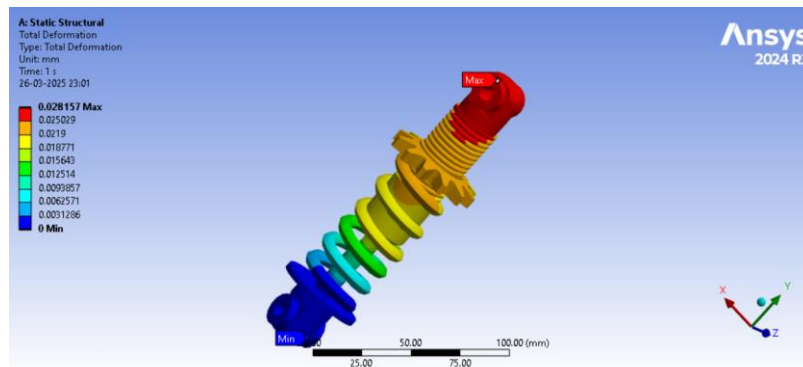


Figure 5: Total deformation

The figure shows the total deformation of a shock absorber subjected to a load of 450 kg (4412.99 N). The maximum total deformation is 0.028157 mm, as indicated in the legend. The location of the maximum total deformation is shown by the red region on the shock absorber.

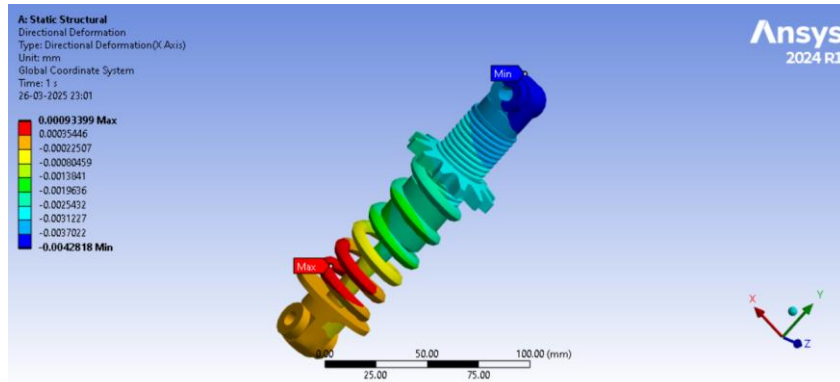


Figure 6: Directional deformation

The directional deformation of a shock absorber subjected to a load of 450 kg (4412.99 N). The maximum directional deformation is 0.000934 mm, as indicated. The location of the maximum directional deformation is shown by the red region on the shock absorber.

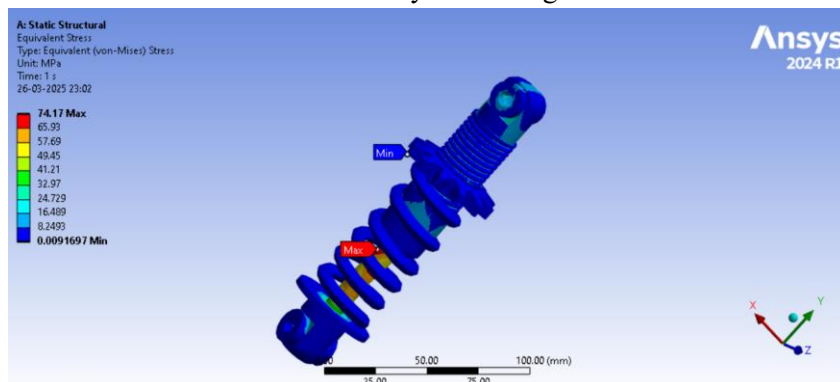


Figure 7: Equivalent stress

A structural steel shock absorber is subjected to a load of 450 kg (4412.99 N) in the picture, which represents the corresponding stress distribution. The maximal equivalent stress is 74.17 MPa, as previously mentioned.

