Design and Analysis of composite leaf spring for four Wheel Vehicle

Sagar B. Deshmukhpatil [1] Ajit V. Shinde [2] Omkar R. Pokharkar [3] Abhijeet L. Nande [4]
Guided by Pradip G. Karale [5]

[1],[2],[3],[4] *Student of Mechanical Engineering, Keystone school of Engineering, Savitribai Phule Pune University, Maharashtra, India.*
[5] *Assistant Professor, Department of Mechanical Engineering, Keystone school of Engineering, Savitribai Phule Pune University, Maharashtra, India.*

Abstract - *For better results automobile industries are mostly concentrating on weight reduction and in improving the riding quality. To reduce vehicle weight various techniques are used like utilizing lightweight materials for parts and decreasing the size of the vehicles. Leaf springs in the automobiles consume considerable amount of weight. Leaf springs are one of the oldest form of suspension systems and they are used in various automobile industries even today. This paper aims in reducing weight of the leaf spring by changing material from conventional to composite material. Also, no compromise is done in the functionality and strength is improved. The modelling is done using CREO and finite element analysis is done using ANSYS Workbench. The design constraints are stress and displacement.*

Key Words: **Monoleaf spring, Composites, ANSYS, Von Mises stress, Weight reduction.**

1.INTRODUCTION

In now a day the fuel efficiency of automobiles is an important issue. To fulfil this problem the automobile industries are trying to make new vehicle which can provide high efficiency with low cost. Suspension system of automobile consume considerable amount of weight. The leaf spring is main element of the suspension system. It can control for the wheels during acceleration, braking and turning, general movement caused by the road irregularities. Leaf springs are designed in two methods: multi-leaf and mono leaf. We have chosen a mono leaf spring for our study.

The best way to increase the fuel efficiency is to reduce the weight of the automobile. The weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The achievement of weight reduction with adequate improvement of mechanical properties has made composite material a very good replacement material for conventional steel. In automobile, one of its components which can be easily replaced is leaf spring. A leaf spring is a simple form of spring, commonly used for the suspension in four wheeled vehicles. The suspension of leaf spring is the area which needs to focus to improve the suspensions of the four-wheel vehicle for comfort ride. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for 10 to 20% of unsprung weight. It is well known that springs are designed to absorb shocks. So, the strain energy of the material becomes a major factor in designing the springs. The introduction of composite material will make it possible to reduce the weight of the leaf spring without reduction in load carrying capacity and stiffness. Since the composite material have high strength to weight ratio and have more elastic strain energy storage capacity as compared with steel.

The achievement of weight reduction with adequate improvement of mechanical properties has made composite material a very good replacement material for conventional steel.

2. OBJECTIVES

1) Reduction in overall weight:

The weight density of composite material is much lower when compared to steel and also the steel leaf spring assembly replaced by mono leaf spring can reduce the weight of the vehicle. Upto 50% to 70% weight reduction can be achieved.

2) Increase in Fuel Efficiency:

Overall weight of the vehicle is one of the areas which effects the efficiency of the vehicle, by reducing the overall weight of the vehicle efficiency of the vehicle can be increased. Upto 60% to 80% weight reduction can be achieved.

3) Re cambering of leaf spring:

In conventional leaf spring there is a need to provide camber due to variable loading and shock effect which causes deformation, there is no such need in a composite leaf spring.

4) Increasing stability of vehicle:

Lower noise level, Softer ride, excellent stability due to better damping characteristics.

3. METHODOLOGY

1)Study of material and selecting appropriate material for design.

2)Design and modelling of steel and composite leaf spring (using creo).

3)Analysis of steel & composite leaf spring using ANSYS.

4)Experimental testing.

5)Results and Comparison chart

6)Conclusion.

4. SELECTION OF MATERIAL

The material used for leaf springs is usually a plain carbon steel having 0.90 to1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel produces greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties. Material used for steel leaf spring is EN47 and for composite leaf spring Eglass/Epoxy, then compare results for both.

