# Design and static structural analysis of leaf spring using fea: a review

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***Abstract*: A spring is an elastic machine element which deforms under the application of load and tends to regain its original shape upon removal of load. In modern scenario Automobile Industry has shown a lot of interest in reducing weight of the vehicle. The suspension leaf spring is one of the potential item for the weight reduction in Automobiles. Introduction of composite materials made it possible to reduce the weight of leaf spring without losing load carrying capacity. Many of authors suggested that weight reduction can be achieved by using suitable composite materials. The aim of this review paper is to review all such works and to represent a general study on conventional steel leaf spring, composite leaf spring and hybrid leaf spring that utilizes steel – composite combinations.**

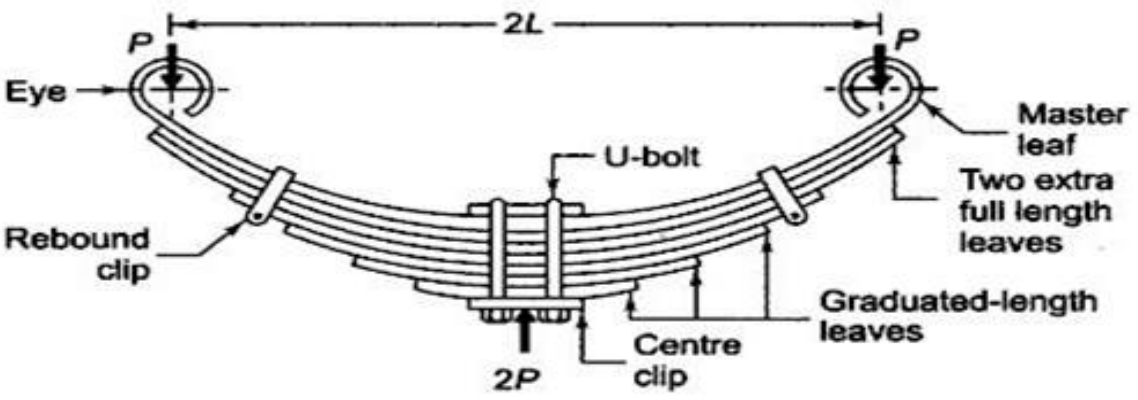
***Keywords*: Leaf Spring, Composite, Hybrid Leaf Spring, Static Structural Analysis.**

## I. INTRODUCTION

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. It is also called as laminated spring or carriage spring sometimes referred to as a semi-elliptical spring or cart spring. It is one of the oldest form of the spring appearing on carriage in England after 1750 and from there migrating to France and Germany. A multi - leaf spring or laminated spring is very important component in automobile suspension system.

It is one of the oldest suspension component too and still today it is extensively used in all the heavy and light duty commercial vehicles, railway wagons and usually in the rear suspension of passenger vehicles. A leaf spring can either be attached directly to the frame at the both ends or attached directly at one end usually the front with the other end attached through a shackle, a short swinging arm.

A leaf spring takes the form of a slender arc – shaped length of spring steel of rectangular cross – section. In the most common configuration, the centre of arc provides location for the axle while loops formed at either end provide for attaching to the vehicle chassis. For very heavy vehicles a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves.




In its construction the leaf spring consist of series of flat plates or leaves usually of semi-elliptical shape, which are held together with the help of U-Bolt and centre clip. Generally two types of leaves may be observed in a multi-leafspring i.e. some graduated length leaves and a few extra full length leaves. The length of the leaves gradually decrease from top to bottom. The longest leaf in the top is known as a master leaf which is bent at both the ends to form spring eyes. The extra full-length leaves are inserted between the master leaf and the graduated-length leaves to support the transverse shear force. In order to maintain proper alignment and to resist the lateral shifting of leaves rebound clips are used. In practice, these springs rest on the axle of an automobile. Its front end is connected with the frame by means of simple pi joint and the rear end is connected through a flexible link (known as shackle).

Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. 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.According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Fortunately, composites have these characteristics.

## II. LITERATURE REVIEW

**[1] Dara Ashok, M.V. Mallikarjun, and Venkata Ramesh Mamilla**

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.Leaf spring consist two full length leaves and five graduated leaves. The material of the conventional leaf spring was 65Si7 and the material of the composite material was E-Glass/Epoxy.Dimensions of the composite leaf spring are to be taken as the same dimensions of the conventional leaf spring for modeling.It is concluded that composite multi leaf spring is an effective replacement for the existing steel leaf spring in vehicles.

**[2] MouleeswaranSenthilkumar, SabapathyVijayarangan**

This paper describes static and fatigue analysis of steel leaf spring and composite multi leaf spring made up of glass fiber reinforced polymer using life data analysis.Compared to steel spring, the composite leaf spring is found to have 17.35 % lesser stressand weight reduction of 68.15 %is achieved.It is found that the life of composite leaf spring is much higher than that of steel leaf spring.

**[3] Rohit Ghosh, Sushovan Ghosh and ShirishGhimire**

Average costof E-Glass that can be used to manufacture the springs, ranges from 40-55 USD per square foot. Whereas steel ranges from 16-20 USD per square foot, hence, if the entire spring is made of composite material then it would not be cost effective at all. He further concluded that, stresses in extra full-length leaves were almost 50% more (1.5 times) than that of the graduated-length leaves. Finally, the present work offers an exclusive idea regarding the construction of multi-leaf spring through its proposal for manufacturing the extra full-length leaves with composites, while using steels for the rest of the leaves, to minimize the cost.

