DESIGN AND MANUFACTURING OF A LEAF SPRING USING COMPOSITE MATERIALS

Srikanth Sudhani[1]
[1](Mechanical, Sri Venkateswara Engineering college, INDIA, sudani.srikanth999@gmail.com)

Abstract— *A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There are mono leaf springs, or single-leaf springs, that consist of simply one plate of spring steel. These are usually thick in the middle and taper out toward the end, and they don't typically offer too much strength and suspension for towed vehicles. Drivers looking to tow heavier loads typically use multi leaf springs, which consist of several leaf springs of varying length stacked on top of each other. The shorter the leaf spring, the closer to the bottom it will be, giving it the same semielliptical shape a single leaf spring gets from being thicker in the middle.*

Keywords—Leaf Spring, Composite Materials

1. INTRODUCTION

The aim of the project is to design and model a leaf spring according to the loads applied for the material carbon epoxy. While designing leaf spring we are going to consider following five cases.
Case I – Thickness is the variable
Case 2- Camber is the variable
Case 3 – Span is variable
Case 4 – Number of leaves is the variable
We are also considering these cases also

- Modeling of Road Irregularity
- Variation of Exciting frequency with vehicle speed

Presently Used Material For Leaf Spring Are Forged Steel. In This Project We Are Going To Design Leaf Spring For The Material Composite Material Carbon Epoxy By Varying Reinforcement Angle And Layers. We Are Going To Check The Strength Variations While Changing Reinforcement Angle And Layers. For Validating This Design We Are Conducting Fea Structural Analysis Is Done On The Leaf Spring By Using Two Different Material Carbon Epoxy

2. COMPOSITE MATERIALS

These are materials with two or more compositions mainly now a days composite materials are became more popular and friendly because of its various advantages in this I have worked on two different composite materials and compared with conventional materials.

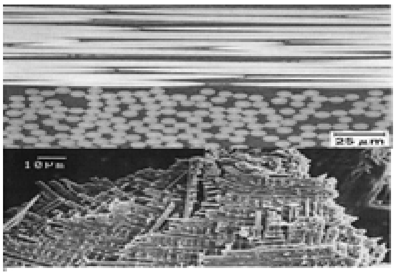


FIGURE 1 Cross section of a graphite fiber–reinforced epoxy polymer

Physical Properties	Metric
Density	2.46 g/cc
Mechanical Properties	Metric
Tensile Strength, Ultimate	4890 MPa
Elongation at Break	5.70 %
Modulus of Elasticity	86.9 GPa
Poissons Ratio	0.230
Shear Modulus	35.0 GPa

3. DESIGN CALCUCULATION OF LEAF SPRING

When n=10, Rear suspension
Number of leaf springs = 4
Overall length of the spring = 2L1 = 137.2cm = 1372mm
Width of leaves = 76.2 = 80mm
Number of full length leaves = 2 = nf
Number of graduated leaves = 8 = Ng
Number of springs = 10 (Ng+Nf)
Center load = 2W =115 tones = 11500kg
2W =11500 9.8 = 112700N
2W = 112700/4 = 28175N

$$2W = \frac{total\ load}{no\ of\ springs} = 28175N$$

W = 14087.5N

3.3.1 Bending Stress

Bending stress, $\sigma = \frac{6\,W\,L_1}{nbt^2}$

$$= \frac{6 \times 14101.875 \times 686}{10 \times 80 \times 16^2}$$

$$= 283.4146\ N/mm^2$$

Bending stress, σ = 283.4146 N/mm^2

Spring is simply supported beam

Width length = 2L

Central load =2W

Deflection for both full length and graduated leaves

y= $\delta = \frac{6WL^3}{n\epsilon bt^3} = \frac{6\times 14101.875\times 686^3}{10\times 80\times 86900\times 16^3}$ = 95.923 mm

Radius of curvature

R = $\frac{{L_1}^2+y^2}{2y} = \frac{686^2+95.923^2}{2\times 95.923}$ = 2500.91 mm

