Finite Element Analysis-Modeling and simulation of coil springs

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Abstract

Several mechanical systems employed helical coil spring. It can be designed to show nonlinear performance. Spring stiffness exhibits nonlinear behavior depending on their role in various applications. This means that the stiffness of the spring is not continual, but governed by the compression. Nonlinear motion arises when the number of active coils of variable compression declines or rises. When coil springs are used as conical springs in dynamic systems, it becomes mandatory to identify the consequence of springs on dynamic performance. This article looks at the nonlinear dynamic behavior of conical springs with higher mass. In this article, coil springs considered have a constant pitch and elasticnature wise.This article compares experimental data for deformations of coil springs taken with those obtained by finite element method.

Keywords: Helical conical spring, Helical cylindrical spring and, CAD and CAE Tool(Pro-Engineer, Abqaus)

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1. Introduction

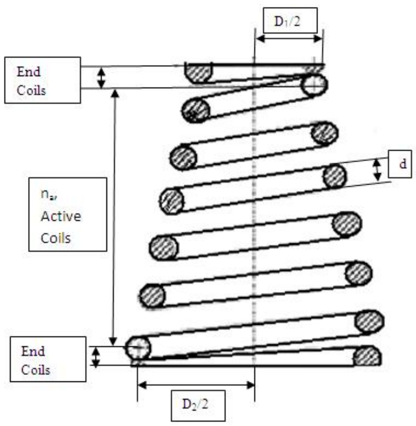
The main function of a mechanical spring is to store energy through bending or deformation under applied forces. The spring can be considered an elastic part with linear elastic properties as long as the material is not loaded beyond the elastic limit. The actual application of this spring can be seen in the brake regulator used for balancing as soon as the hydraulic pressure is released. Cylindrical springs are open pitch springs used to withstand compressive forces or store energy. Depending on the application, it can be done in different configurations and in the form of different shapes [1].

Helical conical springs are comparable to helical cylindrical springs .The mean diameter is not constant in helical conical spring. In several systems, less space necessity replaces cylindrical spring by conical spring [2].
Considerations required for spring selection include load bearing capacity, stiffness, deviation under compression etc. Space requirements related to maximum outer diameter, minimum inner diameter, and spring lengths with unlike loads [3].

Computer aided design plays a vital role in process and product simulation for achieving optimum results [4-5]. Application of CAD also includes testing of process design like water collector system using renewable energy [6-7].

2.Proposed Helical Springs Models

It represents both coil springs with constant pitch and round threads, and the design is fully defined based on the following considerations such as n_a= Number of active turns, figure 1.The coil spring is designed taking into account the inner and outer diameter, wire cross section, height and number of active coils of the helical spring [8]. Spring steel material with specific grades is used for helical spring [9-10].



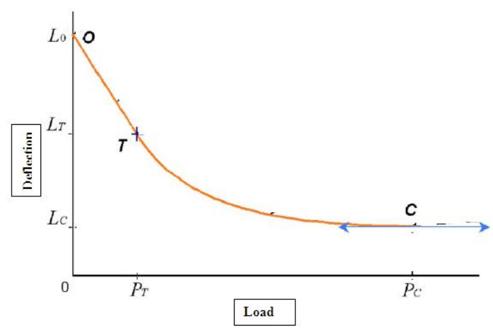


Fig.1Helical conical springdesigning considerations [2]

Fig.2 Helical spring load-deflection curvature[2]

