# Design, Analysis and Fabrication of a Composite Leaf Spring for Weight Reduction in Light Weight Automobile

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***Abstract-*** *Looking to the present situation of Automobile industry, Weight reduction of an automobile is a major area of concern to the manufacturer. Generally Leaf spring is used for the suspension characteristics and having 10 to 20% of the unsprung weight. Thus a reduction in weight of the spring will improve efficiency of the vehicle. These springs are generally made of steel material which is having more weight. In order to reduce weight, here composite leaf spring is used instead of steel leaf spring.This Paper describes the design and analysis of existing steel and laminated composite material leaf spring. The conventional steel leaf spring used in Maruti Omni is taken for basic dimensioning and moulding purpose. ANSYS is used for Static structural analysis. Fatigue analysis for analyzing life cycles is performed on nCode. In the present work Hand lay-up composite fabrication process is used for making the composite (Polyester resins with chopped strand mat) leaf spring. The specimen is tested on UTM for the static Load carrying capacity. Then E-glass/epoxy composite material is suggested for leaf spring and fatigue analysis is performed for the same. Results are compared with the steel (55Si2Mn90) leaf spring.*

## I. INTRODUCTION

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring. A leaf spring takes the form of a slender arc-shaped and rectangular cross section.

The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. 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. 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 stiction in the motion of the suspension. For this reason manufacturers have experimented with mono-leaf springs.

## II. LITERATURE REVIEW

**H. A. Al-Qureshi** presented a general study on the analysis, design and fabrication of composite leaf spring. The suspension spring of a car, “jeep” was selected as a prototype. A single leaf, variable thickness spring of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf steel spring, was designed fabricated (molded and hoop wound) and tested. The testing was performed experimentally in the laboratory and was followed by the road test. Comparison between the performance of the GFRP and the multi leaf steel spring was presented [1].

**Mahmood M. Shokrieh & Davood Rezaei** analyzed four-leaf steel spring used in the rear suspension system of light vehicles using the ANSYS V5.4 software. The finite element results showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main consideration is 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 (Tsai–Wu failure criterion) and displacements. The results showed 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 [2].

**G S Shiva Shankar and Sambagam Vijayarangan** described a low cost fabrication of complete mono composite leaf spring and mono composite leaf spring with bonded end joints. Also, general study on the analysis and design. A single leaf with variable thickness and width for constant cross sectional area of unidirectional glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated (hand-lay up technique) and tested. Computer algorithm using C-language has been used for the design of constant cross-section leaf spring. The results showed that an spring width decreases hyperbolically and thickness increases linearly from the spring eyes towards the axle seat. The finite element results using ANSYS software showing stresses and deflections were verified with analytical and experimental results. The design constraints were stresses (Tsai-Wu failure criterion) and displacement. Compared to the steel spring, the composite spring has stresses that are much lower, the natural frequency is higher and the spring weight is nearly 85 % lower with bonded end joint and with complete eye unit[3].

**K K Jadhao and Dr. R S Dalu** described that the composite material has high strength to weight ratio, good corrosion resistance properties. The objective of present study was to replace material for leaf spring. The material selected was glass fiber reinforced plastic (GFRP) and the polyester resin (NETPOL 1011) can be used which was more economical this will reduce total cost of composite leaf spring. A spring with constant width and thickness was fabricated by hand lay-up technique which was very simple and economical. The experiments were conducted on UTM and numerical analysis was done via (FEA) using ANSYS software. Stresses and deflection results were verified for analytical and experimental results. Result shows that, the composite spring has stresses much lower than steel leaf spring and weight of composite spring was nearly reduced up to 85%[5].

**Thippeswamy Ekbote, K.S.Sadashivappa and D. Abdul budan** analyzed a nine-leaf steel spring used in the rear suspension system of a light duty vehicle by ANSYS software. The finite element analysis results of stress and deflection were verified with the analytical solution and experimental results. It was proposed to replace the existing steel spring with composite spring. [6].

## III. DESIGN

### Assumptions

The following assumptions are made to obtain the objectives of the leaf spring.

1. The vehicle is assumed to be stationary.
2. There are four suspension devices, two at front and two at back..
3. Static analysis is done for rear axle single leaf spring.

