

Finite Element Analysis of Elliptical Leaf Spring Using Epoxy Materials

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ABSTRACT: The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The objective is to compare the different types of composite material and load carrying capacity, stress stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle TATA ACE EDGE are selected for this work investigation. Similar dimensions of conventional leaf spring are used to design in Solid works of composite semi elliptical leaf spring material for analysis that is E- Glass/Epoxy, Carbon Epoxy and Graphite Epoxy unidirectional laminate. Finite Element Analysis with full load on 3-D model of composite Semi elliptical leaf spring is done using FEA and the analytical results are compared with experimental results. Run the 16 experiment with the combination of load and material which gives output responses in terms of stress, deflection and weight. Compare the all material with their respective load and select the best one by comparison. Optimize the responses of 16 combinations by Grey Relation Analysis for the better input parameter against output responses.

KEYWORDS: Leaf Spring, Solid Works, ANSYS, FEA Analysis.

I. INTRODUCTION

Leaf springs are mainly used in suspension systems used to absorb the shock loads in automobiles such as L.C.V, H.C.V. It used to carry lateral loads, brake torque and driving torque with shock absorbing [1]. Leaf spring covers advantages over helical spring are that the ends of the leaf spring can be guided along a definite path because it deflects to act as a structural member along with energy absorbing device. According to previous studies made, a material which had maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring [2]. The leaf springs get more affected due to fatigue loads, as they are a part of the unstrung mass of the automobile. Performance measures of any leaf springs are its stiffness and fatigue life.[1].

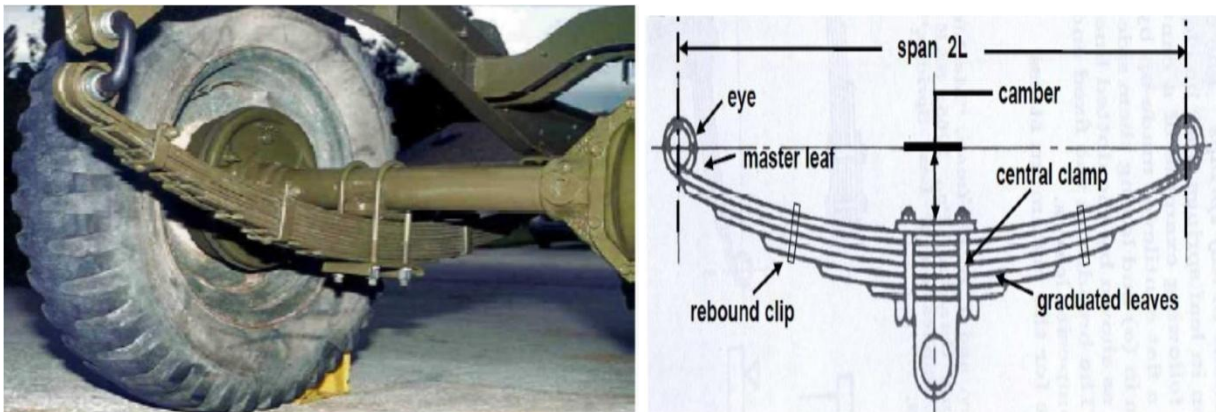


Fig.1 Leaf spring assembled at rear axle of automotive & Multi-Leaf Spring [2]

A. Principle of LeafSpring

With the introduction of composites, a better suspension system along with better ride quality can be achieved. In designing of springs, strain energy becomes the major factor [1]. The relationship of the specific strain energy can be expressed as;

$$U = \sigma^2/\rho E$$

Where σ is the strength, ρ is the density and E is the Young's Modulus of the spring material.

B. CompositeMaterials

When two or more materials are combined then it results in better properties than those of the individual components which can be used alone, can be defined as Composite material. Every material retains its separate chemical, physical, and mechanical properties, when compared to metallic alloys. Composite materials offers advantages such as high strength and stiffness, combined with low density, when compared with bulk materials, which allows for weight reduction for the finished part [3].

C. Applications

Composites material has their commercial and industrial applications on major structural application areas which includes aircraft, space, automotive, sporting goods, and marine engineering.

Other applications include such as structural chassis components, such as drive shafts and road wheels, have been successfully tested in the laboratories and are currently being developed for future cars and vans.