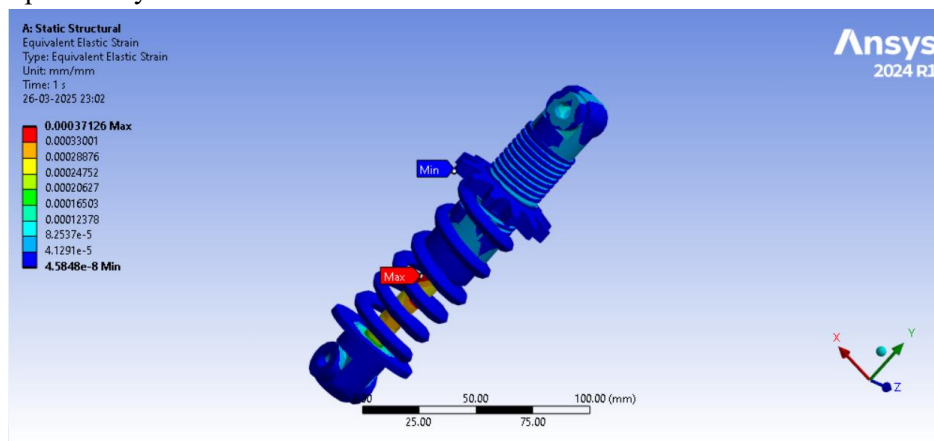


Figure 8: Equivalent strain

When a shock absorber is loaded, the picture depicts the corresponding strain distribution. The highest equivalent strain may be seen as 0.00037126 mm/mm. The red area on the shock absorber shows where the highest equivalent strain is.

Structural steel Shock absorber at 600 KG

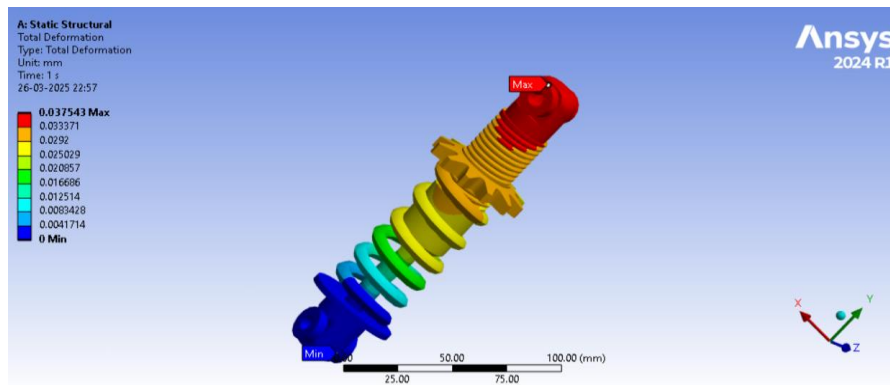


Figure 9: Total deformation

The figure shows the total deformation of a shock absorber made of structural steel under a load of 600 kg. The maximum total deformation is 0.037543 mm, as indicated in the legend. The location of the maximum total deformation is shown by the red region on the shock absorber.

