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Mechanical Characteristics and Analysis of Composite Leaf Spring Reinforced With Aluminum

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Abstract-The objective of this paper is to present a composite material as an alternative to conventional steel leaf spring. The subject gives a brief look on the suitability of composite leaf spring on vehicles and their advantages. Efforts have been made to replace the composite leaf spring to that of steel leaf spring, without affecting the properties and strength. Modeling and analysis is carried by CATIA V5 and static analysis of a 3D model is performed in ANSYS 13.0 software.The design constraints are stress and deflection. The result shows that composite leaf spring reinforced with aluminium has better strain energy storage capacity suitable for suspension and large displacement which increase the failure duration than the conventional steel leaf spring.

Keywords: composite, glass fiber, aluminum, leaf spring, stress, strain

I. INTRODUCTION

The number of automobile manufactured is drastically increasing year by year which made the researches to concentrate on switching over to composite materials for manufacturing the automobile components. The weight of unsprung components can be reduced by 10% to 20% if the component's material is replaced with composite material. The leaf spring in the LCV (Light commercial vehicle) is one of the important parts which carry the load of the vehicle as well as the passenger comfortness and stability are compromised in the conventional material leaf spring. The material must have very good strain energy in order to absorb the vibrations more effectively. Composite materials have very good strain energy which makes them as an alternative for conventional leaf spring. The comparisons on the performance of glass fiber reinforced with aluminium and the conventional leaf spring was analyzed in ANSYS software. E-glass fiber reinforced plastic was used as the material for the spring. By finite element method the results were compared the result shows that the deflection and bending stress is less in composite material than the steel leaf spring [1]. Modeling and analysis of a mono leaf spring using composite material is done using CATIA V5 and ANSYS software. The results reveal that the bending stress is minimum in case of composite material by 10% but the deflection of the spring is found to be higher by 9% [2].

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Finite element analysis of composite leaf spring with epoxy resin in which the result is compared with the experimental analysis. The composite leaf spring has less stress and reduction of weight 22.15% compared to convention leaf spring [3]. The static analysis of a composite mono leaf spring is compared. Composite leaf spring has less stress, high natural frequency, high stiffness compared to conventional steel leaf spring [4]. The design and analysis of a leaf spring of a Tata Sumo car is analyzed in ANSYS in which composite leaf spring shows good mechanical properties like bending stress and deflection than the conventional leaf spring [5].

II. MATERIALS AND METHODS

A. E-Glass Fiber

The material used for improving the mechanical properties for leaf spring material is an E-glass fiber. The reinforcing of E-glass fiber is achieved through epoxy resin. The mechanical properties of the E- Glass fiber is shown in table 2. It has a density of 1600 kg /m^3 with a Poisson ratio of 0.3. The material properties are required to determine the five layer of glass fiber.

B. Aluminum

Aluminium is light weight and very easy to machine. As shown in table 2 aluminum has a density 2700 kg/m^3 with a Poisson ratio of 0.3. The young's modulus of aluminium is 70 Gpa. Its material properties are to determine the four layer of aluminium sandwiched in the intermediate layers of glass fiber.

C. DESIGN PARAMETERS

The design parameters for the conventional leaf springs and their dimensions are shown in table 1. The total length of the spring was taken as 1540 mm the maximum load given on the spring is limited to 2500 N. The no of leaves taken for the analysis is limited to mono leaf because of its simplicity [7].

Table 1 Design Specification of steel leaf spring

Parameters	Value
Total Length of the spring	1540 mm
Free Camber (At no load condition)	136 mm
No. of full length leave (Master Leaf)	01
Thickness of leaf	13 mm

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Width of leaf spring	70 mm
Max Load given on spring	2500 N
Young's Modulus of the spring	22426.09 Kgf/mm^2

D. MATERIAL PROPERTIES

Table 2 Material Properties of Steel , Aluminium and GFRP

Material	Young'smodulus E(Gpa)	Poissonratio	Density (kg/m^3)
Steel	210	0.21	7800
Aluminium	70	0.3	2700
GFRP	15.1	0.21	2000

The mechanical properties of the materials used for the analysis is shown in Table 2. The young's modulus of the materials were found to be 210 Gpa for steel, 70Gpa for Aluminium and 15.1 Gpa for GFRP. The poisson ratio for the materials are 0.21, 0.3 and 0.21 for Steel, Aluminium and GFRP respevtively. The density also found to be 7800 kg/m^3, 2700 kg/m^3 and 2000 kg/m^3 respectively for Steel, Aluminium and GFRP.

III. FINITE ELEMENT ANALYSIS OF COMPOSITE LEAF SPRING

The analysis of composite mono leaf spring is done in ANSYS 13.0. The dimensions of the composite leaf spring are similar to the conventional leaf spring modeled in CATIA V5. The composite leaf spring model is of 13mm thickness which is divided into 9 layers consisting of reinforcing glass fiber (5 layers) with aluminium (4 layers) in the intermediate layers. The model is saved and imported to ANSYS 13.0. In preprocessing the material properties, meshing, load data is given. The material properties such as young's modulus, Poisson ratio and density respectively are given for conventional leaf and composite leaf spring. Then meshing is done, the basic concept of FEA is that the structure of the body is divided into finite dimensions called finite element. The fixed support is provided at both eye ends and load is applied in terms of 500 N to 2500 N and solved. In post processing the results such as bending stress, deflection and elastic strain values for the composite leaf spring reinforced with aluminium were plotted in graphs and compared with conventional leaf spring.