∴ Radius of curvature = 2500.91 mm

3.3.2 Length of leaf springs

$2L_1 = overall\ length\ of\ spring$

Ineffective length l = width of band/distance between centers of u-tubes

Effective lengths 2L = $2L_1 - \frac{2}{3}l$ (when u bolts are used)

$L_1 = 1372$mm

l= 300 (assume)

2L = 1372-$\frac{2}{3}\times 300 = 1172$mm

It may be noted that when there is only one full length leaf (master leaf only) then the no of leaves to be cut will be n and when there are two full length leaves (including one master leaf) then the no of leaves to be cut will be (n-1) if a leaf spring has two full length leaves then the length of leaves is obtained as follows

Length of smallest leaf = $\frac{effective\ length}{n-1} + ineffective\ length$

n= 12

$= \frac{1172}{9} + 300$

= 430.22 mm

Length of next leaf = $\frac{effective\ length}{n-1} \times 2 + ineffective\ length$

$= \frac{1172}{9} \times 2 + 300$

= 560.44 mm

Length of 3rd leaf = $\frac{1172}{9} \times 3 + 300 = 690.66$ mm

Length of 4rd leaf = $\frac{1172}{9} \times 4 + 300 = 820.88$ mm

Length of 5rd leaf = $\frac{1172}{9} \times 5 + 300 = 951.1$ mm

Length of 6rd leaf = $\frac{1172}{9} \times 6 + 300 = 1081.32$ mm

Length of 7rd leaf = $\frac{1172}{9} \times 7 + 300 = 1211.54$ mm

Length of 8rd leaf = $\frac{1172}{9} \times 8 + 300 = 1341.76$ mm

Length of 9rd leaf = $\frac{1172}{9} \times 9 + 300 = 1471.98$ mm

The nth leaf will be the master leaf and it is of full length since the master leaf has eyes on both sides therefore

Length of master leaf = $2L_1 + \pi(d+t) \times 2$

d = Inside diameter of eye

t = thickness of master leaf

d =22 mm

t= 1372+π (22+22)× 2

t = 1648.46 mm

The approximate relation between the radius of curvature (R) and camber (Y) of spring is given by R = $\frac{{L_1}^2}{2y}$

$L_1 = half\ span\ of\ spring$

Y = δ (the maximum deflection of spring is equal to camber(y) of spring)

$L_1 = \frac{1372}{2} = 686$mm ; $\delta =$ 95.923mm

R = $\frac{{L_1}^2+y^2}{2y} = \frac{686^2+95.923^2}{2\times 95.923}$ = 2500.91 mm, $\delta = 95.923$ mm

3.3.3 Radius values

1	=	2644.91 mm
2	=	2628.91 mm
3	=	2612.91 mm
4	=	2596.91 mm
5	=	2580.91 mm
6	=	2564.91 mm
7	=	2548.91 mm
8	=	2532.91 mm
9	=	2516.91 mm

3.3.4 Modelling and analysis of the leaf spring

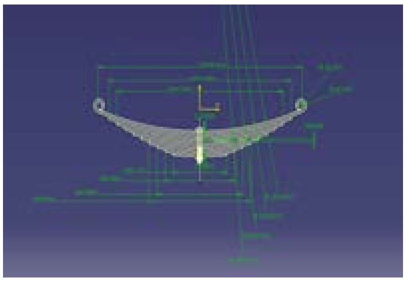


FIGURE 2 3D MODEL OF LEAF SPRING

CASE 1:- MATERIAL - MILD STEEL

Save CATIA Model as .iges format

→→Ansys → Workbench→ Select analysis system → static structural → double click

→→Select geometry → right click → import geometry → select browse →open part → ok