C –Maximum compression.T – End coils compressedO –No deflection

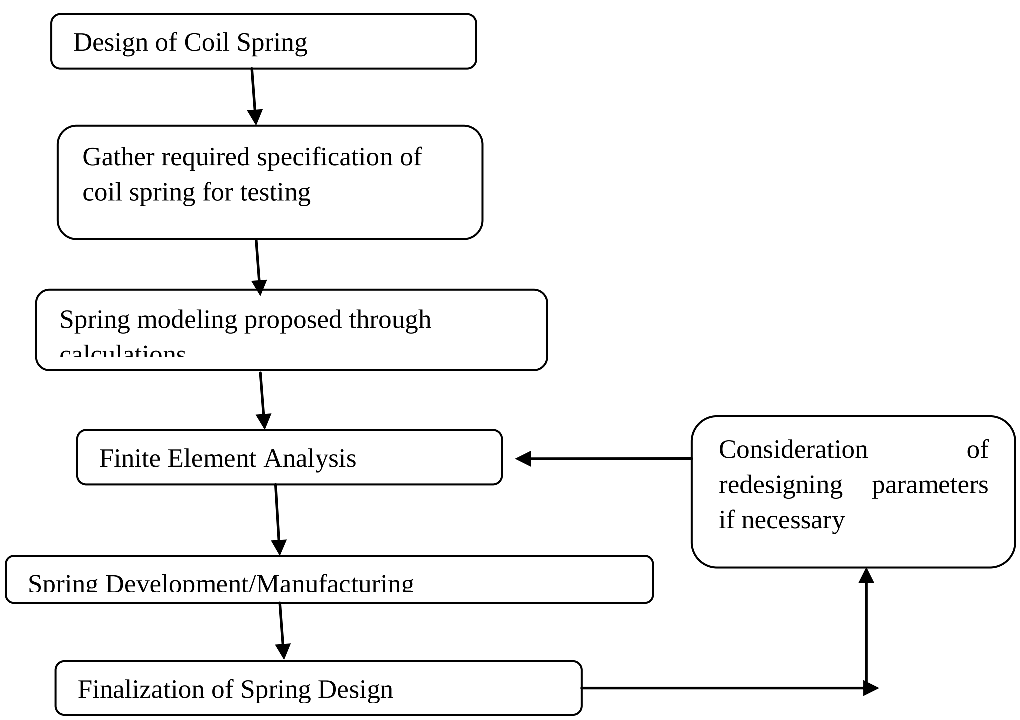


Fig.3Coil spring flowchart [8]

3 FEA/FEMand Experimental investigational Work

Simulation Work: Analysis process contains the description ofdefining the Discretizedcross section of coil spring and section properties, material inputs(Spring steel), applied forceconstraints,description of boundary condition's, investigation type (linear or non-linear) [11-12].

Cylindrical Spring
Outer diameter = 34mm
Mean diameter = 15mm
Height of spring= 60mm
Wire diameter = 4.2mm
na= 7

Conical spring
Height of spring = 60mm
Outer diameter (Big end) = 34mm
Outer diameter (Small end) = 24mm
Wire diameter = 4.2mm
na = 7

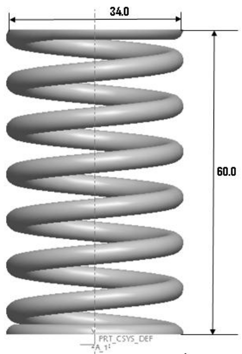


Fig.4Helical cylindrical spring using Pro-Engineer

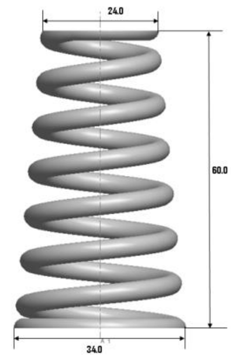


Fig.5 Helical conical spring using Pro-Engineer.

Consideration of material properties (spring steel of grade II) are used for Finite Element simulation purpose:Young's Modulus = 2.1e5 N/mm2,Density = 7.86e-9 Kg/mm^3,Possion's ratio = 0.3. Coefficient of friction is 0.2 [16-18].The upper disc of helical spring is taken as stamp while the bottom disc is base. Here, the spring is defined as a deformable structure, and the stamp and base are rigid analysis bodies defined as reference points. Base reference point is constrained in all degree of freedoms. Further displacement from the punch reference point is given towards base until the spring reaches asolid length [11-12].

