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ANALYSIS AND OPTIMIZATION OF LIGHT VEHICLE'S SUSPENSION SYSTEM USING COMPOSITE MATERIALS

P Lakshmi Nalini[1]

[1]Lecturer in Mechanical Engineering, Government Polytechnic, Gomaram(Narsapur), Telangana, India

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ABSTRACT

The main aim of this project is to study the potential of composite materials, particularly carbon/epoxy as replacements for conventional steel coil springs in light vehicles. Most engineering technologies, gadgets, and systems have been developed around the use of sophisticated materials. Composite laminates have found widespread application in various significant and innovative industries, such as aviation, automobiles, and civil engineering. In this project , analysis of mechanical properties under static and dynamic loading conditions is carried out to demonstrate the superior performance of composite springs compared to their steel. The result showed these springs have the ability to perform in dynamic conditions. The carbon/epoxy composite exhibited remarkable improvements in shear stress, fatigue life, strain energy, and deformation properties. The study highlights the ability of carbon/ epoxy composite springs to significantly reduce weight, enhance efficiency, and extend fatigue life, making them a promising alternative for next-generation vehicle suspension systems.

Keywords: Composites, Optimization, suspension system, carbon/epoxy, light vehicles.

1. INTRODUCTION

The suspension system plays a significant role in the passenger's safety and comfort. It dissipates kinetic energy to regulate shocks and vibrations caused by the road surface. In most auto- mobile vehicles, shock absorbers and springs are used to decrease the influence of traveling over the harsh road, which leads to improved vehicle control and quality of the ride A coil spring is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock, or to maintain a force between contacting surfaces. They are made of an elastic material which is formed into the shape of a helix which returns to its natural length when unloaded. Metal coil springs are made by winding a wire around a shaped former or a cylinder is used to form cylindrical coil springs. Coil springs for vehicles are typically made of hardened steel. Fuel efficiency and can be improved by minimizing the weight of components in the system of a vehicle. The coil springs of light vehicles have been made lighter than steel springs without significant loss of load-carrying capacity or stiffness by using composite materials, as composite materials have a higher strength-to-weight ratio than steel materials, which means they can store more elastic strain energy.

Fig 1 Coil spring suspension system

The most common spring shape which are in use in most wheeled vehicles suspension systems is the helical spring. Helical springs in automotive suspension reduce the road seismic and vibrations by absorbing impacts abruptly, and then releasing the energy slowly during a physical deformation and dissipating the energy as heat. Therefore, springs performance optimization plays an important role in improving the dynamic and comfort of ride within vehicles. In recent years, the automotive industry has shown an increasing tendency to improve the comfort and cost of manufacturing of the steel springs. This has been by moving towards high strength-to-weight materials such as carbon fibre composite coil springs. carbon fibre coil springs offer a better dynamic performance and help reducing the fuel consumption by as much as 40% due to being lighter (by 70 %) compared to the steel springs .The design of spring is critical in terms of durability and strength and the reduction of spring weight is also an important factor in improving automotive dynamics. Replacing steel helical spring with a composite helical spring reduces spring weight while also increasing resistance to applied stress. In this study, composite materials are selected and compared with the existing conventional steel. Major composite to be used for coil spring applications are carbon/epoxy (single fiber and single matrix composite) . Analysis are carried out to study the behavior of steel and composite helical springs in light car suspension systems. A steel spring was replaced by composite springs, and the load-carrying capacity, stiffness, and weight savings (strength-to-weight ratio) of the composite helical spring are compared with those of a steel helical spring. The material is selected based on their advanced properties for the application of compression coil springs.

2. METHODOLOGY

Carbon fibers are a high- strength materials composed of graphitic and noncrystalline regions. Carbon fibers have the strongest specific modulus and strength of all reinforcing fibers. They may also maintain their tensile strength even at high temperatures and are moisture-resistant. In contrast to glass and other organic polymer fibers, carbon fibers do not necessarily break when stressed. They are extremely versatile because of their out- standing strength-to-weight and stiffness-to-weight ratios

The matrix binds the fiber reinforcement, gives the composite component its net shape, and determines its surface quality. A composite may be a polymer, ceramic, metal, or carbon. matrices by themselves generally have low mechanical properties compared to those of fibers, they can still influence many mechanical properties of the composites such as transverse modulus and strength, shear modulus and strength, compressive strength, inter laminar shear strength, thermal expansion coeficient, thermal resistance, and fatigue strength.

Epoxy Resins:Epoxy plays a major role in composite fibers. Although reinforcing fibers are used in many applications, epoxy is the substrate that we will be dealing with. The substrate materials are used to bind whatever strengthening fiber is being used and to lock them in position so they can stay in position to do their job. Ten, for these composite fibers, epoxy is as a substrate material. Epoxy is a thermosetting polymer with varied qualities including mechanical conductivity, thermal conductivity. In general, epoxy resins have very good adhesive properties, superior mechanical properties, i.e., strength and stiffness, better resistance to fatigue and micro-cracking, high resistance to water penetration, faster curing at room temperature, and good chemical resistance properties .

