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LEAF SPRING FOR LIGHT VEHICLE: COMPARISON AMONG CONVENTIONAL STEEL, COMPOSITE MATERIALS (EPOXY-E CARBON & EPOXY-E GLASS) BY ANSYS WORKBENCH

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Abstract

Leaf spring made of conventional steel and composite materials are analyzed in this paper by ANSYS workbench 15. First the design was made for light vehicle then it was imported to ANSYS static structural analysis tool. Analysis on the total deformation, Equivalent stress (von-mises) and Equivalent elastic strain have been observed and analyzed taking conventional steel, Epoxy-E Carbon and Epoxy-E glass material in consideration. By comparison leaf spring for different material from ANSYS Workbench, it is seen that there are many variation between conventional steel and composite material. But the variation between Epoxy- E carbon and Epoxy- E glass is small. Considering these parameters with effectiveness, durability and weight of the leaf spring, the analysis shows that the Epoxy-E Carbon leaf spring is comparatively better for medium and low heavy vehicle than other type of conventional leaf spring. This paper would help researchers for further development of leaf spring for vehicle.

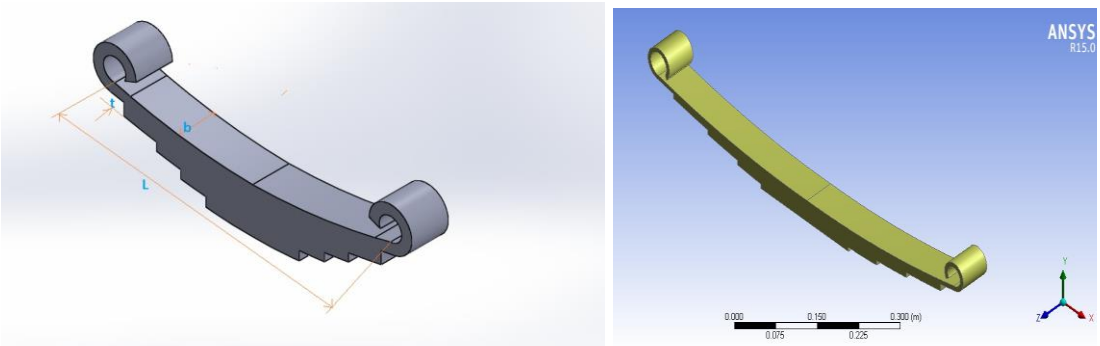
Keywords - Epoxy-E Carbon, Epoxy-E glass material, steel, ANSYS workbench 15.

1. Introduction

Springs are significant suspension components on automobile vehicles, rail road important to absorb and store energy and then release it slowly to make an agreeable ride. A leaf spring absorb vertical vibration due to the road as well as impact of irregularities by the small deflection of spring. A leaf spring, particularly the longitudinal sort, is a dependable and tenacious component in automobile suspension frameworks. These springs are for the most part shaped by stacking leafs of steel, in dynamically more lengths over each other, with the goal that the spring is thick in the center to oppose twisting and thin at the finishes where it appends to the body. A leaf spring ought to bolster different sorts of outer powers. But the most essential task is to oppose the variable vertical loads**.** Now a days, manufacturer are focusing to reduction of weight of leaf spring having better load carrying capacity and stiffness. In order to conserve natural resources and keeping in mind different cost parameters, durability and weight reduction of the vehicle now a days is the main concern of the automobile manufacturer. This criteria can be happened by applying better material such as different types of composite material and proper designing. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unstrung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of proper materials made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness. From many years researchers are trying to find appropriate material for designing leaf spring. Different works on leaf spring for light vehicle were done. M.venkatesan, et al., 2012 [1] mainly focused on the light weight of the material and succeed to reduce weight of leaf spring. Gulur Siddaramanna, et al. [2] designed a low cost leaf spring with bounded end joints. Used C-programming language to simulate the design. Trivedi Achyut V., et al., [3] compared the load enhancing property and weight saving of the TATA-ACE medium heavy vehicle by using composite leaf spring. N. Anu Radha et al. [4] suggest that the boron fiber composite material can be replaceable with existing steel for master leaf spring. Rohit Ghosh et al., 2017 [5] Based on composite material design & fabricated of a laminated leaf spring. Rajagopal, A. et al., 2017 [6] suggested that E-glass /epoxy mono-composite leaf spring can be used to replace the conventional Manganese silicon steel multi- leaf spring in TATA 407. Jaimon, D. Q, et al. [7] conducted experimental investigations on E glass/Epoxy Resin hybrid composites and concluded that for the compositions of 50:50%, 40:60%, 30:70% by volume of E-glass/Epoxy, 40:60% composition yielded maximum tensile strength, impact strength and flexural strength. Singh, S. J et al, [8] Compared to the steel spring and the composite spring, suggested that the composite spring has stresses and deflection that are much lower, and the spring weight is nearly 85.02% lower using Particle Swarm Optimization and 78.87% lower using Simulated Annealing. Mahmoud M. Shokrieh, et al. [9] developed a leaf spring for rear suspension system and did a finite element analysis. Sugiyama, et al. [10] did a simulation of the body and conducted a finite element analysis. Found excellent stiffness of the spring materia**l.** Form the literature it is seen that all the previous works have been conduction focusing the weight and cost reduction of the leaf spring. In this paper with weight and cost the deformation, stress and equivalent stress of different material has been compared and finally a best material has been selected for leaf spring for using in medium heavy vehicle. The simulations were conducted using ANSYS software. The properties of the materials have been collected from reliable sources.