1) Benefits

- a) Weight reduction & High strength: Composites are light in weight, compared to most woods and metals & far stronger than aluminum or steel.
- b) Corrosiveness & Low Thermal Conductivity: Composites resist damage from the weather and from harsh chemicals & are low conductor of heat and cold and are good insulator.
- c) Design Flexibility & Durable: As compare to other materials composites can be molded into complicated shapes more easily & have a long life and need little maintenance.

II. PROBLEM FORMULATION

Based on the problems and past research gap analysis objective of work are focused on compare the load carrying capacity, stresses, deflection and weight savings of composite leaf spring with that of steel leaf spring. And paying attention on composite materials by replacing steel in conventional leaf springs of a suspension system to reduce stresses, deflection are follow some objective;

- A. Select the vehicle leaf spring for calculate its dimension and its effective load.
- B. Design the leaf spring in CAD software with assemble which provide the requisite dimension to the body structure as well as to bear the load in actual condition.
- C. Design the input parameters for analysis in ANSYS tool. As per the design with selected parameters perform the analysis and record the responses.
- D. Optimize the responses with suitable multi-objective technique.
- E. Compare these responses with respect to load for selected the material of leaf spring.

III. MATERIAL SELECTION

Basis of composite material selection

1. Composite materials exhibit superior mechanical properties such as high strength, toughness, young's modulus, fairly good fatigue and impact properties.
2. As fiber composite are light weight materials, the specific strength and specific modulus are much higher than the conventional materials.

Composite materials are

1. E-glass/epoxy
2. carbon epoxy
3. E-glass/polyurethane

1. E-glass/epoxy

Glass Fiber Reinforced Plastics (GFRP) are considered a potential material system

The main emphasis of the investigation was to evaluate the roles of percentage matrix phase and interfacial areas on the inter laminar shear failure mechanism of glass/epoxy composites at ultra-low temperatures for different loading speeds.

Properties of E-glass epoxy

1	Fiber volume fraction v_f (%)	52
2	Tensile strength (MPa)	767
3	Tensile modulus(GPa)	36.9
4	Tensile strain to failure (%)	2.2
5	Flexure strength (GPa)	1023
6	Flexure modulus(GPa)	43.3
7	Shear modulus(GPa)	3.3
8	Poisson ratio	0.3

2. Carbon epoxy

Epoxy or poly epoxide is a thermosetting epoxide polymer that cures (polymerizes and cross links) when mixed with a catalyzing agent. Stress transfer in the fiber/matrix interphase requires a strong interfacial bond between the two components. Carbon fibers, when used without any surface treatment, produce composites with low inter laminar shear strength which, in turn, affects most of the other mechanical properties. Consequently, in order to optimize their mechanical properties and use their full potential, a variety of surface modification techniques has been developed to promote interfacial bonding..

Table 2 Properties of carbon epoxy

1	Fiber volume fraction v_f (%)	50
2	Tensile strength (MPa)	600
3	Tensile modulus(GPa)	36.9
4	Tensile strain to failure (%)	2.2
5	Flexure strength (GPa)	1023
6	Flexure modulus(GPa)	43.3
7	Shear modulus(GPa)	5
8	Poisson ratio	0.3

3. E-glass/ polyurethane

It is usually made from petroleum based polyols and isocyanates and have widespread application in automotive parts, coatings, adhesives. Polyurethanes are finding a growing interest for application as composites due to the cost effective compounds for sectors such as the automotive product. Reinforced of such polyurethane with fibers, natural, synthetic, should improve mechanical properties if good fiber matrix adhesion is achieved.

Properties of e-glass polyurethane

1	Fiber volume fraction v_f (%)	58
2	Tensile strength (MPa)	860
3	Tensile modulus(GPa)	44.2
4	Tensile strain to failure (%)	2.06
5	Flexure strength (GPa)	1247
6	Flexure modulus(GPa)	50.6
7	Shear modulus(GPa)	3.7
8	Poisson ratio	0.3



IV. CALCULATION

The following parameters should be considered for calculation:

- Length of the leaf spring =1280mm
- Width (b) =88mm
- Sustain load =70*10³ N=2W
- Full length leaves (n_f) =3
- Band width (a) =100mm
- Stress = 400N/mm²
- Ratio of total spring depth/width =2
- Young's modulus (E) =2*10⁵ N/mm²

