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Design and Analysis of Leaf Spring with Composite materials

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Abstract

In automobile sector tends to increasing competition and innovation in design and tends to modify the existing products by new and advanced materials. Leaf springs are special kind of springs used in automobile suspension systems. The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. 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 (E-Glass/Epoxy and Jute E-Glass) leaf spring and conventional leaf spring. Leaf spring is modeled in CATIA V5R20 software and it is imported in ANSYS 12.0. The conventional composite leaf springs were analyzed under similar conditions using ANSYS software and the results are presented.

Keywords: Leaf spring, Composite, E-Glass/Epoxy, Jute E-Glass.

Introduction

A leaf spring is a simple type of suspension spring commonly used in vehicles. This type of spring is typically constructed of one or more flat, thin, flexible steel strips that are joined together in order to work as a single unit. The steel strip of a leaf spring are curved into an arc and attached at each end to the underside of a vehicle to help position and support the axle, and also to absorb shock.

Leaf springs are usually more able to evenly distribute the weight of a heavy load than ordinary coil-type springs. Although leaf springs have been in use for hundreds of years, they are generally only used for trucks and other heavy-duty vehicles today.
Leaf springs are sometimes referred to as semi-elliptical, cart, or laminated springs. The center of this arc-shaped spring is usually attached to the axle of the vehicle it supports, while the ends of the spring are attached to the frame itself. In some cases, a leaf spring may be attached to the vehicle frame on one end and other end will be attached to a short swinging arm known as a shackle. This type of spring configuration often helps to provide a softer, less rigid suspension system. Some automobile manufacturer has recently developed a leaf spring that is constructed of a composite material similar to plastic in order to provide a softer type of rear suspension.

Leaf springs are probably one of the oldest forms of spring-type suspension systems, having been in use since Medieval times. Until recently, leaf springs were a common rear suspension component of most automobiles. The introduction of light weight front-wheel drive vehicles has basically made the use of leaf springs unnecessary, and automobile manufacturers are now using coil springs for both front and rear suspension systems. Leaf springs are now generally used only for heavier commercial-type vehicles such as trucks, vans, trailers, and railroad cars.

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

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- To the replace conventional steel leaf springs with Eglass/Epoxy and Jute EGlass/ Epoxy composite leaf spring without change in stiffness.
- To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with composite leaf spring.

TOOL

ANSYS is engineering simulation software used for general purpose finite element analysis and for numerically solving mechanical problems. Here ANSYS 12.0 is used for analyzing the performance of conventional and composite leaf spring. Leaf spring is modeled in CATIA V5R20 software and it is imported in ANSYS 12.0. 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.

Table: 1 DIMENSIONS Of Master Leaf Spring

Parameters	Value
Total Length Of Leaf Spring (Eye to Eye)	1100 mm
Arc Height At Axle Seat	170 mm
Thickness Of Leaf Spring	6 mm
Width Of Leaf Spring	56 mm
Outer Diameter Of Eye	50 mm
Inner Diameter Of Eye	44 mm
Number of graduated leaves	6

Notations
T - Thickness of each leaf
N - Number of graduated leaves
L - Length of the spring
E - Elastic modulus
F- Force applied at the end of the leaf spring
B - Width of each leaf spring
a – Steel leaf spring
b – E-glass/epoxy leaf spring
c - Jute/e-glass/epoxy leaf spring

Theoretical calculations

Bending stress is the normal stress that is induced at a point in a body subjected to loads that cause it to bend. When a load is applied perpendicular to the length of a beam (with two supports on each end), bending moments are induced in the beam.

Bending stress $\sigma b = \frac{\text{mmax}}{\text{z}}$,

Where $z = \frac{nbt^2}{6} \quad = \quad \sigma b = \frac{6F\,l}{nbt^2}$

Deflection is the degree to which a structural element is displaced under a load.

Maximum deflection, $\delta\ max = \frac{6Fl^3}{Enbt^2}$

Strain energy is defined as the internal work done in deforming the body by the action of externally applied forces.

