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A Study of Composite Materials for Leaf Spring

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Abstract—*Automobile industries are focusing on weight reduction for vehicles to increase efficiency and better ride comfort. Weight reduction may be achieved by introducing a better material, a better design or an improved and economical manufacturing process. Composite materials are providing a better solution due to their high specific strength and stiffness also they are up to five times more durable than a steel spring. The achievement of weight reduction with an adequate improvement of mechanical properties has made composite materials a good replacement option. They are designed to absorb and store energy so the selection of material is based on strain energy. Also, fatigue reliability is an important aspect of design and analysis and economical production. In this work there is a comparative study of different types of composite materials feasible for leaf spring such as fiber reinforced composites(E-glass/Epoxy), carbon fiber reinforced plastic, metal matrix composites(Aluminum and Boron Carbide), hybrid composites(Unidirectional glass fibers with fly ash in epoxy resin) and natural composites (flax/vinyl ester) is carried out it was found that the fiber reinforced composite material is the most efficient material for replacement with leaf spring.*

Keywords *Leaf Spring, fiber reinforced composites, carbon fiber reinforced plastic, metal matrix composites, hybrid composites, natural composites.*

1. INTRODUCTION

With rising energy and environmental concerns, weight reduction has been the main focus of automobile manufacturers in the present scenario. In the suspension system of an automobile, the leaf spring is one of the critical parts for weight reduction in the vehicle as it takes ten to twenty percent of the unsprung weight. The advantage of parabolic leaf spring on top of helical spring is that the last parts of the spring possibly guided beside a specific trail as it repels to operate as a structural member in accumulation to energy absorbing device. For heavy vehicles, a leaf spring can be made from many leaves stacked on top of each other in several layers, often with decreasing the length of the leaves. Multi-leaf springs can serve to locate and to some extent damping as well as springing functions. While the interleaf friction between them provides a damping action but it is not well controlled and results in stiction in the motion of the suspension. For this reason, manufactures have experimented with mono leaf spring. Various analyses and optimization with the help of FEA through ANSYS software and MATLAB has been already done on typical leaf springs to establish the pay loads and safe design stress and it is observed that there is a considerable weight reduction is observed. It is well known that springs are an elastic body, is designed to absorb and store energy and then recovers its original shape when the load is removed. Therefore, the strain energy of the material becomes an important factor in designing the springs. The specific strain energy can be expressed as:

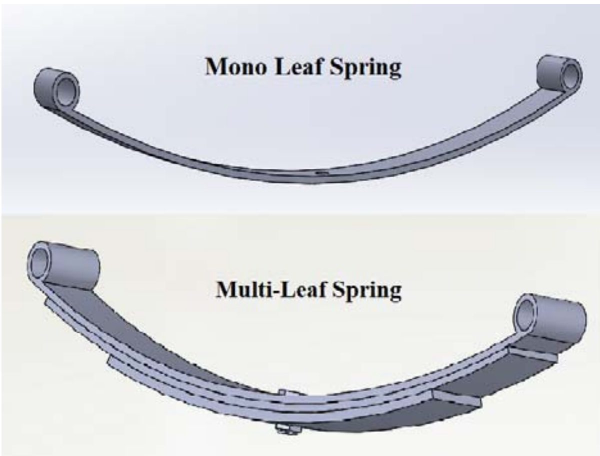
$$S = \frac{\sigma^2}{2E}$$

Where 'σ' is the strength, and 'E' is Young's modulus of the spring material in longitudinal and transverse directions. From this relation, we can observe that material having lower modulus and higher strength will have a greater specific strain energy capacity. The reduction in weight can be possible by introducing better material, the properties of a composite material like high strength to weight ratio, good thermal conductivity, high stiffness to weight ratio, low coefficient of thermal expansion and improved corrosion resistance is desirable in leaf springs without any reduction on load carrying capacity and stiffness.

Thippesh L [1] in their research paper Fabrication of Hybrid Composite Mono-Leaf Spring with Unidirectional Glass Fibers and fly ash, manufactured and tested a mono leaf hybrid composite of unidirectional glass fibers (60%) and fly ash (10%) in epoxy resin with hardener HY951. The spring deflections are observed for different loads, and there is less deflection and bending stresses for the same load also 80% of weight reduction is achieved as compared to the steel leaf spring. M.Sureshkumar,[2] have done fabrication and testing of Hybrid Fiber Mono Composite Leaf Spring for Automobile Applications. In their experiment, they selected a hybrid composite spring of glass and Kevlar fiber reinforced plastic with fiber selection of 0.7. Calculation of bending stress and deflection is done by analytical method, and then the calculated value is to be compared with the design values to check whether the design is safe or not. Harmeet Singh[3] in their research paper done various experimental analysis for Mechanical Properties of Composite Materials used for Leaf Spring, manufactured and tested leaf springs of different materials one is carbon/epoxy fabricated by hand layup technique and the other one is Aluminum and boron carbide (7075 Al @ 25% B_4C) fabricated by stir casting technique then they are analyzed for mechanical properties like tensile strength, bending stress and hardness.

