STATIC AND DYNAMIC ANALYSIS ON COMPOSITE LEAF SPRING IN HEAVY VEHICLE

[1]MR.SHIVAKUMAR, [2]M.BABU RAO, [3]T.SHAHINSHA
[1]*M Tech Scholar,* [2,3]*Assistant Professor*
Arjun College of Technology & Sciences, *Sy.No.376/7, Batasingaram (V), Hayathnagar (M), R.R. District, Andhra Pradesh. INDIA.*

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.

The objective of this project is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring that of steel leaf spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel leaf spring of a Heavy commercial vehicle are taken Same dimensions of conventional leaf spring are used to fabricate composite multi leaf spring using e-glass/epoxy, Graphite/epoxy, carbon/epoxy unidirectional laminates. One of cad tool is used for modeling and Ansys is used for cae tool.

Keywords: solid works, ansys, leaf spring, composite material

1. INTRODUCTION TO LEAF SPRING

Originally Leaf spring called laminated or carriage spring, a leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles It is also one of the oldest forms of springing, dating back to medieval times.

Sometimes referred to as a semi-elliptical spring or cart spring, it takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and

2. LITERATURE REVIEW

Gulur Siddaramanna Shiva Shankar∗, Sambagam Vijayarangan(2006)[6],The development of a composite mono leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective; o The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings;

M.Venkatesan,D.Helmen Devaraj(Jan-Feb 2012) [1], 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. A comparative study has been made between composite and steel leaf spring with respect to weight, cost and strength

3. DESIGN OF LEAF SPRING

The leaf spring behaves like a simply supported beam and the flexural analysis is done considering it as a simply supported beam. The simply supported beam is subjected to both bending stress and transverse shear stress. Flexural rigidity is an important parameter in the leaf spring design and test out to increase from two ends to the center.

Table 1 specification of leaf spring

specification			
		value	units
1	Total length of the spring (eye to eye)	1540	mm
2	Free camber (at no load condition)	136	mm
3	No.of full length leave (master leaf)	01	Mm
4	Thickness of leaf spring	13	Mm
5	Width of leaf spring	70	Mm
6	Maximum load given on spring	3750	N
7	Young's modules of the spring	22426.09	N/mm^2
8	Weight of the leaf spring	23	Kg

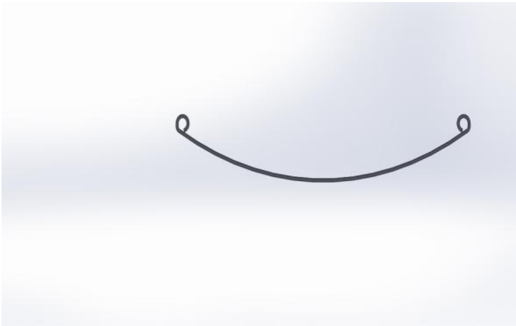


Figure 1 master leaf spring

Figure 2 springs assembly

4. MATERIALS FOR LEAF SPRING

A composite is a material that is formed by combining two or more materials to achieve some superior properties. Almost all the materials which we see around us are composites. Some of them like woods, bones, stones, etc. are natural composites, as they are either grown in nature or developed by natural processes. Wood is a fibrous material consisting of thread-like hollow elongated organic cellulose that normally constitutes about 60-70% of wood of which approximately 30-40% is crystalline, insoluble in water, and the rest is amorphous and soluble in water. Cellulose fibres are flexible but possess high strength. The more closely packed cellulose provides higher density and higher strength. The walls of these hollow elongated cells are the primary load-bearing components of trees and plants. When the trees and plants are live, the load acting on a particular portion (e.g., a branch) directly influences the growth of cellulose in the cell walls located there and thereby reinforces that part of the branch, which experiences more forces. This self-strengthening mechanism is something unique that can also be observed in the case of live bones. Bones contain short and soft collagen fibres i.e., inorganic calcium carbonate fibres dispersed in a mineral matrix called apatite. The fibres usually grow and get oriented in the direction of load. Human and animal skeletons are the basic structural frameworks that support various types of static and dynamic loads. Tooth is a special type of bone consisting of a flexible core and the hard enamel surface. The compressive strength of tooth varies through the thickness. The outer enamel is the strongest with ultimate compressive strength as high as 700MPa. Tooth seems to have piezoelectric properties i.e., reinforcing cells are formed with the application of pressure. The most remarkable features of woods and bones are that the low density, strong and stiff fibres are embedded in a low density matrix resulting in a strong, stiff and lightweight composite (Table 1.1). It is therefore no wonder that early development of aero-planes should make use of woods as one of the primary structural materials, and about two hundred million years ago, huge flying amphibians, pterendons and pterosaurs, with wing spans of 8-15 m , could soar from the mountains like the present day hang-gliders. Woods and bones in many respect, may be considered to be predecessors to modern man-made composites.

