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DESIGN, ANALYSIS AND COMPARISON BETWEEN COMPOSITE MATERIALS WITH CONVENTIONAL MATERIAL OF LEAF SPRING

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KEYWORDS

Composite
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Design
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ABSTRACT

This paper reveals the investigation of composite leaf spring and themodeling of the leaf spring with the use of different composite materials. The automobile industries are more competitive with low mass density with higher strength. Here is the work that compares the different composite leaf spring in which the parameters are considered such as static analysis and dynamic analysis. The modelingg of the composite leaf spring is done in SOLIDWORKS and then the static analysis is performed in ANSYS Workbench. It is also done in SOLIDWORKS to compare both the results and the dynamic analysis is also performed in the SOLIDWORKS software. A comparison has been made between laminated composite leaf springs, the materials are carbon steel grade (SUP9), *S*2 Glass Fibre, and Carbon Fibre(T300) which are having the same design and same load-carrying capacity. From that 79.22% weight reduction in composite material has been achieved for the same number of leaves and also high natural frequencies compared with other composites. From the result, the composite material of carbon fibre (T300) is best for leaf spring manufacturing.

1 Introduction

The suspension system is to absorb the shock loads and stores the energy in the automobile vehicle, the leaf spring is the main role in the suspension system. It is provided between the chassis frame and the wheels which do not transmit the shock loads to the superstructure. The leaf springs are used in the automobile is a multi-leaf spring that acts as an addition to the suspension system. This point is to fabricate, inspect and verify the multi-leaf spring models. The investigation of composite materials which are suitable to the leaf spring, better assembling forms and advancement of plans, which is the main aim to decrease the weight in order to save the fuel and energy which gives better riding with economic.[1] The leaf springs are mostly composite materials that help to reduce the density and have more strength. While using the multi-leaf spring, when the composite materials were introduced as a composite leaf spring then it is replaced with the mono leaf composite spring for adaptable weight in relation to steel. According to research, there is a significant quality and low flexible modulus in the longitudinal direction of a sensible material for leaf spring[3].There are a greater number of loads for an automobile such as loads on account of wheels while turning, shock loads on irregular road surfaces, etc. Due to unstrung mass of automobiles, the leaf spring is more affected owing to the fatigue loads. [1-68]

2 Leaf Spring

The leaf spring is Fibre Reinforced Polymer analysis and pattern and it is a key role of the vehicle to decrease the weight in which the implementation of new composite materials, improvement in design and manufacturing process. This is possible without a decrease in load carrying capacity by introducing Fibre Reinforced Polymer (FRP) products.[2]

Table-1 [4]

Specification of composite leaf spring

Total span length (eye to eye)	1450 mm
No. of full-length leaves	02
Length of full-length leaves (L-1 and L-2)	1450 mm (each)
Width	70 mm
Thickness	12 mm
No. of graduated length leaves	07

Table 2

Natural frequencies (Hz) for each material

Material	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6
Carbon Steel SUP9	113.88	123.67	261.84	366.9	378.59	645.26
Carbon fibre T300	268.14	290.4	615.26	863.95	902.33	1517
S2 Glass	133.04	143.8	304.84	428.65	451.9	751.83

