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Design and Analysis of Helical Compression Spring used in a Suspension System for Light Vehicle

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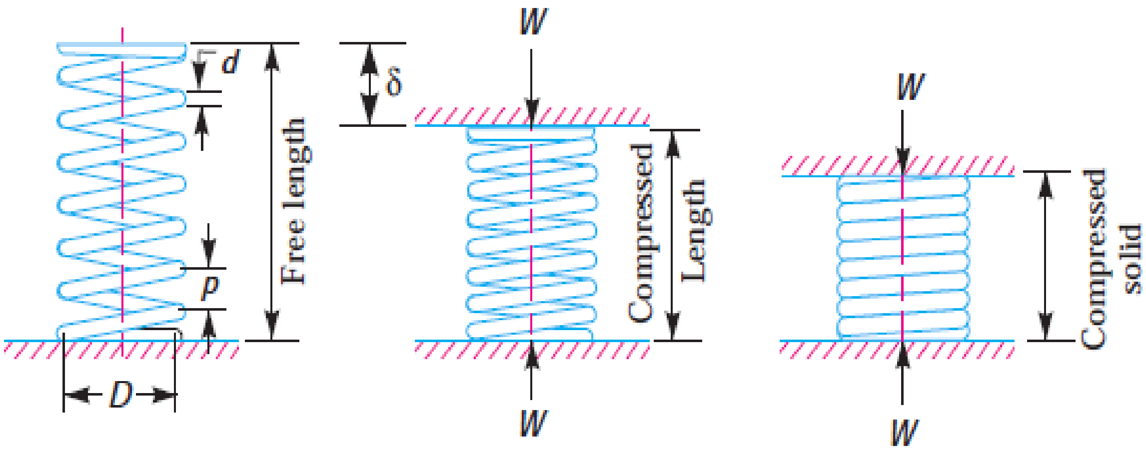
Abstract
Compression springs are one of the most important mechanical parts using in cars, airplanes, trains, machines and many other applications because of their flexibility. In this study, the investigation includes a comparison between two compression helical spring materials, the first made of "chromium-vanadium steel" and second made of "low carbon structural steel" to choose the optimum design. This study provides the designer with the possibility to choose the suitable springs in suspension systems and other uses in terms of wire diameter, a number of turns, deformation, shrinkage and coil diameter. Modelling by the Solidworks-17 has been done. As well as the use of ANSYS-16.1in the analysis. Where appears the variance in total stresses and total deflection of the spring for choosing the materials.

Keywords: Helical compression spring, Deformation, suspension system.

Introduction

The Helical Springs are mainly used in the many industries, and springs are at most used in the industry as a mechanical part so that they get back the first position of a part into displacement for beginning a specific function as well as for absorbing shock energy.[1] such as a vehicle where the vehicle chassis is fixed on the axle, by some helical spring and not directly on the structure of automobile in this way insulate the automobile has been done from the chassis.[2] In carriage by the vehicles, the passenger's comfort is important for the designer, byway decrease the vibration to which he is subjected. The conditions have become more important for the growth of new conveyance systems. however, the new model of a system with consideration allowed vibration can reason it to be inconvenient and hence inadmissible to the travelling people.[3] Helical Compression Springs are coil wire that resists axially loaded. Usually to be cylindrical, and there is a type as tapered, conical concave or convex in shape. They are often wrapped in a circular shape [1].



Compression spring nomenclature.

Literature Review

After Studying somepapers, which discussed different types of helical compression spring, can be concluded that more work has been done in the analysis, design, and material selection. And some papers study looks the several species of coils springs used in the suspensions of the vehicles. And performance, various methods of failure in coil, increase modification, and analysis of fatigue stress

[1] used a large coil of helical compression spring relative to the wire radius ratio, which found high stress in the surface area at outer rather than the inside surface. And has calculated the fatigue and maximum principal tensile stress after positioned the fatigue crack origin on the outer surface of the helix spring, the author found that (Fatigue Design) should be depended on the rate of the (Max. Principal Tensile) of the coil [4].

