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Modeling and Analysis of Laminated Composite Leaf Spring under the Static Load Condition by using FEA

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ABSTRACT: *This paper describes design and analysis of laminated composite mono leaf spring. Weight reduction is now the main issue in automobile industries. In the present work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle is taken for modeling and analysis of a laminated composite mono leaf spring with three different composite materials namely, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The three different composite mono leaf springs have been modeled by considering uniform cross-section, with unidirectional fiber orientation angle for each lamina of a laminate. Static analysis of a 3-D model has been performed using ANSYS 10.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found to have 47% lesser stresses, 25%~65% higher stiffness, 27%~67% higher frequency and weight reduction of 73%~80% is achieved.*

Keywords: *Laminated Composite leaf spring (LCLS), Static analysis, E- Glass/Epoxy, S-glass/Epoxy, Carbon/Epoxy,*

I. INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers 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 automobiles as it accounts for 10% - 20% of the unstrung weight. This achieves the vehicle with more fuel efficiency and 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 with those of steel, multi- leaf steel springs are being replaced by mono- leaf composite laminated springs. The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of vibrations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system. According to the studies made a material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. Fortunately, composites have these characteristics. In the present work, an attempt is made to replace the existing mono steel leaf spring used in maruti 800 passenger car with a laminated composite mono steel leaf spring made of three different composite materials viz., E-glass/epoxy, S-glass/epoxy and Carbon/epoxy composites. Dimensions and the number of leaves for both steel leaf spring and laminated composite leaf springs are considered to be the same.

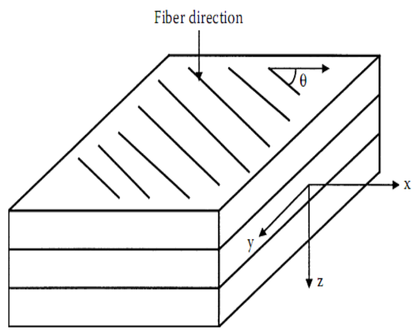

Fig. No.1 Schematic diagram of a laminate.

II. LITERATURE REVIEW

The review mainly focuses on replacement of steel leaf spring with the composite leaf spring made of glass fibre reinforced polymer (GFRP) and majority of the published work applies to them.

Mouleeswaran et al. [1] describes sataic and fatigue analysis of steel leaf spring and composite multi leaf spring made up of glass fibre reinforced polymer using life datanalysis. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle are taken and are verified by deisgn calculations. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 7.1 and compared with experimental results.

Al-Qureshi et al. [2] has described a single leaf, variable thickness spring of glass fiber reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi leaf spring, was designed, fabricated and tested.

Rajendran I, et al.[3] investigated the formulation and solution technique using genetic algorithms (GA) for design optimization of composite leaf springs. Gulur Siddaramanna et al. [4] explain the automobile industry has shown interest in the replacement of steel spring with fibreglass composite leaf spring due to high strength to weight ratio.

Peiyong et al. [5] describes that the leaf spring design was mainly based on simplified equations and trail and error methods. The simplified equation models were lilmited to the three-link mechanism assumption and linear beam method. This work presents detailed finite element modeling and analysis of a two stage multi leaf spring, a leaf spring assembly, and a Hotchkiss suspension using ABAQUS.

III. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design and analyses, of mono steel leaf spring and also laminated composite leaf spring made of three different composite materials viz., E-glass/epoxy, S- glass/ epoxy and Carbon/epoxy composites. Laminated composite leaf of four layers with uni-directional fiber orientation angle i.e., 0^0 is considered. A virtual model of both steel and laminated mono composite leaf spring was created in Pro-E. Model is imported in ANSYS 10.0 for analysis by applying normal load conditions. After analyis a comparison is made between exisisting conventional steel leaf spring and laminated mono composite leaf spring viz., e-glass/epoxy, s-glass/epoxy, carbon/epoxy in terms of deflections and stresses, to choose the best one.

IV. LEAF SPRINGS

Leaf springs also known as flat spring are made up of flat plates. Leaf springs are designed in two ways: 1. Multi leaf 2. Mono leaf. The importance of leaf spring is to carry bump loads (i.e due to road irregularities), brake torque, driving torque, etc… in addition to shocks.

The multi-leaf spring is made up of several steel plates of different length stacked together, while mono-leaf spring is made up of single steel plate. During normal operation, the spring compresses to absorb road shock. The leaf spring bend and slide on each other allowing suspension movement.

