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Probabilistic design of helical coil spring for Translational invariance by using Finite Element Method

Sagar N Khurd, Prasad P Kulkarni, Samir D Katekar

1Research scholar, Department of mechanical Engineering, SKN Sinhgad College of Engineering, Korti,

2Department of mechanical Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur ,

3Department of mechanical Engineering, SKN Sinhgad College of Engineering, Korti, Pandharpur ,

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Abstract - The study represents new approach to design helical coil spring by using workbench. Response surface modeling and analysis of helical spring by considering Translational invariance have been carried out. In previous paper we had considered longitudinal invariance. Design parameters are wire diameter, coil diameter, height, number of turns elastic modulus in X and Y direction, force. Simple equation is proposed which gives value of compressive stress of helical coil spring by carrying out regression analysis done by M S excels, It is observed that force and material property are significant parameters which affect compressive stress because their P value is 1. Relationship among design parameters and compressive stress has been obtained. In this analysis it is observed that coil diameter increases stress on the the spring decreases.

***Key Words*: - Analysis by FEA and Response surface modeling, Simulation.**

I.INTRODUCTION

Spring act as a flexible joint in between two parts or bodies. Spring is the energy storing and releasing element whenever required. This paper demonstrates by taking the combination of steel and composite material for design of helical compression spring. In this case instead of steel is used combination of steel and composite material Glass fiber/Epoxy because of low stiffness of single composite spring, which limits its application to light weight vehicle only. Composite material is light weight and corrosion resistance, it can withstand high temperature. It increase efficiency of vehicle and overcome the cost. He had concluded combination of steel and composite material can increase the stiffness which is the major requirement of regular vehicle due to higher weight this done by using the FEA.[1].This study investigates static behavior of helical structure under axial loads. In this paper, authors have taken two helical structure first one is single wire on which homogeneous theory applied and second is axial elastic properties of seven wire strand are computed. This approach, based on asymptotic expansion, gives the first-order approximation of the 3D elasticity problem from the solution of a 2D microscopic problem posed on the cross-section and a 1D macroscopic problem, which turns out to be a Navier–Bernoulli–Saint-Venant beam problem and result compared with reference results.[2] This paper researchers taken four composite material (structure)these are unidirectional laminates (AU), rubber core unidirectional laminates (UR), Unidirectional laminates with braided outer layer (BU), and rubber core unidirectional laminates with braided outer layer (BUR). They investigated effect of rubber core and braided outer layer on the mechanical properties of the above mentioned helical springs. According to the experimental results, the helical composite spring with a rubber core can increase its failure load in compression by about 12%; while the spring with a braided outer layer cannot only increase its failure load in compression by about 18%, but also improve the spring constant by approximately 16%. [3]This study deals with the stress analysis of a helical coil compression spring, which is employed in three wheeler's auto-rickshaw belonging to the medium segment of the Indian automotive market. This spring's have to face very high working stresses, so in this design of the spring both the elastic characteristics and the fatigue strength have to be considered as significant aspects. This done by using finite element analysis. These springs have to face very high working stresses. The structural reliability of the spring must therefore be ensured. [4]The linear zed disturbance equations governing the resonant frequencies of a helical spring subjected to a static axial compressive load are solved numerically using the transfer matrix method for clamped ends and circular cross-section to produce frequency design charts.This paper summarize the behavior of the lowest resonant frequency obtained from the model of a helical compression spring with an initial number of turns.[5]In this paper, long term fatigue test on shot peened compression spring were conducted by means of special spring fatigue testing machine at 40 Hz. Three different types of material is taken and the influence of different shot peening conditions were investigated. In this paper fractured test spring were examined under scanning electron microscope, optical microscope and by means of metallographic micro section in order to analyse the fracture behavior and the failure mechanisms [6]

It is observed from literature review that probabilistic approach for the design of helical coil spring by using FEA is not taken into consideration. Also probabilistic design by considering longitudinal invariance, Translational and combined translation plus longitudinal invariance is necessary to consider for design under dynamic loading condition. Validation of the analysis will be done by analytical techniques in finite element method or solid mechanics. Also results of probabilistic design are to be optimized. Results will provide new approach and key to improve design of helical coil spring.