The leaf spring models are exposed to a similar static burden. The creators inferred that the utilization of covered composite leaf spring shows better outcomes when contrasted with mono steel leaf spring [5].The goal of this examination work was to analyze the heap bearing and weight decrease limit of a composite leaf spring to that of an ordinary steel leaf spring. Static burden investigation of the leaf spring model is acted in ANSYS Workbench, and the outcomes are archived. The creators of this work concluded that composite leaf spring has 400% less weight when contrasted with traditional steel leaf spring [6]. The creators have portrayed the plan and examination of a composite leaf spring model in this paper. They have thought about the anxieties and weight distinction of composite leaf spring to that of steel leaf spring. The creators deduced in their exploration that utilization of E-glass/epoxy as a material for leaf spring shows lesser anxieties to steel. Composites diminished the heaviness of the leaf spring by 81-92% when contrasted with steel [7]. The creators of this paper performed a modular investigation of a leaf spring utilized by a medium utility vehicle. The creators looked at the normal recurrence esteems got in ANSYS for both steel and composite materials with hypothetical computations. The outcomes show that there was a slight contrast between the hypothetical and mathematical upsides of recurrence got [8]. The creators of this paper completed exploration work on a multi-leaf spring having five leaves utilized by a business vehicle. They swapped the current steel material for multi-leaf spring with composite material. three distinct composite materials were investigated, for example, Carbon Steel SUP9, Carbon fibre T300, S2 Glass, and modular examination was acted in ANSYS Workbench for every one of the material properties. The correlation was done between logical got regular frequencies and hypothetical qualities. The outcomes inferred that the got ANSYS results in nearly coincide with the hypothetical modular examination. The consonant investigation was additionally done to discover the reverberation recurrence of every material. This work reasoned that utilization of composite materials prompted weight decrease in the leaf spring model [9]. In the current review, a semi-elliptic leaf spring is subjected to static and dynamic stacking conditions utilizing ANSYS Workbench. Four unique materials are compared, i.e., Carbon Steel SUP9, Carbon fibre T300, and S2 Glass. Through the outcomes, S2 Glassshows lower initiated burdens and higher strain energy putting away limit because of which ride quality is benefitted. The weariness life of S2 Glassis higher to different materials because of its material properties and can go through more noteworthy patterns of stacking till disappointment. Carbon fibre T300 shows higher regular frequencies contrasted with Carbon Steel SUP9 and S2 Glass because of its mechanical properties. The utilization of Carbon fibre T300 prompts a prevalent weight decrease in the leaf spring which thusly builds the ride quality and mechanical productivity of the vehicle (Table 3).

By using the composite material, the main advantage is to reduce the mass and development of mechanical properties which acts as a substitute for conventional steel. The selection of products is based on the quality of material and solidity. The composite material has the adaptable strain essentials and high solidity for weight as differentiated and those of steel, hence the multi-leaf spring with steel material is replaced by mono leaf spring with composite material. This paper gives a brief on the effective and favorable conditions of composite leaf spring used in cars[10]. The product which is utilized for examining the limited components is ANSYS and it is also performed in SOLIDWORKS. It was an attempt to financially produce the composite leaf spring than the regular leaf spring used in automobiles[11].

