A Finite Element Analysis Of Helical Compression Spring For Electric Tricycle Vehicle Automotive Front Suspension

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Abstract

This paper deals with the finite element analysis of a helical compression spring, which is employed in electric three wheelers as per considering various road conditions in India. In the design of this kind of spring both the elastic characteristics and the fatigue strength have to be considered as significant aspects. In addition to this particular elastic property, as a consequence of the research effort in reducing the mass of components typical of the automotive industry, these springs have to face very high working stresses. The structural reliability of the spring must therefore be ensured. So for this purpose the static stress analysis using finite element analysis gives Von-Mises stresses and total deflection of helical compression spring at various loads.

1. Introduction

A Electric Three-Wheeled Vehicles are mostly used private public transport or in small scale industries for easily moving for nearest places. The suspension system for such three wheeler's vehicles is very poor as concerned with the ride comfort of the passengers. Relatively higher centre of gravity, the lack of differential for the driving rear axle have been cited as contributors to rollovers and pitching. This also adds the discomfort to passengers. Nowadays the trend in the industries is moving towards the weight reduction in every component of the electric vehicle is important to improve the efficiency of battery of the electric three wheeler. The stress analysis is essential in helical coil compression spring for shear stress and maximum deflection induced in the spring at maximum loading condition. As these springs undergo the fluctuating loading over the service life, it becomes essential to find out the fatigue limit of the same.

Mechanical spring is defined as an elastic body that has the primary function to deflect or distort under load, and to return to its original shape when the load is removed. First step in the design of spring in general, is to determine the loads and the deflections required for a given spring application depending upon the type of the loading. In addition to this tentative selection of the material must be made. In case of the most general approach for the spring design, the maximum stress in the spring wire may be In case of the most general approach for the spring design; the maximum stress in the spring wire may be computed by superposition of direct shear and the torsional shear stress. To design the helical coil compression spring for small pitch angle, a very common approach called as approximate theory

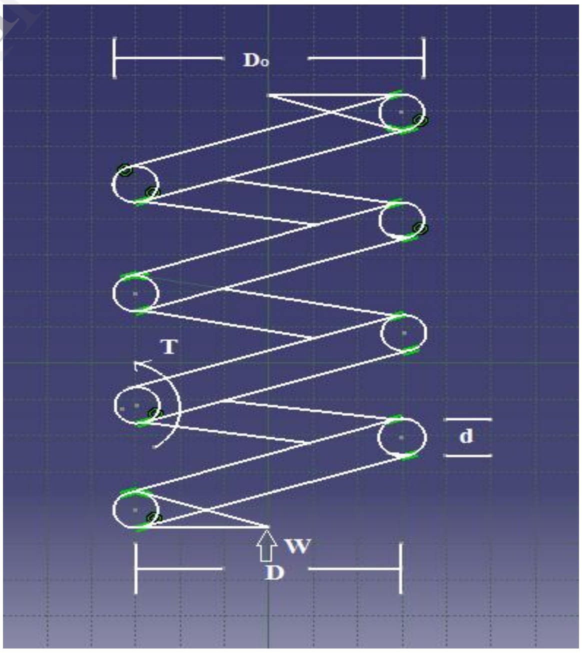

Figure 1 2D Model of Helical Coil Spring

The assumption is that an element of an axially loaded helical spring behaves as a straight bar in pure torsion. If *W* be the load acting axially on the spring, *d* is the diameter of the spring wire D_O is the outer diameter of coil, *D* is the mean diameter of the coil, and then forces acting on the element are resolved into a twisting moment *WD/2 acting* in a radial plane and a direct axial shearing force *W*. The stresses set up by the twisting moment are considered first and then superimposed on the stresses due to the direct shear. The shear stress due to the direct axial load *P* added such that it produces the torque moment *WD/2 at* this point. Thus the stress range at inner side of the coil is normally much higher than elsewhere and for this reason fatigue failure generally starts at this region. Therefore maximum shear stress at the inside of the coil given by

$$\tau_{max} = \frac{k8WC}{\pi d^2}$$

Where C (spring index) = $\frac{D}{d}$

$$K\ (Wahl's\ \text{factor}) = \frac{4C-1}{4C-4} + \frac{0.615}{C}$$

The maximum deflection produced in the helical coil compression spring is given by

$$\delta = \frac{8WC^3 n}{Gd}$$

Where *G* is the shear modulus of material and *n* is the number of active coils in the spring.
The maximum deflection produced by the spring in theoretically is 62.39mm at the maximum loading conditions.

2. FINITE ELEMENT ANALYSIS

An FEA-based design begins with the selection of the element type, how the model should be constructed, how accurate the results should be, and how fast the model should run. The most accurate FEA results can be obtained by creating 3-D parts of a coil spring and its seats, followed by meshing the parts with 3-D solid element. Finer meshing with higher-order elements will produce more accurate results.