5. MATERIALS FOR LEAF SPRING

Analysis of E-Glass /Epoxy Composite Leaf Spring FEM Model details
Mechanical properties:

Extensional Elastic Modulus E_1 = 43E+3 MPa
Transverse Elastic Modulus E_2 = 9E+3 MPa
In-plane Shear Modulus G12 = 4.5E+3 MPa
Major Poisson's Ratio μ_{12} = 0.27
Minor Poisson's Ratio μ_{21} = 0.06
Density ρ = 2000kg/m3
Yield strength S_y =2000MPa

Analysis of Graphite / Epoxy Composite Leaf Spring FEM Model details Mechanical Properties:

Extensional Elastic Modulus E1 = 294E+3MPa
Transverse Elastic Modulus E_2 = 6.4E+3 MPa
In-plane Shear Modulus G12 = 4.9E+3 MPa
Major Poisson's Ratio μ_{12} = 0.23
Minor Poisson's Ratio μ_{21} = 0.01
Density ρ = 1590kg/m3
Yield strength S_y =2067MPa

Analysis of Carbon / Epoxy Composite Leaf Spring FEM Model details Mechanical Properties:

Extensional Elastic Modulus E_1 = 177E+3MPa
Transverse Elastic Modulus E_2 = 10.6E+3 MPa
In-plane Shear Modulus G12 = 47.6E+3 MPa
Major Poisson's Ratio μ_{12} = 0.27
Minor Poisson's Ratio μ_{21} = 0.02
Density ρ = 1600kg/m3
Yield strength S_y =1900MPa

can return to their original shape when the force is released. In other words it is also termed as a resilient member.

6. DELAMINATION PROPERTIES

This section describes an overview of experimental techniques used to characterize delamination thresholds and energies. A number of delamination modes are considered and are illustrated schematically in Figure :

Delamination Modes.

(a) Mode I : Normal Delamination.(opening mod
(b) Mode II : Shear Delamination.(tearing mode)
(c) Mode III : Shear Delamination.(sliding mode)

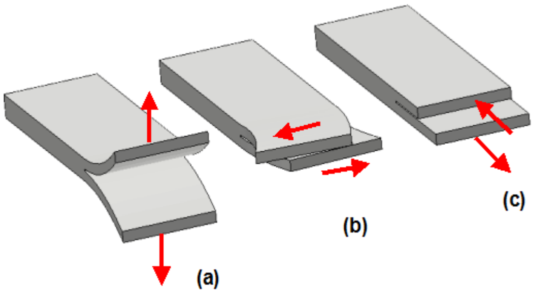


Figure 3 Delamination Modes

7. RESULT ANALYSIS

Table 2 Details of The object (leaf spring)

s.no		Numerical value of object
1	Number of nodes	2673
2	Number of key points	55
3	Number of lines	34
4	Number of areas	17
5	Number of volumes	2
6	Number of elements	1290

Table 3 graph values of deflection vs load of the leaf spring

Deflection load	Applied load (N)	Deflection of the leaf spring with composite materials (mm)		
		E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
1	100	22.138	30.531	18.868
2	150	81.124	821.88	69.251
3	200	94.69	94.99	80.03
4	250	17.22	24.1	14.36

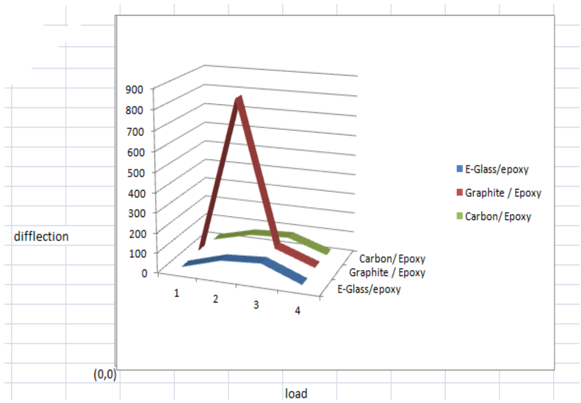


Figure7 the graph between load vs deflection of safety

Range of Deflection in Leaf Spring

Maximum - Graphite / Epoxy
Medium - E-Glass /Epoxy
Low - Carbon/ Epoxy

11.3 Graph Values of Von Misses Stress Vs Load of the Leaf Spring

Table 4 graph values of von misses stress vs load of the leaf spring

Von misses load	Applied load (N)	Von Misses Stress of the leaf spring (mm)		
		E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
1	100	244.662	242.778	240.972
2	150	878.875	886.594	851.708
3	200	1040.6	1182.21	1000.28
4	250	1912.83	1897.97	1880.94

