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DESIGN AND PROFILE IMPROVEMENTATION OF SUSPENTION COIL SPRING

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ABSTRACT

In this study, a helical spring which is used in two wheeler and three wheeler front suspension system was taken in to consideration for optimizing coil size and shape. The existing problem is observed that, the vehicle drifts towards one side due to heavy weight and poor performance of the helical spring. This problem can be rectified by optimizing the size and shape of the coil spring. For optimizing, the existing model of solid circular coil with straight profile spring were compared with solid elliptical model springs. The stiffness, stress and deflection were calculated using numerically and verified with analytically, moreover the shape factor for efficiency was verified numerically. The analytical results were obtained using FEA code Ansys15.0 software. Finally, it was concluded that the elliptical coil spring exhibits better shape factor for efficiency, high stiffness with occupying less amount of space, very low stress and deflection when compared to existing model spring

1. INTRODUCTION

Helical springs subjected to static load have been investigated by numerous studies over the years, most of which were limited to circular cross-section springs with only few studies have been conducted for elliptical cross-section springs. The study of elliptical cross-section springs goes back to 1950 with Shiguma and 1959 with Fuchs where both have emphasized some significant advantages of helical springs manufactured of elliptical wire as compared with circular wire, unfortunately without an elaborated analytical support.

Springs are elastic bodies that can be twisted, pulled, or stretched by some force. They can return to their original shape when the force is released. In other words it is also termed as a resilient member

The following advantages were mentioned: for the same free height, elliptic cross-section helical springs enable larger stroke than the circular one; as a result reduction in the mounting height is possible, by selecting a certain aspect ratio the shear stress distribution can be made more uniform along the section, and some reduction in the maximum stress across the wire can be obtained compared to the equivalent circular cross-section helical spring, thus permitting support of larger loads for the same dimensions.

Consideration of these advantages is important and provides more freedom in springs design. It is especially important because of recent developments in materials and manufacturing methods promote down-sizing of machines

Helical springs having doubly symmetric cross-sections such as a circle, a square and an ellipse were analytically analyzed in terms of static deflection under an axial force by Yıldırım. Stresses in elliptical cross-section helical springs were analyzed by various numerical approaches such as the Fourier collocation, finite element and boundary element methods. Unfortunately, no analytical expression to support a firm understanding of the parameters affecting the stresses in those springs was presented.

In particular, Finite Elements Analysis (FEA) has been employed in some applications of springs, such as on leaf springs and helical springs with round wire, with the goal to determine the spring rate and stresses distribution in the cross- section and to validate analytical approaches. But no published application of FEA for elliptical cross- section helical springs was available to the authors of this study.

To satisfy the designer need, in the present study an analytical expression for the stresses in an elliptical cross-section helical springs is developed taking into account the helix curvature effect and the aspect ratio of the elliptical wire cross-section. The provided expression eases the design process of those useful springs.

A spring is a mechanical device which is used for the efficient storage and release of energy. Depending upon the requirements, a spring can take different shapes, such as helical coil of a wire, a piece of stamping, or a flat, wound-up strip.

To validate the analytical expression developed, a detailed finite element modeling and analysis of an elliptical cross section helical springs using the commercial FEA package is performed. Finally, the proposed analytical and the computed FEA results are validated experimentally.

2. PROJECT METHODOLOGY

PROBLEM IDENTIFICATION

DEFINE & SET OBJECTIVE

LITERATURE SURVEY

MODELLING

FEA ANALYSIS

THEORITICAL ANALYSIS

RESULTS & CONCLUTION

3. MATERIALS AND METHODS

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Table2.1 Properties of steel

S.No	Properties	Unit	Steel
1.	Density	Kg/m3	7850
2.	Modulus of Elasticity	GPa	206
3.	Poisson's ratio	-	0.3
4.	Tensile Ultimate strength	MPa	1250
5.	Modulus of rigidity	GPa	78

The Existing coil spring dimensions are given in Table.2 for this analysis. Moreover the dimensions of hollow circular, solid elliptical and hollow elliptical model spring were tabulated in Table. 3, 4, 5.