[2]in this study Here the researcher used [SI–CR] alloyed valve wire of spring and was a (d) dia. of the wire 2 and 5- mm, high cycle fatigue tests on spring was done. Extended to 10^8 cycles or more in the fatigue tests. all this to evaluate the value of fatigue range in the stress cycle over 10^9 cycle came to 10^7 to nearly10^8 cycles value in a nearly 10% lowering of the fatigue limit, and from 10^7 cycles to 1.2 x 10^9 is increasing reduces the fatigue limit by 25 % to 90% eventuality remaining[5]

[3] had given results of helical spring from studied the type of the material Epoxy-Glass were used to made of wire spring in the suspension system when replaced helix spring by Epoxy-Carbon. In that paper study, FEA to coil spring has analyzed by using Ansys and in final theout values of all paramters.[6]

[4]The analysis was conducted by Achyut P. Banginwar when working on analysis, design of shock absorber, in this paper carried out the work by FEM. Analysis and used Pro-Eng. to evaluate and discussion about shock absorbing system in this design, also structural and model analysis he has done on the Shock-Absorber System.[7]

Table (1)**Some of the important terms and considerations used in design helical spring.**

No.	Name of Parameters	Symbol	Units
1	Mean Diameter	D	mm
2	Outer-Diameter	D_o	mm
3	Wire-Diameter	d	mm
4	Modulus of rigidity	G	GPa
5	Axial Load	W	N
6	Spring Index	C	-----
7	Number of Total Turns	n'	-----
8	Number of Active Turns	n	-----
9	Wahl's Stress Factor	K	-----
10	Stress Factor due to shear	K_S	-----
11	Stress Factor dueto curvature	K_C	-----
12	Pitch of the coils	P	mm
13	Solid length.	L_s	mm
14	Free length.	L_f	mm
15	Deflection of the spring	δ	mm
16	Maximum shear stress	τ_{Max}	MPa
17	Mean Shear Stress	τ_m	MPa
18	Variable Shear Stress	τ_y	MPa

Design and Selection of Material

Generally, the operating conditions are the one most important consideration for the selection of spring material proper. For the appropriate application, the material must be proper with the conditions operating, work and resist effects of high temperature and corrosion or rust without a redundant loss in the helical spring performance. Corrosion and high temperatures lowering helical spring reliability. Hence, in order to the selection of material proper for a successful application, the material must be appropriate with the environment. Hence, in order to the selection of material proper for a successful application, the material must be appropriate with the environment. So, Materials were select as showing table (2) to the chemical composition and table (3) shows the properties of materials.

Material property: For Chromium vanadium steel material properties and for low carbon structural steel material properties.[8]

table (2)

Material	Young"s modulus MPa	Poisson's Ratio	Density kg/m3
Chromium vanadium steel	207000	0.27	7860
low carbon structural steel	198000	0.37	7700

DESIGN OF HELICAL SPRING

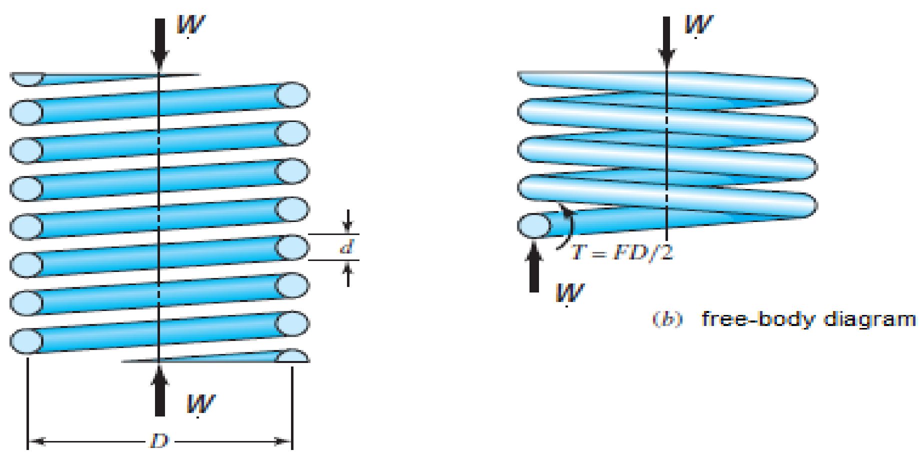
Table (3) Geometrical parameters of helical spring.

No.	Parameter	Symbol	Value	Unit
1	Diameter of Wire	d	9.49	mm
2	Mean Diameter	D	127	mm
3	Outer Diameter	D_o	56.94	mm
4	Free Length	L_f	152	mm
5	Pitch	P	13.8	mm
6	Number of Active Turns	n	11	mm
7	Number of Total Turns	n'	9	mm
8	test load on each spring	W	2750	N

The calculation for helical compression Spring.

Consideration of a spring:

Made of circular wire and subjected to an axial load, axially loaded (W) compression helical spring and (FBD) that the coil is subjccted to a direct shear- and a torsional shear.