2.1 Modelling

The spring selected for the electric three wheelers is squared and ground ends. In all the spring, the end coils produce an eccentric application of the load, increasing the stress on one side of the spring. Under certain conditions, especially where the number of coils is small, this effect must be taken into account. The nearest approach to an axial load is secured by squared and ground ends, where the end turns are squared and then ground perpendicular to the helix axis. It may be noted that part of coil which is in contact with the seat does not contribute to spring action and hence are termed as inactive coils. The turns which impart spring action are known as active turns.

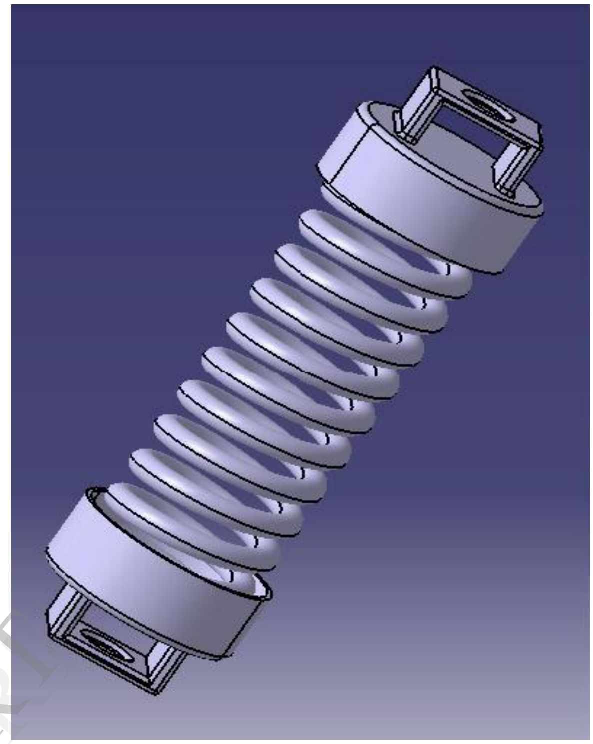

Figure 2 Helical Suspension System

2.2Geometricle properties of helical coil compression spring

Outer Diameter D_O	71.94mm
Inner Diameter D_i	49.998mm
Mean Diameter D	60.976mm
Wire Diameter d	10.976mm
Spring Index C	5.5
Free Length L_f	227.45mm
Solid Length L_S	142.688mm
No of Active Turns N_A	11
No of Total Turns N_T	13
Pitch (p)	17.5mm

Table no.1 Spring Dimensions

The effect of residual stresses has been neglected in this analysis. A basic solid model of the spring is made in the CATIA V5 R20 software as shown in figure 1. The spring seats are modelled in this analysis and contact of seats with spring surface is considered as rigid body.

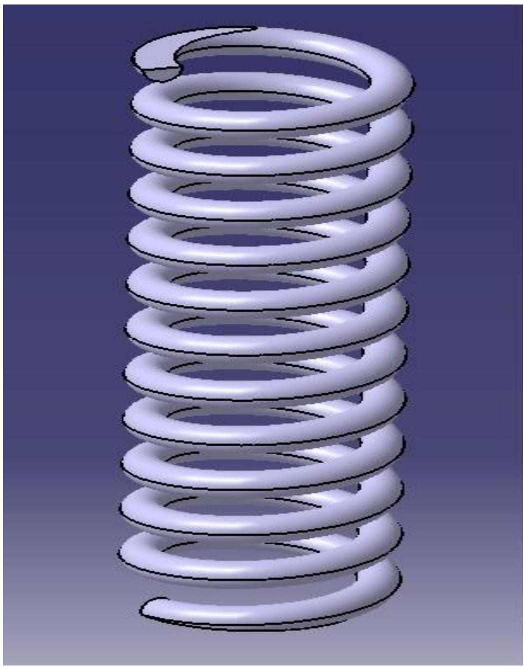

Figure 3 Helical Coil

The spring seat are with grounded ends are clearly seen in fig. 2. The caps are fitted on the grounded ends of both side, is shown in fig1.

The figure 1 is complete model of helical compression spring which is directly mounted on the front suspension of three wheeler.

2.3 Material properties

Modulus of Elasticity *E*	210 GPa
Shear Modulus *G*	80 GPa
Poisson's Ratio *μ*	0.28
Density	7850 kg m^-3
Coefficient of thermal expansion	1.2e-005 C^-1
Specific Heat	434 J kg^-1 C^-1
Thermal Conductivity	60.5 W m^-1 C^-1

Table no. 2

3. MESHING

ANSYS 13.0 is the software used for the pre and post processing. This spring is meshed with different elements and different meshing types and then comparative study has been done in order to find out the convergence criteria. At first the spring was meshed with element SOLID187. This element is a higher order 3-dimentional.

