

# Design and Analysis of Composite Leaf Spring

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**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 multileaf 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 paper is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with 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 a composite multi leaf spring using E-GLASS/EPOXY, C- GLASS/EPOXY, S- GLASS/EPOXY unidirectional laminates. CATIA V5R20 software is used for modelling and ANSYS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using ANSYS.

**KEYWORDS:** Ansys, Catia, FEA of conventional leaf spring.

## I. INTRODUCTION

It is well known that springs, are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system. Fortunately, composites have these characteristics. The introduction of composite materials was made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. Since; the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel.



Fig.1 Leaf spring assembled at rear axle of automotive

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## Objective of Suspension:-

- i. To safeguard the occupants against road shocks and provide riding comfort.
- ii. To keep the body of the motor vehicle while travelling over rough ground or when turning in orders to minimize the rolling, pitching, or vertical movement tendency.
- iii. To minimize the effects of stresses due to road shock on the mechanism of the motor vehicle and provide the cushioning effect.
- iv. To provide the requisite height to the body structure as well as to bear the torque and the braking reactions.
- v. To keep the body perfectly in level while travelling over the rough uneven ground i.e. the up and down movement of the wheels should be relative to the body.
- vi. To isolate the structure of the vehicle from shock loading and vibrations due to irregularities of the road surface without impairing its stability.

## Problem Statement:-

The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the un-sprung weight.

The conventional steel leaf spring has some problems which are listed as follow:

- Due to continuous running of the mini loader vehicle there is a decrease in the level of comfort provided by the spring.
- It is observed that the leaf springs tend to break and weaken at the eye end portion which is very close to the shackle and at the centre.
- The conventional steel leaf spring has higher weight, which also affect the fuel efficiency.

## Objective of the work:-

The objective of this project is:

- To reduce the weight
- Reduce product development cost.
- Increase the comfort.

## Methodology:-

1. First we select the project topic.
2. Then we Study the material.
3. Select the material for design component.
4. Design for leaf spring
  - A) Conventional steel leaf spring
  - B) Carbon fibre/epoxy
5. Theoretical design for all above material
6. FEA using Ansys workbench for all material.
7. Result and comparison chart
8. Result
9. Future scope
10. Conclusion

## II. DESIGN OF CONVENTIONAL STEEL LEAF SPRING

### Design Data

“TATA SUMO GRANDE”

Weight of vehicle = 2625 kg

Total unsprung weight = 1525 kg

Max. load carrying capacity =  $8 \times 100 = 800$  kg

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Total weight = 1525 + 800 = 2325

Acceleration due to gravity = 9.81 (m/S<sup>2</sup>)

Factor of safety (Nf) = 1.4

∴ Total weight of vehicle (w) = 2523 x 9.81 x 1.4  
= 31931.55 ≈ 31932 N

### Specification or Dimension of spring

Straight length	1200 mm
Leaf thickness	7 mm
Leaf width	70 mm
Camber	100 mm
OD of eye end	62 mm

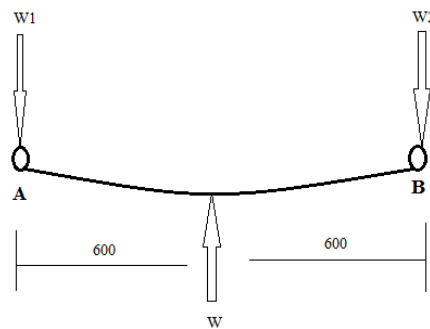
### Design of conventional steel leaf spring

#### Material properties of EN47

Density	7700 kg/m <sup>3</sup>
Modulus of Elasticity	210 x 10 <sup>3</sup> Mpa
Tensile strength	1158 Mpa
Yield strength	1034 Mpa

