Finite Element Analysis of Helical Compression Spring Using ANSYS

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Abstract

A spring is a machine component that deflects under external load and regains its original shape on removal of the force. A helical compression spring is commonly used type of spring where length of spring reduces on application of force. This paper discusses the modeling of helical compression spring and then finite element analysis using the popular software Ansys Workbench. Comparison of results with analytical solution is done to verify the procedure.

Introduction

A spring is defined as an elastic member that deflects when subjected to external force and regains its original shape on removal of force. A spring is used for storing energy, applying force, measuring force and absorbing vibrations. A helical spring find its use in a variety of applications ranging from a pen to an automobile. A helical compression spring is usually made up of circular wire. When the spring is compressed, its coils gets closer and energy is stored in the coils due to the deformation. The wire of the spring is subjected to shear stresses even though the spring is subjected to compression.

This paper presents finite element approach to determine stresses and deflection in a helical compression spring. A helical spring is usually distinguished by its wire diameter (d), spring index (C) and number of active coils (N). Spring index is the ratio of mean coil diameter (D) to the wire diameter (d). Hence, using wire diameter and mean coil diameters spring index can be calculated or mean coil diameter can be calculated using spring index and wire diameter. The spring index varies from 4 to 12 so that spring can be handled easily and there are no excessive stresses due to bending of spring into helix. For the analysis, a spring with wire diameter, d = 6 mm and spring index, C = 8 has been considered. The spring is assumed to have 10 active coils with initial gap of 1 mm between adjacent coils.

Table 1 Spring Dimensions

Wire Diameter	**d**	*6 mm*
Mean Coil Diameter	**D**	*48 mm*
Spring Index	**C**	*8*
Active Coils	**N**	*10*

Modeling and Analysis

The spring has been modelled as a helix with circular cross-section. For modeling, Creo Parametric software have been used. To apply the force at center of the spring, supports have been added on both ends of the spring. This matches the assumptions [1] taken for deriving the analytical load-stress and load-deflection relations for the helical compression spring. Supports are created at the end of helix using the extrude option available in the software. The CAD model is then exported in 'igs' format so that it can be imported into Ansys Workbench [2] for analysis.