II .SIMULATION

Finite element analysis of helical spring

Analysis has been carried out in ANSYS work bench. Constrained spring geometry is as shown in figure 2.1.

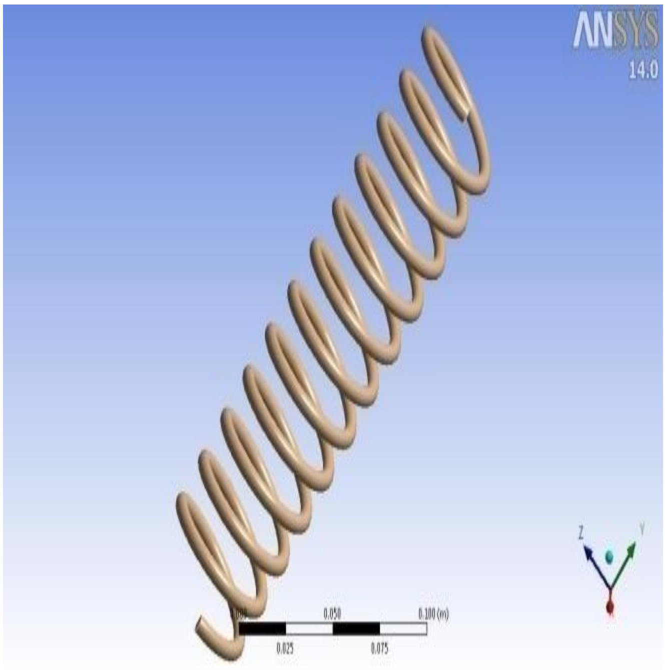

Fig.2.1 Geometry of the spring in ANSYS

In table No. 2.1 Simulation of helical coil spring is done by using response surface modeling in ANSYS workbench (FEA). Geometry is meshed by using brick element. Total number of nodes 25620 and elements 4850 are generated after meshing. One end of the spring is fixed in all direction while load is applied in Y direction at another end. It is shown in figure 2.2

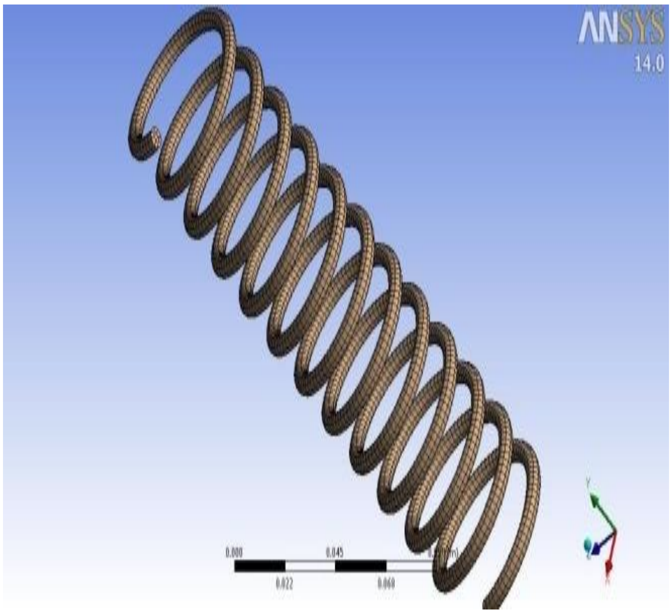

Fig.2.2 Meshed model of helical coil spring

Sr. No.	Material Property	Value
1	Young's modulus (EX), MPa	34000
2	Young's modulus ((EY) MPa	6530
3	Young's modulus (EZ) MPa	6530
4	Shear modulus along XY-direction (Gxy), MPa	2433
5	Shear modulus along XY-direction (Gyz), MPa	1698
6	Shear modulus along XY-direction (Gzx), MPa	2433
7	Force on x direction, N	1000
8	Poisson ratio along XY-direction (NUxy)	0.217
9	Poisson ratio along YZ-direction (NUyz	0.366
10	Poisson ratio along ZX-direction (NUzx)	0.217

Table No.2.1 Material properties of spring for analysis (Epoxy)

Table 2.1 shows material properties in X, Y and Z directions which are used for analysis.