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3 Methodology

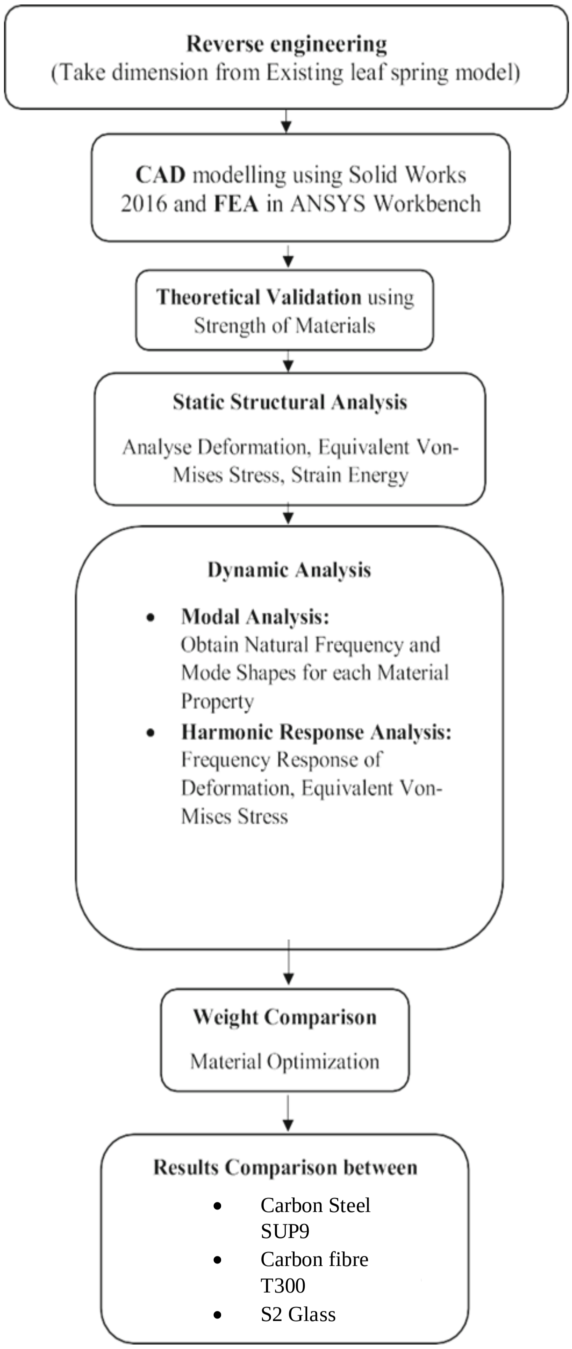


Table 3

Maximum responses and corresponding frequencie

Material Property	Maximum responses (mm)	Frequency (Hz)
Carbon Steel SUP9	2766	113.88
Carbon fibre T300	171.9	268.14
S2 Glass	38.3	113.04

Table 3

Maximum Von- Mises stress and corresponding frequencies

Material Property	Maximum Von-mises stress (Mpa)	Frequency (Hz)
Carbon Steel SUP9	297.52 MPa	113.88
Carbon fibre T300	292.93 MPa	268.14
S2 Glass	289.23 MPa	113.04

Table 4

Percentage difference in weight

Material Property	Weight (Kg)	%Weight Reduction
Carbon Steel SUP9	54.74	0
Carbon fibre T300	11.37	79.22
S2 Glass	17.48	68.07

Modeling

The 3D displaying of the semi-elliptic leaf spring is conveyed out in Solid turns out 2016 for the above-indicated plan boundaries. Every one of the parts has been displayed independently and afterward gathered into one spot utilizing get-together mates. Mates allocate mathematical connections between different parts of the get-together. At the point when mates are allocated, it characterizes the passable bearing of movement (translational or rotational) of every part of the get-together. The leaf spring get-together is then imported to ANSYS Workbench for static and dynamic examination (Fig. 1).[12]

Meshing and Boundary Condition

The calculation as hubs and components in the planning modeler. For this math, pertinence is set to 100 prompting better lattice. The high-level size work is turned on with the greatest face size allocated 6 mm. The decent progressed work doesn't refine the leaf spring model based on closeness and curve however refines the whole model as a solitary element. A refinement order with a profundity of 2 is allowed subsequently prompting the parting of the edges of components into half components. In the arrangement data under the versatile cross-section refinement portion, the most extreme refinement circle is taken as 3, while a refinement profundity of 2 is allowed[14]. This is done to reproduce stacking like genuine conditions. Load is applied consistently on the base most leaf toward the positive y-pivot Fig. 4.[12]

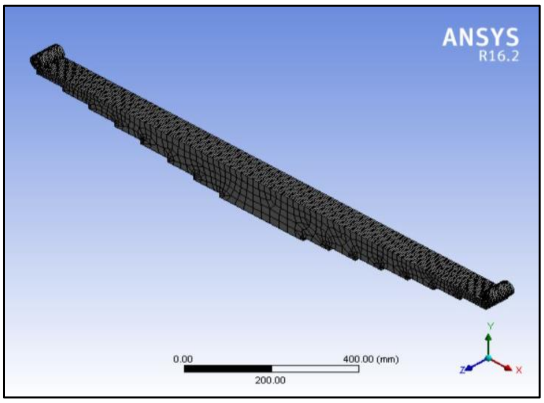


Fig. 2. The meshing of Composite Leaf spring in ANSYS Software

Software used

ANSYS (version: R16.2) is one of the world's leading CAM / CAD / CAF packages, which is produced by Dassault Systems. In this package, the solid modeling tool helps to integrate the 3D parametric feature with the 2D tools and it also tackles any type of concept in the process of fabrication. This product facilitates the cooperation between the companies and it provides with the advantage over their rivals, in addition to that it offers an insight into the product content.[14]

Specification of composite leaf spring

In this work, the design parameters of a composite leaf spring are referred, as listed in Table1.