(a) Axially loaded helical spring; (b) free-body diagram

Stress in spring

Torsion shear stress $W * \frac{D}{2} = \frac{\pi}{16} * \tau_t * d^3$

$\tau_t = \frac{8*W*D}{\pi d^3}$ -------------------(1)

Direct shear stress (τ_d) $\tau_d = \frac{W}{\frac{\pi * d}{4}} = \frac{4W}{\pi d^2}$ --------------(2)

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Max. shear stress (τ) $\tau = \tau_t + \tau_d$

$$\tau = \frac{8 * W * D}{\pi d^3} + \frac{4W}{\pi d^2}$$

$$\tau = \frac{8 * W * D}{\pi d^3}[1 + \frac{d}{2D}]$$

$\tau = K_s \frac{8*W*D}{\pi d^3}$ ----------------(3)

$K_s = 1 + \frac{1}{2C}$; $K = \frac{4C-1}{4C-4} + \frac{0.615}{C}$ **K=Wahl's correction factor.**

$\tau = K_s \frac{8*W*D}{\pi d^3}$ **When neglecting the curvature effect.**

$\tau = K \frac{8*W*D}{\pi d^3}$ **When considering the curvature effect.**

$C = \frac{D}{d}$; $\tau = K \frac{8*W*D}{\pi d^2}$

Deflection of helical spring

$\delta = \frac{8*W*C^3*n}{G*d}$ --(4)

Modelling and analysis of coils spring

A helical compression is designed by SolidWorks-17 as have to it. And by ANSYS-16-software analyzed is doneIn this study, the behaviour will be Monitoring by using differente materials, to the optimum design and the result shows the best model or material.

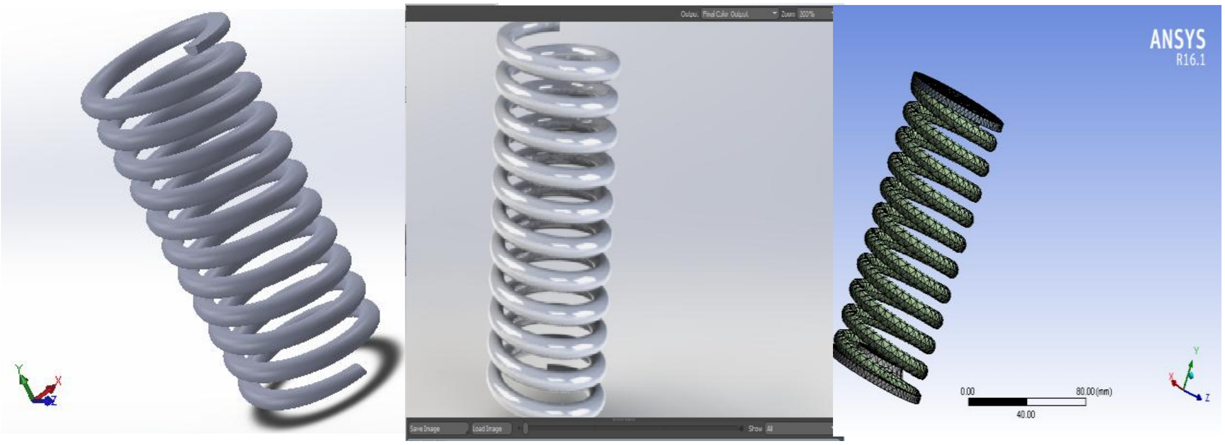

Fig.(1) and (2) modelling of fig.(2)Fig(3) Mesh generation of helical compression spring coil compression spring

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Analysis of helical spring: Chromium vanadium steel

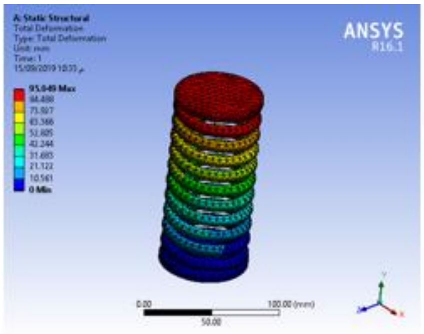


Fig.(4) Total Deformation

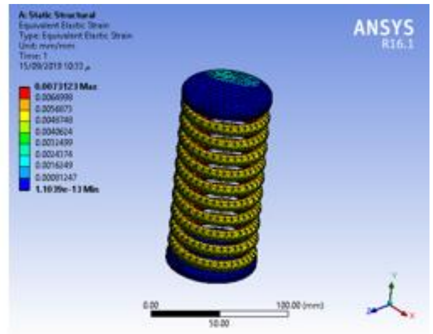
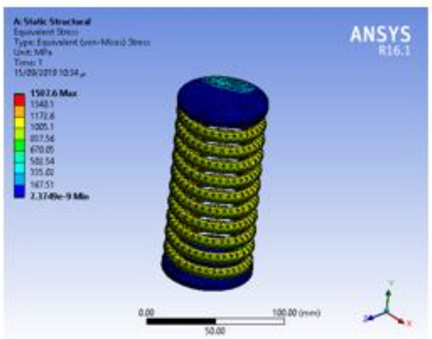