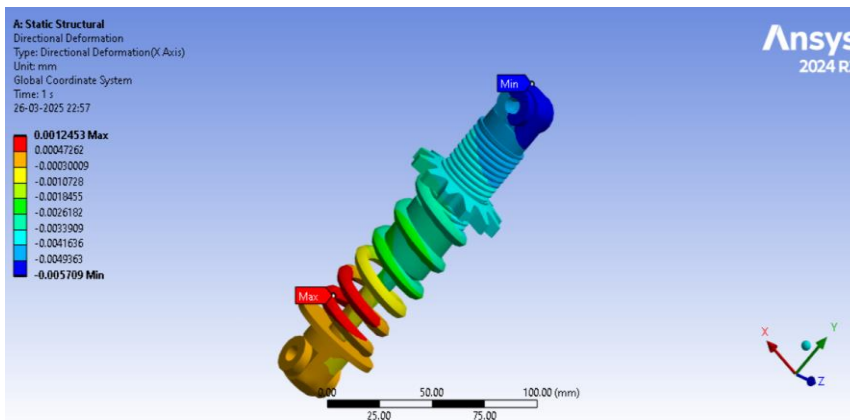


Figure 10: Directional deformation

The image shows the directional deformation of a shock absorber subjected to a load. The maximum directional deformation is 0.0012453 mm, as indicated in the legend. The location of the maximum directional deformation is shown by the red region on the shock absorber.

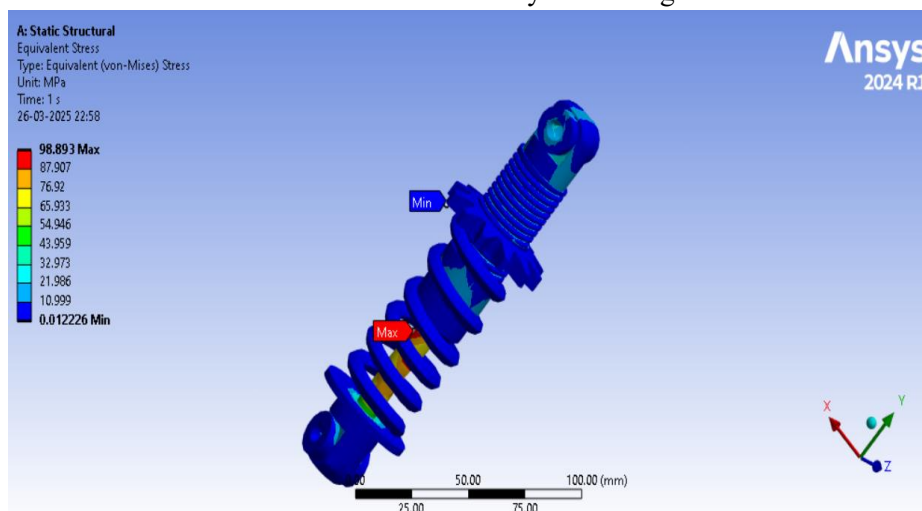


Figure 11: Equivalent stress

A shock absorber that has been exposed to a load is depicted in the figure, which illustrates the corresponding stress distribution. According to the legend, the maximal equivalent stress

is 98.03 MPa. In the red section of the shock absorber, the position of the maximal equivalent stress is shown for visualization purposes.

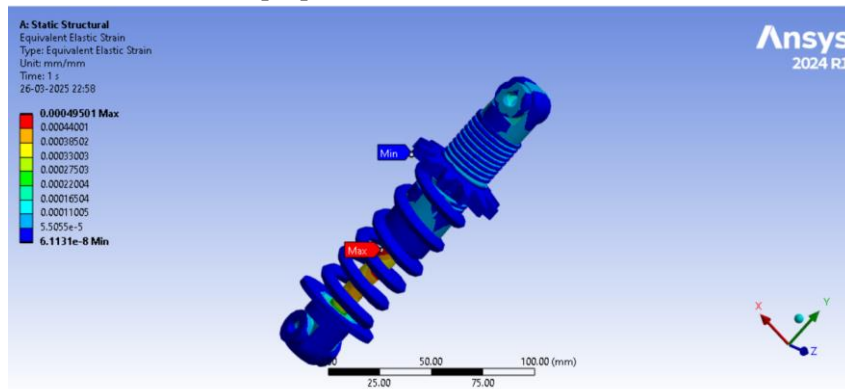


Figure 12: Equivalent strain

The figure illustrates the same strain distribution in a shock absorber. As the label notes, the maximum equivalent strain is 0.0004951 mm/mm. The red area on the shock absorber shows the site of the greatest equivalent strain.

