DESIGN OF HELICAL SPRING USED IN TWO-WHEELER REAR SUSPENSION

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CERTIFICATE

This is to certify that the Project Report entitled "**DESIGN OF HELICAL SPRING USED IN TWO WHEELER REAR SUSPENSION**" being submitted by ROUTHU DEVASAI (317126520165), KATTA UDAYKIRAN (317126520140), KODAMA HEMANTH VENKAT (317126520143), MEDABALIMI VAMSI PRANEETH (317126520152), in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **DR.M. RAJA ROY**, Associate Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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ABSTRACT

The helical spring used in suspension system or shock absorber is a mechanical device designed to smooth out damp shock impulse and dissipate kinetic energy. In a vehicle, it reduces the effect of traveling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. A helical compression coil spring which used in transport is belonging to the medium segment of the Indian automotive market. The use of different alloy steel materials is increasing in the design of automobile components due to their light weight and costs. The present work attempts to study the feasibility of select steel alloy in the design of helical compression spring used in automobile suspension systems. The design of helical compression spring is first analyzed for the conventional steel material and then compared with that of for the composites used as spring materials study their behaviors at the different loading conditions. The design of helical spring is to designed a 3D model by using **SOLID-WORKS** and analysis is done in **ANSYS** to predict the stresses, deflection at the stated loads. Structural and static analysis are done on shock absorber by varying material for spring. The theoretical calculation done to find out the load and deflection of the spring.

INTRODUCTION

The shock absorbers duty is to absorb or dissipate energy. One design consideration, when designing or choosing a shock absorber, is where that energy will go. In most dashpots, energy is converted to heat inside the viscous fluid. In hydraulic cylinders, the hydraulic fluid will heat up, while in air cylinders, the hot air is usually exhausted to the atmosphere. In other types of dashpots, such as electromagnetic ones, the dissipated energy can be stored and used later. In general terms, shock absorbers help cushion cars and bikes on uneven roads.

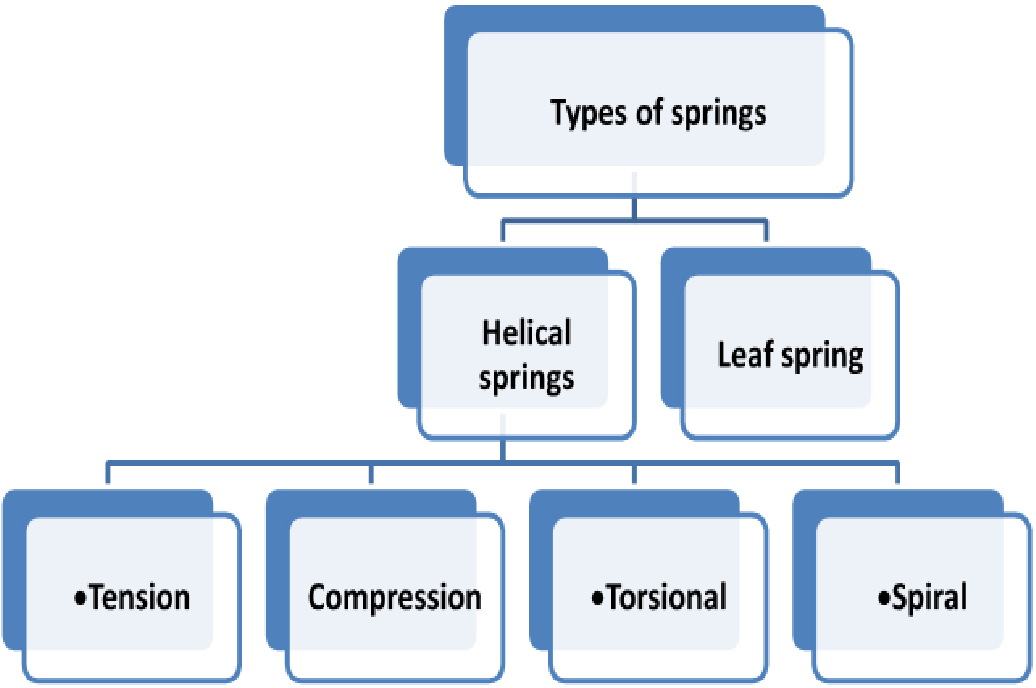
Shock absorbers are an important part of automobile and motorcycle suspensions, aircraft landing gear, and the supports for many industrial machines. Large shock absorbers have also been used in structural engineering to reduce the susceptibility of structures to earthquake damage and resonance. A transverse mounted shock absorber, called a yaw damper, helps keep railcars from swaying excessively from side to side and are important in passenger railroads, commuter rail and rapid transit systems because they prevent railcars from damaging station platforms.

In a vehicle, it reduces the effect of traveling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances. Without shock absorbers, the vehicle would have a bouncing ride, as energy is stored in the spring and then released to the vehicle, possibly exceeding the allowed range of suspension movement. Control of excessive suspension movement without shock absorption requires stiffer (higher rate) springs, which would in turn give a harsh ride. Shock absorbers allow the use of soft (lower rate) springs while controlling the rate of suspension movement in response to bumps. They also, along with hysteresis in the tire itself, damp the motion of the unspring weight up and down on the springiness of the tire. Since the tire is not as soft as the springs, effective wheel bounce damping may require stiffer shocks than would be ideal for the vehicle motion alone. Spring-based shock absorbers commonly use coil springs or leaf springs, though torsion bars can be used in tensional shocks as well. Ideal springs alone, however, are not shock absorbers as springs only store and do not dissipate or absorb energy. Vehicles typically employ springs and torsion bars as well as hydraulic shock absorbers. In this combination, "shock absorber" is reserved specifically for the hydraulic piston that absorbs and dissipates vibration.

Metal springs

Simply locating metal springs to absorb the impact loads are a low cost method of reducing the collision speed and reducing the shock loading. They are able to operate in very arduous conditions under a wide range of temperatures. These devices have high stopping forces at end of stroke. Metal springs store energy rather than dissipating it. If metal sprint type shock absorbers are used then measures should be provided to limit Oscillations. Metal springs are often used with viscous dampers.

There are a number of different types of metal springs including helical springs, bevel washers(cone-springs), leaf springs, ring springs, mesh springs etc etc. Each spring type has its own operating characteristics.



Compression helical spring:

The helical springs are said to be closely coiled when the spring wire is coiled so close that the plane containing each turn is nearly at right angles to the axis of the helix and the wire is subjected to torsion. In other words, in a closely coiled helical spring, the helix angle is very small; it is usually less than 10°. Springs used in this role resists forces moving in two objects away from each other.

Tension helical springs:

Open coiled helical springs, the spring wire is coiled in such a way that there is a gap between the two consecutive turns, as a result of which the helix angle is large. Typical applications are bike suspension and matters spring.

Torsional spring:

A torsion spring is a spring that works by twisting its end along its axis; that is, a flexible elastic object that stores mechanical energy when it is twisted. When it is twisted, it exerts a torque in the opposite direction, proportional to the amount (angle) it is twisted.

Spiral spring:

a spring consisting of a wire coiled usually in a flat spiral or in a helix

When forces act on elastic systems subject to small displacements, the displacement corresponding to any force co-linear with the force is equal to the partial derivative to the total strain energy with respect to that force. Springs, are designed to absorb and store energy, strain energy plays major role

$U = \sigma^2 / \rho E$.

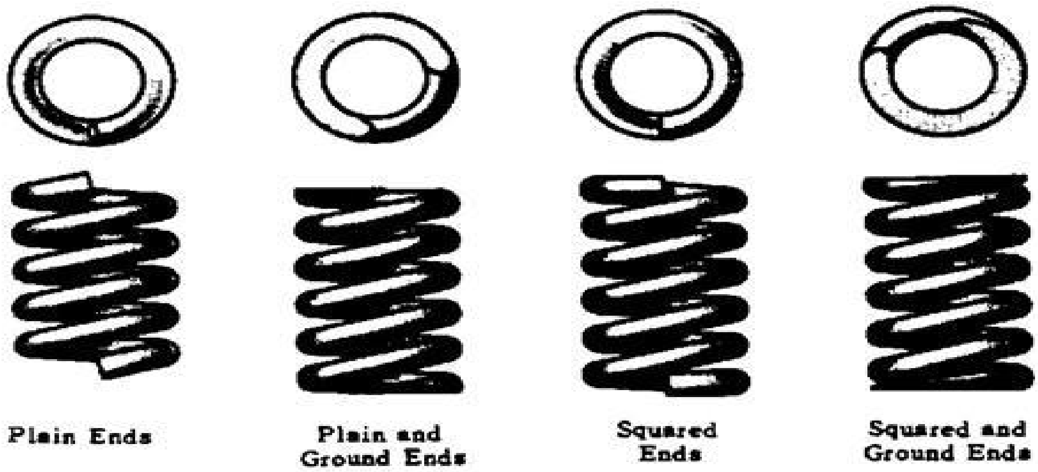
ρ=density, E= young's modulus, σ = yield strength. It is observed that material having lower the young's modulus and density, greater the strain energy.