Tetrahedral meshing produces high quality meshing for boundary representation solids model imported from the most CAD system.

10-node element. SOLID187 has quadratic displacement behaviour and is well suited to modelling irregular meshes (such as those produced from various CAD/CAM systems). The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. This element is used for the Tet-Meshing.

. This element is used for Hex-meshing. In the second case the spring was modelled with element SOLID95/SOLID186. This is used for 3-D modelling of solid structures having 20 nodes. It can tolerate irregular shapes without as much loss of accuracy. SOLID186 elements have compatible displacement shapes and are well suited to model curved boundaries. It is defined by eight nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions

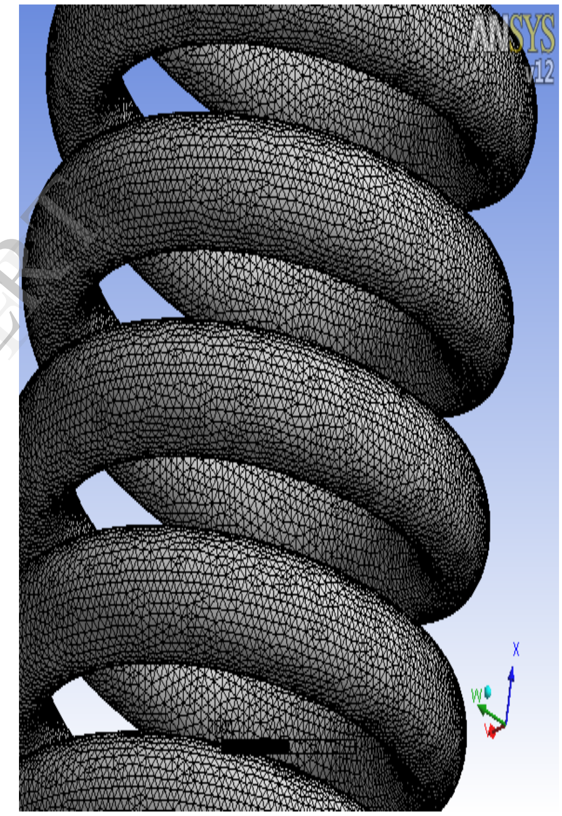

Figure 4 Mesh Component

Mesh study is performed on the FE model to ensure sufficiently fine sizes are employed for accuracy of calculated results but at competitive cost (CPU time). In the process, the shear stress is the specified field variable is selected and its convergence is monitored.

4. LOADING CONDITION

The load is distributed equally by all the nodes associated with the centre of the spring. The both the ends are fixed in cap and the load is applied on x direction. The loading at static and dynamic condition gives different stresses and deflection.

This spring is used in the Electric three wheeled vehicle front suspension so to find out the load acting on the spring in actual practice in static condition as well as in dynamic condition. The kerb weight of the electric tricycle is 650 Kg. It is assumed that this total weight is equally divided into two springs of rear suspension and one spring of front suspension. So the front suspension spring is experiencing approximately maximum 250 Kg load. This load is modelled in the analysis with the help of mass element. Then rigid body constraint equations are applied for giving contact between this element and the surface elements of the spring on upper side.