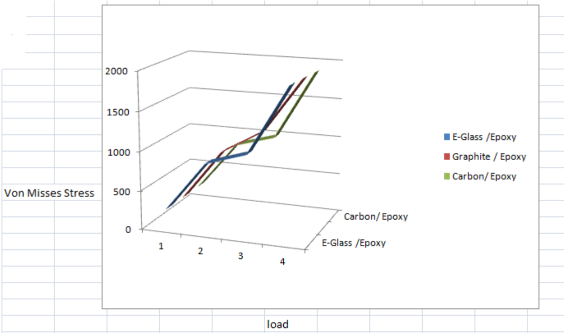


Figure 8 the graph between cra vs factor of safety

Range of von-misses stress In Leaf Spring

Maximum - Graphite / Epoxy
Medium - E-Glass /Epoxy
Low - Carbon/ Epoxy

1.4. Factor of Saftey

11.4.1. without crack of the leaf spring

Table 5 Factor of safety of e-glass/epoxy (at load 333 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	129.107	2000	15.491
Y		17.575		113.798
Z		6.949		287.811
XY		20.024		99.880
YZ		1.886		1060.445
ZX		9.529		209.885
VON		241.739		8.273

Table 6 Factor of safety of e-glass/epoxy (at load 2000 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	2000	969.269	2000	2.063
Y		131.95		15.157
Z		52.1758		38.331
XY		150.334		13.303
YZ		14.114		141.703
ZX		71.542		27.955
VON		1814.28		1.102

Table 7 Factor of safety of graphite/epoxy (at load 333 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	226.511	2067	9.125
Y		35.466		6.372
Z		7.800		265
XY		46.469		44.481
YZ		1.918		1077.685
ZX		10.898		189.667
VON		471.556		4.383

Table 8 Factor of safety of graphite/epoxy (at load 1000 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	1000	800.356	2067	2.582
Y		106.327		19.440
Z		23.423		88.246
XY		139.547		14.812
YZ		5.761		358.791
ZX		32.728		63.156
VON		801.356		2.579

Table 9 Factor of safety of carbon/epoxy (at load 333 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	117.467	1900	16.174
Y		13.094		145.104
Z		18.64		101.931
XY		77.250		24.595
YZ		8.445		224.985
ZX		23.315		81.492
VON		313.228		6.065

Table 20 Factor of safety of carbon/epoxy (at load 1500 N)

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	1500	313.228	1900	6.065
Y		58.9843		32.212
Z		83.997		22.619
XY		320.947		5.919
YZ		38.040		49.947
ZX		105.024		18.091
VON		1410.141		1.347

Table 31 Factor of safety of e-glass/epoxy, with crack length 2 cm and load 333 N

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	207.935	2000	9.618
Y		9.957		200.863
Z		14.9293		133.967
XY		48.945		40.862
YZ		5.208		384.024
ZX		17.481		114.409
VON		207.935		9.618

Table 42 Factor of safety of e-glass/epoxy, with crack length 2 cm and load 1800

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		693.151		2.885
Y		54.206		36.896
Z		99.509		20.098
XY	1800	266.302	2000	7.510
YZ		28.318		70.626
ZX		95.081		21.034
VON		1006.64		1.986

Table 53 Factor of safety of e-glass/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		175.727		11.381
Y		10.353		193.180
Z		15.928		125.565
XY	333	50.7422	2000	39.415
YZ		5.379		371.816
ZX		18.0879		110.576
VON		187.419		10.671

Table 64 Factor of safety of e-glass/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		949.875		2.105
Y		55.963		35.737
Z		166.701		11.997
XY	1800	274.282	2000	7.291
YZ		29.079		68.778
ZX		97.7724		20.455
VON		1013.07		1.974

Table 75 Factor of safety of e-glass/epoxy, with crack length 6 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		208.896		9.574
Y		11.1556		179.291
Z		39.544		50.576
XY	333	54.384	2000	36.775
YZ		5.7272		349.222
ZX		19.317		103.535
VON		210.983		9.479

Table 86 Factor of safety of e-glass/epoxy, with crack length 6 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	2000	1254.63	2000	1.594
Y		67.0007		29.847

Z		237.502		8.420
XY		326.633		6.123
YZ		34.3978		58.144
ZX		116.019		17.238
VON		1267.17		1.578

Table 17 Factor of safety of graphite/epoxy, with crack length 2 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		368.481		5.609
Y		24.699		83.687
Z		15.466		133.648
XY	333	102.952	2067	20.077
YZ		6.9255		298.483
ZX		8.126		254.368
VON		363.063		5.693

Table 18 Factor of safety of graphite/epoxy, with crack length 2 cm (1800 N

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		1669.41		1.238
Y		130.267		15.867
Z		83.6051		24.723
XY	1800	556.498	2067	3.714
YZ		37.435		55.215
ZX		43.927		47.055
VON		1962.5		1.053

Table 19 Factor of safety of graphite/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		321.271		6.433
Y		19.350		106.821
Z		18.711		110.469
XY	333	99.129	2067	20.851
YZ		43.708		47.291
ZX		16.568		124.758
VON		355.862		5.808

Table 90 Factor of safety of graphite/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X		1736.6		1.190
Y		104.596		19.761
Z		101.144		20.436
XY	1800	535.833	2067	3.857
YZ		89.559		23.079
ZX		236.262		8.748
VON		1923.58		1.074

