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A Review on Helical Coil Suspension System

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Abstract: *The suspension system is used to observe the vibrations from shock loads due to irregularities of the road surface. It is perform its function without impairing the stability, steering (or) general handling of the vehicle. Generally for light vehicles, coil springs are used as suspension system. A spring is an elastic object used to store mechanical energy and it can be twist, pulled (or) stretched by some force and can return to their original shape when the force is released. The present work attempts to analyze the safe load of the light vehicle suspension spring with different composite materials. The best way to increase the fuel efficiency is to reduce the weight of the automobiles by employing composite materials in the structure of automobiles. Metal coil springs can be replaced by composite springs because of high strain energy, less weight and high corrosion resistance.*

Keywords: *suspension system, composite materials, coil springs*

1. INTRODUCTION

The complete suspension is to observe the vehicle body from road shocks and vibrations otherwise it is transferred to the passengers and load. It must keep the tires in contact with the road, regardless of road surface. A basic suspension system consists of the parts springs, axles, shock absorbers, arms rods and ball joints. The spring is the flexible component of the suspension. Modern passenger vehicles usually use light coil springs. Light commercial vehicles have heavier springs than passenger vehicles, and can have coil springs at the front and leaf springs at the rear. Each side of the vehicle wheels connected by solid or beam, axles. Then the movement of a wheel on one side of the vehicle is transferred to the other wheel with independent suspension, the wheel can move independently of each other, which reduce body movement. And it is also prevents the other wheel being affected by movement of the wheel on the opposite side and reduces body movement. Coil springs are used on the front suspension of most modern light vehicles. Then the spring act as an elastic object used to store mechanical energy. They can twist, pulled (or) stretched by some force and can return to their original shape when the force is released. A coil spring is made from a single length of special wire, which is heated and wound on a former, to produce the required shape. The load carrying ability of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape, and the spacing of the coils.

Normally, helical spring failure occurs due to high cyclic fatigue in which the induced stress should remain below the yield strength level and also with poor material properties. K PavanKumar1 et.al. (2013) discussed about the static analysis of primary suspension system, their work is carried out on modeling helical spring in Pro/E and analysis in ANSYS of primary suspension spring with two materials Chrome Vanadium is a existing material and 60Si2MnA steel is a new material, the conventional steel helical spring 60Si2MnA is proved as best material for helical spring by reduction of deflection and overall stress. PriyankaGhate2 et al. investigated the failure of A Freight Locomotive helical spring by redesigning to improve the durability and ride index in this the composite suspension system can sustain the loads in under normal operation conditions and maintains the ride index but the failure occurs during cornering and hunting speeds to avoid this the study of dynamic behavior of a composite spring is analyzed. The dynamic analysis was performed using ADAMS/Rail at four different velocities and three different track conditions and numerical simulation also carried out. The results shows that the stress value obtained from numerical simulations in ADAMS was verified with analytical design

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calculations for the spring and the ride index was found to 1.78 which was 8% better than the earlier spring. It is concluded that the new spring design can enhance durability and ride index.

Many studies are carried out to investigate the behavior of composite springs. SenthilKumar and Vijayarangan investigated behavior of composite leaf spring for light passenger vehicles. Their studies included design and experimental analysis of composite multi leaf spring made of glass fiber reinforced polymer. Static analysis of 2-D model of conventional leaf spring was performed using ANSYS and compared with experimental results. Compared to steel spring, the composite leaf spring was found to have lesser stress, higher stiffness and higher natural frequency than that of existing steel leaf spring and weight of spring was reduced by using optimized composite leaf spring.

In their study, the effects of the number of active loops, the helix pitch angle and material types on the first six natural frequencies of helical springs with circular section and fixed– fixed ends were investigated. Gobbi and Mastinue designed composite helical spring with a hollow circular section. In their study, the technical specifications, (e.g. stiffness, maximum deflection) were given and the method allows defining the spring geometrical and mechanical parameters in order to get the best compromise among spring performances (minimum mass, maximum strength) with constraints on local and global stability and on resonance frequency. An optimization study on helical compression springs has been performed by Azzam. The objective functions and constrains were mathematically formulated to minimize the spring weight and maximize the spring stiffness by changing composite material.

