Analysis and Optimization of a Helical Compression Coil Spring used for TWV

Mr. Harshad B. Pawar[1], Prof. Amol R. Patil[2], Dr. Sanjay B. Zope[3]

[1] *P. G. Student, Mechanical Department, Sahyadri Valley College of Engineering & Technology, Rajuri, Pune, Maharashtra - 412409, India.*

[2] *Professor, Sahyadri Valley College of Engineering & Technology, Rajuri, Pune, Maharashtra - 412409, India.*

[3] *Principal, Sahyadri Valley College of Engineering & Technology, Rajuri, Pune, Maharashtra - 412409, India.*

ABSTRACT

Suspension system of three wheeled vehicle (TWV) consists of springs as well as hydraulic shock absorber which is usually designed for passenger's safety and to improve passenger's comfort. There is literature review of some papers was done in this paper which was related to the design and analysis of spring. Helical compression springs are commonly used in the most of the automobile vehicle. Most automobile company now days have interest in the reduction of spring weight without changing the remaining system. For this reason in present paper the numerical method and finite element analysis was used for the selection of minimum number of coils. Using modeling software solid works completed the modeling and by using Ansys software meshing and post processing of spring was done. For validation purpose comparison of software and theoretical values was done. For this load verses deflection values were calculated. The main aim of this paper is to suggest the alternate minimum number coils for helical compression spring which used for three wheeler and reduce the weight of the existing coil spring.

Keyword: - *optimization, shear stress, spring, weight.*

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1. Introduction

Springs are mechanical shock absorber system. A mechanical spring is defined as an elastic body which has the primary function to deflect or distort under load and to return to its original shape when the load is removed. Springs are mainly used in the industry for absorbing shock member energy and for resetting the part at its initial position upon displacement for a given function. Helical Compression springs are helical coil springs that resistance to a compressive force. Helical Compression springs having shapes like cylindrical, conical, tapered, concave or convex etc. Coil compression springs are wound in a helix usually out of round wire. The springs are designed to withstand the cycle of loading or unloading during operation. The front suspension helical coil compression spring used for three wheeler front suspension has high in weight so it needs to optimize in weight. Therefore in this present work it is proposed to carry out the numerical design and finite element analysis of helical compression spring used for front suspension in a three-wheeler transport vehicle so as to reduce the weight.

2. Literature Review

2.1 S. Kilian, U. Zander and F.E. Talke (2003):- A finite element based optimization software Altair OptiStruct is used to optimize the design of suspensions in hard disk drives. Topology optimization, topography optimization and combinations of both techniques are used to optimize a contact start-stop suspension with respect to torsion, bending and sway mode frequencies. The suspension, gimbal, slider and air bearing are modeled. The air bearing is modeled with linear springs to represent stiffness in the z-direction, pitch and roll. Modal analysis is compared to experimental resonance data to verify the model. The results show that improvements of more than 50% can be achieved with respect to increasing sway or torsional modes. [1]

2.2 S. K. Das, N. K. Mukhopadhyay, B. Ravi Kumar, D. K. Bhattacharya (2007):- Investigation on the premature failure of suspension coil spring of a passenger car, which failed within few months after being put into service, has been carried out. Besides visual examination, other experimental techniques used for the investigation were (a) microstructural analysis and fractography by scanning electron microscopy (SEM), (b) inclusion rating by optical microscopy, (c) hardness testing, (d) residual stress measurement by X-Ray diffraction (XRD) and (e) instrumental chemical analysis. Inherent material defect in association with deficient processing led to the failure of the spring. The spring was failed prematurely due to the inadequate shot peening process used to impart residual compressive stresses on the surface. The presence of excessive oxide inclusions in the steel might have also aggravated the case. [2]

