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Design And Analysis Of Helical Spring With Combination Of Conventional And Composite Materials

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ABSTRACT

Aim of this paper is to analyze feasibility of adopting composite material for design of helical coil spring. Combination of springs with steel and composite material i.e. Glass fiber epoxy resin is to be used in place of conventional spring steel. The cause of implementing combination of steel and composite material is the low stiffness of single composite spring, which limits its application to light vehicles. Fuel efficiency of automobiles can be maximized by lowering the weight of the vehicle. The spring of the suspension system plays an important role for a smooth and jerk free ride. So it is required to design the springs very precisely. The use of conventional steel as spring increases the weight and manufacturing process energy required is more so manufacturers are willing to use composite materials light in weight and also have corrosion resistance, it can also withstand high temperature. Manufacturing composite material is quite costlier than the steel spring. The use of composite material is beneficial if manufacturing process is standardized it can increase the efficiency of the vehicle adherence overcome the material cost.

Keywords— **Helical spring, composite material, Glass fiber, epoxy resin, stiffness, Fuel efficiency**

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I. INTRODUCTION

Spring is an elastic body whose function is to store energy when deflected by force and return equivalent amount of energy on being released. Helical compression springs are widely used for suspension in light vehicle and locomotives worldwide. Generally springs made of hardened steel are used. Small springs can be wound from pre-hardened stock while larger ones are made from annealed steel and hardened after fabrication. Non-ferrous metals are also used such phosphor bronze and titanium for parts requiring corrosion resistance and beryllium copper for springs carrying electrical current because of its low electrical resistance.

The rate of spring is called the change in the force it exerts, to the change in deflection of the spring. On the basis of design and required operating environment, any material can be used to construct a spring , so long as the material has the required combination of rigidity and elasticity: technically, a wooden bow is a form of spring. In the present scenario the automobile industry is regularly trying to reduce the fuel consumption of the automobile vehicles. Fuel efficiency of automobiles can be maximized by lowering the weight of the vehicle. The suspension system of an automobile is one of the important segments of the automobile vehicle. The use of steel helical coil spring in suspension system is generally used by the automobile manufacturers. We know that, the spring of the suspension system plays an important role for a smooth and easy ride. So it required to design the springs very exactly. The use of conventional steel in spring increases the weight and with the current scenario the automobile manufacturers are interested in replacing steel springs with light weight composite materials.

Some of important studies carried out by researchers are summarized as

[1] Abdul Budan, T.S.Manjunathathe checked feasibility of replacing the metal coil spring with the composite coil spring. Three different types of springs were made using glass fibre, carbon fibre and combination of glass fiber and carbon fibre. The objective of the study was to reduce the weight of the spring. According to the experimental results the spring rate of the carbon fiber spring is34% more than the glass fiber spring and 45% more than the glass fibre/carbon fiber spring. The weight of the carbon fiber spring is18% less than the glass fiber spring, 15% less than the Glass fibre/carbon fibre spring and 80% less than the steel spring. Three types of composite coil springs have been developed in this study; they are lighter than steel spring and the stiffness achieved in these springs are less than the steel springs. (Spring rate of the same dimension steel spring is approximately 14 N /mm and weight of the steel spring is 1.078 kg). The following conclusions can be drawn from the analysis of experimental results of these springs. The weight of the springs manufactured from carbon fiber roving is less than the glass fiber and glass fiber/carbon fiber roving springs. The stiffness of the carbon fiber springs is greater than the other two types of composite coil springs. The springs developed from the glass fiber/carbon fiber roving does not exhibit a favourable results compare to other two types of springs.

The cost of the glass fiber springs are 25% more than the steel springs and the cost of the carbon fiber springs is 200%more than the steel springs. The selection of the glass fiber or a carbon fiber springs depends upon the cost and application of the spring which can be compensated by saving the fuel from weight reduction. As compared to steel springs of the same dimensions, the stiffness of composite coil springs is less. In order to increase the stiffness of the spring the dimensions of the composite spring is to be increased which in turn increases the weight of the spring. Hence the application of the composite coil springs can be limited to light vehicles, which requires less spring stiffness, e.g. electric vehicles and hybrid vehicles.

