Effect of Stresses on Square and Rectangular Helical Spring

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Abstract—Springs are elastic bodies (generally metal) 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. Generally springs are work on the principle of fluid displacement on both the compression and expansion cycle. Helical springs are used for different applications like in automobile, in brakes and clutches, in watches and toys etc. This work deals with the stress analysis of different cross sectional helical springs and its validation with analytical method.

Keywords-Circular Helical Spring, Square spring,Stress Analysis, etc.

1. INTRODUCTION

A coil is a thing which mainly used in different springs which stores energy or provides a force over a distance by elastic deflection. Energy may be stored in a compressed gas or liquid, or in a solid that is bent, twisted, stretched, or compressed. The energy is recoverable by the elastic return of the distorted material. Spring structures are characterized by their ability to withstand relatively large deflections elastically. The energy stored is proportional to the volume of elastically distorted material, and in the case of metal springs, the volume of distorted material is limited by the spring configuration and the stress-carrying capacity (elastic limit) of the most highly strained portion. For this reason, most commercial spring materials come from the group of high-strength materials, including high-carbon steel, cold-rolled and precipitation-hardening stainless and nonferrous alloys, and a few specialized nonmetallic such as laminated fiberglass. Thus spring design is basically an analysis of machine elements which undergo relatively large elastic deflections and are made of materials capable of withstanding high stress levels without yielding.

For FE analysis, a circular helical spring of material Carbon steel SAE 1050 is considered in which one side of the spring is fixed and axial load is applied at the other end of the spring. The dimensions of circular spring considered are as follow.

Wire diameter (d) =8mm
Mean diameter (D) =46mm
Pitch (p) =11mm
Spring index(C) =5.75
Axial force (F) =1000N

Here, different cases of circular springs are considered by changing free length of spring. The analysis is carried out using finite element method with FE software ANSYS. Shear stress and deflection are calculated analytically and compared with FE results. After, circular springs are converted into square and rectangular springs with keeping same material and same volume. Here breadth and width of square and rectangular spring can be calculated by using following cases

1. b=h
2. b=1.5h
3. b=2h
4. b=2.5h

Analysis of square and rectangular helical springs is carried out using FE method. Shear stress and deflection are evaluated analytically and compared with FE results.

2. DETERMINATION OF STRESSES FOR CIRCULAR, HELICAL SPRINGS USING ANALYTICAL METHOD

For analysis of circular helical spring, following dimensions are considered. Wire diameter (d) =8mm, Mean diameter (D) =46mm, Pitch (p) =11mm, spring index (C) =5.75, Wahl's correction factor (K_s) =1.263, Free length (L_f) =124mm, Axial force (F) =1000N for stress analysis and Axial force (F) =1N for buckling analysis. From free length and pitch, number of turns are calculated as n=10.27

For material Carbon steel SAE 1050, following material properties are used as shown in Table I.

TABLE I: MATERIAL PROPERTIES OF CARBON STEEL SAE 1050

Sr.No.	Symbols	Parameters	Values
1	E	Young's modulus	2.1×10^5Mpa
2	µ	Poisson's ratio	0.295
3	G	Modulas of rigidity	80×10^3Mpa

Deflections (δ) and shear stresses ofcircular helical spring are evaluated by equation 2.1 to 2.2

$$\delta = \frac{8FD^3 n}{Gd^4} \quad \text{.............................. (2.1)}$$

$$\tau_{\max} = \frac{Ks8FD}{\pi d^3} \text{ ……......................... (2.2)}$$

3. DETERMINATION OF STRESSES OF SQUARE AND RECTANGULAR HELICAL SPRINGS USING ANALYTICAL METHOD

Here, Circular springs are converted into square and rectangular spring by keeping the same volume.Breadth and width can be calculated by using aboce cases.