Sr.No.	Parameters	Lower Limits	Higher Limits
1	Height(mm)	210	220
2	Wire diameter(mm)	5	6
3	Turns(mm)	11	13
4	Coil diameter(mm)	22	26
5	Ex (Mpa)	32000	34000
6	Ey (Mpa)	6210	6530
7	Force Y Component (N)	950	1050

In table 2.2, lower and upper limit of input parameters are specified for uniform distribution.
In table No. 2.3 Material properties of structural spring has taken for reference of helical coil spring is done by using response surface modeling in ANSYS workbench (FEA).(3)

Table No.2.3 Material properties of spring for Analysis (structural steel)

Sr.No.	Material Property	Value
1	Density (kg/m3)	7850
2	Young's modulus (Pa)	2.10e11
3	Poisson's ratio	0.3
4	Bulk modulus (Pa)	1.666e11
5	Shear modulus (Pa)	7.633e11
6	Ultimate tensile strength (Pa)	4.6e8
7	Yield tensile strength (Pa)	2.5e8
8	Yield comp. strength (Pa)	2.5e8

Table No.2.3 Corresponding parameters according to RSM (Response Surface Modeling)

Sr.No.	P1	P13	P3	P4	P5	P6	P7	P8	P9	P10
1	12	25	6	210	6.53E+12	-1000	3.4E+13	2600	0.012773	2.28E+09
2	10.8	25	6	210	6.53E+12	-1000	3.4E+13	2600	0.015393	2.46E+09
3	13.2	25	6	210	6.53E+12	-1000	3.4E+13	2600	0.017737	2.46E+09
4	12	22.5	6	210	6.53E+12	-1000	3.4E+13	2600	0.010156	2.07E+09
5	12	27.5	6	210	6.53E+12	-1000	3.4E+13	2600	0.01579	2.49E+09
6	12	25	5.4	210	6.53E+12	-1000	3.4E+13	2600	0.01944	3.11E+09
7	12	25	6.6	210	6.53E+12	-1000	3.4E+13	2600	0.008738	1.73E+09
8	12	25	6	189	6.53E+12	-1000	3.4E+13	2600	0.011796	2.28E+09
9	12	25	6	231	6.53E+12	-1000	3.4E+13	2600	0.013794	2.28E+09
10	12	25	6	210	5.88E+12	-1000	3.4E+13	2600	0.012784	2.28E+09
11	12	25	6	210	7.18E+12	-1000	3.4E+13	2600	0.012765	2.28E+09
12	12	25	6	210	6.53E+12	-1100	3.4E+13	2600	0.014051	2.51E+09
13	12	25	6	210	6.53E+12	-900	3.4E+13	2600	0.011496	2.05E+09
14	12	25	6	210	6.53E+12	-1000	3.06E+13	2600	0.012911	2.28E+09
15	12	25	6	210	6.53E+12	-1000	3.74E+13	2600	0.01266	2.28E+09
16	12	25	6	210	6.53E+12	-1000	3.4E+13	2340	0.012773	2.28E+09
18	11.40297	23.75619	5.701487	199.552	6.21E+12	-1049.75	3.23E+13	2729.356	0.014687	3.07E+09
19	12.59703	23.75619	5.701487	199.552	6.21E+12	-1049.75	3.23E+13	2470.644	0.016909	3.28E+09
20	11.40297	26.24381	5.701487	199.552	6.21E+12	-1049.75	3.57E+13	2729.356	0.018177	3.35E+09