Total unsprung load = 31932 N

Load on each wheel =  $\frac{31932}{4} = 7983$



- Bending Stress of the leaf spring-

$$\sigma_{\max} = (6wL/bt^2)$$

where, W = cantilever load

t = leaf thickness

b = leaf width

- Deflection of Plate-

$$\delta_{\max} = (WL^3/3EI)$$

where, W = central load

E = modulus of elasticity

I = moment of inertia

Where, w = central load

W<sub>1</sub> & W<sub>2</sub> = cantilever load

Taking moment about point B,

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$$1200 W_1 = 600 w$$

$$\therefore W_1 = 0.5 w$$

- Bending stress

$$\sigma_{\max} = \frac{M}{Z} = \frac{Lw_1}{\frac{bt^2}{6}} = \frac{6w_1 \times 600}{70 \times 7^2}$$

$$\sigma_{\max} = 0.524 W_1$$

- Deflection

$$\delta = \frac{wL^3}{3EI} = \frac{2\sigma L^2}{3Et} = \frac{2 \times \sigma \times 600^2}{3 \times 210 \times 10^3 \times 7}$$

$$\delta = 0.1632 \sigma_{\max}$$

**Result table**

Sr. No.	Central load 'W' N	Cantilever Load 'W <sub>1</sub> '	EN47( steel)	
			Stress (Mpa)	Deflection (mm)
1	2000	1000	524	85.51
2	4000	2000	1048	171.0336
3	6000	3000	1572	256.55
4	7983	3992	2091.80	341.38

### III. DESIGN OF COMPOSITE (CARBON FIBRE) LEAF SPRING

*Composite spring carbon epoxy(45% & 55%)*

The material selected as carbon fibre/epoxy(55% & 45%) for leaf spring. The material properties for design are calculated and listed in below table. The material properties are most necessary to calculate or to know for design.

SR NO.	PARAMETER	VALUES
1	Tensile modulus along X-direction (E <sub>x</sub> )	132.5 Gpa
2	Tensile modulus along Y-direction (E <sub>y</sub> )	85.10 Gpa
3	Tensile modulus along Z-direction (E <sub>z</sub> )	85.10 Gpa
4	Shear modulus along X-Ydirection (G <sub>xy</sub> )	4.90 Gpa
5	Shear modulus along Y-Z direction (G <sub>yz</sub> )	5.10 Gpa
6	Shear modulus along X-Zdirection (G <sub>xz</sub> )	4.90 Gpa
7	Poisson ratio along X-Y direction (NU <sub>xy</sub> )	0.279
8	Poisson ratio along Y-Z direction (NU <sub>yz</sub> )	0.277
9	Poisson ratio along Z-X direction (NU <sub>zx</sub> )	0.279
10	Tensile strength	1825 Mpa
11	Compressive strength	1300 Mpa
12	Mass density of the material (ρ)	1556.25 kg/m <sup>3</sup>

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- Bending stress

$$\sigma_{\max} = \frac{M}{Z} = \frac{Lw_1}{\frac{bt^2}{6}} = \frac{6w_1 \times 600}{36 \times 25^2}$$

$$\sigma_{\max} = 0.16 w_1$$

- Deflection

$$\delta = \frac{wL^3}{3EI} = \frac{2\sigma L^2}{3Et} = \frac{2 \times \sigma \times 600^2}{3 \times 132.5 \times 10^3 \times 25}$$

$$\delta = 0.07245 \sigma_{\max}$$

**a. Thickness of spring-**

$$t = \frac{2\sigma L^2}{3\delta E}$$

Put,  $\sigma = 1300$  Mpa

**Properties of composite**

L = 600 mm

Properties of composite carbon fibre

$\delta = 100$  mm

E = 132.5e3 Mpa

$$t = \frac{2 \times 1300 \times 600^2}{3 \times 100 \times 132.5e3}$$

$$t = 23.5 \sim = 25\text{mm}$$

**a. Width of spring-**

$$b = \frac{6WL}{\sigma t^2}$$

$$b = (600 \times 7983 \times 600) / (1300 \times 25^2)$$

$$b = 35.37 \sim = 36\text{mm}$$

$$\sigma_{\max} = \frac{M}{Z} = (LW) / \left[ \frac{bt^2}{6} \right]$$

$$= (600 \times 7983) / \left[ \frac{36 \times 25^2}{6} \right]$$

$$= 1277.28 \text{ mpa} < 1300$$

.....From above design is safe

**Dimension of composite spring**

Straight length	1200 mm
Leaf thickness	25mm
Leaf width	36mm
Camber	100 mm
OD of eye end	62 mm

**Result table**

Sr. No.	Central load	Cantilever	Composite-Class I (55% & 45%)	
	'W' N	Load 'W <sub>1</sub> '	Stress (Mpa)	Deflection (mm)
1	2000	1000	160	11.592