Thickness of the leaf spring

$$(n \cdot t) / b = 2$$

$$(13 \cdot t) / 88 = 2$$

$$t = (2 \cdot 88) / 13$$

$$t = 13.57 \text{ mm} = 14 \text{ mm}$$

Length of the leaf spring

$$2L = 2L_1 - a$$

$$= 1280 - 100$$

$$= 1180$$

$$L = 590 \text{ mm}$$

Initial gap

$$C = \frac{2 \cdot W \cdot L^3}{n \cdot E \cdot b \cdot t^3}$$

$$C = [2 \cdot 15.33 \cdot 10^3 \cdot 590^3] / [13 \cdot 2 \cdot 10^5 \cdot 88 \cdot 14^3]$$

$$C = 6296920140000 / 627827200000$$

$$C = 10.03 \text{ mm}$$

Load exerted on the band after the spring is assembled

$$W_b = \frac{[2n_f \cdot n_g \cdot W]}{[n(2n_g + 3n_f)]}$$

$$W_b = [2 \cdot 3 \cdot 10^3 \cdot 15.33 \cdot 10^3] / [13 \cdot [(2 \cdot 10) + (3 \cdot 3)]]$$

$$W_b = (919800) / 377$$

$$W_b = 2439.78 \text{ N}$$

Deflection of spring

$$\delta = \frac{12WL^3}{E \cdot b \cdot t^3 \cdot (2n_g + 3n_f)}$$

$$\delta = 12 \cdot 15.33 \cdot 10^3 \cdot 590^3 / [2 \cdot 10^5 \cdot 88 \cdot 14^3 \cdot [(2 \cdot 10) + (3 \cdot 3)]]$$

$$\delta = 26.98 \text{ mm}$$

Inner diameter of eye

- d = inner diameter of eye
- l₁ = length of pin = b = 88mm

P_b = bearing pressure on the diameter of eye = 8 N/mm²

Clearance = 2mm

$$l_2 = l_1 + (2 \cdot 0.2)$$

$$l_2 = 88 + 0.4 = 88.4 \text{ mm}$$

Maximum bending moment

$$M = (W \cdot l_2) / 4$$

$$= 15330 \cdot 88.4 / 4$$

$$M = 338793 \text{ Nmm}$$

Inner diameter of eye

$$Z = (\pi/32)*d^3$$

$$= 0.0982* d^3$$

Bending stress $f_b = 800 = M/Z$
 $800 = 338793/0.0982* d^3$
 $d=16.27\text{mm}=16\text{mm}.$

Shear stress

$$W=2*(\pi/4)*d^2*f_s$$

$$15330 = 2*(\pi/4)*16^2* f_s$$

$f_s=38.12\text{N/mm}^2$

Length of the leafs

Length of smallest leaf =effective length/(n-1) + ineffective length(a)

Effective length $2L=1180$

Smallest leaf = $1180/(14-1) + 100$
 $=198.33\text{mm}$

Length of 2nd leaf = $1180*2/13 + 100$
 $= 296.66\text{mm}$

Length of 3rd leaf = $1180*3 /13 + 100$
 $=395\text{mm}$

Radius of which the leaves should be initially bent

R =radius to which leaves should be initially bent

y =camber of the spring

$$y(2R-y) =L_1^2$$

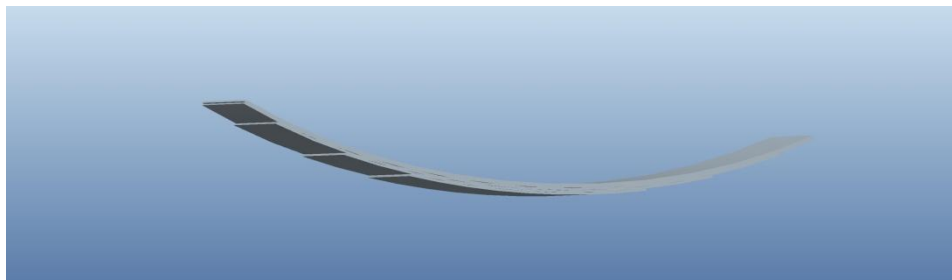
$$710^2 =19(2R-23)$$

$(2R-19) =30400$

$2R =30419$

$R =15209.5\text{mm}$

V. MODELING



Basic requirements of load: Maximum capacity = 2250 Kg = 2250 x 10 =22500N TATA ACE EDGE 102 is equipped with 4 nos. of semi-elliptical leafspring,