21	12.59703	26.24381	5.701487	199.552	6.21E+12	-1049.75	3.57E+13	2470.644	0.020943	3.28E+09
22	11.40297	23.75619	6.298513	199.552	6.21E+12	-1049.75	3.57E+13	2729.356	0.009833	2.32E+09
23	12.59703	23.75619	6.298513	199.552	6.21E+12	-1049.75	3.57E+13	2470.644	0.011321	2.23E+09
24	11.40297	26.24381	6.298513	199.552	6.21E+12	-1049.75	3.23E+13	2729.356	0.012304	2.75E+09
25	12.59703	26.24381	6.298513	199.552	6.21E+12	-1049.75	3.23E+13	2470.644	0.014162	2.43E+09
26	11.40297	23.75619	5.701487	220.448	6.21E+12	-1049.75	3.57E+13	2470.644	0.015874	3.49E+09
27	12.59703	23.75619	5.701487	220.448	6.21E+12	-1049.75	3.57E+13	2729.356	0.01826	3.32E+09
28	11.40297	26.24381	5.701487	220.448	6.21E+12	-1049.75	3.23E+13	2470.644	0.019764	3.39E+09
29	12.59703	26.24381	5.701487	220.448	6.21E+12	-1049.75	3.23E+13	2729.356	0.022744	3.59E+09
30	11.40297	23.75619	6.298513	220.448	6.21E+12	-1049.75	3.23E+13	2470.644	0.010738	2.59E+09
31	12.59703	23.75619	6.298513	220.448	6.21E+12	-1049.75	3.23E+13	2729.356	0.012355	2.28E+09
32	11.40297	26.24381	6.298513	220.448	6.21E+12	-1049.75	3.57E+13	2470.644	0.013231	2.56E+09
33	12.59703	26.24381	6.298513	220.448	6.21E+12	-1049.75	3.57E+13	2729.356	0.015231	2.48E+09
34	11.40297	23.75619	5.701487	199.552	6.85E+12	-1049.75	3.57E+13	2470.644	0.014595	3.06E+09
35	12.59703	23.75619	5.701487	199.552	6.85E+12	-1049.75	3.57E+13	2729.356	0.016817	3.28E+09
36	11.40297	26.24381	5.701487	199.552	6.85E+12	-1049.75	3.23E+13	2470.644	0.018267	3.33E+09
38	11.40297	23.75619	6.298513	199.552	6.85E+12	-1049.75	3.23E+13	2470.644	0.009882	2.31E+09
39	12.59703	23.75619	6.298513	199.552	6.85E+12	-1049.75	3.23E+13	2729.356	0.011376	2.22E+09
40	11.40297	26.24381	6.298513	199.552	6.85E+12	-1049.75	3.57E+13	2470.644	0.012227	2.74E+09
41	12.59703	26.24381	6.298513	199.552	6.85E+12	-1049.75	3.57E+13	2729.356	0.014086	2.42E+09
42	11.40297	23.75619	5.701487	220.448	6.85E+12	-1049.75	3.23E+13	2729.356	0.01595	3.47E+09
43	12.59703	23.75619	5.701487	220.448	6.85E+12	-1049.75	3.23E+13	2470.644	0.018348	3.3E+09
44	11.40297	26.24381	5.701487	220.448	6.85E+12	-1049.75	3.57E+13	2729.356	0.01964	3.38E+09
45	12.59703	26.24381	5.701487	220.448	6.85E+12	-1049.75	3.57E+13	2470.644	0.022621	3.61E+09
46	11.40297	23.75619	6.298513	220.448	6.85E+12	-1049.75	3.57E+13	2729.356	0.010669	2.58E+09
47	12.59703	23.75619	6.298513	220.448	6.85E+12	-1049.75	3.57E+13	2470.644	0.012286	2.27E+09
48	11.40297	26.24381	6.298513	220.448	6.85E+12	-1049.75	3.23E+13	2729.356	0.013296	2.55E+09
49	12.59703	26.24381	6.298513	220.448	6.85E+12	-1049.75	3.23E+13	2470.644	0.015306	2.47E+09
50	11.40297	23.75619	5.701487	199.552	6.21E+12	-950.248	3.57E+13	2470.644	0.013221	2.78E+09
51	12.59703	23.75619	5.701487	199.552	6.21E+12	-950.248	3.57E+13	2729.356	0.015227	2.98E+09
52	11.40297	26.24381	5.701487	199.552	6.21E+12	-950.248	3.23E+13	2470.644	0.016546	3.03E+09
53	12.59703	26.24381	5.701487	199.552	6.21E+12	-950.248	3.23E+13	2729.356	0.019055	2.97E+09
54	11.40297	23.75619	6.298513	199.552	6.21E+12	-950.248	3.23E+13	2470.644	0.008952	2.1E+09
55	12.59703	23.75619	6.298513	199.552	6.21E+12	-950.248	3.23E+13	2729.356	0.010301	2.02E+09
56	11.40297	26.24381	6.298513	199.552	6.21E+12	-950.248	3.57E+13	2470.644	0.011075	2.49E+09
57	12.59703	26.24381	6.298513	199.552	6.21E+12	-950.248	3.57E+13	2729.356	0.012753	2.2E+09
58	11.40297	23.75619	5.701487	220.448	6.21E+12	-950.248	3.23E+13	2729.356	0.01445	3.16E+09
59	12.59703	23.75619	5.701487	220.448	6.21E+12	-950.248	3.23E+13	2470.644	0.016615	2.99E+09
60	11.40297	26.24381	5.701487	220.448	6.21E+12	-950.248	3.57E+13	2729.356	0.017791	3.07E+09
61	12.59703	26.24381	5.701487	220.448	6.21E+12	-950.248	3.57E+13	2470.644	0.020482	3.27E+09
62	11.40297	23.75619	6.298513	220.448	6.21E+12	-950.248	3.57E+13	2729.356	0.009665	2.34E+09
63	12.59703	23.75619	6.298513	220.448	6.21E+12	-950.248	3.57E+13	2470.644	0.011126	2.06E+09