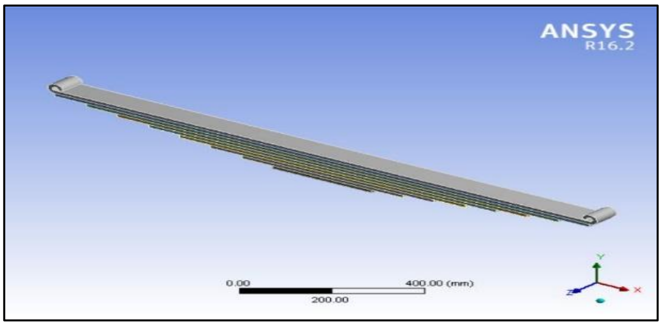


Fig. 1. Composite Leaf spring in ANSYS Software

Theoretical Validation

The first step is to determine the leaf spring whether it is operating in safe conditions; which is given by,

Maximum Allowable stress: $\frac{6FL}{nbt^2}$Units- Mpa

(Eq 1)

where 'F' is the force applied to the leaf spring, 'L' is the length of the leaf spring, 'n' is the no. of leaves, 'b' is the width and 't' is the thickness of the leaf spring. [12]

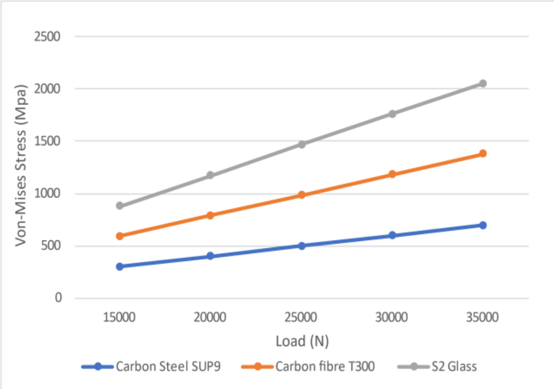
From the above equation, there is a comparison between theoretical calculations and obtained ANSYS results. Loading is done from 2,142.85 to 35,000N, and the results are in the below:

The stresses induced in Carbon Steel grade SUP9, S2 Glass fibre, and Carbon Fibre T300 are lower than the maximum allowable stress limit. From this, the conclusion is that the leaf spring is operating in safe conditions.

4 Results

Static Structural Analysis

The automobile is assumed to in stationary, and the leaf spring undergoes the static loading conditions and this is analyzed the von mises stress, total deformation, and strain energy values for each material property. The loading conditions are applied. Results are obtained for deformation, Von-Mises stress, and strain energy as shown in fig. 4, 5 and 6.



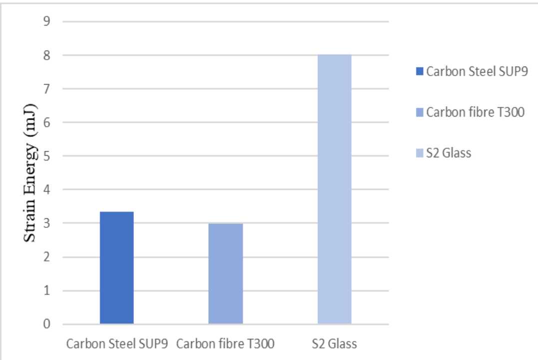


Figure.6. Maximum Strain energy of each material

Modal Analysis

The modal analysis is mainly used to find the natural frequency and the mode shape of a structure under free vibrations. These are the most important design parameters for a model that undergoes dynamic loading. The resulted natural frequencies for each material should be higher than the frequency of road irregularities, i.e., 12 Hz. In this software, the Lanczos algorithm is used for formulating the eigenvalues (natural frequencies) and eigenvectors (mode shapes) (Fig. 7).

