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A Comprehensive Review of Recent Advances in Composite Leaf Spring for Light Motor Vehicle

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ABSTRACT: Leaf springs are used in the suspension system are oldest one component but they are still used, especially in light vehicles. The main issue of automobile industry is to reduce the weight. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. Automobile industry has shown increased interest in the replacement of conventional steel leaf spring with composite leaf spring due to have high strength to weight ratio and more strain energy storage. The study of CFRP material is made it possible to reduce the weight of spring without any reduction on load carrying capacity. Selection of material is based on cost and strength of material. The objective of the present work is design analysis and fabrication of CFRP leaf spring for light motor vehicle to obtain a spring with minimum weight that is capable of carrying given static external forces without failure.

KEYWORDS: Conventional Leaf spring, Carbon Fiber Reinforced Plastic (CFRP) Leaf Spring, Static Load Condition.

I. INTRODUCTION

As the competition in the automobile sector increases tends to modify the existing products or simply replace old product by new and advanced material product. A suspension system of light motor vehicle is also an area where these innovations are carried out regularly. To improve working of the suspension system many changes have taken place over the time. Development of parabolic leaf spring, use of composite materials for these springs is some of these latest modifications in suspension systems. It is possible to reduce the weight of the leaf spring without any reduction on the load carrying capacity and stiffness by the introduction of various composite materials. Now a day's automobile sector shows an increased interest in the area of composite material leaf springs due to their very high strength to weight ratio. Hence the manufacturing and analysis of composite material leaf spring is become essential in shown the comparative results with conventional steel leaf spring.^[5]

The main function of leaf spring is to absorb the vibrations and impacts due to road abstracts by means of changing in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly. As per the different studies made a material with more strength is the most suitable material for a leaf spring. Composites have these characteristics.^[7] This work is mainly focused on the replacing the steel spring with implementation of CFRP composite material for light motor vehicles.

II. OBJECTIVES

- Manufacturing of CFRP composite leaf spring for light motor vehicle.
- Design and analysis of CFRP leaf spring for light motor vehicle.
- The purpose of this study is to compare the static properties of CFRP composite leaf spring with the conventional steel leaf spring.

III. LITERATURE REVIEW

Several papers were devoted to the application of composite materials for automobiles. Some of these papers are reviewed here.

M. Raghavedra, et.al. [1], described design and analysis of laminated composite mono leaf spring. this work is carried out on an existing mono steel leaf spring of a Maruti 800 passenger vehicle and compared with 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. 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%. Kumar Krishan and Agarwal M. L., [2], described the Finite Element Analysis of mono steel leaf spring and a mono leaf spring made of composite materials i.e. Glass Reinforced Plastic (GRP) which is having high strength to weight ratio. The mono leaf spring is modelled with similar mechanical and geometrical properties to a conventional multi-leaf spring. The mono leaf spring model is having one full length leave with eyes at both ends & two pins in each eye end. The material used for the mono steel leaf spring is SUP9. The FE analysis of leaf spring is performed for the calculations of stresses and deflection. Sachin Kr. Patel, et.al. [3], studied the use of alternate materials, effect of material on leaf spring performance and fatigue life prediction of leaf spring. The aim was review papers about performance of epoxy glass fibre reinforced materials used in leaf spring and various methods of fatigue life prediction. M. Venkateshan and D.Helmen Devraj, [4], described design and testing of composite leaf spring made of glass fibre reinforced polymer. The aim is to differentiate the load carrying capacity, stiffness and weight savings between the composite leaf spring with that of steel leaf spring. As per the comparison made between steel springs, the composite leaf spring is found to have 67.35% lesser stress, 64.95% more stiffness and 126.98% more natural frequency than that of existing steel leaf spring. A weight reduction of 76.4% is achieved by using optimized composite leaf spring. A. S. Singh and V. K. Thakur, [6], studied that mechanical property such as tensile strength, compressive strength and wear resistance etc. of the urea-formaldehyde resin increases to considerable extent when reinforced with the fibre. Thermal (TGA/DTA/DTG) and morphological studies (SEM) of the resin and bio composites have also been carried out. M. S. Kumar and Sabapathy Vijayarangan, [7], described the fatigue and static analysis of steel leaf spring and composite multi leaf spring made up of glass fibre reinforced polymer using life data analysis is described in this paper. The dimensions of an existing conventional steel leaf spring of a light motor vehicle are verified with design calculations. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 7.1 and compared with experimental results. To manufacture the composite multi leaf spring using E-glass/Epoxy unidirectional laminates, similar dimensions are used as that conventional steel spring. Gulur Siddaramanna Shiva Shankar and Sambagam Vijayarangan, [8], studied the steel leaf spring was replaced with a composite one. The objective was to obtain a spring with minimum weight which is capable of carrying given static external forces by constraints limiting stresses (Tsai-Wu criterion) and displacements. The weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring. Thus, the objective of the unsprung mass is achieved to a larger extent. The stresses in the composite leaf spring are much lower than that of the steel spring.

