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*Research Paper*

# PERFORMANCE ANALYSIS OF STEEL LEAF SPRING WITH COMPOSITE LEAF SPRING AND FABRICATION OF COMPOSITE LEAF SPRING

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Increasing competition and innovation in automobile sector tends to modify the existing products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are one of the oldest suspension components that are being still used widely in automobiles. Weight reduction is also given due importance by automobile manufacturers. The automobile industry has shown increased interest in the use of composite leaf spring in the place of conventional steel leaf spring due to its high strength to weight ratio. The introduction of composite materials has made it possible to reduce the weight of the leaf spring without any reduction in load carrying capacity and stiffness. Therefore the objective of this paper is to present a general study on the performance comparison of composite (Glass Fibre Reinforced plastic - GFRP) leaf spring and conventional leaf spring. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The conventional steel leaf spring and the composite leaf spring were analyzed under similar conditions using ANSYS software and the results are presented. An Eglass/Epoxy composite leaf spring is fabricated using hand layup method. The composite and steel leaf spring is tested using universal testing machine and the results are compared.

***Keywords:*** Leaf spring, Composite, Glass Fibre Reinforced Plastic (GFRP)

## INTRODUCTION

Increasing competition and innovation in automobile sector tends to modify the existing products or replace old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of vibrations in the spring and the energy absorbed is stored in spring as strain energy and then released slowly. Thus strain energy of material used for

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spring is the important property to be considered. The specific strain energy is inversely proportional to the density and Young's modulus. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Hence, composite material becomes a very strong candidate for such applications. The introduction of composite materials has made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity. Hence, steel leaf springs are being replaced by composite leaf springs.

## TOOL

ANSYS is engineering simulation software used for general purpose finite element analysis and for numerically solving mechanical problems. Here ANSYS 11.0 is used for analyzing the performance of conventional and composite leaf spring. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The conventional steel leaf spring and the composite leaf spring were analyzed under similar conditions using ANSYS software and the results are presented in Table 1.

## DIMENSIONS

**Table 1: Dimensions of the Master Leaf Spring**

| Parameters | Value |
|---|---|
| Length of master leaf spring | 1200mm |
| Free camber | 200mm |
| Thickness | 6mm |
| Width | 50mm |

## DIMENSIONS OF THE LEAF SPRING

Number of graduated leaves = 6

Ineffective length = 200 mm

Length of second leaf = 1150 mm

Length of third leaf = 1000 mm

Length of fourth leaf = 700 mm

Length of fifth leaf = 580 mm

Length of sixth leaf = 430 mm

Length of seventh leaf = 300 mm

This leaf spring is used in Ambassador car. Material used for steel leaf spring is 55 Si 2 Mn 90 steel.

## THEORETICAL CALCULATIONS

Deflection $\delta = 6\ WL^3/nEbt^3$ ...(1)

$= 6 * 4000*500^3/ 7*2*10^5*50*6^3$

$= 198$ mm

Bending stress $\sigma = 6\ WL/nbt^2$ ...(2)

$= 6*4000*500/7*50*6^2$

$= 952.38 N/mm^2$

## SELECTION OF COMPOSITE MATERIAL

The ability to absorb and store more amount of energy ensures the comfortable operation of a suspension system. However, the problem of heavy weight of spring is still persistent when using steel leaf spring. This can be remedied by introducing composite material instead of steel which is normally used in the conventional leaf spring. It is well known that springs are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as

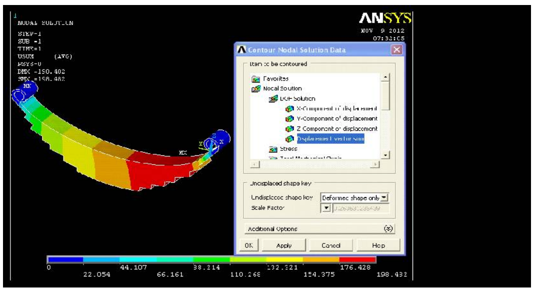
$$U = \sigma^2/\rho E \qquad ...(3)$$

where $\sigma$ is the strength, $\rho$ the density and E is the Young's modulus of the spring material. It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Research has indicated that E-Glass/Epoxy has good characteristics for storing specific strain energy. Hence, E Glass/ Epoxy is selected as the composite material.

## ANALYSIS OF LEAF SPRINGS USING ANSYS

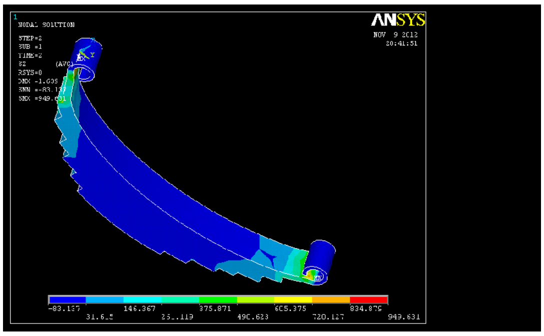
All the analysis for the springs is done by using ANSYS 11.0. For composite leaf spring the same parameters are used as that of conventional leaf spring. For designing of leaf spring the camber is taken as 200 mm. Leaf spring is modelled in Unigraphics NX4 software and it is imported in ANSYS 11.0. The constraint is given at the two eye-rolled ends. One of the end is provided with translational movement so as to adjust with the deflection. This eye end is free to travel in longitudinal direction .This particular motion will help leaf spring to get flattened when the load is applied. The stress and deflection analysis is done for conventional and composite leaf spring using ANSYS software. The results for both composite and conventional leaf spring is compared and given below.