Figure.3. Equivalent Von- Mises Stress and Load applied

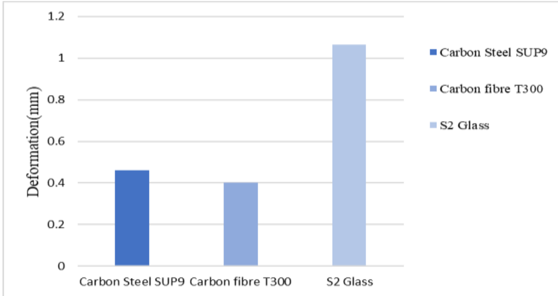


Figure.4. Maximum Deformation of each material

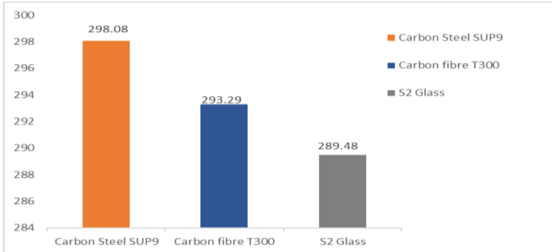


Figure.7. The Natural Frequencies of each material

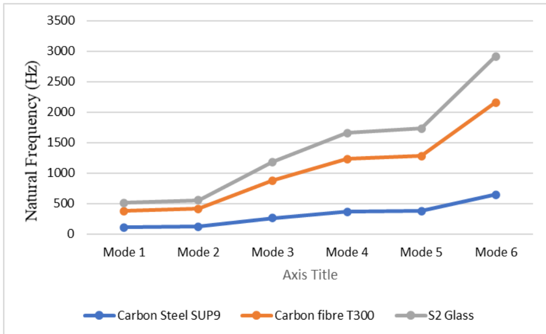


Figure.5. Maximum Von-Mises stress of each material

By performing this modal analysis, the natural frequencies and mode shapes are obtained for each material and the harmonic response is linked to the solution of the modal analysis domain for determining the maximum response and corresponding frequencies. [18]

As in static loading conditions, it is applied harmonically and frequency is varied from 0 to ∞, then the response results are plotted. The obtained resonating point should be dealt with carefully in the design of the structure. The theory behind the harmonic response analysis is the mode superposition theorem and it can be formulated by

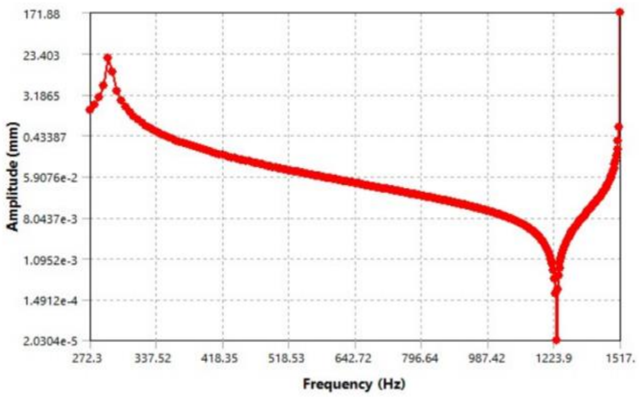


Fig. 8.Frequency response of deformation Carbon fibre T300

superposition technique of small eigenvalues which reduces the computational time. To obtain the natural frequency and mode shape there is a pre-requirement for mode superposition. ANSYS uses Rayleigh's damping to determine the response at each frequency. If there is no damping incorporated then the response would shoot to ∞.[16]

Rayleigh's damping given by,

$$[C] = [M]\,\alpha + [K]\,\beta \qquad \text{(Eq 2)}$$

where, [C], [M], [K] are the damping, mass, and stiffness matrix; α, β are constants of proportionality.

The frequency response of equivalent von mises stress and deformation is obtained for each material property. The figures represent the frequency response of deformation for each material.

For each material the frequency sweep in the range lower than the first natural frequency upto the fourth natural frequency. This is performed to reduce the overall processing time and memory allocation required by the system.

