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Design And Analysis Of Helical Compression Spring

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Abstract: A helical spring is a mechanical device which is typically used to store energy and subsequently release it, to absorb shock or to maintain a force between contracting surface. They are made of an elastic material formed into the shape of a helix which returns to its natural length when unloaded. When a spring is compressed or stretched, the force it exerts is proportional to its change in length. The present work is carried out on modeling and analysis of a helical compression spring of different dimensions for various types of loading. The stress and deformation values are calculated for different dimensions of the spring and compared it's accuracy with the values of software generated results. The modeling is done with the help of CATIA V5R20 designing software suite. The finite element analysis of the spring is accomplished by ANSYS 15.0 package. The stress and deformation results calculated for an archetype spring is compared with the results of the spring with dimensions slightly changed. All the factors that define a spring such as, shear stress, maximum deflection are calculated and compared. The results of the new spring are found to be more reliable and the efficiency is raised up a notch.

Keywords: Helical Spring; Deformation; Shear Stress; Wire Diameter; Mean Coil Diameter; CATIA V5; ANSYS 15.0

I. INTRODUCTION

The helical springs are helix-shaped coiled wire use for tensile or compressive loads. The cross-section of the coil spring wire may be circular, rectangular or square in shape. There are two forms of helical springs namely compression helical spring and tension helical spring. Major advantages of helical springs are its easy assembly and availability in wide ranges. These springs have constant spring rates and performance that are accurately predictable. The characteristics of these springs vary by changing its dimension and wire diameter.

The characteristics of the coil springs depend on the material and design from which it is manufactured. These are generally made from various materials like steel alloys, high carbon wire, non-ferrous metals, and stainless steel. A coil spring, also known as a helical spring, is a mechanical device which is typically used to store energy and subsequently release it to absorb shock or to maintain a force between contacting surfaces.

The compression spring is the most used type of spring. As its name indicates, it is designed to be compressed. The effort must thus be mainly axial and directed towards the spring. To facilitate the application of the force, the ends of the springs are often brought closed and ground.

These springs are open coil helical spring. A helical coil is pressed or squeezes by load. It resists compressive or push forces. It also shows resistance to linear compressive forces. Sometimes fluid behave as compression springs such as fluid pressure systems.

Figure 1: Helical Compression Spring

II. HELICAL SPRING USED IN AUTOMOBILES

A. TWO WHEELER

Suspension of a vehicle absorbs shock impulse and dissipates it in the form of kinetic energy it handles the stability of vehicle as well as provides comfort on vehicle rides. It works in two cycle that is compression cycle and expansion cycle. When vehicle passes through potholes the compression energy is stored and after that it is dissipated during expansion. Use of mono and dual suspension in vehicle is challenging as it affects the stability of vehicle.

Figure 2:Mono suspension

Figure 3: Dual Suspension

The suspension system absorbs shocks received due to uneven surface or when vehicle is subjected due to potholes and bumps in uneven surface. This paper describes the comparison of mono and dual suspension it deals with the impulse due to shocks and produces kinetic energy. Telescopic suspension is used widely in two wheeler but telescopic forks are replaced by mono suspension as it has an better shock absorbing ability and also comfort and bouncing free motion it also improves the stability on uneven surfaces. Shock absorber is used to dissipate kinetic energy and absorb vibration. Spring is used in suspension system whose function is to store energy when deflected by force and return equivalent amount of energy on being released. For two wheelers helical compression springs are widely used. Springs are made of hardened steel. Today's manufacturers are mainly concentrated on weight optimization of product.

B. FOUR WHEELER

According to Newton's laws of motion, all forces have both magnitude and direction. A bump in the road causes the wheel to move up and down perpendicular to the road surface. The magnitude of this depends on whether the wheel is striking a giant bump or a tiny speck. Either way, the car wheel experiences a vertical acceleration as it passes over an in perfection. Without an intervening structure, all the wheels vertical energy is transferred to the frame, which moves in the same direction. In such a situation, the wheels can lose contact with the road completely. Then due to the downward force of gravity, the wheels can slam back into the road. Thus we need is a system that will absorb the energy of the vertically accelerated wheels. Also, allowing the frame and body to tide undisturbed while the wheels follow bumps in the road.