Table2.2 Dimensions of existing solid circular spring

S.No	Parameter	Values(mm)
1	Mean Coil diameter(D)	75
2	Diameter of wire (d)	15
3	No of turns(n)	15
4	Free length(L)	300
5	Pitch	200
6	Number of active turns	12

Table2.3 Dimensions of solid elliptical spring

S.No	Parameter	Values(mm)
1	Width(2b)	20
2	Height(2a)	15
3	No of turns(n)	15
4	Pitch	20
5	Number of active turns	12

4.LITERATURE SURVEY

- Agarwal and Jain(2017) had investigated that the design and analysis of helical spring in two wheeler suspension system using finite element method (FEM) by changing the cross section of the helical spring under the static structural analysis. Three cross sections have been selected namely circular, square and square fillet. The spring models for the existing design of CBZ extreme bike helical coil spring have been created by using Pro/E Creo 2.0. The deflection and the Von-Misses stress of three spring models are obtained by finite element analysis. The maximum displacement and Von-Misses stress are achieved in circular cross section and the least by square cross section.
- Chaudhury and Datta (2017) created methodology for designing prismatic springs of non-circular coil shape and non-prismatic springs on circular coil shape using analytical and numerical methods. A prismatic spring with a rectangular coil shape bounded by semicircles on the smaller sides and a triangular profile with rounded edges under axial load has been attempted. A non-prismatic spring of circular coil with conical spring shape and volute spring shape are also analyzed. The CAD models are developed for all the types of springs and finite element analysis was carried out for all the spring types
- Yu and Hao (2011) had investigated using an analytical study on natural frequency of cylindrical helical springs with non-circular cross sections such as ellipse, rectangular and equilateral triangle. The increase in the spring length, No. of turns and decrease in stiffness, reduces the frequency in elliptical cross section. The increase in cross section area increases the natural frequency of the spring. For square section the warping has no effect on the natural frequency. The geometric properties of cross sectional areas and the different arrangements of the cross section have major effect on the natural frequency.
- Rajurakar and Swami (2016) had carried out a feasibility check for the properties of helical spring by changing the cross section and by changing the material under varying load from 55N to 95N. The results proved that stresses are almost equal but the deflection in spring of chrome vanadium material when compared to hard carbon steel spring proved more deflection. Although the deflection is more it Works efficiently with less maintains. The check also ensured that structural reliability is more in circular cross section than in rectangular.
- Hao et al. (2016) made a parametric study on the influence of warping upon natural frequency of die springs by Riccati transfer matrix. The spring parameters such as height-to-weight ratio of cross section, the cylinder diameter, helix angle and the No. of coils produce warping effect. There occurs an error of 40% when warping is neglected. For the aspect ratio of rectangle 1:0.6 and less, warping has to be consider to minimize the error between analytical and FEA results. It has proposed differential equations of motion for die springs with

warping effect and has solved examples under different boundary condition.

- Lavany et al. (2014) investigated the design and analysis of a suspension coil spring for automotive vehicle with two different materials. Low carbon structural steel and chrome vanadium steel were chosen for the analysis. The load carrying capacity of the spring depends on the diameter of the wire, the overall diameter of the spring, its shape, and the spacing between the coils. Normally, helical spring's failure occurs due to high fatigue cycle, high induced stress that is above the yield strength and poor material properties. Spring optimization was also made by changing the spring material there by reducing the spring weight and maximum stress considerably. From the results the induced stress for low carbon structural steel is less compared to chrome vanadium. It also enhances the cyclic fatigue of helical springs.

5.RESULT AND DISCUSSION

5.1 Numerical Evaluation Of Circular Spring

Mean coil diameter(D)	75mm
Diameter of wire(d)	15mm
No of turns(n)	15
Free length(l)	300mm
Pitch	20mm
Young's modules(E)	2*e^5N/mm^2
Torque Applied	80000 N.mm
Modulus of rigidity(G)	76923
Load(W)	2500N

