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PERFORMANCE ANALYSIS OF COMPOSITE LEAF SPRING IN A DEFENCE SUMO VEHICLE

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Abstract

The composite material has taking place a major role in an automobiles industries. The leaf spring, which is considered for this study is a specially designed leaf spring used in SUMO design by the ordinance factory. The leaf spring which is an automotive component used to absorb vibrations induced during the motion of vehicle. It also acts as a structure to support vertical loading due to the weight of the vehicle and payload. In this study the Finite element method is used for analysing the composite spring for different parameters such us stress, deformation and mode frequencies for three different ratios of epoxy and E-fiberglass materials. The composite specimen has been made in the three different ratios of material combination by hand layout moulding technique. The three different samples are 40% epoxy and 60% E-fiberglass, 60% epoxy and 40% E-fiberglass, 70% epoxy and 30% E-fiberglass. The experiments were carried out for different test like tensile test, flexural test and hardness test. The experimental results are well within the simulation results and identified that the 40% epoxy and 60% E-fiberglass composite leaf spring is suitable for designing a spring in SUMO vehicle.

Keywords: Leaf spring, Composite material, Tensile test, Flexure test, Hardness.

1. Introduction

Many papers have been published denoting the application of composites in leaf spring. Other conventional suspension systems work on the same principles as a conventional leaf spring. However leaf springs use excess material when compared to other suspension systems for the same load and shock absorbing performance which makes it heavy. This can be improved by composite leaf springs Considering the fact that the conventional leaf spring is one of the potential components for weight reduction it has been an area of interest for automobile industries The various advantages possessed by the composite materials make this an attractive alternative material for the designers. In an experimental investigation comparison between the single leaf spring of variable thickness composite spring of fiber glass reinforced with mechanical and dimensional properties similar to the conventional steel leaf spring was done by

Nomenclatures

b	Breadth of the specimen, mm
h	Height of the specimen, mm
L	Length of the specimen, mm
P	Load applied, N
Greek Symbols	
σ_f	Flexural strength, N/mm^2
σ_t	Tensile strength, MPa

Al-Qureshiet et al. [1] with mechanical and dimensional properties similar to the conventional steel leaf spring was done and shown in the Table 1.

Table 1. Properties of Fiber Glass Reinforced.

S. No.	Properties	Value (MPa)
1	Tensile modulus along X-direction (Ex)	34000
2	Tensile modulus along Y-direction (Ey)	6530
3	Tensile modulus along Z-direction (Ez),	6530
4	Tensile strength of the material	900
5	Compressive strength of the material	450
6	Shear modulus along XY-direction (Gxy)	2433
7	Shear modulus along YZ-direction (Gyz)	1698
8	Shear modulus along ZX-direction (Gzx)	2433
9	Poisson ratio along XY-direction (NUxy)	0.217
10	Poisson ratio along YZ-direction (NUyz)	0.366

2. Literature Review

Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. The past literature survey shows that leaf springs are designed as generalized force elements where the position, velocity and orientation of the axle mounting gives the reaction forces in the chassis attachment Positions. Al- Qureshi [1] has presented in his paper, a general study on the analysis, design and fabrication of composite leaf spring .He utilised hand lay-up vacuum bag process for fabricating composite leaf spring with variable thickness using fibre glass epoxy resin. Shokrieh [2] 16 analysed and optimised the design of a fibre glass epoxy resin composite leaf spring using ANSYS V 5.4 software and concluded that the optimum spring width decreases hyperbolically and thickness increases linearly from spring eye towards axle seat. Hou, et al. [3] evolved the eye end design of a composite leaf spring for heavy axle loads by analysing there different designs of eye end attachments and found that in first and second design delamination failure occurred at interface of fibres that have passed around eye and spring body. The third design (open eye end design) was selected which overcame the delamination failure by ending the fibres at the end of the eye section.