End types of compression rings:

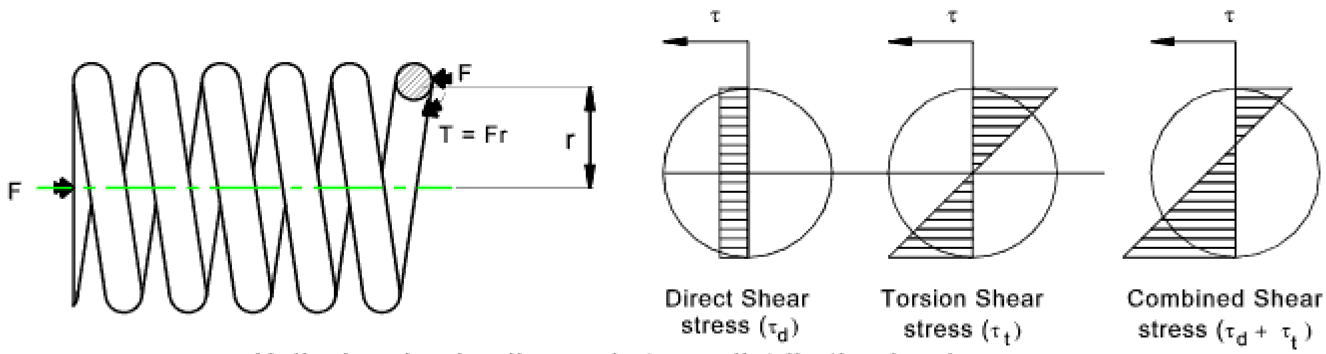
1.plain end
2.plain and ground
3.squared
4.squared and ground

Type of Ends	Total Coils	Solid Length	Free Length
Plain	n	$(n+1)d$	$np+d$
Plain ground	n	nd	np
Squared	$n+2$	$(n+3)d$	$np+3d$
Squared and ground	$n+2$	$(n+2)d$	$np+2d$

p = pitch, n = number of active coils, d = wire diameter



METHODS FOR ANALYSIS OF HELICAL SPRING:



Helical spring loading and stress distribution in wire

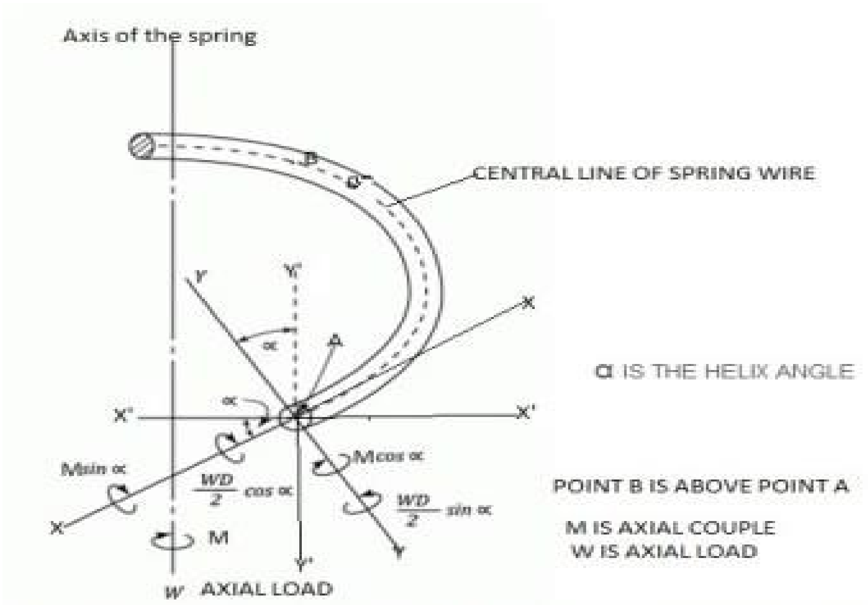


Fig. SECTION AB OF OPEN COILED HELICAL SPRING, DETAILS UNDER AXIAL LOAD 'W' AND AXIAL COUPLE 'M'

Von mises stress:

Let α be the angle of the helix

Then the length of n turns of spring L =πD n/cos α Consider a small length of the spring as CD

When an axial load W is applied, the spring is twisted and have bending (Coil radius will change)

Torque =T = W R will be resolved into two components

T cos α=W R cosα will produce twist on all sections of the spring wire

Component T sin α=W R Sinα will cause bending of the spring wire

Determination of axial deflection δ*:*

$\delta = (8W D^3 n/d^4 \cos \alpha) [\cos^2 \alpha/G) + (\sin^2 \alpha/E)]$

shear stress:

The component WD Cosα/2 will cause the shear stress in the spring wire.

$\tau = 8WD\cos\alpha/ \pi d^3$

Bending stress*:*

The component (WD Sin α)/2 will cause the bending stress in the spring wire.

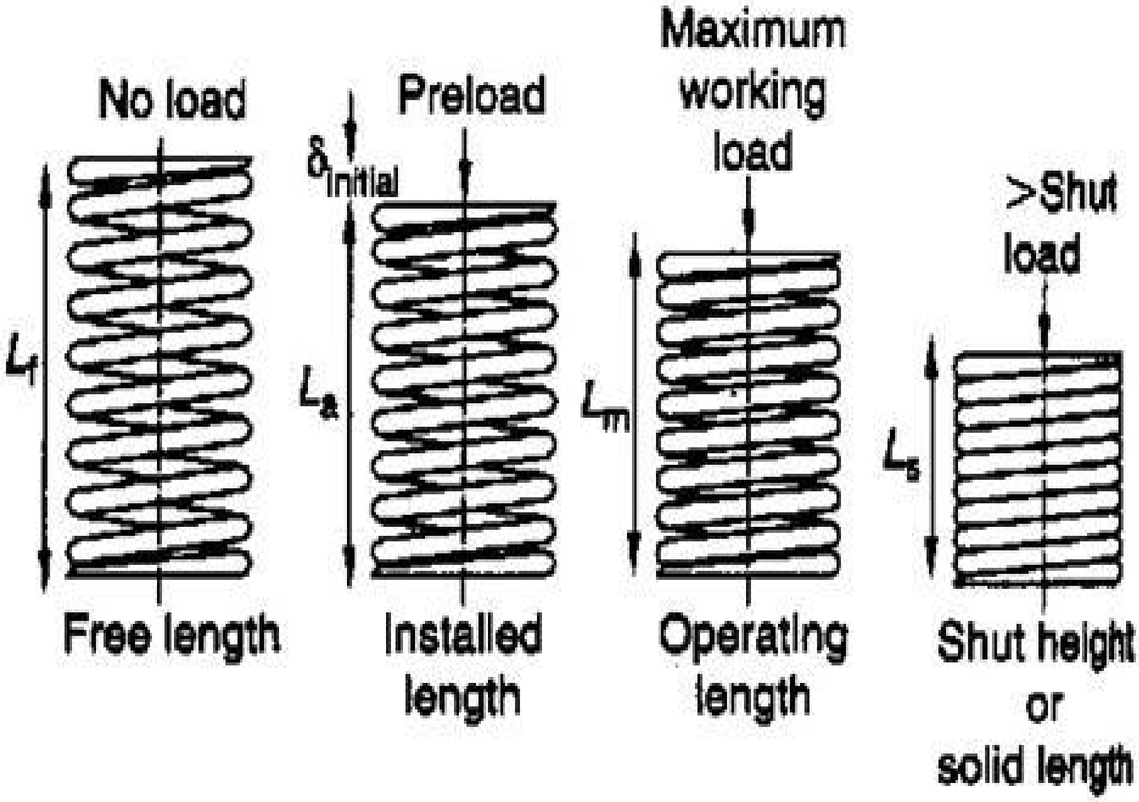
$\sigma_b = 16WD \sin \alpha / \pi d3$

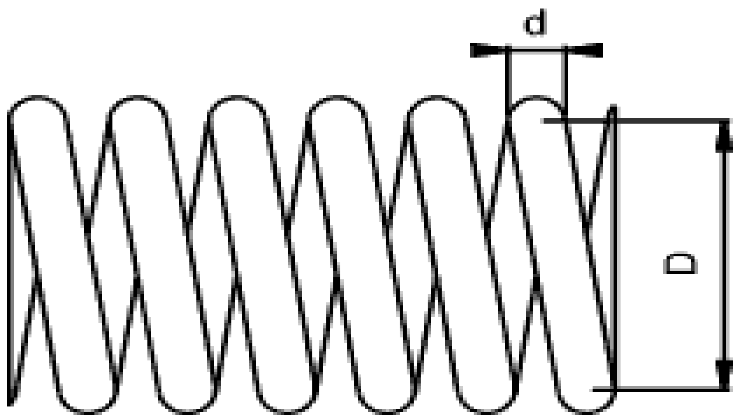
Maximum Principal Stresses*:*

$\sigma_1 = (1/2)\,\sigma_b + (1/2)\,(\sigma\ 2 + 4\ \tau 2)0.5$

von mises stress:

$$\bar{\sigma}_{\text{Mises}} = \sqrt{\frac{(\sigma_1-\sigma_2)^2+(\sigma_1-\sigma_3)^2+(\sigma_2-\sigma_3)^2}{2}} = \sigma_{\text{yld}}$$





Maximum shear stress:

To design the spring and determine the stresses developed in the spring. consider a helical spring subjected to an axial load.

- C = Spring Index D/d
- d = wire diameter (m)
- D = Spring diameter = (Di+Do)/2 (m)
- Di = Spring inside diameter (m)
- Do = Spring outside diameter (m)
- Dil = Spring inside diameter (loaded)
- E = Young's Modulus (N/m2)
- F = Axial Force (N)
- Fi = Initial Axial Force (N)
- (close coiled tension spring)
- G = Modulus of Rigidity (N/m2)
- K d = Traverse Shear Factor = (C + 0,5)/C
- K W = Wahl Factor = (4C-1)/(4C-4) + (0,615/C)
- L = length (m)
- L 0 = Free Length (m)
- L s = Solid Length (m)
- n t = Total number of coils
- n = Number of active coils
- p = pitch (m)
- y = distance from neutral axis to outer fibre of wire (m)
- τ = shear stress (N/m2)
- τ i = initial spring stress (N/m2)
- τ max = Max shear stress (N/m2)
- θ = Deflection (radians)
- δ = linear deflection (mm)

Spring Index:

The spring index (C) for helical springs in a measure of coil curvature ...

$$C=D/d$$

Spring stiffness:

Generally, springs are designed to have a deflection proportional to the applied load (or torque -for torsion springs). The "Spring Rate" is the Load per unit deflection Rate (N/mm)

$$K=F/\delta \ (N/mm)$$

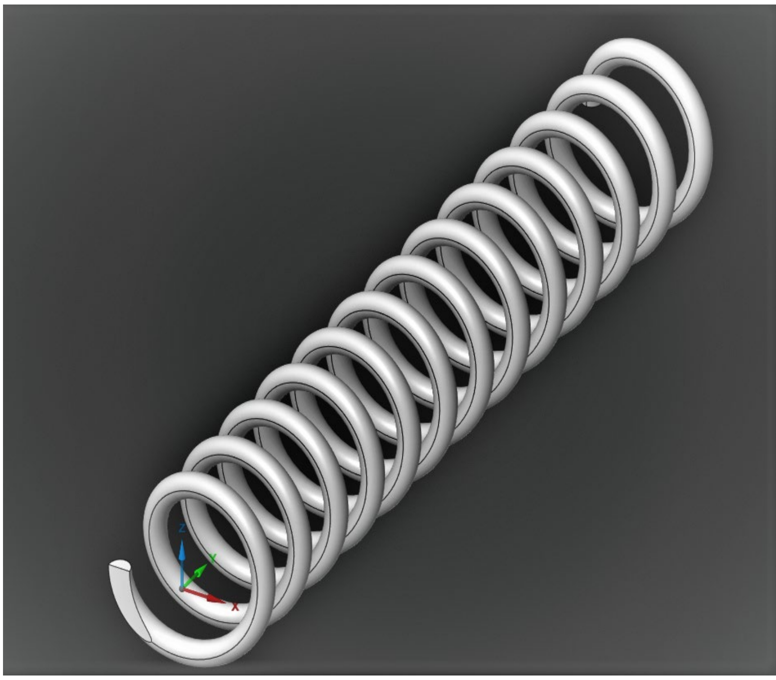
Wahl factor:

$$K_W = \frac{4C - 1}{4C - 4} + \frac{0,615}{C}$$

Maximum shear stress:

$$\tau_{max} = \frac{8FD\,K_W}{\pi\, d^3}$$

Specification of the helical spring:



