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Design & Analysis of Composite Mono Leaf Spring

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ABSTRACT

Light weight vehicle is now the trend in automobile industries. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The introduction of composite material has made it possible to reduce the weight of spring without any reduction on load carrying capacity. The automobile industry has shown increased interest in the replacement of steel spring with composite mono leaf spring due to high strength to weight ratio. Therefore; the aim of this project is to design and develop a low cost fabrication of composite mono leaf spring which can satisfy present need of automotive sector. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel. Selection of material is based on cost and strength of material. The composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, so multi-leaf steel springs are replaced by mono-leaf composite springs. This project gives the brief look on the suitability of composite mono leaf spring on vehicles and their advantages. The objective of the present work is to design, analyze and fabricate a composite mono leaf spring. The design constraints are stress and deflections. The attempt has been made to fabricate the composite mono leaf spring economically than that of conventional leaf spring through identifying process capability.

Keywords- **Automobile Suspension, Leaf spring, Composite Material, CATIA, ANSYS.**

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I. INTRODUCTION

Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. To improve the suspension system, many modifications have taken place over the time. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. Inventions of parabolic leaf spring, use of composite materials for these springs are some of these latest modifications in suspension systems. This seminar mainly focuses on the implementation of composite materials by replacing steel in conventional leaf springs of suspension system. The introduction of composite materials was made it possible to reduce the weight of 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 with those of steel, multileaf steel springs are being replaced by mono-leaf composite springs.

II. LITERATURE REVIEW

In the past work Mahmood M. Shokrieh,et.al [1] had studied the four-leaf steel spring used in the rear suspension system of light vehicle. Main consideration was given to the optimization of the spring geometry. The objective was to obtain a spring with minimum weight that is capable of carrying given static external forces without failure. The design constraints were stresses and displacements. In this study they concluded that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eyes towards the axle seat. Compared to the steel spring, the optimized composite spring has stresses that are much lower, the natural frequency is higher and the spring weight without eye units is nearly 80% lower. The stresses in the composite leaf spring are much lower than that of the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough.

H.A.Al-Qureshi [2] had selected the suspension spring of the car, jeep as a prototype. In this paper he had studied the single leaf, variable thickness spring of GFRP. In general this study demonstrates that composites can be used for leaf springs for light vehicles with substantial weight reduction.

M.venkatesan,et.al [3] had worked 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. In this they had concluded that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings, with the help of comparative study between composite and steel leaf spring with respect to weight, cost and strength. From the results, it was observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications. Composite leaf spring reduces the weight by 85 % for E-Glass/Epoxy, over conventional leaf spring.

Parkhe Ravindra, et.al [4] described design and analysis of composite mono leaf spring. In this work, existing mono steel leaf spring of a light vehicle was taken for modeling and analysis. A composite mono leaf spring with Carbon/Epoxy composite materials is modeled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. In this work they had done comparative study between composite leaf spring and steel leaf spring with respect to weight and strength. By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 22.5% than the steel spring. Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel material considered in this investigation.

S.Rajesh, et.al [5] had worked on replacing the conventional leaf spring with composite leaf spring. A single leaf with constant cross sectional area similar to that of conventional leaf spring in each case such as bidirectional glass fiber reinforced plastic (GFRP), bidirectional carbon fiber reinforced plastic (CFRP), bidirectional carbon-glass reinforced plastic (C-GFRP) and bidirectional glass-carbon reinforced plastic (G-CFRP) were fabricated by hand layup technique and tested by universal testing machine. By using universal testing machine, load per deflection and maximum load that a leaf spring can withstand were measured. They had concluded that, The composite leaf springs can take more amount of load than the conventional leaf spring for constant specified deflection. Also among the composite leaf springs, the glass – carbon composite leaf spring can take up more amount of load than others. The composite mono leaf spring reduces the weight by 71% for glass/epoxy, 70% by carbon/epoxy, 67% for carbon glass/ epoxy and 68% for glass-carbon/ epoxy over the conventional leaf spring. If these kind of composite leaf springs are replaced in the automobiles, an improved vehicle performance will be obtained with appropriate load bearing properties due to the lower weight.

Shiva Shankar et.al [6] had developed 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. The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings. He did the comparative study between composite and steel leaf spring with respect to weight, cost and strength.

M. Raghavedra et.al [7] has been made a comparative study between laminated composite leaf spring and steel leaf spring with respect to weight, stiffness and strength. By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 73% to 80%, natural frequency of composite leaf springs are 27% to 67% higher than steel leaf spring and 23 to 65% stiffer than the steel spring. Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel and other composite materials considered in this investigation. From the results, it is observed that the laminated composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.

