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DESIGN AND ANALYSIS OF A FRONT SUSPENSION COIL SPRING FOR THREE WHEELER VEHICLE

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ABSTRACT

Basically the spring is a flexible component of suspension system. In Modern transport vehicles usually use light coil springs. For this reason present paper used the analytical methods and finite element analysis for the selection of helical compression spring with number of turns. Using Finite Element Analysis completed the modelling, meshing and post processing of front suspension spring. The present work attempts to analyze the load of the three wheeler vehicle front suspension spring with SP ST GRD II material. This investigation includes comparison of software and theoretical analyses of coil spring made of SP ST GRD II material suggested the suitability for optimum design. This work also determined the structural strength of coil spring using the finite element analysis. Based on theoretical and software result comparison the optimum turns which meet all requirements was suggested.

Key Words – coil spring, FEA, optimization, turns

INTRODUCTION

A spring is defined as an elastic body, whose function is to deform when loaded and to recover its original shape when the load is removed. It is an elastic object used to store mechanical energy. The spring is a very important component of the suspension system that provides ride comfort. The spring supports the weight of the vehicle, maintain ride height and absorb road shock. The most commonly used springs is the helical compression coil spring. The force of a coil spring depends on wire diameter, mean coil diameter, number of coils and materials. The primary design constraints are that the wire size should be commercially available and that the stress at the solid length be no longer greater than the torsional yield strength. For present study the helical compression coil spring of three wheeler front suspension system was consider.

LITERATURE REVIEW

Y. Prawoto, M. Ikeda, S.K. Manville, A. Nishikawa This paper is a discussion about automotive suspension coil springs, their fundamental stress distribution, materials characteristic, manufacturing and common failures. An in depth discussion on the parameters influencing the quality of coil springs is also presented. To assure that a coil spring serves its design, failure analysis of broken coil springs is valuable both for the short and long term agenda of car manufacturer and parts suppliers. This paper discusses several case studies of suspension spring failures. The failures presented range from the very basic including insufficient load carrying capacity, raw material defects such as excessive inclusion levels, and manufacturing defects such as delayed quench cracking, to failures due to complex stress usage and chemically induced failure. FEA of stress distributions around typical failure initiation sites are also presented. [3]

Gajendra Singh Rathore, Upendra Kumar Joshi The objective of this review paper is to provide the information about the fatigue stress for the helical compression spring. 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. The researchers throughout the years had given various research methods such as Theoretical, Numerical and

Experimental. Researchers employ the Theoretical, Numerical and FEM methods. This study concludes Finite Element method is the best method for numerical solution and calculating the fatigue stress, life cycle and shear stress of helical compression spring. [4]

OBJECTIVE

Three Wheeled Vehicles form a major part of transport of public as well as goods for the urban middle class population of India. From literature it is seen that very few work was done on deciding the minimum number of turns required for front suspension coil spring. Now a day the trend in the industries is the weight reduction in every component and springs are not exception for it. This work considers the number of turns for optimisation purpose.

METHODOLOGY

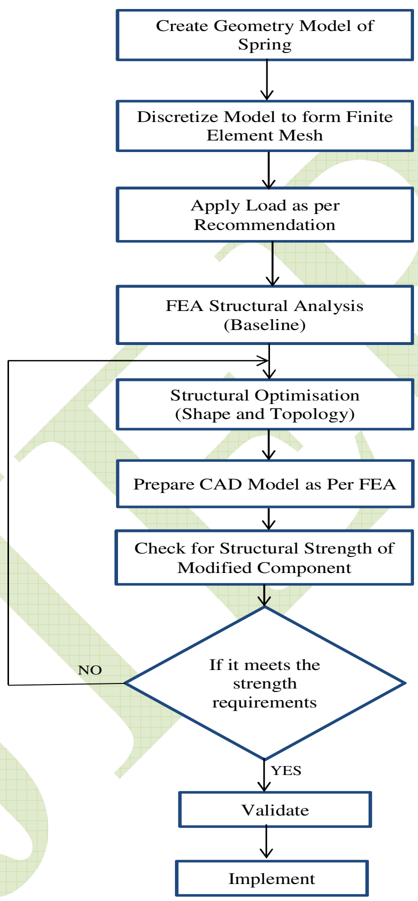

Figure 1 Flow Chart of Methodology

Numerical Illustration of Suspension Spring

Equations for Spring Design

To design the spring and determine the stress developed in the spring consider a helical spring subjected to an axial load P. [7]