Case -2 Carbon steel 1020 shock absorber at 300 KG

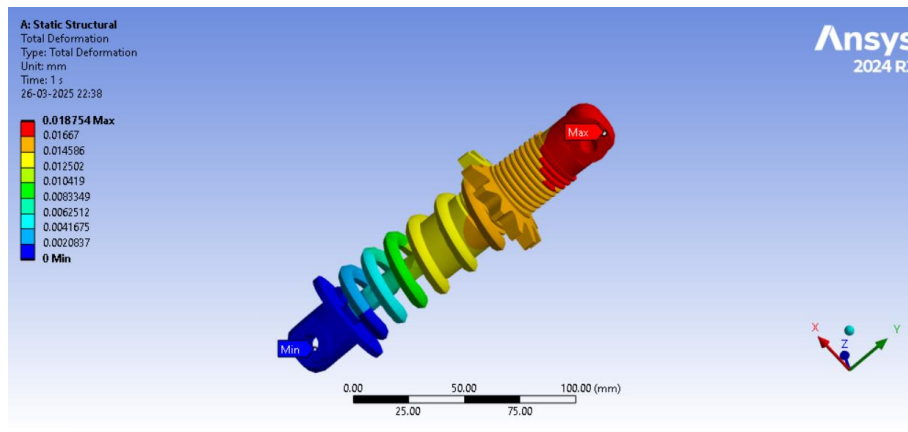


Figure 13: Total deformation

The total deformation of a carbon steel 1020 shock absorber subjected to a load of 300 kg. The maximum total deformation is 0.018754 mm, as indicated in the legend. The location of the maximum total deformation is shown by the red region on the shock absorber.

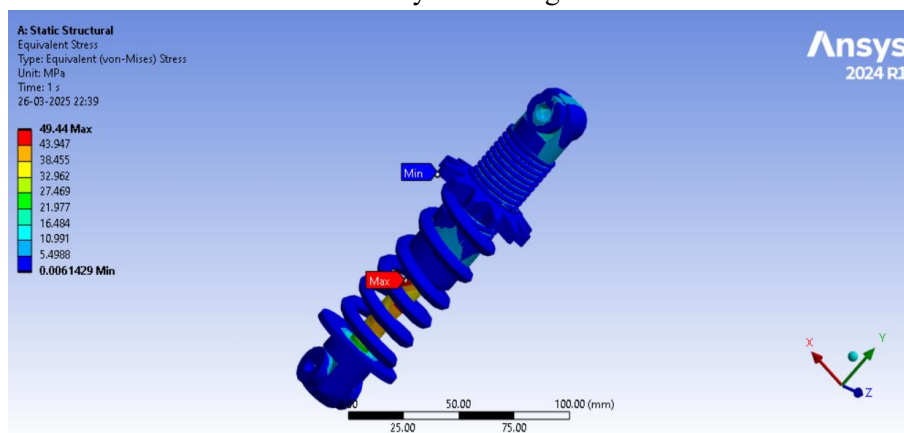


Figure 14: Equivalent stress

The distribution of equivalent stress in a shock absorber made of carbon steel 1020. Specified in the legend, the highest equivalent stress recorded is 49.441 MPa. The red patch on the shock absorber indicates the spatial position of the maximal equivalent stress.