So load acting on the leaf spring assembly =

$22500 \div 4 = 5625 \text{ N}$ Calculation of load and

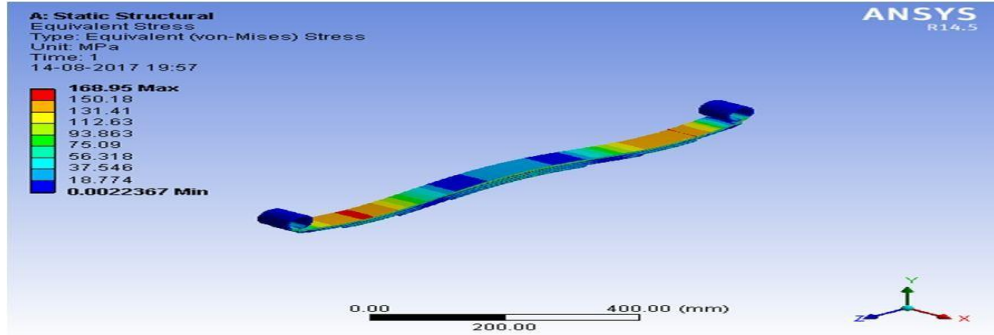
effective length of leaf spring:

Consider the leaf spring is cantilever beam, $2 \times W = 5625$, $W =5625 \div 2$, $W= 2812.5 \text{ N}.$

Now On basis of parameters calculation leaf spring are designed in SOLID WORKS and FEA in ANSYS v14.5.

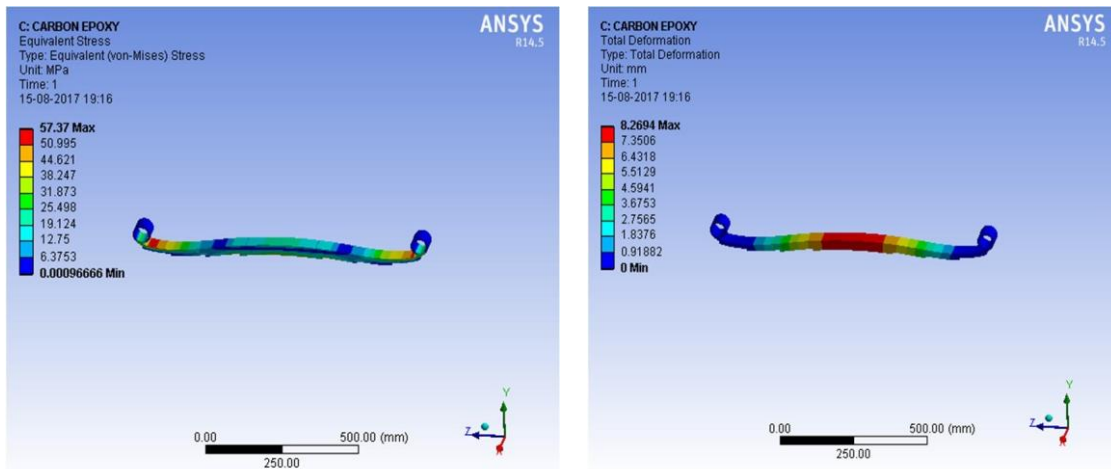
FEA of every material are run and results are shown in below fig.

VI. ANALYSIS



VII. RESULT AND DISCUSSION OBTAINED

From optimization done above we get result for optimum load, stress, deflection and optimum material to be suggested for replacement of conventional steel.



Optimum stress and deflection for Carbon epoxy at load 5550N is shown in Fig.3

Fig 3 CARBON EPOXY stress and deflection at 5550 N

A. Comparison of GRG

	5625	5600	5575	5550	Average GRG	Rank
EN47	0.661066	0.66363	0.666322	0.668927	0.66498625	2
E glass	0.656606	0.65953	0.662481	0.665446	0.66101575	4
Carbon Epoxy	0.740515	0.74375	0.747022	0.750343	0.7454075	1
Graphite Epoxy	0.659909	0.662846	0.665809	0.6688	0.664341	3

