# Design and Analysis of Composite Leaf Spring – A Review

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***Abstract*— Overall Weight reduction of the vehicle is the main issue in automobile industries. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. In this paper main focus is to review all such work in which the weight reduction of the vehicle was achieved by considering leaf spring. Many of authors suggested that weight reduction can be achieved by using composite material having suitable properties and capable of carrying such heavy load of the vehicle. Different methods for analysing and manufacturing for composite leaf spring are also discussed. It was shown that the weight reduction can be easily achieved but there are more aspects which should also be consider i.e. cost, new composite materials.**

***Keywords*— leaf spring, composite material E-glass/Epoxy.**

## I. Introduction

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. 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, which is considered to be the mass not supported by the leaf spring. The main focus of this paper is to review all the work having aim to reduce overall weight of the vehicle. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness so composite materials are now used in automobile industries to take place of metal parts. Since, the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. Composite materials offers opportunity for substantial weight saving. Spring are design to absorb & store energy & then release it hence strain energy of material & shape becomes major factors in designing the spring. The spring allows the movement of wheel over obstacles & then after returns the wheel to its normal position.

## II. Literature review

Erol Sancaktar et. al. (1999) [1], in his work described the design and manufacture of a functional composite leaf spring for solar powered light vehicle. The main objective of this work was to provide and understanding of the manufacture, use and capabilities of composite leaf spring. The material selected for the fabrication of the initial design leaves consisted of a full thickness of unidirectional E-glass fibers with two layers of bi-directional fabric on the outer layers embedded in a vinyl ester resin matrix. The bi-directional fabric used to prevent leaf deformation and subsequent failure in bending about its longitudinal axis it was selected due to overall weight reduction of the vehicle primarily considered. This work attempted due to some failure aspect which occurs in the previous leaf spring. The reason behind the failure was:

- Cracks perpendicular to leaf longitudinal axis
- Stress whitening on the outer layer

The reasons discussed in this paper were sort out by giving the alternative designs by modification of the initial leaf spring. The design offered many advantages over the initial design. By tapering the leaves in the thickness direction as well as in the width direction towards the ends, an even distribution of stresses was achieved providing efficient material usage. The low stress region at the tips of the hole, as well as the holes themselves, present in the initial design is now eliminated. Also, the fibres have a more uniform orientation resulting in a spring, which was easier to model analytically and manufacture. In the alternative design the material selected as E-glass due to their high extensibility, toughness and low cost. In order to facilitate the wetting of the fibres, epoxy resin with 2 h pot life was selected. When the comparison was done, it was found that the redesign of the solar car’s front suspension leaf springs was successful as it met all design targets and requirements.

Mahmood M. Shokrieh et. al. (2003) [2], in their work they focused on the objective of shape optimization of the spring to give the minimum weight for the objective of a light commercial vehicle. For the purpose, they considered a LCV (Light commercial vehicle) and analysed a conventional leaf spring used in the rear suspension system using ANSYS V5.4 software and the results were verified with analytical and experimental solutions. The experimental results were not sufficient to design the leaf spring. So, a stress analysis was performed using finite element method. In this approach every leaf was modelled with eight-node 3D brick elements (SOLID 45) and then five node 3D contact elements (CONTACT 49) were used to represent contact and sliding between adjacent surfaces of leaves. Considering several types of vehicles that have leaf springs and different loading on them, various kinds of composite leaf spring have been developed. But in this study the simplified assumptions were removed and the spring was designed using a more realistic situation. The main criterion was considered for selecting the composite material as the storable energy in the leaf spring. The amount of elastic energy that can be stored by a leaf spring volume unit is given by the equation [2]. This paper provided a graph (Fig.1) which clearly shows the specific strain energies of the spring materials. The given figure was specify the percentage of strain energies for static loading and hatched region shows for dynamic loading when the fatigue strength is used.

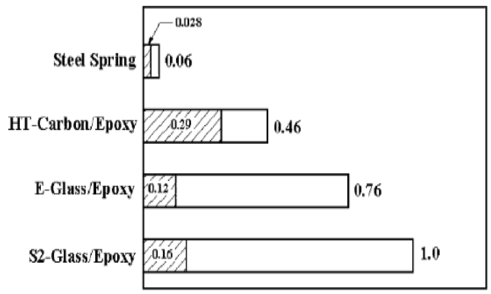


**Fig.1 Strain energies of the spring materials**

Form above graph (Fig. 1) it was found that the composite material which well suited for the given problem as E-glass/epoxy. After selection the leaf spring again analysed by changing the material. Then comparison was done of conventional leaf spring with the composite one. It was found that the stresses in the composite leaf spring were much lower than that of the steel leaf spring. It was also found that the weight of the composite leaf spring reduced about 80% than that of the steel leaf spring and natural frequency was higher than the steel leaf spring.