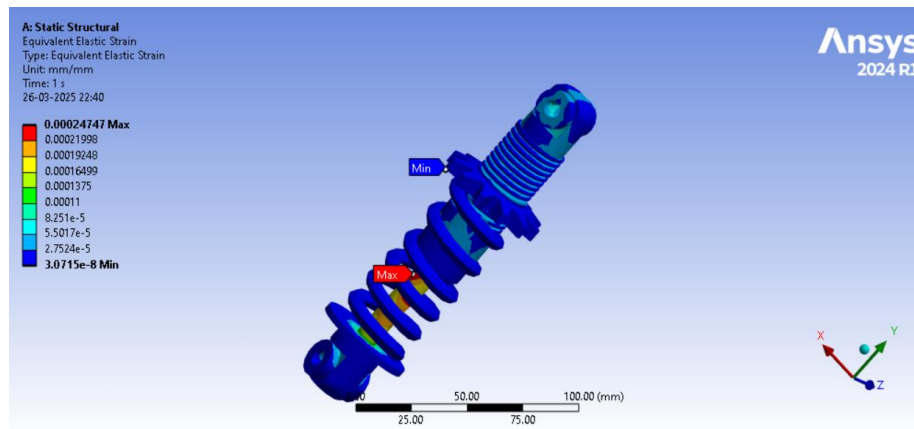


Figure 15: Equivalent strain

the equivalent strain distribution in a carbon steel 1020 shock absorber. The maximum equivalent strain is 0.00049501 mm/mm, as indicated in the legend. The location of the maximum equivalent strain is shown by the red region on the shock absorber.

Carbon steel 1020 Shock absorber at 450 KG

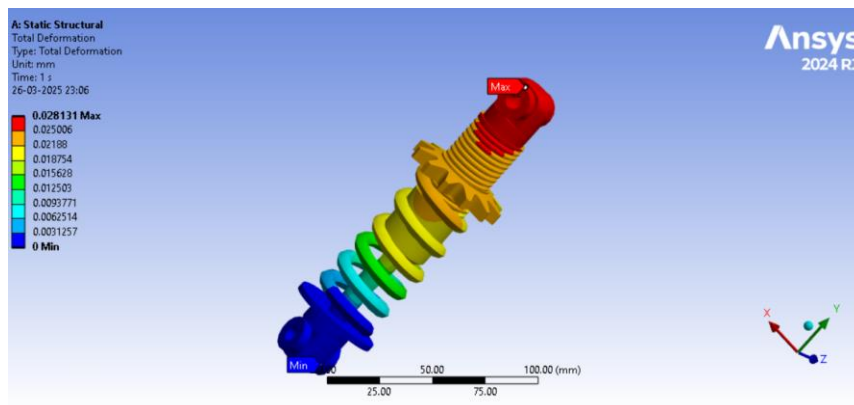


Figure 16: Total deformation

The Total deformation of a carbon steel 1020 shock absorber under a 450 kg load. According to the legend, the highest recorded overall deformation is 0.028138 mm.

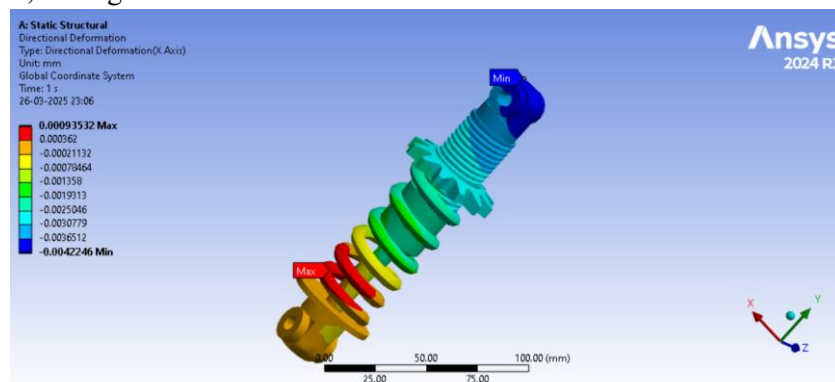


Figure 17: Directional deformation

The directional deformation of a carbon steel 1020 shock absorber subjected to a load of 450 kg. The maximum directional deformation is 0.00093469 mm, as indicated. The location of the maximum directional deformation is shown by the red region on the shock absorber.