[2]Mehdi Bakhshesh and Majid Bakhshesh studied replacement of a helical steel spring by three different composite helical springs. Numerical results have been compared with theoretical results and found to be in good agreement. Compared to steel spring, the composite helical spring has been found to have lesser stress and has the most value when fiber position has been considered to be in direction of loading. Weight of spring has been reduced and has been shown that changing percentage of fiber, especially at Carbon/Epoxy composite, does not affect spring weight. Longitudinal displacement in composite helical spring is more than that of steel helical spring and has the least value when fiber position has been considered to be in direction of loading. The most safety factor is related to case that fiber position has been considered to be perpendicular to loading and it is for Carbon/Epoxy composite helical spring. Resin transfer moulding process is used for manufacturing spring.

Steel helical spring has been replaced by three different composite helical springs including E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy. The loading conditions are assumed to be static. Spring Shear stress has been obtained using FEM and has been compared with steel helical spring. Composite spring properties have been studied with changing fiber angle relative to spring axial. The element is SOLID 46, which is a layered version of the 8-nodes structural solid element to model layered thick shell or solids. The element has three degree of freedom at each node and allows up to 250 different material layers. From results it is concluded that Spring has the most Shear stress when fiber position has been considered to be in direction of loading. With changing fiber angle, Shear stress reduces so that it reaches the least value when fiber position has been considered to be perpendicular to loading.

[3]Suresh.G, Vignesh.R, Aravinth.B, Padmanabhan.K, A.Thiagararajan done design and experimental analysis of composite helical spring made of fiber reinforced polymer of Woven Roving Fiber (WRF), and Thermo set polymer (Epoxy

Resin) with Nano clay. The addition of nanoclay provides unique mechanical and tribological properties combined with low specific weight and a high resistance to degradation in order to ensure safety and economic efficiency. A

Comprehensive study was carried out a series of Nano composites containing varying amount of nano particles (Nano clay). The objective was to compare the load carrying capacity, stiffness and weight savings of composite helical spring with that of steel helical spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel helical spring of a light commercial vehicle are taken. Same dimensions of conventional helical spring are used to fabricate a composite spring.

The types of composite coil springs had been developed in this study; they are lighter than steel spring and the stiffness achieved in these springs are less than the steel spring. As compared to steel springs of the same dimensions, the stiffness of composite coil springs is less. In order to increase the stiffness of the spring the dimensions of the composite spring is to be increased which in turn increases the weight of the spring. Hence the application of the composite coil springs can be limited to light vehicles, which requires less spring stiffness, e.g. electric vehicles and hybrid vehicles. The manufacturing of the composite coil springs is also difficult and time consuming compare to steel spring, however with the use of CNC winding machine and automated process which can be made easy and also the manufacturing cost can be reduced if produced in mass.

II.DESIGN OF SPRINGS

Load considerations :
Total wt of bike 120kg+ wt of two persons 130kg,
Considering Dynamic wt we will take it as 4000N
Rear suspension 60% of total weight=2400N
On single spring suspension-1200N
Design of springs for payload 1200N And deflection 30mm
No of designs are possible with different wire dia, coil dia, length and deflections. Trial and error method used for spring design for composite and spring steel material. Design is carried for shear stress allowed up to 50% of ultimate tensile strength, Ultimate tensile strength for spring steel is 1050Mpa for 8 mm wire and for spring steel 350 Mpa for glass fibre epoxy resin with fibre content 60%
Spring index C taken as 6
Design for spring carried keeping length, and deflection to be same i.e.
K=K1+K2
For circular sections using formula,

$$T = kS * \frac{8WD}{\pi.d^3} \quad (\delta) = \frac{WD^3n}{G.d^4},$$

KS=4C-1+0.615C=1.3105
For rectangular section using formulas

$$K = \frac{W}{\delta} = \frac{Gb3\,(t-0.56b)}{2.45nD3}, \ \tau = \frac{KWD\,(1.5t+0.9b)}{b^2t^2}$$

$$K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

TABLE I
PROPERTIES OF STRUCTURAL STEEL

PARAMETER	VALUE
Density (kg/m3)	7850
Young's modulus (Pa)	2.1011
Poisson's ratio	0.3
Bulk modulus (Pa)	1.6667.1011
Shear modulus (Pa)	7.6923.1010
Ultimate tensile strength (Pa)	4.6.108
Yield tensile strength (Pa)	2.5.108
Yield compressive strength (Pa)	2.5.108