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2	4000	2000	320	23.184
3	6000	3000	480	34.77
4	7983	3992	638.72	46.27

## IV. FEA OF STEEL FOR MAX LOAD (7983N)

Fig 2 shows the deflection of Steel Leaf Spring under the application of 7983N total load. The maximum deflection is at the base frame and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. And Fig 3 shows the equivalent von-misses stress induced in Steel Leaf Spring under the action of 7983N load. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

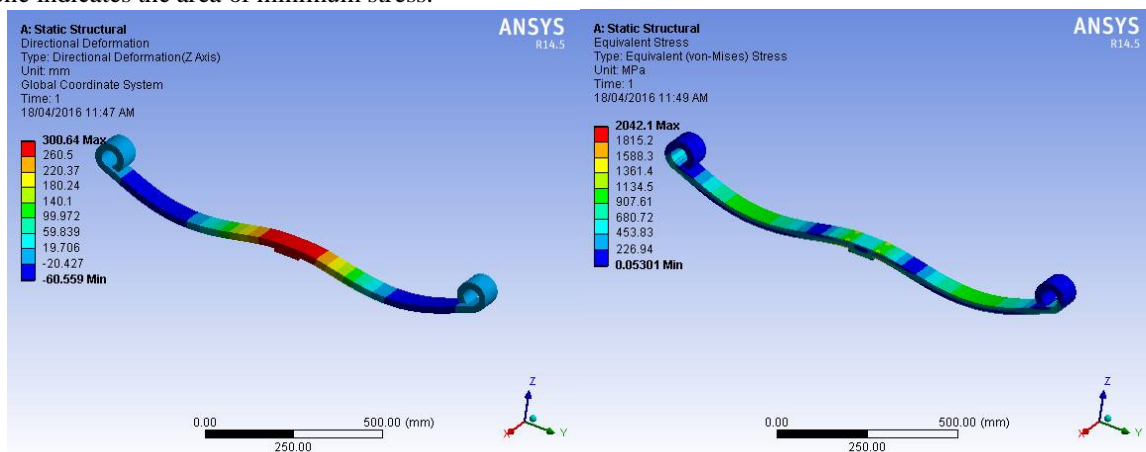


Fig 2 deflection of steel leaf spring

Fig 2 stress of steel leaf spring

### FEA Result for steel Leaf Spring

Sr. No.	Central load 'W' N	EN47( steel)	
		Stress max (Mpa)	Deflection (m)
1	2000	480.48	97.70
2	4000	960.97	120.25
3	6000	1249.3	225.48
4	7983	2042.1	300.64

## V. FEA OF CMPOSITE LEAF SPRING FOR MAX LOAD (7983N)

Fig 4 shows the deflection of Steel Leaf Spring under the application of 7983N total load. The maximum deflection is at the Matrix Leaf Spring and its maximum with Red zone indicates the area of maximum deflection and blue zone indicates the area of minimum deflection, which is shown by colour band. And Fig 5 shows the equivalent von-misses stress induced in Matrix Leaf Spring under the action of 7983N load. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.

