Design and Analysis of Helical Springs with Non-Circular Cross Section

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Abstract- **A spring is designed to fit into the space available and to give desired stiffness while withstanding maximum load/deflection. Spring design in general is a compromise between many factors such as available space, design stresses, frequency of vibration, buckling resistance, resistance to corrosion. In this paper helical springs related to the light vehicle suspension systems under the effect of uniform loading has been modelled with non-circular wire cross sections using CATIA V5.**

This paper deals with the static structural analysis of the helical springs by using ANSYS Workbench 15.0 simulation software. Using the finite element approach the results are compared for various wire cross section.

Key Words: **Helical springs, Non-circular wire cross section, static structural analysis, ANSYS.**

I. INTRODUCTION

The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross-section of the wire from which the spring is made may be circular, square or rectangular. Helical compression springs have applications to resist applied compression forces or in the push mode, store energy to provide the push.

The helical springs are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of the helix and the wire is subjected to torsion. In other words, in a closely coiled helical spring, the helix angle is very small, it is usually less than 10 degree. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring.in open coiled helical springs,the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which helix angle is large.

II. LITERATURE REVIEW

Agarwal and Jain(2017) reported 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-Mises stress of three spring models are obtained by finite element analysis. The maximum displacement and Von-Mises stress are achieved in circular cross section and the least by square cross section.

Chaudhury and Datta (2017) presented a 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 have been attempted. A non-prismatic spring of circular coil with conical spring shape and volute spring shape are also analysed. 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) carried out 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) aimed in caring 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 maintance. 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 minimise 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. It also proved there is significant variation in natural frequency with warping effect.

Tsubouchi et al. (2014) describedthe manufacturing and application of rectangular cross section spring. It presented three different cases for the analysis. Case 1 is ordinary spring available in market, Case 2 is rectangular cross section spring fabricated by machining and Case 3 is spring formed by work hardening of rectangular cross section. The work hardened spring is produced by upsetting the ordinary springs with circular cross section in the direction of coil axis. The spring constant in Case 2 is less than that of Case 1. Case 3 has higher elastic limit than that of Case 2.

Lavanya 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 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 spring.

Pawar et al. (2016) proposed an optimisation technique for spring in three wheeler suspension system. The number of coils of the springs is reduced from 14 to 13 (keeping all other parameter same), in order to reduce the weight of the spring. Hence, the efficiency of vehicle improved and fuel consumption rate decreased. The weight of spring is reduced by 6% whereas the stress by 13%. The stiffness and the load carrying capacity of suspension system has also increased considerably.

Christopher and Pavendhan (2014) established a comparison of coil springs of two wheeler shock absorber system by varying the diameter, ignoring the effects of inertia and damping caused by time varying loads. The comparison clearly depicted that reduction in diameter, reduced the stress induced and deflection. This also added advantage of weight reduction.

III. STATIC STRUCTURAL ANALYSIS

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time.

IV. RESEARCH METHODOLOGY

The 3D modelling is a process of transformation program which creates an ANSYS input record from the geometry portrayal created in CATIA V5.The model is imported to ANSYS as input in IGES format for further processing. The modelled spring specification is tabulated in Table 1.

TABLE 1

SPRING SPECIFICATION

Mean coil diameter (D)	48mm
Diameter of wire(d)	8mm
No. of turns (n)	16
Free length (L_f)	256mm
Spring index (C)	6

The other cross sections that are taken for analysis are square, pentagon, hexagon, octagon, nonagon, and decagon. The sides of the polygon are found by keeping the cross sectional area of circular cross section as constant.

The IGES file is imported into ANSYS for further processing. After importing the model, it is meshed for analysis. For better results the spring is fine meshed.

For analysis, constrains are applied on one side and a compressive load of 3000N (bike weight with two person) is applied. The deformations and shear stress values are calculated.