Coil diameter: 48 mm

Outer diameter: 52mm

Inner diameter: 40 mm

Wire diameter: 8 mm

Free Length : 300 mm

Number of total coils : 15

Spirng type : plain and grounded

Number of active total coils : 15

Total weight acting on spring:kerb weight of bike+2 persons

weight =100+145=245 kg =2404N

Load acting on single suspension =1200N

Work materials:

Music wire:

ASTM A228 music wire is a carbon (non-alloy) steel formulated for primary forming into wrought products. Cited properties are appropriate for the cold worked (strain hardened) condition. ASTM A228 is the defining standard for this material. K08500 is the UNS number.It has the highest tensile strength among wrought carbon or non-alloy steels. In addition, it has a fairly low ductility and a moderately low thermal conductivity.

Iron (Fe)	98 to 99
Carbon (C)	0.7 to 1.0

Manganese (Mn)	0.2 to 0.6
Silicon (Si)	0.1 to 0.3
Sulfur (S)	0 to 0.030
Phosphorus (P)	0 to 0.025

50Cr1v23 :

Chromium-vanadium steel (symbol Cr-Vor CrV; 6000-series SAE steels) is a group of steel alloy Some forms can be used as high speed steel. Chromium and vanadium both make the steel more hardenable. Chromium also helps resist abrasion, oxidation, and corrosion. Chromium and carbon can both improve elasticity

Iron (Fe)	97.5 to 97
Carbon (C)	0.008 to 0.5
Manganese (Mn)	0.7 to 0.9
Silicon (Si)	0 to 0.3
Chromium(cr)	0.8 to 1.1
vanadium(v)	0 to 0.18

Stainless steel S45500 :

S45500 stainless steel is a precipitation-hardening stainless steel formulated for primary forming into wrought products. XM-16 is the ASTM designation for this material. S45500 is the UNS number. And Alloy 455 is the common industry name.It has a moderately high embodied energy among wrought precipitation-hardening stainless steels. In addition, it can have a moderately high tensile strength and has a moderately high base cost.

Iron (Fe)	71.5 to 79.2

Chromium (Cr)	11 to 12.5
Nickel (Ni)	7.5 to 9.5
Copper (Cu)	1.5 to 2.5
Titanium (Ti)	0.8 to 1.4
Manganese (Mn)	0 to 0.5
Silicon (Si)	0 to 0.5
Molybdenum (Mo)	0 to 0.5
Niobium (Nb)	0 to 0.5
Tantalum (Ta)	0 to 0.5
Carbon (C)	0 to 0.050
Phosphorus (P)	0 to 0.040

Parameters	Density (kg/m3)	Young's modulus (Gpa)	Poission's ratio	Shear modulus (Gpa)	Tensile yeild strength (Mpa)
Music wire	7800	190	0.29	76.7	2050
50cr1v23	7850	200	0.30	76.9	1800
Stainless steel S45500	7850	190	0.28	78	1580

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element

Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software Implements equations that govern the behavior of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

Generic Steps to Solving any Problem in ANSYS:

Like solving any problem analytically, you need to define (1) your solution domain, (2) the physical model, (3) boundary conditions and (4) the physical properties. You then solve the problem and present the results. In numerical methods, the main difference is an extra step called mesh generation. This is the step that divides the complex model into small elements that become solvable in an otherwise too complex situation. Below describes the processes in terminology slightly more attune to the software.

LITERATURE REVIEW:

1. Harshad B. Pawar et al [2016] reported the finite element analysis methodology to the obtain the weight reduction of the helical compression spring. Using modeling software solid works completed the modeling and by using Ansys software meshing.

2. Pinjarla.Poornamohan et al [2012] studied beryllium copper springs by reducing diameter, the weight of the spring is reduced, by comparing the stress values of both the materials the spring material value is less.

3. Ganesh Bhimrao Jadhav et al [2015] studied the combination of conventional steel and composite material analyzing the feasible region for the material. Conventional steel is simply replaced by the Glass Fiber Epoxy resin and aching the weight of composite material. Also, the composite material has corrosion resistance, it can also supportable for high temperature.

4. Bhavesh R. Valiya et al [2015] studied the Non alloy steel helical spring suspend vehicle system. The uniform loading effect has been studied and Experimental, FEA analysis will be compared with analytical solution. The proposed redesign will reduce the deformation and induced stress magnitude for the same applied loading conditions when compared with the existing design. It is also changing the wire diameter of coil and number of turns to life of spring.

5. Sangmesh Pattar et al [2014] Considered helical compression spring as a part of automobile horn. The spring is analyzed the deformation value as well as the maximum shear stress value by using the analytical and finite element method. Helical compression spring is modeled and static analysis carried out by using ANSYS result.

6. T.S. Manjunath et al [2012] studied three different types of springs, made of glass fiber, carbon fiber and combination of glass fiber and carbon fiber. The objective of the study was to reduce the weight of the spring. According to the experimental results the spring rate of the carbon fiber spring is 34% more than the glass fiber spring and 45% more than the glass fiber/carbon fiber spring. The weight of the carbon fiber spring is18% less than the glass fiber spring, 15% less than the Glass fiber/carbon fiber spring and 80% less than the steel spring.

7. Yogesh P Shingane et al [2017] reported that composite helical springs can be easily replaced in light weight vehicles with slight endure of the size. In regular vehicles, combination of springs with composite and conventional material can be used to overcome low stiffness of composite materials and weight of spring can be optimized

8. Tausif M. Mulla et al [2013] studied the applied loads, obtained when compared with the values calculated by using simple analytical model which is found in textbooks. The stress distribution clearly shows that the shear stress is having maximum value at the inner side of every coil. The distribution of the stress is similar in every coil. So the probability of failure of spring in every coil is same except end turns.

9. Aakash Bhatt et al [2016] reported that the yield strength in compression of E- Glass is 756Mpa while yield strength in tension is 2415Mpa.Hence after carrying out the analysis of the designed spring using ANSYS, it is found that the values of deflection and stress are within the permissible limits. The design is safe and applicable for suspension system under 1000N axial force

10. A. Chinnamahammad bhasha et al [2017] studied the helical spring of a shock absorber by using 3D parametric software CATIA. To validate the strength of the model, the structural analysis on the helical spring was done by varying different spring materials like steel, titanium alloy, copper alloy and Phosphor bronze Modal analysis is done to determine the displacements for different frequencies for Number of modes

11. Assaad Alsahlani et al [2018] reported that Three different materials were chosen to manufacture the spring under various values of load. The results showed that the less value of total deformation happened in spring made of carbon composite for all the values of load. The deformation reduced by 15% in carbon composite comparing with the deformation in steel and reduced by about 54% comparing with total deformation in copper alloy. The deformation, strain stress and shear stress increased by increasing the load.

12. Mehdi Bakhshesh et al [2012] studied and reported that Compared to steel spring, the composite helical spring has been found to have lesser stress and has the most value when fiber position has been considered to be in direction of loading. Longitudinal displacement in composite helical spring is more than that of steel helical spring and has the least value when fiber position has been considered to be in direction of Loading

13. K.Sathishkumar et al [2019] reported that They have done analysis by varying material such as C40 Steel, C70 Steel, and Al-SiC composite material. By comparing the results for all three materials, the stress value is less for Al-Sic composite than C40 & C70 Steel.

14. Harshal Rajurakar et al [2016] studied the helical coil spring of hard carbon steel & chrome vanadium spring steel for circular & rectangular cross sections are studied using FEA analysis. The FEA results proves that even though the stresses are almost equal, but the deflection of suspension spring is more when comparative to the hard carbon steel

15. Mallick Kamran et al [2018] examined design-1 the wire diameter is 7mm and in design-2 wire diameter is 6mm the deflection in modified design-2 of the helical spring is slightly higher than that of baseline design. The mass of the design-2 is 25% lighter than baseline design-1. Design -2 with wire diameter -6 mm is efficient for the applied loading conditions and stands out to be efficient design for spring especially at higher loads.

16. Prince Jerome Christopher J et al [2014] explained that The shock absorber design is modified by reducing the diameter and stress analysis is performed. The stress value is lesser in the designed spring than in original which adds an advantage to our design. By comparing the results in the table, we could analysis that our modified spring has reduced in weight and it is safe.

17. Vijayeshwar BV et al [2017] reported that it is proved theoretically and through ANSYS that the spring in which maximum shear stress is induced i.e. 345.213 M pa ANSYS result and 342.5 M pa theoretically for provided load is hard drawn carbon spring than in chrome silicon spring where maximum shear stress induced in 340.603 M pa ANSYS result and 342.5 M pa theoretically and deflection induced in chrome silicon spring is very much less than deflection induced in hard drawn carbon spring

18. Anil Agarwal et al [2017] studied the design optimization of helical spring profile results shows that, square fillet profile in static and transient analysis is better as compared to other profiles. From the static analysis results it is found that circular profile has 31.28% greater maximum displacement from square profile and 27.82% from square fillet and 13.63% greater maximum equivalent stress from square fillet and 12% from square profile.

19. Arko Banerjee [2020] studied the design optimization of helical springs with a circular and a triangular profile was studied. From the analysis the circular profile has a lesser total deformation and a lesser equivalent maximum strain compared to triangular profile

20. Chandrakant Khare et al [2019] explained that the FEA analysis is conducted to determine shear stress and deformation using Aluminium material in helical coil suspension design. Along with FEA analysis design optimization is also performed to determine the sensitivities of parameters in stress generation, deformation and mass of helical coil suspension. The sensitivity graph has shown that coil diameter has higher contribution in weight as compared to coil mean radius.

