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STATIC ANALYSIS OF COMPOSITE MONO LEAF SPRING

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ABSTRACT:

The automobile industry has shown increased interest in the replacement of steel spring with fiberglass composite leaf spring due to high strength to weight ratio. The aim of this paper is to suggest the best composite material for design and fabrication of complete mono composite leaf spring. A single leaf with variable thickness and variable 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 modeled and analyzed. The results showed that the best composite the 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 results. The design constraints were stresses and displacement. Compared to the steel spring, the composite spring has stresses and deflection that are much lower, and the spring weight is nearly 78 % lower with complete eye unit. Also the same analysis is carried out for different composite materials and compared the results for suggesting the best composite material for fabrication of composite mono leaf spring.

Key words: leaf spring; composite; bonded end joints;

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 unsprung weight. This helps in achieving the vehicle with improved riding qualities. 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

$$U = \frac{\sigma^2}{\rho E}$$

Where σ is the strength, ρ the density and E 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. The introduction of composite materials was made it possible to reduce the weight of the leaf spring with out any reduction on load carrying capacity and stiffness. Since; the composite materials have more elastic strain energy storage capacity (1) and high strength-to-weight ratio as compared to those of steel.

Several papers were devoted to the application of composite materials for automobiles I. Rajendran [1, 2] Studied the application of composite structures for automobiles and design optimization of a composite leaf spring. Great effort has been made by the automotive industries in the application of leaf springs made from composite materials [3, 4].

S. Vijayarangan [5] showed the introduction of fiber reinforced plastics (FRP) made it possible to reduce the weight of a machine element without any reduction of the load carrying capacity. Because of FRP materials high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel, multi-leaf steel springs are being replaced by mono leaf FRP springs [6, 7]. In every automobile, i.e. four wheelers and railways, the leaf spring is one of the main components and it provides a good suspension and it plays a vital role in automobile application. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. The advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. The geometry of the Steel leaf spring is shown in Fig. 1.

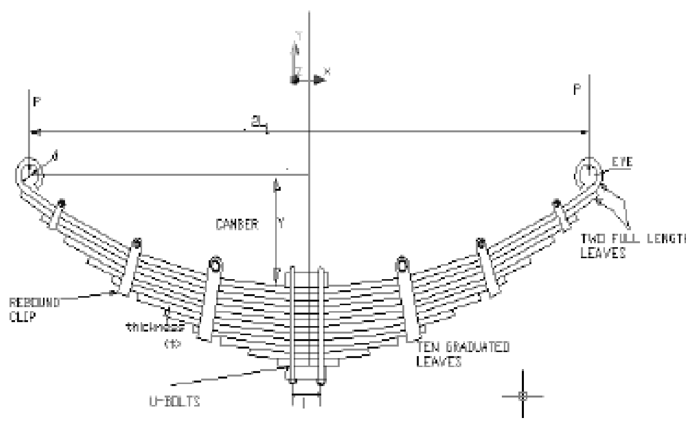

Fig.1.Leaf spring

2. SPECIFICATION OF THE PROBLEM:

The objective of the present work is to suggest a best composite material for design, analyses, fabricate of unidirectional Glass Fiber/Epoxy complete composite mono leaf spring. This is an alternative, efficient and economical method over wet filament-winding technique [1].

3. DESIGN PARAMETERS OF STEEL LEAF SPRING:

Parameters of the steel leaf spring used in this work are shown in Table 1.

Parameter	Value
Material selected – Steel	55Si2Mn90
Tensile strength (N/mm^2)	1962
Yield strength (N/mm^2)	1470
Young's modulus E (N/mm^2)	$2.1 \cdot 10^5$
Design stress (σ_b) (N/mm^2)	653
Total length (mm)	1190
The arc length between the axle seat and the front eye (mm)	595
Arc height at axle seat (mm)	120
Spring rate (N/mm)	32
Normal static loading (N)	3850
Available space for spring width (mm)	60 – 70
Spring weight (kg)	26

Table.1. Parameters of steel leaf spring [2]

4. DESIGN AND ANALYSIS OF 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.

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 results showed that a spring width decreases hyperbolically and thickness increases linearly from the spring eyes towards the axle seat. The parameters of composite leaf spring are shown in Table 2.