5.2 Numerical Analysis

The stiffness, stress and deflection values is the most important factor for optimization of spring, so it can be numerically calculated and verified with analytical value. The values are tabulated below. For Numerical calculation, and to obtain the stress, stiffness and deflection values, the following formula were used. Model Calculation-Solid circular (existing) Type of End: Plain and Ground end Inner diameter D_i = 65mm.Outer diameter D_o = 85mm, Mead coil dia (D) = 75mm, R=D/2= 37.5mm.Coil dia (d) = 15mm, No of turns (n) = 15, Free length (L_f) = P*n = 15*15= 225mm Solid length (L_s) = d*n= 15*15 = 225mm.For critical load (W) = 2500 N

Now,

(i) Stiffness (K)

K = G D / 64nR3

= 78*103 *154 64 *15*37.53

 77 N / m

(ii) Stress (τ)

= 8 * W * D / 3.14 d^3

=8 * 2500 * 75 / 3.14 * 15^3

=141.4 N / mm^2

(iii) Deflection (δ)

= 8 * W * D^3 n / G d^4

= 8 * 2500 *75^3 *15 / 78*10^3 * 15^4

= 32.5mm

Result of Circular Spring	
Stiffness	77
Stress	141.4
Deflection	32.5mm

5.3 Numerical Evaluation of Elliptical Spring

Wire cross section diamention(a,b)	a=20,b=15
No of turns(n)	15
Free length(L)	300mm
Pitch	20mm
Young's modulus(E)	2*e^5N/mm^2

Torque Applied	80000 N.mm
Modulus of rigidity(G)	76923
Load(W)	2500N

(i) Stiffness (K)

K = G a3 * b3 / 2n D3(a + b)^2

= 76293 * 10^3 * 7.5^3

□ 106.2 N / m

(iv) Stress (τ)

= 2 * T / 3.14 a *b2

= 2 * 80000 / 3.14 * 10 * 7.5^2

=90.54 N / mm^2

(v) Deflection (δ)

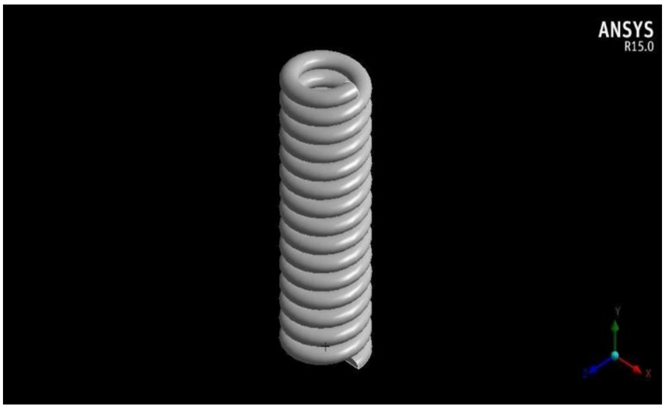
= W / K

= 2500 / 106.62

= 23.4mm

Result of elliptical spring	
Stiffness	106.2
Stress	90.54
Deflection	23.4mm

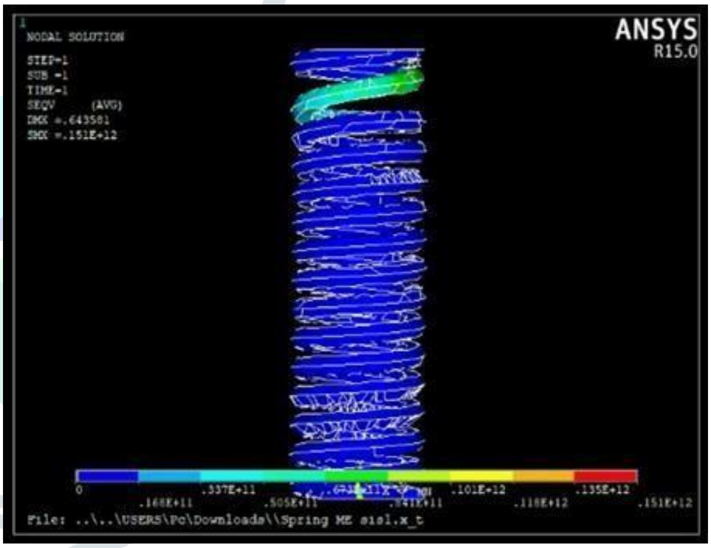
5.4 Design analysis



Finite Element Modelling

5.5FEA Analysis of coil spring (elliptical)

The FEA model of Elliptical spring for static analysis was modeled using SOLIDWORKS 2014 modeling software, and it’s imported to FEA code ANSYS
15.0 software. Also the stress and deflection values



were obtained for critical loading condition.