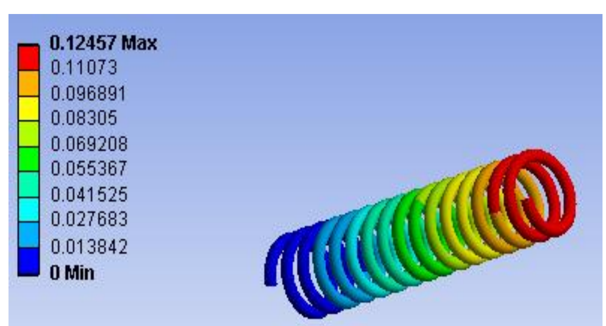

Fig. 1 Deformation in circular profile spring in m

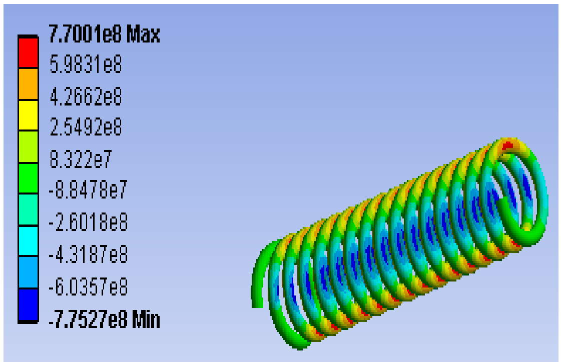

Fig. 2 Shear stress in circular profile spring in Pa

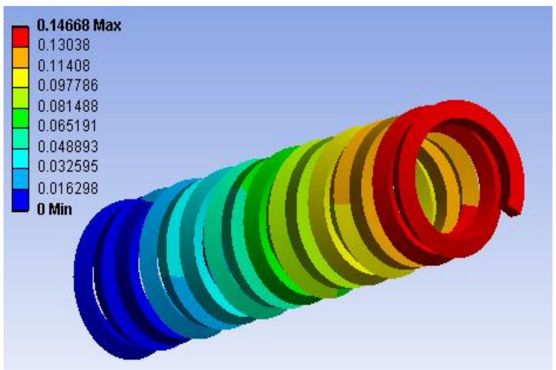

Fig. 3 Deformation in square profile spring in m

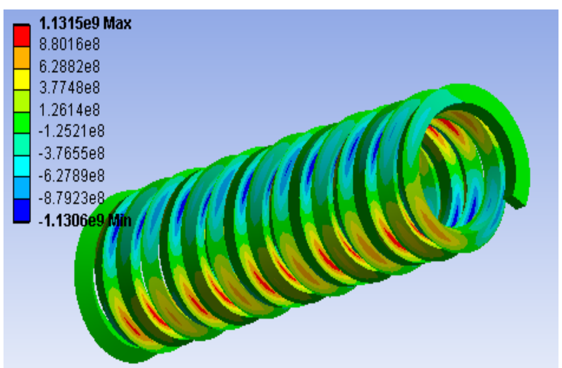

Fig. 4 Shear stress in square profile spring in Pa

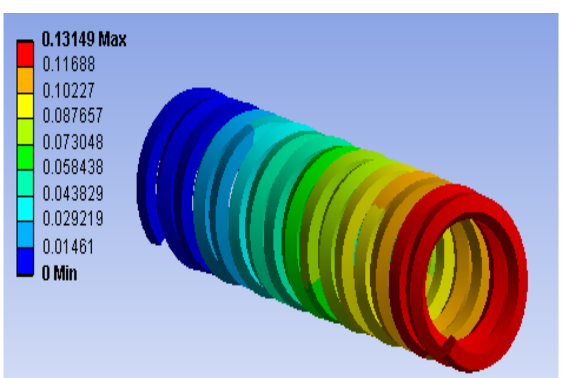

Fig. 5 Deformation in pentagon profile spring in m

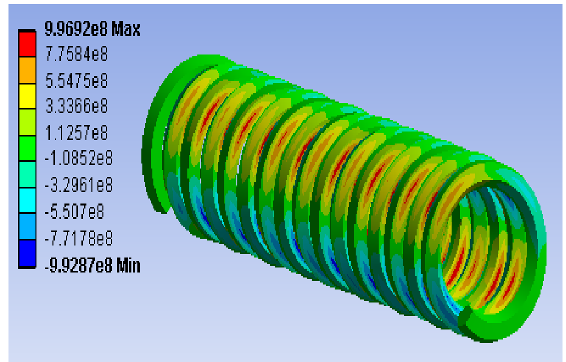

Fig. 6 Shear stress in pentagon profile spring in Pa

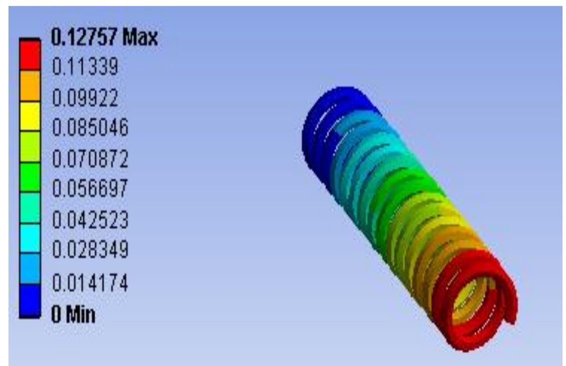

Fig. 7 Deformation in hexagon profile spring in m

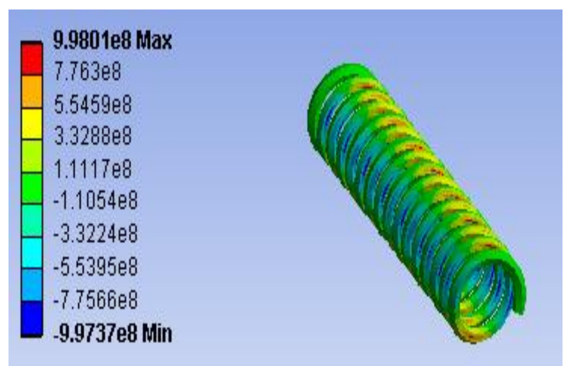

Fig. 8 Shear stress in hexagon profile spring in Pa

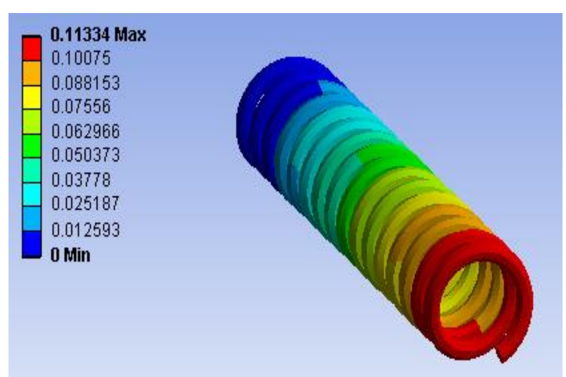

Fig. 9 Deformation in octagon profile spring in m