Mahdi et al. [4] concluded that it is essential for the composites to control the failure by utilizing their strength in principal direction instead of shear during the suspension. Subramaninan [5] declared that in glass fibre reinforced polypropylene leaf springs, the joint strength can be increased by decreasing the clearance between fastener and composite plate hole and that endurance strength of the joint is higher than that of the leaf spring design load and this can be used to improve the strength of joints. Rahim et al. [6] experimented modal analysis of composite based elliptic spring in structural mechanics to determine the natural shapes and frequencies of an object or structure modes and it has an alternative to solving the full set of equations for ‘n’ unknown displacements. Digambar et al. [7] presented the static analysis of two conventional steel leaf springs made of SUP 10 & EN 45. These springs are comparing for maximum stress, deflection and stiffness. SUP 10 springs has lower value of maximum stress, deflection and stiffness in compare to 55 Si 2 Mn 90 spring. Ramakanth and Sowjanya [8] studied fatigue analysis on multi leaf springs having nine leaves used by a commercial vehicle. The material of the leaf springs is 65Si7 (SUP9), composite leaf springs and hybrid leaf springs. Dara Ashok et al. [9] has presented the FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining them under defined boundary condition. Arora et al. [10] studied the CAE analysis of the leaf spring for various parameters like deflection, Von-mises stress, normal stress, etc.

This work is to determine the better eye end design and reduce the time and cost related to actual experimental testing by provided a CAE solution. Nadargi et al. [11] has presented a performance evaluation of leaf spring replacing with composite leaf spring. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit. Gebremeskel [12] presented the design and simulation of composite leaf spring for light weight three wheeler vehicles. The stresses are much below the strength properties of the material, satisfying the maximum stress failure criterion. The designed composite leaf spring has also achieved its acceptable fatigue life. Venkatesan and Devaraj [13] presented the design and analysis of composite leaf spring in light vehicle. Compared to steel spring, the composite leaf spring is found to have 67.35% lesser stress, 64.95% higher stiffness and 126.98% higher natural frequency than that of existing steel leaf spring. A weight reduction of 76.4% is achieved by using optimized composite leaf spring. Kumaravelan et al. [14] has studied the finite element analysis of leaf spring for two different cases by considering the Young's modulus to yield strength ratio. In the present work the static and dynamic analysis has been carried out for three different ratios of epoxy and E-fiberglass composite material for different parameters and compared the results with experimental study.

3. Material and Methods

The composite specimen has been fabricated for three different ratios of epoxy and E-fiberglass material. The percentage of epoxy and E-fiberglass material composition are considered for this study are 40% epoxy and 60% E-fiberglass, 60% epoxy and 40% E-fiberglass, 70% epoxy and 30% E-fiberglass. The composite specimen is fabricated by hand layout moulding for the specification such us Camber = 78mm, Span = 900mm, Thickness = 11mm and Width = 107mm. Hand lay technique was used to manufacture the fiber glass reinforced specimen. For this an E - fiber glass material was used with the diameter of the fiber glass approximately epoxy (DiGlycidyl Ether of Bisphenol A) and a hardener (Tri-ethylene Tetra-amine).

Figures 1-3 shows the three different composite specimens fabricated by three different compositions by hand lay technique.

Fig. 1. Specimen - I 40% epoxy and 60% E-fiberglass.

Fig. 2. Specimen - II 60% epoxy and 40% E-fiberglass.

Fig. 3. Specimen - III 70% epoxy and 30% E-fiberglass.

3.1. Experimental study

The experimental study has been made for different tests in three different composite specimens. The different mechanical properties are analysed by tensile test, flexural test and hardness test. The mechanical properties like tensile strength, flexural strength and hardness are calculated.

3.1.1. Tensile strength

The tensile test was carried out in a universal testing machine. The test specimen is prepared according to ASTMD standard. The load applied on the specimens are 6500 N, 5280 N and 3250 N respectively for specimen - I, II and III**.** The tensile strength is calculated from the following Eq. (1):

$$\sigma_t = \frac{P}{bh} \tag{1}$$

Figure 4 shows the three different composite tested specimens. The tensile strength calculated from the experimental study has been reported for the three composite specimens in Table 2.

Fig. 4. Tested Specimen.

Table 2. Tensile Strength.

S. No.	**Parameter**	**Specimen - I (40% and 60%)**	**Specimen - II (60% and 40%)**	**Specimen - III (70% and 30%)**
1.	Load Applied	5280 N	6500 N	3250 N
2.	Tensile strength	92.2 MPa	107 MPa	46 MPa

3.1.2. Flexural strength

The flexural test is carried out in the universal testing machine. The test specimen was prepared according to ASTM D standard. The flexural strength is calculated from the following Eq. (2).

$$\sigma_f = \frac{3PL}{2bh^2} \tag{2}$$

Figure 5 shows the experimental set up for testing the composite specimen for calculating the flexural strength. The bending strength and displacement for different specimens are given in the Table 3.