### Loading Condition

The parabolic leaf spring of a MARUTI OMNI rear suspension is taken into consideration

It is a light weight passenger vehicle having a Max Gross Weight of 1550 kg.

Total weight of the vehicle at full load
= Gross Weight of vehicle × gravity
= 1500 x 9.81
= 14715 N.

There are four suspensions, two at the front and two at the back.
So, Load on one suspension = 14715/4
= 3500 N (Approx)
FOS = 2.5 – 3

Table 1: Material Properties of existing PLS (55Si2Mn90)

| PARAMETER | VALUE |
|---|---|
| Young's Modulus (E) | 200GPa |
| Poisson's Ratio | 0.3 |
| Tensile Strength Ultimate | 1962 MPa |
| Tensile Strength Yield | 1500 MPa |
| Density | 7850 kg/m3 |
| Thermal Expansion | 11x10-6 / oC |

Table 2: Material Properties of fabricated polyester resins with chopped strand mat[13]

| PARAMETER | VALUE |
|---|---|
| Tensile Strength | 90 – 118 MPa |
| Tensile Modulus (E) | 7.5 – 8.8 GPa |
| Failure strain | 1.5 – 2.0 % |
| Flexural strength | 165-243 MPa |
| Flexural Modulus | 5.9 -7.2 GPa |
| Density | 2550 kg/m3 |
| Failure strain | 3.1 – 3.6 % |

Table 3 Material Properties of the E-glass/epoxy [6]

| Properties | Units | Value |
|---|---|---|
| Tensile modulus along X-direction (E x) | MPa | 36040 |
| Tensile modulus along Y-direction (E y) | MPa | 5 195 |
| Tensile modulus along Z-direction (E z) | MPa | 5 195 |
| Shear modulus along XY-direction (G xy), | MPa | 2 127 |
| Shear modulus along YZ-direction (G yz) | MPa | 1550 |
| Shear modulus along ZX-direction (G zx), | MPa | 2 127 |
| Poisson's ratio along XY-direction (u xy) | | 0.26 |
| Poisson's ratio along YZ-direction (u yz) | | 0.29 |
| Poisson's ratio along ZX-direction (u zx) | | 0.26 |
| Mass density of the material (ρ), | kg/m3 | 1720 |
| Tensile strength of the material | MPa | 900 |
| Compressive strength of the material | MPa | 450 |
| Flexural modulus of the material | GPa | 40 |
| Flexural strength of the material | MPa | 1200 |

## IV. STATIC ANALYSIS RESULT

- Frontal eye of the leaf spring is provided with cylindrical support.
- The other end of the leaf spring allowed for rotation to deflect the spring in X and Y direction along its length to meet the actual conditions.
- A Load of 3500 N is then applied in the upward direction at the centre of the spring.

