# Design and analysis of composite leaf spring

**S.Anandakumar (1) G.Balakrishnan(2)**

[1]*Asst professor, Department of Mechanical Engineering, Surya engineering college , Erode, Tamilnadu, india*
*anandakumared@gmail.com*

[2] *Asst professor, Department of Mechanical Engineering, Shree venkateshwara hi-tech engg college,Gobi , Tamilnadu, India*
*balakrishnanmech1989@gmail.com*

**Abstract: In the current situation, the number of automobiles in the world is increasing at a faster rate. Due to this reason, the automobile manufacturers are looking for a replacement of parts with composite materials in order to improve the strength and reduce the weight of the vehicle. The parts made up of composite materials are now increasing popularity in aircraft and shipbuilding. In automobiles, the weight of the leaf spring accounts to a major proportion. Therefore, the automobile manufacturers are looking for replacement in this part. There are many composite materials used for manufacturing of leaf spring. The composite material which is we use here, Glass-Fiber Reinforced Polymer alone with Isophathalic resin. The leaf spring made of GFRP has better properties than that of a conventional leaf spring made of steel. As this material has a higher strength than that of steel spring, the size and the weight of the spring is reduced, similarly the cost also reduced. The leaf spring is to be here, will be fabricated by hand layup technique and then curing will be done. The testing for the GFRP leaf spring for deflection and maximum load will be done.**

Key words: leaf spring, GFRP

## 1. Introduction

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 better material, design optimization and better manufacturing processes. 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 spring weight. This helps in achieving the vehicle with improved riding qualities.

The introduction of composite materials was made it possible to reduce the weight of the 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 to those of steel, multi leaf steel spring are being replaced by mono leaf spring. The composite material offer opportunities for substantial weight saving, but not always are cost effective over their steel counterparts.

In every cars and commercial vehicles leaf spring is one of the main components. It plays a vital role in providing a suspension for the vehicle. Many types of spring are used in vehicle suspensions. Multi leaves steel springs have often been used for rear suspensions. Torsion bar were used in 1960s for rear suspensions. Independent rear suspension often feature steel coil springs. Springs generally experience only a primary single stress during in operation. Torsion bars and coil springs primarily torsion while leaf spring experience bending stress. It carries loads, brake torque, driving torque in additional to shock absorption.

The advantage of leaf spring over helical spring that the ends of the spring may be guided along a definite path as it deflects to act as a structural in addition to the energy absorbing device. Conventionally, the material used for the leaf spring is steel. Steel leaf spring has a very high modulus of elasticity. Thus a single thick leaf spring is too stiff for automotive vehicle use. This adds to the un spring weight of the automobiles since multi steel leaves are used for whole suspension. Hence the automobile industry has show a great interest in replacing the steel leaf spring by a material whose weight is considerably lesser with the same properties as that of that of multi leaf spring, with high damping nature

## 2. Steel leaf spring

Multi-leaf springs are widely used for automobile and rail road suspensions. It consists of a series of flat plates. The leaves are held together by means of two U-bolts and a centre clip. Rebound clips are provided to keep the leaves in alignment and prevent lateral shifting of the plates during the operation. The longest leaf, called the master leaf, is bent at both ends to form the spring eye. At the center, the spring is fixed 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 master leaf and the graduated-length leaves. The extra full-length are provided to support the transverse shear force.

For the purpose of analysis, the leaves are divided into two groups namely master leaf along with graduated-length leaves forming one group and extra full-length leaves forming the other. The following notations are used in the analysis:

$n_f$ = number of extra full-length leaves

n= total number of leaves

b= width of each leaf (mm)

t= thickness of each leaf (mm)

L=length of the cantilever or half the length of semi- elliptic spring (mm)

Table I Composition of steel leaf spring

| Properties | Values |
|---|---|
| %C | 0.5 – 0.6 |
| %Si | 1.5 – 2 |
| %Mn | 0.8 – 1.0 |
| Tensile Strength | 1600 – 2000 N/mm$^2$ |
| Yield Strength | 1500 N/mm$^2$ |
| Brinell Hardness Number HB | 440 – 510 |
| Young's Modulus | $2.1\times10^5$ |

F= force applied at the end of the spring (N)

$F_f$=portion of F taken by the extra full-length leaves (N)

The group of graduated-length leaves along with the master leaf can be treated as a triangular plate. In this case, it is assumed that the individual leaves are separated and the master leaf placed at the centre. The second leaf is cut longitudinally into two halves, each of width (b/2) and placed on each side of the master leaf.