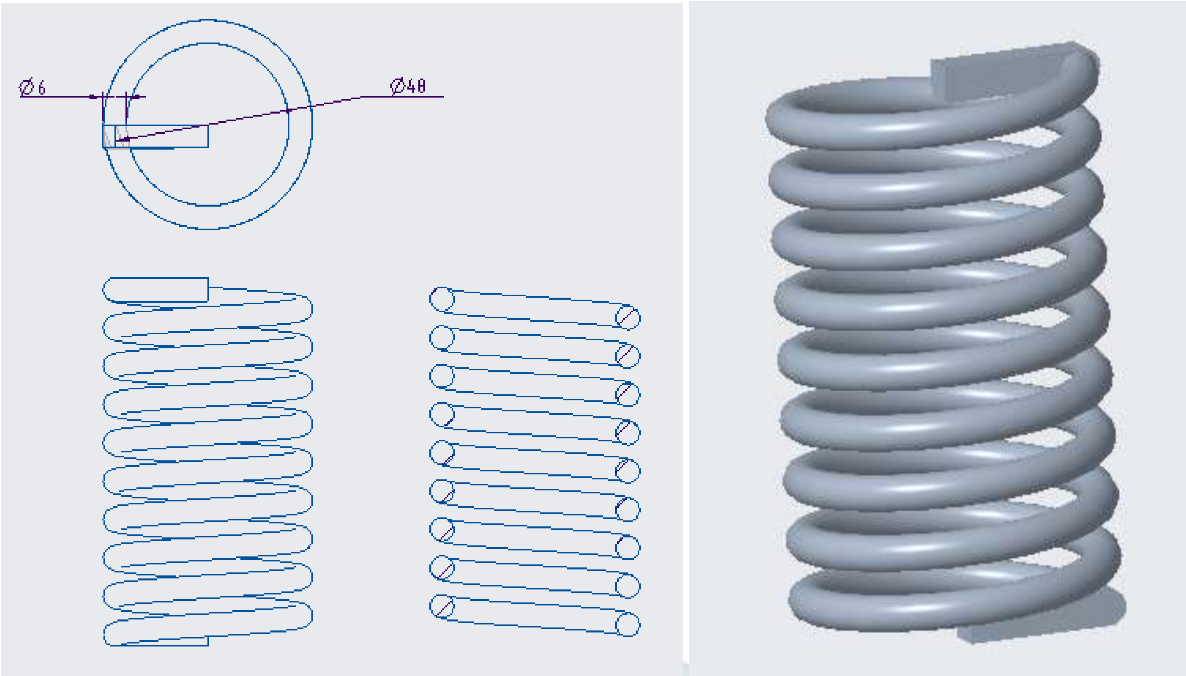
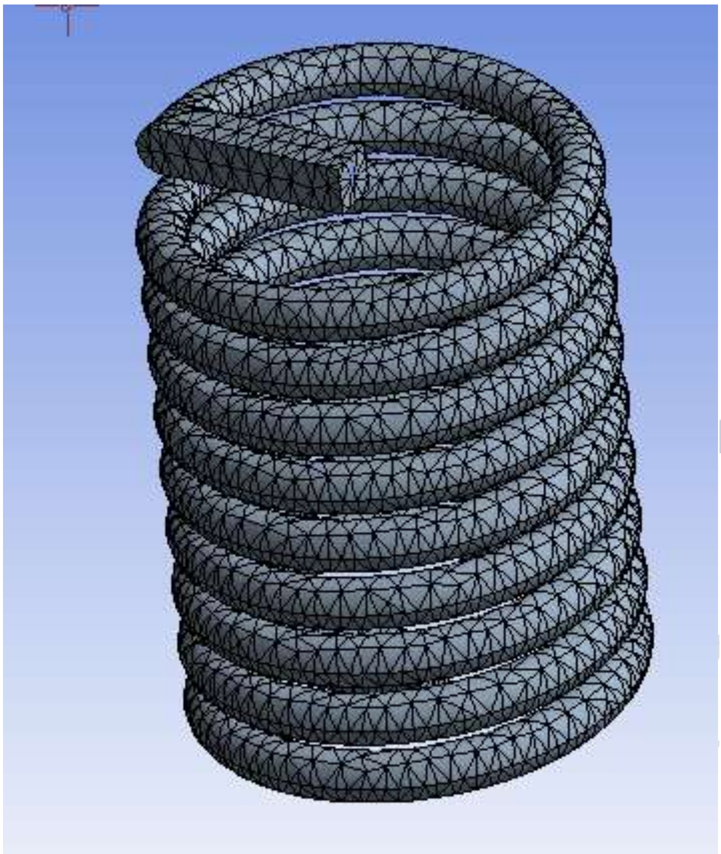


Figure 1 Orthographic Views and 3d CAD Model

Ansys Workbench [2] is used for carrying out static analysis of the spring and Static Structural module is used for this purpose. Material for the spring used is Spring steel and is defined using modulus of rigidity, G = 81370 MPa and Poisson's ratio, μ = 0.29.

Figure 2 Imported Model in Ansys Workbench

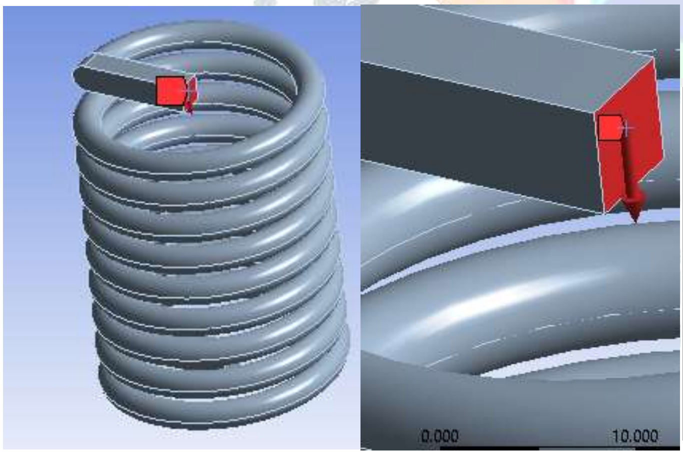
Meshing is done for dividing the model into nodes and elements so that finite element calculations can be carried out. Element type 'SOLID187' is used for meshing and an element size of 1.5 mm have taken to keep the number of elements and nodes within the limits of the academic version of the software.



Details of "Mesh"	
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Mechanical
Element Order	Program Controlled
Element Size	1.5 mm
Sizing	
Quality	
Inflation	
Advanced	
Statistics	
Nodes	28878
Elements	13266

Figure 3 Meshed Model and Details of Mesh

A downward force is applied on upped face as shown, and lower end is supported using a fixed support. To apply the force, the option of force using components is selected and the force is applied in positive y-direction so as to have a compressive effect on the spring.