→→ select mesh on work bench → right click →edit

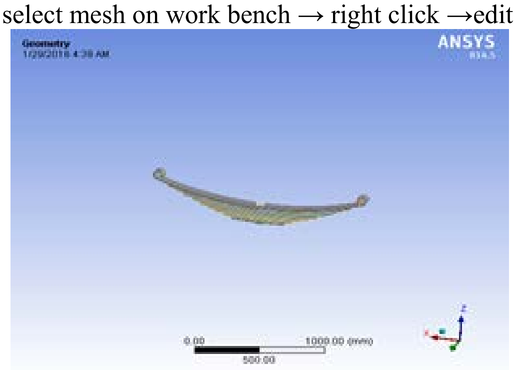


Figure3 Imported model into ANSYS work bench

Double click on geometry → select geometries → edit material →

4. MATERIAL PROPERTIES OF STEEL

Density : 0.00000785kg/mm^3
Young's modulus : 20000Mpa
passions ratio : 0.3

Select mesh on left side part tree → right click → generate mesh →

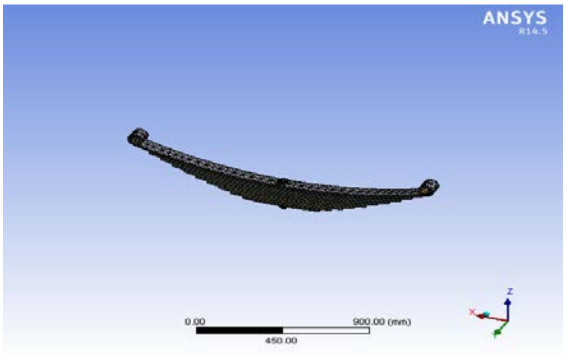


Figure4: Meshing of the component

Select static structural right click → insert → select force - 14088 N

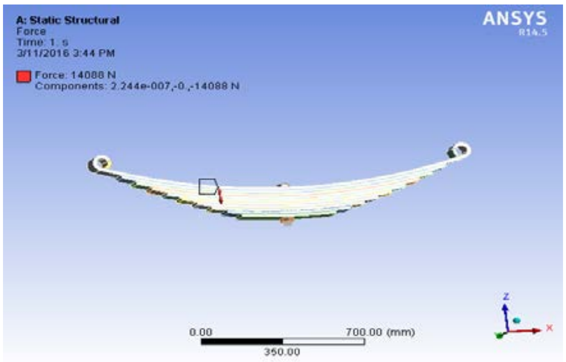


Figure5: Applying force on the leaf spring

Select displacement → select required area → click on apply → put X,Y,Z component zero →

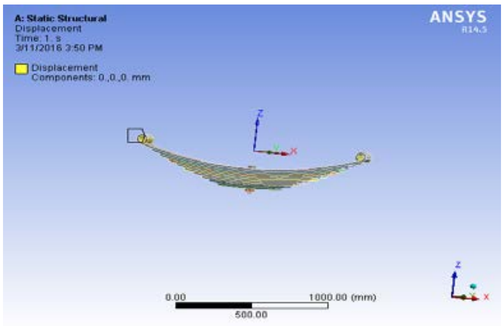


Figure6: constraining both ends

Select solution right click → solve →

Solution right click → insert → deformation → total →
Solution right click → insert → strain → equivant (von-mises) →
Solution right click → insert → stress → equivant (von-mises) →
Right click on deformation → evaluate all result