2. Solid Modeling of Metal Helical Spring

Helical springs have the characteristic parameters that affect their behaviors. In addition to the physical properties of its material, the wire diameter (d), loop diameter (D), number of loops (Na) and the distance between two consecutive loops (P) are the parameters that affect the behavior of spring. These parameters have been illustrated in Fig. 1.

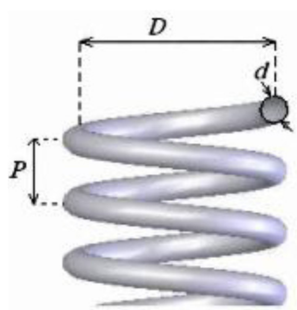

Fig. 1.The parameters of helical spring

Before analysis of helical spring, the rate of spring, shear modulus and poison coefficient are needed to be calculated.

3. Simulation of Steel Helical Spring

Spring Geometry is modeled in SOLIDWORKS Software and then is analyzed under uniform loading condition in ANSYS Software. Axial displacement and shear stress have been compared with analytical results. Load is in direction of spring axis and is exerted on the one end of spring and other end is fixed in X, Y and Z directions. Meshes with different resolutions are generated to insure grid independence. Mesh of spring and its loading has been illustrated in Fig. 2.

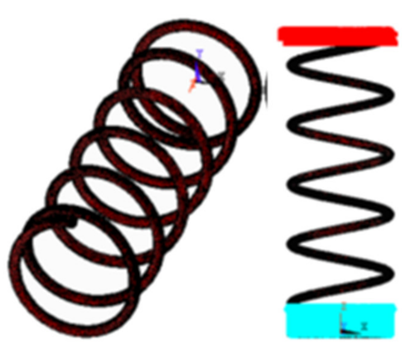

Fig.2. Manner of mesh and loading in spring

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Element selected for this analysis is SOLID45. SHELL element does not show stress variation in the course of diameter. BEAM element represented stress along the length only and doesn't show other information about stress.SOLID92 is a pyramid element that increases time of calculations and it has error in nonlinear complex models. Therefore, a cubic SOLID45 element has been used in the stress analysis. This element is defined by eight nodes having three degrees of freedom at each node: translations in nodal x, y and z directions. Axial and lateral displacements have been shown in Fig. 3 and Fig. 4.

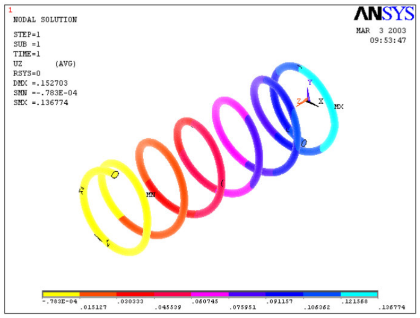

Fig. 3

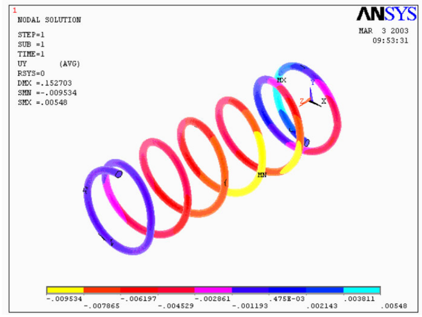

Fig. 4

Fig. 3 and Fig. 4 show that lateral displacement of spring is nominal in compare with longitudinal displacement. This is because that loading is in longitudinal direction and poison coefficient is very small. Table 2 shows axial displacement and shear stress using finite element method (FEM) and have been compared with analytic results.
Shear stress can be written as

Where, is shear stress correlation coefficient, is index spring (D/d), is static force, is mid diameter of spring, d is wire diameter.

4. Replacement Steel Spring with Composite 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.

A. Composite Helical Spring Weight

Before modeling of composite helical spring, its weight has been calculated and compared with steel helical spring. Compared to steel helical spring, Composite helical spring has been found to have lesser weight. Also it is concluded that changing percentage of fiber, especially at Carbon/Epoxy composite, does not affect spring weight.