Design and analysis of spring:

The **SOLIDWORKS-CAD** software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

A SOLIDWORKS model consists of 3D geometry that defines its edges, faces, and surfaces.The SOLIDWORKS software lets you design models quickly and precisely.

SOLIDWORKS uses a 3D design approach. As you design a part, from the initial sketch to the final result, you create a 3D model. From this model, you can create 2D drawings or mate components consisting of parts or subassemblies to create 3D assemblies. You can also create 2D drawings of 3D assemblies.When designing a model using SOLIDWORKS, you can visualize it in three dimensions,the way the model exists once it is manufactured.

Design procedure of the spring:

The spring is deigned in solidworks 2021.

Step 1: Select the top plane select the sketch and make one circle of mean diameter

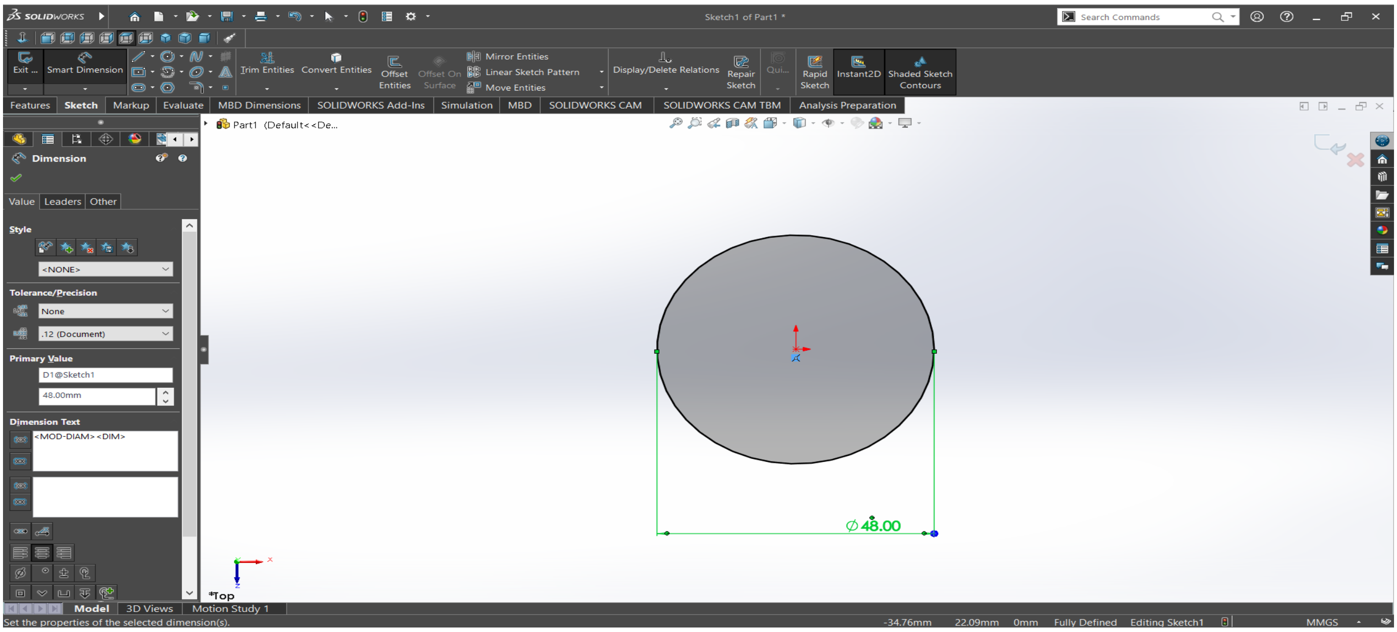


Fig.1: Mean diameter

Step 2: Go to features---> Curve ---> Helix.Adjust the parameters like Pitch, No of revolution

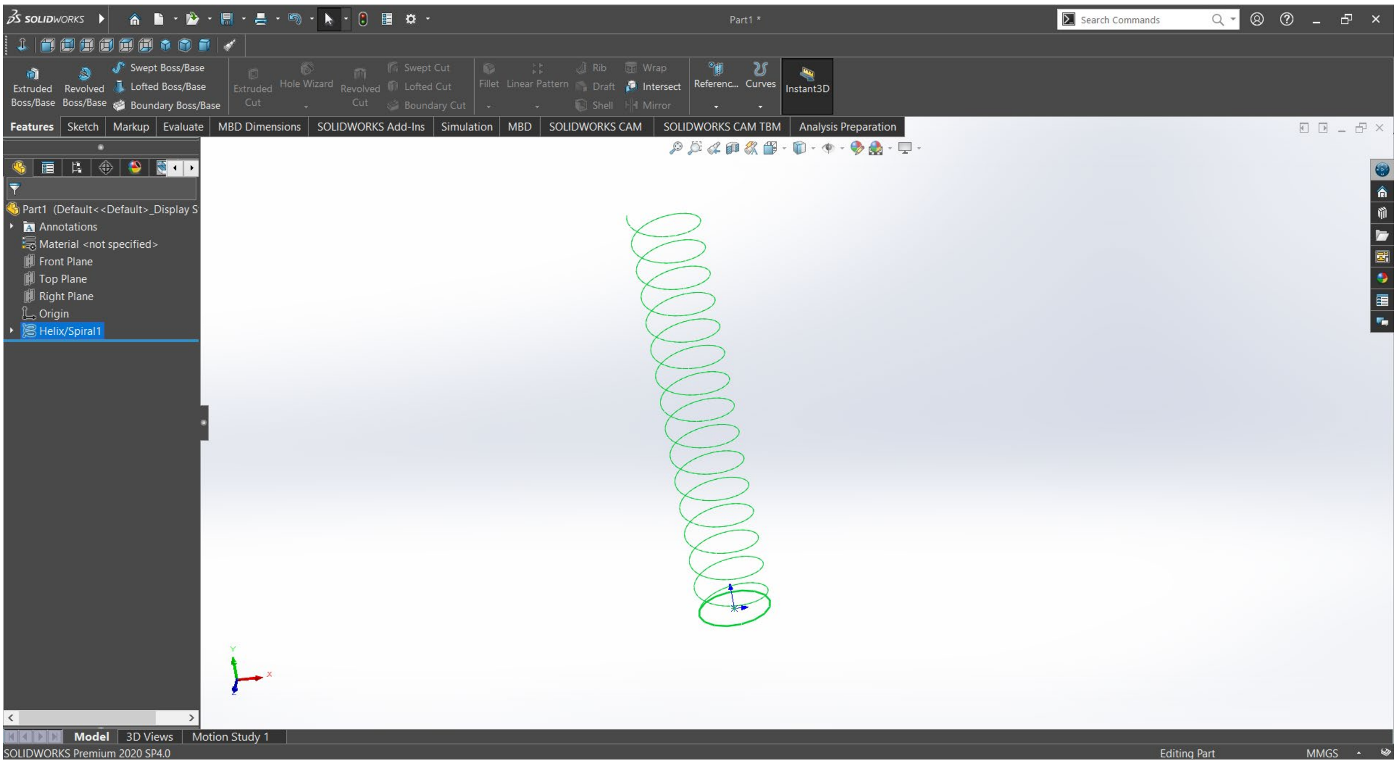


Fig 2: helix curve

Step 3: Go to feature tab select Swept Select the helix as Path and Circle profile

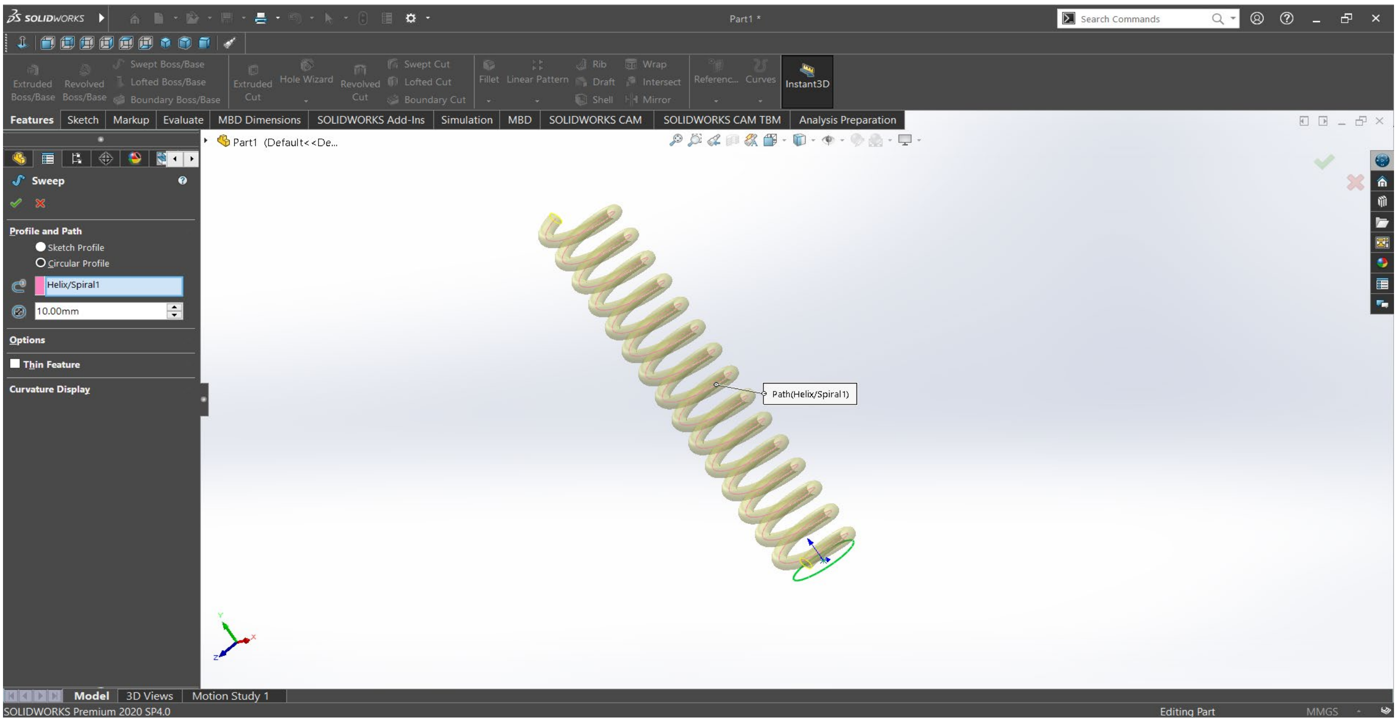


Fig 3 : sweep path

Step 4: For equal distribution of load and for fixed link merge two circular plate on top and bottom