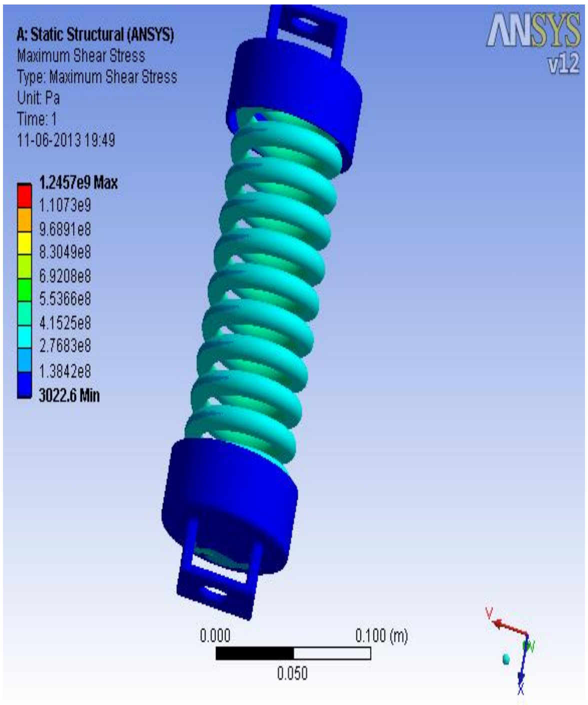

Figure 5 Maximum shear stress

5. Static Stress Analysis

The linear static analysis was performed to determine the stress and strain results from the finite element model. The material utilized in this work consists of a linear elastic, isotropic material. The choice of the linear elastic material model is essentially mandated. Model loading consist of the applied mechanical load, which is modelled as the load control and the displacement control. From the analysis, the inner side of the coil is found to experience the largest stresses. The maximum shear stress induced in the spring is 1.246×10^3 MPa and the Von- Mises stress produced as shown in Fig.6 is given as 2.169×10^3MPa. The deformation produced in the spring at dynamic condition is shown in Fig. 7 is 61.77 mm. The deformation value of helical compression spring is within the safe value. The deformation produced theoretically is also 62.39mm so the design is in safe condition, so we can use this spring for three wheeler.

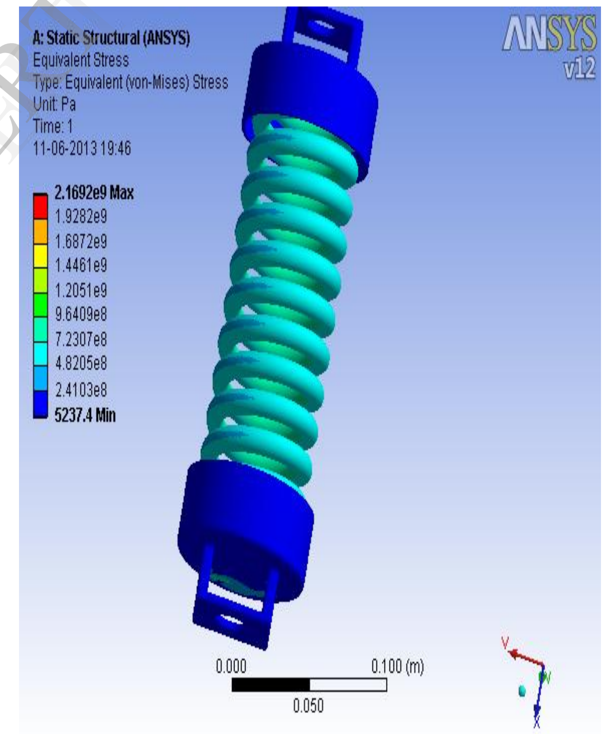

Figure 6 Von-Mises stress

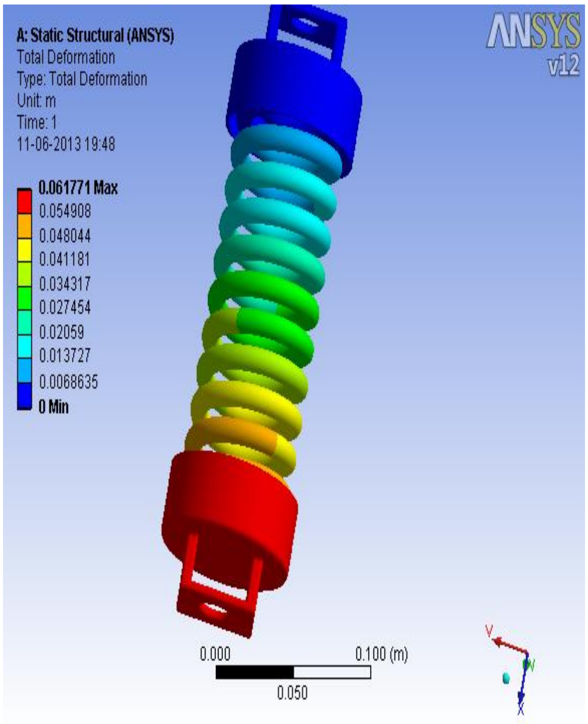

Figure 7 Total Deformation at maximum loading.

5. CONCLUSION

The elastic behaviour and the stress analysis of springs employed in the TWV's front automotive suspension have been presented and discussed in this paper. The shear stress produced in the spring at the loading condition is in safe. The deformation produced by the spring is also in given limit value so we can implement this spring to our electric tricycle. The results obtained by a fully 3D FE analysis also highlighted the poor accuracy that can be provided by the classical spring model when dealing with these spring geometries. Relative errors on maximum shear stress ranging from 1.5 to 4 per cent, with reference to the applied loads, obtained when compared with the values calculated by using simple analytical model which is found in textbooks. The stress distribution clearly shows that the shear stress is having maximum value at the inner side of the every coil. The distribution of the stress is similar in every coil. So the probability of failure of spring in every coil is same except end turns. In such case residual stress in every coil may be important factor which influence the failure.

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