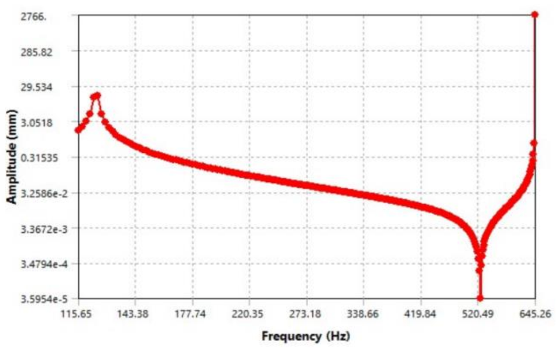


Fig. 9.Frequency response of deformation Carbon steel SUP9

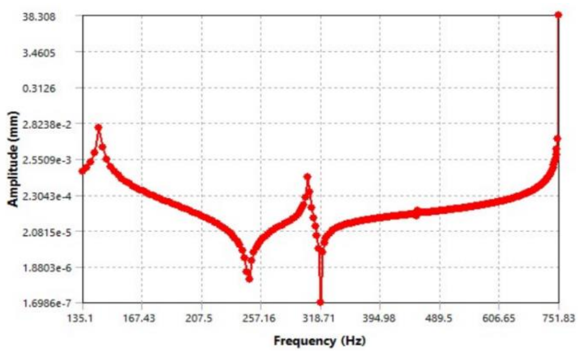


Fig. 10.Frequency response of deformation S2 Glass

Comparison in weight

In automobile, the weight reduction is utmost important role which leads to the greater mechanical efficiency and the better ride quality. As the leaf spring is for the unsprung mass of the vehicle, while the reduction in this unsprung mass cam leads to the lesser vertical acceleration forces which the vehicle is in motion state. As it increases the quality of ride and handling of the vehicle.[15]

In the below table, there is a comparison of weight reduction for each material of leaf spring. It is compared between the Carbon Steel grade SUP9 to S2 Glass fibre and Carbon Fibre T300 material leaf springs.

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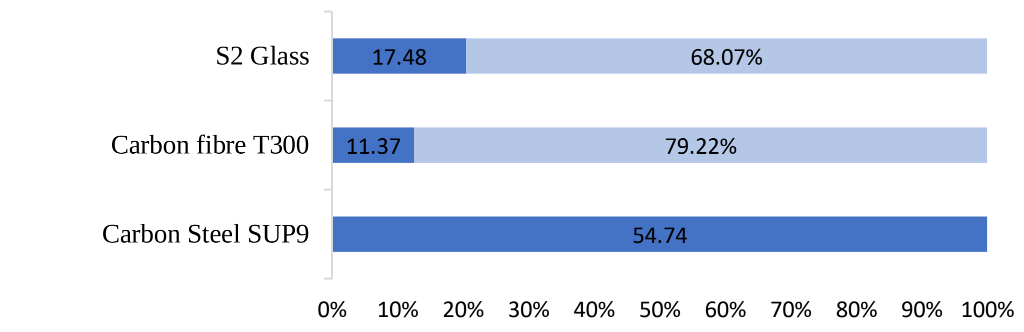

	Carbon Steel SUP9	Carbon fibre T300	S2 Glass
Weight of each Material (Kg)	54.74	11.37	17.48
%Weight Reduction	0	79.22	68.07

Figure. 11. Percentage weight reduction in composite materials with EN45 steel

5 Conclusion

The quasi-isotropic composite T300 and S2 glass were utilized for leaf spring static and dynamic analysis. The stresses in composite leaf springs were viewed as much lower than steel leaf springs with significant weight redeemable. The deformation in composite leaf spring is not exactly the predefined camber range and the increment in load shows a straight variety in anxieties. Since advancement of composite leaf spring builds the heap bearing propensity of spring and decrease in weight. Consequently, optimization of spring utilizing first-request strategy is thought of as because of the simplicity of union.

In this report, the Carbon fiber T300 composite leaf spring with the conventional leaf spring is due to higher strength to the weight ratio, and it is observed that there is a reduction in stress of this composite leaf spring. In composite leaf springs like Carbon fiber T300 and S-2 Glass, there is a minor amount of weight reduction of 79.22% and 68.07% were achieved respectively. There is less total deformation in these composite leaf spring compared with Carbon Steel SUP9 leaf spring. Hence, the utilization of composite leaf spring ends up being practical. Besides, the design enhancement was accomplished to demonstrate a more conventional framework that has diminished stresses, and weight to give better efficiency with fuel economy. Carbon fiber T300 is viewed as better compared to regular leaf spring with higher natural frequency compared with other composite leaf spring. Along these lines, it is considered as the substitution of steel leaf spring.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

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