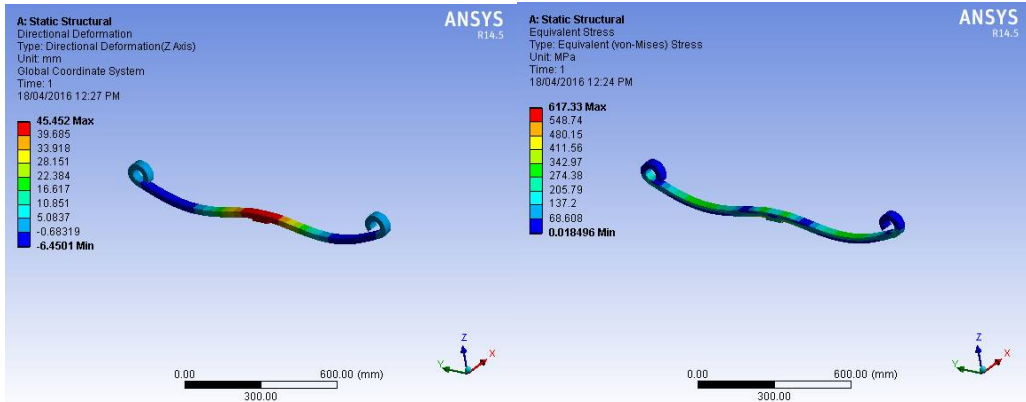


Fig 4 deflection of composite leaf spring

Fig 5 stress of composite leaf spring

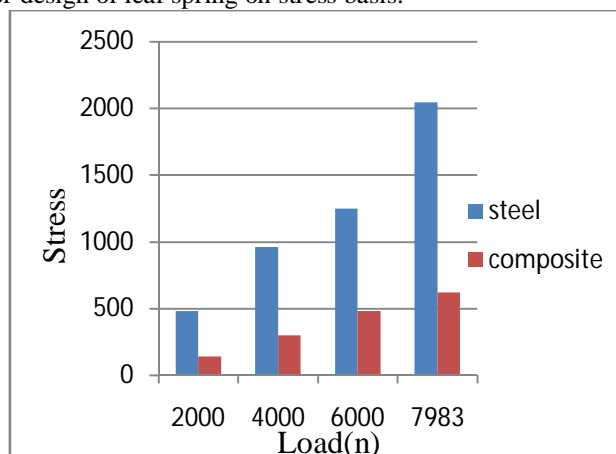
**FEA Result for Composite Leaf Spring**

Sr. No.	Central load 'W' N	Composite Class I (55% & 45%)	
		Stress (Mpa)	Deflection (mm)
1	2000	141.1	11.36
2	4000	299.84	16.233
3	6000	440.95	32.466
4	7983	617.33	45.452

**VII. RESULT**

*Comparison On The Basis Of Stress*

As shown in below graph the stresses of composite are lower than the steel material stresses. Hence the composite material is better for design of leaf spring on stress basis.

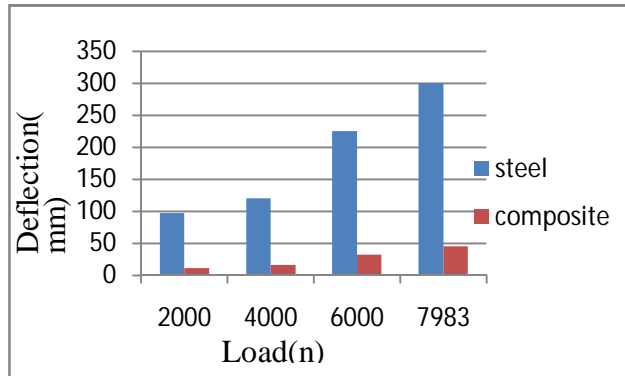


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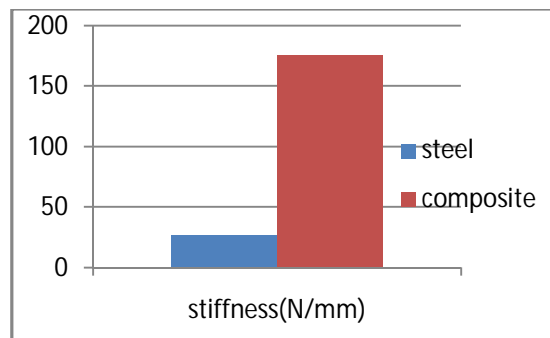
### Comparison On The Basis Of Deflection



As shown from above graph the deflection of steel w.r.t. load is high and deflection of composite material w.r.t. load is less. The steel leaf spring has very high deflection; it is not suitable result for the design however the deflection composite material is moderate w.r.t. load. Hence it is better material for design of leaf spring.

### Comparison For Stiffness

MATERIAL	LOAD (N)	DEFLECTION (mm)	STIFFNESS (N/mm)
Steel	7983	300.64	26.55
Composite	7983	45.452	175.63



As shown from above table and graph the values of stiffness is varying for both material. the stiffness for steel is very low hence it is not suitable for the design of suspension system. However the stiffness of composite material is high w.r.t. load it is suitable for good suspension system design.

### Wight Reduction

Material	Density (kg/mm <sup>3</sup> )	Volume (mm <sup>3</sup> )	Mass (kg)	% Weight Saving
Steel	7850e-9	2.41e6	18.557	—
composite	1556.3e-9	1.47e6	2.40	87

As shown in above table the weight of composite spring is less than hence it is better than steel spring.