64	11.40297	26.24381	6.298513	220.448	6.21E+12	-950.248	3.23E+13	2729.356	0.012044	2.32E+09
65	12.59703	26.24381	6.298513	220.448	6.21E+12	-950.248	3.23E+13	2470.644	0.013859	2.25E+09
66	11.40297	23.75619	5.701487	199.552	6.85E+12	-950.248	3.23E+13	2729.356	0.013286	2.77E+09
67	12.59703	23.75619	5.701487	199.552	6.85E+12	-950.248	3.23E+13	2470.644	0.015302	2.96E+09
68	11.40297	26.24381	5.701487	199.552	6.85E+12	-950.248	3.57E+13	2729.356	0.016444	3.02E+09
69	12.59703	26.24381	5.701487	199.552	6.85E+12	-950.248	3.57E+13	2470.644	0.018953	2.96E+09
70	11.40297	23.75619	6.298513	199.552	6.85E+12	-950.248	3.57E+13	2729.356	0.008895	2.09E+09
71	12.59703	23.75619	6.298513	199.552	6.85E+12	-950.248	3.57E+13	2470.644	0.010245	2.01E+09
72	11.40297	26.24381	6.298513	199.552	6.85E+12	-950.248	3.23E+13	2729.356	0.011131	2.48E+09
73	12.59703	26.24381	6.298513	199.552	6.85E+12	-950.248	3.23E+13	2470.644	0.012816	2.19E+09
74	11.40297	23.75619	5.701487	220.448	6.85E+12	-950.248	3.57E+13	2470.644	0.014357	3.15E+09
75	12.59703	23.75619	5.701487	220.448	6.85E+12	-950.248	3.57E+13	2729.356	0.016523	3E+09
76	11.40297	26.24381	5.701487	220.448	6.85E+12	-950.248	3.23E+13	2470.644	0.017878	3.06E+09
77	12.59703	26.24381	5.701487	220.448	6.85E+12	-950.248	3.23E+13	2729.356	0.020582	3.25E+09
78	11.40297	23.75619	6.298513	220.448	6.85E+12	-950.248	3.23E+13	2470.644	0.009712	2.34E+09
79	12.59703	23.75619	6.298513	220.448	6.85E+12	-950.248	3.23E+13	2729.356	0.01118	2.06E+09
80	11.40297	26.24381	6.298513	220.448	6.85E+12	-950.248	3.57E+13	2470.644	0.011968	2.31E+09
81	12.59703	26.24381	6.298513	220.448	6.85E+12	-950.248	3.57E+13	2729.356	0.013784	2.24E+09

As shown in the table No.2.4. Regression analysis of helical coil spring is carried out by using M S excels 2014 or for obtaining regression equation. Regression analysis of helical coil spring has been done by using M S excel and following equation of regression is obtained.