Parameters	At center	At end
Breadth in mm	45	69
Thickness in mm	150	21

Table.2.Parameters at center and end points for composite leaf spring [3]

5. THREE DIMENSIONAL FEA:

To design steel leaf spring, a stress analysis was performed using the finite element method done usingANSYS software. Modeling was done for every leaf with eight-node 3D brick element (solid 45) and five-node 3Dcontact element (contact 49) used to represent contact and sliding between adjacent surfaces of leaves. Also, analysis carried out for composite leaf spring for Glass/Epoxy, Graphite/Epoxy, Carbon/Epoxy, Kevlar epoxy, Boron Aluminum composite materials and the results were compared with steel leaf spring. The maximum peel and shear stresses along the adhesive layer were measured. Figs. 2 to 14 represent FEA results for steel and composite mono leaf spring (Glass/Epoxy). The maximum peel and shear stresses along the bonded adhesive layer for glass/epoxy were measured and plotted as shown in Figs.15 and 16.

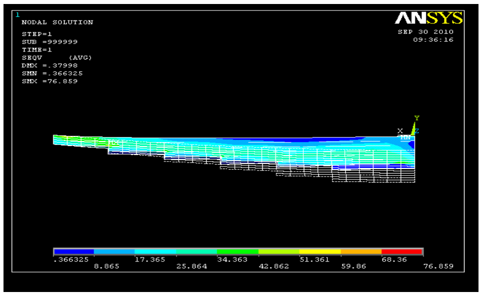

Fig.2.Displacement pattern for steel Leaf spring

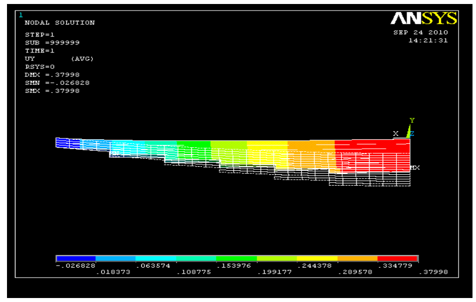

Fig.3.Stress pattern for steel Leaf spring

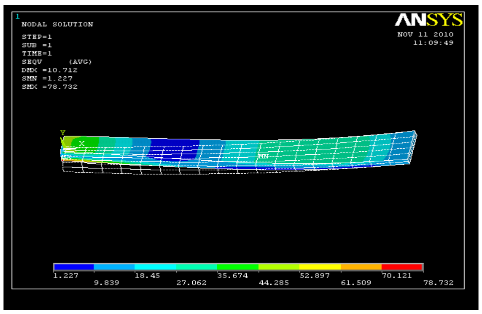

Fig.4.Displacement pattern for E-Glass/Epoxy

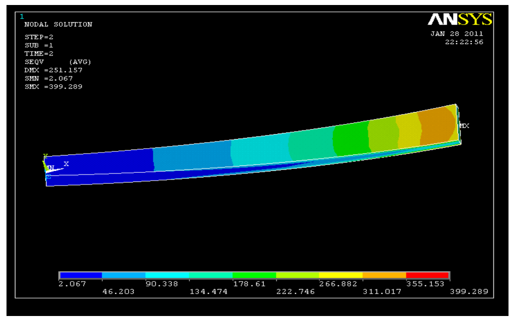