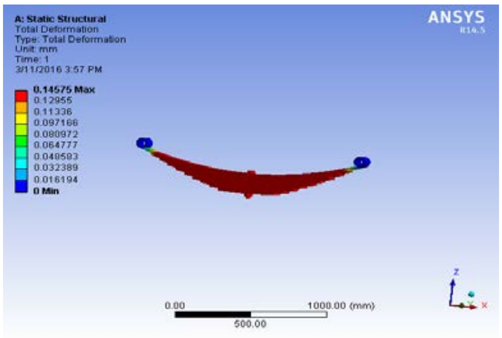


Figure7: total deformation of Steel

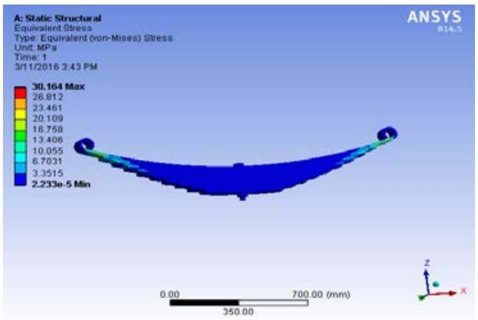


Figure8: Von-Mises Stress of Steel

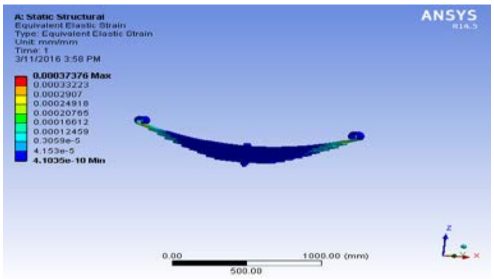


Figure9: Von-Mises strain of steel

CASE 2:- MATERIAL - CARBON EPOXY

MATERIAL PROPERTIES OF CARBON EPOXY

Density : 1.60 g/cc
Young's modulus : 70.0GPa
Possions ratio : 0.3

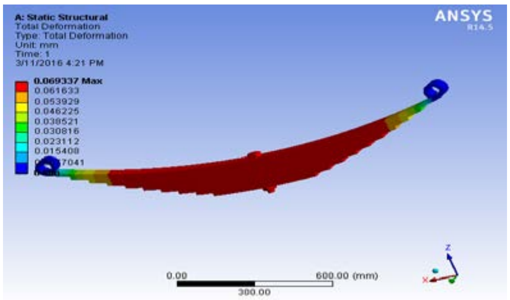


Figure10: Total Deformation of Carbon Epoxy

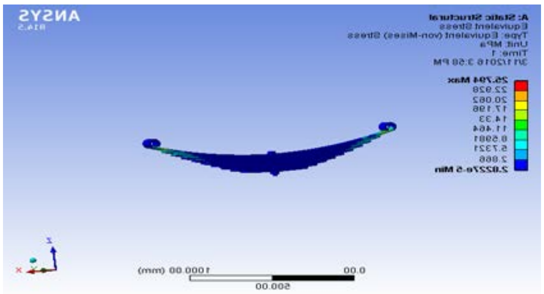


Figure11: Von-Mises Stress of Carbon Epoxy

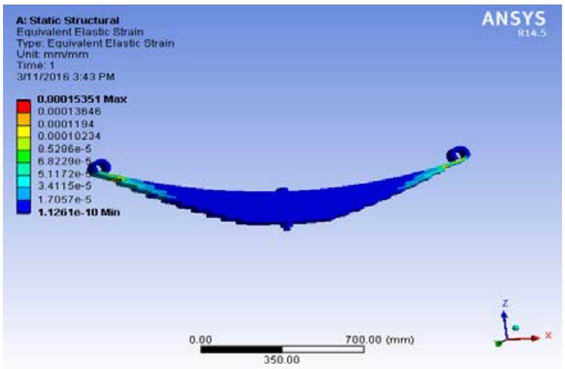


Figure12: Von-Mises Strain of Carbon Epoxy

CASE 3:- MATERIAL - S2 GLASS

MATERIAL PROPERTIES OF S2 glass

Density : 2.46 g/cc

Young's modulus : 86.9GPa

Possions ratio : 0.28

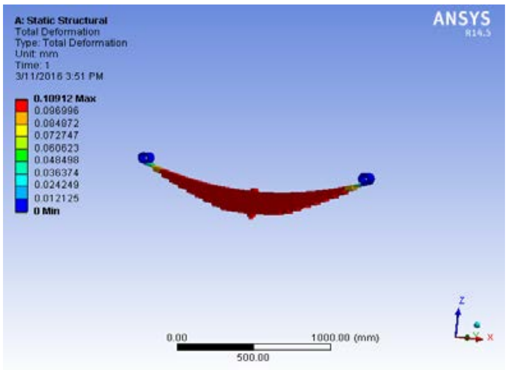


Figure 13: Total deformation of S2 Glass

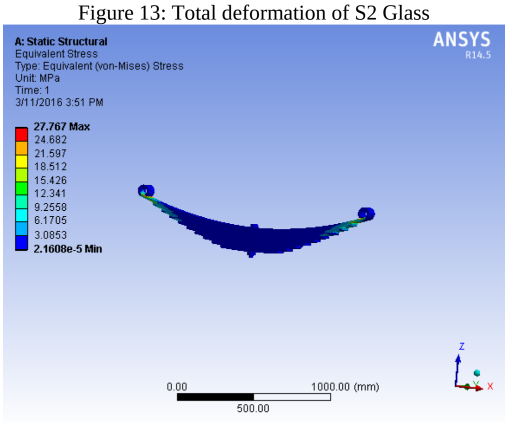


Figure 14: von-mises Stress of S2 Glass

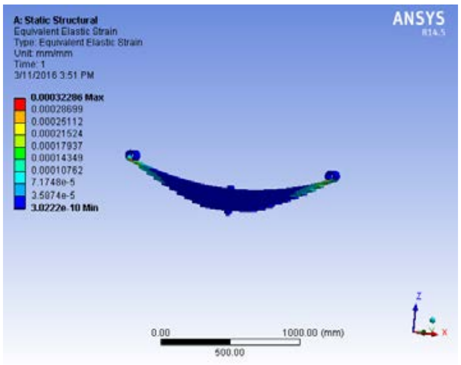


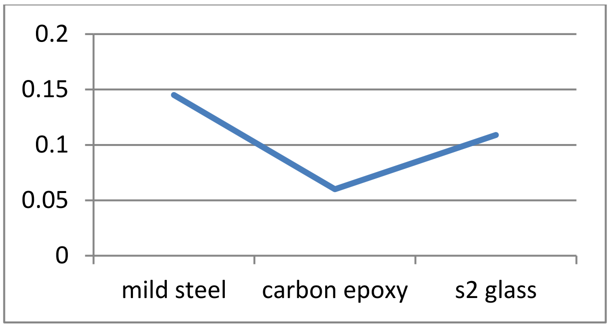
Figure 15: Von-Mises Strain of S2 Glass

5. RESULTS AND DISCUSSIONS