1. b=h
2. b=1.5h
3. b=2h
4. b=2.5h

For analysis of square helical spring, following dimensions are considered.
For b=h, Breadth (b=7mm), Width (h=7mm)
For b=1.5h,Breadth (b=8.7mm), Width (h=5.8mm)
For b=2h, Breadth (b=10mm), Width (h=5mm) and
For b=2.5h,Breadth (b=11.18mm), Width (h=4.47mm)
Mean diameter (D) =46mm, Pitch (p) =11mm, Free length (L_f) =124mm, Axial force (F) =1000N for stress analysis and Axial force (F) =1N for buckling analysis. From free length and pitch, number of turns are calculated as n=10.27Table I shows the material properties forsquare helical springs.

Here deflection and shear stresses for square and rectangular spring are evaluated analytically by using equation 2.3 to 2.6.

$$\delta = \frac{5.66nFD^3}{Gh^4} \text{ …………………… (2.3)}$$

$$\tau_{\max} = \frac{4.8FD^{0.75}}{h^{2.75}} \text{ …………………..… (2.4)}$$

$$\delta = \frac{2.83nFD^3(b^2+h^2)}{b^3h^3G} \text{ …………….. (2.5)}$$

$$\tau_{\max} = \frac{FD}{K_1bh^2} \text{ ……………………..……(2.6)}$$

4. DETERMINATION OF STRESSES AND BUCKLING LOAD FOR CIRCULAR, SQUARE AND RECTANGULAR HELICAL SPRINGS USING FE APPROACH

For FE analysis, CAD model of circular, square and rectangular are created and imported in FEA software ANSYS.For stress analysis, constraints are applied at the one side of spring and the force is applied on the center of other side of spring. By giving these conditions, deflection and shear stresses of circular, square and rectangular springs are calculated.

The shear stress and deflection for circular, square and rectangularsprings are determinedshown in Fig.1 to Fig.10.