3. Methodology

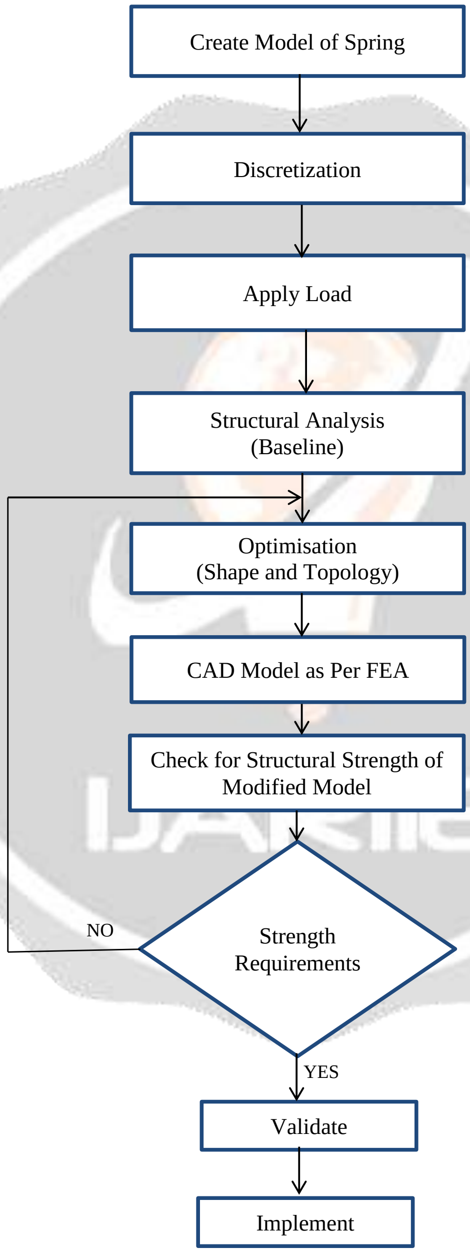

Figure 1 Flow Chart of Methodology

4. Spring Design

4.1. Stresses in Spring of Circular Wire [4]

To determine the stress generated in the spring consider a helical spring subjected to an axial load F.

Let,
D = Mean Diameter of the spring coil,
d = Diameter of the spring wire,
n = No. of active coils,
G = Modulus of rigidity for the spring material,
F = Axial load on the spring,
τ = Max. Shear stress induced in the wire,
C = spring index = D/d
P = Pitch of the coils, and
δ = Deflection of the spring, as a result of an axial load F.
If we remove a portion of the spring, the internal reactions will be a direct shear and a torque T = F×D/2 where each will cause a shear stress, and the maximum shear will occur at the inner surface of the wire which is equal to,
$\tau_{max} = T\ r/J + F/A$
Substituting T= F× D/2, r= d/2, $J = \pi/32\ d^4$, $A= \pi\ /4\ d^2$ gives
$\tau = \frac{8FD}{\pi d^3} + \frac{4F}{\pi d^2}$
Defining the spring index which is a measure of coil curvature as, C = spring index = D/d, for most springs C ranges from 6 to 12
We get,
$\tau = \frac{2C+1}{2C}\left(\frac{8FD}{\pi d^3}\right) = K_s\left(\frac{8FD}{\pi d^3}\right)$
Where Ks is called the "Shear stress correction factor" This equation assumes the spring wire to be straight and subjected to torsion and direct shear. However, the wire is curved and the curvature increases the shear stress and this is accounted for by another correction factor K_c and thus the equation becomes,
$\tau = K_c K_s\ 8FD/\pi d^3$
Where Kc is the "curvature correction factor" Or easier the two correction factors are combined together as a single correction factor K_B where:[17]
$K_B = Kc \times Ks = \frac{4C+2}{4C-3}$
Thus,
$\tau = K_B \times 8FD/\pi d^3$

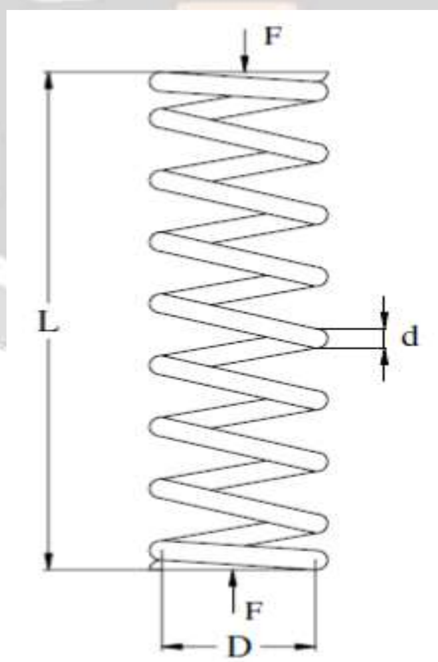

Figure 2 Helical Spring with Axial Load

4.2 Existing Spring

The existing suspension spring is heavy hence needed to be optimized and a lighter design of the spring is needed. The calculations were made with the help of above mention formulae and different values came for existing design given below. The existing spring having following specifications;

Outside Diameter = 8.8 cm, Inside Diameter = 6.4 cm, Wire Diameter = 1.2 cm, Free Length = 31.5 cm, Number of Active Coils = 12, Number of Total Coils = 14, stiffness = 3.936 kg/mm