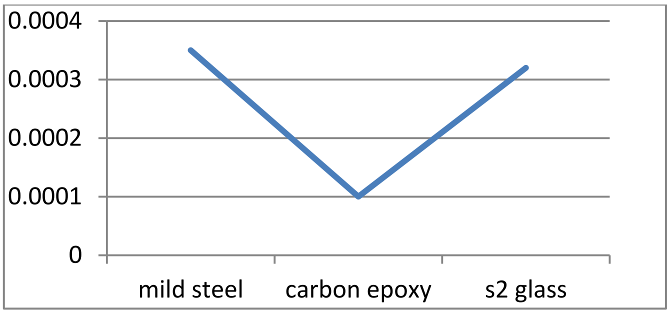
TABLE 2 : RESULTS OF THE LEAF SPRING

	Mild steel	Carbon epoxy	S2 glass
Deformation (mm)	0.145	0.0693	0.10912
STRESS (N/mm^2)	30.164	25.79	27.76
STRAIN	0.00035	0.00015	0.00032

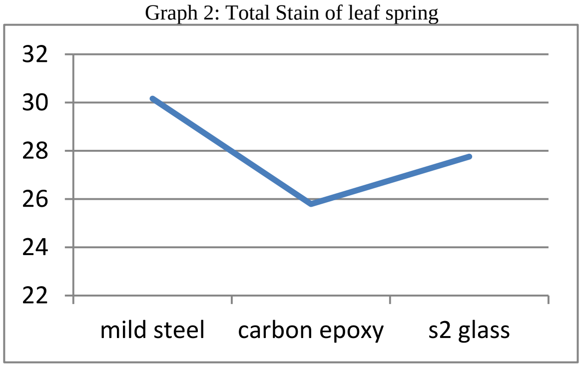
Graphs



Graph 1: Total Deformation of leaf Spring



Graph 2: Total Stain of leaf spring



Graph3: Total stress of leaf spring

6. CONCLUSION

The data is collected from net for the specifications of the model. The leaf spring is designed for the load of 14087.5N. Theoretical calculations have been calculated for leaf spring dimensions at different cases like varying thickness, camber, span and no. of leaves by mathematical approach. In this thesis, analysis have been done by taking materials steel, carbon Epoxy and s2 glass Structural analysis are conducted on total assembly of leaf spring. The stresses in the composite leaf spring of design are much lower than that of the allowable stress. The strength to weight ratio is higher for composite leaf spring than conventional steel spring with similar design.