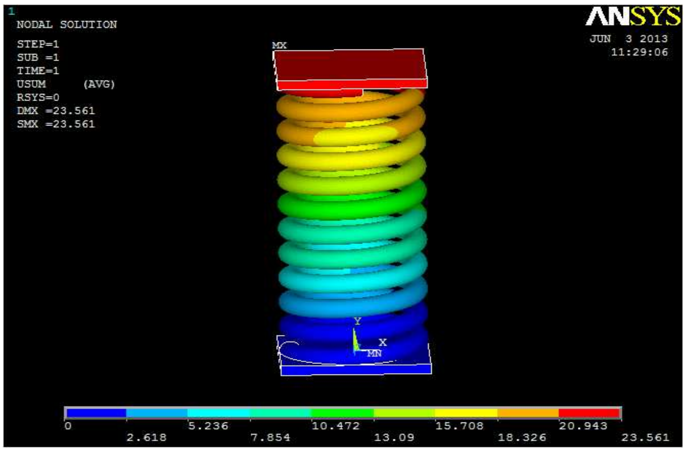

Fig.1 Deflection contour for circular springs

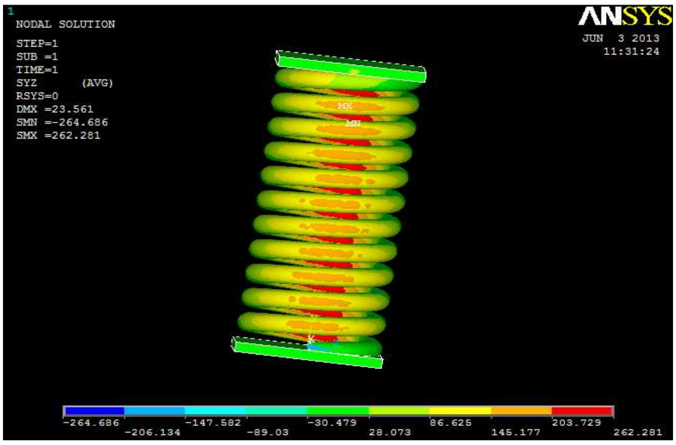

Fig.2 Shear stress contour for circular springs

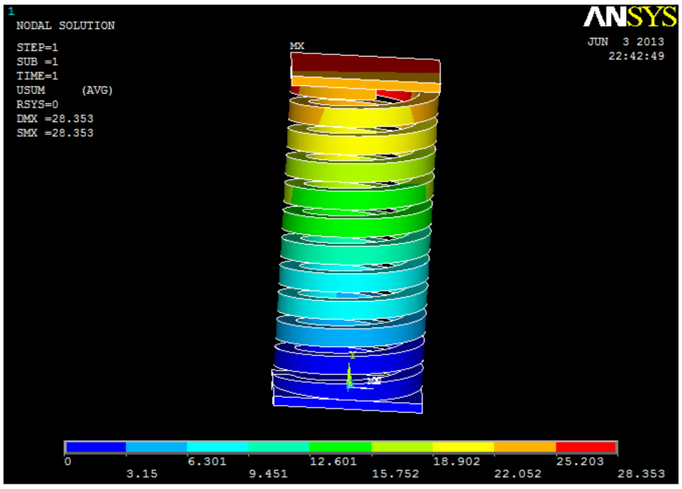

Fig.3Deflectioncontour for square springs (b=h)

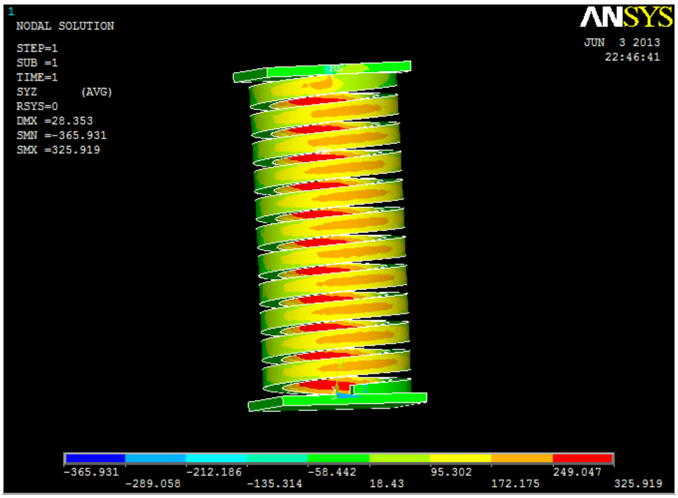

Fig.4 Shear stress contour for square springs (b=h)

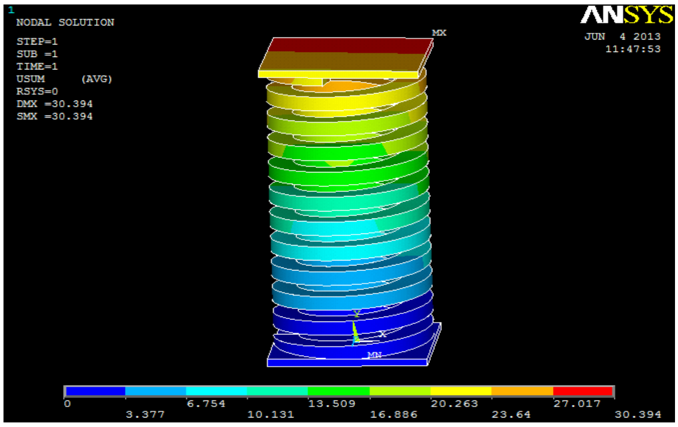

Fig.5 Deflection contour for square springs (b=1.5 h)