Figure 4: Four Wheeler Suspension System

III. DESIGN OF HELICAL COMPRESSION SPRING

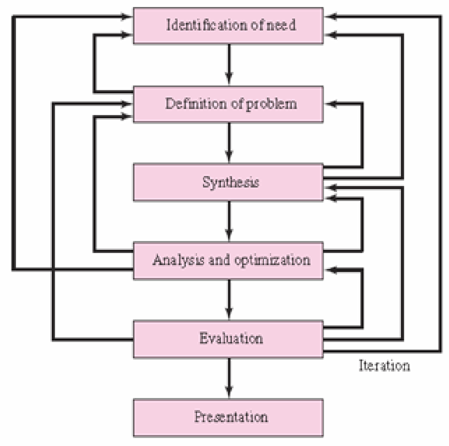

Figure 5: Design Process

The complete design process from start to finish is often outlined as shown in the Figure 5. The process begins with the identification of a need and a decision to do something about it. After much iteration, the process ends with the presentation of the plans for satisfying the need. Depending on the nature of the design task, several design phases may be repeated throughout the life of the product, from inception to termination.

A. DESIGN CONSIDERATIONS

The design of a new spring involves the following considerations:

- ✓ Space into which the spring must fit and operate.
- ✓ Values of working forces and deflections.
- ✓ Accuracy and reliability needed.
- ✓ Tolerances and permissible variations in specifications.
- ✓ Environmental conditions such as temperature, presence of a corrosive atmosphere.

✓ Cost and qualities needed.

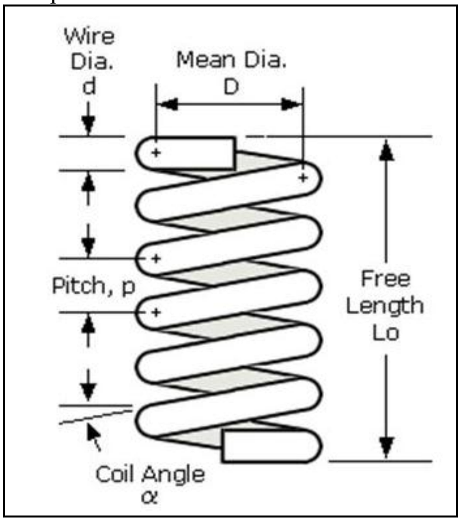

Figure 6: Spring Nomenclature

The designers use these factors to select a material and specify suitable values for the wire size, the number of turns, the coil diameter, the free length, type of ends and the spring rate needed to satisfy working force deflection requirements. The primary design constraints are that the wire size should be commercially available and that the stress at the solid length be no longer greater than the torsional yield strength. Further functioning of the spring should be stable.

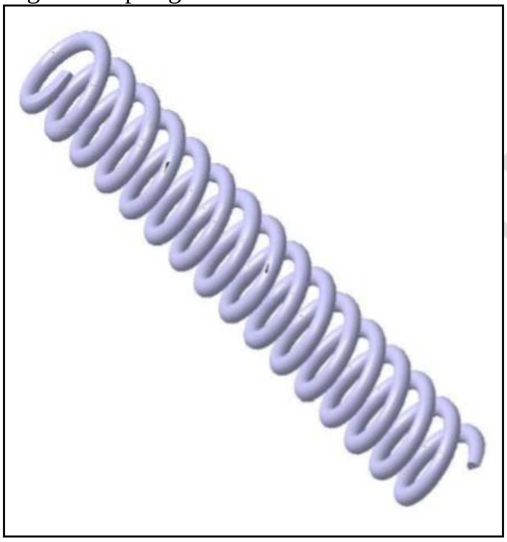

Figure 7: CATIA Model of helical spring

B. DESIGN CALCULATION FOR HELICAL COIL SPRING OF TWO WHEELER SHOCK ABSORBER

Spring Steel, modulus of rigidity (G)	78600N/mm^2
Mean diameter of a coil (D)	33.3 mm
Diameter of wire (d)	6.7 mm
Total no of coils (i')	17
No of active turns (i)	15
Height (h)	210 mm
Outer diameter of spring coil (D_o = D+d)	40 mm
Inner diameter of spring coil (D_i = D-d)	26.6 mm
Weight of bike	131 kg
Let weight of 1person	75 kg
Weight of 2 persons = 75×2	150 kg
Weight of bike + persons	263 kg
Rear Suspension	65%
65% of 263	171 kg