P9 = - 0.00466 + 0.00164 P1 + 0.00126 P2 - 0.00953 P3 + 0.000055 P4 - 0.000000 P5 - 0.000014 P6- 0.000000 P7 + 0.000000 P8……………………………………………[1.1]

Where,
P1 – Turns, P2 – Coil diameter, diameter(mm) , P3 – Wire diameter(mm) , P4-Height(mm) , P5 - Young's Modulus Y direction (Pa) , P6 - Force Y Component (N), P7 - Young's Modulus Y direction (Pa) , P8 – Total Deformation Maximum (Pa), P9 – Equivalent stress Maximum (mm)

III .RESULTS AND DISCUSSION

In this chapter, analysis of helical coil spring by using the response surface modeling has been discussed. This analysis provides the resulting graphs of design parameters Vs compressive stress. Under the loading condition, compression strength of helical coil spring is obtained. Stress distribution of helical coil spring is as shown below in figure 3.1.In this case, static analysis is done by using the finite element method, in the figure blue color indicates the minimum stresses 4.8343E6 acting on the turns and red color indicates maximum stresses 4.7378E9. The force applied in y direction .Material properties in Z direction are kept constants i.e. translational invariance while material properties in other two directions are varied within range 190e3 to 220e3.

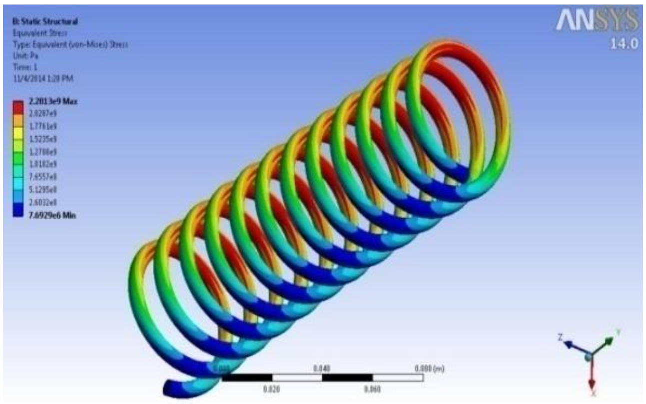

Fig.3.1. Equivalent stress of helical coil spring

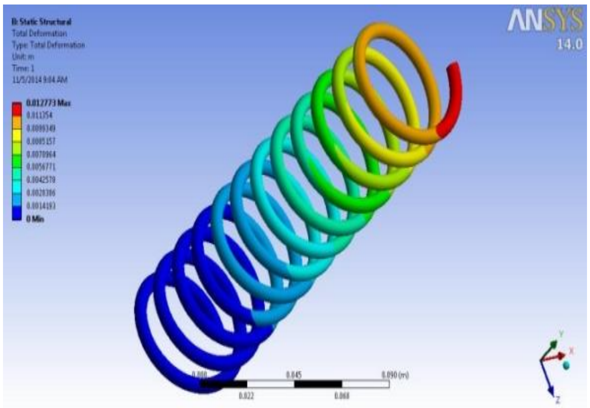

Fig.3.2. Total deformation of helical coil spring

a). Coil diameter Vs Compressive stress

Figure shows relationship between coil diameter Vs compressive stress has been obtained. In this fig showing that when mean diameter of spring increases compressive stress also goes on increasing upto 27 mm. There compressive stress decreases because stress exceeds elastic limit.