2. Design parameters of leaf spring

The assumptions for analysis of the design leaf spring- automobile is stationary, only vertical load is applied, analysis is carried out on one semi-elliptical spring.



(a) (b)

Fig. 1. Design of a leaf spring using (a) solid works software (b) ANSYS workbench 15

Table 1. Design parameters of leaf spring

Design parameters	Dimensions
Length (L) eye to eye	806.35 mm
Width(b)	111.81 mm
Thickness(t)	60 mm
Load (W)	2000 N

3. Materials of conventional steel, composite materials (epoxy-e carbon & epoxy-e glass) leaf spring

Generally, material 65si7 is used as steel leaf spring. The chemical and mechanical properties is given below table 2 and table 3 respectively.

Table 2. Chemical composition of 65si7

Grade	C%	Si%	Mn%	P%	S%
65si7	60-.68	1.5-1.8	7-1	.05	.05

Table 3. Mechanical properties of 65si7

Density (kg/m^3)	Young's modulus, E (N/mm^2)	Poisson's ratio	Spring stiffness(N/mm)	Tensile strength ultimate (Mpa)	Tensile strength yield (Mpa)	BHN
7850	2.1×10^5	.266	97	460	250	455-461

Composite consists of two or more material phase to combine a material which have an excellent properties. Most important composite material in which the disperse phase exist in form of fiber. Here Carbon fiber and glass fiber composite material are used to comparison. The dimension of composite leaf spring is same like as conventional steel leaf spring. Properties of Epoxy-E Carbon & Epoxy-E Glass are represent in table 4 & table 5. .

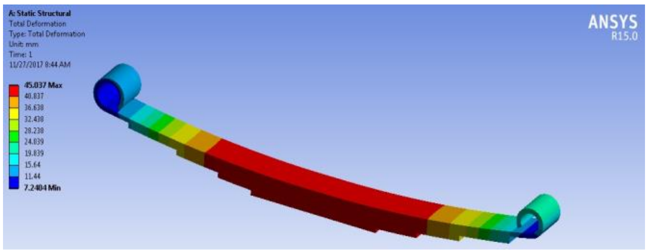
Table 4. Mechanical properties of Epoxy-E Carbon

Material	Epoxy-E carbon
Density (kg/m^3)	1490
Young's modulus X direction (Mpa)	121000
Young's modulus Y direction (Mpa)	8600
Young's modulus Z direction (Mpa)	8600
Poisson's ratio XY	0.27
Poisson's ratio YZ	0.4
Poisson's ratio XZ	0.27
Shear modulus XY (Mpa)	4700
Shear modulus YZ (Mpa)	3100
Shear modulus XZ $(Mpa$	4700
Behavior	Orthotropic

Table 5. Mechanical properties of Epoxy-E Glass

Material	Epoxy-E Glass
Density (kg/m^3)	2000
Young's modulus X direction (Mpa)	**45000**
Young's modulus Y direction (Mpa)	10000
Young's modulus Z direction (Mpa)	10000
Poisson's ratio XY	0.3
Poisson's ratio YZ	0.4
Poisson's ratio XZ	0.3
Shear modulus XY (Mpa)	5000
Shear modulus YZ (Mpa)	3846.1
Shear modulus XZ $(Mpa$	5000
Behavior	Orthotropic

4. Simulation results of conventional steel, composite materials (epoxy-e carbon & epoxy-e glass) leaf spring



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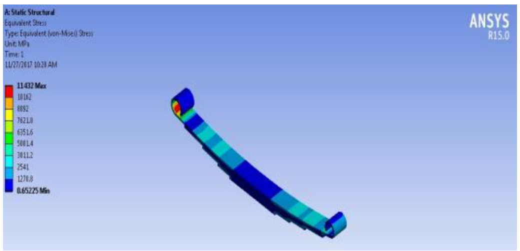