Let,

D = Mean Diameter of the spring coil (mm), D_o = Outside Diameter of the spring coil (mm), D_i = Inside Diameter of the spring coil (mm), d = Diameter of the spring wire (mm), N = Number of active coils, N_t = Total number of coils, G = Modulus of rigidity for the spring material, P = Axial load on the spring (N or Kg), p = Pitch (mm), J = Polar moment of inertia of bar, L = Free Length (mm)

The equations required for the design of the spring are as follows;

a) Spring Index (C) = $\frac{D}{d}$
b) Wahl's Stress factor (K) = $\frac{(4C-1)}{(4C-4)} + \frac{0.615}{C}$
c) Stiffness = k = $\frac{G \times d^4}{8 \times D^3 \times N}$ N/mm
d) Shear Stress(τ) = $\frac{(K \times 8 \times P \times D)}{(\pi \times d^3)} = \frac{K \times 8 \times P \times C}{\pi \times d^2}$ N/mm^2
e) Solid Length = $N_t \times d$
f) Deflection (δ) = $\frac{P}{k}$ mm

Existing Spring Data

The existing suspension spring is heavy hence needed to be optimized and a lighter design of the spring is needed.

Table 1 Specification of Existing Helical Compression Spring

Sr. No.	Specification	Value
1	Outside Diameter	88 mm
2	Inside Diameter	64 mm
3	Wire Diameter	12 mm
4	Free Length	315 mm
5	Number of Active Coils	12
6	Number of Total Coils	14
8	Ultimate Tensile Strength	1500 MPa
9	Material Grade	IS 4454 Grade II
10	End Type	Closed and Ground

Existing Design

Total number of coils = 14
Number of active coils = 12

Stiffness = $k_1 = \frac{G \times d^4}{8 \times D^3 \times N} = \frac{80 \times 10^3 \times 12^4}{8 \times 76^3 \times 12}$

k_1 = 39.36 N/mm = 3.94 kg/mm

New Design

Total number of coils = 12.5
Number of active coils = 10.5

Stiffness = $k_2 = \frac{G \times d^4}{8 \times D^3 \times N} = \frac{80 \times 10^3 \times 12^4}{8 \times 76^3 \times 10.5}$

k_2 = 44.99 N/mm = 4.50 kg/mm

Maximum Shear Stress

$$\tau = \frac{K \times 8 \times P \times C}{\pi \times d^2} = \frac{1.24 \times 8 \times 3200 \times 6.33}{\pi \times 12^2}$$

τ = 444.2 N/mm^2

FINITE ELEMENT ANALYSIS OF SUSPENSION SPRING

Material Properties

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

Table 2 Material Properties

Material	Modulus of Elasticity MPa	Density g/cc	Poisson's Ratio	Ultimate Tensile Strength
SP ST GRD II	207000	7.85	0.26	1350 – 1500

Modelling

The CAD model for existing design and new design is shown in figure 2 and 3 respectively. These models are created by the use of modeling software Solid Works. These models have 14 and 12.5 coils respectively with closed and ground end. The 3-D model of suspension springs were then imported in ANSYS software for analysis purpose.

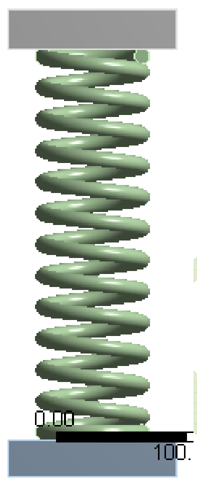

Figure 2 Model of Existing Design

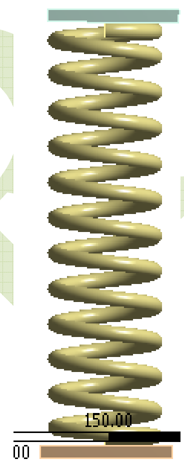

Figure 3 Model of New Design

Meshing

Meshing is done in ANSYS. The suspension spring being a solid component, hence 3D meshing is required. In existing design meshing the nodes used are 54794 and elements are 10692 and in new design meshing the nodes used are 23874 and elements are 4062.

Boundary Conditions for Static Calculations

The weight of 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 is applied on the spring centre and the fixed support given to spring and displacement due to applied load measured. In this way the suspension spring is constraint for static analysis.

Post Processing

In the figure of existing design below the deflection plot of suspension spring shows a maximum stress of 484.5 MPa which is observed at the inner section of the spring under a vertical load of 3200N. In the figure of new design below the deflection plot of suspension spring shows a maximum stress of 491.6 MPa which is observed at the inner section of the spring under a vertical load of 3200N.

