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Modeling and Analysis of Carbon Fiber Epoxy Based Leaf Spring under the Static Load Condition by using FEA

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Abstract— This paper describes design and analysis of composite mono leaf spring. Weight reduction is now the main issue in automobile industries. In the present work, existing mono steel leaf spring of a light vehicle is taken for modeling and analysis. A composite mono leaf spring with Carbon/Epoxy composite materials is modeled and subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The composite mono leaf springs have been modeled by considering Varying 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 12.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found lesser stresses and weight reduction of 22.5% is achieved.

Keywords: Composite leaf spring (LCLS), Static analysis, Carbon/Epoxy, ANSYS 12.

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.

In the present work, an attempt is made to replace the existing mono steel leaf spring used in light passenger car with a laminated composite mono steel leaf spring made of composite materials Carbon/epoxy. Composite leaf spring is designed with varying width and varying thickness design.

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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 data analysis. 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.

Malaga Anil Kumar et al. [2] describes that three different composite materials have been used for analysis of mono-composite leaf spring. They are E-glass/epoxy, Graphite/epoxy and carbon/epoxy. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite mono leaf spring reduces the weight by 85% for E-Glass/Epoxy, 94.18% for Graphite/Epoxy, and 92.94 % for Carbon/Epoxy over conventional leaf spring. For the modal analysis, same boundary conditions are applied and the load need not be applied.

Al-Qureshi et al. [3] 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.[4] investigated the formulation and solution technique using genetic algorithms (GA) for design optimization of composite leaf springs.

Gulur Siddaramanna et al. [5] 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.

M. Raghavedra et al [6] 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 light vehicle is taken for modeling and analysis of 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

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stiffness, 27%~67% higher frequency and weight reduction of 73%~80% is achieved.

III. SPECIFICATION OF THE PROBLEM

The objective of the present work is to design the Carbon/Epoxy composite leaf spring for automobile Suspension system and analyze it. This is done to achieve the following.

To the replace conventional steel leaf springs with Carbon/Epoxy composite leaf spring.

• To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with composite leaf spring.

A virtual model of both steel and mono composite leaf spring was created in Pro-E. Model is imported in ANSYS 12.0 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 in terms of deflections and stresses.

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.

V. MATERIALS FOR LEAF SPRINGS

Many industries are manufactured steel leaf spring by EN 47 material; these materials are widely used for production of parabolic leaf spring and conventional multi leaf spring. Leaf spring absorbed the vertical vibrations, shocks and bumps loads (induced due to road irregularities) by means of spring deflection, so that the potential energy stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy insures the comfortable suspension system.

a. 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 tradigonal 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.

b. Selection Of Material

Materials of the leaf spring should be consist of nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

c. Fibres Selection

The commonly used fibers are carbon, glass, keviar, etc. Among these, the Carbon fiber has been selected based on strength. Carbon fibers: Their advantages include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength. Thus, Carbon fiber was found appropriate for this application.

d. Resins Selection

In a FRP leaf spring , the inter laminar shear strengths is controlled by the matrix system used. Since these are reinforcement fibers in the thickness direction, fiber do not influence inter laminar shear strength. Therefore, the matrix system should have good inter laminar shear strength characteristics compatibility to the selected reinforcement fiber. Many thermo set resins such as polyester, vinyl ester,

VI. SPECIFICATION OF EXISTING LEAF SPRING

Table 1and 2 shows the specifications of a mono leaf steel spring and Carbon/epoxy leaf spring light 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 steel leaf spring

S.No	Parameters	Value
1.	Material	Steel(55Si2Mn90)
2.	Tensile Strength	1962 N/mm2
3.	Young’s Modulus of leaf spring	2.07e5 N/mm2
4.	Total length of the spring(Eye to Eye)	965 mm
5.	Free camber (At no load condition)	110 mm
6.	No.of full length leave(Master Leaf)	01
7.	Thickness of leaf	10 mm
8.	Width of leaf spring	50 mm

9.	Maximum load given on spring	3400 N
10.	Spring Weigth	3.16 Kg

Table: 2 Specifications of composite leaf spring

S.No	Parameters	Value
1.	Material	Carbon/Epoxy)
2.	Tensile Strength	1841 N/mm2
3.	Young's Modulus of leaf spring	1.23e5 N/mm2
4.	Total length of the spring(Eye to Eye)	965 mm
5.	Free camber (At no load condition)	110 mm
6.	No.of full length leave(Master Leaf)	01
7.	Thickness of leaf	20 mm
8.	Width of leaf spring	35 mm
9.	Maximum load given on spring	3400 N
10.	Spring Weigth	2.46 Kg

VII. SOLID MODELING OF STEEL LEAF SPRING

Steel leaf springs have the characteristic parameters that affect their behaviors. In addition to the physical properties of its material, the spring length (L), Spring thickness (t), Spring width (b) and the camber are the parameters that affect the behavior of leaf spring. These parameters have been illustrated in Fig. 1 and 2.