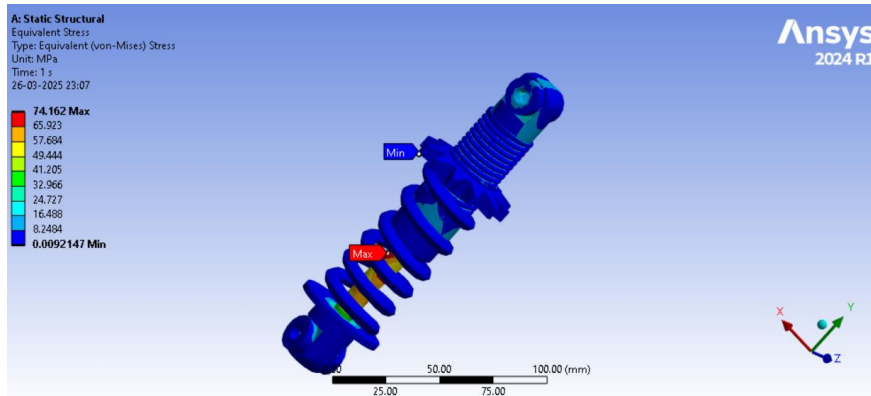


Figure 18: Equivalent stress

the equivalent stress distribution in a carbon steel 1020 shock absorber subjected to a load of 450 kg. The maximum equivalent stress is 74.164 MPa, as indicated in the legend. The location of the maximum equivalent stress is shown by the red region on the shock absorber.

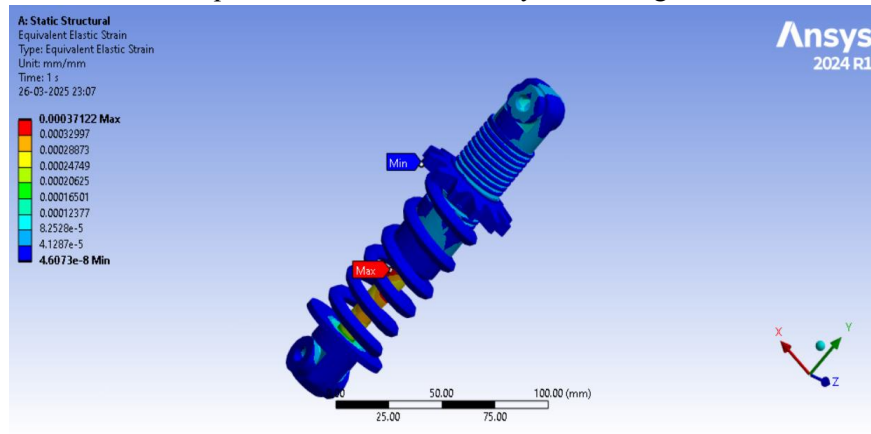


Figure 19: Equivalent strain

the equivalent strain distribution in a carbon steel 1020 shock absorber subjected to a load of 450 kg. The maximum equivalent strain is 0.00049501 mm/mm, as indicated in the legend. The location of the maximum equivalent strain is shown by the red region on the shock absorber.

Carbon steel 1020 Shock absorber at 600 KG

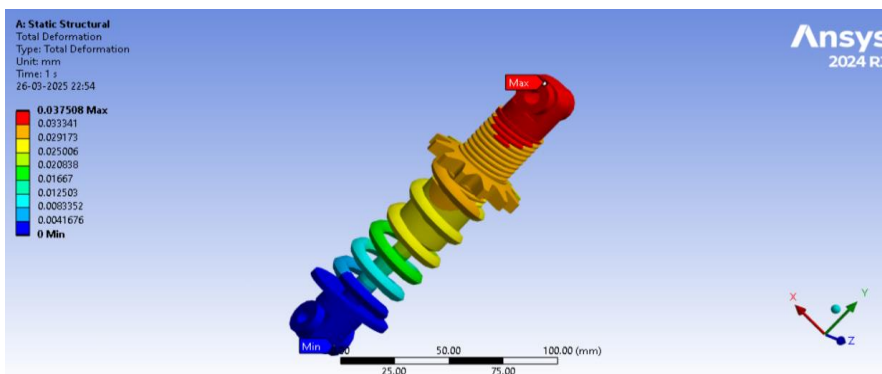


Figure 20: Total deformation

the total deformation of a carbon steel 1020 shock absorber subjected to a load of 600 kg. The maximum total deformation is 0.037508 mm, as indicated in the legend. The location of the maximum total deformation is shown by the red region on the shock absorber.