Gulur Siddaramanna Shiva Shankar et. al. (2006) [3], aim of their paper was to present a low cost fabrication of complete mono composite leaf spring and mono leaf spring with bonded end joints and also general study was done on the analysis and design. In this work a single leaf designed and fabricated by hand lay-up technique and tested. The single leaf of leaf spring variable in thickness and width and material used for the fabrication as unidirectional glass fibre reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring. In this work computer algorithm using C-language was used for the design of constant cross-section leaf spring. For this work design constraints were stresses (Tsai-Wu failure criterion) and displacement, a stress analysis was performed using the finite element method done using ANSYS software. Modelling was done for every leaf with eight-node 3D brick element (solid 45) and five-node 3D contact element (contact 49) used to represent contact and sliding between adjacent surfaces of leaves. Also, analysis carried out for composite leaf spring with bonded end joints for Glass/Epoxy, Graphite/Epoxy and Carbon/Epoxy composite materials and the results were compared with steel leaf spring with eye end. It was concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. It was observed that the major disadvantage of composite leaf spring is chipping resistance. The matrix material is likely to chip off when it is subjected to poor road environments which may break some fibres 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. It was concluded that the weight of the composite leaf spring 85% lesser than the conventional leaf spring.

Fig.2 shows algorithm prepared in C- language for design of leaf spring.

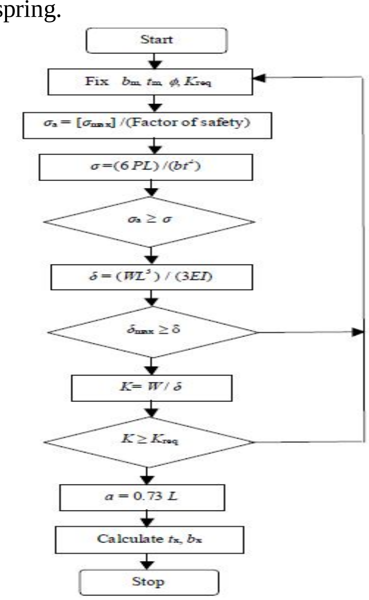


**Fig.2 Flowchart of computer algorithm for design of composite leaf spring**

Notations of the given Fig.2 are $b_m$ – width at middle (mm), $t_m$ – thickness at middle (mm), φ – Taper ratio, $K_{req}$ – stiffness of the spring, $\sigma_a$ – design bending stress (N/mm$^2$), δ – deflection of the spring (mm), $\delta_{max}$ – camber of the spring (mm), a – distance from the centre to which the width varies with thickness, L –distance between the centres to one end of the eye (mm).

Patunkar M. M. et. al. (2011) [4], the objective of their work was to present modelling and analysis of composite mono leaf spring and compare its results. In this work conventional leaf spring was tested for the static load conditions and the material of the conventional leaf spring was 60Si7 (BIS). According to the same design data a virtual model was created of a composite material leaf spring the material E-glass/Epoxy was selected as for composite one. In this work leaf spring was modelled in Pro/E 5.0 and analysed in ANSYS 10.0. The tested results of the conventional leaf spring were compared with the virtual model of the composite material leaf spring. For analysing the leaf spring finite element method was used. On the basis of comparison graphs were plotted as shown in the Figure.3

Form the comparison (Fig.3) it was found that the deflection of the composite leaf spring lesser than that of the conventional leaf spring.