Conical coil springs modeled in Pro-Engineer are imported or converted to CAE software in IGES format. The spring geometry is defined as a deformable structure. The model is not scaled and the topology is robust.

Table.1Simulation results (Helical cylindrical spring)

Deflection (millimeters)	Reaction Force (Newton)
0	0
1.57	24.821
3.12	49.695
4.55	75.177
6.2	102.518
7.75	129.990
9.3	157.494
10.85	184.982
12.4	212.398
13.95	239.688
15.5	266.830
17.05	293.910
18.6	320.932
20.15	347.883
21.7	374.777
23.25	401.653
24.8	428.699
26.35	455.972
27.9	483.488
29.45	513.504
31	554.989

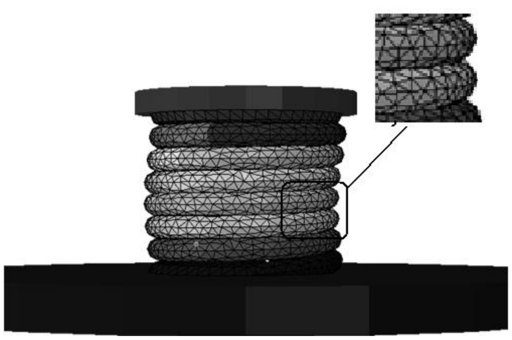


Fig.6 Cylindrical coil spring deformation

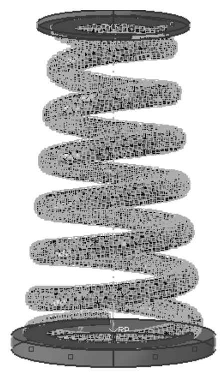


Fig.7 Spring, base and conical spiral punch arrangement

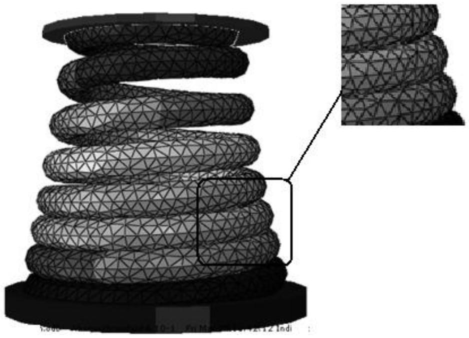


Fig.8Conical spring is deformed up to 27 mm.

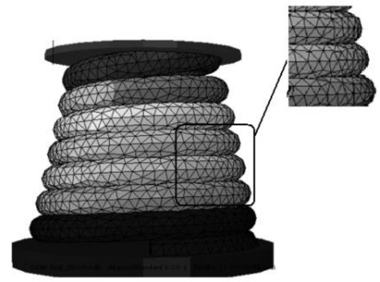


Fig.9Conical coil spring deformed to a fixed (Solid) length

Table.2 Simulation results (Helical conical spring)

Deflection (millimeters)	Reaction force (Newton)
0	0
2.8	77.85
5.8	156.88
8.6	243.62
10.9	328.39
13.7	417.13
16.5	504.76
19.2	594.26
21.9	688.54
25.4	805.46
27	960.12

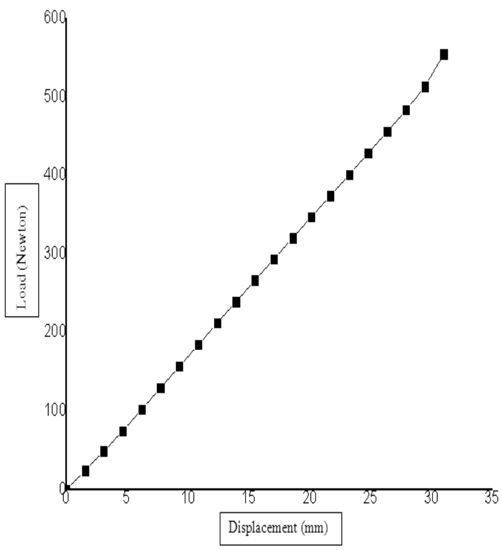


Fig.10Fixed length of load displacement curve of spiral cylindrical spring (Simulation Graph)