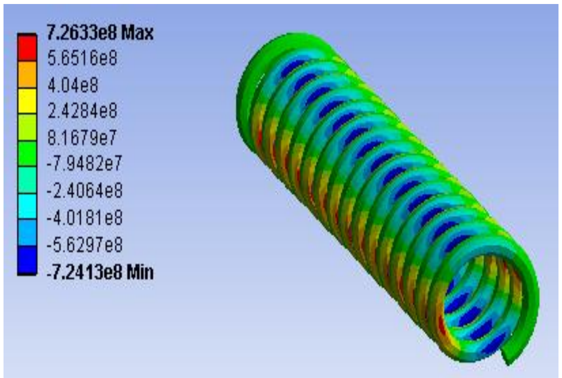

Fig. 10 Shear stress in octagon profile spring in Pa

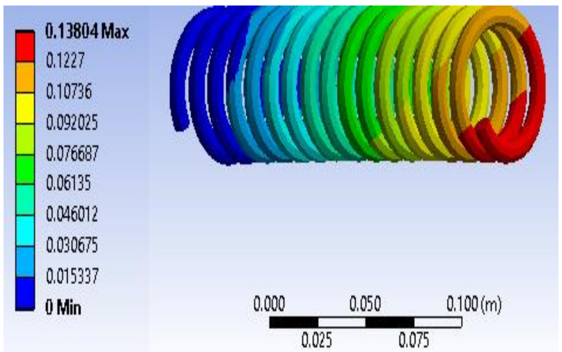

Fig. 11 Deformation in nonagon profile spring in m

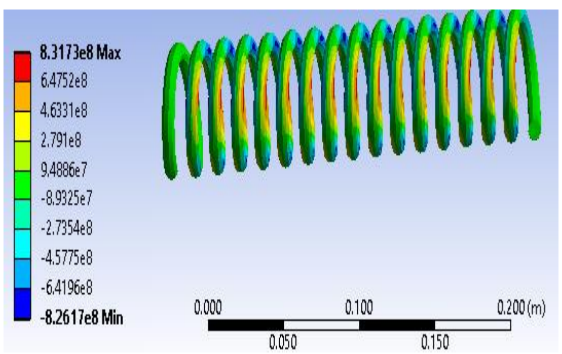

Fig. 12 Shear stress in nonagon profile spring in Pa

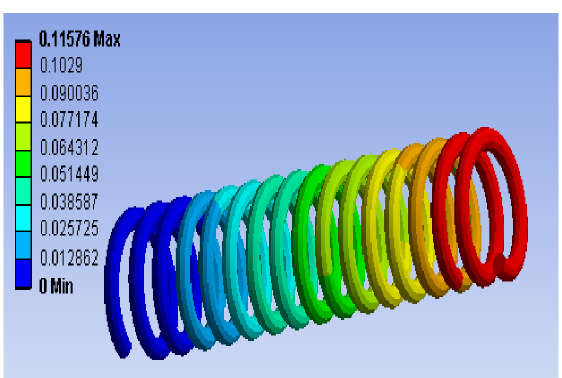

Fig. 13 Deformation in decagon profile spring in m

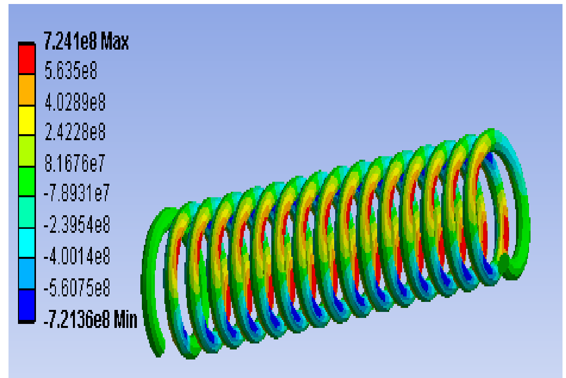

Fig. 14 Shear stress in decagon profile spring in Pa

V. RESULTS AND DISCUSSION

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

TABLE 2

STATIC STRUCTURAL ANALYSIS RESULTS

WIRE CROSS SECTIONS	DEFORMATION (mm)	SHEAR STRESS (MPa)
Circle	124.57	770.00
Square	146.68	1131.50
Pentagon	131.14	996.92
Hexagon	127.57	998.01
Octagon	113.34	726.33
Nonagon	138.04	831.73
Decagon	115.76	724.10