Strain energy $u = \frac{P^2}{A\,x\,e}$

Selection of Materials

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. The heat treatment of springs steel products are greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

The matrix material used was medium Epoxy resin widely used in industries due to their strong adhesive properties, chemical resistance and toughness. The reinforcement material employed was E-glass which is a popular fiber primarily made up of silica oxide, along with oxides of aluminum, boron, calcium and other compounds. The hardener HY951is used in the proportion of 1:10. The choice of hardener is governed by the curing temperature and pot life. The experimentation includes fabrication and testing of different % by volume of E-Glass/Epoxy. The composite leaf spring is fabricated using best composition of E-glass/Epoxy.

Jute fiber reinforced epoxy composites in the forms of lamina and laminates were determined. The lamina prepared with natural fiber mat showed lower mechanical properties compared to laminas with glass mat. All with a lot laminates were made with a total of 10 plies, by varying the number and position of glass layers so as to obtain six different stacking sequences. One group of all jute laminate was also fabricated for comparison purpose.

Material	**Young's modulus**	**Poisson's ratio**	**Tensile strength**	**Density**
Steel	190-210 MPa	0.27-0.30	572.3 MPa	1000 kg/m^3
E-glass /Epoxy	24000 MPa	0.3	205 MPa	1520 kg/mm^3
Jute/E-glass /epoxy	21000 MPa	0.22	185 MPa	1460 kg/mm^3

Design and finite element analysis of composite leaf spring

The leaf spring behaves like a simply supported beam and the flexural analysis is done considering it as a simply supported beam. The simply supported beam is subjected to both bending stress and transverse shear stress. Flexural rigidity is

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an important parameter in the leaf spring design and test out to increase from two ends to the center.

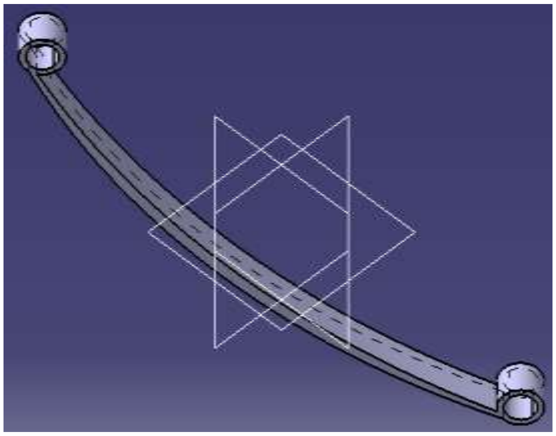

Fig: 1 Leaf Spring Designed in CATIA V5R20

To design composite leaf spring, a stress analysis was performed using the finite element method done using ANSYS software. Modeling was done for every leaf with CATIA V5R20 as shown in fig1. Also, analysis carried out for composite leaf spring with bonded end joints for Mild Steel, E-Glass/Epoxy and Jute E- Glass/Epoxy. The maximum and shear stresses along the adhesive layer were measured; represent FEA results for composite leaf springs of (Mild Steel E-Glass/Epoxy and Jute E-Glass/Epoxy). The maximum and shear stresses along the bonded adhesive layer for Mild Steel E-glass/Epoxy and Jute E-Glass/Epoxy were measured and plotted as shown in Figs.