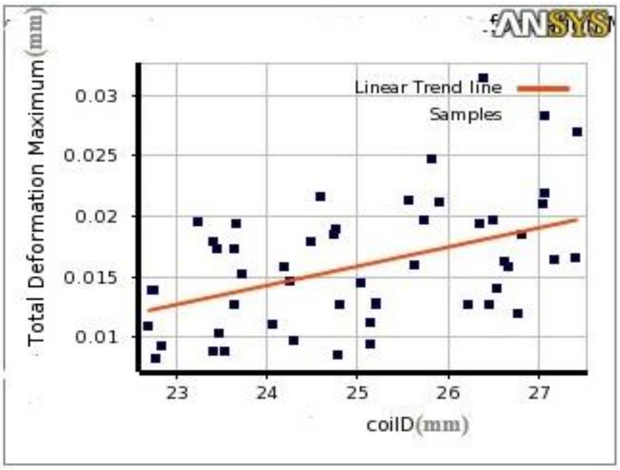

Fig.3.2. Mean diameter Vs Compressive stress

b) Young's modulus Vs Compressive stress

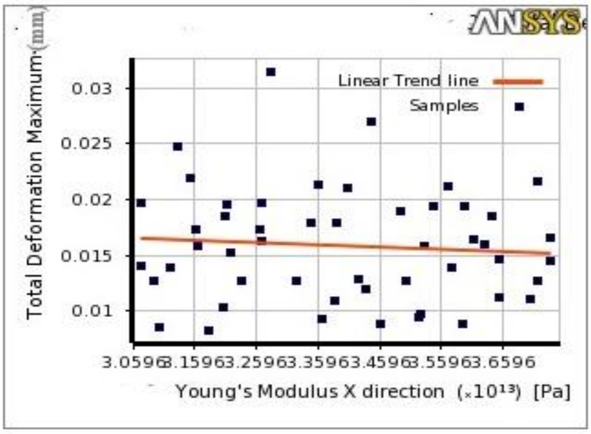

Fig.3.3. Young's modulus Vs Compressive stress

Figure shows young's modulus Vs compressive stress in this case, when young's modulus increase the compressive stress increases .It happens due to high stiffness value of spring.

c). Wire diameter Vs Compressive stress

Figure shows the compressive stress Vs wire diameter. When wire diameter of spring is increases compressive stress decrease, As shown in figure diameter increases deformation increases. From this graph it observed that wire diameter important parameter. up. From fig. it is also observed that 5mm is optimum wire diameter.