**[4] AmolBhanage& Dr. K. Padmanabhan**

In this research paper, steel leaf spring used in passenger cars is replaced with a composite leaf spring made of a glass/epoxy composite. The primary objective is to compare fatigue characteristics of SAE1045-450-QT steel and E – Glass/ Epoxy Composite material. Due to Weight reduction and stress, stiffness criteria, multi steel leaf spring is proposed to be replaced with E- Glass Epoxy composite leaf springs.Finite element method using CAE tool like ANSYS Workbench prove the reliability of the validation methods based only on simulation, thereby saving time, material and production costs for a complete product realization. The fatigue life of the leaf spring has also been improved.

**[5] Manjunath H.N,**

In this paper a comparative study has been made between different composite(E-Glass/Epoxy, Graphite/Epoxy, Boron/Aluminum, Carbon/Epoxy, Kevlar/Epoxy) materials and steel in respect of stiffness, deflection and stress.It is found that all the composite leaf spring has good performance characteristics as compared to conventional steel spring with similar design specifications. Boron/Aluminum has minimum deflection and stress, and posses high stiffness as compared to other composites.

[6] **PinaknathDewanji**

This paper deals with the Design and analysis of composite leaf spring. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus, the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring. Totally it is found that the composite leaf spring is the better that of steel leaf spring.

**[7] P Sai Krishna**

In this paper design and analysis of leaf spring is done. Modeling of leaf spring is done in solidworks 2016 design software. First 4mm thickness leaf spring then 5 and 6mm are modeled. The models are saved as igs files to import in ansys. Structural analysis is carried out in ansys by applying three different materials such as carbon epoxy carbon steel and e glass epoxy at 6685N force is applied on leaf spring for three different thickness leaf spring. The material properties of the above materials are studied. It is concluded that already 6mm thickness is existing by we reduced it to 5mm and 4mm by varying the thickness reduction in weight occurred from the analysis carbon steel material for 5mm thickness is showing less stress compared to 4mm thickness leaf spring. Leaf spring containing 4mm thickness undergone maximum stress though the weight reduction is maximum but stability to oppose the load is low but 5mm thickness leaf spring got the values nearer to 6mm and it has low weight compared to 6mm leaf spring. Author has concluded that the leaf spring containing 5mm thickness applied with carbon steel material is showing best results.

**[8] Pankajsahini, Ashish Goyal**

In this paper design and analysis of composite leaf spring has been done. From the static analysis results, it is found that there is maximum displacement of 10.16 mm in the steel leaf spring and the corresponding displacement in E-glass/Epoxy, graphite/epoxy and carbon/epoxy are 15mm, 15.75mm and 16.21mm and all the values are below the camber length for a given uniformly distributed load 67 N/mm over the ineffective length. From the static analysis results we see that the von-mises stress in the steel is 453.92 MPa and the von-mises stress in E-glass/Epoxy, graphite/epoxy and carbon/epoxy is 163.22 MPa, 653.68 MPa and 300.3 Mpa respectively. Among the three composite leaf springs, only graphite/epoxy composite leaf spring has higher stresses than the

steel leaf spring. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from the stress and stiffness point of you. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite mono leaf spring reduced the weight by 81.22% for E-glass/epoxy, 91.95% fir graphite/epoxy, and 90.51% for the carbon/epoxy over conventional leaf spring.

**[9] D. Lydia mahanthi**

In this paper design and analysis of composite of leaf spring is done for light weight vehicles.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, we introducing Kevlar material which is least in weight and bears more load with less deformation when compared to other materials. The results of static analysis of both steel and composite leaf springs like EN47, KEVLAR, S-Glass Epoxy & E-Glass shows that Kevlar material is better than conventional steel, E-Glass/Epoxy, S-Glass Epoxy and the other composite materials.

**[10] S. Rajesh**

In this paper experimental investigation has been done on laminated composite leaf springs subjected to cyclic loading. The fabrication of mono composite leaf spring was done by using hand layup method. The deflection test was carried out for mono composite leaf spring of all categories by using the universal testing machine. A cam like arrangement has been designed and fabricated to expose the cyclic loading for the leaf spring, through milling machine. After applying the cyclic loading such as 3780 cycles, 7560 cycles and 11340 cycles using milling machine, the deflection test was conducted. From the results, it is found that load bearing capacity is increased after applying the cyclic load in all types of composite leaf springs. 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 hybrid 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.

## III. CONCLUSION

From the above literature survey we find that many researches have been done related to replacement of conventional leaf spring with that of composite leaf spring. The Automobile Industry has shown a lot of interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, and good corrosion resistance properties. From above researches we have seen that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was nearly reduced up to 85%.But the only problem in replacing conventional steel leaf spring with composite material is that the cost of composite material is very high as compared to steel hence, if the entire spring is made of composite material then it would not be cost effective at all. Also stresses in the extra full-length leaves were found almost 50% more (1.5 times) than that of the graduated leaves. Hence I proposed to make a model of leaf spring in which extra full length leaves (where stresses are found to be high) are made up of composite material instead of making all the leaves of composite material, and rest of graduated length leaves (where stresses are found to be lower comparatively) are made up of conventional steel, to reduce the overall cost of composite leaf spring. And then compare the stresses, deflection, weight saving and cost of this hybrid leaf spring with that of the conventional steel leaf spring and composite leaf springs.

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