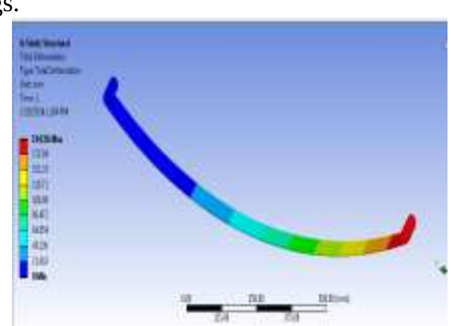

Fig: 2 Static Structural Analysis for Mild Steel

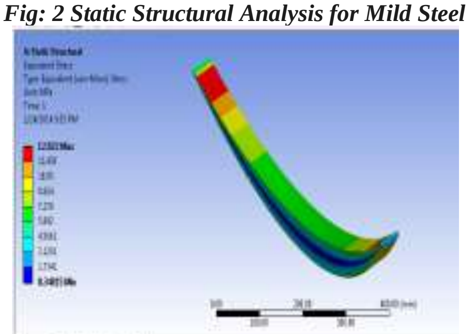

Fig: 3 Static Structural Analysis for E-Glass/Epoxy

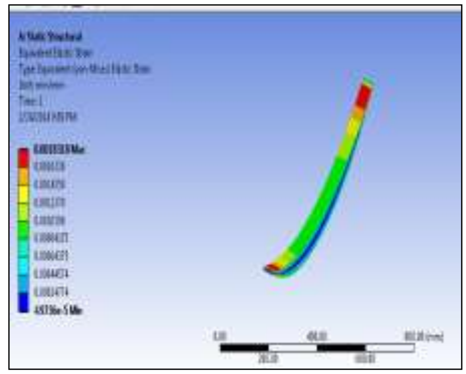

Fig: 4 Static Structural Analysis for Jute E-Glass/Epoxy

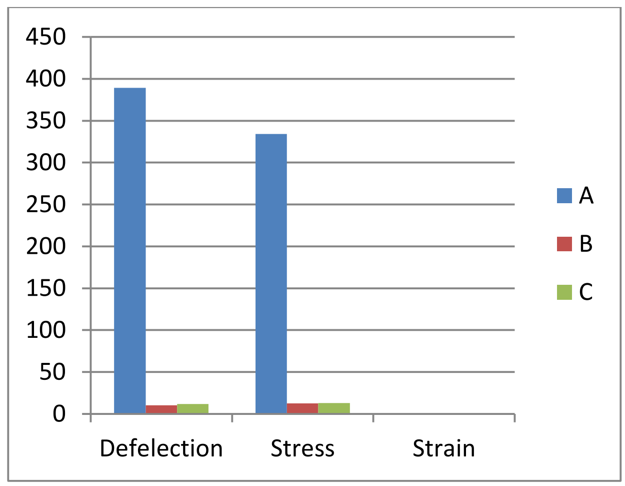

Fig: 5 Comparison of Materials Based on the Stress, Strain, Deflections with 1000N load

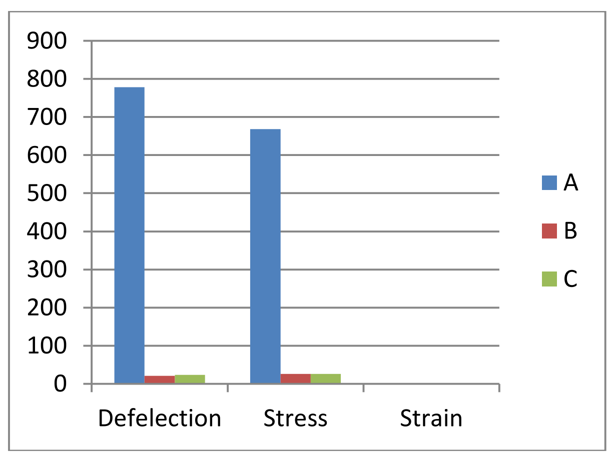

Fig: 6 Comparison of Materials Based on the Stress, Strains, Deflections with 2000N load

Note: a – steel leaf spring, b – e-glass/epoxy leaf spring, c - jute/e-glass/epoxy leaf spring

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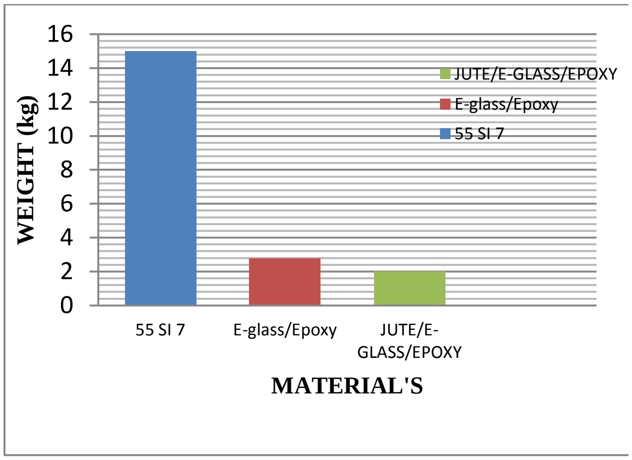

Fig: 7 Comparison of Weight of Different Materials

Conclusion

The automobile chassis is mounted on the axles, not direct but with some form of springs. The stresses and deflection 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. Weight and cost are also less in composite leaf spring as compared to steel leaf spring with the same parameters. Conventional steel leaf spring is also found to be 5.5 times heavier then Jute E-Glass/Epoxy leaf spring. Material saving of 71.4 % is achieved by replacing Jute 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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