Fig.5.5.1Deflection values of elliptical spring

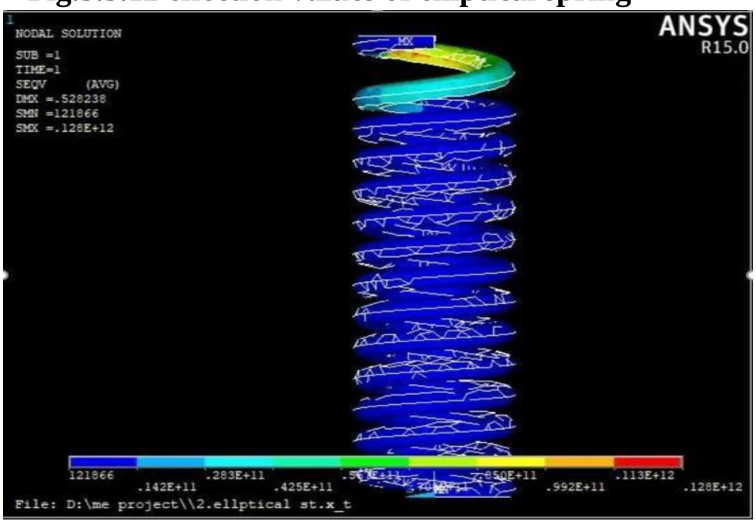
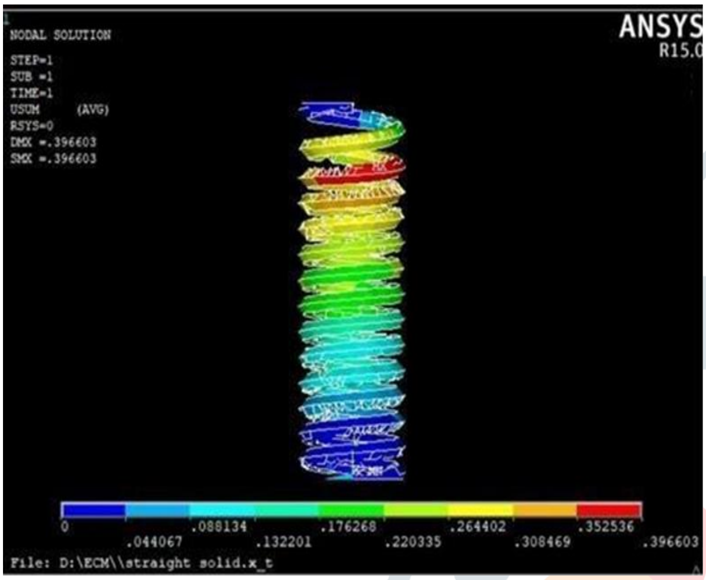


Fig. 5.5.2. Stress value for Elliptical spring

5.6 FEA Analysis of coil spring (circular)

The FEA model of Solid circular spring for static analysis was modeled using SOLIDWORKS 2014 modeling software, and it's imported to FEA code ANSYS 15.0 software. Also the stress and deflection values were obtained for critical loading condition.

Fig. 5.6.1 Stress value for Solid circular spring



5.7 Result of Ansys

From the FEA, the stress and deflection for all the model of spring are taken and tabulated in Table.5.7.1

Factors	Stress	Deflection
Circle	151	39
Elliptical	128	33

Table 5.7.1

7. CONCLUSION

By static numerical analysis the spring profile can be elliptical, hollow elliptical as it has better properties i.e. stiffness, stress & deflection than circular cross section.

The spring is subjected to different forces under different conditions. The forces are static load due to self-weight and dynamic load from road profile

Factors	Circular spring	Elliptical spring
Stiffness	77	106.62
Stress	141.4	90.54
Deflection	32.5mm	23.4mm

9. ACKNOWLEDGEMENT

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