COMPUTER AIDED MODELING AND ANALYSIS OF NON-CIRCULAR HOLLOW CROSS-SECTION HELICAL SPRINGS

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Abstract - *A spring is a mechanical member which is used to provide cushioning effect in automotives to get comfort of the travel. In order to perform such function spring must withstand different load and deflection. To understand complete operation of spring, great compromise needs to be done by the designer such as buckling, carousing, impact frequency of vibration, stiffness of the material, material selection and many more. This paper deals with a noncircular hollow circular spring under constant load which has been designed using SolidWorks software. Present work deals with static structural analytics of noncircular helical cross section springs using ANSYS Workbench and finite element approach is used. Results are compared for different cross section helical springs.*

Keywords: **Non-Circular cross section springs, automotive springs, square springs**

1. INTRODUCTION

Helical Springs are elastic bodies that when force is applied, they can be twisted, compressed and elongated. They retain their original shape and size upon releasing the applied force. Thereby they act as a member which absorbs shock without permanent deformation or rupture. Helical springs are made by the coiled wire in the form of a spring. A helical spring consists of a wire wounded spirally with constant coil cross section and various pitch. The most common form of helical spring is the compression spring. Twisted helical springs has many applications in automobiles such as engine starters, rocker arm mechanism, hydraulic brakes, two-wheeler stand, automotive suspensions, centrifugal clutch and many more. Hence a study is necessary on springs to make optimized spring dimensions for different applications. One of the important parameters of an optimized spring is its strength which is obtained by its base material.

2. LITERATURE SURVEY

J.Kanimozhi et al. (2018) reported that the design and analysis of non circular helical springs using FEM by using different cross sectioned springs. The cross sections that were selected namely circular, square, pentagon, hexagon, octagon, nanogon and decagon. The springs were modeled using Catia V5 and analyzed by using ANSYS 1.50 by applying uniform load. Results of various cross section springs were compared with the result of circular by static structural analysis and concluded that Octagon and decagon has better properties than circular cross section. Results showed stress were better in octagon and decagon springs.

S.B Raijade et al. (2015) studied on the dynamic characteristic of springs by varying different speed and loads for the variable wire diameter and uniform diameter for sprung and unsprung mass on a test rig of quarter model of a car. Results showed that as the load increases, displacement of upper C channel decreases and for low loading condition difference between taper wire spring and equivalent spring is minimum.

Agarwal and Jain (2017) modeled the suspension helical spring of CBZ extreme two-wheeler using Creo Parametric 2.0 with different cross sections such as square fillet and analyzed using ANSYS Workbench 1.4 simulation software with FEM approach. Result showed that the filleted square profile in transient and static analysis is better as compared to other profiles. Also it was tabulated that circular profile has 31.28% higher maximum displacement from square cross section, 27.82% from filleted square and 13.63% greater maximum equivalent stress from square fillet and 12% from square profile and concluded that the square fillet cross sectioned spring has lesser result than circular and square cross sectioned spring.

Chaudhury and Datta (2017) used analytical and numerical methods for the design of prismatic springs of non-prismatic springs of circular coil shape and non-circular coil shape. It consisted of standard springs and demonstrated with respect to stiffness offered with lower overall height. Third part demonstrated location and values of maximum shear stresses in the springs by using FEA. The last part explains about damping characteristics of different springs.

Yu and Hao (2011) conducted an analytical approach on cylindrical helical spring's natural frequency with different cross sections such as rectangle, ellipse and equilateral triangle. He found that an elliptical cross section frequency decreases with spring length, number of turns and decrease in stiffness. 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. He found that the natural frequency was dependent on the geometric properties of cross section. The results showed that stresses are probably equal but the deflection in spring of chrome vanadium material when compared to hard carbon steel spring proved more deflection. Rajurakar and Swami (2016) had a feasibility check for helical spring which consisted of changing the cross section and material for varying load from 55N to 95N. It was seen that the stress was same, and the deflection of chrome vanadium spring had more deflection when compared to hard carbon steel spring and works capably with less care though deflection is more. Circular cross-section gives more structural reliability than rectangular cross-section.

Hao et al. (2016) studied the influence warping of die springs of natural frequency using Riccati transfer matrix. Parameters like helix angle, diameter of the spring, strength to weight ratio and number of coils were studied. The error of 40% while warping is neglected. To minimize the error during analytical and FEA analysis warping must be considered for an aspect ratio 1:0.6. The results consisted of motion's differential equations with warping effect and examples which are solved under various boundary conditions for die springs. Hence warping effect provides significant variations in natural frequency.

3. STATIC STRUCTURAL ANALYSIS

A static structural analysis is applied to calculate the steady load conditions effects on the structure ignoring damping effects and inertia which are produced by loads that are varying with time. The static analysis includes time varying loads and steady inertial loads that can be estimated. This analysis is used determine the stress, strain, forces and displacement in components that are caused by loads. Response conditions and steady loads are assumed i.e. structure response and the load condition to vary slowly with time.