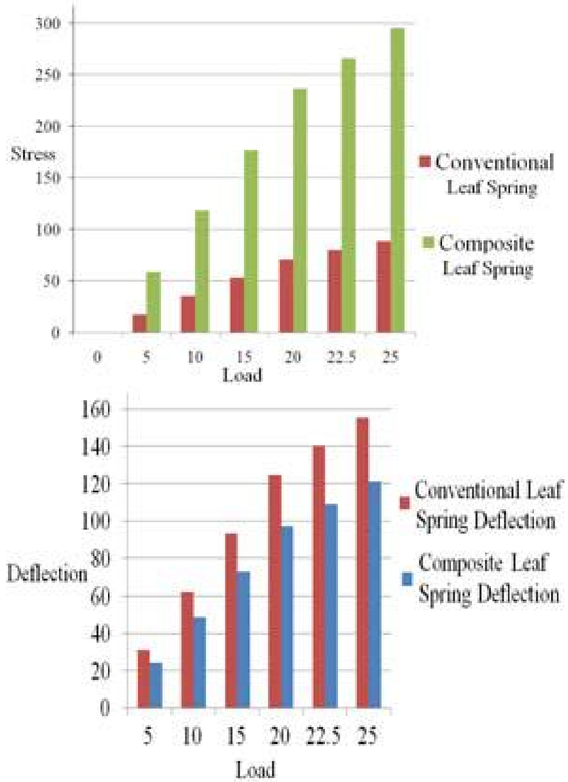


**Fig.3 Shows the behaviour of the leaf springs when subjected to load and its effect on Deflection and Stress**

It was also concluded that the weight of the composite leaf spring 84.40% lower than that of the conventional steel leaf spring.

Venkatesan M. et. al. (2012) [5], in their work design and experimental analysis of composite leaf spring were described. This work attempted to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. In this work the dimensions of leaf spring taken from existing conventional steel leaf spring of a light commercial vehicle and the material was used for fabricating the composite one as E-glass/epoxy unidirectional laminates. Here in this work using design data the conventional steel leaf spring was modelled and analysed using ANSYS 10.0 and compared with the experimental results. Modelled leaf spring again analysed by changing the material as composite one and compared with experimental results. After comparing analytical and experimental results, conventional steel leaf spring and composite leaf spring were compared with each other. From comparison it was concluded that composite material can be use in place of steel for leaf spring and also the weight of the leaf spring was reduced by using composite material without affecting its load carrying capacity.

Shishay Amare Gebermeskel (2012) [6], in this work he focused on reducing the weight of vehicle simultaneously increase or maintain the strength of their spare parts. So here this work considered leaf spring because of it contributes considerable amount of weight to the vehicle and needs to be strong enough. This work considered for light weight three wheeler vehicles and a single E-glass/epoxy leaf spring designed, simulated by following design rules of the composite materials and fabricated by hand lay-up method. The leaf spring was tested and analysed for static load only. It was concluded that E-glass/epoxy leaf spring designed and simulated in this work having stresses much below the strength properties of the material satisfying the maximum stress failure criterion. It has observed that the fatigue life of the single E-glass/epoxy leaf spring of $221.16*10^3$cycles.

Kumar Y. N. V. Santosh et. al. (2012) [7], this study focused on many advantages of composite structures for conventional structures because of higher specific stiffness and strength of composite materials. The aim of this work was to compare the conventional leaf spring with the composite one in several aspects such as weight, cost, and strength and load carrying capacity. The objective of this work was to consider an existing automobile leaf spring model TATA SUMO EZRR PARABOLIC REAR and to design and analyse a composite leaf spring with upturned eye without changing stiffness in order to replace the existing steel leaf spring with a composite leaf spring. In this work a leaf spring modelled in Pro/E was imported to ANSYS in IGES format and where it was analysed in metaphysics using steel material (55Si2Mn90) and than by changing the material as composite one (E-glass/epoxy) again analysed. The comparison was done after analysing. On comparing it was found that the deflection in the composite leaf spring almost equal to the conventional leaf spring and hence stiffness of both same. It was also concluded that, the weight reduction was achieved by using composite material and reduced by 60.48% with good strength and load carrying capacity of the leaf spring.

Jadhav Mahesh V. et. al. (2012) [8], in this work it has been looked on the suitability of composite leaf spring on vehicles and their advantages. This work was attempted to reduce the cost of composite leaf spring to that of steel leaf spring and weight reduction as well. For this work material and manufacturing process were selected upon on the cost and strength factor. The design method was selected on the basis of mass production. The study was made to select the material and study was concluded that the E-glass as a fiber and Epoxy graded Dobeckot 520 F as a resin most suitable for this work and the material of the existing conventional leaf spring was EN 47. The composite leaf spring was fabricated by hand lay-up method. In this work the leaf spring was designed using Pro/E 4.0 and analysed using ANSYS 14 and the results of both conventional leaf spring and composite one compared with each other. It was 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 was considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective.