2. LEAF SPRINGS

There are various types of springs available for the suspension system. A leaf spring can be considered as the basic type of spring, normally used for the suspension in heavy vehicles. It's generally liked a slender arc-shaped having some length of a steel spring of rectangular cross-section. The axle is placed at the center of the arc, at the end eyes are used for attaching to the vehicle body. The key characteristic that gives the smoothness and comfortable ride of a vehicle is its suspension. Now a day's extensively used suspension systems in automotive are the Leaf springs. It is also called by its shape as a semi-elliptical spring or cart spring, which is similar to an arc-shaped length of a steel spring with a rectangular cross-section. We can fasten a leaf spring directly at both ends (eyes) of the frame or directly to the one end usually the front end, whereas the other end is attached with the shackle, a short swinging arm. For the smooth riding in very heavy vehicles, a leaf spring prepared out of multiple leaves in multiple layers stacking at the top of each other often started with gradually shorter leaves in the end and is used to provide ease in riding in very heavy vehicles as shown in figure 1.



"Figure 1: Types of Leaf Spring"

The automotive manufacturer tends to enhance the soothe of the user and achieve appropriate stability of comfort riding virtues and economy. The researchers are interested in the replacement of steel leaf spring by some composite leaf spring because of high strength to weight ratio. On the other hand, there is a restriction for the number of applied loads in springs. The amplification in applied load creates complexity at a geometrical arrangement of vehicle height and erodes other parts of the vehicle. So, springs design in concerned of strength and toughness is enormously significant. Minimization of spring mass is also a key parameter in the enhancement of car dynamic. By replacement of steel leaf, spring with composite leaf spring will minimize spring mass in addition to resistance increase under the effect of applied loads. Increasing opposition and innovations in the automotive field tend to alter existing products or replacing old products through new and sophisticated material products. A suspension system of automotive is one of the areas where these innovations are carried out regularly. Leaf springs are generally used in suspension systems to absorb shock loads in automobiles like light vehicles, heavy-duty trucks and in rail systems [4].

3. STEEL LEAF SPRING

The material conventionally used in leaf springs are 65Si7 consisting of the Chromium Vanadium, Chromium, Nickel, Molybdenum, and Silicon. The leaves are heat treated after the manufacturing forming process. The heat treatment of spring steel produces improved strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

The mechanical properties of conventional leaf spring are shown in table 1.

"Table 1 Mechanical properties of Steel Leaf Spring"

Sr. No.	Property	Value
1	Yeild Strength	1158 Mpa
2	Tensile Strength	1272 Mpa
3	Poison Ratio	0.26
4	Young Modulus	2.1×10^5

Depending on the type of application, springs are made of carbon steels, silicon-manganese steels, silicon and manganese containing steels, alloyed steels, stainless steels. Springs is an elastic body and it must be capable of storing and releasing the energy. After repeated applications of load, they must recover to their original shape and dimensions. This property of the spring may be attained by the use of a highly elastic material with higher strength because the allowable stress values determine the choice of material and design.

4. COMPOSITE MATERIAL

4.1 Characteristics

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale with significantly different physical or chemical properties that remain separate and distinct on a macroscopic level by mechanical and chemical bonds. The constituents retain their identities in the composite Because of their low specific gravities, the strength-weight ratio and modulus weight-ratios of these composite materials are markedly superior to those of metallic materials. The fatigue strength to weight ratios as well as fatigue damage tolerances of many composite laminates excellent. These are some reasons, fiber composite has emerged as a major class of structural material is either used or being considered for the metal in any weight critical components in aerospace, automobile and other industries. The main difference between an alloy and composites are constituent materials which are insoluble in each other and the individual constituents retain those properties in case of composites, where as in alloys, constituents are soluble in each other and forms a new material which has different properties from their composites [5]. The advanced composites materials such as Graphite, Carbon, Kevlar, Glass, with suitable resin are widely used because of their high specific strength (strength/density) and high specific modulus (modulus /density) [6]. But complex mechanical characterization, high fabrication cost and difficulty in their rework and repair are some of the limitations of composite materials [7].

4.2 Composite Leaf Spring

Considering several types of vehicles that have leaf springs and different loading on them, various kinds of composite leaf spring have been developed. In some designs, the thickness and width of the spring are fixed along the longitudinal axis [5]. In some types, the width is kept fixed and thickness is variable along with the spring [6]. In other types width is fixed and, in each section, the thickness is varying hyperbolically in such a manner that the two edge the thickness is minimum in the center and maximum in the edges [7]. Also, in some type, the width and thickness are fixed from eyes to the middle of spring and towards the axle seat the width decreases hyperbolically and thickness increases linearly. In their design, the curvature of leaf spring, the fiber misalignment in the width and thickness direction are neglected. Composite leaf spring can be classified on the basis of their type of fiber.