IV. ANALYSIS RESULTS OF MONO LEAF SPRING

A. Results for Bending Stress

It is observed from the table 3 that the variation of bending stress for different loading condition for conventional steel and aluminium reinforced with GFRP. Bending stress of composite leaf spring is 48% higher than conventional leaf spring. It is observed from figure 3 that loads increases bending stress also increases linearly.

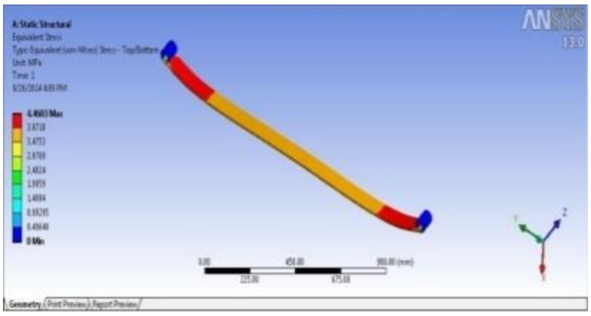

Fig. 1 Stress at 2500 (N) for steel leaf spring

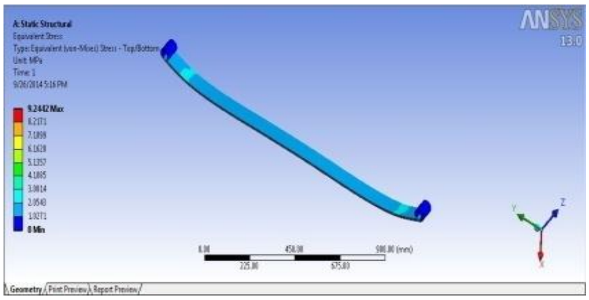

Fig. 2 Stress at 2500 (N) for GFRP with Al

Table 3. Comparative analysis of Load (N) Vs Stress (Mpa)

Load [N]	Bending stress for steel [Mpa]	Bending stress for GFRP with aluminum [Mpa]
500	0.89366	1.8488
1000	1.7873	3.6977
1500	2.681	5.5465
2000	3.5746	7.3954
2500	4.4683	9.2442

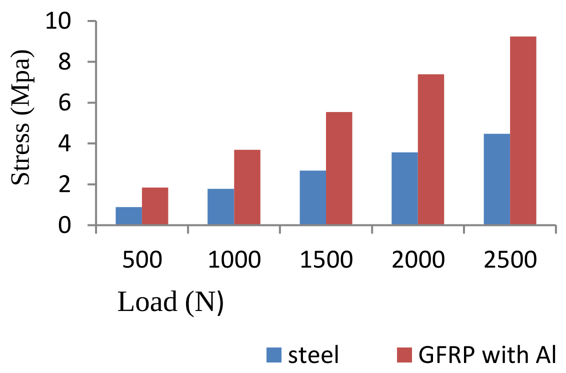

Fig. 3 Load (N) Vs stress (Mpa)

B. Results for Deflection

Earlier investigation from [4] shows glass fiber composite leaf spring shows minimum deflection to that of steel leaf spring whereas it is seen from figure 6 that the variation of deflection for the different loading condition of conventional steel and aluminium reinforced with GFRP, deflection of composite leaf spring is higher as compared to the steel leaf spring and GFRP with aluminium material deflects 52% higher than conventional steel leaf spring which will increase the failure duration and provide more cushioning effect and it can be applicable in suspension system.

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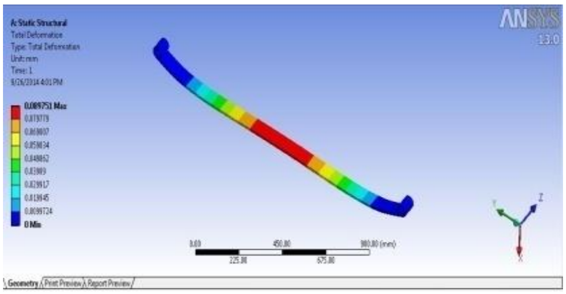

Fig. 4 Deflection at 2500 N for steel leaf spring

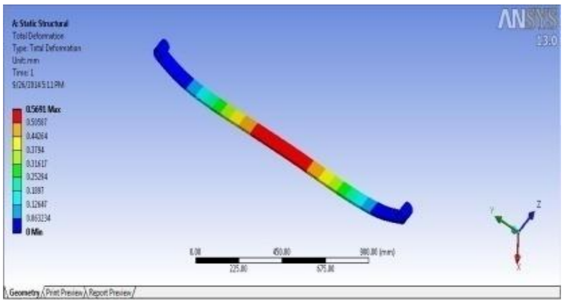

Fig. 5 Deflection at 2500 N for GFRP with Al

Table 4 Comparative analysis of load (N) Vs deflection (mm)