Fig. 5. Universal Testing Machine.

Table 3. Bending Strength, Displacement and Hardness.

S. No.	Parameter	Specimen - I (40% and 60%)	Specimen - II (60% and 40%)	Specimen - III (70% and 30%)
1.	Load applied	800 N	1000 N	800 N
2.	Bending strength	330 N/mm^2	442 N/mm^2	330 N/mm^2
3.	Displacement	7 mm	7.5 mm	8 mm
4.	Hardness (Average)	3.33	4.67	3.33
5.	Modal Frequency	234	263	242

3.1.3. Hardness test

The Hardness test is conducted in the Rockwell L- scale, which is especially for plastic materials, Bakelite and vulcanized rubber. The diamond indenter is chosen for measuring hardness for the load of 60 kg. Figure 6 shows the hardness tested specimen. The harness is measured at various locations in a specimen and the average hardness is given in the Table 3.

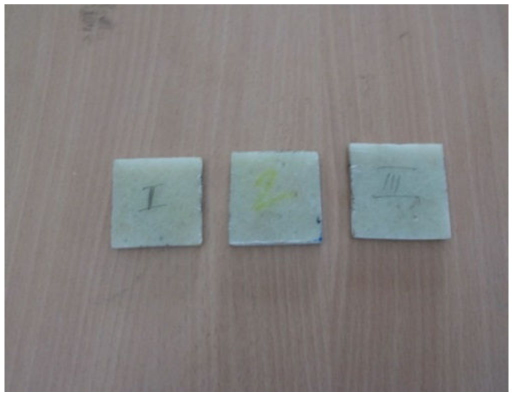

Fig. 6. Hardness Tested Specimens.

3.2. Finite Element Study of composite leaf spring

The finite element analysis of composite leaf spring has been study for static and dynamic loading for various parameters such us bending strength, displacement and modal analysis. The "ANSYS" software is used for finite element analysis.

Figure 7 shows the plot for bending stress and displacement of the specimen - I for the load of 800 N load. Similarly these parameters are simulated for all the three different specimens. The results are reported in the Table 4.

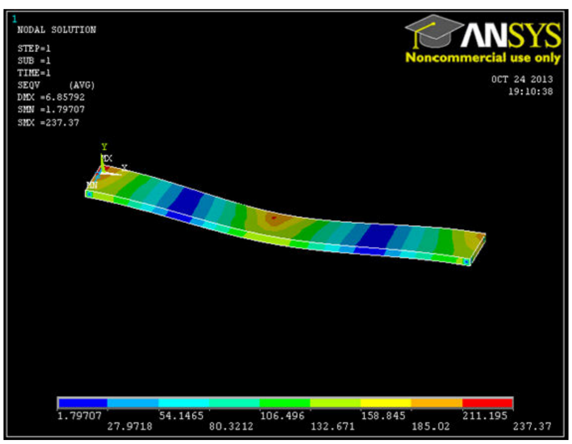

Fig. 7. Plot for Bending Stress and Displacement - Specimen I.

Figure 8 shows the plot for natural frequency of the specimen - II for the load of 1000 N load. Similarly this parameter is simulated for all the three different specimens. The results are reported in the Table 4.

Table 4. Bending Strength and Displacement (FEA).

S. No.	Parameter	Specimen - I (40% and 60%)	Specimen - II (60% and 40%)	Specimen - III (70% and 30%)
1.	Load applied	800 N	1000 N	800 N
2.	Bending strength	237 N/mm^2	341 N/mm^2	213 N/mm^2
3.	Displacement	6.85 mm	10.21 mm	5.95 mm
4.	Modal frequency	413	342	381