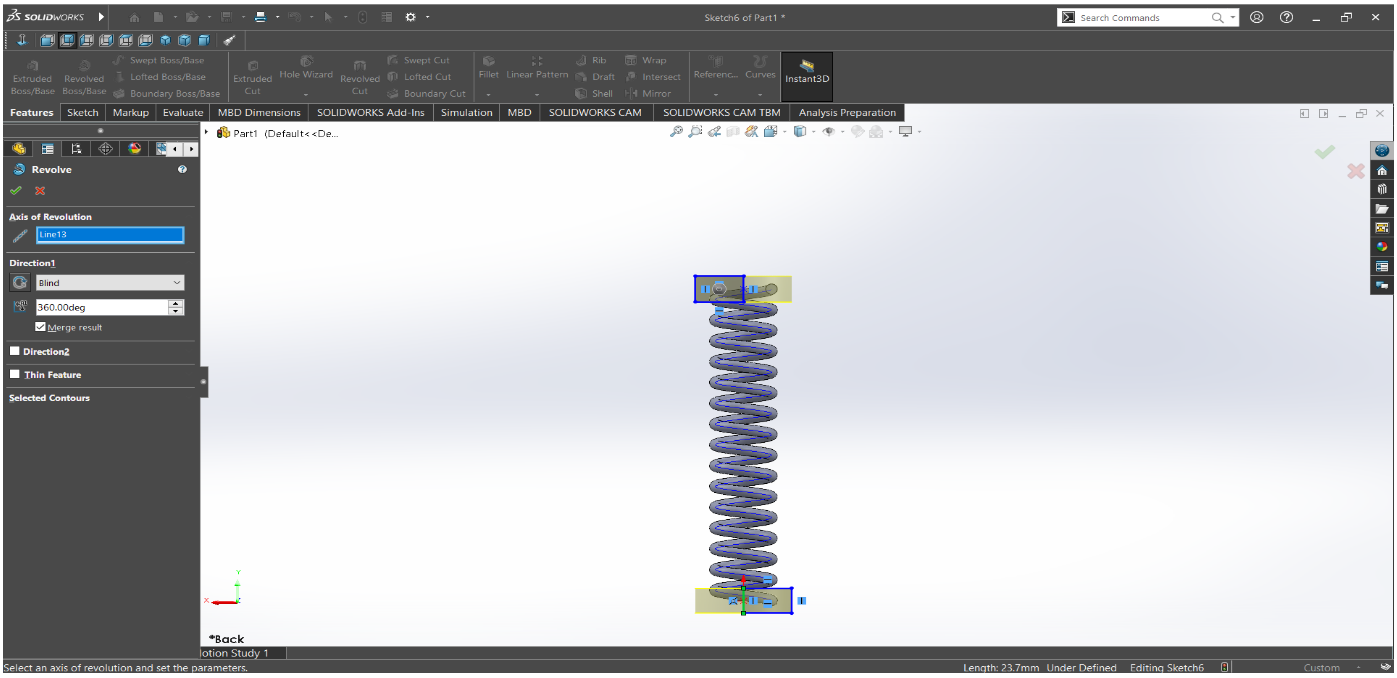


Fig 4 : revolve sweep for supporting plates

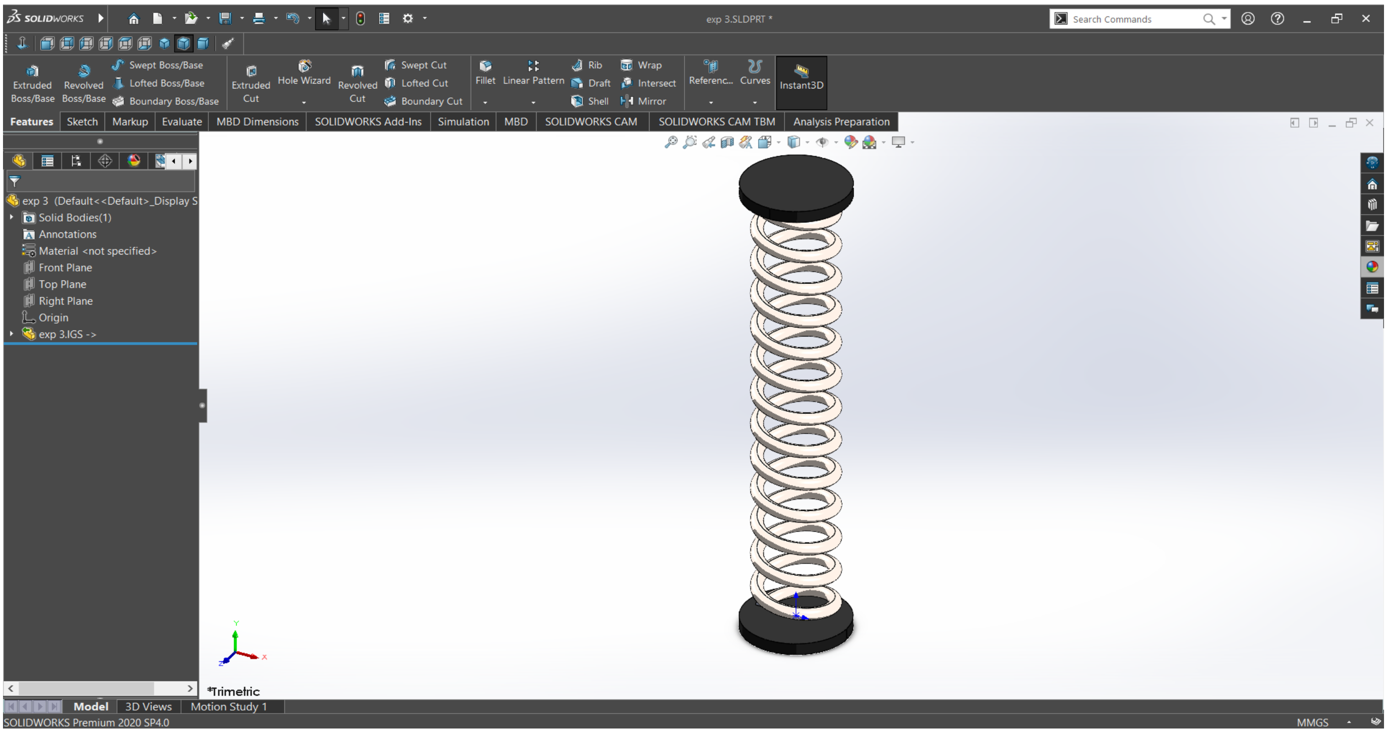


Fig 5: complete spring in solidworks 2021

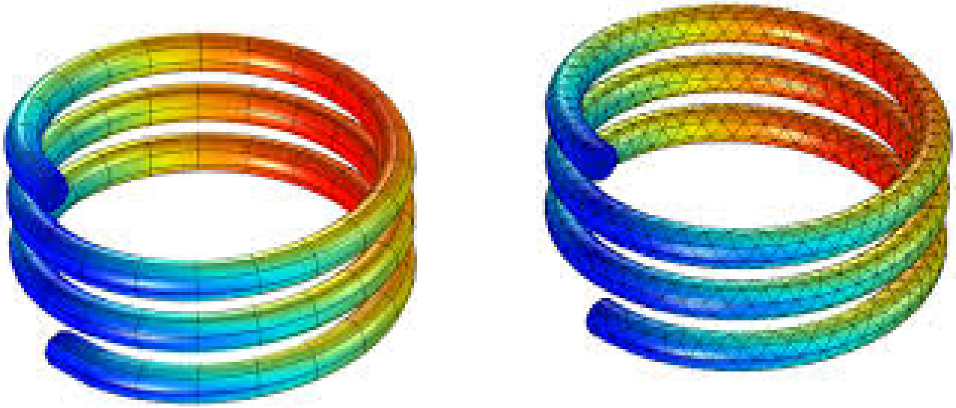
ANSYS Discovery:

Ansys Discovery is the first simulation-driven design tool to combine instant physics simulation, proven Ansys high-fidelity simulation and interactive geometry modeling in a single user experience. More and more engineers are using Solid Modelers with the Finite Element Method to solve daily problems of stress states, deformations, heat transfer, fluid flow, electromagnetism, among others. ANSYS Workbench, one of the most comprehensive and extended solids modeling, simulation and optimization programs

By combining interactive modeling and multiple simulation capabilities in a first-of-its-kind product, Discovery allows you to answer critical design questions earlier in the design process.

FEM MODEL:

The finite element method is a numerical method for solving problems of engineering and mathematical physics. Deconstructing a complex system into very small pieces called elements. The software implements equations that govern the behavior of these elements and solves them all. These results can be presented in tabulated or graphical forms.