Fig.5.Stress pattern for E-Glass/Epoxy

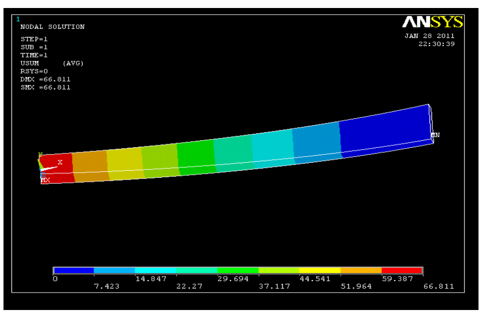

Fig.6.Displacement pattern for Graphite Epoxy

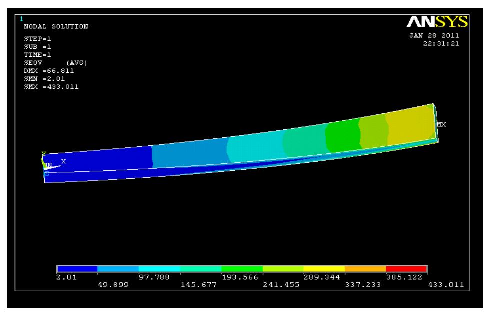

Fig.7.Stress pattern for Graphite Epoxy

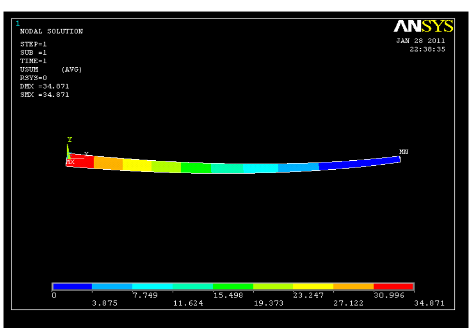

Fig.8 Displacement pattern for Boron Aluminum

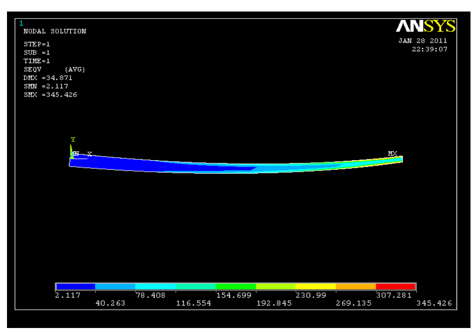

Fig.9 Stress pattern for Boron Aluminum

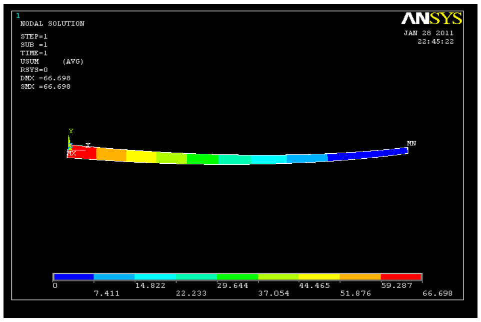

Fig.10.Displacement pattern for Carbon Epoxy

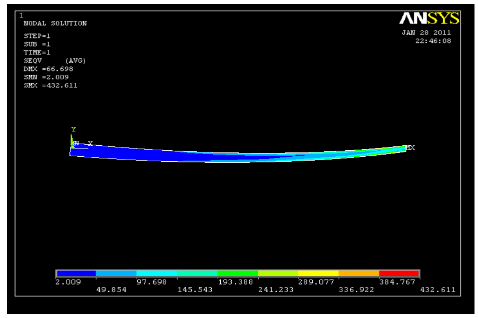

Fig.11. Stress pattern for Carbon Epoxy

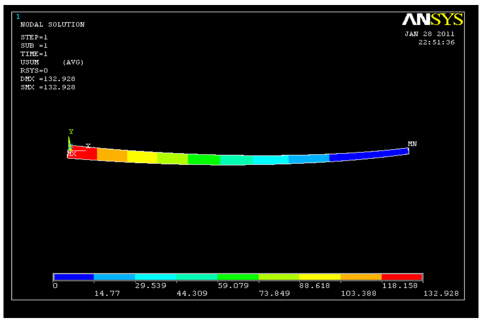

Fig.12. Displacement Pattern for Kevlar Epoxy

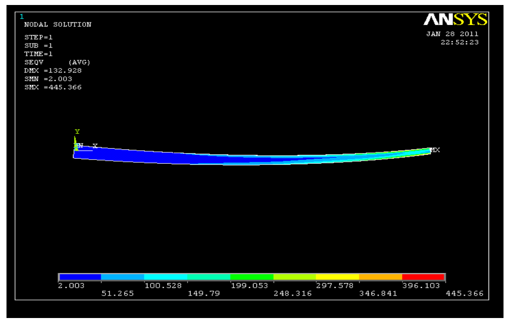

Fig.13. Stress Pattern for Kevlar Epoxy

6. RESULTS AND DISCUSSION:

FEA results of the leaf springs under static loading containing the stresses and deflection are listed in the Table 4.Fig.2 represent the deflection pattern and fig.3 represents the stress distribution. From the fig the maximum deflection and maximum stress values are considered and the composite material has to give the results approximately equal to the values of steel leaf spring. From fig 4 to fig 13 shows the maximum deflection and maximum stress values for different composite materials and these values are tabulated in the Table 4.