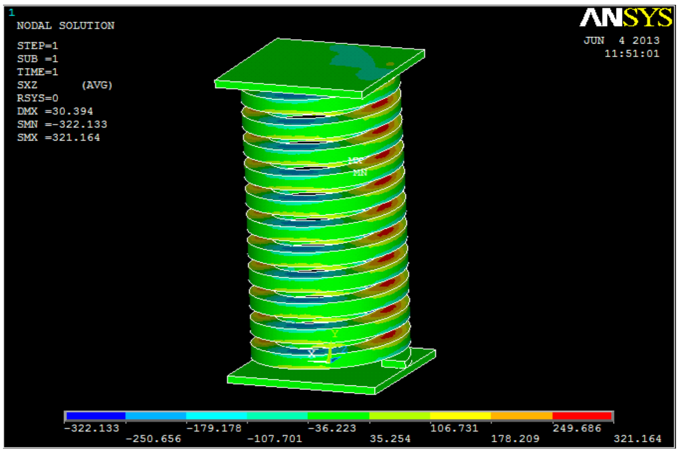

Fig.6shear stress contour for square springs (b=1.5 h)

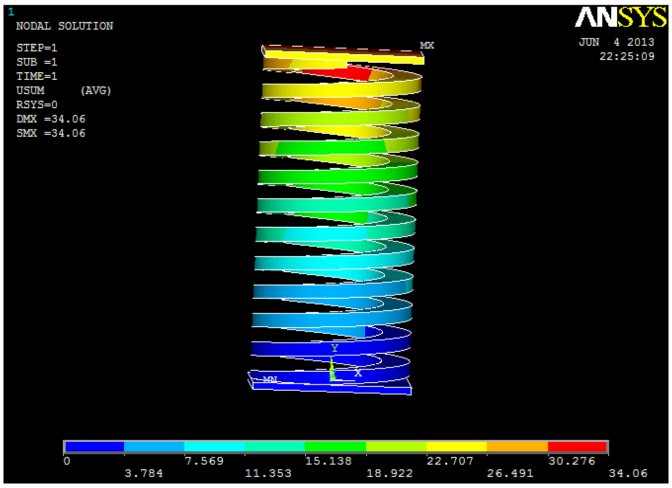

Fig.8 Deflection contour for rectangular springs (b=2h)

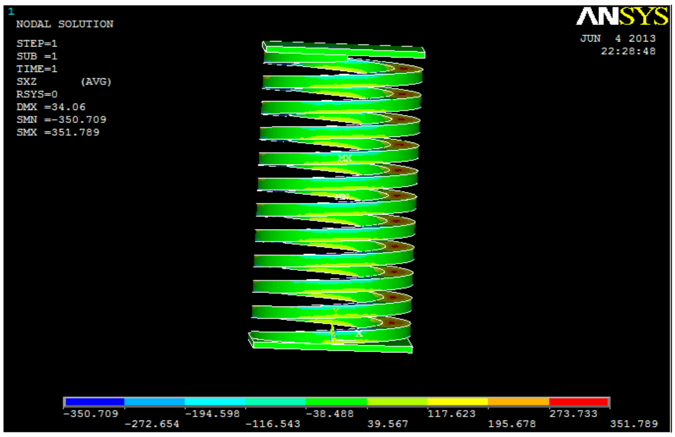

Fig.7 Shear stress contour for rectangular springs (b=2h)

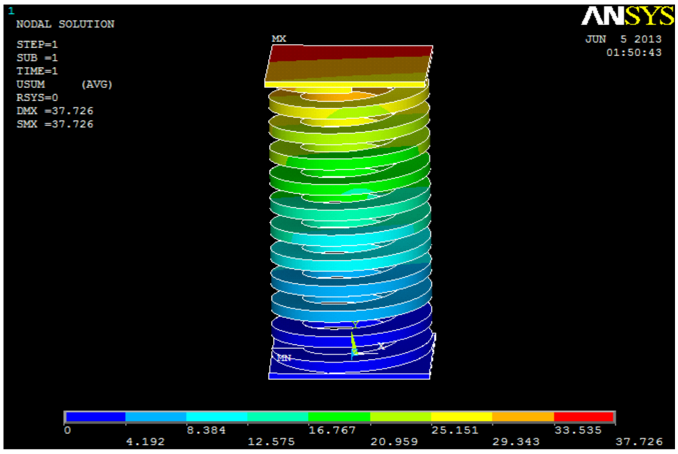

Fig.9 Deflection contour for rectangular springs (b=2.5h)