Analysis of spring:

After the design is done in solidworks 2021,the design is saved in the format of IGSE(igs) format the design is analzied in ANSYS DISCOVERY 2021,the boundary conditions the load is given on top of the plate and the bottom plate is fixed and the material is specified . Click on start evalutionAfter the evalution the results are displayed The equivalent stress,the displacement,the principal stresses are displayed The modal analysis is also done to find the natural frequency

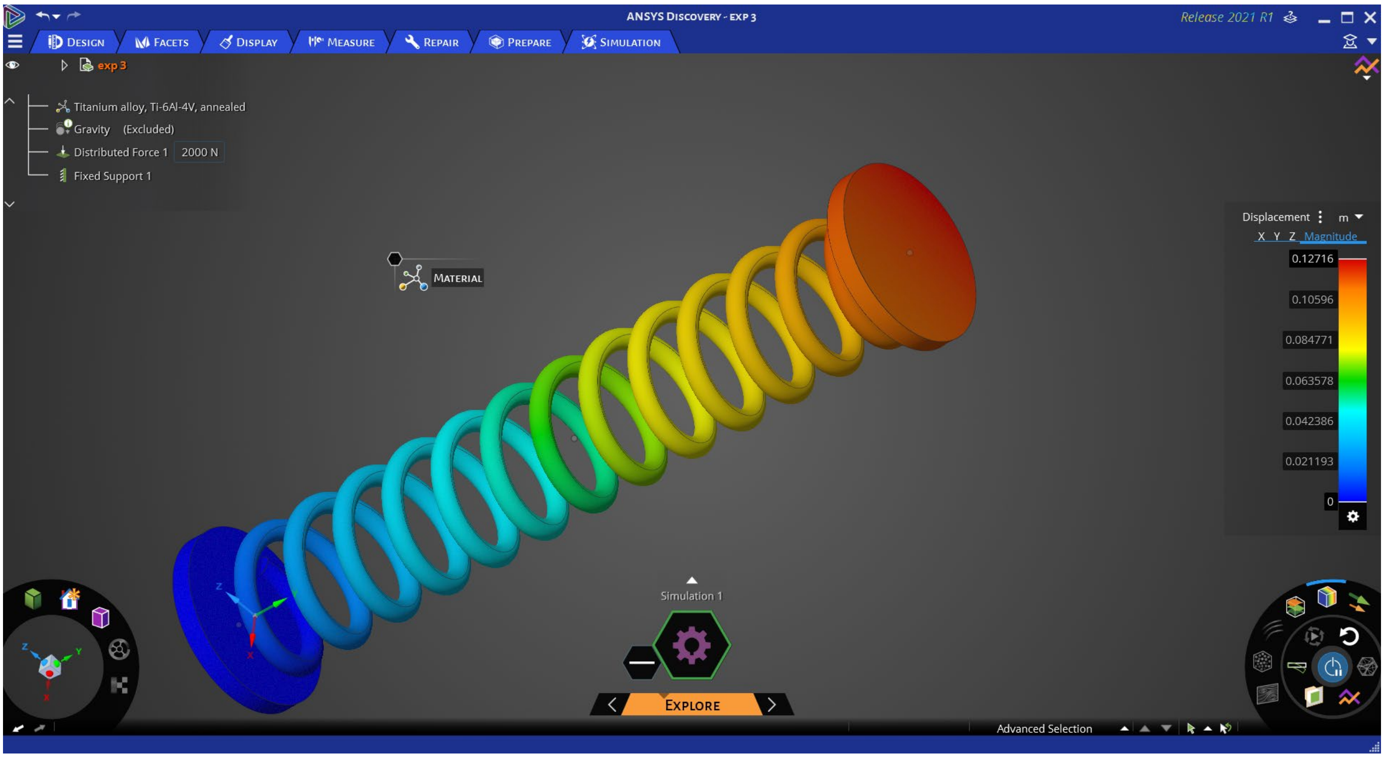


Fig :Analysis of spring in ANSYS DISCOVERY 2021

Insert Geometry

Insert the created spring to the ansys discovery, by open ansys insert geometry and selecting the saved **iges** format

Define Material Properties

Now that the part exists, define a library of the necessary materials that compose the object (or project) being modeled. This includes thermal and mechanical properties.

Generate Mesh

At this point ANSYS understands the makeup of the part. Now define how the Modeled system should be broken down into finite pieces.

Apply Loads

Once the system is fully designed, the last task is to burden the system with constraints, such as physical loadings or boundary conditions.

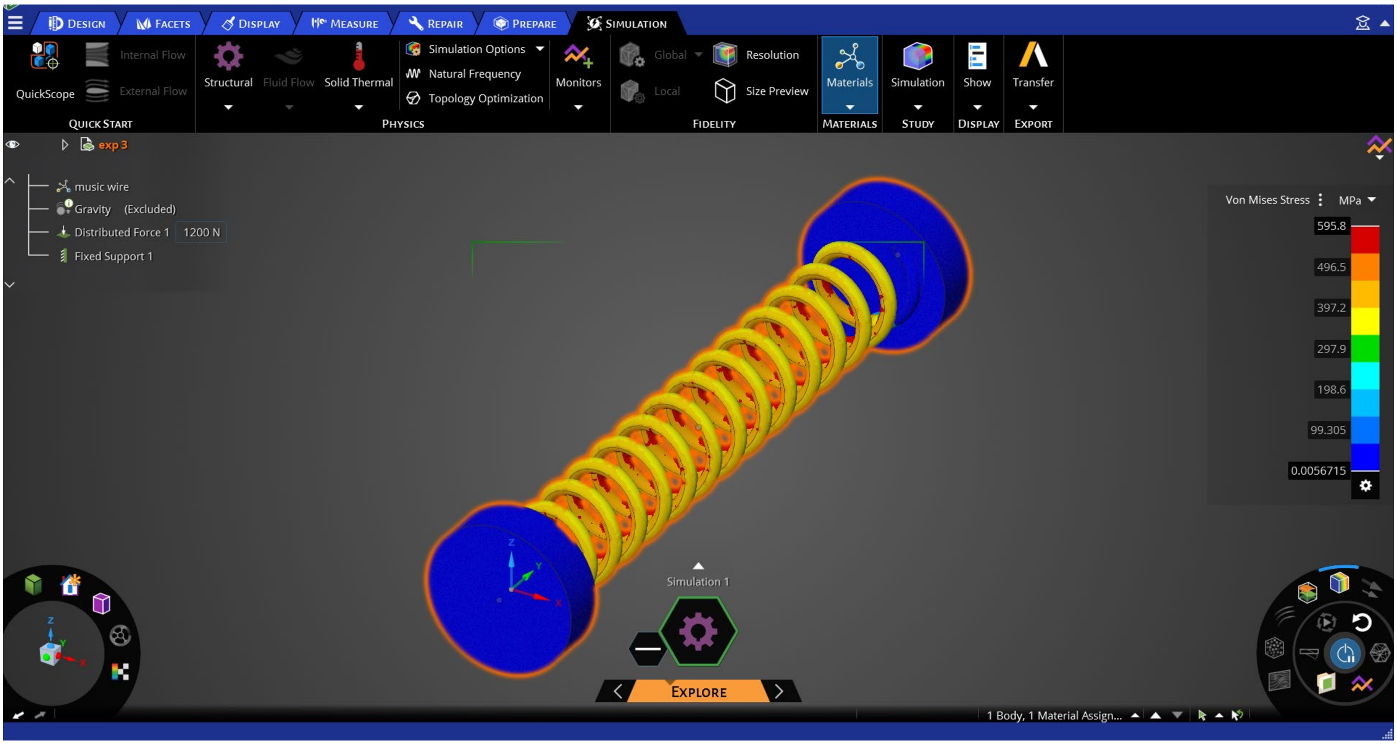
Obtain Solution

This is actually a step, because ANSYS needs to understand within what state (steady state, transient… etc.) the problem must be solved.

Present the Results

After the solution has been obtained, there are many ways to present ANSYS' results, choose from many options such as tables, graphs, and contour plots.