Table 1: Specifications of Helical Spring

Considering dynamic loads it will be double:
W = 342Kg = 3355.02 N
Spring index:
C =D/d =33.3/6.7
C= 4.970
Wahl's Factor:
K= (4C-1/4C-4) + (0.615/C)
K = 1.3126
Maximum shear stress induced in the wire:
τ= 8FDK/πd^3
τ= 1241.616 N/mm^2
Deflection of spring:
y= 8FD^{3}i/d^{4}G
y= 93.861 mm
Free length of spring:
l_o= solid length + maximum compression + clearance between adjustable coil
Style of end- Square and ground end
n= 2
a= 25% of maximum deflection
l_o= (i'× d) + y + a
l_o= (17×6.7) + 93.861 + (0.25×93.861)
l_o= 231.226 mm
Pitch of coil:
P= (l_o-2d)/i
P=14.521 mm
Required spring rate:
F_o= F/y
F_o= 35.744 N/mm
Actual spring rate:
F_o= d^{4}G/8id^3
F_o= 35.744 N/mm
Total length of wire:
l = πDi' = π×33.3×17
l= 1778.445 mm

C. FIRST ITERATION

Keeping Mean coil diameter constant (D = 33.3mm) and Varying the Wire diameter (d) the calculated values of shear stress and deflection are tabulated below

Wire diameter (d) mm	Shear stress (τ) MPa	Deflection (y) mm
6.5	1348.70	105.96
6.6	1293.67	99.68
6.7	1241.62	93.86
6.8	1192.53	88.46
6.9	1145.75	83.44

Table 2: Shear stress vs. Deflection, varying wire diameter

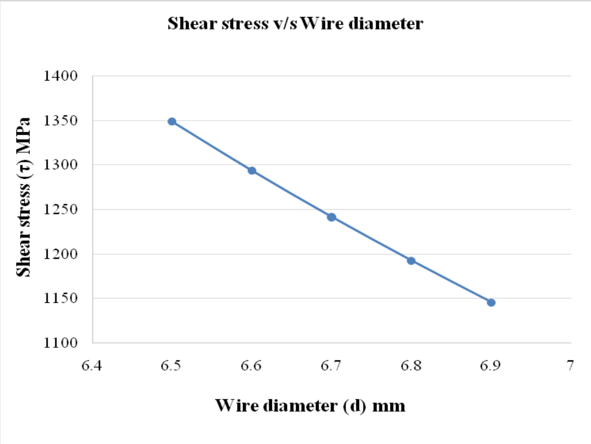

Figure 8: Shear Stress vs. Wire Diameter

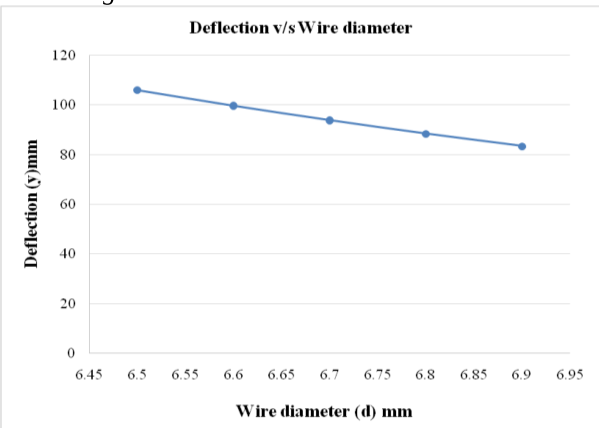

Figure 9: Deflection vs. Wire Diameter

D. SECOND ITERATION

Keeping Wire diameter constant (d = 6.7 mm) and Varying the Mean coil diameter (D) the calculated values of shear stress and deflection are tabulated below

Mean coil diameter (D) mm	Shear stress (τ) MPa	Deflection (y) mm
33.1	1236.13	92.18
33.2	1238.26	93.01
33.3	1241.62	93.86
33.4	1243.83	94.71
33.5	1246.60	95.56