Load (N)	Deflection for steel [mm]	Deflection for GFRP with Aluminium [mm]
500	0.01795	0.11382
1000	0.035901	0.22764
1500	0.053851	0.34146
2000	0.071801	0.45528
2500	0.089751	0.5691

Table 5 Comparative Analysis of Load Vs Strain

Load (N)	Elastic strain for steel	Elastic strain for GFRP with Al
500	0.000004468	0.000030411
1000	0.000008936	0.000060822
1500	0.000013405	0.000091233
2000	0.000017873	0.00012164
2500	0.000022341	0.00015206

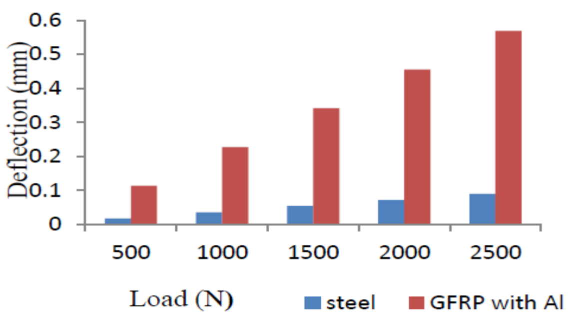

Fig. 6 Load (N) Vs. Defection (mm)

C. Results for Elastic Strain

It is observed from figure 9 that the variation of elastic strain for different loading condition of conventional steel, and aluminium reinforced with GFRP in which GFRP with aluminium material has 14% of elastic strain higher than conventional steel leaf spring. The material which has large strain energy storage capacity is suitable for leaf spring function.

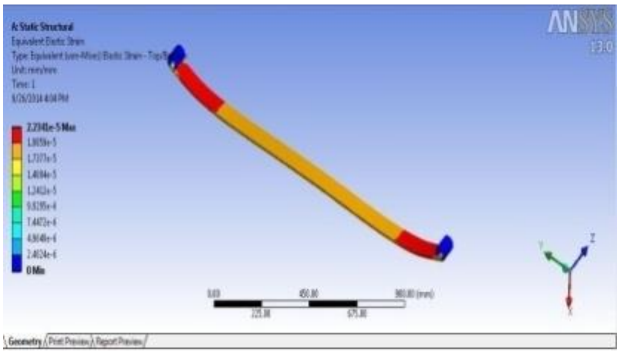

Fig. 7 Elastic strain at 2500(N) for steel leaf spring

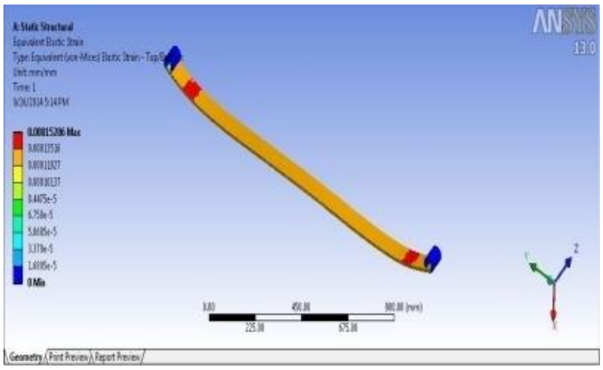

Fig. 8 Elastic strain at 2500(N) for GFRP with Al

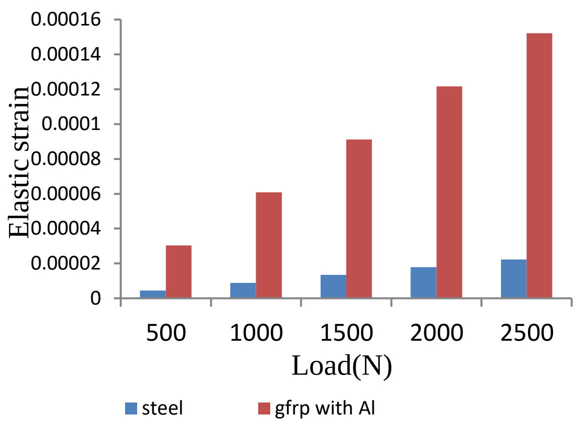

Fig. 9 Load (N) Vs Elastic strain

V. CONCLUSION

The composite mono leaf spring reinforced with aluminum has better mechanical properties when compared to conventional steel leaf spring. The 3D modeling of composite leaf spring is analyzed using ANSYS. A comparative study has been made between composite and steel leaf spring with respect to its mechanical properties.

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The result showed that the bending stress of composite leaf spring is 48% higher than the conventional leaf spring. The failure duration is also increased by 52% deflection compared with conventional steel leaf spring. The strain energy storage is of 14% comparatively high than the conventional steel leaf spring. Thus the proposed composite material is very effective than the conventional leaf spring and also suitable replacement

For conventional leaf spring.

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