Scope	
Scoping Method	Geometry Selection
Geometry	1 Face
Definition	
Type	Force
Define By	Components
Coordinate System	Global Coordinate System
X Component	0. N (ramped)
Y Component	500. N (ramped)
Z Component	0. N (ramped)
Suppressed	No

Figure 4 Loading of Spring

For the results, shear stress and direction deformation in y-direction is requested.

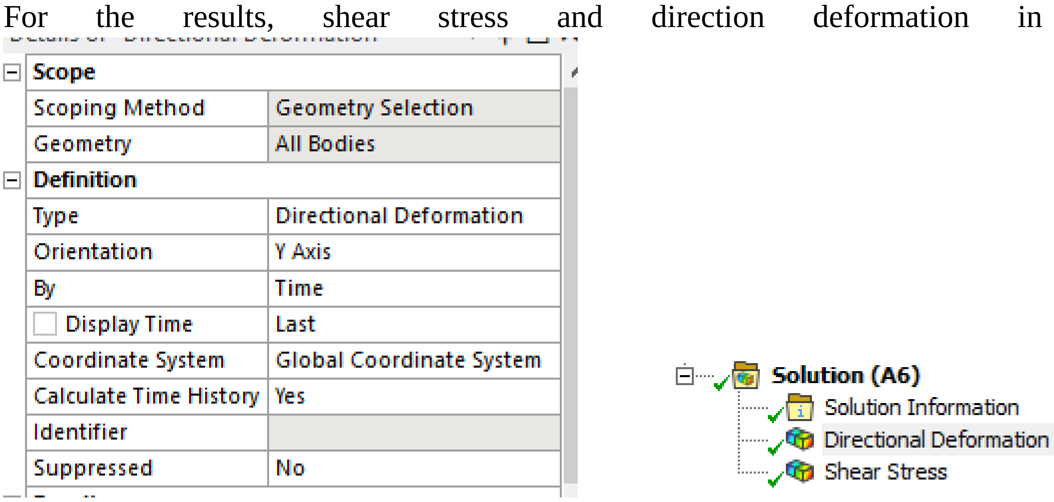


Figure 5 Solution Details

Analytical Solution

The analytical solution is done by assuming spring as a member subjected to torsional and direct shear and stresses are computed using torsion equation [3] and expression for direct shear.

Shear stress is calculated using following load stress relation

$$\tau = K\frac{8PC}{\pi d^2}$$

Where K is Wahl factor, which takes the effect of curvature and direct shear into consideration.

Deflection is calculated using following load deflection relation

$$\delta = \frac{8PD^3N}{Gd^4}$$

Results and Discussion

The results obtained from FEM are in close agreement with the analytical solution showing that modeling technique used represents the actual spring and its end supports correctly.

Table 2 Comparison of FEM & Analytical Results

	FEM		ANALYTICAL	
Force (N)	Shear Stress (MPa)	Deflection (mm)	Shear Stress (MPa)	Deflection (mm)
100	80.02	7.82	67.0	8.39
200	160.04	15.64	134.0	16.78
300	240.06	23.4	201.0	25.17
400	320.08	31.28	268.0	33.56
500	400.1	39.11	335.0	41.95