IV.I Matrials for Leaf springs :

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. After the heat treatment process spring steel products gets greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

IV.II Theoretical calculations of conventional steel leaf spring:

In the present analysis the maximum deflection of the mono leaf spring is limited to 34mm, then the allowable load on the spring is given by

Deflection

$$\delta = 12*W*L^3 / E*b*t^3*(2n_G+3n_F)$$

$$34 = 12*W*L^3 / E*b*t^3*(2n_G+3n_F)$$

W=794.5N

Stress

$$\sigma = 6*W*L / n*b*t^2$$

$$= 6*794.5*482.5 / 1*50*10^2$$

= 460.038Mpa.

V. COMPOSITE MATERIALS:

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds.

Composites are combinations of two materials in which one of the material is called the “matrix phase” is in the form of fibers, sheets, or particles and is embedded in the other material called the “reinforcing phase”.

Many composite materials offer a combination of strength and modulus that are either comparable to or better than any tradional metalic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of mettalic materials.

The fatigue strength weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fiber composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries.

Another unique characteristic of many fiber reinforced composites is their high interal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighboring structures.

High damping capacity of composite materials can be beneficial in many automotive applications in which noise, vibration, and hardness is a critical issue for passenger comfort.

VI. SPECIFICATION OF EXISTING LEAF SPRING:

Table 1 shows the specifications of a mono leaf steel spring of a maruti 800 passenger vehicle. The typical chemical composition of the material is 0.565C, 1.8% Si, 0.7%Mn, 0.045%P and 0.045% S.

Table: 1 Specifications of Mono leaf steel spring

S.No	Parameters	Value
1.	Total length of the spring(Eye to Eye)	965 mm
2.	Free camber (At no load condition)	68 mm
3.	No.of full length leave (Master Leaf)	01
4.	Thickness of leaf	10 mm
5.	Width of leaf spring	50 mm
6.	Maximum load given on spring	794.54 N
7.	Young’s Modulus of leaf spring	2.1e5 N/mm^2

VII. FINITE ELEMENT ANALYSIS OF LAMINATED COMPOSITE LEAF SPRING

Dimensions of Laminated composite leaf spring (LCLS) are taken as that of the conventional steel leaf spring(SLS). Laminated composite leaf spring (LCLS) is assumed to have 4 lmina of 0^0 degree fiber orientation angle (thickness of each lamina of 2.5mm). Width of the leaf is 50mm. Since the properties of LCLS vary with directions of fiber, a 3-D model of leaf spring is used for analysis in ANSYS 10.0. The loading conditions are assumed to be static. The element choosen for the analysis is SHELL 99, which is a layered version of the 8-node structural shell model. The element has six degrees of freedom at each node : translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. The element allows up to 250 layers. The finite element analysis is carried out on mono steel leaf spring as well as on three different types of laminated composite mono leaf spring. From the analysis the equivalent stress (Von-mises stress) and displacements were determined and are shown in figure **1-9**. **Table 2** shows the comparative analysis of mono leaf steel spring and laminated composite mono leaf spring of three different materials. Figure **10-11** shows the variation of deflections and stresses induced in steel spring and lamianted composite leaf spring with respect to the variation of load.

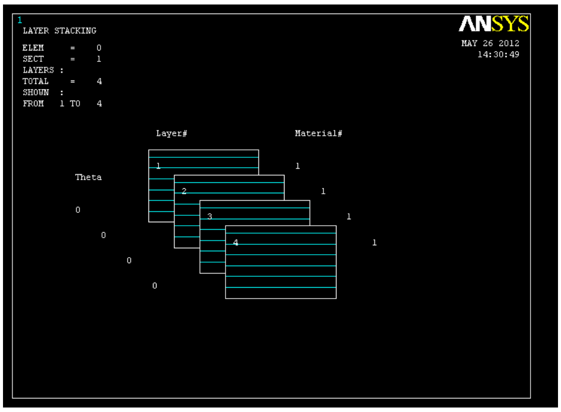

Fig. No.1- Stacking sequence of laminate.