In this study, composite materials are selected to replace the existing conventional steel by comparison. The two major composites to be used for coil spring applications are carbon/epoxy (single fiber and single matrix composite) . The selection of these composites is based on their advanced properties for the application of compression coil springs.

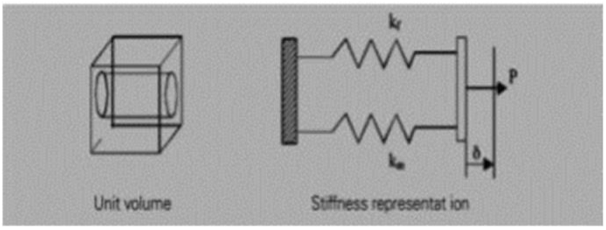

Figure 2: Physical model for the longitudinal properties of a composite .

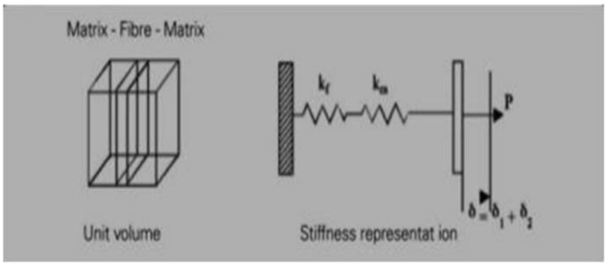

Figure 3: Physical model for the transverse properties of a composite .

In composites the direction and distribution of fibres during fabrication process can be freely selected to be in such a way that ensures the highest available strength and stiffness of material is always being provided along the direction of loading. Hence, to identify the optimum mechanical properties of fibres, the mechanical properties of composites are usually evaluated through tensile testing samples along their fibres direction. Axial stress is expressed as σ= P A and it has relation with the strain and Young's modulus of material via σ=E. The strain is defined as length added due to the deformation over the initial length of the bar as = Δ L0 . So by substituting the stress and strain in the Hook's Law relationship, the deformation of a prismatic bar under axial load will be as:

$\delta = P l / AE$, $M = \rho AL$, $M = P L2 / 4\delta E \rho$ (2.2) where, M is the mass of the bar in (lb. or Kg), P is the pressure (N/m2 or kg·m−1 ·s −2), L is the length of the bar (ft. or mm), A is the cross section of the sample (ft2 or mm2), δ is the actual deflection in the length of the bar (ft. or mm), E is the Young's modulus of the material (Pa or N/m2 or m−1 ·kg·s −2), and ρ is the density of the material (lb./ft3 or kg/m3). E/ρ is the specific modulus ratio for a material.

Parameters in the design of helical springs :The very first factor to be considered when designing coil springs is to consider for the elasticity; this means that how good a spring can absorb the mechanical energy and dissipate it by converting it to other forms of energies (deformation, heat, etc.) whilst remaining within its elastic region. Therefore, the design of a spring should be based on the Hook's Law. In the round springs the basic parameters upon which a typical helical spring can be designed are the coil diameter (D) and the wire diameter (d) . Where: D is the mean diameter of the helix (Dout +Din)/2, d is the diameter of the wire, L0 is the length of an unloaded spring, Ls is the minimum length in fully loaded and close gaps between the coils, p is the distance of two consecutive cycles of the wire in adjacent active coils, N is the number of coils in a loaded spring which have actively deformed, P is the angle between the coil and the base of the spring and is calculated as follows:

$\alpha = \tan^{-1} p/ \pi d$

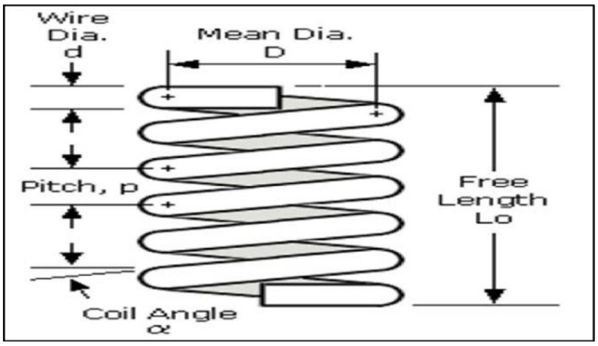

Fig 4: Schematic of coil spring

3. MODELING AND ANALYSIS

Explicit advantages of using composites springs within the today's modern vehicles can be named as: reducing the fuel consumption and weight of vehicle, being stronger and more durable than steel springs, providing a better ride comfort, and requiring less maintenance. As a result, every intention has been to improve the current or conventional fabrication methods to produce novel composite springs that can actually be used in the today's highperformance vehicles.