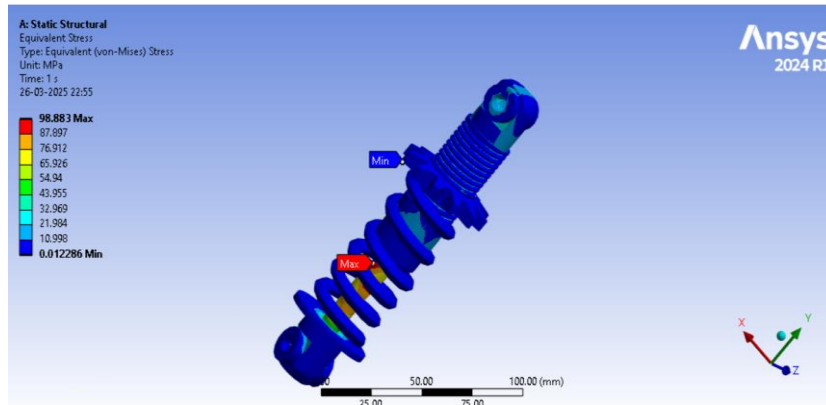


Figure 21: Equivalent stress

the equivalent stress distribution in a carbon steel 1020 shock absorber. The maximum equivalent stress is 68.883 MPa, as indicated in the legend. The location of the maximum equivalent stress is shown by the red region on the shock absorber.

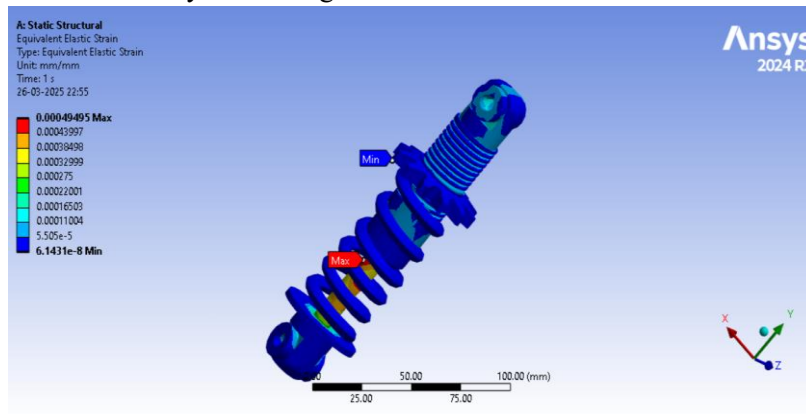


Figure 22: Equivalent strain

The figure shows that equivalent strain distribution in a carbon steel 1020 shock absorber. The maximum equivalent strain is 0.00049501 mm/mm, as indicated in the legend. The location of the maximum equivalent strain is shown by the red region on the shock absorber.