The mechanical Properties of conventional steel EN47 are as shown in table-1

Table -1: Mechanical properties of EN47 steel [1]

Properties	Values	Units
Young's modulus	$2.1*10^5$	MPa
Poisson's ratio	0.266	-
Tensile ultimate strength	1272	MPa
Tensile yield strength	1158	MPa
Density	$7.86*10^{-6}$	Kg/mm^3

The mechanical Properties of composite leaf spring are as shown in table-2

Table-2: Mechanical properties of composite material E-Glass/Epoxy [1]

Properties	Values	Units
Young's modulus	40000	MPa
Poisson's ratio	0.217	-
Tensile strength	900	MPa
Compressive strength	450	MPa
Density	2.16*105	Kg/m3

5. DESIGN AND MODELLING

In the present work, mono leaf springs of steel and composite materials are modelled. For modelling of the steel leaf spring, the load of a lightweight four-wheel vehicle is chosen. Using that values, we make design of mono leaf spring. For composite material we considered two cases – case I, case II. Specifications of the design are taken as,

For EN47 and composite case I design parameters are,

Table -3: Design parameters for EN47 and composite case I

Total length of leaf spring (eye to eye)		1000 mm
Arc height at axle seat		110 mm
Thickness of leaf spring	At Centre	14 mm
	At ends	7 mm
Width of leaf spring	At Centre	45 mm
	At ends	65 mm

For composite case II design parameters are,

Table -4: Design parameters for composite case II

Total length of leaf spring (eye to eye)		1000 mm
Arc height at axle seat		110 mm
Thickness of leaf spring	At Centre	25 mm
	At ends	20 mm
Width of leaf spring	At Centre	45 mm
	At ends	65 mm

For modelling of leaf springs CREO software is used. Following models are prepared by using this software.

Fig -1: Model for EN47 and composite Case I

Fig -2: Model for composite case II

6. ANALYSIS

For analysis we use ANSYS Workbench as a analysis software. Ansys is computer based numerical technique for calculating the strength and behavior of engineering structures.

For analysis methodology is –

1) Insert model from modelling software in .stp format.

2) Meshing

3) Apply material properties.

4) Apply boundary conditions.

5) Apply load.

6.1 Meshing

The numbers of elements produced for case I are 579 and the total numbers of nodes are 1339.

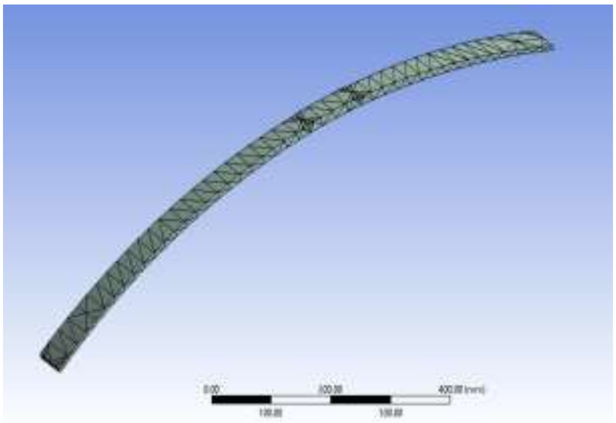


Fig -3: Meshing for case I

The numbers of elements produced for case II are 175 and the total numbers of nodes are 498.