Table 3: Shear stress vs. Deflection, varying mean coil diameter

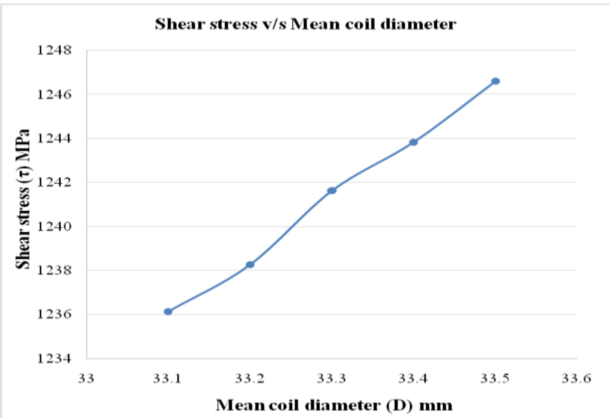

Figure 10: Shear Stress vs. Mean Coil Diameter

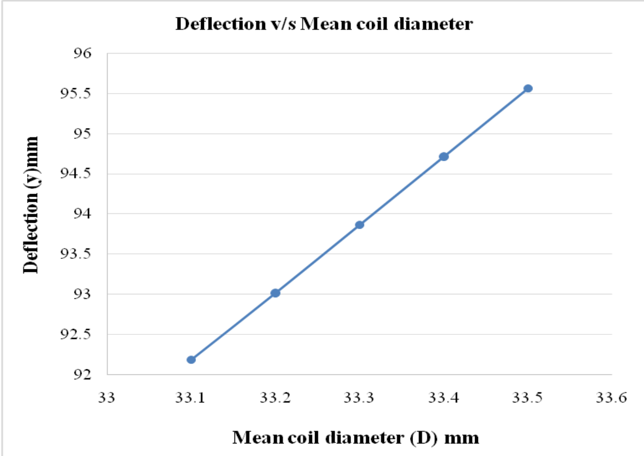

Figure 11: Deflection vs. Mean Coil Diameter

IV. ANALYSIS OF HELICAL COMPRESSION SPRING

Ansys develops and markets finite element analysis software used to simulate engineering problems. The software creates simulated computer models of structures, electronics or machine components to simulate strength, toughness, elasticity, temperature distribution, electromagnetism, fluid flow, and other attributes. Ansys is used to determine how a product will function with different specifications, without building test products or conducting crash tests.

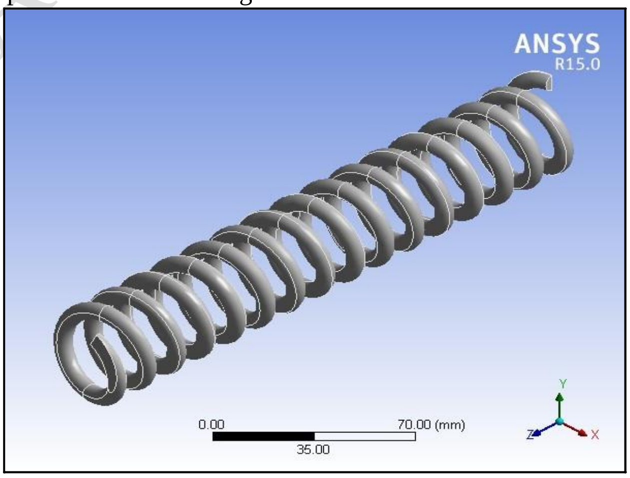

Figure 12: Ansys Model of Helical Spring

A. ANALYSIS OF HELICAL SPRING VARYING WIRE DIAMETER

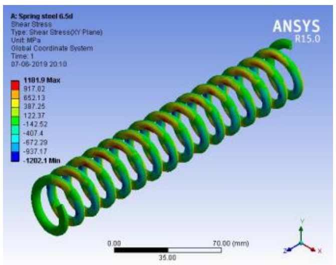

Figure 13: Shear Stress for d= 6.5 mm

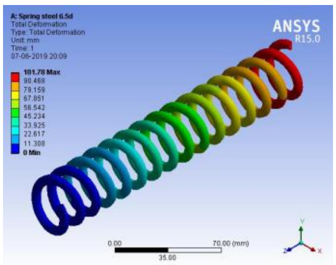

Figure 14: Deflection for d= 6.5 mm

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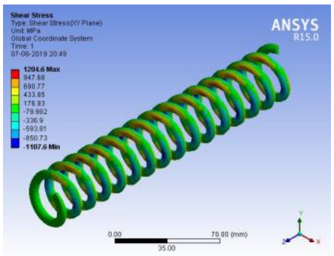