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## VIII. CONCLUSION

We have study the composite material (carbon fibre) for the replacement of convention leaf spring.

1. The result of FEA values shows that the composite material has the lower **stress** than the steel material. Hence the composite material could be better material for replacement of steel leaf spring.
2. The Composite material has the moderate **deflection** w.r.t. load as compare to steel hence composite material is better than steel on base of deflection.
3. As consider the **stiffness** the composite material has the high stiffness than the steel leaf spring hence it is better than steel.
4. As point of view of **weight reduction** the composite material saves the weight about 80 to 87%.

## REFERENCES

- 1] GulurSiddaramanna Shiva Shankar, SambagamVijayarangan, "Mono composite leaf spring for light weight vehicle, Design, End joint analysis and Testing" ISSN: 1392-1320 Materials science, vol.12, Issue 3-2006,pp-220-225
- 2]ShishayAmareGebremeskel "Design, Simulation, and Prototyping of Single Composite Leaf Spring for Light Weight Vehicle" Global Journal of Researches in Engineering Mechanical and Mechanics Engineering Volume 12 Issue 7 Version 1.0 Year 2012 Type: Double Blind Peer Reviewed International Research Journal Publisher: Global Journals Inc. (USA) Online ISSN: 2249-4596 Print ISSN:0975-5861
- 3] Ashish V. Amrute1, Edward Nikhil2,R K Rathore "Design And Assesment of Multi Leaf Spring"ISSN(Online): 2321-3051 International Journal Of Research In Aeronautical And Mechanical Engineering
- 4] M. Venkatesan, D. HelmenDevaraj, "Design And Analysis Of Composite Leaf Spring In Light Vehicle". International Journal of Modern Engineering Research (IJMER) ISSN: 2249-6645 Vol.2, Issue.1, Jan-Feb 2012 pp-213-218
- 5] Ghodake A. P., Patil K.N. "Analysis of Steel and Composite Leaf Spring for Vehicle" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278 1684 Volume 5, Issue 4 (Jan. - Feb. 2013), PP 68-76.
- 6] Mahmood M. Shokrieh \*, DavoodRezaei, "Analysis and optimization Of Composite Leaf Spring" Composite Structures 60 (2003) 317–325.
- 7] Jadhav Mahesh V, ZomanDigamber B, Y R Kharde, r RKharde, "Performance Analysis of Two Mono Leaf Spring Used For Maruti 800 Vehicle". International Journal Of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278- 3075, Vol.2, Issue 1, December 2012
- 8] Malaga Anil Kumar, T. N. Charyulu, Ch.Ramesh,"Design Optimization Of Leaf Spring, International Journal Of Engineering Research And Applications." ISSN: 2248-9622,Vol. 2,Issue 6, November- December 2012,pp-759-765.
- 9] M. M. Patunkar D. R. Dolas"Modelling and Analysis of Composite Leaf Spring under the Static Load Condition by using FEA". International Journal Of Mechanicaland Industrial Engineering, Vol.1, Issue 1-2011,pp1-4.
- 10] Supriya.Koppula1 G.S.R.Sunand2 and R.Vijaya Prakash3 "Static Analysis Of Composite Mono Leaf Spring" International e Journal of Mathematics and Engineering 146 (2012) 1331 - 1337
- 11] M. Raghavedra<sup>1</sup>, Syed Altaf Hussain<sup>2</sup>, V. Pandurangadu<sup>3</sup>, K. PalaniKumar<sup>4</sup>, "Modeling and Analysis of Laminated Composite Leaf Spring under the Static LoadCondition by using FEA" International Journal Of Modern Engineering Research, ISSN: 2249-6645, Vol.2, Issue 4, July-Aug.2012,pp1875-1879.
- 12] Bhaumik A. Bhandari, Bhavesh C. Patel "Parametric Analysis Of Composite Leaf Spring"IJSTE–International Journal of Science Technology & Engineering| Vol. 1, Issue 1, July 2014| ISSN(online): 2349-784X
- 13] R. M. Jones, "Mechanics Of Composite Materials". 2e, McGraw-Hill Book Company, 1990.
- 14] RajaleRanjit, Rana Mayuresh, Praveen k Mali "Design and analysis of composite leaf spring – review paper" Vol 5 issue 1, jan 2016