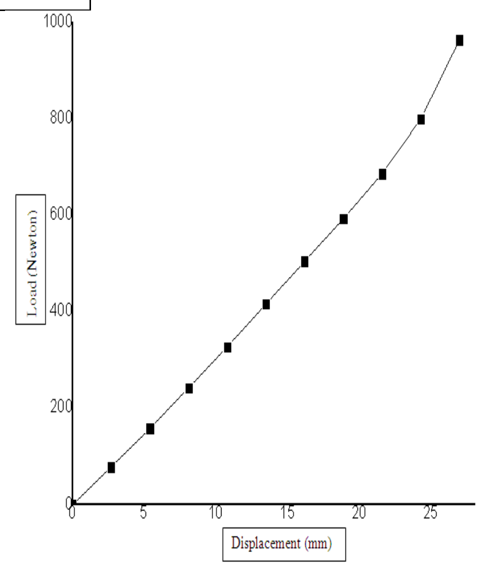


Fig.11 Load-deflection curve of 27mm displacement of conical coil spring (Simulation)

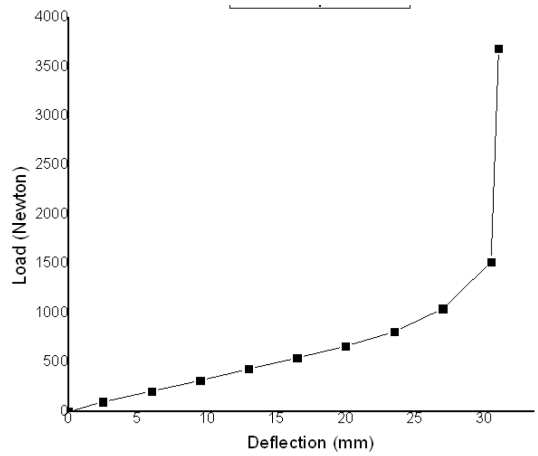


Fig.12 Simulation result of Load-deflection curve of full length coil spring (Helical conical spring)

Experimental Work

Manufacture of coil springs (wire diameter less than 5 mm). Wire with a diameter of 18 mm or less can be manufactured using one of the simple manufacturing techniques.