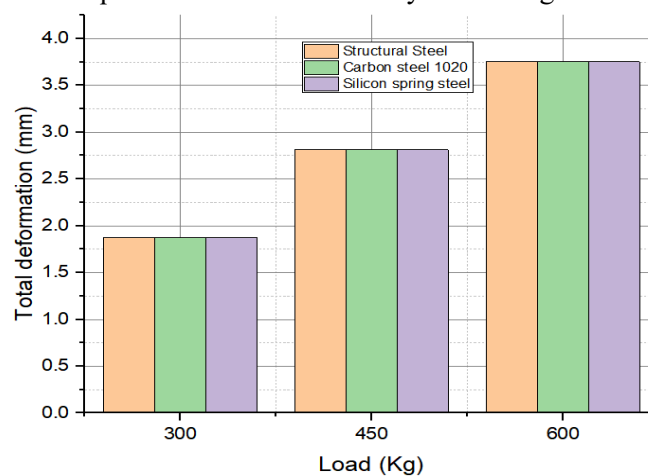


Figure 23: Validation of Total deformation at different materials

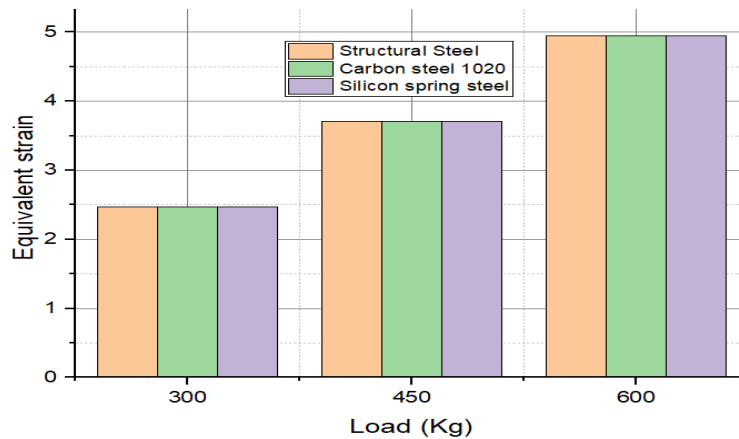


Figure 24: Validation of Equivalent strain at different materials

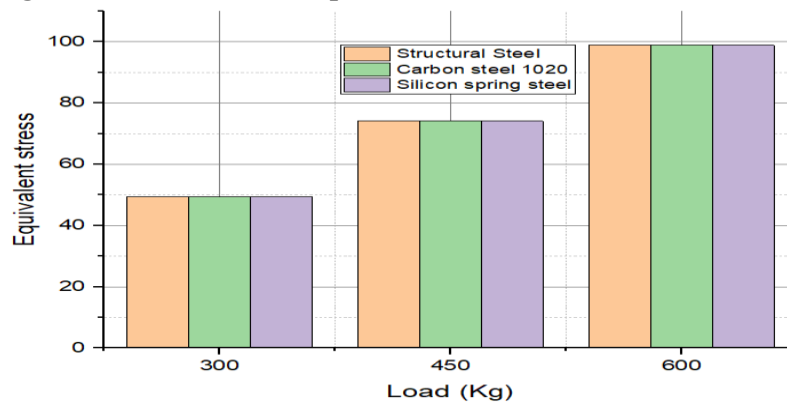


Figure 25: Validation of Equivalent stress at different materials

Conclusion

A static structural analysis was successfully performed on the designed 2-wheeler shock absorber to evaluate its structural integrity under the anticipated loading conditions. The analysis focused on determining the stress distribution, deformation, and factor of safety within the critical components of the shock absorber, such as the spring, damper body, and mounting points. Based on design and static structural analysis of a 2-wheeler shock absorber using Structural Steel, Carbon Steel 1020, and Silicon Spring Steel, the results typically show that Silicon Spring Steel is the best material due to its superior mechanical properties.

- **Structural Steel:** Generally, possesses high elasticity, strength, and durability, making it suitable for absorbing and dissipating energy. Specific grades can vary in their exact properties.
- **Carbon Steel 1020:** This is a low-carbon steel known for good machinability and weldability. It has a moderate balance of strength and ductility. It can be case-hardened to improve surface hardness and wear resistance. Typical applications include structural components and parts that require surface hardening.
- **Silicon Spring Steel:** This is an alloy steel specifically designed for springs. It exhibits high tensile strength, a high elastic limit (allowing for significant deformation without permanent set), good fatigue resistance (essential for components subjected to repeated loading), and shock loading resistance. The

addition of silicon enhances its properties and resistance to softening at higher temperatures.

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