Table 101 Factor of safety of graphite/epoxy, with crack length 6 cm

Deflection Crack length	Deflection of the leaf spring with composite materials (mm)		
	E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
2 cm	19.514	8.573	8.981
4cm	24.242	13.292	12.200
6cm	33.116	21.597	17.975

Table 112 Factor of safety of graphite/epoxy, with crack length 6 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	348.745	2067	5.926
Y		26.276		78.664
Z		20.577		100.451
XY		112.327		18.401
YZ		7.490		275.967
ZX		8.804		234.779
VON		355.908		5.807

Table 123 Factor of safety of carbon/epoxy, with crack length 2 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	1800	1885.11	2067	1.096
Y		142.035		14.552
Z		111.232		18.582
XY		607.173		3.404
YZ		40.487		51.053
ZX		47.589		43.434
VON		1923.83		1.074

Table 134 Factor of safety of carbon/epoxy, with crack length 2 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	213	1900	8.920
Y		14.148		134.294
Z		17.018		111.646
XY		74.937		25.354
YZ		19.097		99.492
ZX		36.326		52.304
VON		289.247		6.568

Table 145 Factor of safety of carbon/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	1500	963.259	1900	1.972
Y		63.732		29.812
Z		76.658		24.785
XY		337.554		5.628
YZ		86.026		22.086
ZX		163.634		11.611
VON		1302.91		1.458

Table 156 Factor of safety of carbon/epoxy, with crack length 4 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	234.323	1900	8.108
Y		14.589		130.235
Z		27.919		68.054
XY		77.024		24.6676
YZ		19.608		96.899
ZX		37.277		50.969
VON		286.687		6.627

Table 27 Factor of safety of carbon/epoxy, with crack length 6 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	1500	1055.51	1900	1.800
Y		65.717		28.911
Z		125.763		15.107
XY		346.958		5.476
YZ		88.328		21.510
ZX		167.916		11.315
VON		1291.38		1.471

Table 28 Factor of safety of carbon/epoxy, with crack length 6 cm

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety
X	333	264.64	1900	7.179
Y		15.642		121.467
Z		34.036		55.823
XY		82.059		23.154
YZ		20.841		91.166
ZX		39.561		48.027
VON		289.911		6.553

Table 29 Graph Values of Deflection Vs Crack Length of the Leaf Spring (load

Along The Axis	Applied Load (N)	Working Stress	Yield Stress	Factor of Safety

X	1500	1192	1900	1.593
Y		70.459		26.966
Z		153.32		12.392
XY		369.636		5.140
YZ		93.882		20.238
ZX		178.203		10.661
VON		1305.9		1.454

E-Glass /Epoxy

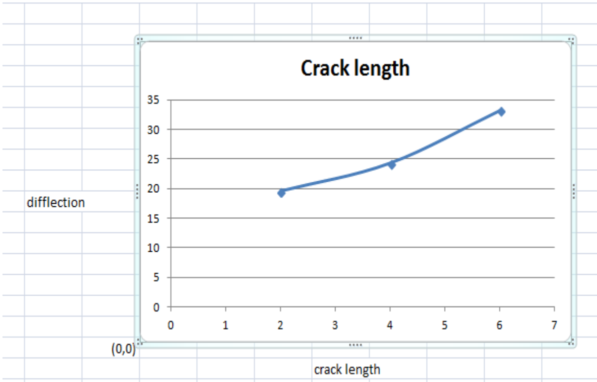
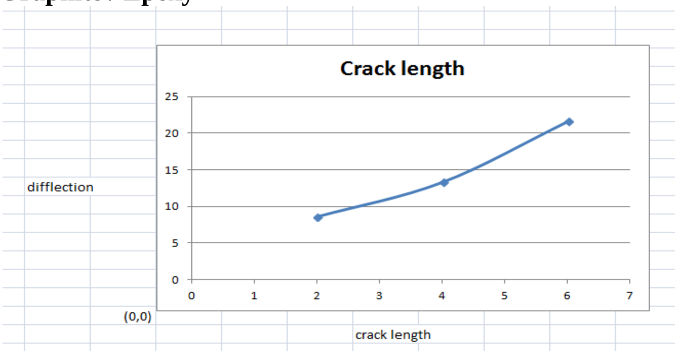


Figure 9 the Graph between Deflection Vs Crack Length(e-glass/epoxy) at load 333 N

Graphite / Epoxy



Factor of safety / Crack length	Factor of safety of the leaf spring with composite materials (mm)		
	E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
2 cm	9.618	5.639	6.568
4cm	10.671	5.808	6.627
6cm	9.479	5.807	6.553

Figure 10 the Graph between Deflection Vs Crack Length(graphite/epoxy) at load 333 N

Carbon/ Epoxy

Deflection / Crack length	Deflection of the leaf spring with composite materials (mm)		
	E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
2 cm	105.483	46.341	40.456
4cm	131.038	71.847	54.956
6cm	198.897	116.744	80.970

