DESIGN, FABRICATION AND TESTING OF COMPOSITE MONO LEAF SPRING

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ABSTRACT

Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers used in the rear suspension system of a light duty vehicle is analyzed by finite element method using ANSYS software, often with progressively shorter leaves. A leaf spring can either be attached directly to the frame at both ends or attached directly at one end, usually the front, with the other end attached through a shackle, a short swinging arm. The shackle takes up the tendency of the leaf spring to elongate when compressed and thus makes for softer springiness. The automobile industry has shown increased interest in the use of composite leaf spring in the place of conventional steel leaf spring due to high strength to weight ratio. To conserve the natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. Actually, there is almost a direct proportionality between the weight of the vehicle and its fuel consumption, particularly in city driving. The advanced composite materials such as Graphite, Carbon, Kevlar and Glass with suitable resins are widely used because of their high specific strength (strength/density) and high specific modulus (modulus/density). Advanced composite materials seem ideally suited for suspension (leaf spring) applications.

The objective of the present work is to design the EGlass/ Epoxy composite leaf spring without change in stiffness for automobile Suspension system and analyze it. This is done to achieve the following.

- To the replace conventional steel leaf springs with Eglass/Epoxy composite leaf spring without change in stiffness.
- Compared to steel spring, the optimized composite mono leaf spring has much lower stress and the spring weight without eye units is nearly 65% lower than steel spring.
- To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with composite leaf spring.
- Keywords: Composite materials, composite leaf springs, FEA .

INTRODUCTION

The springs are designed to absorb, store and release energy. Therefore, the strain energy of the material becomes a major factor in designing the springs. In every automobile, leaf spring is one of the main components that provides a good suspension and plays a vital role in supporting lateral loads, shock loads, brake torque, and driving torque. The composite materials have more elastic strain energy storage capacity and high strength-to weight ratio as compared to steel. Therefore; the aim of this paper is to present 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-layup technique) and tested.
Design and experimental fatigue analysis of composite multi leaf spring using glass fiber reinforced polymer are carried out using life data analysis, in this particular literature. Compared to steel spring, the composite leaf spring is found to have 67.35 % lesser stress, 64.95 % higher stiffness and 126.98 % higher natural frequency than that of existing steel leaf spring. The conventional multi leaf spring weighs about 8.35 kg whereas the E-glass/Epoxy multi leaf spring weighs only2.365 kg. Thus the weight reduction of 71.45 % is achieved. Besides the reduction of weight, the fatigue life of composite leaf spring is predicted to be higher than that of steel leaf spring. Life data analysis is found to be a tool to predict the fatigue life of composite multi leaf spring. It is found that the life of composite leaf spring is much higher than that of steel leaf spring. The design variables are the width and the thickness of the composite spring. The design constraints were stress (Tsai-Wu failure criterion) and displacement. The objective was to obtain a spring with minimum weight capable of carrying intended static external force without failure.
Many papers were devoted to find spring geometry. The recently vehicle such as Ford, and Volvo buses are using leaf spring made up of carbon fiber as it gives good advantage but costly. So in this select glass fiber and general purpose resin for spring material on the basis of cost factor and strength.

LITERATUREREVIEW

In this paper gives the brief look on the suitability of composite leaf spring on vehicles and their advantages. The material selected is glass fiber reinforced plastic (GFRP) and the epoxy resin can be used which is more economical to reduce total cost of composite leaf spring with similar mechanical and geometrical properties to the multi leaf spring. The weight of the leaf spring is reduced considerably about 74 % by replacing steel leaf spring with FRP leaf spring. Besides the reduction of weight, the fatigue life of composite leaf spring is predicted to be satisfactory. Thus, the objective of reducing the unsprung mass is achieved to a larger extent. The stresses in the GFRP leaf spring are much lower than that of the steel spring.

PRINCIPLE OF LEAF SPRING

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. The introduction of composites helps in designing a better suspension system with better ride quality if it can be achieved without much increase in cost and decrease in quality and reliability. In the design of springs, strain energy becomes the major factor. The relationship of the Specific strain energy can be expressed as,

$$\sigma^2 / \rho E$$

Where σ is the strength,
ρ is 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. The introduction of composite materials made it possible to reduce the weight of the leaf spring without reduction of load carrying capacity and stiffness due to the following factors of composite materials as compared to steel.

PROBLEMS IDENTIFICATION

The objective of present work is to design, fabricate and experimental testing and analysis of composite spring made up of E-glass fiber, chopped strands mat and epoxy resin (general purpose resin) with constant width and thickness throughout its length.