RESULTS: Given below are the Equivalent stress and Displacement for different



materials

Fig : Von Mises stress of Music wire

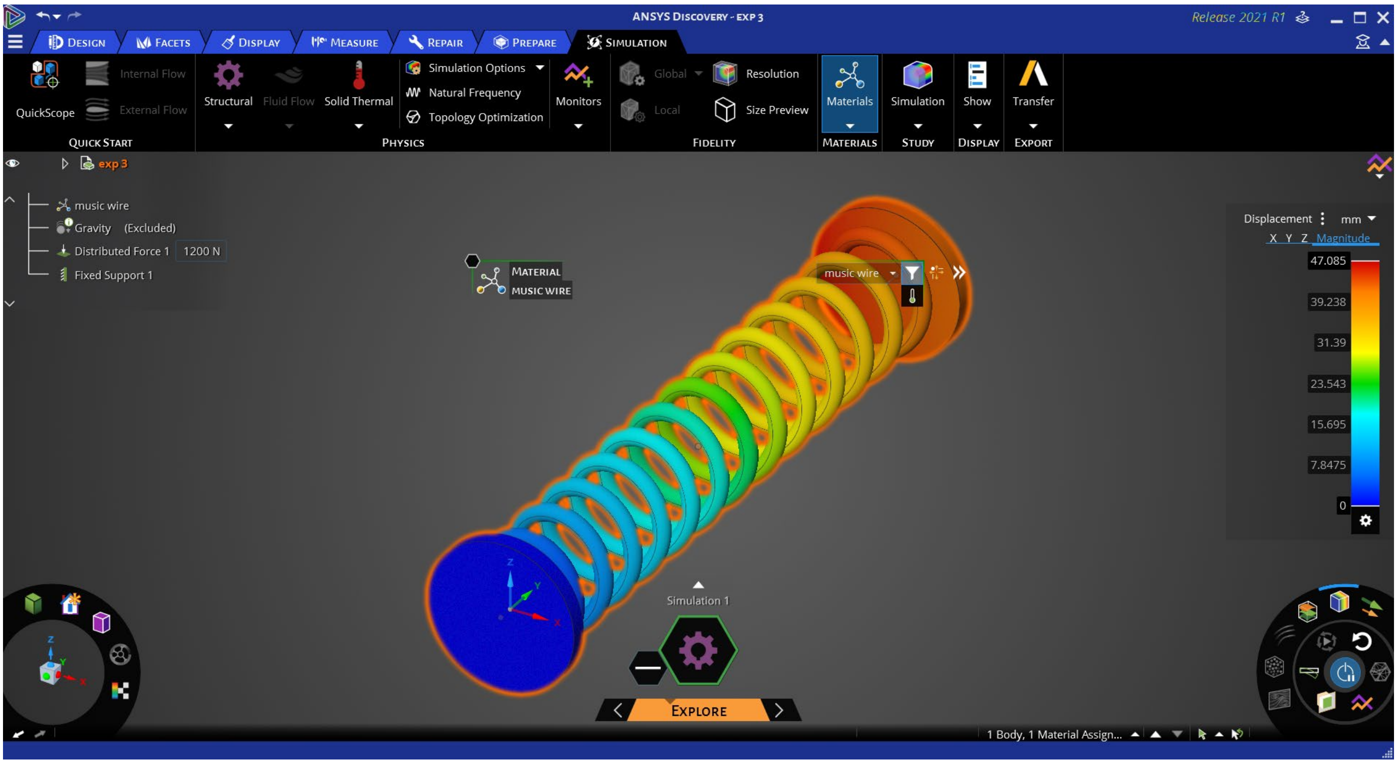


Fig : Axial displacement of music wire

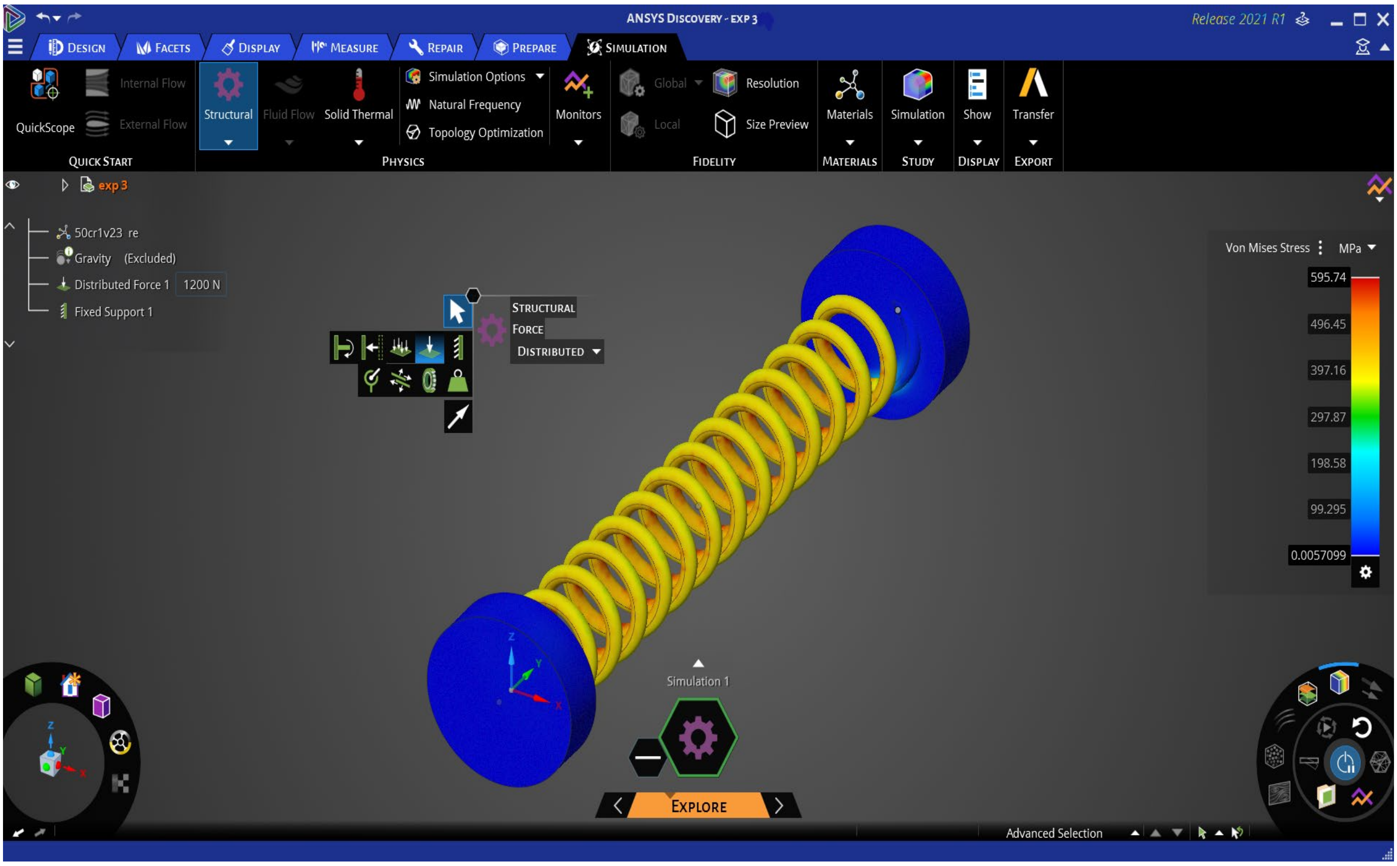


Fig : Von Mises stress of 50cr1v23

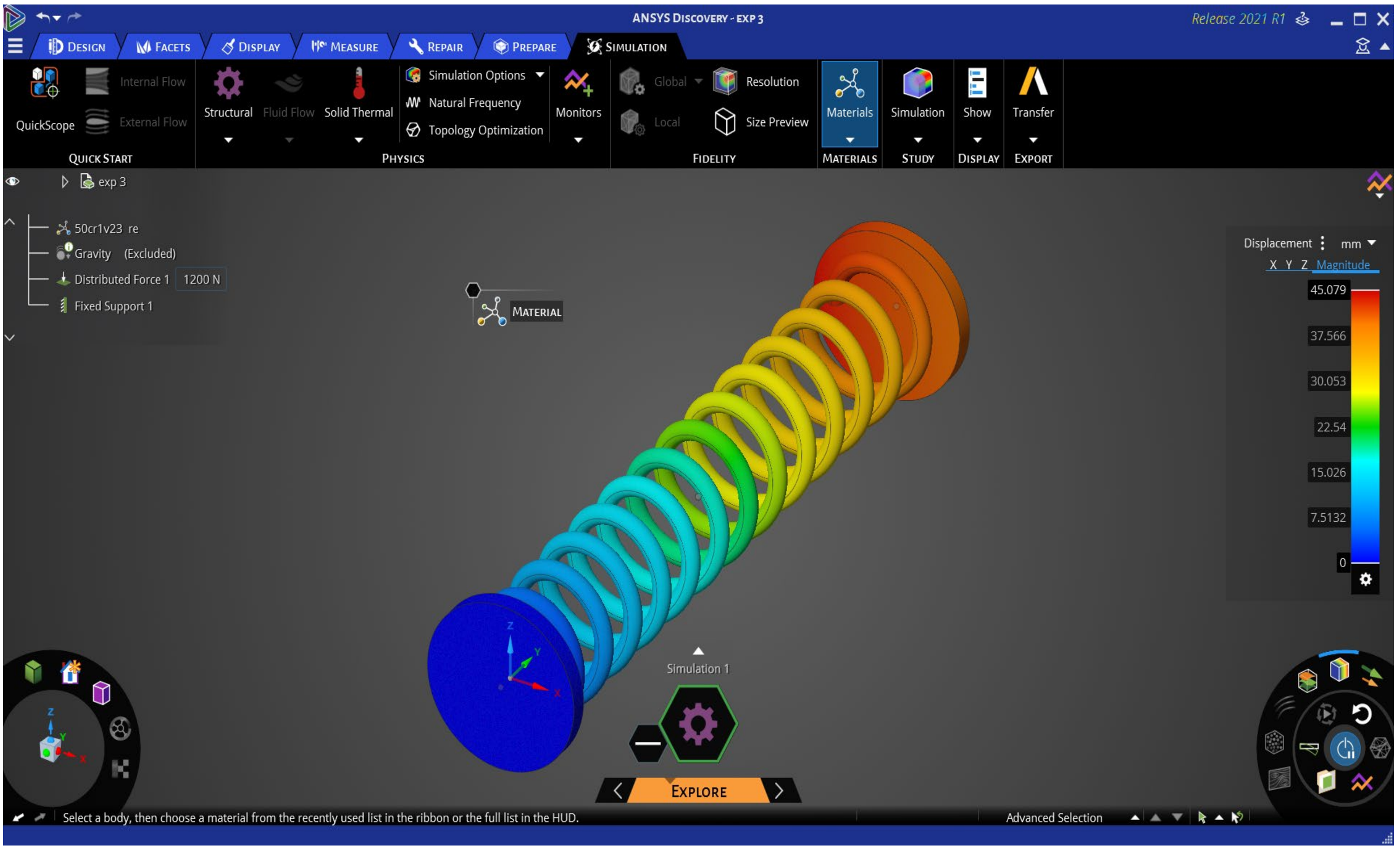


Fig : Axial displacement of 50cr1v23

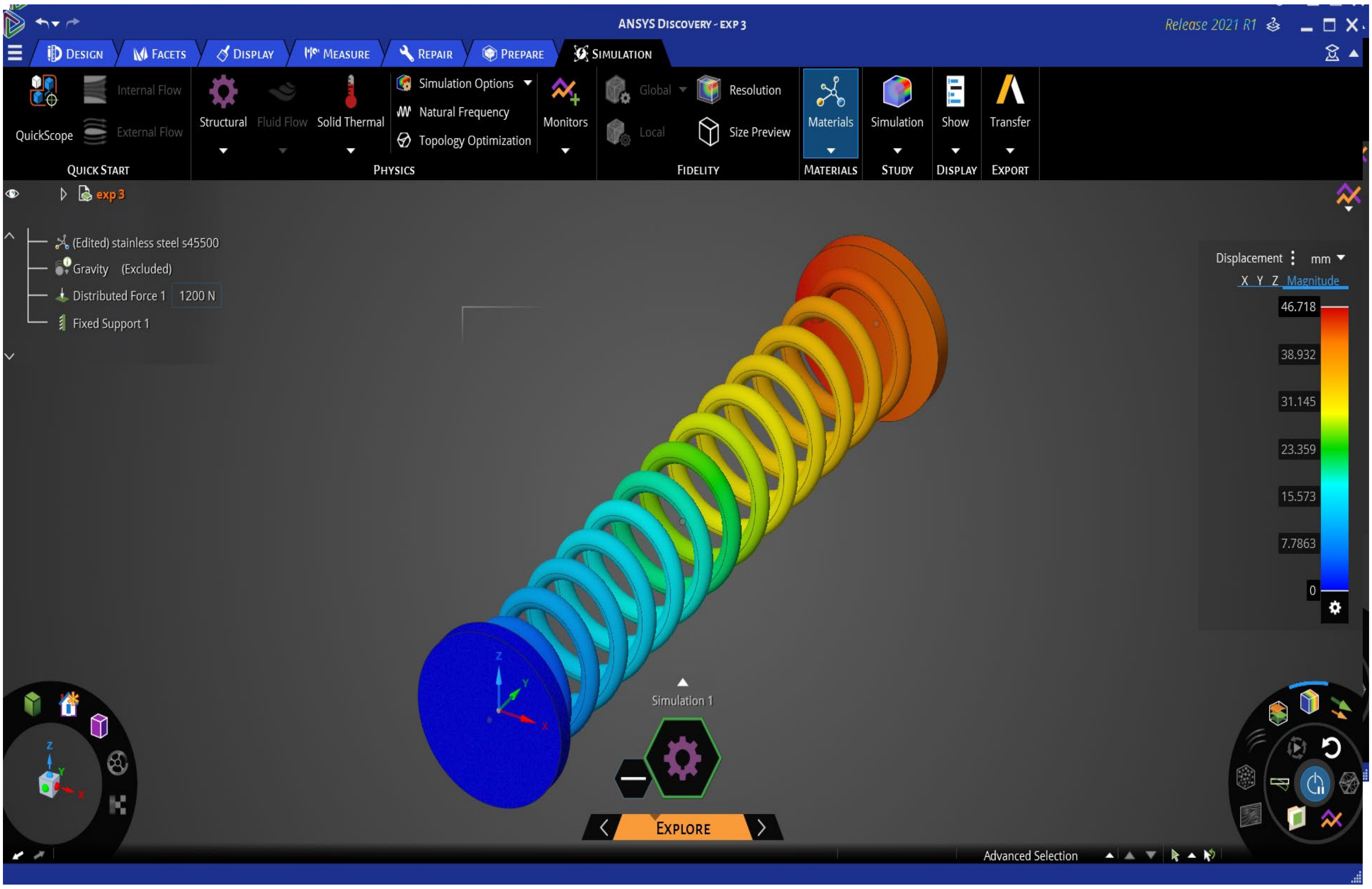


Fig: Axial displacement of Stainless steel S45500

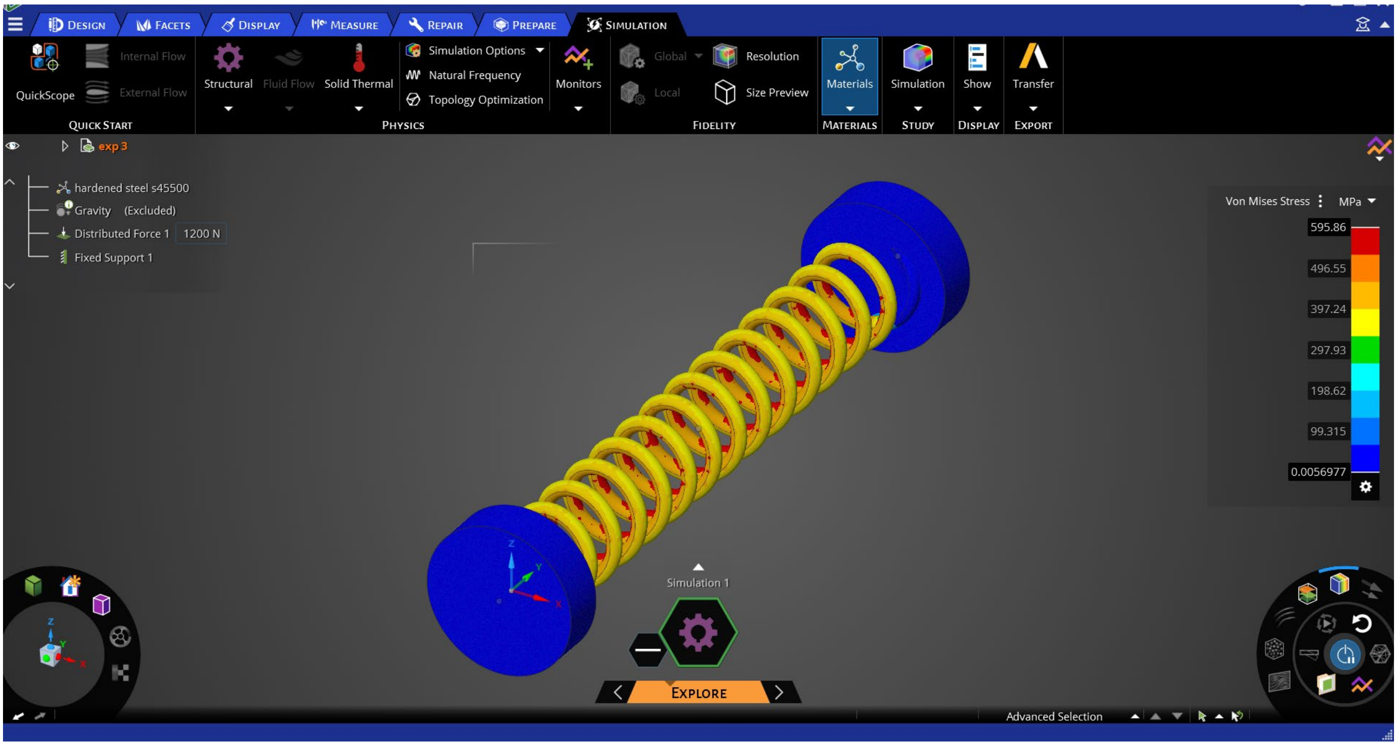


Fig : Von Mises stress of Stainless steel S45500

Calculations:

Deflection in music wire:

$\delta = (8W\,D^3\,n/d^4 \cos\alpha) * [\cos^2\alpha/G) + (\sin^2\alpha/E)]$

$\delta = (8*1200*48^3*14/8^4 \cos 7.55)*[(\cos^2 7.55/7.67e^4) + (\sin^2 7.55/1.9e^5)]$

$\delta = (1.486e10/4060.5) * [(1.28e^{-5}) + (9.08e^{-8})]$

$\delta = (3659647.827) * (1.29e^{-5})$

$\delta = 47.175$ mm

Deflection in 50cr1v23:

$\delta = (8W\,D^3\,n/d^4 \cos\alpha) * [\cos^2\alpha/G) + (\sin^2\alpha/E)]$

$\delta = (8*1200*48^3*14/8^4 \cos 7.55)*[(\cos^2 7.55/7.69e^4) + (\sin^2 7.55/2e^5)]$

$\delta = (1.486e10/4060.5) * [(1.278e^{-5}) + (8.63e^{-8})]$

$\delta = (3659647.827) * (1.2866e^{-5})$

$\delta = 47.086$ mm

Deflection in steel s45500:

$\delta = (8W\,D^3\,n/d^4 \cos\alpha) * [\cos^2\alpha/G) + (\sin^2\alpha/E)]$

$\delta = (8*1200*48^3*14/8^4 \cos 7.55)*[(\cos^2 7.55/7.8e^4) + (\sin^2 7.55/1.9e^5)]$

$\delta = (1.486e10/4060.5) * [(1.2599e^{-5}) + (9.086e^{-8})]$

$\delta = (3659647.827) * (1.2689e^{-5})$

$\delta = 46.44$ mm