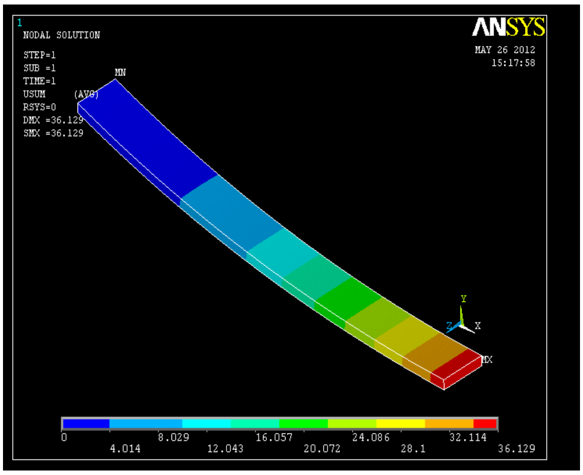

Fig. No.2- Displacement pattern for steel leaf spring

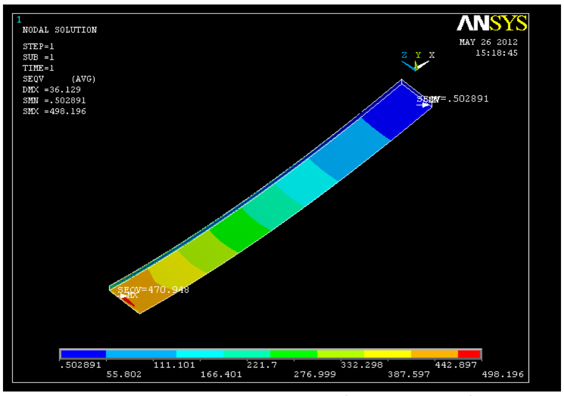

Fig. No.3- Stress distribution for steel leaf spring

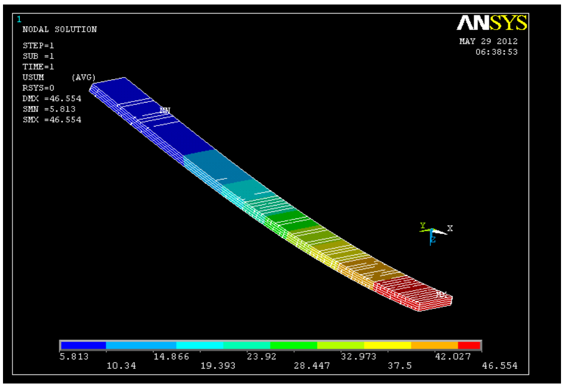

Fig. No. 4- Displacement pattern for E-glass/epoxy laminated composite leaf spring

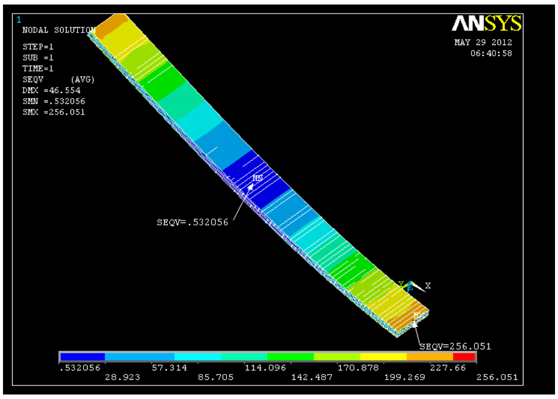

Fig. No.5- Stress distribution for E-glass/epoxy laminated composite leaf spring.

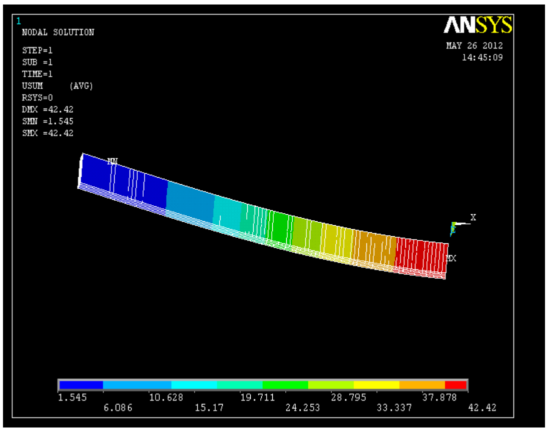

Fig. No.6- Displacement pattern for S-glass/epoxy laminated composite leaf spring.

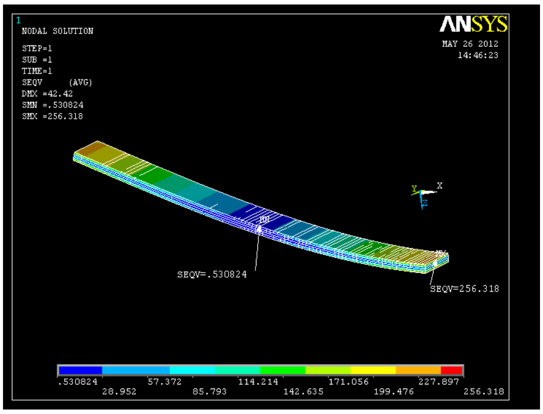

Fig. No.7-Stress distribution for S-glass/epoxy laminated composite leaf spring.