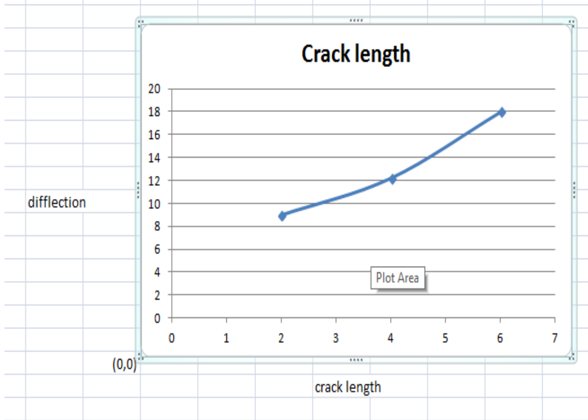


Figure 11 the Graph between Deflection Vs Crack Length(carbon/epoxy) at load 333 N

Table 30 Graph Values of Deflection Vs Crack Length of The Leaf Spring

Table 161 Graph Values of Factor of safety Vs Crack

Table 32 Factor of safety of the leaf spring with composite

E-Glass /Epoxy

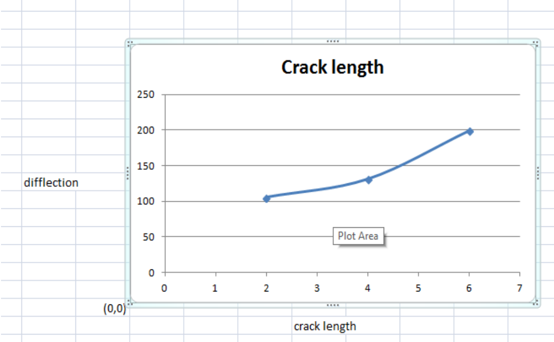


Figure 12 the Graph between Deflection Vs Crack Length(e-glass/epoxy) load at 1500 N

Graphite / Epoxy

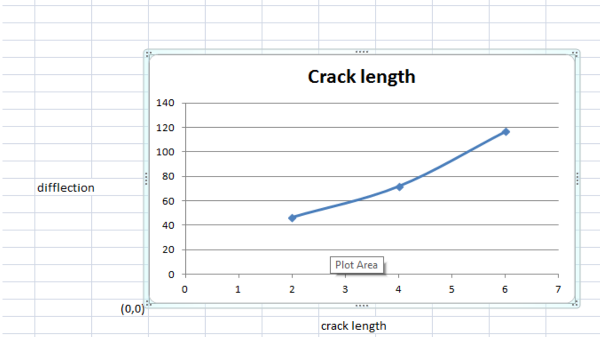


Figure 13 the Graph between Deflection Vs Crack Length(graphite/epoxy) load at 1500 N

Factor of safety Crack length	Factor of safety of the leaf spring with composite materials (mm)		
	E-Glass /Epoxy	Graphite / Epoxy	Carbon/ Epoxy
2 cm	1.986	1.053	1.458
4cm	1.974	1.074	1.471
6cm	1.578	1.075	1.454

Carbon/ Epoxy

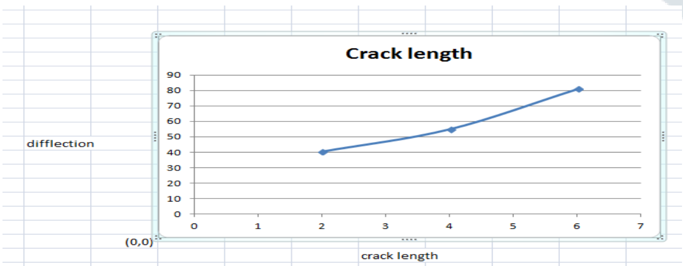


Figure 14 the Graph between Deflection Vs Crack Length(carbon/epoxy) load at 1500 N

E-Glass /Epoxy

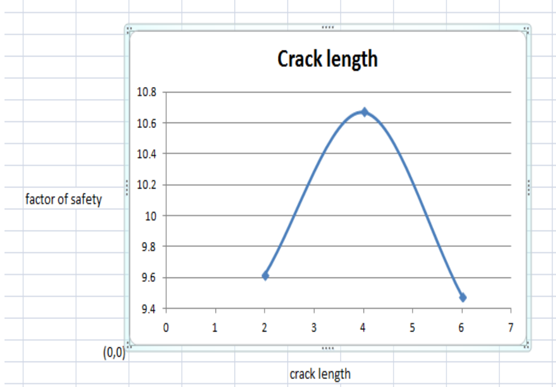


Figure 15 Graph between the Factor of safety Vs Crack Length (E-Glass /Epoxy) at load of 333 N