Ayman A. Aly [8]studied the basic types of car suspension systems which range from simple spring-dampers, through semi-active dampers, and active suspensions systems. As the purpose of a suspension system is to support the vehicle body and increase ride comfort. Also discussed the conflicting of these two requirements.

Ranjeet Mithari et.al [9] concluded that under the dynamic load conditions natural frequency and stresses of steel leaf spring and composite leaf spring are found with the great difference. Here also the natural frequency of composite material is high than the steel leaf spring. Conventional steel leaf spring was found to weigh 23Kg. whereas E-Glass/Epoxy mono leaf spring weighs only 3.59 Kg. Indicating reductions in weight by 84.40% same level of performance. Conventional Leaf spring shows failure at eye end only. Composite leaf spring can be used on smooth roads with very high performance expectations. However on rough road conditions due to lower chipping resistance failure from chipping of composite leaf spring is highly probable. That is the composite leaf spring is having greater vibration absorbing capacity than conventional steel leaf spring. Also the stress of composite leaf spring is higher than conventional steel leaf spring. Because of using only mono leaf spring space also reduced. The corrosion resistance of composite leaf spring is higher i.e. it will work in environmental condition than conventional steel leaf spring.

Jadhav Mahesh V et.al [10] concluded that 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.

III.PROBLEM STATEMENT

As Leaf springs are important suspension elements used on light passenger's vehicle needs to minimize the vertical vibration impact and bump due to road irregularities and to create a comfortable ride. The existing conventional leaf spring is analyzed for static strength and deflection using finite element analysis. The general purpose composite mono leaf spring is designed, modeled with CATIA and finite element analysis is done by using ANSYS software for present study. Composite Mono Spring is fabricated and tested under UTM for actual results The variations of stress and deflection values are compared.

IV.SUSPENSION SYSTEM

The leaf spring suspension system is the oldest suspension system used for automobile device. The leaf spring system was used from 1970s production cars and many racers even prefer to utilize the leaf spring rear suspension design in their fabricated late model stock and modified race cars. The leaf spring supports some or all of the chassis weight and controls chassis roll more efficiently. Control axle dampening and braking forces. Better maintaining wheelbase lengths under acceleration and braking.

A. *Composite Material*

A composite is a structural material which consists of combining two or more constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and another which is embedded is called the matrix [1]. Advanced compositesare traditionally used in the aerospace industries, but now a days also use in automobile industries. Advance composite materials are Carbon, Graphite, Kevlar and Glass fiber with suitable matrixes is widely used because of their higher specific strength & higher specific modulus. Composite leaf springs are a fairly new component in racing that has been further refined recently. They are made of unidirectional E-glass fiber/epoxy composite material instead of steel. It has good mechanical properties for required design.

B. *Composite Mono Leaf Spring*

In this paper we have replaced conventional steel leaf spring which has unsprung weight into light weight material unidirectional E-glass fiber/epoxy composite material. The glass/epoxy composite leaf springs fatigue lives have five times more durable than steel leaf springs. It's also gives a smoother ride than steel leaf springs & also gives more rapid response to stress cause by road shock. Moreover, it is offer less chance of catastrophic failure and has excellent corrosion resistance.

C. *Selection of Material*

Materials of the leaf spring should be consist of nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

1) *Fiber Selection*

The commonly used fibers are carbon, glass, keviar, etc. Among these, the glass fiber has been selected based on the cost factor and strength. The types of glass fibers are C-glass, S-glass and E-glass. Vertical vibrations and impacts are buffered by 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. The material used directly affects the quantity of storable energy in the leaf spring. The specific strain energy can be written as Eq. (1).

$$S = \frac{\sigma}{2\rho\ E}^{2} \qquad (1)$$

Where,
σ is the allowable stress,
E is the modulus of elasticity and
ρ is the density.

From the Eq. (1) the material with maximum strength and minimum modulus of elasticity is the most suitable material for the leaf spring application.

In the following table the physical properties of some of the fiber are compared

TABLE I
PROPERTIES OF DIFFERENT FIBERS

Sr. No	Material	Strain Energy Stored By Material (KJ/Kg)
1	steel (EN47)	0.3285
2	Carbon/epoxy	8.611
3	E-glass/Epoxy	4.5814
4	C-glass/Epoxy	18.76
5	S-2-glass/Epoxy	32.77

The C-glass fiber is designed to give improved surface finish. S-glass fiber is design to give very high modular, which is used particularly in aeronautic industries. The E-glass fiber is a high quality glass, which is used as standard reinforcement fiber for all the present systems well complying with mechanical property requirements. Thus, E-glass fiber was found appropriate for this application.