4. RESEARCH METHODOLOGY

3D model is a created geometry portrayal using different modeling software such as Solid Edge, NX CAD, CATIA, SolidWorks etc. In this work, SolidWorks is used to create 3D model of springs of different hollow cross-sections and the model is imported to ANSYS Workbench Version 19.2 using IGES format for further processing. All the dimensions are in mm. Specifications of modeled circular cross-section spring is tabulated in Table 1.

Table 1: Dimensions of Solid Circular Spring

Mean coil diameter (D)	48mm
Wire diameter (d)	13mm
No. of turns (n)	12
Free length (L_f)	223mm
Spring index (C)	3.7

The other cross-sections also include hollow in nature such as rectangular hollow, circular hollow, pentagonal hollow and hexagonal hollow. For all models cross-section and free length are kept constant.

Now by using ANSYS a load of 3000N is applied on this spring and simultaneously shear stress and deformation values are calculated and compared with different cross-section.

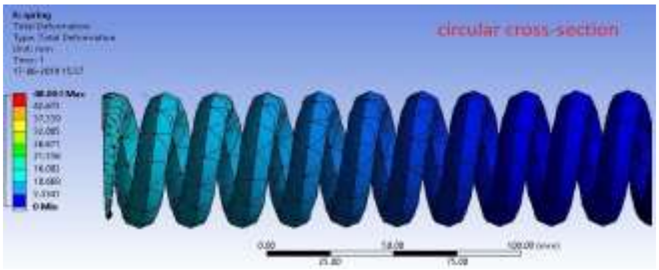

Fig 1: Deformation in circular profile spring in mm

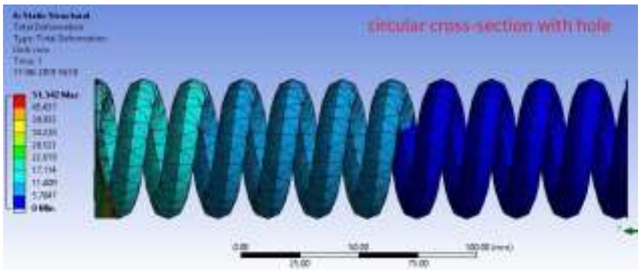

Fig 2: Deformation in hollow circular profile spring

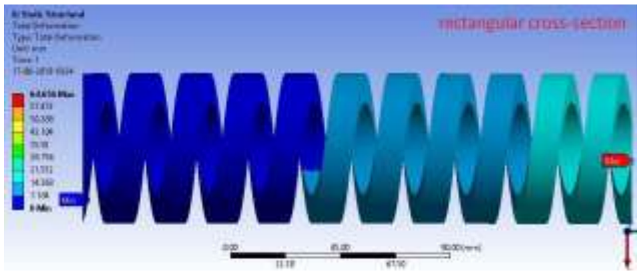

Fig 3: Deformation in hollow rectangular profile spring

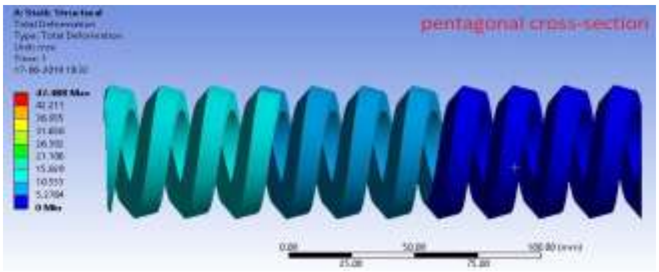

Fig 4: Deformation in hollow pentagonal profile spring

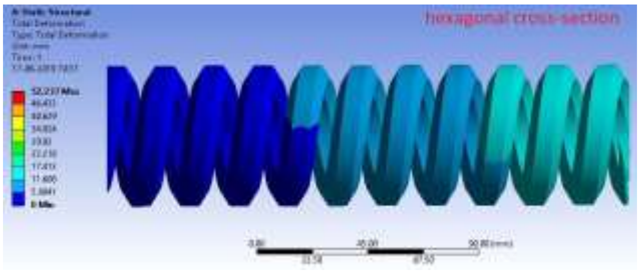

Fig 5: Deformation in hollow hexagonal profile spring

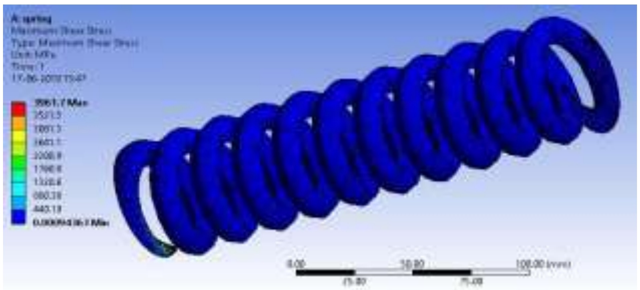
Fig 6: Max Shear stress in circular profile spring