Graphite / Epoxy

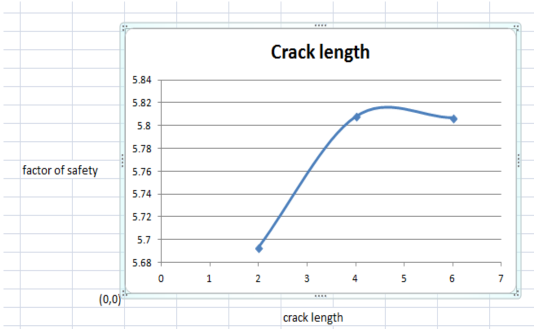


Figure 16 Graph between the Factor of safety Vs Crack Length (graphite /Epoxy) at load of

Carbon/ Epoxy

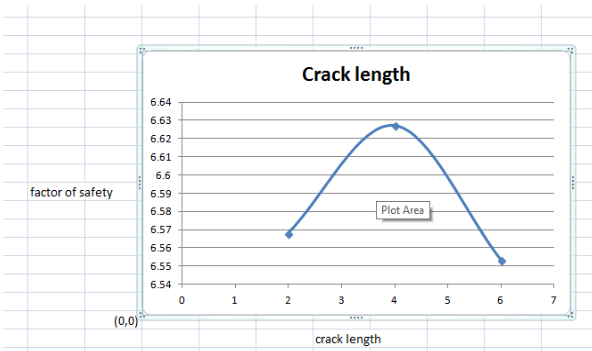


Figure 17 Graph between the Factor of safety Vs Crack Length (carbon /Epoxy) at load of 333 N

E-Glass /Epoxy

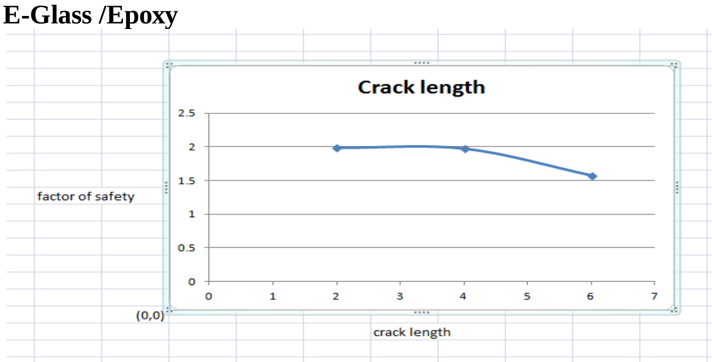


Figure 18 Graph between the Factor of safety Vs Crack Length (E-Glass /Epoxy)at load

Graphite / Epoxy

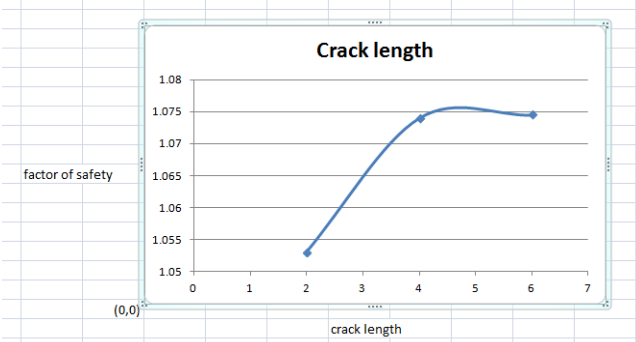


Figure 19 Graph between the Factor of safety Vs Crack Length (graphite /Epoxy)at load of 1500 N