Since the composite leaf spring is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. Since, the composite spring is designed for same stiffness as that of steel leaf spring, both the springs are considered to be almost equal in vehicle stability. The major disadvantages of composite leaf spring are chipping resistance. The matrix material is likely to chip off when it is subjected to a poor road environments (that is, if some stone hit the composite leaf spring then it may produce chipping) which may break some fibers in the lower portion of the spring. This may result in a loss of capability to share flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problem will not be there. Composite leaf springs made of polymer matrix composites have high strength retention on ageing at severe environments.

The steel leaf spring was replaced with a composition. The objective was to obtain a spring with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacements.. Thus, the objective of the unsprung mass is achieved to a larger extent.

S.no	Element name	Max deflection(mm)	Max stress (mpa)
1	Steel	77	425.17
2	E Glass Epoxy	79	400.15
3	Graphite Epoxy	66.91	433.91
4	Boron Aluminum	35.97	345.78
5	Carbon Epoxy	66.69	432.51
6	Kevlar Epoxy	82.1	439.15

Table.4. Comparison results of deflection and stress

From Table 4 Graphite/Epoxy and Carbon/Epoxy were not considered for fabrication as well as testing of leaf spring due to higher cost of the material. Boron Aluminum is not suitable form with stand the static load. Kevlar is also not considering as a best one even though it gives maximum deflection because of high cost and scarce availability. So from the table the best composite material is E-Glass/Epoxy.

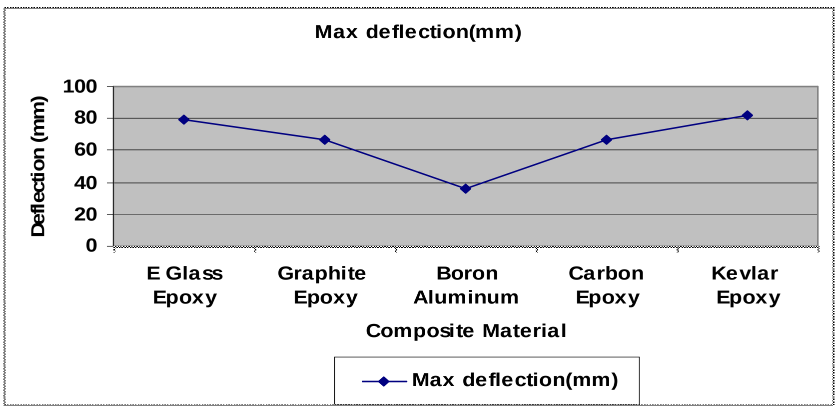

Fig.14.Maximum deflection distribution graph

The graph (fig.14) shows the maximum deflection, from the graph E-Glass/Epoxy gives the maximum deflection and Boron Aluminum gives the minimum deflection. Among the five composite materials E-Glass /Epoxy best suits to replace steel leaf spring.

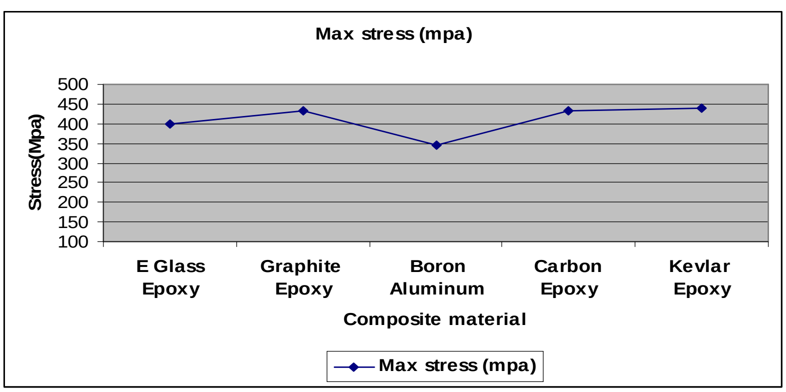

Fig.15.Maximum stress distribution graph

The graph (fig.15) shows the maximum Stress distribution from the graph Graphite-Epoxy gives the maximum Stress and Boron Aluminum gives the minimum Stress. Among the five composite materials E-Glass /Epoxy best suits to replace steel leaf spring.

CONCLUSION:

- The development of a composite mono 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;
- The 3-D modeling of both steel and composite leaf spring is done and analyzed using ANSYS;
- A comparative study has been made between composite and steel leaf spring with respect to weight, cost and strength;
- The analytical results were compared with FEA and the results show good agreement with test results.
- From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.

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