TABLE III
PROPERTIES FOR GLASS FIBRE EPOXY RESIN

PARAMETER	VALUE
Density (g/cc)	2.6
Tensile modulus	81.4 GPa
Shear modulus (GPa)	15
Fiber strength (GPa)	3.45
Elongation	4.88%

Design1- Material spring steel
1. Mean diameter – 56 mm
2. Pitch
3. Cross sectional diameter – 9 mm
4. Length of spring – 200 mm
5. Thickness of cover plate – 2 mm

Design2- Material spring steel
1. Mean diameter – 56 mm
2. Pitch
3. Cross sectional diameter – 9 mm
4. Length of spring – 200 mm
5. Thickness of cover plate – 2 mm

Design3- Material Glass fibre epoxy resin composite
1. Mean diameter – 56 mm
2. Pitch
3. Cross sectional diameter – 9 mm
4. Length of spring – 200 mm
5. Thickness of cover plate – 2 mm

Design4- Material Glass fibre epoxy resin composite
1. Mean diameter – 56 mm
2. Pitch
3. Cross sectional diameter – 9 mm
4. Length of spring – 200 mm
5. Thickness of cover plate – 2 mm

III .MANUFACTURING OF STEEL AND COMPOSITE SPRING

Rectangular Composite spring is manufactured winding filaments around mandrel in rectangular slots. A mandrel having the profile of the spring is prepared first from aluminium stack. This mandrel is fixed in the lathe chuck. A mould release agent like silicone gel is applied on the mandrel. Glass fibre roving is dipped in the measured quantity of resin and wound on the mandrel by rotating it on a lathe. After the complete winding of the roving in the profile of the mandrel a shrink tape is wound on the mandrel. This shrink tape applies the required pressure on the material. The mandrel along with the material and the shrink tape is cured in atmospheric temperature for 24 hours. After curing shrink tape is removed. The excess resin on the surface of the spring is removed by filing. The cured spring is removed from the mandrel by rotating in the reverse direction. Fig shows the fabricated composite coil springs. The fabricated spring is having the dimensions L=230mm, D=56mm, n=10, b=10mm, t=8mm and pitch=20mm.

Fig1.Alluminium mandrel

Sr no	Material	Max load	Max Deflection	Stiffness	Max. shear stress	Wt of spring in Kg
Design 1	Spring steel	1200	40	30	350N/mm2	1.22
Design 2	spring steel	600	40	15	570N/mm2	0.2953
Design 3	Glass fibre(% 60% in epoxy resin)	600	40	15	130 N/mm2	0.4539
Design 4(rectangular section)	Glass fibre(% 60% in epoxy resin)	600	40	15	170 N/mm2	0.5123
Assembly 1(spring2 and 3)	Spring steel & glass fibre epxy resin	1200	40	30	570N/mm2	0.7492
Assmbly2(spring2 and4)	Spring steel & glass fibre epxy resin	1200	40	30	570N/mm2	0.8076

Fig 2 Composite & steel helical spring.

Steel spring is coiled at room temperature using coil spring manufacturing machines with wire diameter and required pitch.

IV.Testing and results:

Testing of spring is to be done on spring testing machine for finding out graph of load and deflection.

IV.CONCLUSION

From analytical and experimental results it has been found that steel helical springs can be replaced with combination of conventional steel and composite material helical spring with stiffness remaining same. If we have to achieve more stiffness it can be done by b increasing spring volume i.e. by increasing cross section or by increasing pitch. By using combination of springs in series weight reduction can be achieved up to 35% which is basic need of current automobile spring manufacturers. Cost of manufacturing composite springs is more compared to helical springs but it can be justified by producing composite components in mass and cost of fuel saved.

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