Ghodake A. P. et. al. (2013) [9], in their work they searched a new material against steel. For this work glass fibre reinforced plastic (GFRP) and polyester resin (NETPOL 1011) selected against conventional steel i.e. 65Si7. Here leaf spring of constant width and thickness was fabricated by hand lay-up technique. The entire dimensions were taken for design and analysis from existing conventional steel leaf spring used in the light commercial vehicle. The composite leaf spring was fabricated using hand lay-up technique and the leaf spring was also designed and numerical analysed using ANSYS by finite element method. Stresses, deflection and strain energy results for both steel and composite leaf spring material were obtained and compared. It has been observed that the composite leaf spring was lighter and more economical than the conventional steel spring with similar design specifications. It was also observed that the weight reduction of mono leaf spring was achieved up 84.94% in case of composite than steel.

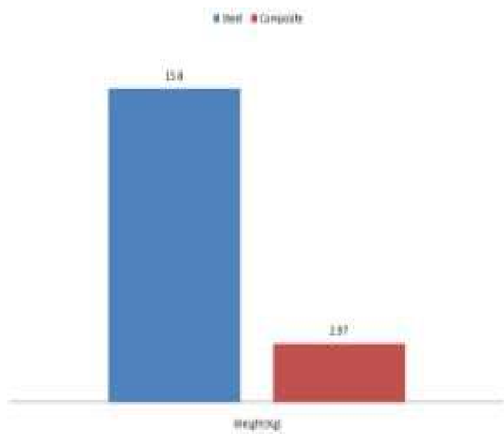


**Fig. 5 Comparison of weights in steel and composite**

Ramakanth U. S. et. al. (2013) [10], this work was carried out on multi leaf springs having nine leaves used by a commercial vehicle. The material of the existing leaf spring was 65Si7 (SUP9) and for getting suitable material there were two material selected as composite material as E-glass/Epoxy and hybrid (just alternate layers of steel 65Si7 and Epoxy GFRP). The leaf spring by taking dimensions from existing one designed on solid works, analysed using ANSYS and for analysing finite element method was approached. Fatigue analysis of leaf springs is carried out for steel leaf springs, and Static analysis for steel leaf springs, composite leaf springs and hybrid leaf springs. There were some results found out are as follows:

- Stresses in composite leaf springs was found out to be less as compared to the conventional steel leaf springs, also a new combination of steel and composite leaf springs (hybrid leaf springs) are given the same static loading and was found to have values of stresses in between that of steel and composite leaf springs.
- Conventional 65Si7 (SUP9) leaf springs were found to weight about 58.757kgs, while the composite leaf springs weighed only 19.461kgs, and the hybrid leaf springs weighed 41.14kgs for the same specifications.
- The cost of the GFRP composite was found very high when compared to conventional steel leaf springs, while the cost of hybrid leaf springs may be lesser when compared to GFRP composite leaf springs.
- The fatigue analysis of the steel leaf springs were carried with four approaches, Soderberg's approach is found out to give better results for the analysis of life data for leaf springs.

Meghavath Peerunaik et. al. (2013) [11], in their work they aimed to estimate the deflection, stress and mode frequency induced in the leaf spring of an army jeep locally manufactured. In this work finite element method was used for the analysis of leaf spring. It was observed that the behaviour of the leaf spring is complicated due to its clamping effects and interleaf contact; hence its analysis is essential to predict the displacement, mode frequency and stresses induced during the operation. For this work the model of leaf spring created in Pro/E with existing design data, and then analysed on ANSYS and the finite element of leaf spring was created using solid tetrahedron elements. The analysis of both conventional and composite leaf spring (carbon/epoxy) and compared with each other.

It was found that the stresses in the composite leaf spring were much lower than that of the steel spring. It was also concluded that the composite spring can designed to strength and stiffness much closer to steel leaf spring by varying.

## III. CONCLUSION

As a lot of work has been done in designing of leaf springs which is discussed briefly in this text, on the basis of this study, problems in overall weight reduction by using composite materials are identified. Many of the authors suggested various methods of designing, manufacturing and analyses of composite leaf springs. After studying all the available literature it is found that weight reduction can be easily achieved by using composite materials instead of conventional steel, but there occurs a problem during the operation while using the composite leaf spring i.e. chip formation when the vehicle goes off road. Therefore there is an immense scope for the future work regarding use of composite materials in leaf springs to reduce the overall weight of the vehicle as well as the cost of the vehicle.

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