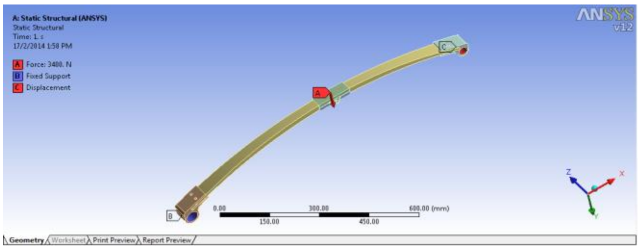

Fig 2 Solid Modeling of Composite Leaf Spring

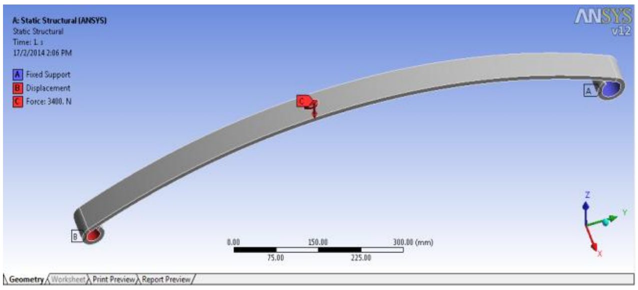

Fig 2 Solid Modeling of Steel Leaf Spring

VIII. ANALYSIS USING ANSYS

The model of leaf spring now imported into ANSYS 12 the boundary conditions and material properties are specified as for the standards used in the practical application. The material used for the leaf spring for analysis is structure steel, which have approximately similar isotropic behavior and properties as compared to EN47 and Composite material. Model of parabolic spring was partition into small region for easier mashing process method is used patch conforming method the boundary condition was set according to rear static load which is the front eye was allowing on a rotational at y axis and rear eye was constrained in y and z translation and x and z rotations alloying free x translation and y rotation. Contact from main to helper leaf also been defined helper leaf was constant 2nd degree of freedom to represent the clip that holds that to spring together. Finally vertical load was applied at the center of the leaf spring.

From the analysis the equivalent stress (Von-mises stress) and displacements were determined and are shown in figure 3-6. Table 3 shows the comparative analysis of mono leaf steel spring and composite mono leaf spring of three different materials. Figure.7 shows the variation of stresses induced in steel spring and composite leaf spring with respect to the variation of load.

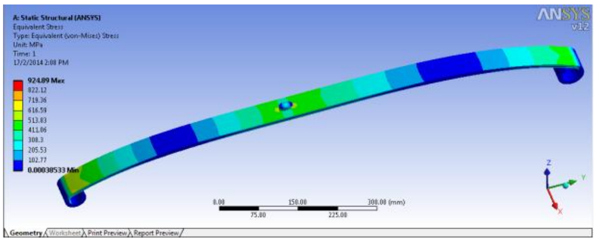

Fig.3- Stress distribution for steel leaf spring.

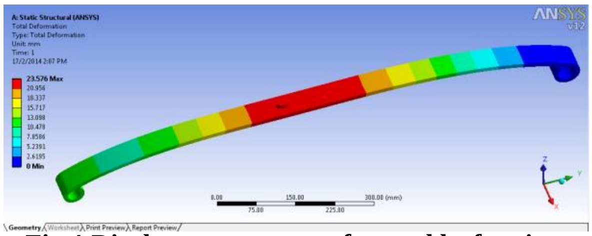

Fig.4-Displacement pattern for steel leaf spring.

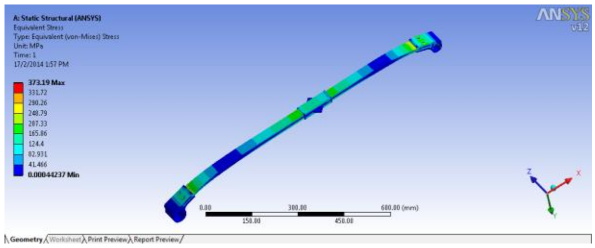

Fig.5- Stress distribution for carbon/epoxy composite leaf spring.

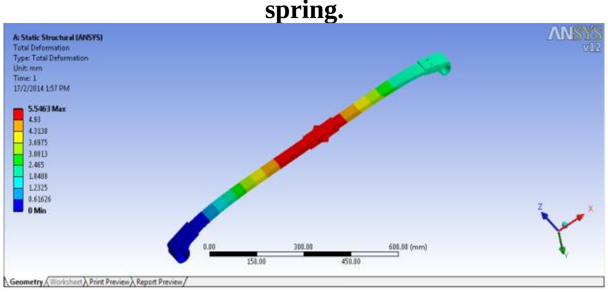

Fig.6-Displacement pattern for carbon/epoxy composite leaf spring

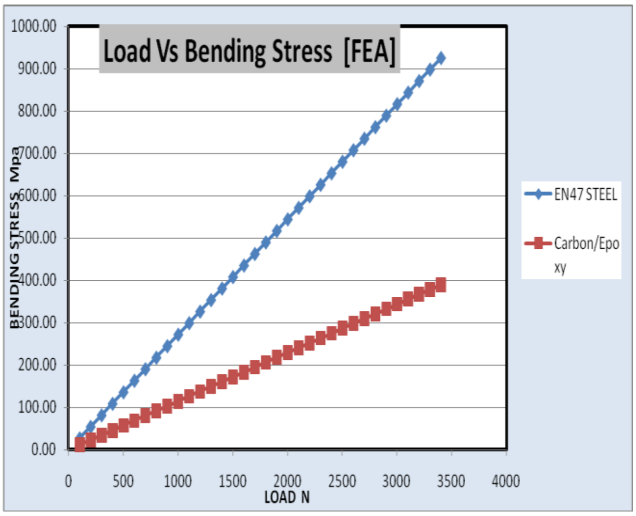

Fig.7- Load - Von-Mises stress for Steel and Composite leaf spring

Table 3 shows the comparative analysis of mono steel and composite leaf spring

Sr.No	parameter	steel spring	composite leaf spring
1	Weight (kg)	3.79	2.46
2	Stress (Mpa)	924.89	373.19

IX. CONCLUSIONS

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

By employing a composite leaf spring for the same load carrying capacity, there is a reduction in weight of 22.5% 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 material considered in this investigation.

From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring.

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