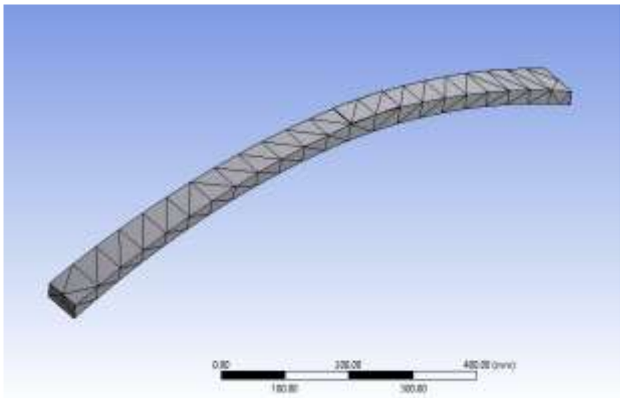


Fig -4: Meshing for case II

6.2 Analysis

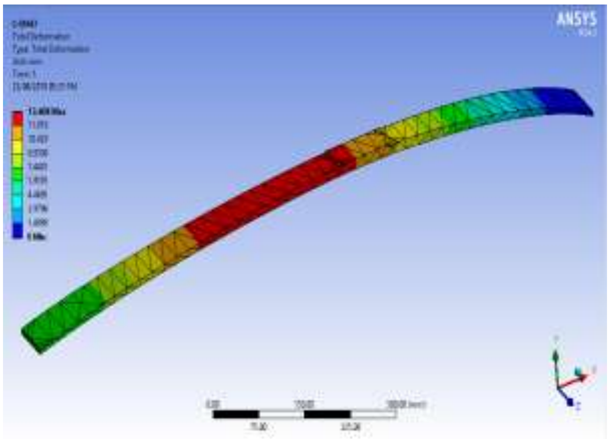


Fig -5: Total deformation for EN47 steel

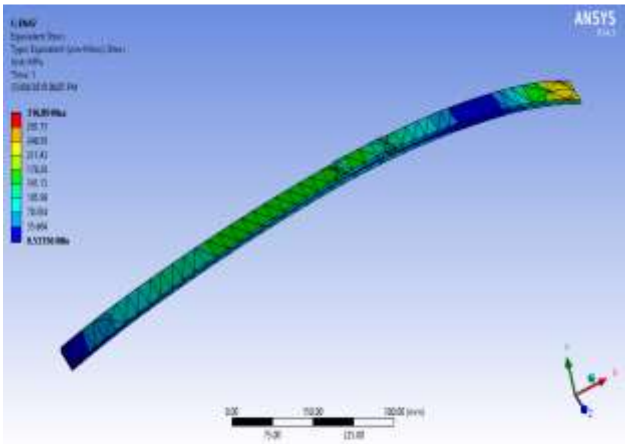


Fig -6: Equivalent stress for EN47 steel

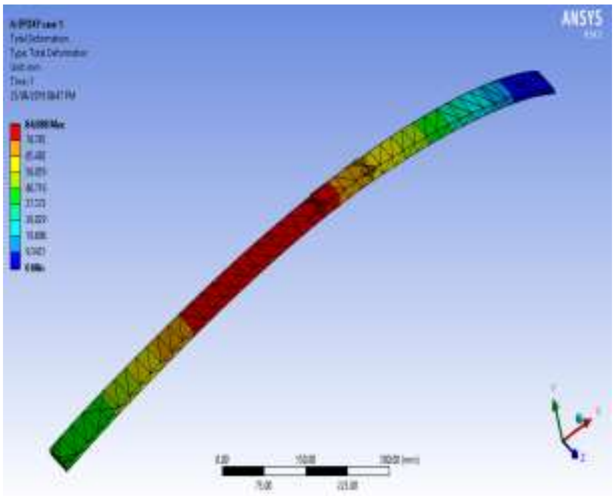


Fig -7: Total deformation for composite case I

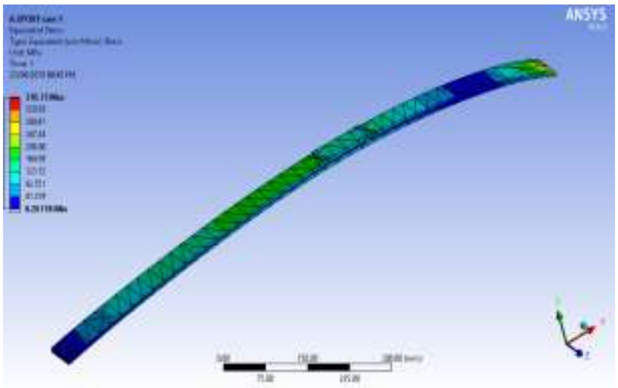


Fig -8: Equivalent stress for composite case I

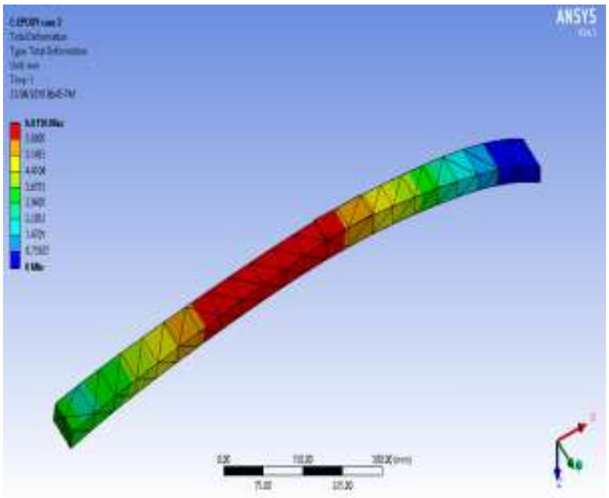


Fig -9: Total deformation for composite case II

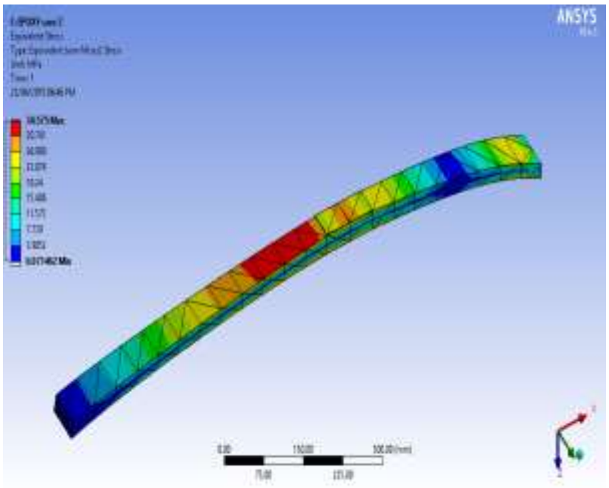


Fig -10: Equivalent stress for composite case II

7. EXPERIMENTAL TESTING