PROTOTYPE MANUFACTURING

We used a hand-lay-up method to produce the prototype of a single composite leaf spring.Theconstant cross section design is used which accommodate continuous reinforcement of fibers and quite suitable for hand lay-up technique. 40 layers of Eglassfibre of 0.4 mm thick each are used to achieve 17 mm thickness of the designed leaf spring.
The steps below are followed during prototyping:

- Preparing moulds as per the shape of the leaf spring and the setup.
- Preparing stiffener and clamping plates.
- Cutting fibers to desired dimensions.

- Applying wax/gel on the fiber side of the lower mould for ease of removal.
- Preparing mixture of epoxy resin and polyamine hardener.
- Apply the mixture just above the wax.
- Start laying up the first ply and apply the matrix on it again, repeat the same procedure up tothe desiredthickness.
- Apply the matrix well on the topmost layer and Cover the upper mould after the wax film is done onits fibre side.
- Put the stiffener on the covered mould and clamp tightly using the plates and c-clamps.
- Allow the composite leaf spring to cure enough at room temperature.
- Remove it from the set up and trim the excess material.

EXPERIMENTALTEST

In the experimental analysis the comparative testing of GFRP leaf spring and the steel leaf spring are taken. The deflection or bending tests of both the spring for comparative study is taken on the universal testing machine (UTM).The load is gradually applied on steel and GFRP leaf spring and the following graph are obtain from the testing.

Figure: Load applying on GFRP Leaf spring

DESIGN OF LEAF SPRING:
Considering several types of vehicles that have leaf springs and different loads on them, various kinds of composite leaf spring have been developed. In the case of multi- leaf composite leaf spring, the interleaf spring friction plays a spoil spot in damage tolerance. It has to be studied carefully. In the present work, only a leaf spring with constant thickness, constant width design is analyzed.

MAIN PARTS OF LEAF SPRING:
The following cross-sections of leaf spring for manufacturing easiness are considered.
1. Constant thickness, constant width design.
2. Constant thickness, varying width design.
3. Varying width, varying width design.

Table: Design Specifications

Parameter	Specification
Material Steel	(55Si2Mn90)
Tensile Strength	1962N/Sq. mm
Yield Strength	1470N/Sq.mm
Young's Modulus	2.1e5 N/Sq.mm
Spring Weight	8.35 Kg
Thickness at the Center	12mm
Thickness at extreme ends	9mm

For steel leaf spring cross section is according to considered design and not altered. Due to manufacturing ease, a composite leaf spring with uniform rectangular cross section is considered and analyzed.

RESULT AND DISCUSSION

The performance of existing steel leaf spring was compared with the fabricated composite leaf spring. Testing has-been done for unidirectional E-Glass/Epoxy mono composite leaf spring. 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 sometimes breaking of fibers. When composite leaf spring hit by stone then there is chances of breaking of fibers. This may result in a loss of capability to flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problem will not occur.

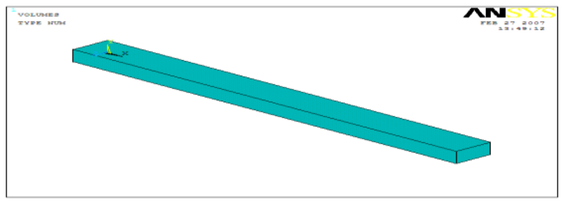


Figure: Finite element model of composite leaf spring.

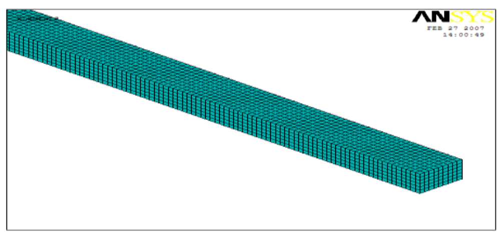


Figure: Mesh model of composite leaf spring

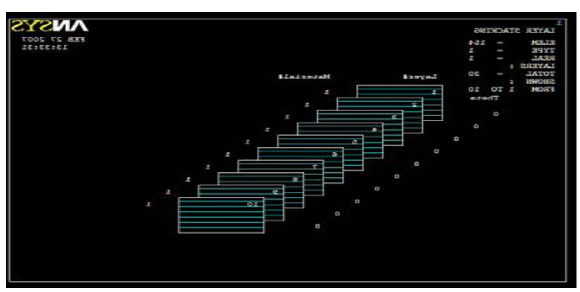


Figure: Stacking sequences of layers.