## 3. Design and fabrication composite mono leaf spring

Considering several types of vehicles that have leaf springs and different loading on them, various kinds of composite leaf spring have been developed. In multi-leaf composite leaf spring, the interleaf spring friction plays a spoil spot in damage tolerance. It has to be studied carefully.

The following cross-sections of mono-leaf composite leaf spring for manufacturing easiness are considered.

unidirectional layup may weaken the spring at the mechanical joint area and require strengthening the spring in this region.

1. Constant thickness, constant width design.
2. Constant thickness, varying width design.
3. Varying width, varying thickness design.

In this paper, only a mono-leaf composite leaf spring with varying width and varying thickness is designed and manufactured. The parameters of composite leaf are shown in Table II

Table II. Parameters at center and end points for composite leaf spring

| Parameters | At center | At end |
|---|---|---|
| Breadth in mm | 45 | 69 |
| Thickness in mm | 15 | 21 |

### 3.1. Lay up selection

The amount of elastic energy that can be stored by a leaf spring varies directly with the square of maximum allowable stress and inversely with the modulus of elasticity both in the longitudinal direction. Composite materials like the E Glass/Epoxy in the direction of fibers have good characteristics for storing strain energy. So, the layup is selected to be unidirectional along the longitudinal direction of the spring. The between the fibreglass and the mold. Additional resin is applied and possibly additional sheets of fibreglass. Rollers are used to make sure the resin is between all the layers, the glass is wetted throughout the entire thickness of the laminate, and

3.2 Fabrication process

Resin is mixed with a catalyst or hardener if working with epoxy, otherwise it will not cure (harden) for days/weeks. Next, the mold is wetted out with the mixture. The sheets of fibreglass are placed over the mold and rolled down into the mold using steel rollers. The material must be securely attached to the mold, air must not be trapped in between the fibreglass and the mold. Additional resin is applied and possibly additional sheets of fibreglass. Rollers are used to make sure the resin is between all the layers, the glass is wetted throughout the entire thickness of the laminate, and any air pockets are removed.

The work must be done quickly enough to complete the job before the resin starts to cure. Various curing times can be achieved by altering the amount of catalyst employed. It is important to use the correct ratio of catalyst to resin to ensure the correct curing time. 1% catalyst is a slow cure, 2% is the recommended ratio, and 3% will give a fast cure. Adding more than 4% may result in the resin failing to cure at all. To finish the process, a weight is applied from the top to press out any excess resin and trapped air. Stops (like coins) are used to maintain the thickness which the weight could otherwise compress beyond the desired limit

The fibreglass spray lay-up process is similar to the hand lay-up process but the difference comes from the application of the fibre and resin material to the mold. Spray-up is an open-molding composites fabrication process where resin and reinforcements are sprayed onto a mold. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam or other core material may then be added, and a secondary spray-up layer imbeds the core between the laminates. The part is then cured, cooled and removed from the reusable mold.

any air pockets are removed

Fig.I Wooden template

3.3 Testing of Mono Leaf Spring

The deflection test is carried out in the apparatus for deflection testing of leaf spring and the results are tabulated

**Table III load Vs deflection**

| **Sl. No.** | **Loads in kg** | **Deflection in mm** | **Deflection in mm** | **Stiffness in N/mm** |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 25 | 1 | 1 | 245.25 |
| 3 | 50 | 3 | 3 | 163.5 |
| 4 | 75 | 6 | 6 | 122.62 |
| 5 | 100 | 9 | 9 | 122.62 |
| 6 | 125 | 11 | 11 | 111.47 |
| 7 | 150 | 14.5 | 14.5 | 101.48 |
| 8 | 175 | 17.5 | 17.5 | 98.1 |
| 9 | 200 | 20 | 20 | 98.1 |
| 10 | 225 | 23 | 23 | 95.96 |
| 11 | 250 | 24.5 | 24.5 | 96.17 |
| 12 | 275 | 27 | 27 | 99.91 |
| 13 | 300 | 30 | 30 | 98.1 |