The major disadvantages of composite leaf spring are the matrix material has low chipping resistance when it is subjected to poor road environments which may break some fibers in the lower portion of the spring. This may result in a loss of capability to share flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problem will not be there. Composite leaf springs made of polymer matrix composites have high strength retention on ageing at severe environments.
The steel leaf spring width is kept constant and variation of natural frequency with leaf thickness, span, camber and numbers of leaves are studied. It is observed from the present work that the natural frequency increases with increase of camber and almost constant with number of leaves, but natural frequency decreases with increase of span. The natural frequencies of various parametric combinations are compared with the excitation frequency for different road irregularities. The values of natural frequencies and excitation frequencies are the same for both.

REFERENCES

[1] M.Venkateshan , D.Helmen Devraj, "design and analysis of leaf spring in light vehicles", IJMER 2249-6645 Vol.2, Issue.1,pp.213-218, Jan-Feb 2012.

[2] R.S.Khurmi and J.K.Gupta Machine Design chapter 23. [3]. U. S. Ramakant & K. Sowjanya, "Design and analysis of automotive multi leaf springs using composite material", IJMPERD 2249-6890 Vol. 3, Issue 1,pp.155-162, March 2013,

[3] Rajendran I., Vijayarangan S., "Design and Analysis of a Composite Leaf Spring"Journal of Institute of Engineers, India ,vol.-8,2-2002

[4] Dakshraj Kothari,Rajendra Prasad Sahu and Rajesh Satankar Comparison of Performance of Two Leaf Spring Steels Used For Light Passenger Vehicle, VSRD-MAP 2249-8303 Volume2 (1), 9-16, 2012

[5] Mr. V. Lakshmi Narayana, "Design and Analysis Of Mono Composite Leaf Spring For Suspension in Automobiles" IJERT 2278-0181, Vol. 1 Issue 6, August – 2012

[6] Shishay Amare Gebremeskel, "Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle", Global Journals Inc. (USA) 2249-4596, Volume 12 Issue 7, 21-30, 2012

[7] Manas Patnaik, NarendraYadav, "Study of a Parabolic Leaf Spring by Finite Element Method & Design of Experiments" , IJMER 2249- 6645, Vol.2, 1920-1922, July-Aug 2012

[8] Kumar Krishan, Aggarwal M.L, "Computer Aided FEA Comparison of mono steel and mono GRP leaf spring", IJAERS 2249–8974, vol. 1 issue 2, pp. 155-158, jan- march 2012

[9] Mr. V. K. Aher *, Mr. P. M. Sonawane , Static And Fatigue Analysis Of Multi Leaf Spring Used In The Suspension System Of LCV, (IJERA) 2248-9622 Vol. 2, Issue 4, pp.1786-1791, July-August 2012

[10] B. Raghu Kumar, R.VijayaPrakash and N. Ramesh, Static analysis of mono leaf spring with different composite materials" JMER , 2141- 2383, Vol. 5(2), pp.32-37, February 2013

[11] Y. N. V. Santhosh Kumar & M. Vimal Teja,Design and Analysis of Composite Leaf Spring International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1,pp. 97-100, 2012

[12] Deshmukh.et.al, Design and analysis of fibber reinforced polymer (FRP) leaf spring-A review, International journal of engineering technology and science, Vol.2(4), pp 289-291, 2011.

[13] William D. Callister Material science and engineering. [15]. Robert C. Juvinall, Kurt M. Marshek fundamentals of machine component design

[14] www.auto-data.net