Figure 15: Shear Stress for d= 6.6 mm

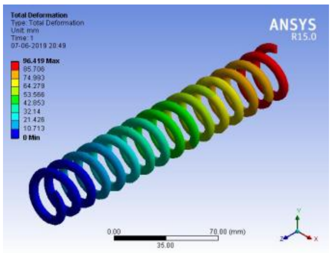

Figure 16: Deflection for d= 6.6 mm

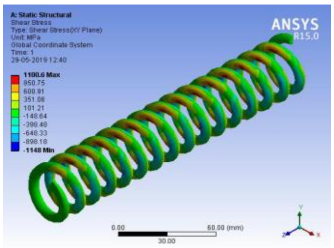

Figure 17: Shear Stress for d= 6.7 mm

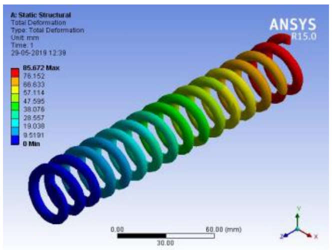

Figure 18: Deflection for d= 6.7 mm

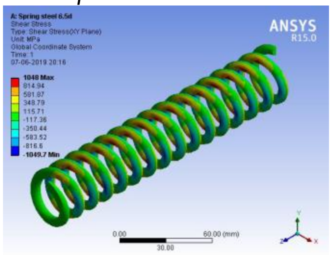

Figure 19: Shear Stress for d= 6.8 mm

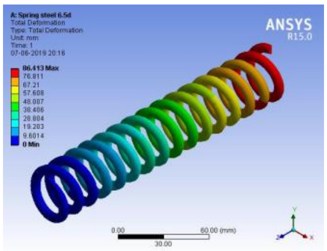

Figure 20: Deflection for d= 6.8 mm

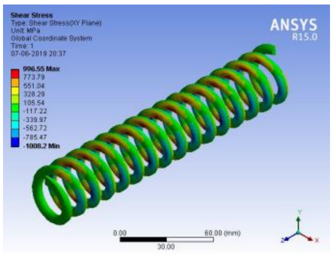

Figure 21: Shear Stress for d= 6.9 mm

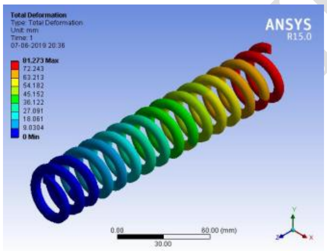

Figure 22: Deflection for d= 6.9 mm

B. ANALYSIS OF HELICAL SPRING VARYING MEAN COIL DIAMETER

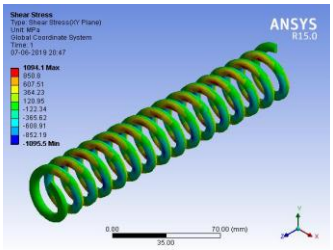

Figure 23: Shear Stress for D= 33.1 mm

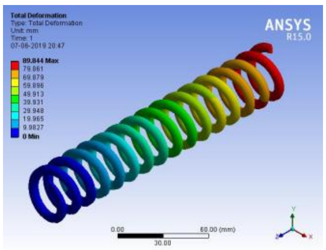

Figure 24: Deflection for D= 33.1 mm

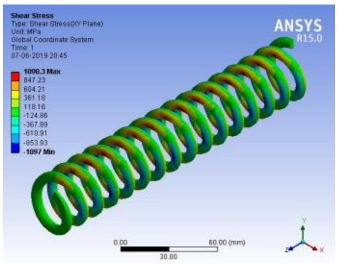

Figure 25: Shear Stress for D= 33.2 mm

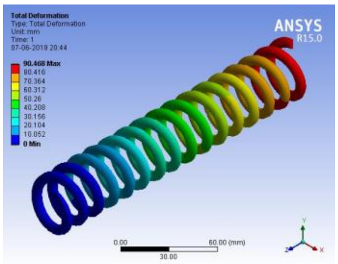

Figure 26: Deflection for D= 33.2 mm

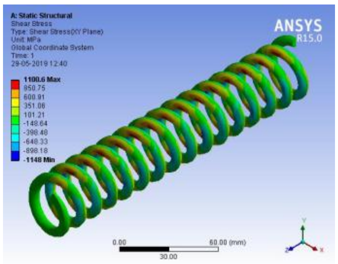

Figure 27: Shear Stress for D= 33.3 mm

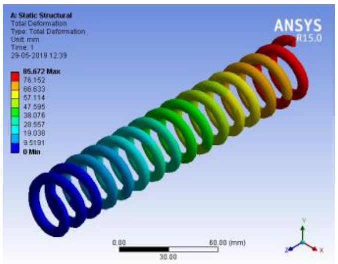

Figure 28: Deflection for D= 33.3 mm

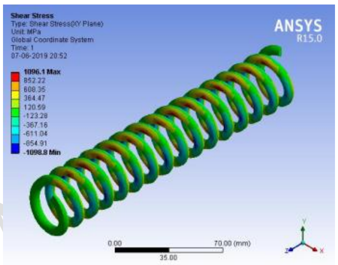

Figure 29: Shear Stress for D= 33.4 mm

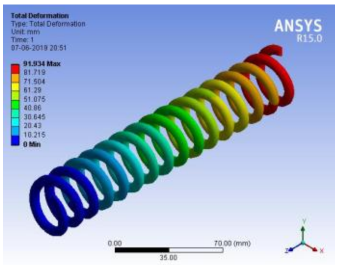

Figure 30: Deflection for D= 33.4 mm

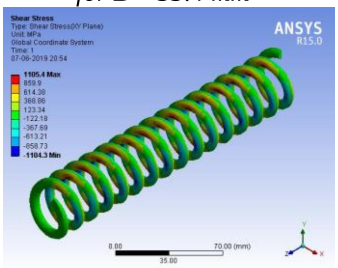

Figure 31: Shear Stress for D= 33.5 mm

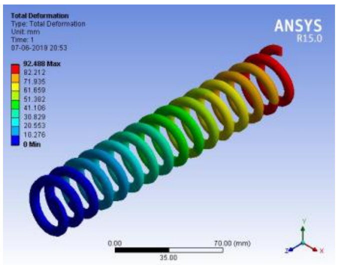

Figure 32: Deflection for D= 33.5 mm

Wire Diameter (d) mm	**Shear stress (τ) MPa**		**Deflection (y) mm**	
	Theoretical	**ANSYS**	**Theoretical**	**ANSYS**
6.5	1348.70	1226.4	105.96	101.78
6.6	1293.67	1204.6	99.68	96.42
6.7	1241.62	1093.9	93.86	90.87
6.8	1192.53	1048	88.46	86.41
