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Research Article

Design Analysis and Fabrication of Composite Mono Leaf Spring for Automobile Vehicle

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Abstract

Leaf spring is a simple form of suspension spring used to absorb vibrations induced during the motion of a vehicle. The automobile industry has shown increased interest in the replacement of steel leaf spring (65Si7) with composite leaf spring with E-glass/Epoxy due to high strength to weight ratio, higher stiffness, high impact energy absorption and lesser stresses. This research is aimed to investigate the suitability of natural and synthetic fiber reinforced composite material in automobile leaf spring application. By using natural fibers efforts have been made to reduce the cost and weight of leaf spring. A composite leaf spring with E-glass/Epoxy composite materials is modeled and subjected to the same load as that of a steel spring. The composite leaf spring has been modeled by their consideration. Static structural analysis of a leaf spring has been performed using ANSYS 11.

Keywords: *Steel leaf spring, E-glass/Epoxy.*

1. Introduction

A composite is combination of two materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environmental damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. Composite materials are generally used for buildings, bridges and structures such as boat hulls, race car bodies, shower stalls, bathtubs, and storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft in demanding environments.

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, dating back to medieval times. A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the centre of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves.

Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason some manufacturers have used mono-leaf springs. 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. Some springs terminated in a concave end, called a spoon end (seldom used now), to carry a swivelling member

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2. Aim and Scope of the Project

The aim of this project work is to prepare a composite leaf spring which is used in automobile industry. The fibre considered is glass fibre, which is collected from Ecmas resins, Hyderabad. The epoxy resin with hardener is collected from nearby market. The glass fibres are in the form of long roving's, which is trimmed as per requirement. The mould is prepared as per standards by using old leaf spring.

3. Objective of the Project

The objective of the present work is to design, analyze and propose a method of fabrication of composite mono-leaf spring for automobile suspension system. This is done to achieve the following

This design helps in the replacement of conventional steel leaf springs with composite mono-leaf spring with better ride quality.

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

4. Material Selection for Leaf Spring

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 spring steel products greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

4.1 Carbon/Graphite fibers

Their advantages include high specific strength and modulus, low coefficient of thermal expansion and high fatigue strength. Graphite, when used alone has low impact resistance. Its drawbacks include high cost, low impact resistance and high electrical conductivity.

4.2 Glass fibers

The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low elastic modulus poor adhesion to polymers, low fatigue strength and high density, which increase leaf spring weight and size. Also crack detection becomes difficult.

5. Fabrication of Composite Leaf Spring

Typically, most common polymer-based composite materials, including fibreglass, carbon fiber, and Kevlar, include at least two parts, the substrate and the resin. Epoxy resin is almost totally transparent when cured. In the aerospace industry, epoxy is used as a structural matrix material or as structural glue.

Fabrication of composite leaf spring using hand layup process

The constant cross section design is selected due to its capability for mass production, and to accommodate continuous reinforcement of fibers and also it is quite suitable for hand lay-up technique. Many techniques can be suggested for the fabrication of composite leaf spring. Composite leaf spring was fabricated using wet filament winding technique. In the present work, the hand lay-up process was employed.

5.1 Material used

Fig.1 Chopped strand mat (0.75mm thickness)

Fig.2 Rovings (0.3mm thickness)

Fig.3 Epoxy resin and Hardener

5.2 Steps involved

Step 1: This is a process of mixing epoxy resin with its accelerators, for 1kg of resin 100gms of hardener should be added.

Fig.4 preparation of Epoxy resin

Step 2: Cut the CSM (is a form of reinforcement used in fibre glass) and roving mats according to leaf dimensions. Here we are using in total 7 fiber layers and 7 roving layers to achieve a total thickness of 8mm.

Fig.5 Roving mats

Step 3: Leaf springs of swaraj mazda are welded to a stand, these leaf springs are act as a mould die, we are using these leaf springs to make composites on them.

Fig.6 positioning leaf spring

Step 4: In the conventional hand lay-up technique, First we need to apply wax polish (releasing agent) and dry it for 10 min and then apply PV (polyvinyl) so that the composite leaf springs will not stick to the metal leaf springs and it will give good surface finish.

Fig.7 Applying wax

Step 5: First apply epoxy resin and then keep one fibre layer and again apply resin on it and then keep one roving layer and follow the same procedure with one fibre layer and one roving layer alternatively.