Carbon/ Epoxy

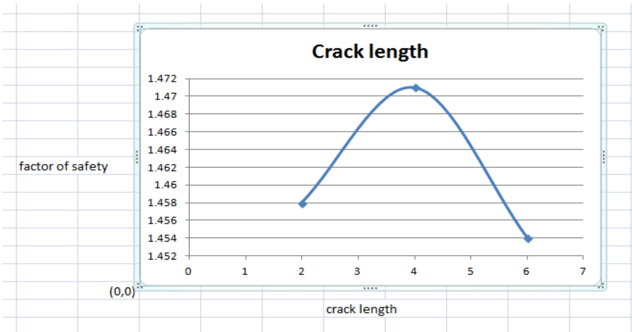


Figure 20 Graph between the Factor of safety Vs Crack Length (graphite /Epoxy)at

Deflection And Von Misses Stress

i) E-Glass/Epoxy Deflection

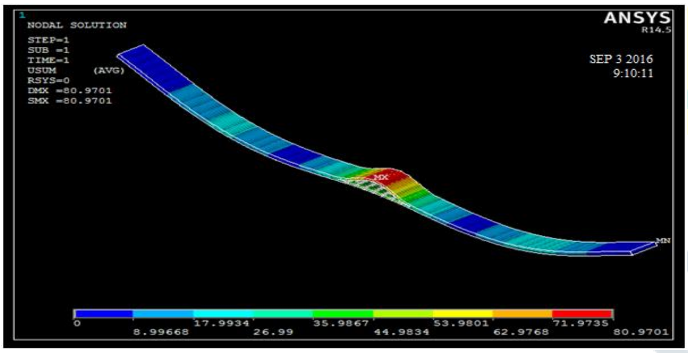


Figure 21 E-Glass/Epoxy Deflection

ii) E-Glass/Epoxy von misses stress

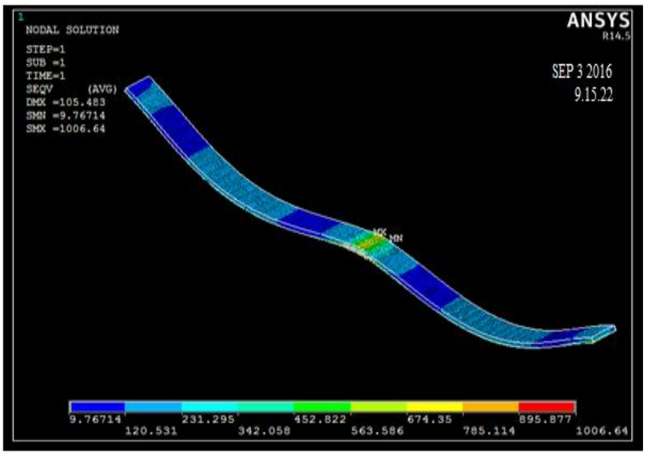


Figure 22 E-Glass/Epoxy von misses stress

iii) Graphite/Epoxy Deflection

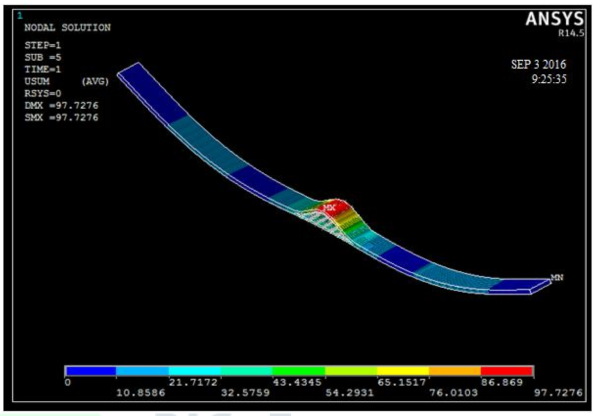


Figure 23 Graphite/Epoxy Deflection

iv) Graphite/Epoxy von misses stress

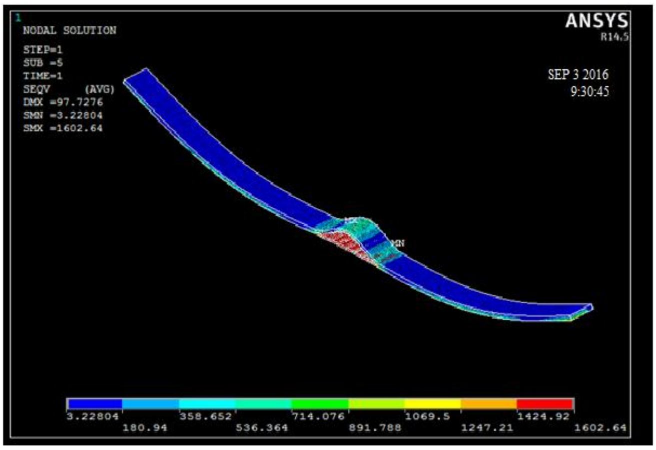


Figure 24 Graphite/Epoxy von misses stress

v) Carbon/Epoxy Deflection

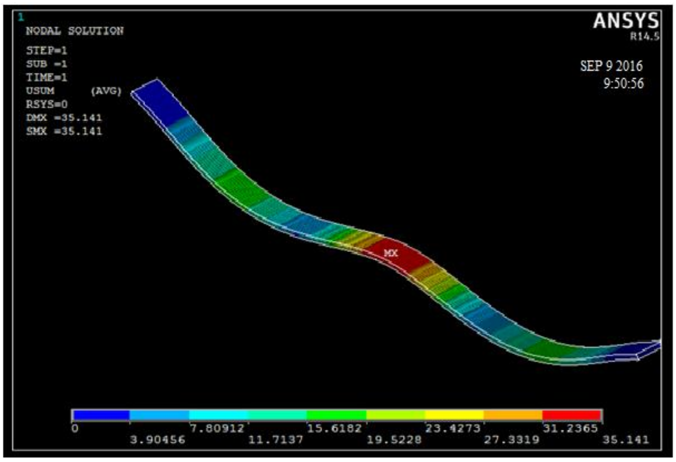


Figure 25 Carbon/Epoxy Deflection

vi) Carbon/Epoxy von misses stress

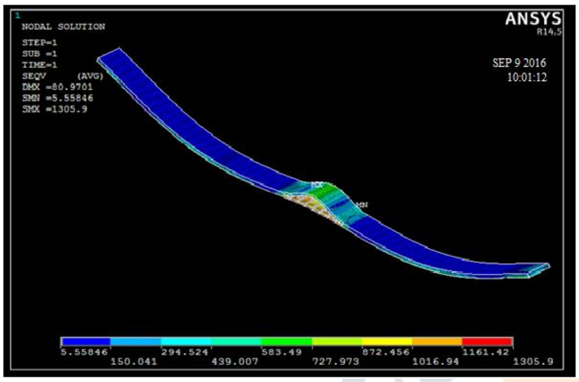


Figure 26 Carbon/Epoxy von misses stress

10. DISCUSSIONS&CONCLUSIONS

In the present work, a composite leaf spring was replaced by a mono composite leaf spring(second leaf) due to high strength to weight ratio for the same load carrying capacity and . The dimensions of a leaf spring of a light weight vehicle are chosen and modeled using ANSYS 14.5. As the leaf spring is symmetrical about the axis, only half part of the. The boundary conditions are UY, UZ at the front eye end and UX, UZ in the middle.

A load of 3300N was applied at the base in the middle of the leaf spring in the Y-direction. Later a mono composite leaf spring of uniform thickness and width was modeled so as to obtain the same displacement of leaf spring. Three different composite materials have been used for analysis of mono-composite leaf spring. They are

E-glass/epoxy,
Graphite/epoxy and
carbon/epoxy.

Static analysis has been performed.

1. From the static analysis results it is found that there is a maximum displacement of
E-glass/epoxy, graphite/epoxy, and carbon/epoxy are 30.140 mm, 34.864 mm and
35.141mm. And all the values are nearly equal and are below the camber length for a given
load of 3300N. this values are without crack of the leaf spring

2. From the static analysis results it is found that there is a maximum displacement of
E-glass/epoxy, graphite/epoxy, and carbon/epoxy are 198 mm, 116.744 mm and
80.970 mm. And all the values are nearly equal and are below the camber length for a
given load of 3300N. this values are with crack of the leaf spring

deflections of the leaf spring is more in crack include in a spring

E-glass/epoxy	198-30.140	= 167.86
graphite/epoxy	116.744-34.86	= 81.884
carbon/epoxy	80.970-35.141	= 45.829

2.From the static analysis results, we see that the von-mises stress in the E-glass/epoxy,
Graphite /epoxy and Carbon/epoxy is 1814MPa, 801.356MPa and 1410.4MPa. Among the