4.3 Glass Fiber Reinforced Composites

Glass Fiber Reinforced Plastics (GFRP) is considered a potential material system offering, non-magnetic, good chemical resistance, good mechanical strength and non-conductive. The loading rate sensitivity of the polymer composites considered to be inconsistent and contradictory at some points of conditioning time and as well as at a temperature of conditioning. This Phenomenon may be attributed to matrix cracking, low-temperature hardening, misfit strain due to differential thermal coefficient of the constituent phases, and also to enhanced mechanical keying factor by compressive residual stresses at low temperatures. The main emphasis of the investigation was to evaluate the roles of percentage matrix phase and interfacial areas on the inner laminar shear failure mechanism of glass/epoxy composites at ultra-low temperatures for different loading speeds. The mechanical performances of the laminated specimens at low temperatures were compared with room temperature property. Phenomena may be attributed by matrix cracking, low temperature hardening, and misfit strain due to differential thermal coefficient of the constituent phases [8].

4.4 Carbon Fiber Reinforced Composite

Carbon Fiber Reinforced Composite (CFRP) is very light weight, high strength and specific strength and high specific modulus (modulus /density) materials. But due to its very high fabrication cost it is not readily used in manufacturing of the leaf springs in automobiles. But due to its very light weight it is used in aerospace industries.

4.5 Metal Matrix Composite

A metal matrix composite (MMC) is composite material which use two or more material to form new metallic bond material. Aluminium, titanium and alumina, boron carbide, magnesium, silicon carbide, are mostly used to manufacture metal matrix composite based automobile component. In metal matrix composite the other material is reinforced in primary material. When other material is use as reinforcement, it does not force to make new material as in case of alloys, but also used to change the thermal and mechanical properties of the existing material such as wear resistance and thermal conductivity. The other material (reinforcement) can be either metal, ceramic or organic. In manufacturing of metal matrix composite material, the use of advanced metal matrix micro and Nano-reinforced material not only reduce mass but can also improve strength and life. The most widely used methods for the manufacture of metal matrix composite materials and composite parts are stir casting, centrifugal casting, squeeze casting and powder metallurgy. Composite material is excellent physical, mechanical and development properties of composite materials. These are mostly used in aircraft industry, marine industry, automobile industry and electronic and electrical industry.

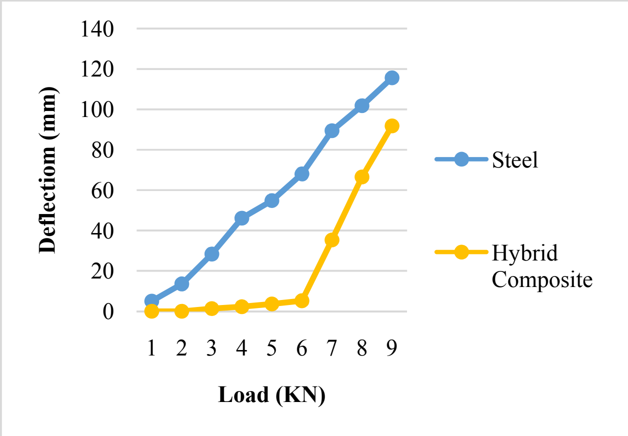
4.6 Hybrid Composite

When more than two materials are used as fibres materials to manufacture composite material that material is known as hybrid composite material. By adding a small amount of another material such as fly ash in glass fibre reinforced composite we can alter the different properties of composite materials such as strength, corrosion resistance etc.

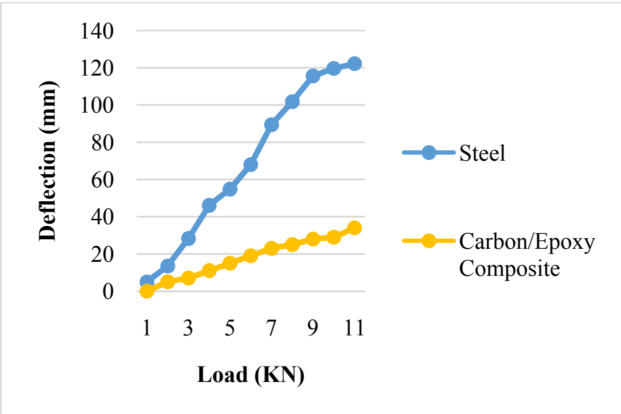
5. RESULT AND DISCUSSION

The different materials such as E-glass/Epoxy composite, hybrid composite, Metal matrix composite, Kevlar/Epoxy composite and carbon fiber reinforced composite are considered from various research papers [9-11] for data collection of bending tests and analyze the deflection and displacement with load for various composite material with steel. The load was applied at the center of spring and the ends are kept at a fixed position and the deflection of the spring center has recorded with gradually varying load.