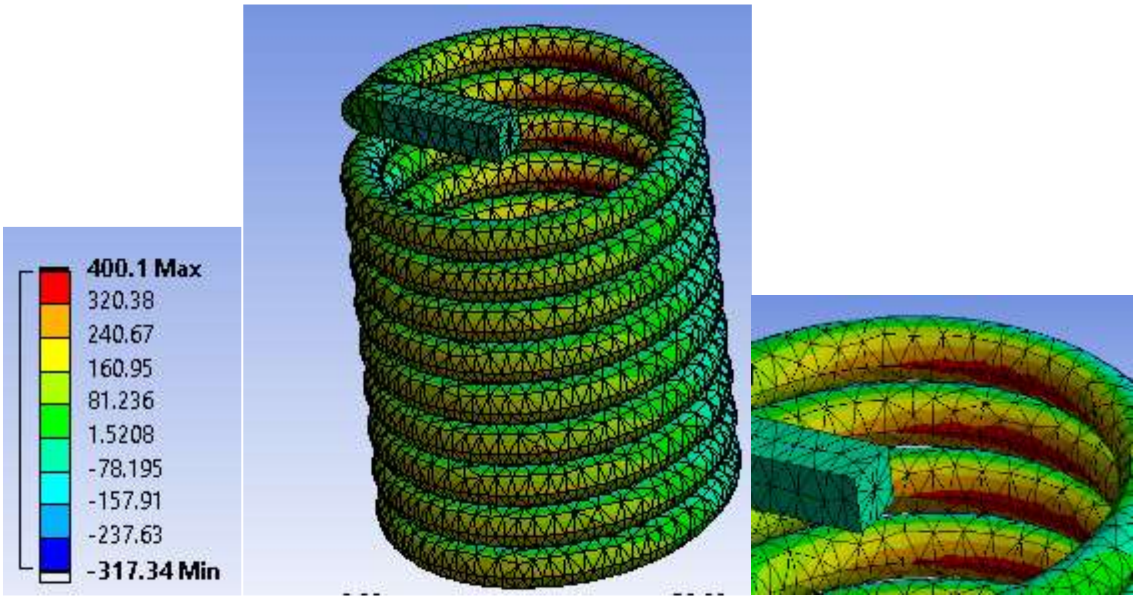


Figure 6 Shear Stress at P =500 N

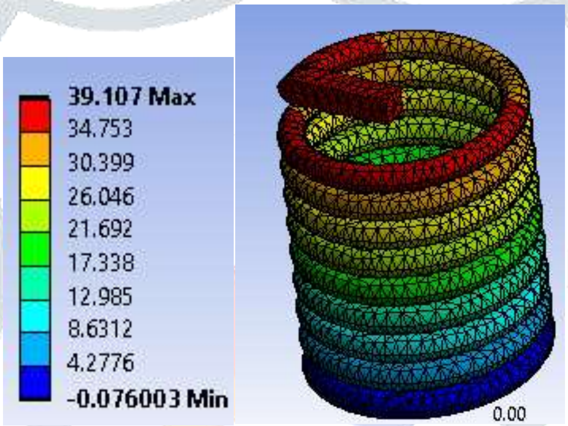


Figure 7Deflection at P = 500 N

From the FEM result, it is found that deflection is maximum at the upper coil which is point of application of force and according to torsion theory also maximum twist (and hence deflection) occurs at point farthest from support in the case when shaft is fixed at one end and free at other end.

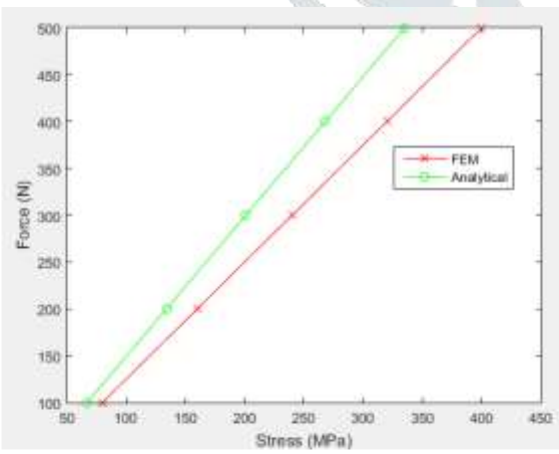


Figure 8 Plot of Load Stress Curve

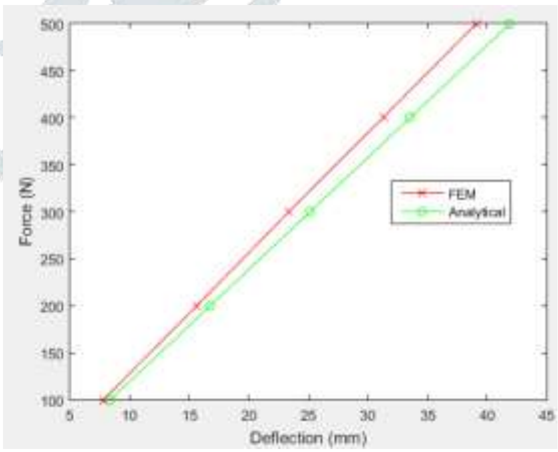


Figure 9Plot of Load Deflection Curve

From the plot of load deflection and load stress curve it is observed that the relation is linear. The difference between FEM and analytical results are very less.

Conclusion

Analysis of spring is necessary for its safe use. As spring is used in lot of systems, analysis of spring using finite element method can reduce the design time of the system. The maximum stress is found to be present on inner side of the coil. FEM results follow same trend as the actual and analytical results, thereby suggesting that FEM can be used for effectively analyzing the helical compression spring.

References

[1] V. B. Bhandari, "Springs," in *Design of Machine ELements*, Tata McGraw Hill Education Private Limited, 2010, pp. 393-446.

[2] *ANSYS Workbench Academic, Release 19.3,* Ansys Inc.

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