three composite leaf springs, only Graphite/epoxy composite leaf spring has lower stresses
in leaf spring. this result is without crack of leaf spring

3. From the static analysis results, we see that the von-mises stress in the E-glass/epoxy,
Graphite /epoxy and Carbon/epoxy is 1006.64MPa, 1962.5MPa and 1291.38MPa. Among
the three composite leaf springs, only E-glass/epoxy composite leaf spring has lower
stresses in leaf spring.

E-glass/epoxy	1814-1006.64	= 807.36
graphite/epoxy	1962.5-801.356	= 1161.144
carbon/epoxy	1410.4-1291.38	= 119.02

6. A comparative study has been made between steel and composite leaf spring with respect
to strength and weight. Composite mono leaf spring reduces the weight by 85% for E-
Glass/Epoxy, 94.18% for Graphite/Epoxy, and 92.94 % for Carbon/Epoxy over
conventional leaf spring.

FUTURE SCOPE

Take total assembly part of the leaf sprig, doing the delamination analysis. Same process without crack of the leaf spring, what is the behavior of leaf spring. Crack includes the inside of the spring, what is the behavior of the leaf spring.

REFERENCES

1. 1.design and analysis of composite leaf spring in light vehicle [international journal of

engineering research (ijmer)],[vol.2, issue.1, jan-feb 2012]

2. design and analysis of a leaf spring for automobile suspension system review [international journal of emerging technology and advanced engineering], [volume 3, issue 6, june 2013]
3. performance analysis of two mono leaf spring used for maruti 800 vehicles [international journal of innovative technology and exploring engineering] [issn: 2278-3075, volume-2, issue-1, december 2012]
4. 4.performance analysis of steel leaf spring with composite leaf sprin and fabrication of composite leaf spring [international journal of engineering research and science &technology (ijerst) [vol. 2, no. 3, august 2013]
5. analysis of natural fiber composite leaf spring[international journal of latest trends in engineering and technology] vol. 3 issue 1 september 2013
6. mono composite leaf spring for light weight vehicle – design, end joint analysis and testing[mechanical engineering department, psg college of technology] vol. 12, no. 3. 2006
7. .“a textbook of machine design”by r.s.khurmi_and_j.k.gupta. william d callister. “fundamentals of material science and engineering”. fifthedition. john wiley & sons, inc 1985 metals handbook. volume 1 microsturcture
8. "machine design" dr n c pandya and dr c s shah."elements of fracture mechanics" by prashant kumar
9. a textbook of "strength of materials" by r.k,bansala .An Introduction to the Finite Element Method (Engineering Series)Hardcover – January 11, 2005