We did actual experimental testing on manufactured model of composite (E-glass/Epoxy) leaf spring (case I type) using universal testing machine (UTM), we get results as follows,

Table -5: Values of deflection at various load using UTM

Sr.no.	Deflection in mm	Observed load in N
1	10.0	224.42
2	20.0	420.42
3	30.0	613.48
4	40.0	798.70
5	50.0	984.90
6	60.0	1164.24
7	70.0	1322.02
8	80.0	1480.78
8	80.0	1480.78

8. RESULTS AND COMPARISON CHART

Results considering load is 1500 N,

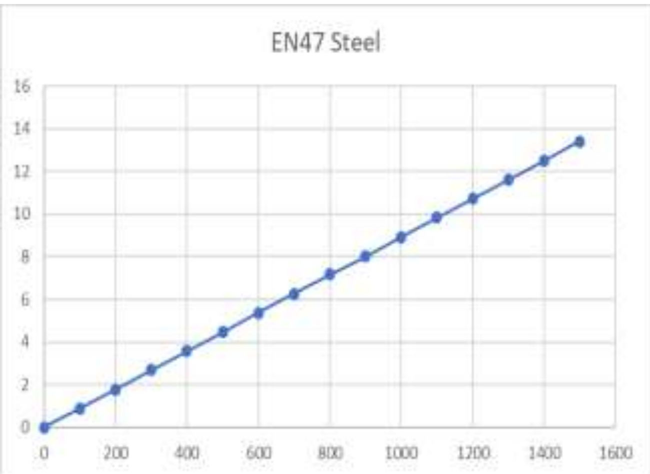
Table -6: Stress and deflection results

Material	Ansys results		Experimental testing results Deflection(mm)
	Stress (MPa)	Deflection(mm)	
EN47	316.89	13.4	15
Epoxy case I	370.75	84	80
Epoxy case II	34.575	6.62	6