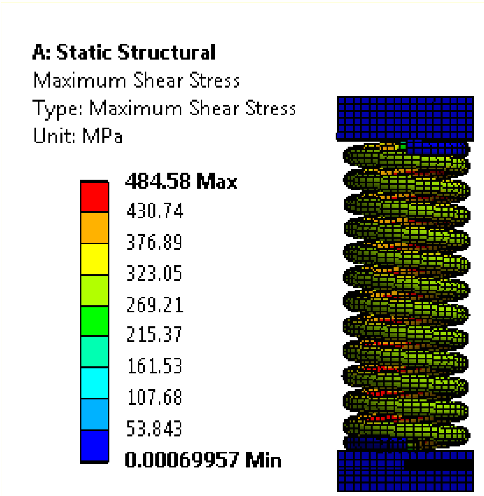

Figure 4 Stress Analysis of Existing Design

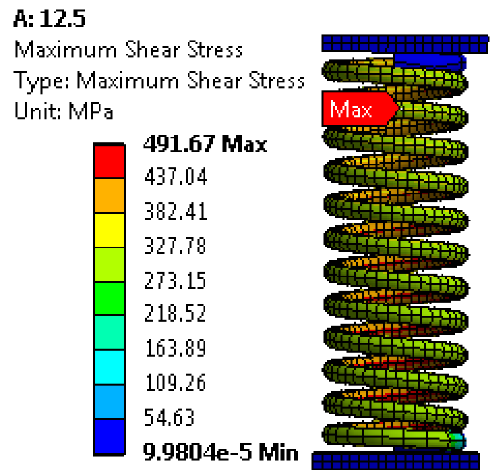

Figure 5 Stress Analysis Meshing of New Design

RESULT DISCUSSION

The load at various deflections, in N was analysed and show in below graph for various springs. In the graph below theoretical and software shows existing design values while theoretical I and software I shows new design values of load verses deflection. From graph it is seen that the new design has maximum load carrying capacity than the existing design. The theoretical and software values are close to each other so it implies that the modeling of the spring is acceptable. The stress induced in the new design of spring for given load is with in the design limit i. e. less than 0.56 UTS. The weight of the spring is also reduced due to change in number of turns.

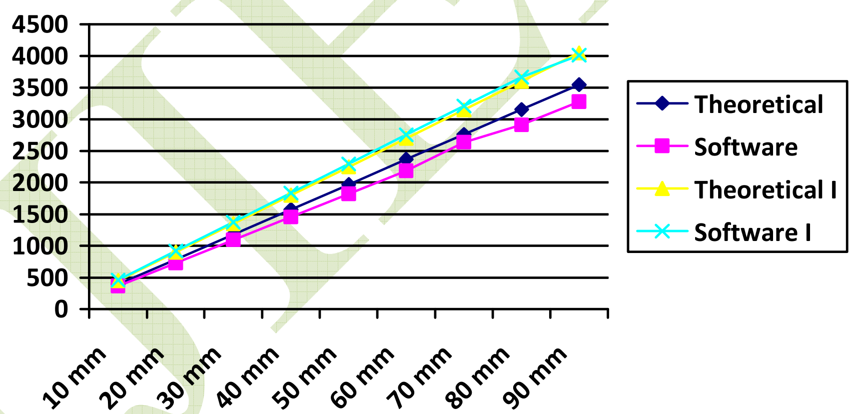

Figure 6 Software and Theoretical Values of Load vs. Deflection

CONCLUSION

The stress analysis of front suspension helical coil spring used in the three wheeled vehicle have been presented and analysed in this paper. The shear stress and deformation produced in the spring at the loading condition is in limit so it is safe. Relative error of maximum shear stress ranging from 6 to 10 % with reference to the applied load compared with the values calculated by using simple analytical formulae which were found in reference books. The shear stress is having maximum value at the inner side of the every coil which shows stress distribution clearly. From above analysis it has been observed that the stiffness of the suspension spring is increased which increases load carrying capacity of the system. Because of the reducing number of turns the weight of the spring is reduced. It has been observed that the weight of the system is reduced up to 9% for same loading conditions. Therefore the light weight system is achieved which will help to increase the fuel efficiency of the TWV. The load carrying capacity also increased by 11%. Based on the modeling and analyses conclude that the new design is suitable for used so it can be implement.

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