By reviewing and studying these papers and consider the design the CFRP Leaf spring for light motor vehicle and analysis is carried out in ANSYS. The results of these are comparing with the static testing in Universal Testing Machine.

IV. LEAF SPRINGS

Leaf springs also known as flat spring are made up of flat plates. There are basically two types of leaf springs:

1. Multi leaf
2. Mono leaf.

The importance of leaf spring is to carry bump loads (i.e. due to road irregularities), break torque, driving torque, etc... in addition to shocks. The multi-leaf spring is made up of steel plates of different length joined together, while mono leaf spring is made up of single steel plate. During normal operation, the spring compresses to absorb road shocks and vibrations. The leaf springs bend and slide on each other allowing suspension movement.

Material for Leaf Springs: -

The material used for fabricating the conventional leaf spring is usually a plain carbon steel having 0.90 to 1.0% carbon. The different leaves are heat treated after the forming process for removing internal stresses. Due to the heat treatment process spring steel gets more strength and therefore higher load capacity, higher range of deflection and improved fatigue properties. Automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring due to have more strain energy storage and high strength to weight ratio. The introduction of CFRP material is used to reduce the weight of spring without any reduction on load carrying capacity.^[1]

Composite Materials¹

A composite material is defined as a material composed of two or more elements combined on a macroscopic scale by mechanical and chemical bonds. In the composites there are two materials in which one material is called the “matrix phase” is in the form of fibres, sheets, or particles and is embedded in the other material called the “reinforcing phase”. In the world wide there are many composite materials which offer a combination of strength and modulus that are either comparable to or better than any conventional metallic metals. Because of their low specific gravities, high strength to weight-ratio and modulus to weight-ratios of these composite materials are superior to those of conventional metallic materials.

The fatigue strength, weight ratios as well as fatigue damage tolerances of many composite materials are excellent. For these reasons, fibre composite used as a major class of structural material and is 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 fibre reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighbouring 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.^[1]

Two types of fibres are widely used viz. glass fibres and carbon fibres.^[10]

V. METHODS OF FABRICATIONS^[9]

A. Hand Layup: -

This is the most basic of fabrication techniques for fibre glass reinforced plastics. Sometimes it also referred to as “contact moulding”. A simple mould, either male or female is used. It is first coated with an appropriate release agent and the layup fabrication is started.

B. Spray up: -

This is very similar to hand layup, and is also included in the general category of “contact moulded” fabrication. Spray up is simply an automated way of depositing the chopped glass.

C. Filament winding: -

In this fabrication method, which is primarily applicable to round or cylindrical parts, continuous glass fibres, again in the form of a very thin rope (like “binder twine”), are pulled through a dipped of catalysed resin. In the bath the glass fibres are thoroughly wetted and the excess resin removed. The resin-impregnated fibres are then wrapped around a rotating mandrel. Typically this is mounted in a winding machine resembling a lathe. The glass fibres traverse the length of the rotating mandrel, laying the fibres in a predetermined pattern. Typical products that are produced by filament winding include pipe of various sizes and large diameter tank.

D. Pultrusion: -

This fabrication technique involves pulling fibre glass filaments and resin through a die in a continuous process that is somewhat analogous to the extruding of thermoplastic materials. The parts fabricated by this technique are used for structural application, such as I beams, channels, bar and rod stock, box beams etc.

E. Press moulding: -

In the construction of the corrosion resistant equipment, press moulded parts are usually limited to flanges, small diameter pipe fitting, fan parts and pump parts. Press moulding involves a two part mould having a cavity of the shape and configuration of the finished moulded part. This cavity is charged with compound prepared from resin, glass fibres (either in a loose chopped form or in the form of a mat) and selected fillers. The mould is closed, whereby the compound is squeezed and caused to flow in to all parts of the mould cavity. With the cavity still under pressure, the part is cured. Usually the mould is heated to speed up this curing process, through for certain large parts a new fabrication technique known as “cold moulding”.

F. Centrifugal casting: -

A technique less frequently used in the fabrication of corrosion resistant equipment, centrifugal casting, uses a rotating mould or mandrel. In this technique the fibre glass reinforcement and resin are applied to the inside of the mould.

V. RESULTS AND DISCUSSIONS

Case Study:- A comparative study is been made between laminated composite leaf spring and steel leaf spring with respect to weight, stiffness and strength as shown in table I

TABLE I
COMPARATIVE ANALYSIS OF MONO LEAF STEEL SPRING AND LAMINATED COMPOSITE MONO LEAF SPRING

Sr. No.	Parameter	Steel spring	Laminated composite mono leaf spring		
			E-glass/Epoxy	S-glass/Epoxy	Carbon/Epoxy
1	Weight in Kg	3.79	1.01	0.965	0.762
2	Von-Mises Stress in N/mm ²	498.19	256.05	256.32	262.56

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. It is inferred that carbon/epoxy laminated composite mono leaf spring is superior strength and stiffness and lesser in weight compared to steel and other composite materials considered.

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

VI. CONCLUSION

The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings. A comparative study is made between composite and steel leaf spring with respect to weight, cost and strength. The composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.

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