2) *Resins selection:*

In a FRP leaf spring , the inter laminar shear strengths is controlled by the matrix system used. Since these are reinforcement fibers in the thickness direction, fiber do not influence inter laminar shear strength. Therefore, the matrix system should have good inter laminar shear strength characteristics compatibility to the selected reinforcement fiber. Many thermo set resins such as polyester, vinyl ester**,** epoxy resin are being used for fiber reinforcement plastics

(FRP) fabrication. Among these resin systems, epoxies show better inter laminar shear strength and good mechanical properties. Hence, epoxide is found to be the best resins that would suit this application. Different grades of epoxy resins and hardener combinations are classifieds, based on the mechanical properties. Among these grades, the grade of epoxy resin selected is Dobeckot 520 F and the grade of hardener used for this application is 758. Dobeckot 520 F is a solvent less epoxy resin. This in combination with hardener 758 cures into hard resin. Hardener 758 is a low viscosity polyamine. Dobeckot 520 F, hardener 758 combinations is characterized by good mechanical and electrical properties, faster curing at room temperature and good chemical resistance properties.

V. Design of Leaf Spring

TABLE II

SPECIFICATION OF COMPOSITE LEAF SPRING

Properties	Values
Material	E Glass Epoxy
Young's Modulus	33548 MPa
Tensile strength	400 MPa
Poisson's ratio	0.27
Camber	130 mm
Length	965 mm
Thickness at middle	30 mm
Thickness at ends	8 mm
Width at middle	30 mm
Width at ends	60 mm

There are three design possibilities of leaf springs like 1)Constant thickness ,Constant width 2) Varying thickness Constant width 3)Varying thickness, Varying width. So out of this I have selected varying thickness, varying width shape of leaf and made a bellow shown model with CATIA V5R19.

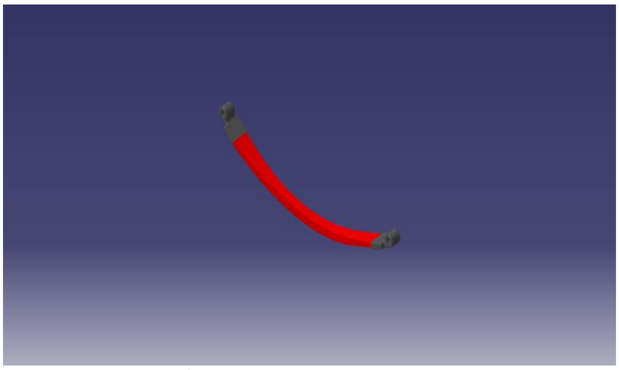

Fig.1 Composite Leaf Spring with end Brackets.

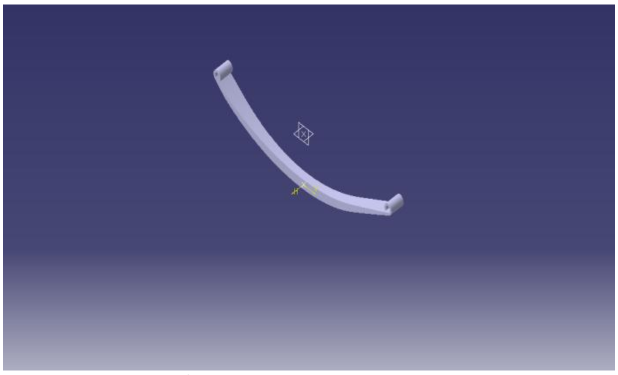

Fig.2 Composite Leaf Spring.

TABLE III

SPECIFICATION OF COMPOSITE LEAF SPRING

Properties	Values
Young's Modulus	200000 MPa
Tensile strength	770 MPa
Yield strength	450 MPa
Camber	130 mm
Length	965 mm
Width	60 mm
Thickness	24 mm

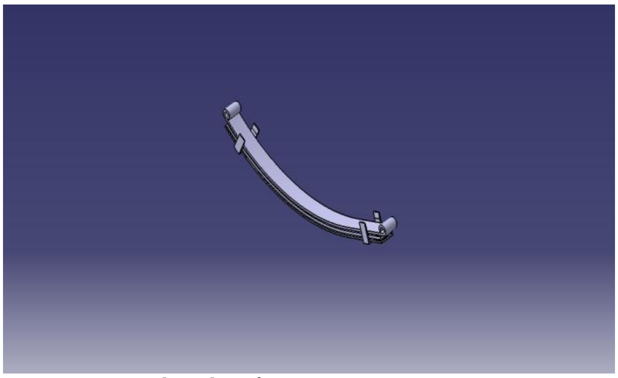

Fig.3 Conventional Steel Leaf Spring

A. *Analytical Solution for Steel spring*

Leaf spring in automobile suspension is acting as a cantilever beam. Therefore Bending Stress(σ) and maximum deformation(δ) of conventional spring is calculated by analytical method as below.

$$\sigma = \frac{6WL}{nbt^2} \quad (2)$$

$$\delta = \frac{12WL^3}{(2Ng+3Nf)Ebt^3} \quad (3)$$

VI.Finite Element Analysis

Finite element analysis is done with ANSYS 14 for the results of Stress and Deformation in steel as well as Composite Leaf Springs. Results of analysis are shown below in figures.