4.3 New Spring

The calculations were made with the help of above mention formulae and different values came for new design given below. The new spring having following specifications;

Outside Diameter = 8.8 cm, Inside Diameter = 6.4 cm, Wire Diameter = 1.2 cm, Free Length = 31.5 cm, Number of Active Coils = 11, Number of Total Coils = 13, stiffness = 4.29 kg/mm

4.4 Maximum Shear Stress

Shear stress was calculated for 3200 n force.

$$\tau = K_s \left(\frac{8FD}{\pi d^3} \right) = 444.2 \ \text{N/mm}^2$$

5. Finite Element Analysis of Suspension Spring

5.1 Material Properties

Material properties are applied for the suspension spring shown in the table number 4 below;

Table 1 Material Properties

Material	Modulus of Elasticity MPa	Density g/cc	Poisson's Ratio	Ultimate Tensile Strength
IS 4454 Grade 2	207×10^3	7.85	0.26	1350 – 1500

5.2 CAD Model

The CAD model for existing design and new design was shown in figure 3 and 4 respectively. By the use of modeling software Solid Works these models were created. These models have 14 and 13 coils respectively with closed and ground end.

Figure 3 Model of Existing Design

Figure 4 Model of New Design

5.3 Boundary Condition

The weight of three wheeled vehicle is 975 kg so the vertical load 3200 N is applied on spring by considering load equally distributed to all three wheels. The vertical load was applied to the spring centre and the fixed support given to spring and displacement due to applied load measured. By the use of above values suspension spring was constraint for static analysis.

5.4 Stress Analysis

In the figure below of existing design the deflection plot of suspension spring shows a maximum stress of 484.58 MPa which is observed at the inner section of the spring under a vertical load of 3200N. In the below figure of new design the deflection plot of suspension spring shows a maximum stress of 420.85 MPa which was observed at the inner section of the spring under a vertical load of 3200N.

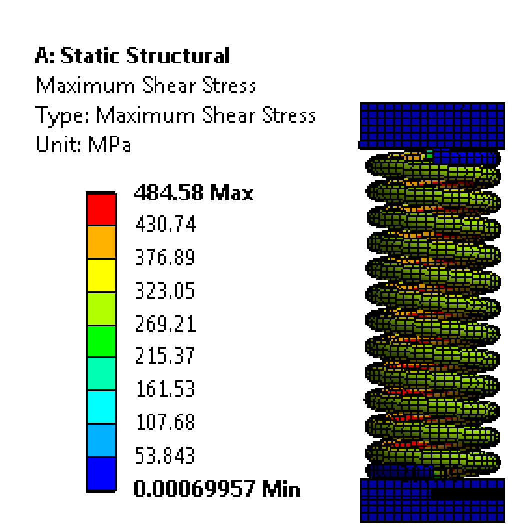

Figure 5 Stress Analysis of Existing Design

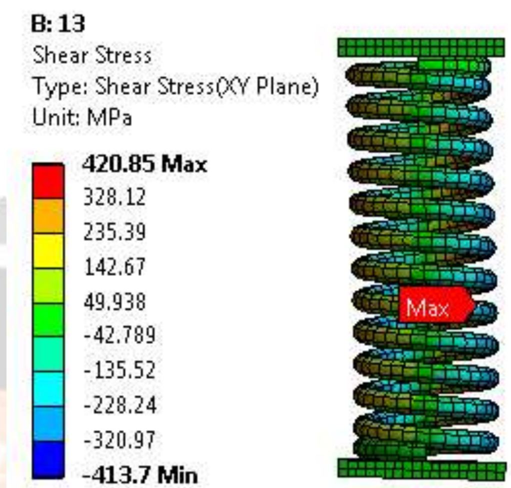

Figure 6 Stress Analysis Meshing of New Design

6. Conclusion

The stress analysis of helical compression coil spring used in the three wheeler vehicle had been presented in this paper. The shear stress and deformation produced in the new spring at the loading condition was less than existing design so new design is safe. The stress reduction for new design is 13% than the existing. Relative error of maximum shear stress was 7 to 9 % with reference to the applied load compared with the calculated values by using simple numerical formulae which were found in the text books. From above analysis it has been observed that the stiffness of the suspension spring is increased which in turn increases load carrying capacity of the system. Because of the reduction in number of turn by one the weight of the spring is reduced. It has been observed that the reduced weight of the system is 6% than the existing one. Therefore the light weight system will achieved which will help to increase the fuel efficiency of the vehicle. The load carrying capacity also increased by 9%. Based on the above study it is concluded that the new design is suitable for use so it can be implement.

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