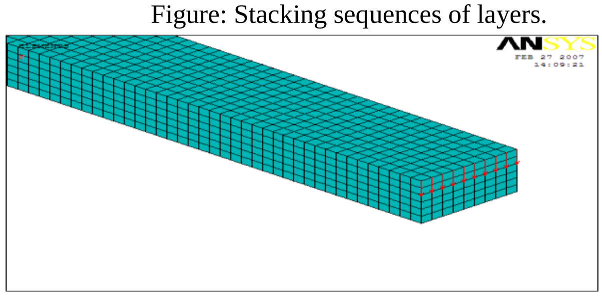


Figure: Mesh model with application of load

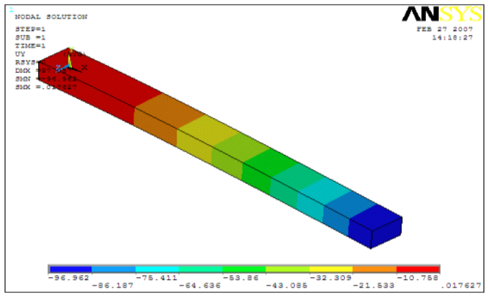


Figure: Deflection along z-direction

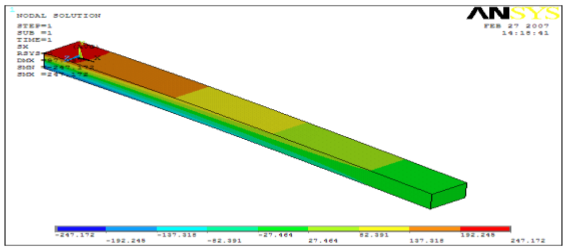


Figure: stresses along x-direction

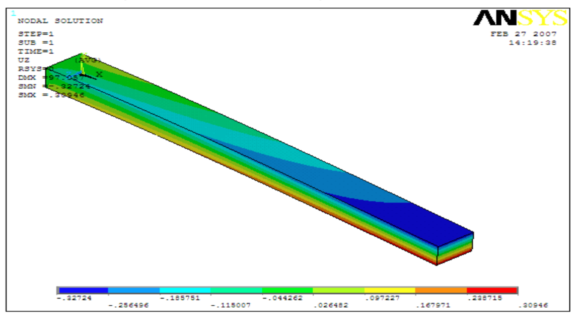


Figure: Stresses along y-directon

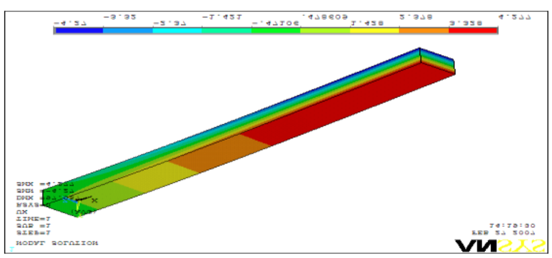
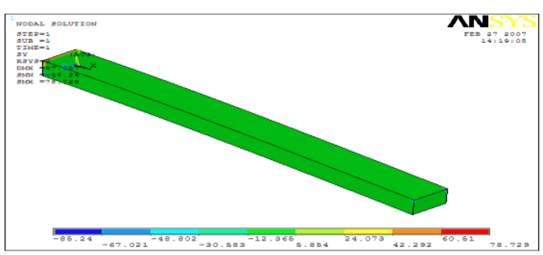
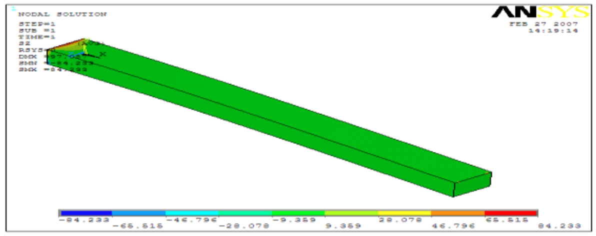


Figure: Stresses along z-direction





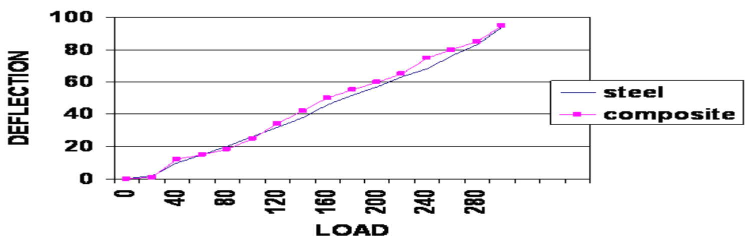


Table – Weight Comparison

Leaf spring	Type Steel	Composite
Weight (Kg)	8.35 (With eye)	2.365 (Without eye)

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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