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A Review Paper on Design Analysis of Hybrid Leaf Spring

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Abstract - This topic deals with the past literature survey which shows that leaf springs are designed as generalized force elements where the reaction forces in the chassis attachment positions depends upon the position, velocity and orientation of the axle mounting. Another part has to be focused, is the automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring due to high strength to weight ratio. Increasing competition and innovation in automobile sector tends to modify the existing products by new and better material products. A suspension system of vehicle is also a potential area where these innovations are carried out frequently. Therefore, analysis of the composite material becomes equally important to study the behaviour of Composite Leaf Spring. In this work is focussed on hybrid spring that utilizes a steel-composite combination uses the weight criteria while this gives maximum stiffness-to strength.
Evaluating a multi-leaf system with the understanding the effects of steel and composite epoxy-glass with more than one leaf.

Index Terms - *composite material, hybrid spring, leaf spring,*

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I. INTRODUCTION

In any industry, In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. Weight reduction can be achieved primarily by the introduction of advanced material, design optimization and manufacturing processes. The suspension leaf spring is one of the reasons for weight reduction in automobile as it accounts for ten to twenty percent of the unstrung weight. This helps in achieving the vehicle with better riding qualities. It is known that springs, are designed to release the absorbed and stored energy. Hence, the strain energy of the material becomes an important factor in designing the springs. Composite materials has helped in reduction of weight of the leaf spring without any reduction on stiffness and load carrying capacity. Since; the composite materials have high elastic strain energy storage capacity and strength-to-weight ratio as compared to those of steel and other materials. Several papers were published on the application of composite materials for automobiles. Multi leaf springs used in automotive vehicles normally consists of full length leaves and graduated length leaves.

II LITERATURE SURVEY

Mahmood M. *et all* [1]. A steel leaf spring used in the rear suspension of light passenger cars was analyzed by two analytical and finite element methods. The experimental results verified the analytical and the finite element solutions. The steel leaf spring was replaced with an optimized composite one. Main consideration was given to the optimization of the leaf spring geometry. The objective was to obtain a spring with minimum weight that is capable of carrying given static external forces by constraints limiting stresses (Tsai–Wu criterion) and displacements.

The results showed that the optimum spring width decreases hyperbolically and the thickness increases linearly from spring eye towards the axle seat. The stresses in the composite leaf spring are much lower than that of the steel spring. Compared to the steel leaf spring the optimized composite leaf spring without eye units' weights nearly 80% less than the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance. To join the spring to the vehicle body, an additional layup was used on the spring end and the steel eyes were mounted through bolts.

M.Venkatesan, *et all* [2]. The objective was to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle were taken. Same dimensions of conventional leaf spring were used to fabricate a composite multi leaf spring using E- Glass/Epoxy unidirectional laminates. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 10 and compared with experimental results. The development of a composite 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. A comparative study has been made 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.

V. Pozhilarasu and T Parameshwaran Pillai, [3]. under the same static load conditions deflection and stresses of steel leaf spring and composite leaf spring are found with great difference. Deflection of composite leaf spring is less as compared to steel leaf spring with the same loading condition. Bending stress is also less in composite leaf spring as compared to steel leaf spring with the same loading condition.

Conventional steel leaf spring is also found to be 3.5 times heavier then E-Glass/Epoxy leaf spring. Material saving of 71.4 % is achieved by replacing E-Glass/epoxy in place of steel for fabricating the leaf spring. Composite leaf spring can be used on smooth roads with very high performance expectations.

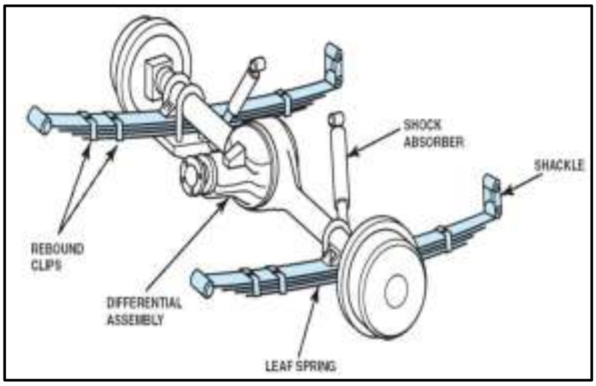
Manjunath H.N *et all* [4]. Static Analysis and Fatigue Life prediction of Composite Leaf Spring for a Light Commercial Vehicle (TATA ACE). In this research work an attempt has been made to check the suitability of composite materials like EGlass/ Epoxy, Graphite/Epoxy, Boron/Aluminum, Carbon/Epoxy and Kevlar/Epoxy for light commercial vehicle leaf spring. First the static analysis is carried out for steel and different composite leaf spring using ANSYS V10. The obtained results are compared with theoretical values and observed that they have good agreement with each other. The fatigue lives of various composite leaf Springs are calculated using Hwang and Han relation. From the results it can be concluded that Boron/Aluminum and Graphite/Epoxy are best suitable composite material for leaf spring.