Fig.8 Applying resin

Step 6: Rolling process done to remove the air bubbles if present. This process is carried out for each laying of glass fiber strip. After the rolling process, the mould is closed from top by applying load so as to make it a compression moulding.

Care must be taken during the individual lay-up of the layers to eliminate the fiber distortion, which could result in lowering the strength and rigidity of the spring as a whole. The duration of the process may take up to 30 min. The mould is allowed to cure about 4 – 5 days at room temperature. Mono composite leaf springs with and without eye ends was fabricated by using above said technique.

Step 7: These are the leaf spring after removing from the mould and these need finishing.

Fig.9 After removed from mould

Step 8: The leaf springs are finished by cutting and grinding process in order to obtain final leaf spring.

Fig.10 Cutting and grinding

Fig.11 Final leaf spring

Table 1 Properties of material

S.No.	Properties	Values
1	Tensile modulus along x direction, Mpa	34000
2	Tensile modulus along ydirection, Mpa	6530
3	Tensile modulus along z direction, Mpa	6530
4	Tensile strength of the material, Mpa	900
5	Compressive strength of the material, Mpa	450
6	Shear modulus along XY-direction (Gxy), Mpa	2433
7	Shear modulus along YZ-direction (Gyz), Mpa	1698
8	Shear modulus along YZ-direction (Gyz), Mpa	2433
9	Poisson ratio along XY-direction (Nuxy)	0.217
10	Poisson ratio along YZ-direction (NUyz)	0.366
11	Poisson ratio along ZX-direction (NUzx)	0.271
12	Mass density of the material (⍰), kg/mm3	$25*10^5$
13	Flexural modulus of the material, MPa	40000
14	Flexural strength of the material, MPa	1200

6. Finite element analysis

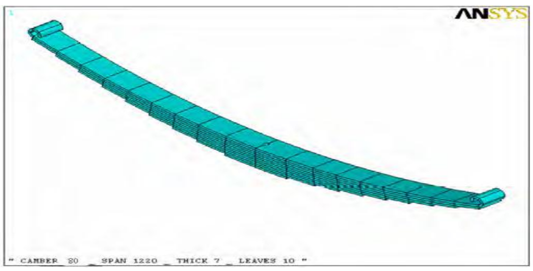

Fig.12 Full model of leaf spring

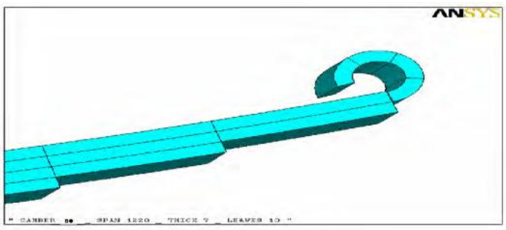

Fig.13 Enlarged view of leaf spring

6.1 Steel leaf spring (SLS)

Table 2 Parameters of steel leaf spring

Parameters	Values
Total length (eye-to-eye),	1150 mm
Arc height at axle seat(Camber),	175 mm
Spring rate,	20 N/mm
Number of full length leaves	2
Number of graduated leaves	5
Width of the leaves,	34 mm
Thickness of the leaves,	5.5 mm
Full bump loading,	3250 N
Spring weight,	13.5 kg

A stress analysis was performed using two-dimensional, plane strain finite element model (FEM). A plane strain solution is considered because of the high ratio of width to thickness of a leaf. Model is restrained to the right half part only because the spring is symmetric. The contact between leaves is emulated by interface elements and all the calculations are done using ANSYS .Nodes are created based on the values of coordinates calculated and each pair of coincident nodes is joined by the interface elements that simulate action between neighboring leaves. Element selected for this analysis is SOLID42 which behaves as the spring having plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities. Element is defined by four nodes having two degrees of freedom at each node: translations in the nodal x and y directions. Interface elements CONTA174 that is defined by eight nodes and TARGE170 are used to represent contact and sliding between adjacent surfaces of leaves. The contact elements themselves overlay the solid elements describing the boundary of a deformable body and are potentially in contact with the target surface, defined by TARGE170. This target surface is discretized by a set of target segment elements (TARGE170) and is paired with its associated contact surface via a shared real constant set. An average coefficient of friction 0.03 is taken between surfaces (SAE manual). Also, analytical solution is carried out using spring design SAE manual.