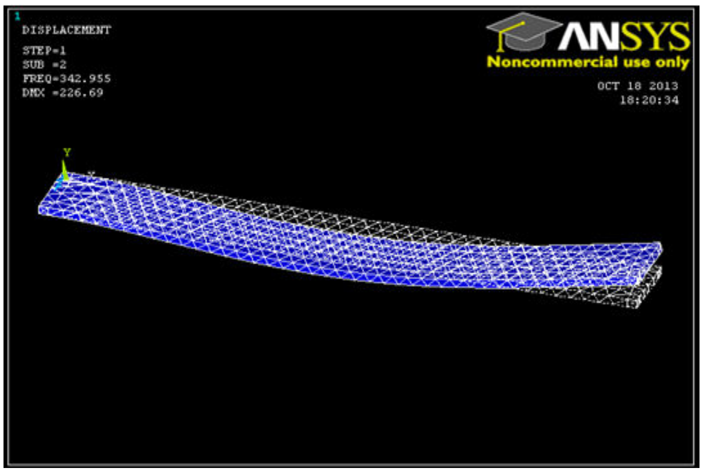

Fig. 8. Plot for Natural Frequency - Specimen II.

4. Results and Discussion

The experimental and Finite element analysis of composite material for three different compositions such as 40% epoxy and 60% E-fiberglass (Specimen-I), 60% epoxy and 40% E-fiberglass (Specimen-II), 70% epoxy and 30% E-fiberglass (Specimen-III) has been studied. The different mechanical properties are determined to study the appropriate composition of epoxy and E-fiberglass for leaf spring manufacturing.

The following are the results obtained from the experimental study of the three different composite specimens. In the experimental study the tensile strength and displacement of the specimens are calculated.

Figure 9 shows the relation between load and tensile stress developed in the specimens. It is observed that the specimens II and III has less tensile stress compared with specimen - I. And also the specimen - I has carried high load compared with rest of specimens. The maximum tensile stress developed in the specimen - I is 107 MPa.

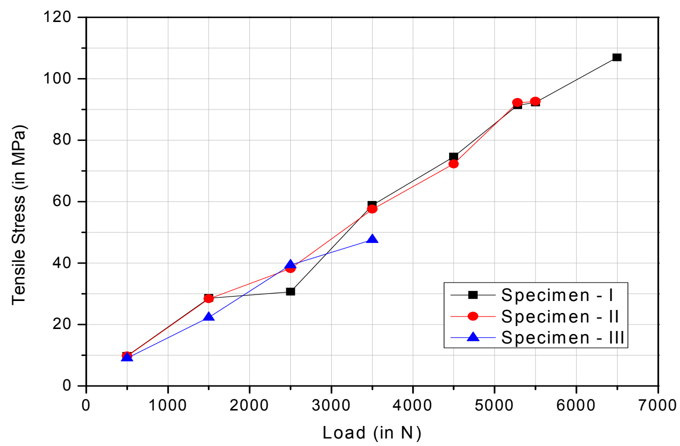

Fig. 9. Load vs. Tensile Stress.

Figure 10 shows the relation between load and displacement developed in the specimens. It is observed that the specimens II and III has less displacement compared with specimen - I. And also the specimen - I has carried high load for the same deflection compared with specimen- I. The maximum deflection developed in the specimen - I is 8 mm.

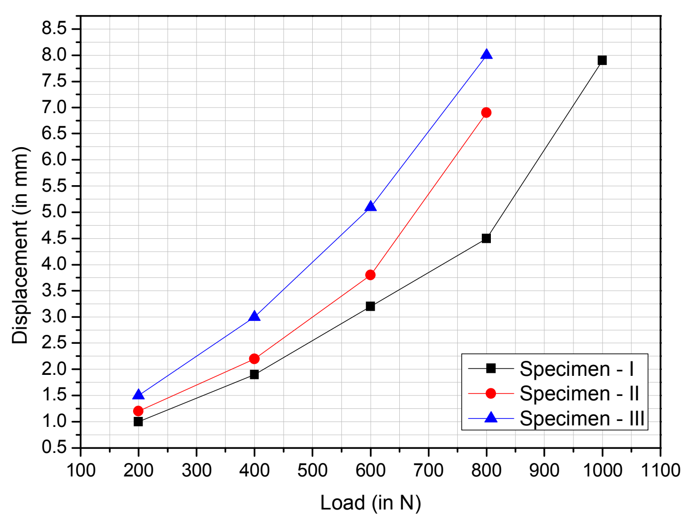

Fig. 10. Load vs. Displacement.

The following are the results obtained from the finite element study (ANSYS) of the three different composite specimens. The stress and deflection of the specimens are studied.

Figure 11 shows the relation between load and stress developed in the specimens. It is observed that the stress developed in the specimens II and III is less compared with specimen - I. And also the specimen - I has carried high load. The maximum stress developed in the specimen - I is 342 N/mm^2 for a load of 1000 N.