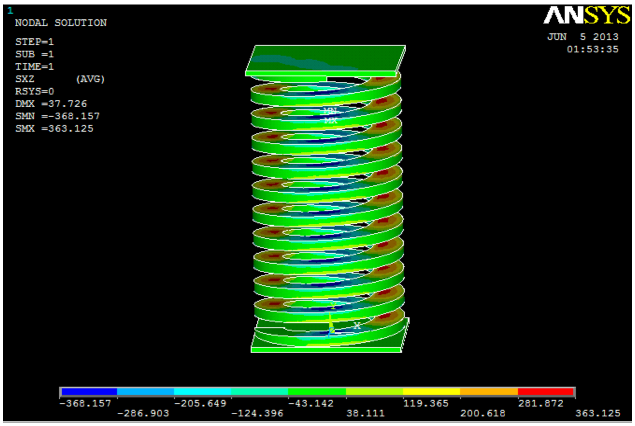

Fig.10 shear stress contour for square springs (b=2.5 h)

5. DISCUSSION AND CONCLUSION

The analytical and FE results of circular, square and rectangular coils determined with varying its free length are given in Table II to Table VI.

TABLE II: ANALYTICAL AND FE RESULTS OF CIRCULAR HELICAL SPRING

CASES	DEFLECTION (mm)		SHEAR STRESS (N/mm^2)	
	THEORY	FEA	THEORY	FEA
L_f=225	46	45	289	265
L_f=200	41	42	289	269
L_f=150	30	30	289	265
L_f=124	24	24	289	262
L_f=75	14	15	289	260
L_f=225	8	9	289	261

TABLE III: ANALYTICAL AND FE RESULTS OF SQUARE HELICAL SPRING (b=h=7)

CASES	DEFLECTION (mm)		SHEAR STRESS (N/mm^2)	
	THEORY	FEA	THEORY	FEA
L_f=225	56	56	402	325
L_f=200	49	49	402	331
L_f=150	36	37	402	330
L_f=124	29	28	402	326
L_f=75	17	16	402	352
L_f=225	12	11	402	332

TABLE IV: ANALYTICAL AND FE RESULTS OF RECTANGULAR HELICAL SPRING (b=1.5h)(h=5.8,b=8.7)

CASES	DEFLECTION (mm)		SHEAR STRESS (N/mm^2)	
	THEORY	FEA	THEORY	FEA
L_f=225	57	58	340	347
L_f=200	50	49	340	314
L_f=150	37	36	340	366
L_f=124	30	30	340	321
L_f=75	17	17	340	308
L_f=225	10	10	340	293

TABLE V: ANALYTICAL AND FE RESULTS OF CIRCULAR HELICAL SPRING(b=2h)(h=5,b=10)

CASES	DEFLECTION (mm)		SHEAR STRESS (N/mm^2)	
	THEORY	FEA	THEORY	FEA
L_f=225	67	69	374	394
L_f=200	59	60	374	347
L_f=150	43	43	374	402
L_f=124	35	34	374	352
L_f=75	20	19	374	334
L_f=225	12	13	374	347

TABLE VI: ANALYTICAL AND FE RESULTS OF CIRCULAR HELICAL SPRING (b=2.5h)(h=4.5,b=11.25)

CASES	DEFLECTION (mm)		SHEAR STRESS (N/mm^2)	
	THEORY	FEA	THEORY	FEA
L_f=225	76	78	391	369
L_f=200	67	65	391	354
L_f=150	49	48	391	446
L_f=124	40	38	391	363
L_f=75	23	24	391	375
L_f=225	14	14	391	360

In circular helical spring, deflection and shear stress are lower. But in square and rectangular coils, maximum shear stress is concentrated at the corners due to sharp edges. This is further increases with increase in breadth to width ratio. From this analysis, it is observed that circular springs are more preferable than square and rectangular spring.

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