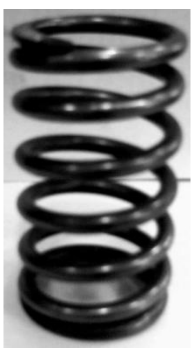


Fig.13 Cylindrical spring

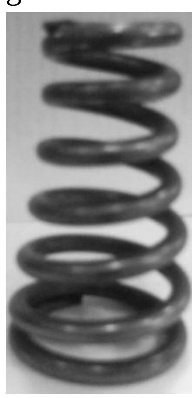


Fig. 14 Conical spring

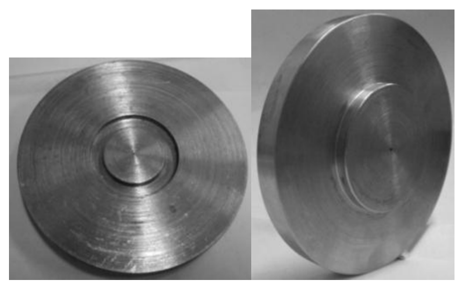


Fig. 15 Punch and Base with clamp

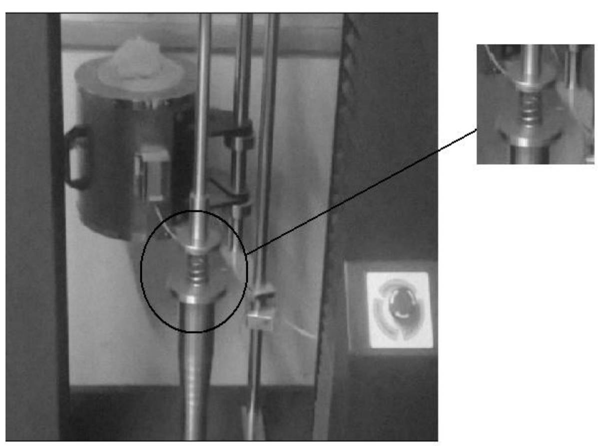


Fig.16 Experimental setup for compression testing. (Universal testing machine)

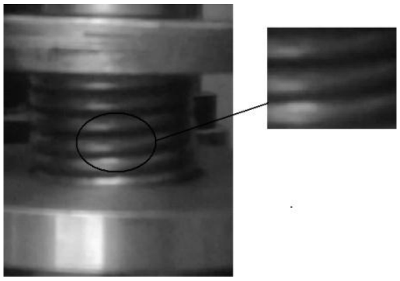


Fig.17Compressed spring (Cylindrical Type)

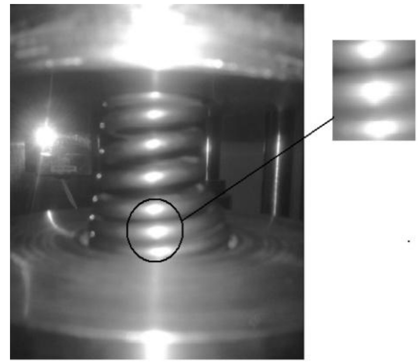


Fig.18 Compressed conical spring (Conical Type)

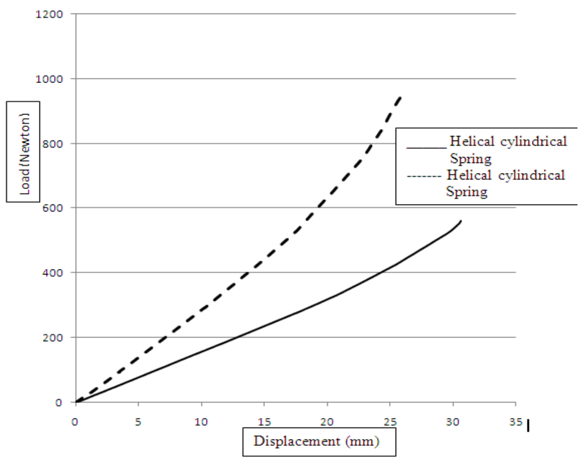


Fig.19Experimental data- Load displacement curves (Helical cylindrical v/s Helical conical spring)

4.Simulationand Experimental dataassessment

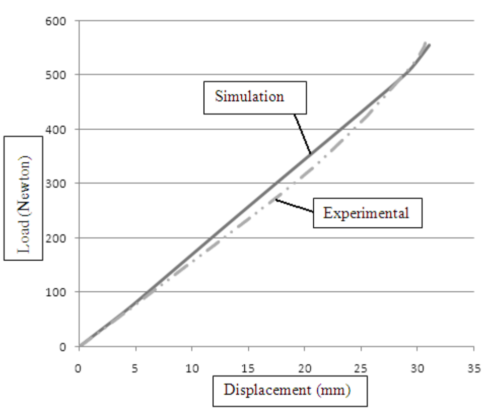


Fig.20FE simulation and experimental results comparison of helical cylindrical spring