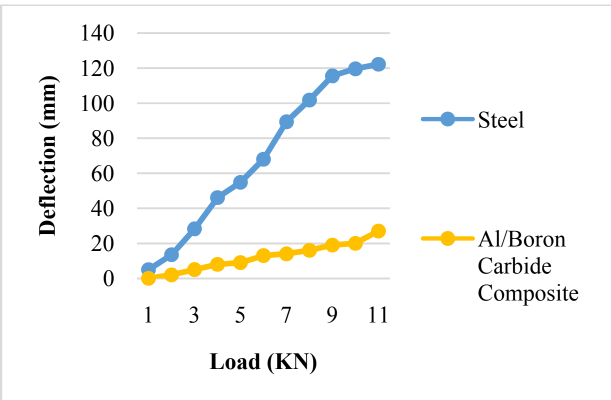
In figure 2,3 and 4 the defection of the hybrid composite, CFRP, and metal matrix composite leaf spring is compared with the convention steel leaf spring and according to values the deflection of composite material leaf spring in all of it types is lower as compared to the steel leaf spring.



”Figure 2 – Graph between the Steel and Hybrid Composite for Deflection and load”

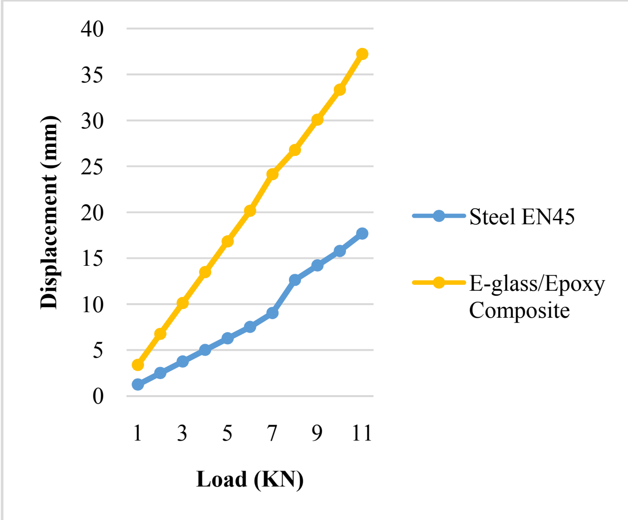


“Figure 3 – Graph between the Steel and Carbon/Epoxy Composite for Deflection and load”

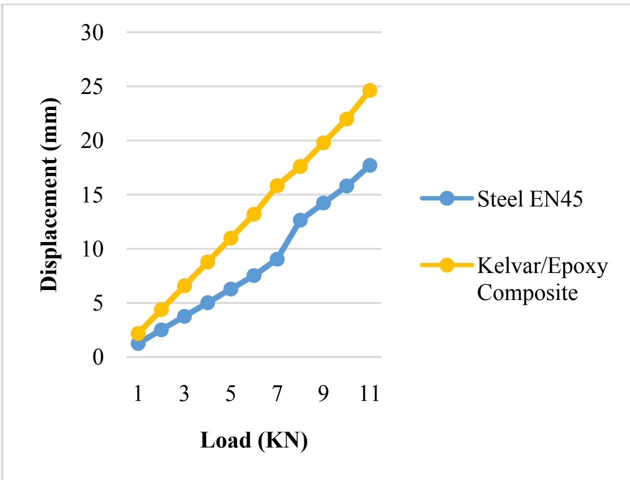


“Figure 4 – Graph between the Steel and Al/B_3C Composite for Deflection and load”

In figure 5 and 6 the displacement of the E-glass/Epoxy and Kevlar/Epoxy composite leaf spring is compared with the convention steel leaf spring and according to values the displacement of composite leaf spring is higher as compared to the steel leaf spring.



“Figure 5 – Graph between the Steel and E-glass/Epoxy Composite for Displacement and load”



“Figure 6 – Graph between the Steel and Kevlar/Epoxy Composite for Displacement and load”

6. CONCLUSION

From this study and the results, we can conclude that in case of deflection almost all the composite materials leaf springs are less deflected as compared to the conventional steel leaf spring whereas in case of displacement the composite leaf springs are more displaced as compared to the steel leaf springs. Also, the E-glass/Epoxy composite material is the most suitable material as compared to others due to its economic cost. Carbon/Epoxy composite is having very good properties like high strength to weight ratio and less deflection but due to its high cost, it is not feasible for economic purposes.

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