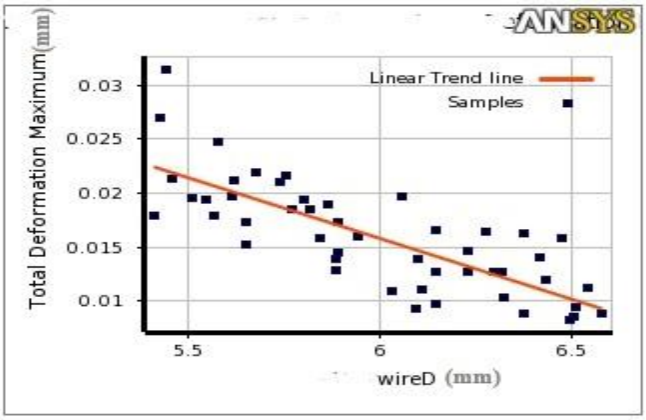

Fig.3.4. Wire diameter Vs Compressive stress

d) Force Vs Compressive stress

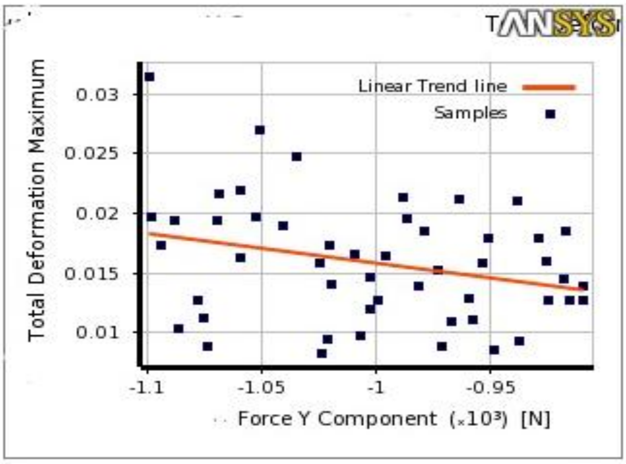

Fig.3.5. Force Vs Compressive stress

Figure shows graph of force Vs compressive stress. In this graph shown that when force increases compressive stress also increase, so compressive stress depend on applied force. From obtained regression model it is observed that force is one among significant parameter.

e) Free length Vs compressive stress

Figure shows graph of free length VS compressive stress. graph obtained shows exactly reverse nature as that of wire diameter Vs compressive stress. As shown in the fig. free length increases there after compressive stress increases up to free length because energy stored in spring is released.

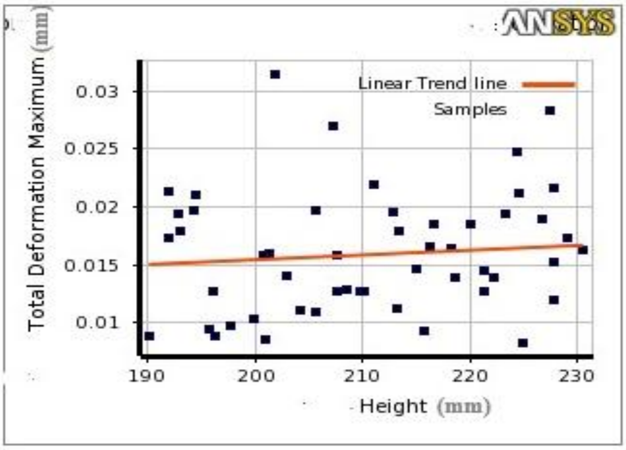

Fig.5.6. Free length Vs compressive stress

IV. CONCLUSION

-Simple equations proposed which gives value of compressive stress of helical coil spring by carrying regression analysis

-It is observed that force and material property are significant parameters which affect compressive stress because their P value is 1.

-Finite element analysis of helical coil spring has been carried out.

-Response surface modeling of helical coil spring under Translational invariance has been carried out for compression stress.

-Relationship among design parameters and compressive stress has been obtained

REFERENCES

[1] Saurabh Singh- "Optimization of Design of Helical Coil Suspension System by Combination of Conventional Steel and Composite Material in Regular Vehicle" International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11 (2012)

[2].Ahmed Frikha, Patrice Carried, Fabien Trussed "Mechanical modeling of helical structures accounting for translational invariance. Part 1: Static behavior/ Frikha et al. / International Journal of Solids and Structures 50 (2013) 1373–138

[3].Chang-Hsuan Chiu , Chung-Li Hwan , Han-Shuin Tsai , Wei-Ping Lee An experimental investigation into the mechanical behaviors of helical composite springs C.-H. Chiu et al. / Composite Structures 77 (2007) 331–340

[4].Tausif M. Mulla1, Sunil J. Kadam2, Vaibhav S. Kengar3, "Finite Element Analysis Of Helical Coil Compression Spring For Three Wheeler Automotiv Front Suspension", International Journal Of Mechanical and Industrial Engineering (IJMIE) ISSN No. 2231 –6477, Vol-2, Iss-3, 2012

[5].Becker L.E., G.G.Chasssies:- " On the Natural frequencies of helical compression springs" L.E. Becker et al. / International Journal of Mechanical Sciences 44 (2002) 825–841

[6].B. Pyttel, I.Brunner, B. Kaiser, C.Berger, Mahendran, "Fatigue behaviour of helical compression springs at a very high number of cycles .Investigation of various influences B. Pyttel et al. / International Journal of Fatigue (2013)

[7]. A.M. Yu, Y. "Free vibration analysis of helical spring with noncircular cross section"/ Hao Journal of Sound and Vibration 330 (2011) 2628–2639