Figure 12 shows the relation between load and displacement in the specimens. It is observed that the displacement in the specimens II and III is less compared with specimen - I. And also the specimen - I has carried high load. The maximum displacement developed in the specimen - I is 11.4 mm for a load of 1000 N.

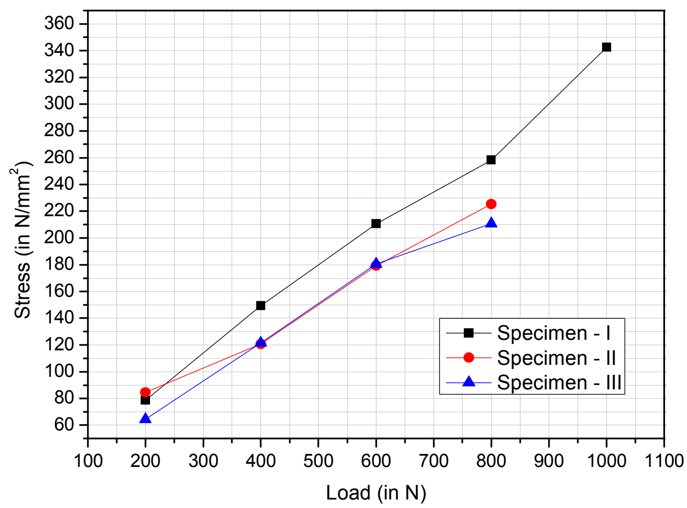

Fig. 11. Load vs. Stress.

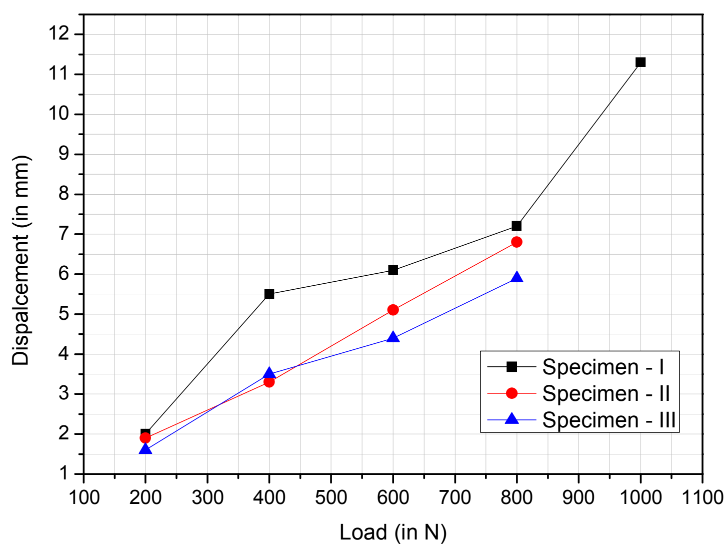

Fig. 12. Load vs. Displacement.

Modal analysis has been study for determine the dynamic properties of structure under vibration excitation. The modal analyses are carried out to determine the natural frequency and modal shape of the leaf spring in both an experimental and finite element analysis. Table 5 shows the natural frequency of Composite specimens.

Table 5. Natural Frequency of Specimens - Experimental (Exp.) and FEA.

S. No	Natural frequency					
	40% and 60%		60% and 40%		70% and 30%	
	Exp.	FEA	Exp.	FEA	Exp.	FEA
1	34	68	39	54	35	71
2	234	413	263	342	242	381
3	600	428	694	405	543	447

5. Conclusion

The composite leaf spring has been studied both in an experimental and finite element analysis. For this study the three different composite material specimens are prepared and examined. The epoxy and E-fiberglass composite is chosen in the following compositions such us 40% epoxy and 60% E-fiberglass (Specimen-I), 60% epoxy and 40% E-fiberglass (Specimen-II), 70% epoxy and 30% E-fiberglass (Specimen-III). The results shows that the 40% epoxy and 60% E-fiberglass is having high value of tensile stress, bending stress, deformation, and natural frequency compare with rest of composition of materials in both experimental and Simulation. It is concluded that 40% epoxy and 60% E-fiberglass (Specimen-I) is the best composition of material for design and manufacturing of leaf spring for this application.

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