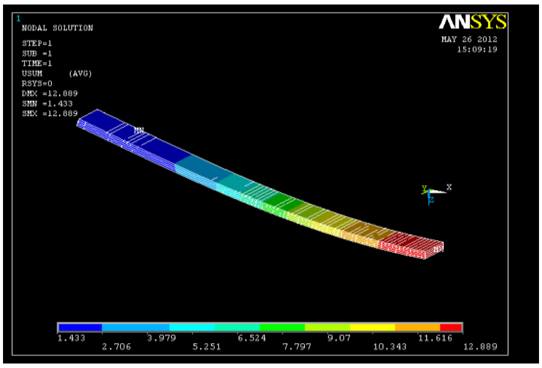

Fig. No. 8-Displacement pattern for carbon/epoxy laminated composite leaf spring.

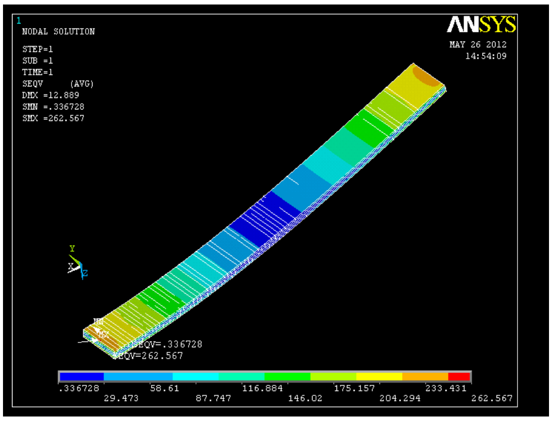

Fig. No. 9- Stress distribution for carbon/epoxy laminated composite leaf spring.

Table 2. Comparative Analysis of mono leaf steel spring and laminated composite mono leaf spring.

S.No	parameter	steel spring	Laminated composite leaf spring		
			Comp:1	Comp:2	Comp:3
1	Weight (kg)	3.79	1.01	0.965	0.762
2	Stress (N/mm^2)	498.19	256.05	256.32	262.56

Comp:1- E-glass/Epoxy, Comp:2-S-glass/Epoxy, Comp:3- Carbon/Epoxy

Graphs:

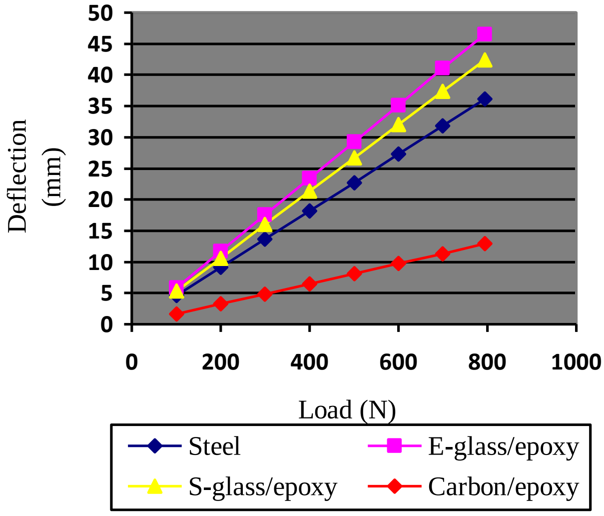

Fig. No. 10- Load - Deflection curves for Steel and Laminated composite leaf spring

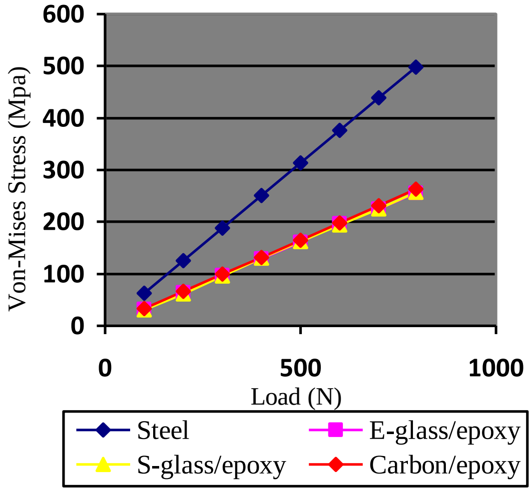

Fig. No. 11- Load - Von-Mises stress for Steel and Laminated Composite leaf spring

VIII. CONCLUSIONS

A comparative study has been made between laminated composite leaf spring and steel leaf spring with respect to weight, stiffness and strength.

By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 73%~80%**,** natural frequency of composite leaf springs are 27%~67% higher than steel leaf spring and 23~65% stiffer than the steel spring**.**

Based on the results, it was inferred that carbon/epoxy laminated composite mono leaf spring has superior strength and stiffness and lesser in weight compared to steel and other composite materials considered in this investigation.

From the results, it is observed that the laminated composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.

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