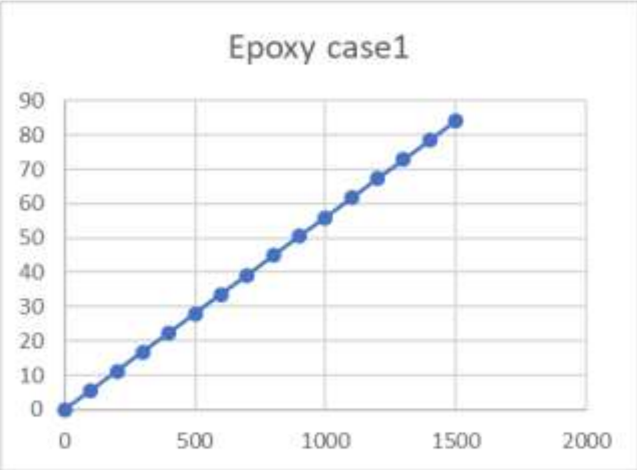
Weight reduction result,

Table -7: Weight reduction results

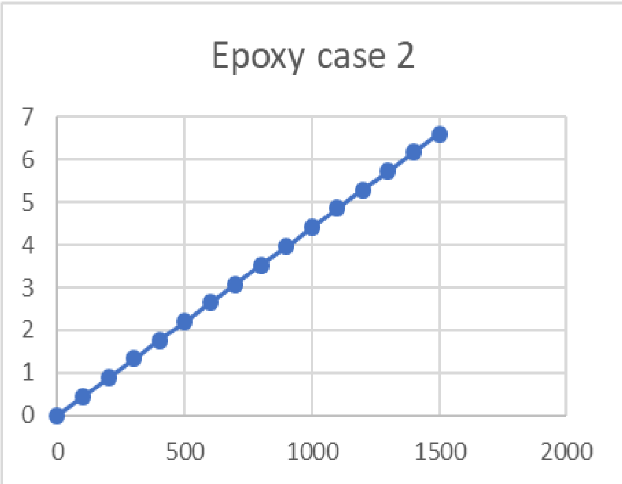
Material	Weight (Kg)	% weight reduction
EN47	4.57	-
Epoxy case I	1.188	74 %
Epoxy case II	2.48	45 %



Graph -1: Deflection Graph for Steel



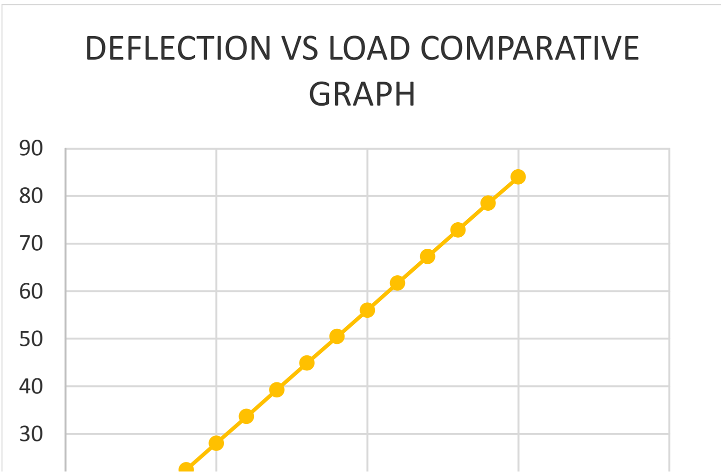
Graph -2: Deflection Graph for Epoxy Case 2



Graph -3: Deflection Graph for Epoxy Case 2

Comparative graph for all three cases,

(Deflection vs. Load)



Graph-4: Comparative result for all cases

8. CONCLUSION

As automobile world demands research of reducing weight and increasing strength of products, composite material should be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough.

In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring. A semi-elliptical multi leaf spring is designed for a four-wheel automobile and replaced with a composite multi leaf spring made of E-glass/epoxy composites. Under the same static load conditions the stresses and the deflection in leaf springs are found with great difference.

This project work provides optimum output for design parameters (leaf spring thickness and width) of hybrid composite leaf spring by using finite element analysis. Weight can be reduced from in kgs to 2kg if steel leaf spring is replaced by E-Glass/epoxy hybrid composite leaf spring. Weight reduction reduces the fuel consumption of the vehicle. Eglass/epoxy hybrid composite has higher elastic strain energy storage capacity than steel because it has lower young's modulus and lower density as compared to both. Hence hybrid composite leaf spring can absorb more energy which leads to good comfortable riding.

For case II composite leaf modelled such that thickness of leaf spring increase due to low modulus of elasticity. Also, it improves results of deflection as well as stress of leaf spring.

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BIOGRAPHIES

Student of Mechanical Engineering,
Keystone school of Engineering,
Savitribai Phule Pune University,
Maharashtra, India.

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Keystone school of Engineering,
Savitribai Phule Pune University,
Maharashtra, India.

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Keystone school of Engineering,
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Maharashtra, India.

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Keystone school of Engineering,
Savitribai Phule Pune University,
Maharashtra, India.