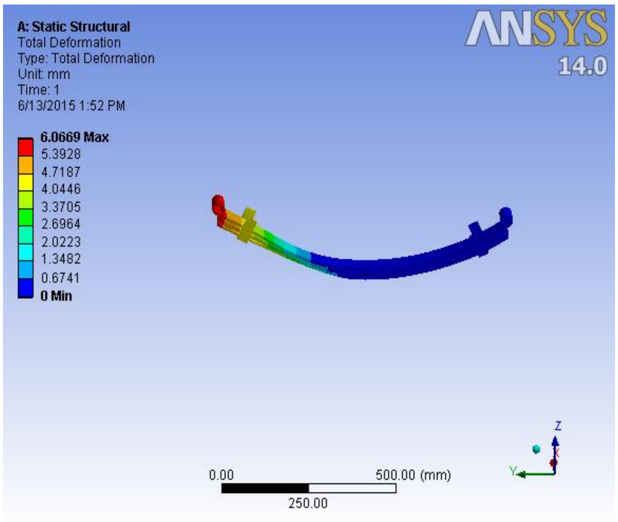

Fig.4 Deformation in Conventional Leaf Spring

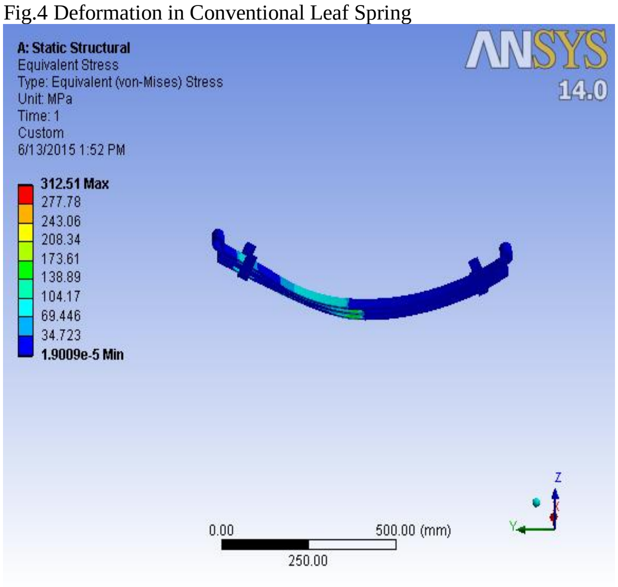

Fig.5 Stress Distribution in Conventional Leaf Spring

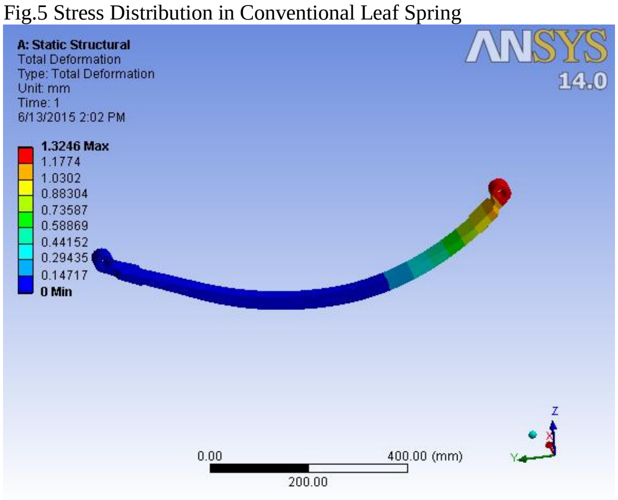

Fig.6 Deformation in Composite Leaf Spring

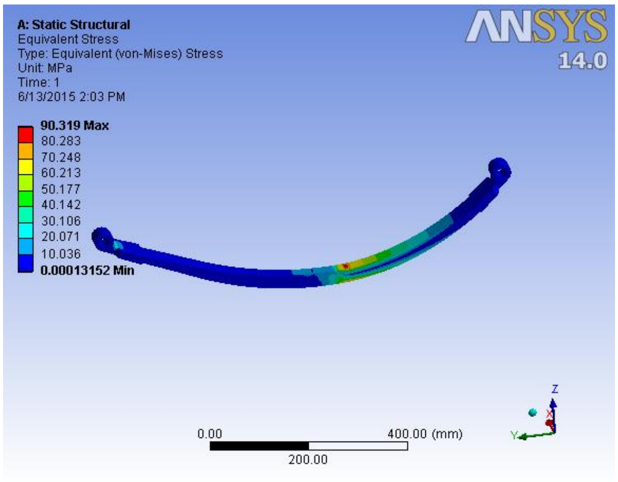

Fig.7 Stress distribution in Composite Leaf Spring

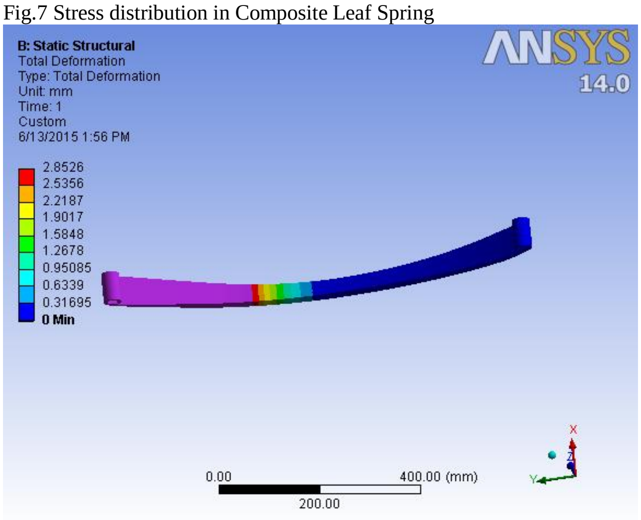

Fig.8 Deformation in Composite Leaf Spring

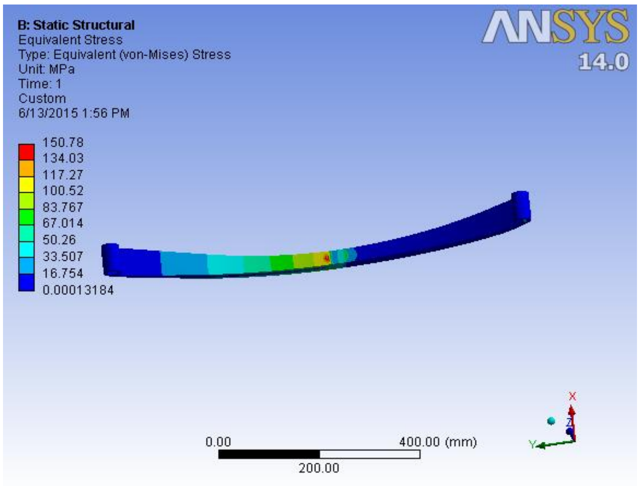

Fig.9 Stress Distribution in Composite Leaf Spring

VII.Testing of Composite Leaf Spring

The experimentation is done by applying load of 4000N on the composite leaf spring. The load from UTM machine was applied at the centre of leaf spring as shown in figure 5.4. The machine creates point load at centre of leaf spring. These loading conditions simulate the load being applied on a leaf spring in actual working condition. The height of fixture is maintained to accommodate deflection of spring. During experimentation one end of the leaf spring is fixed and other end is kept movable to resemble actual working conditions in an automobile.

Fig.10. Test set-up on Universal Testing Machine.

VIII.Results and Discussion

Results of work done are tabulated as below

TABLE IV

RESULT TABLE

Parameter	Steel Leaf Spring		Composite Leaf spring	Composite Leaf Spring with Brackets	
	Analytical	FEA	FEA	FEA	Experimental
Load (N)	4000	4000	4000	4000	4000
Weight (Kg)	13.4		5.6	6.6	
Stress (MPa)	223.3796	312.51	150.78	90.319	126.4088
Deformation(mm)	3.7146	6.0669	2.8526	1.3246	3.9880

It was seen that maximum stresses induced in composite leaf spring are less than that of conventional leaf spring. Deformations in composites are also less with compared to steel spring. Weight of conventional steel leaf spring assembly was reduced too much by composite material.

IX.Conclusion

As we have came across above results, composite material called E Glass Epoxy is the best option for leaf springs of automobiles. Weight of the suspension here is reduced by 50.74% which affects lot on vehicle performance. As stresses induced and deformation caused are too less than conventional, it results in comfortable and safe drive for passengers. On mass production it will be cost effective. It is having wide scope in practical application of composite material like E-Glass Epoxy for vehicle suspensions.

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