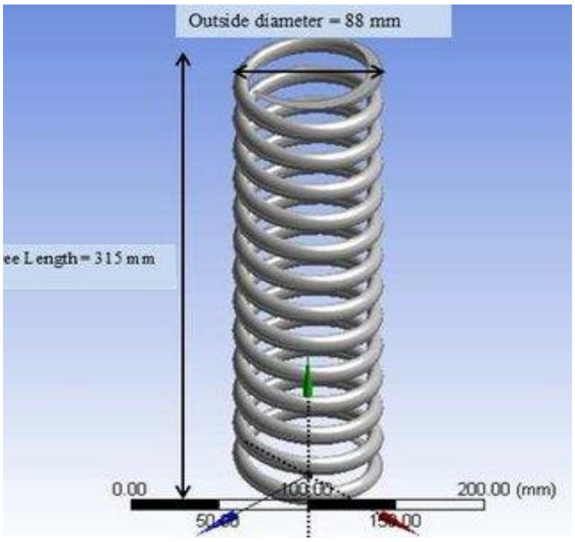

Fig 5:CAD Model of coil spring

4. RESULTS AND DISCUSSION

coil Spring Deformation Results. The deformation analysis results are tabulated in Table 10 below for the steel material as well as carbon/CNT/epoxy and carbon/epoxy composite materials.

The results show that the composite material springs have a much larger defection when compared with the same dimension steel spring. Especially for very large loads, the deformation of the composite spring is very large. Therefore, this leads to the conclusion that composite materials cannot be of good enough performance to be used as spring materials unless some parameter optimization is done.

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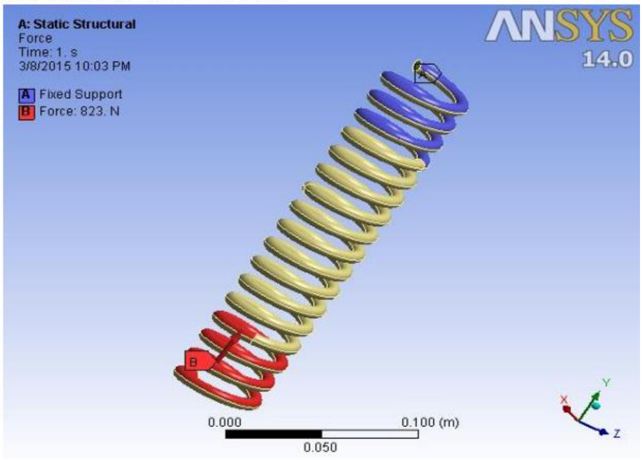
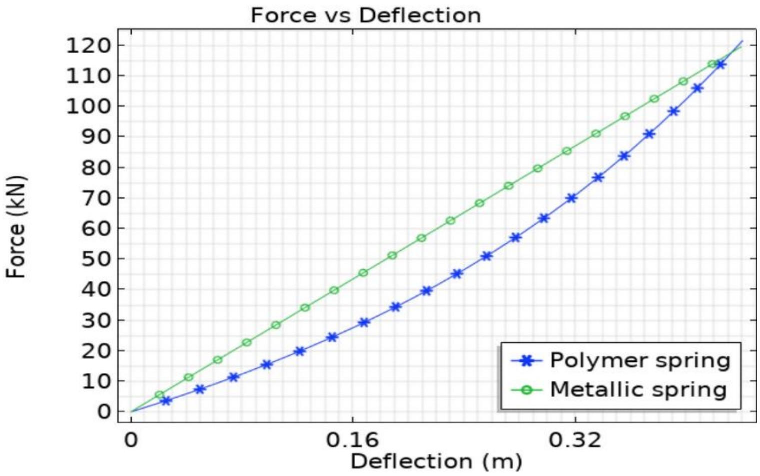
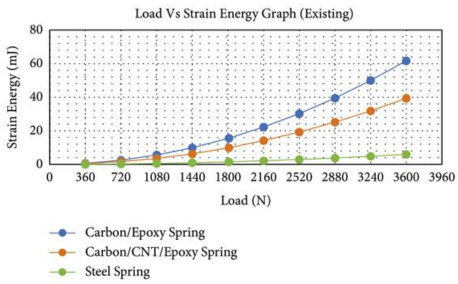
ON APPLYING LOAD:





The lines of different colors represent the defection versus load graph of the individual spring types. The line colored in green represents load versus defection values of steel coil springs, while the yellow and blue-colored lines indicate carbon/CNT/epoxy and carbon/epoxy composite springs, respectively. The defection difference between these springs is clear and visible in the graph. Hence, the composite springs are more deformed than the existing steel springs. And comparing the two composite springs, the carbon/CNT/epoxy deforms less than the carbon/epoxy spring.



5. CONCLUSION

This project shows the advantages of replacing conventional steel springs with optimized composite springs made of carbon/epoxy.There is a significant advantage for lightweight vehicles by replacing steel springs with the optimized carbon epoxy composite springs offers. The following are the benefits from the analysis :

1. Reduced deformation
2. Improved structural integrity and fatigue life
3. Reduced weight for improved fuel efficiency and performance
4. load-carrying capacity for enhanced safety is increased.

This study provides a strong evidence for the potential of composite springs to revolutionize suspension systems in lightweight vehicles, paving the way for a more sustainable and efficient future of transportation. Overall, the findings of this work were promising, although, the issue of producing springs with consistent mechanical and physical properties is an important area to be explored in further research.

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