Nisar S. Shaikh, S.M. Rajmane, [5]. Modelling and Analysis of Suspension System of TATA SUMO by using Composite Material under the Static Load Condition by using FEA. The project is focused on quantifying the stress & deflection analysis using the existing (default) metal leaf springs and then by replacing them with carbon fiber springs. The project gives a brief look on the suitability of composite leaf spring on vehicles and their advantages. Efforts have been made to check the load-deflection of composite leaf spring to that of steel leaf spring. The objective is to present modeling and analysis of composite mono leaf spring and compare its results. From the comparative study, it is seen that bending stresses in composite material is reduced as compared to conventional steel leaf spring & also reduction is observed in bending stresses which is desirable for leaf spring of vehicle & also it has been noticed that , the composite material leaf spring is deflect more as compared to the steel leaf spring. The lower the spring rate, softer the spring. Therefore, smoother the ride.

Ajay B.K. (1), Mandar Gophane(1), P Baskar(2) in this carried out on a multi leaf spring having eight leaves used by a commercial vehicle. In order to reduce the cost and weight of leaf spring, the Automobile sector is replacing steel leaf spring with fiber composite leaf spring, the objective of study was to replace steel material for leaf spring, the material selected was glass fiber reinforced plastic. A spring with constant width and thickness with different arrangements of composite leaves was used for analysis. In this study all models are designed for factor of safety 2.5 and analysis is done using ANSYS software. Deflection and Stresses results were verified for analytical results. Result shows that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was reduced. By capturing the fundamentals of combining dissimilar materials and thus its equivalent modulus affects the overall stiffness characteristics of multi-leaf design.

III. LEAF SPRING

A leaf spring is a simple form of spring usually used for the suspension in vehicles, Originally called a carriage or laminated spring and sometimes referred to as a cart spring or semi-elliptical spring, it is one of the oldest forms of spring. 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 location for the axle is provided by the centre of the arc , while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made by stacking several leaves on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stilton in the motion of the suspension. For this reason some manufacturers have used mono-leaf springs. A leaf spring can either be attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm or directly to the frame at both ends. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. Some springs gets terminated in a concave end, known as a spoon end (seldom used now), which carries a swivelling member.

3.1 Function of Leaf Springs

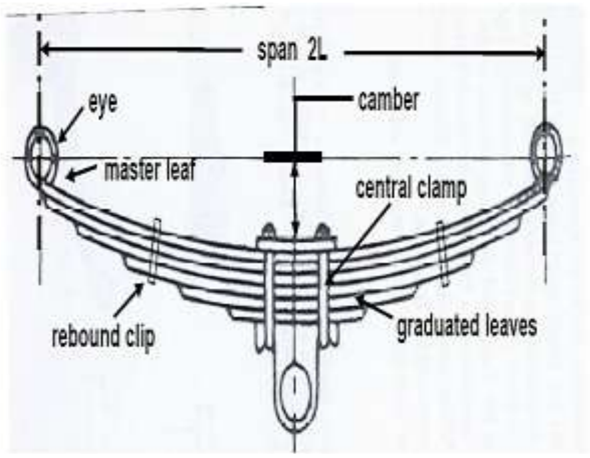
The leaf spring acts as a linkage for holding the axle in position and thus separate linkages are not necessary. It makes the construction of the suspension simple and strong. Other functions are, *a. Weight-bearing:* - One of the purposes of the leaf springs is to bear the weight of the vehicle. The semi-elliptical design helps to support the vehicle, keeping it above the axle and frame. Larger vehicles that must not only support their weight but also their heavier loads may have additional or heavy-duty leaf springs.

b. Tire Contact: - The leaf springs help to control the vehicle so that the tires maintain contact with the road. When the vehicle goes over a bump, the springs help to keep it from bouncing uncontrollably.

c. Suspension: - Leaf springs can help the vehicle stay in alignment as well as help with the suspension. The leaf springs absorb all the bumps and dips in the road, thus providing a more comfortable ride for the vehicle's occupants. The leaf springs also helps in maintaining the vehicle's alignment since their very rigidity keeps the vehicle's wheels tracking straight.