Table 3 Stress analysis of steel leaf spring

Parameters	Experiment	Analytical	FEM
Load, N	3250	3250	3250
Maximum stress, MPa	680.05	982.05	744
Maximum deflection, mm	155	133.03	135
Maximum stiffness, N/mm	20.96	24.43	24.1

6.2 Composite leaf spring (CLS)

In this work, a composite multi leaf spring is designed and tested for its load carrying capacity, stiffness and fatigue life prediction using a more realistic situation.

Table 4 Mechanical properties of E-glass/epoxy

Parameters	Values
Modulus of elasticity, GPa	E11, 38.6
Modulus of elasticity, GPa	E22, 8.27
Modulus of shear, GPa	G12, 4.14
Poisson ratio,	vxy, 0.26
Tensile strength, MPa	1062
Tensile strength, MPa	31
Compressive strength, MPa	610
Compressive strength, MPa	118
Shear strength, MPa	71

With the extensive use of laminated composite materials in almost all engineering fields, the optimal design of laminated composites has been an extensive subject of research in recent years. The dimensions of the composite leaf spring are taken as that of the conventional steel leaf spring. Each leaf of the composite leaf spring consists of 20 plies of thickness 0.275 mm each. The number of leaves is also the same for composite leaf spring. The design parameters selected are listed in Table 4.A 3-D model of the leaf spring is used for the analysis in ANSYS, since the properties of the composite leaf spring vary with the directions of the fiber. The loading conditions are assumed to be static. The element chosen is SOLID46, which is a layered version of the 8-node structural solid element to model layered thick shells or solids. The element allows up to 250 different material layers. To establish contact between the leaves, the interface elements CONTACT174 and TARGET170 are chosen. Individual leaves are fabricated using a filament-winding machine. A fiber volume fraction of 0.6 is used. All individual leaves are assembled together using a center bolt and four side clamps. Also metal spring eyes are fixed at both the ends. CLS is tested with an electro-hydraulic leaf spring test rig (Fig. 1). Four CLSs were manufactured and tested. The spring, which provided the lowest stiffness and highest stress values, has been considered for comparative purpose because it satisfies the fail-safe condition. The reason for the stiffness and stress variations may be due to variation in volume fraction obtained in the fabrication process or due to lack of complete curing. A reasonably good weight reduction (68.15%) is achieved by using CLS (4.3 kg) in place of SLS (13.5 kg).

Table 5 Design parameters of composite leaf spring

Parameters	Values
Thickness of each leaf, mm	5.5
Width of the each leaf ,mm	34
Thickness of the fiber, mm	0.2
Width of the fiber, mm	34
Thickness of the resin, mm	0.075
Width of the resin, mm	34
Thickness of single layer, mm	0.275
Number of layers	20

Fig.14 leaf spring test rig

For a light passenger vehicle with a camber height of 175 mm, static load to flatten the leaf spring is theoretically estimated to be 3250 N. Therefore, a static vertical force of 3250 N is applied to determine the load-deflection curves (Fig. 2).The load is gradually increased to obtain the deflection of steel spring first until it becomes completely flat. Then, for similar deflection in composite leaf spring, the loads are measured for composite leaf spring. FromFig.2, it is understood that the deflection increases linearly as load increases in both steel and composite leaf springs. For a full bump load of 3250 N, composite leaf spring deflects to94 mm only while steel leaf spring deflects 175 mm. The FEM results of longitudinal stress and deflection of CLS are shown in Figs.3&4. During full bump load test, experimental stress measurement (Fig. 5) is carried out to verify the results of FEM analysis (Figs 3 & 4).Fig.3 shows the variation of stress in CLS along the length of the spring. Fig.4 shows the deflection of CLS at various points along the length. It is found that CLS develops the maximum stress of about 215 MPa and it deflects about 60 mm. E-glass/epoxy composite leaf spring has spring constants 34.57-53.59 N/mm. Thus, all the data of spring constants for CLSs are greater than the design value, 20 N/mm. The reason for increased stiffness is lower density of E-glass/epoxy composite combination.