The outer end slides with the bearing on the guide ways provided as it is in the automobile application. When the weight is added to the leaf spring, the leaf spring gets deflected and moves in the guide. Due to this movement to the height of the spring is reduced. This is measured with the help of a vernier caliper. The difference between the initial and the current height gives the amount of deflection for the applied load

4. ANALYSIS IN ANSYS 10.0

The analysis is done by using Ansys 10.0 the analysis is made by considering the leaf spring as a cantilever and fixed on eye ends for both steel and GFRP composite material. The load is applied on the centre of the leaf spring. The solid model is designed in Pro/E and imported in Ansys.

In Ansys the composite material is analysed by considering the material as a solid-tetrahedral 10 node with the properties of GFRP composite laminated structure.

At first composite and steel leaf springs are considered as cantilever type and the analysis is done. After that the analysis is done by considering the structure as a simply supported one. The stress and deflection results are noted from the general postprocessor and the result were tabulated. The stress results and the deflection results taken from the ansys are shown in the figures 2-7

4.1 Materials Properties of GFRP

Tensile modulus along x-direction (Ex), 34000 MPa
Tensile modulus along x-direction (Ey), 6530 MPa
Tensile modulus along x-direction (Ez), 6530 MPa

Shear modulus along XY-direction (Gxy), 2433 MPa
Shear modulus along XY-direction (Gyz), 1698 MPa
Shear modulus along XY-direction (Gzx), 2433 MPa
Poisson ratio along XY-direction (NUxy) 0.217
Poisson ratio along YZ-direction (NUyz) 0.366
Poisson ratio along ZX-direction (NUzx) 0.217
Mass density of the material, (kg/mm$^2$) $2.6\times10^{-6}$