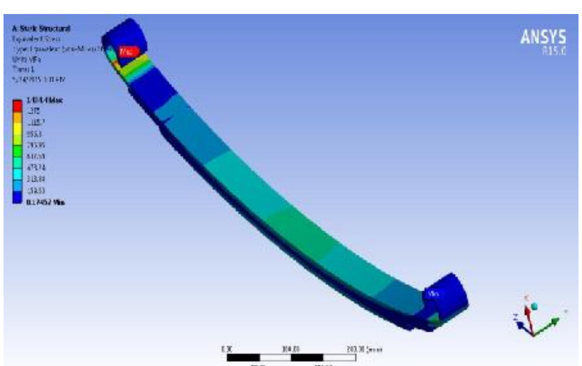


Figure Von-Mises stress in steel material leaf spring

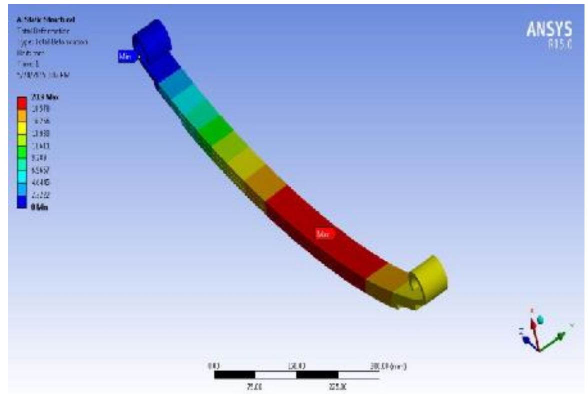


Figure  Deflection in steel material leaf spring

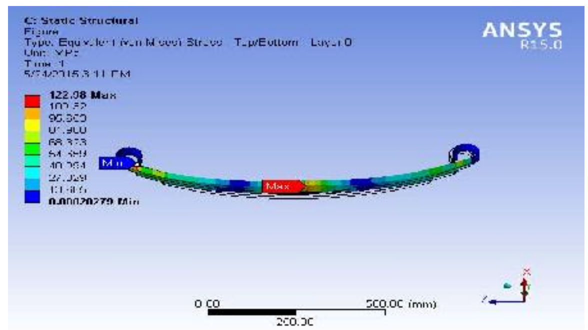


Figure Von-Mises stress in E-glass/Epoxy leaf spring

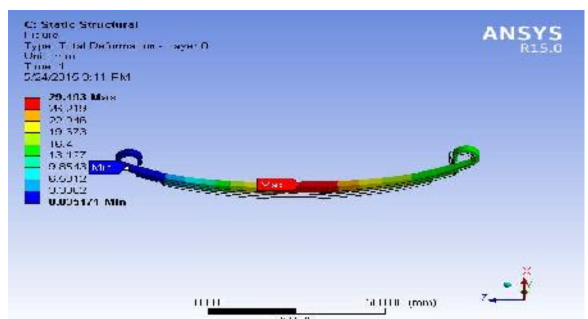


Figure : Deflection in E-glass/Epoxy leaf spring

## V. FATIGUE ANALYSIS OF E-GLASS/EPOXY LEAF SPRING USING NCODE

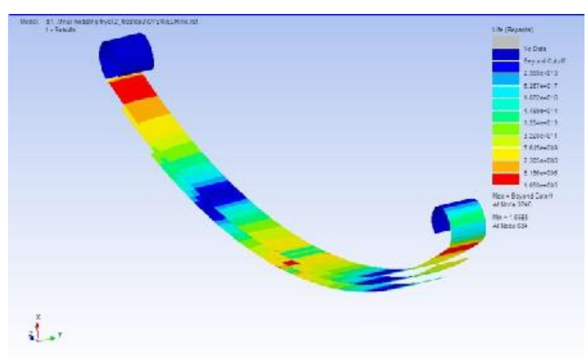

Figure Fatigue Analysis of E-glass/Epoxy Leaf spring

## VI. FABRICATION OF COMPOSITE LEAF SPRING BY HAND LAY UP TECHNIQUE

Figure Fabricated leaf spring

Table 4: Results obtained from Testing on UTM

| Load (in N) | Deflections(in mm) |
|---|---|
| 500 | 47 |
| 1000 | 80 |
| 1200 | 110 |
| 1400 | 130 |
| 1500 | 150 |

The deflection of Polyester resins with chopped strand mat leaf springs is very high, but using E-glass/Epoxy material and a proper technique for manufacturing the desired results can be obtained.

## VII. RESULTS

Table5 : Static steel and E-glass/Epoxy result comparison

| Parameter | Steel | Composite | Difference |
|---|---|---|---|
| Bending Stress | 1434.4Mpa | 122.98 Mpa | 91% |
| Mass | 15.01705 kg | 3.826 kg | 74.522% |

Life cycles for E-Glass/Epoxy Leaf spring is 1,00,000 cycles as obtained from fatigue analysis using nCode.

## VIII. CONCLUSION

The Design, Fabrication and structural analysis of leaf spring has been carried out for composite material. Fabrication is carried out by hand lay-up technic for Polyester resins with the chopped strand mat material. Same specimen was tested on UTM machine had shown greater capability to carry the load with less weight compared to steel.Weight reduction of 75% is achieved which improves the fuel efficiency of the automobile.

To further improve the Load carrying capacity and restrict the deflections to some limiting value E-glass/Epoxy composite material is suggested for manufacturing. Static and fatigue analysis has been carried out for it and shown acceptable life cycles.

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