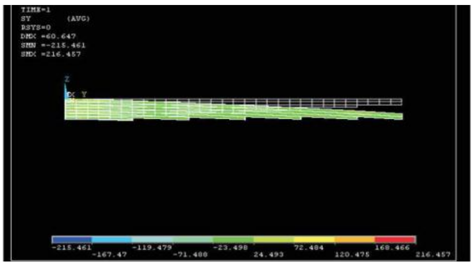

Fig.15 longitudinal stress of composite spring

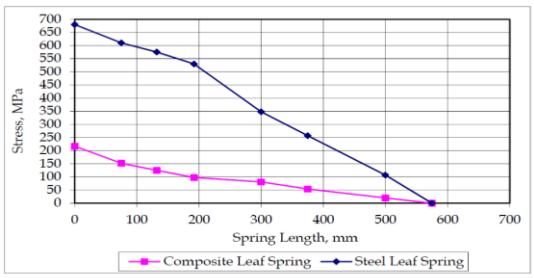

Fig.16 Variation of experimental stress of steel and composite springs

Table 6 Stress analysis of composite leaf spring

Parameters	Experiment	Analytical	FEM
Load, N	3250	3250	3250
Maximum stress, Mpa	222	310	215
Maximum deflection, mm	94	59	30
Maximum stiffness, N/mm	34	54	53

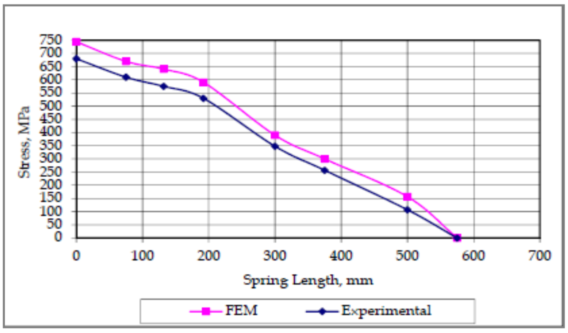

Fig.17 Variation of longitudinal stress of steel leaf spring

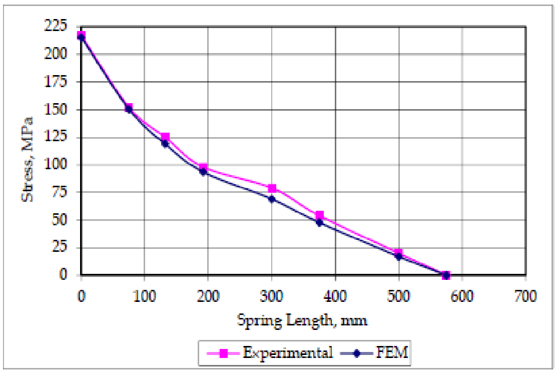

Fig.18 Variation of longitudinal stress of composite leaf spring

7. Testing

Fig.19 Specimen preparation

Fig.20 Specimen for testing

Fig.21 Universal testing machine

Testing results

Fig.22 Testing on UTM

Tensile strength

Conclusions

1) Analysis of conventional and composite leaf spring was successfully done.
2) Analytical, experimental and finite element analysis was done.
3) There was variation between three cases.
4) Developed a methodology to fabricate and test leaf springs using composite material.
5) The tensile strength for composite material is 2035.21kgf/sqcm.
6) The Cross breaking strength for composite material is -2578.57kgf/sqcm.
7) The Shear strength for composite material is - 885.7kgf/sqcm.
8) Compared to steel leaf spring the laminated composite leaf spring weight reduction is achieved.

References

Supranee Sangthong, Thirawudh Pongprayoon, Nantaya Yanumet, (2009) Mechanical property improvement of unsaturated polyester composite reinforced with admicellar-treated sisal fibers. Composites: Part A 40, pp 687–694.

Byoung-Ho Lee, Hyun-Joong Kim, and Woong-Ryeol Yu 2009 Fabrication of Long and Discontinuous Natural Fiber Reinforced Polypropylene Biocomposites and Their Mechanical Properties Fibers and Polymers, Vol.10, No.1, 83-90

Birley A.W, Heath R. J and Scott M. J. 1984, Plastics Materials, Properties and Applications, John Wiley, New York, 1988.

Bertin S and Robin J. J, 2002, Study and characterization of virgin and recycled LDPE/PP blends, Eur Polym J, Vol. 38, Issue 11, pp2255-2264.

Lee S. C, Yang D. Y, Ko J and Youn J. R, 1997, Effect of Compressibility on Flow Field and Fiber Orientation During the Filling Stage of Injection Molding, J Mater Process Techno, Vol. 70, pp83–92.