4.2 ANSYS Result

Steel Leaf Spring Ansys Results- Simply supported type

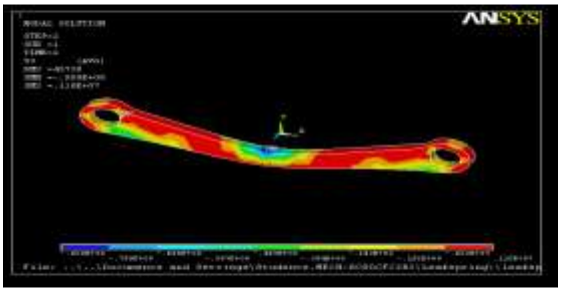

Fig II Third Principle Stress Analysis of Steel Leaf for the load of 3000N

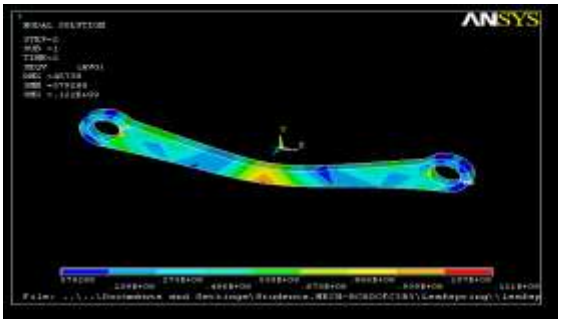

Fig III Von Mises Stress Analysis of Steel Leaf for load 3000N

Composite (GFRP) Leaf Spring Ansys Results- Simply supported type

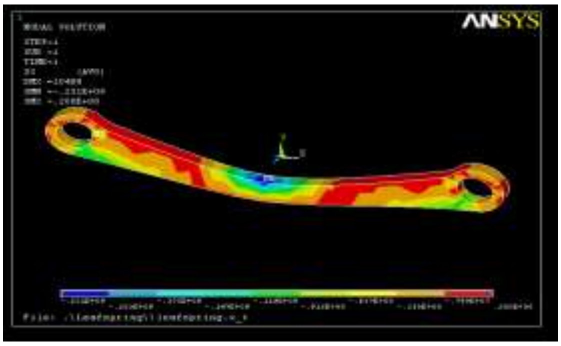

Fig.IV Third Principle Stress Analysis of Composite Leaf for the load of 3000N

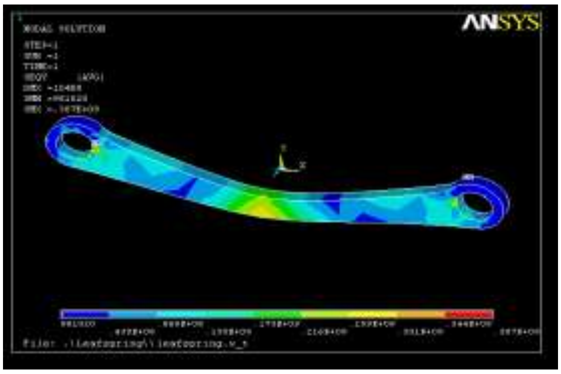

Fig.V Von Mises Stress Analysis of Composite Leaf for load 3000N

 

Composite (GFRP) Leaf Spring Ansys Results- Cantilever type

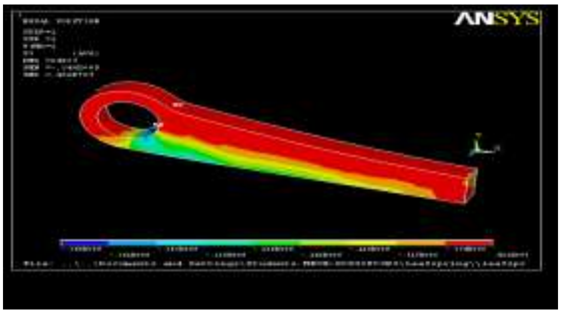


Fig.VI Third Principle Stress Analysis of Composite Leaf for the load of 3000N

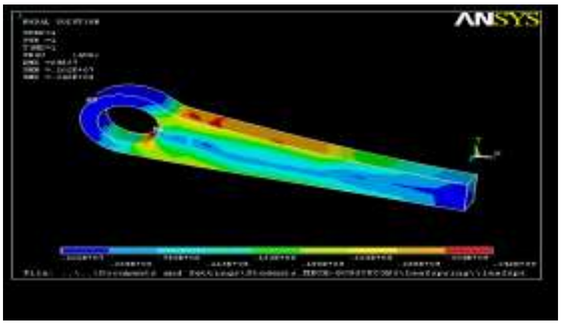


Fig.VII. Von Mises Stress Analysis of Composite Leaf for load 3000N

4.3 Stress Results

Table IV Stress Analysis result for leaf spring (cantilever type)

| Sl.No | Load (N) | Steel ($N/mm^2$) | GFRP ($N/mm^2$) |
|---|---|---|---|
| 1 | 1000 | 149.864 | 44.831 |
| 2 | 2000 | 299.727 | 89.661 |
| 3 | 3000 | 449.591 | 130.071 |
| 4 | 4000 | 586.083 | 173.428 |

Table V Stress Analysis result for leaf spring (simply supported type)

| Sl.No | Load (N) | Steel ($N/mm^2$) | GFRP ($N/mm^2$) |
|---|---|---|---|
| 1 | 1000 | 210.864 | 26.908 |
| 2 | 2000 | 370.726 | 57.071 |
| 3 | 3000 | 510.368 | 90.831 |
| 4 | 4000 | 644 | 113.12 |

5. CONCLUSION

Today's designers of composite structures have gained a thorough understanding of the materials characteristics (and limitations) and have evolved and tailored design tools specifically to suit their needs. Composite GFRP offer many advantages over any form of steel spring. Their weight advantage is the most notable one. There is weight savings over steel leafs. Race-car builders and owners know how valuable this advantage is they do not de-arch as they age as most steel leafs do. They do not corrode. And, the composite material has a compliance characteristic that steel does not have, allowing selection from a greater range of spring rates with vastly superior ride and handling characteristics. A composites structure offers the clear advantages of having no susceptibility to corrosion or fatigue cracking, combined with high resistance to collision damage and relative ease of localized repair .In most cases, our composite springs are priced lower than steel produced by the better-known manufacturers. Also by using automated manufacturing techniques there will be further weight reduction and increased strength for the composite GFRP leaf springs.

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