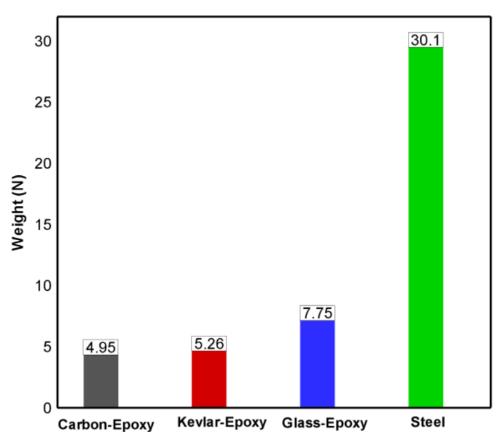

Fig. 5. Comparison of steel and composite spring weight

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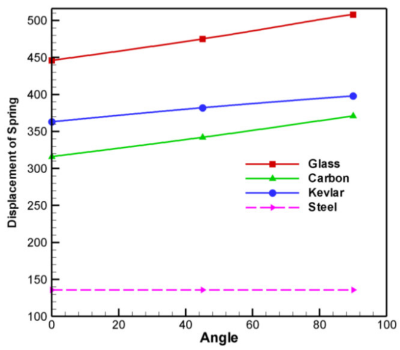
B. Direction of Fiber in Composite Helical Spring

Spring strength must be calculated at fiber along and fiber vertical direction. Fiber volumetric portion is 0.6 and resin volumetric portion is 0.4. Since spring wire diameter is 13 mm, number of layers must be selected in a way that summation of layers thickness is equal to 13 mm. Therefore, number of layers is 26 in which each layer thickness is 0.5 mm. Angle fiber has been changed so that fiber position has been considered in direction of loading, perpendicular to loading and at angles of 30 and 45 degree relative to applied loads. In any case, three different composite helical springs including E-glass/Epoxy, Carbon/Epoxy and Kevlar/Epoxy have been considered and longitudinal displacement and shear stress have been calculated to analyze the effect of spring material upon spring behavior. It is worth mention that fiber has been placed at the same thickness layers which are parallel relative to each other. Longitudinal displacement under the effect of fiber angle has been shown in Fig. 6. Spring has the least longitudinal displacement when fiber position has been considered to be in direction of loading. With changing fiber angle, spring longitudinal displacement increases so that it reaches the greatest value when fiber position has been considered to be perpendicular to loading. Also, Figure 6shows that E-glass/epoxy composite helical spring has the most flexibility and Carbon/Epoxy composite helical spring has the least displacement. It is obvious that longitudinal displacement in composite helical springs is more than that of steel helical spring. Shear stress under effect of fiber angle has been shown in Fig. 7. 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.



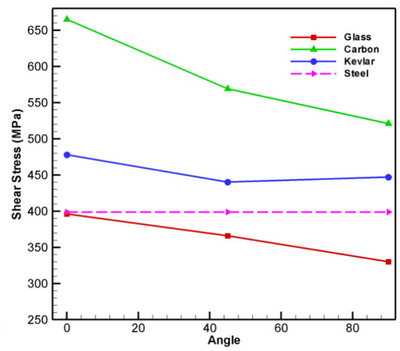


Fig.6. Longitudinal displacement versus fiber angle   Fig. 7. Shear stress versus fiber angle

Factors of safety under the effect of applied loads have been calculated with changing fiber angles. Results have been presented in table4 and have been graphically illustrated. At factor of safety calculations, it has been assumed that resin strength is nominal in comparison with fiber strength and can be neglected.

Conclusion

In this paper, a steel spring has been replaced by three different composite helical springs. Compared to steel spring, the composite helical spring has been found to have lesser stress. Weight ofthe spring has been reduced by using composite material. Due to high strain energy capacity and high corrosive resistance, composite helical springs may be used for high strength engineering applications. It may be replaced by other aluminium metal composite materials.

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