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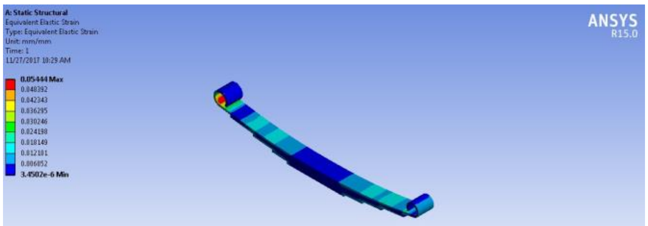

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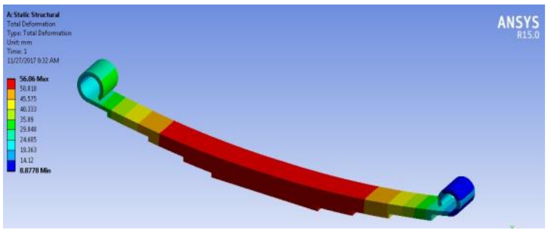

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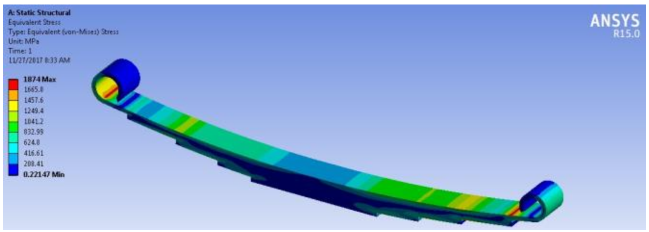

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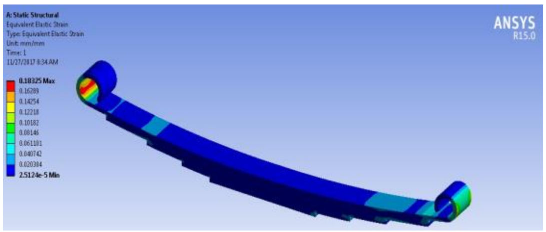

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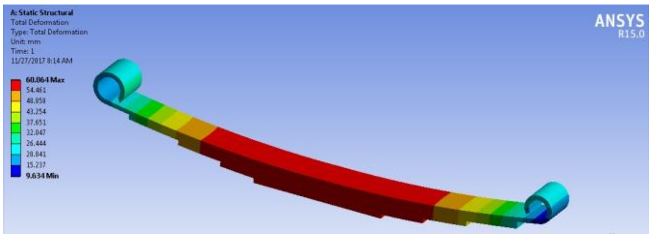

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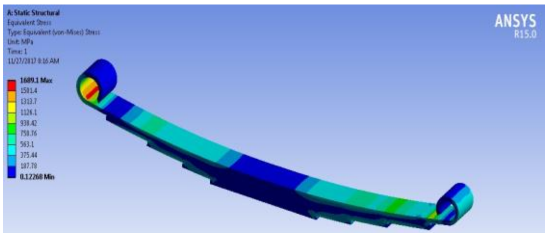

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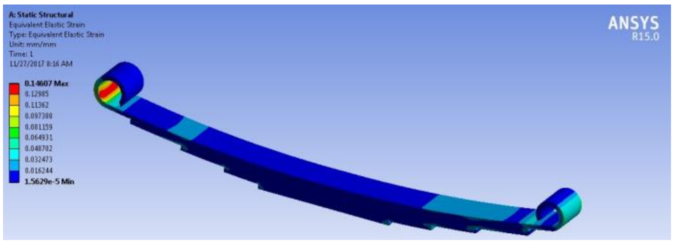
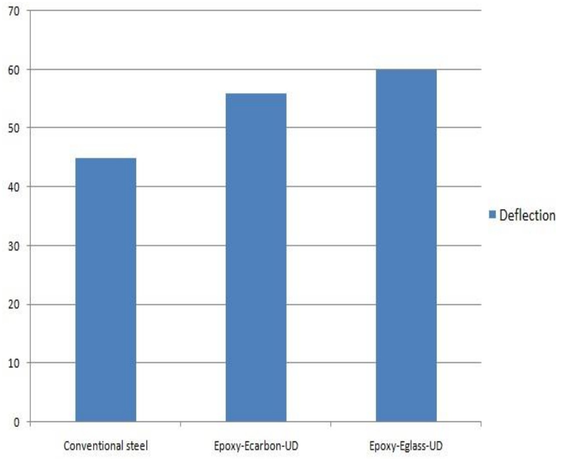


(i)

Fig. 2. Simulation results of conventional steel (a) Total deformation (mm) (b) Bending stress (Mpa) (c) Elastic strain (mm/mm). Epoxy-E Carbon Simulation results (d) Total deformation (mm) (e) Bending stress (Mpa) (f) Elastic strain (mm/mm). Epoxy-E Glass Simulation results (g) Total deformation (mm) (h) Bending stress (Mpa) (i) Elastic strain (mm/mm).