Fig.(5) Equivalent Elastic Strain



Fig(6) Equivalent(Von-Mises) Stress

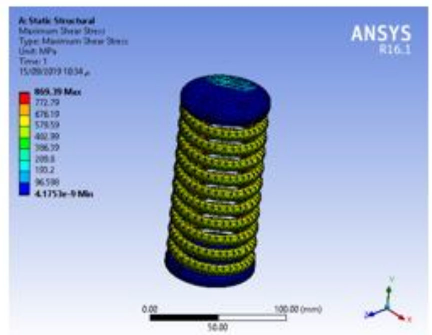


Fig.(7) Max. Shear Stress

Analysis of helical spring: Low Carbon structural steel

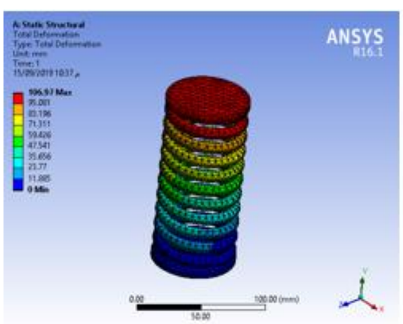


Fig.(8) Total Deformation

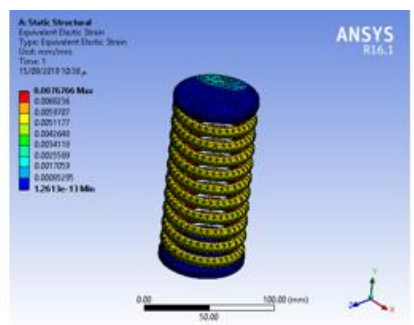
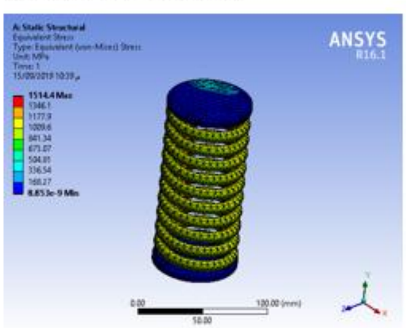


Fig.(9) Equivalent Elastic Strain



Fig(10) Equivalent(Von-Mises) stress

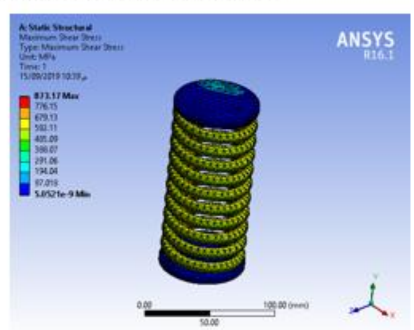


Fig.(11) Max. Shear Stress

Result & Discussion

The stresses analysis and total deflection of compression helical-spring used in the light vehicle suspension system have been presented and discussed in this study, the results which obtained by FEA shows different in overall stresses and deflection in low carbon structural steel compared with the Chromium vanadium steel as shown a table below.

Table (3) Stress and strains of coil spring

No.	Description	Carbon structural steel	Chromium vanadium steel
1	Von misses strain –mm/mm	0.0076766	0.0073123
2	Von misses stress-MPa	1514.4	1507.6
3	Deflection-mm	106.97	95.049
4	Max. shear stress-MPa	873.17	869.3

Conclusion

The work shows the deflection in chrome vanadium material is low compared to low carbon structural steel, also in strain and stress, but in shear stress is bigger than low carbon structural steel. We can see that the Chromium vanadiumsteel as shows is a best compared in low carbon structural steel to used systems in the vehicles through riding on the hump or Rugged road.The following paragraphs are drawn from the results of analyses.

1-The **(Von-misses-stress)** in Chromiumvanadlum steel is **1507.6**MPa and for (low carbon-structural steel) is **1514.4** MPa.

2-The **(Von-misses strain)** The result ofChromiumvanadium steel is **0.0073123 mm/mm** and for(lowcarbon-structural steel)**0.0076766 mm/mm**.

3-The **(Deflection)** in Chromiumvanadium steel is **95.049 mm** and for (low-carbon-structural-steel) is **106.97 mm**.

4-The **(Max. shear stress)** in Chromiumvanadium steel is **869.3 MPa** and for low carbon structural steel **873.17 MPa.**

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