3.2 Multi Leaf Spring

It consists of a series of flat plates, usually of semi-elliptical shape as shown in fig. The leaves are held together by means of two U-bolts and a centre clip. Rebound clips are provided to prevent lateral shifting of the plates during the operation and thus keep the leaves in alignment. The longest leaf, called the master leaf, is bent at both ends to form the spring eye. At the center, the spring is mounted to the axle of the car. Multi- leaf springs are provided with one or two extra full length leaves in addition to the master leaf. These extra full-length leaves are stacked between the graduated-length leaves and the master leaf. The extra full-length are provided to support the transverse shear force.



For the purpose of analysis, the leaves are classified into two groups namely master leaf along with graduated-length leaves forming one group and extra full-length leaves forming the other.

Nipping Of Leaf Springs

The stresses in extra full length leaves are more than that of graduated–length leaves by 50%. One of the methods of equalizing the stresses in different leaves is to pre-stress the spring. The pre-stressing is achieved by bending the leaves to different radii of curvature, before they are assembled with the centre clip. As shown in Figure the full-length leaf is given a greater radius of curvature than the adjacent leaf.

The radius of curvature decreases with shorter leaves. The initial gap C between the extra full-length leaf and the graduated-length leaf before the assembly is called a nip. Such pre-stressing, achieved by a difference in radii of curvature, is known as nipping. Nipping is common in automobile suspension springs.

3.3. Mono Leaf Spring

It Consists of one main leaf where the material's width and thickness are constant. Example - the leaf will be 2" wide throughout its length, and 0.323" in thickness throughout its entire length. Usually parabolic mono leaf springs are manufactured.

IV. MATERIALS FOR LEAF SPRING

Materials used for leaf spring should have adequate strength to account for Bending, Wear, Fatigue and corrosion resistant as it is subjected to dirt's and other atmospheric contamination.

4.1 Conventional Material

Plain carbon steel, Chromium vanadium steel, Chromium- Nickel- Molybdenum steel, Silicon- manganese steel, are the typical materials that are used in the design of leaf springs.

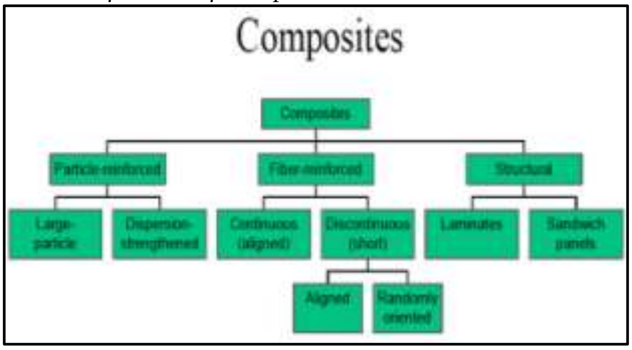
The leaves are heat treated after the forming process. The heat treatment of spring steel products imparts superior strength and therefore increases load bearing capacity. In general terms higher alloy content is mandatory to ensure adequate harden-ability when the thick leaf sections are to be used.

4.2 Composite Material

A composite material (also called a composition material or shortened to composite) is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure.

Natural composites exist in both animals and plants. Wood is a composite – it is made
from long cellulose fibres (a polymer) held together by a much weaker substance called lignin.

4.3 Classification of Composite Materials.



i. composite materials include:

- Mortars, concrete
- Reinforced plastics, such as fiber-reinforced polymer
- Metal composites
- Ceramic composites (composite ceramic and metal matrices)

ii. Composite materials available for leaf springs

a. E-Glass/Epoxy
b. S-Glass/Epoxy
c. Carbon/Epoxy
d. Kevlar/Epoxy.
e. Boron/Aluminum.
f. Graphite/Epoxy.