5. Result and discussion

From simulation, it is seen that different material shows different deformation, bending stress, weight and strain in same conditions.



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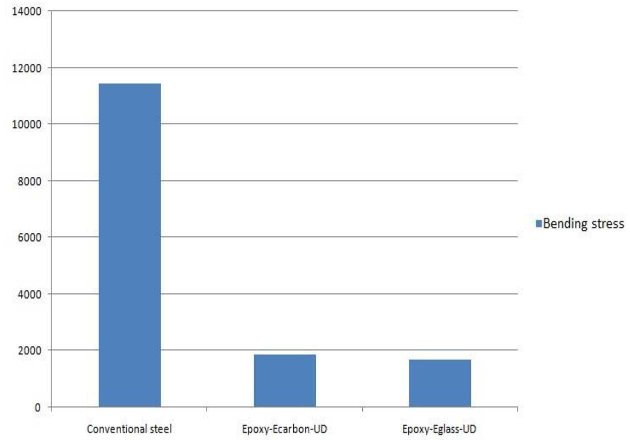

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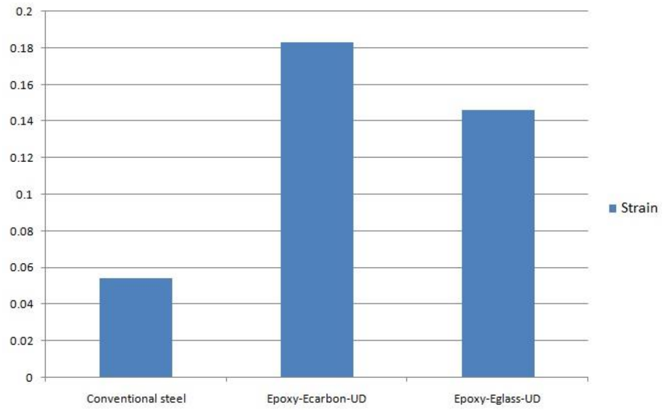

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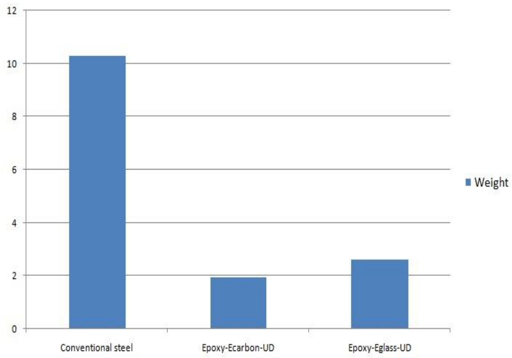

(d)

Fig. 3. The comparison among these 3 types material leaf spring (a) Total Deformation (mm) (b) Bending stress (Mpa) (c) Elastic strain (mm/mm) (d) Weight (kg)

Table 5. Comparison 3 type's material of leaf spring

Parameter(Maximum)	Conventional steel	Epoxy-E Carbon	Epoxy-E Glass
Deflection(mm)	45	56	60
Bending stress(**Mpa**)	11432	1874	1689
Elastic strain(mm/mm)	0.0544	0.1832	0.1460
Weight(kg)	10.3	1.9	2.6

By comparison leaf spring for different material from ANSYS Workbench, it is seen that there are many variation between conventional steel and composite material. But the variation between Epoxy- E carbon and Epoxy- E glass is small. From Figure-3 (a) total deflection of the Epoxy-E glass composite is higher and close to Epoxy-E carbon which can absorb more energy compare to steel leaf spring as both composite material have low stiffness. From Figure-3 (b) bending stress of two composite spring is very lower compare to steel spring. Hence, fatigue life of both composite springs are more. From Figure-3 (c) elastic strain, here also both composite spring show excellent result. As they have small elastic strain, they absorb more shock compare to steel spring for running the vehicle fine and smoothly. From Figure-3 (d) weight, it is very important result which mainly concentrates our mind. The weight of spring is very low for Epoxy-E carbon spring which will help to reduce the weight of a vehicle as well as fuel consumption.

6. Conclusion

In this paper three types of material leaf springs were analyzed. Epoxy-E carbon spring showed better result. The natural frequency of the leaf spring was far enough from the road frequency avoid resonance. The Epoxy-E carbon fiber leaf spring meets all the requirements of a good leaf spring together with substantial weight, shock absorption and cost savings. For better sustainability, durability and strength it is necessary to design the leaf with proper geometrical consideration. The Epoxy-E carbon leaf spring would not only reduce the weight cost and other discussed parameters but would also reduce the tendency of frequent maintenance of the vehicle.

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