The deformation and shear stress for the cross sections octagon and decagon is much less than that of circle.

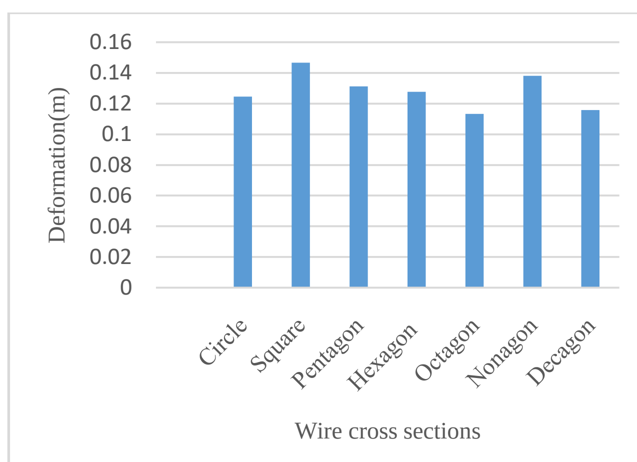

Fig. 15 Graph showing deformation of various profiles under static structural analysis.

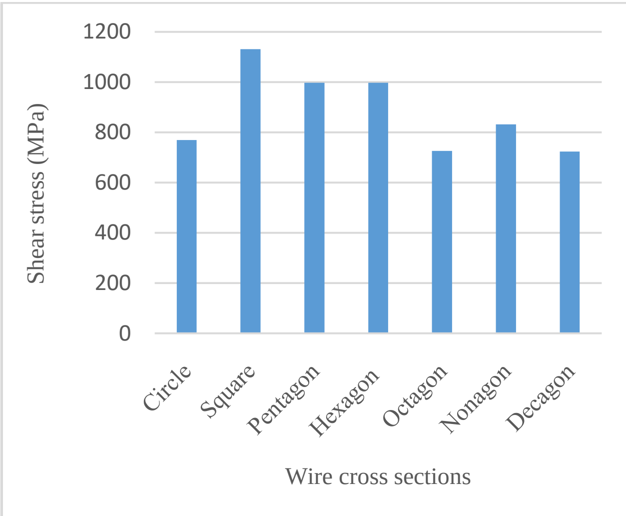

Fig. 16 Graph showing shear stress of various profiles under static structural analysis.

The graph give a clear view that deformation and shear stress of octagon cross sectioned wire is the least.

VI. CONCLUSIONS

By static structural analysis the spring profile can be octagon or decagon as it has better properties than circular cross section. The deformation of decagon cross section 7% less whereas for octagon it is 9%. The difference in shear stress for octagon and decagon with circular cross section is 5.6% and 5.9% respectively.

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