**Figure 1: Deflection Analysis**




## ANSYS RESULTS FOR CONVENTIONAL LEAF SPRING

**Figure 2: Stress Analysis**




## RESULTS COMPARISON

**Table 2: Comparison of Theoretical and Analytical Result**

| Parameters | Theoretical Results | FEA Results | Error |
|---|---|---|---|
| Static load ( N ) | 4000 | 4000 | Nil |
| Deflection (mm) | 198 | 198.48 | 0.24% |
| Bending Stress (N/mm$^2$) | 952.38 | 949.63 | 0.29% |

## ANSYS RESULTS FOR COMPOSITE LEAF SPRING

**Figure 3: Deflection Analysis**

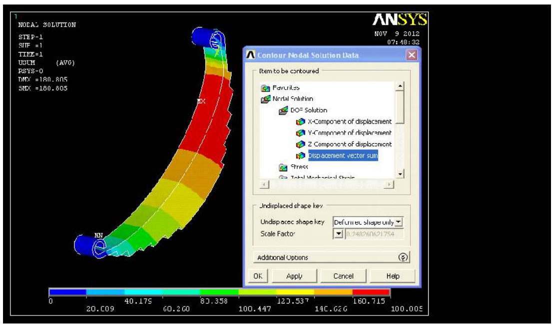
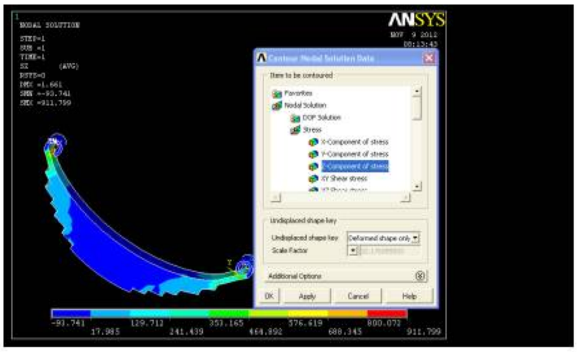


**Figure 4: Stress Analysis**




## RESULTS COMPARISON

For static load of 4000 N the deflection is 198.48 mm and bending stress induced is 949.63 N/mm$^2$ in steel leaf spring and for the same load the deflection is 180.81 mm and bending stress is 911.79 for E – Glass/ Epoxy Leaf spring. Based on the results it is decided to fabricate an E Glass/ Epoxy Leaf spring using hand lay up technique (Table 3).

**Table 3: Comparison of Deflection and Stress**

| Material | Static Load (N) | Defection (mm) | Bending Stress (N/mm$^2$) |
|---|---|---|---|
| Steel | 4000 | 198.48 | 949.63 |
| E-Glass/ Epoxy | 4000 | 180.81 | 911.79 |

**Table 4: Dimensions of the Composite Leaf Spring**

| Parameters | Value |
|---|---|
| Length of master leaf spring | 1200mm |
| Free camber | 200mm |
| Thickness | 6mm |
| Width | 40mm |

## MATERIALS

Materials used for reinforcement is E-Glass fibre rovings which weighs 360 g per sq. m. The epoxy resin selected is liquid diglycidyle ether of Bisphenol A type ( Araldite LY556) which has a density of 1.15-1.20 g/cm$^3$. It is easy to process and has good fibre impregnation properties and good mechanical and thermal properties.

The hardener used is Triethylene Tetra Amine (TETA - Aradur HY951) which has a density of 0.98 g/cm$^3$. It cures at room temperature, has good mechanical strength and is resistant to atmospheric and chemical degradation.

The volume ratio of hardener to resin is 1:10. Due to very low cure shrinkage, Araldite LY556 with hardener HY951 based laminates will be dimensionally stable and free from internal stresses. This forms a low viscosity room temperature curing laminate system.

## FABRICATION PROCEDURE

Hand lay up technique is used for fabrication. The glass fibre rovings are marked at regular intervals of 40 mm (width of the leaf spring) and then they are cut to desired length so that they can be placed layer by layer during fabrication.I nitially the resin is applied and the first layer of glass fibre is placed followed by application of epoxy-resin. Another

**Figure 5: Fibre Glass Rovings**

**Figure 6: Composite Leaf Spring Before Curing**

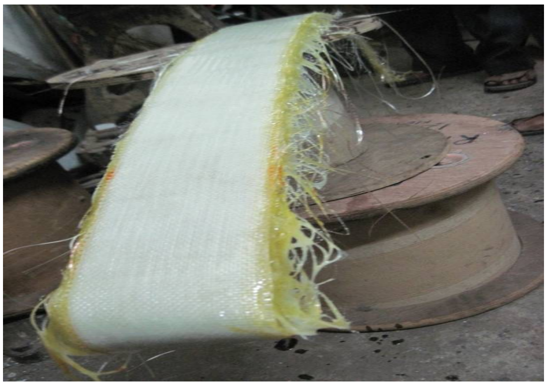


**Figure 7: Composite Leaf Spring**

layer of glass fibre is placed and then using a roller it is press rolled to remove any entrapped air between the layers. Further layers of glass fibre are placed and resin applied alternately and the procedure is repeated till the desired thickness of the leaf spring is obtained. The composite leaf spring is allowed to harden and then it is removed and trimmed to dimensions.