iii. Properties of Composite Materials

Sr N	Properties	E-Glass/ Epoxy	S-Glass/ Epoxy	Carbon/ Epoxy
1	E_X (MPa)	45000	50000	177000
2	E_Y (MPa)	6500	8000	1060
3	Ez	6500	8000	1060
4	σ_{XY}	0.217	0.3	0.27
5	σ_{YZ}	0.366	0.4	0.02
6	σ_{ZX}	0.217	0.3	0.02
7	G_X (MPa)	4500	5000	7600
8	G_Y (MPa)	2500	3846.2	2500
9	G_Z (MPa)	2500	5000	2500
10	ρ (kg/mm^3)	0.000002	2 x 10^{-9}	0.0000016

4.4 Disadvantages of Composite material

- Compare with the wrought metals, composites are more brittle and they are easily damaged
- Cast metals also tend to be brittle
- During the time of transportation material requires chilling.
- Special equipment's are required and hot curing is also necessary
- For curing process it requires time for cold or hot process.
- After the completion of last rivet the process is done.
- The rivets are to be removed without causing any damage to the matrix.
- Pressure and tooling are required to repair at the original cure temperature.
- Before starting the repair the composite must be cleaned.
- They are expensive.

V METHODOLOGY

5.1 Tool used

ANSYS is an engineering simulation software used for general purpose finite element analysis and for numerically solving mechanical problems. Here ANSYS 16.0 is used for analyzing the performance of conventional and composite leaf spring. Leaf spring is modelled in SOLIDWORKS 2012 software and it is imported in ANSYS 16.0. The conventional steel leaf spring and the composite leaf spring were analyzed under identical conditions using ANSYS software.

5.2 Modelling

In 3D computer graphics, 3D modelling (or modelling) is the process of developing a mathematical representation of any three-dimensional surface of an object (either living or inanimate) via specialized software. The product is called a 3d model. It can be displayed as a two dimensional image through a process called 3D rendering or used in a computer of physical phenomena. The model can also be physically created using 3D printing devices. Models may be created automatically or manually. The manual modelling process of preparing geometric data for 3D computer graphics is similar to plastic arts such as sculpting.
Almost all 3D models can be divided into two categories.

A. Solid - These models define the volume of the object they represent (like a rock). These are more realistic, but more difficult to build. Solid models are mostly used for no visual simulations such as engineering and medical simulations, for CAD and specialized visual applications such as ray tracing and constructive solid geometry.

B. Shell/boundary - these models represent the surface, e.g. the thin boundary of the object, not its volume (like an infinitesimally thin eggshell). These are easier to work with than solid models. Almost all visual models used in games and film are shell models.

FEA solution of engineering problems, such as finding deflections and stresses in a
structure, requires three steps:
1. Pre-process or modelling the structure
2. Analysis
3. Post processing

A brief description of each of these steps follows;
The leaf spring model is created by modelling in pro-E and it is imported in to the ANSYS software. all models are designed for suitable factor of safety. As FEA is a computer based mathematically idealized real system, which breaks geometry into element. It links a series of equation to each and very element and then solves simultaneously to evaluate the behaviour of the entire system. This tool is very useful for problem with complicated geometry, loading and

material properties, where exact and accurate analytical solution is difficult to achieve.

1. Meshing

Discretising of model into the small sections called as the element. Mesh element for this analysis was tetrahedron.

2. Loading & Boundary Conditions:

2.1. Fixed Support- For the leaf spring analysis one of the eye ends of the leaf spring is fixed to the chassis of the vehicle. Since fixed support has restriction to move along X and Y direction as well as to rotate about that fixed point. So this fixed eye end of the leaf spring cannot move in any of the directions i.e. for this eye end degrees of freedom is zero.

2.2. Cylindrical support

Since the leaf spring has to translate in one plane and other movements are restricted to move as there is shackle provided at other end of the leaf spring. Therefore a cylindrical support is applied to the other eye end of leaf spring model. This support provides the movement of the leaf spring in X axis, rotation about Z axis and fixed along Y axis. The load is uniformly distributed on the leaf spring.

VI. CONCLUSION

From the above literature review it clearly shows that most of the researches has taken input of materials either steel or Composites in their analysis, whereas a combination of both conventional material and composites can be used in different combinations in a multi leaf spring and the results can be compared with that of conventional multi-leaf steel spring & composite leaf spring.

Steel with epoxy/resin and aluminium-boron are modelled as individual leaves and stacked together in different combinations to form different models of muti-leaf spring. The model with minimum deflection, minimum von misses stress and high strength to weight ratio will be the best combination which can be used for multi-leaf spring with economic in cost.

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