Table GRG Comparison

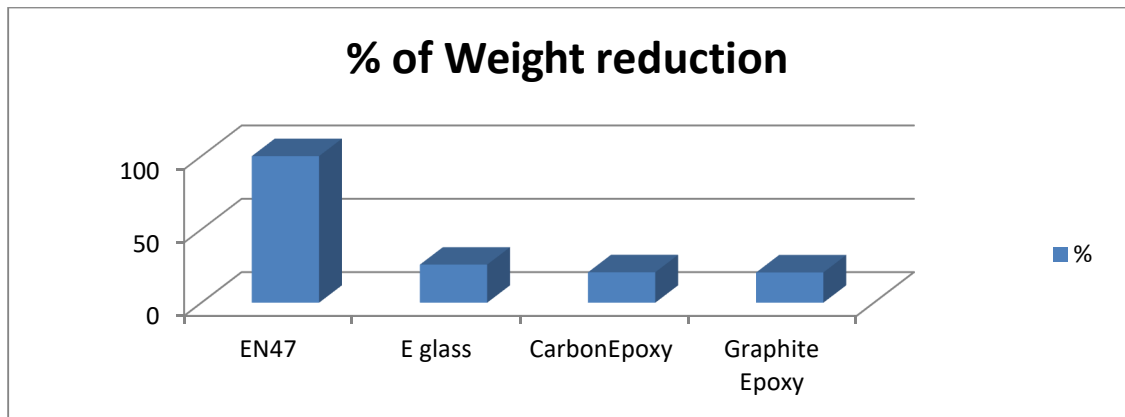
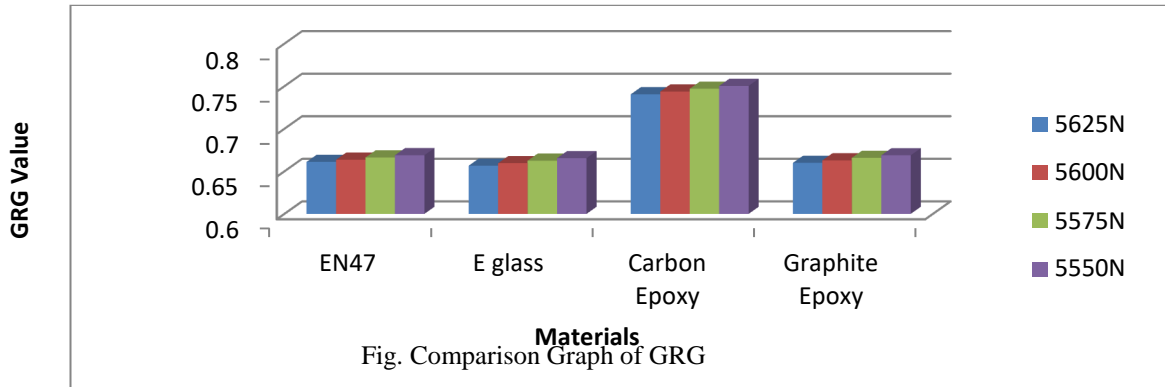


Fig Percent of weight of each material [1]

VII. CONCLUSION

From the static analysis results it is found that there is a maximum displacement of 13.039 mm in the Graphite epoxy spring and the corresponding displacements in Steel E-glass / epoxy, and carbon/epoxy are 3.911mm, 13.008 mm and 8.381mm respectively on maximum load. From the static analysis results it is found that there is a maximum stress of 168.95 MPa in the steel spring and the corresponding displacements in E-glass/epoxy, Graphite epoxy and carbon/epoxy are 58.038 MPa, 57.611 MPa and 58.145 MPa respectively on maximum load. From the optimization by grey relation analysis observed the minimum stress and deflection simultaneously drawn on load 5550 N with Carbon Epoxy material. By comparing GRG with respect to load and material the optimize material is Carbon epoxy with all load, its minimum stress are found 57.37 MPa and deflection 8.2694 mm. Among the three composite leaf springs, only Carbon/epoxy composite leaf spring has optimum stresses and deflection than the other material leaf spring. Carbon/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view. As comparing the weight of steel to other material carbon epoxy has optimum weight is 2.424 as comparing with steel percent the reduction in weight for suggested material is 79.219. But the minimum weight percent reduction is obtained 79.35 % of Graphite epoxy which is almost equivalent to carbon epoxy.

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