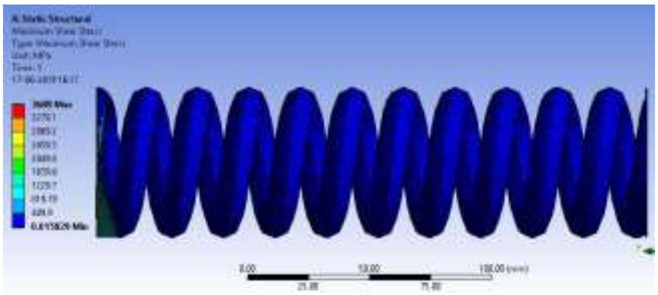
Fig 7: Max Shear stress in hollow circular profile spring

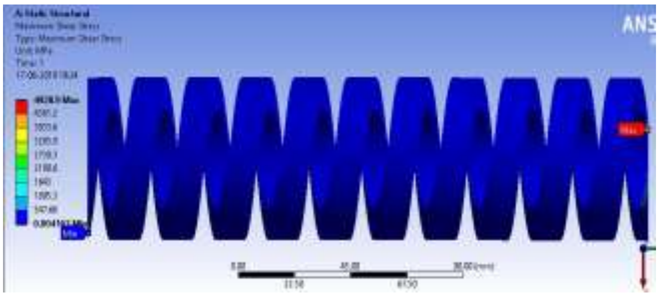
Fig 8: Max Shear stress in hollow rectangular profile spring

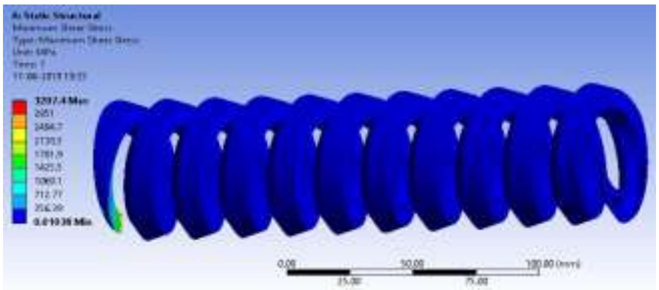
Fig 9: Max Shear stress in hollow pentagonal profile spring

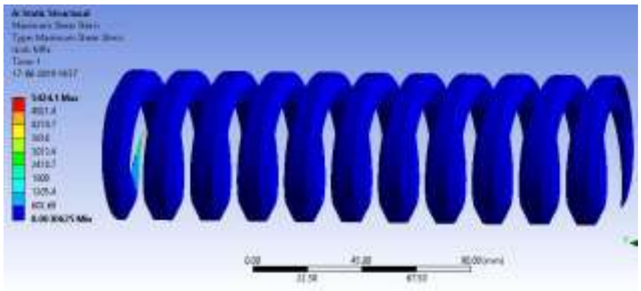
Fig 10: Max Shear stress in hollow hexagonal profile spring

5. RESULTS AND DISCUSSION

The calculated shear stress and deformation for various cross sections are tabulated in Table 2.

Table 2: Static Structural Analysis Results

Cross section	Deformation (in mm)	Maximum shear stress (MPa)
Solid circular	48.007	3961.7
Hollow circular	51.342	3689
Hollow rectangular	64.656	4928.9
Hollow pentagonal	47.488	3207.4
Hollow hexagonal	52.237	5424.1

The deformation in solid circular spring and hollow pentagonal spring are close to each other. Hollow rectangular cross section spring possesses highest deformation and hollow pentagonal cross section spring possesses least deformation. Highest maximum shear stress is possessed by hollow hexagonal cross section helical spring and least by hollow pentagonal cross section helical spring.

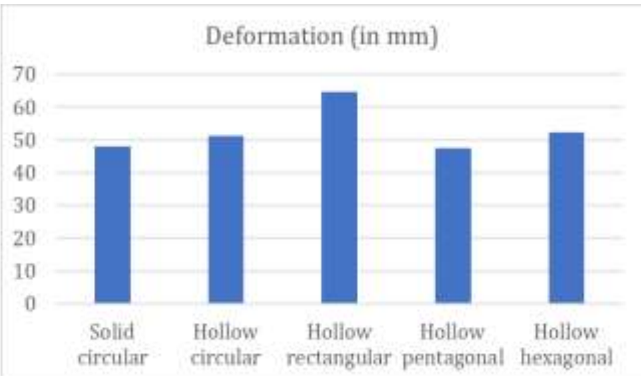

Fig 11: Graph showing deformation of various profiles under static structural analysis

Fig 12: Graph showing shear stress of various profiles under static structural analysis

6. CONCLUSIONS

By static structural analysis, it is found that the hollow rectangular cross section has 34% more deformation than solid circular spring. Hence hollow rectangular cross section can be used to get more cushioning effect in two-wheeler vehicles. Hollow hexagonal spring possesses 37% more maximum shear stress than solid circular cross section spring.

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