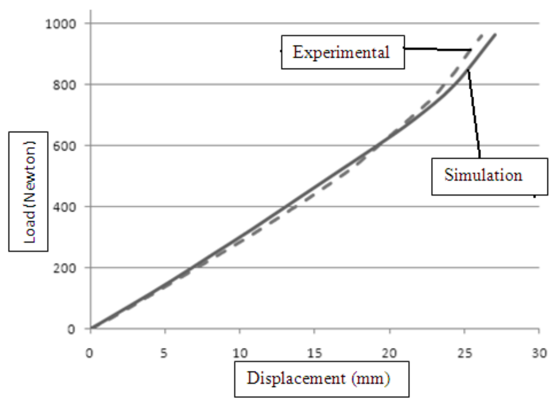


Fig.21 Experimental and FE simulation result comparison

Percentage of load deviation to coil spring deviation

Table.3 Helical spring (Conical)

Experiment Data	Simulation data	Deviation percentage
0	0	0
74.62	78.94	2.5
150.71	154.81	3.1
237.15	246.62	3.07
317.29	328.37	2.41
407.58	411.15	3.24
482.57	506.78	3.22
581.55	594.22	1.34
706.56	689.56	2.25
822.54	802.44	3.52
969.51	969.18	0.24

Table.4 Helical spring (cylindrical)

Experiment Data	Simulation data	Deviation percentage
0	0	0
25.4	25.22	1.35
49.54	47.50	2.24
73.27	76.32	3.83
98.45	106.57	5.0
126.64	127.92	3.55
153.75	155.42	3.25
178.58	183.94	3.45
205.57	216.39	4.68
226.95	237.68	4.09
257.92	264.83	4.05
282.57	295.99	4.36
305.56	321.93	4.24
339.23	342.88	3.77
356.72	373.77	4.22
382.44	402.65	4.25
414.38	421.69	4.06
455.83	454.97	0.27
483.39	483.48	0.24
511.75	515.56	1.2
566.08	552.98	1.0

Table.5 Cylindrical spring slope maximum percentage change

Load (in Newton)	Maximum Pitch Variation (%)
49.60	0.579
102.6	0.596
157.50	0.286
212.40	0.099
266.83	0.035
321.00	0.0305
375.00	0.120
428.94	0.290
483.98	0.263
554.98	0.057

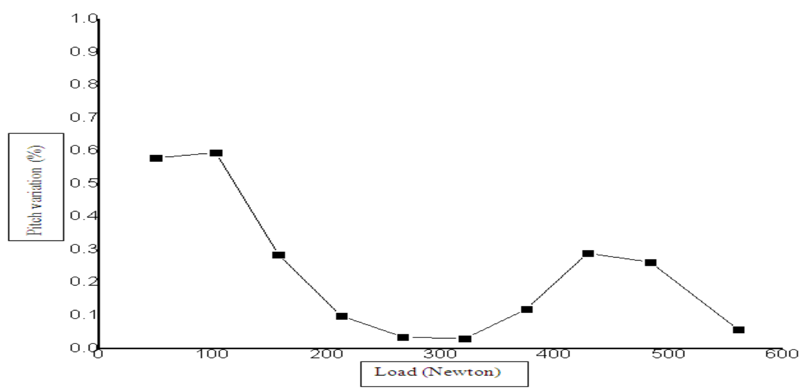


Fig.22Maximum pitch change for spiral cylinder springs with different load values.

5. Conclusions

The verification and experimental results of the FEM simulation were performed at different load values in the spring. Deviation percentage in terms of distance or length is minor as displayed in observation table 3& table 4.

Deviation percentageofhelical spring (Cylindrical type) was 2.2 and for helical spring (Conical Type) was 2.5.Finite element simulation is done under the real conditions used in the experimental work, the deviation of the results may be minor.Comparison of the maximum fluctuations of the coil spring split was performed using the FEM simulation task as shown in table 5.Linear and nonlinear analysis gives better results in Abaqus / Standard, Abaqus / Explicit.

6.Future Scope

Assessment of load deviation curves for unlikevarieties of coil spring, such as barrel springs may be performed. The influence of friction on the force deformation curvature of the coil spring may be calculated.

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