## TESTING PROCEDURE

The experiments were performed on servo – controlled universal testing machine. The leaf spring is mounted in an inverted manner on the test bed .Two eye ends are positioned using clamping devices and the load is applied upto 250 N gradually from the top at the center of the leaf spring. The composite and steel leaf spring are tested under similar conditions. The load versus displacement and load versus stress graphs are obtained for each leaf spring from the automatic computerised chart recorder using data acquisition system inbuilt in the machine. The results are presented for comparison.

**Figure 8: Load vs. Deflection Graph for Composite Leaf Spring**

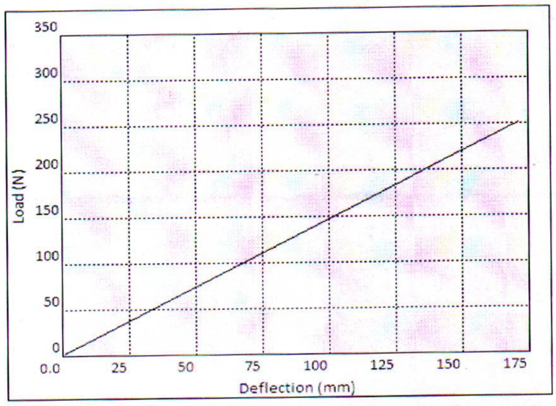



**Figure 9: Load vs Stress Graph for Composite Leaf Spring**

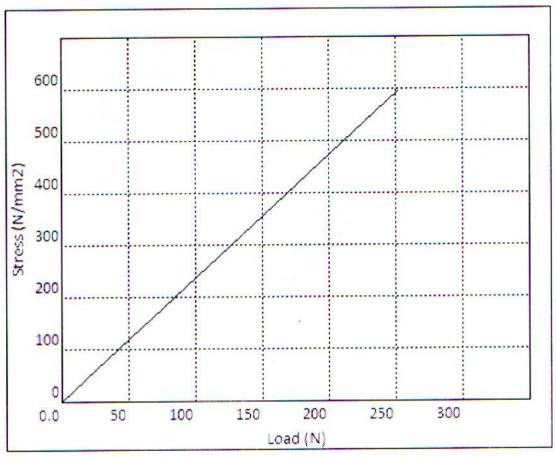


**Figure 10: Load vs Deflection Graph for Composite Leaf Spring**

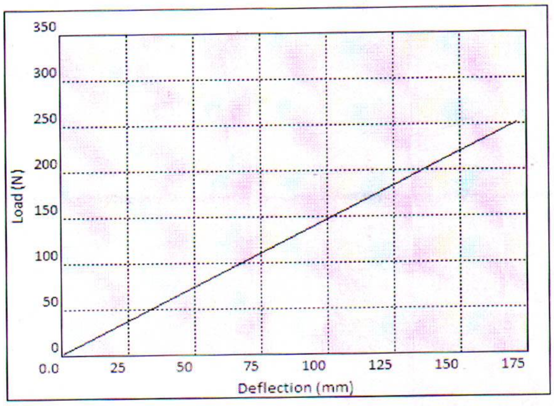
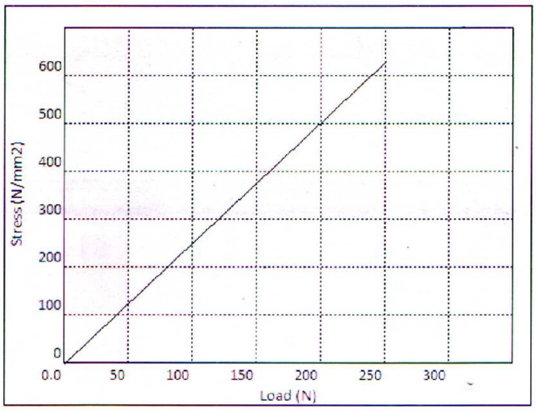



**Figure 11: Load Vs Stress Graph for Steel Leaf Spring**




## RESULTS COMPARISON

**Table 5: Comparison of Deflection and Stress**

| Material | Static Load (N) | Defection (mm) | Bending Stress (N/mm²) |
|---|---|---|---|
| Steel | 250 | 185.50 | 620.00 |
| E-Glass/ Epoxy | 250 | 173.00 | 593.75 |

## WEIGHTS COMPARISON

**Table 6: Comparison of Weights**

| S. No. | Material | Weight(kg) |
|---|---|---|
| 1 | Steel | 2.450 |
| 2 | E – Glass/ Epoxy | 0.700 |

## CONCLUSION

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.

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