6.9	1145.75	996.55	83.44	81.27
Mean Coil Diameter (D) mm	**Shear stress (τ) MPa**		**Deflection (y) mm**	
	Theoretical	**ANSYS**	**Theoretical**	**ANSYS**
33.1	1236.13	1088.9	92.18	89.84
33.2	1238.26	1090.3	93.01	90.47
33.3	1241.62	1093.9	93.86	90.87
33.4	1243.83	1096.1	94.71	91.93

33.5	1246.60	1105.4	95.56	92.48

Table 4: Comparison of Theoretical values with ANSYS Values

V. CONCLUSION

Spring is an elastic material which should take up the load and regain its original shape when load is removed. Spring undergoes static, fluctuating, dynamic loading etc. This work shows the detail designing of helical compression spring with respect to static loading. Comparison of analytical values a of shear stress and deformation are compared with material of the spring taken as steel.

Helical compression spring is modeled using CATIA and analysis is carried out using ANSYS software. The calculations are made for various wire diameter and mean coil diameter. This study shows that shear stress and deflection equation is used for calculating the number of active turns and pitch of helical compression spring. Comparison of the theoretical results obtained by the shear stress equation and Finite Element Analysis (FEM) of springs provides the better solution of the problems arising in the existing design of the mechanical spring.

.Keeping the reference dimensions and varying the wire diameter and mean coil diameter we can conclude that:

By increasing the wire diameter the shear stress decreases whereas the deformation decreases.

By increasing the mean coil diameter the shear stress increases whereas the deformation increases.

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