von mises stress for the spring model :

Torsion shear stress:

$\tau = 8WD\cos\alpha / \pi d^3$

$\tau = (8*1200*48*\cos 7.55)/\pi*8^3$

$\tau = 456805.13/1608.49$

$\tau = 283.54$ Mpa

Bending stress:

$\sigma_b = 16WD \sin \alpha / \pi d3$

$\sigma_b = (16*1200*48*\sin 7.55)/\pi*8^3$

$\sigma_b = 121090.26/1608.49$

$\sigma_b = 75.28$ Mpa

Maximum principal stress:

$\sigma_1 = (1/2)\ \sigma_b + (1/2)\ (\sigma\ 2 + 4\ \tau 2)0.5$

$\sigma_1 = (1/2)\ 75.28 + (1/2)\ (75.28^2 + 4 * 283.54^2)0.5$

$\sigma_1 = 37.64+286.02$

$\sigma_1 = 323.67$ Mpa

Minimum principal stress:

$\sigma_2 = (1/2)\ \sigma_b - (1/2)\ (\sigma\ 2 + 4\ \tau 2)0.5$

$\sigma_2 = (1/2)\ 75.28 - (1/2)\ (75.28^2 + 4 * 283.54^2)0.5$

$\sigma_2 = 37.64-286.02$

$\sigma_2 = -248.38$ Mpa

von mises stress:

$\sigma_v = [((\sigma_1-\sigma_2)2+\sigma1*\sigma1+\sigma2*\sigma2)/2]^{0.5}$

$\sigma_v = [(327241.2+104329.7+61692.624)/2]^{0.5}$

σ_v= 496.62 Mpa

comparing theoretical and actual displacement:

S.No	Material	Theoretical displacement(mm)	Analytical displacement(mm)	Stiffness of spring K(N/mm)
1	Music wire	50.11	47.085	25.485
2	50cr1v23	47.086	45.079	25.98
3	Stainless steel S45500	48.38	46.718	25.686

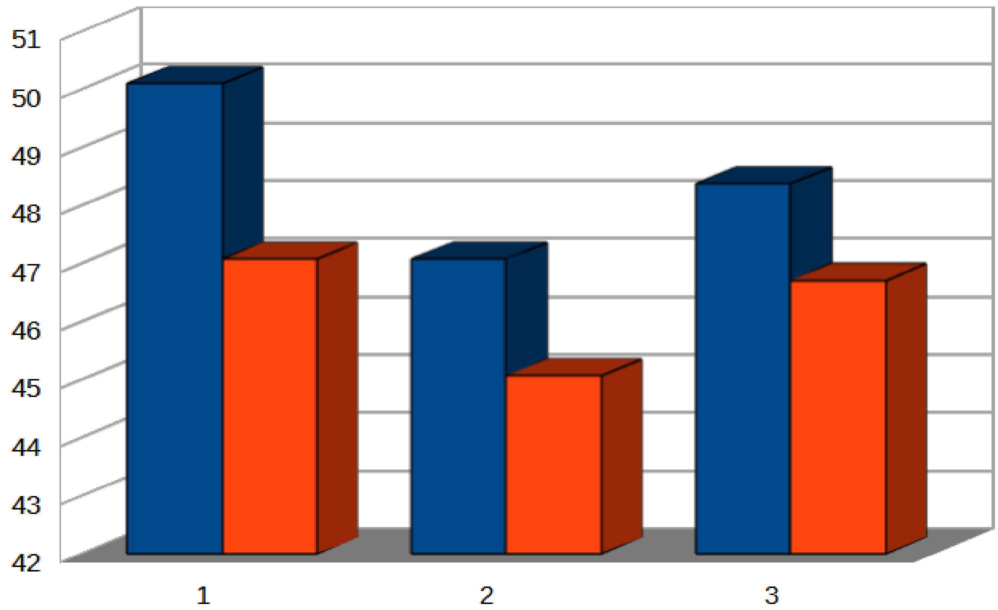


Fig:Theoretical displacement vs Analytical displacement

S.No	Material	Yeild stress(Mpa)	Theoretical equivalent stress(Mpa)	Theoretical F.O.S	Analytical equivalent stress(Mpa)	Analytical F.O.S
1	Music wire	2050	497.6	4.12	595.7	3.44
2	50cr1v23	1800	497.6	3.61	595.7	3.02
3	Stainless steel S45500	1580	497.6	3.17	595.8	2.65

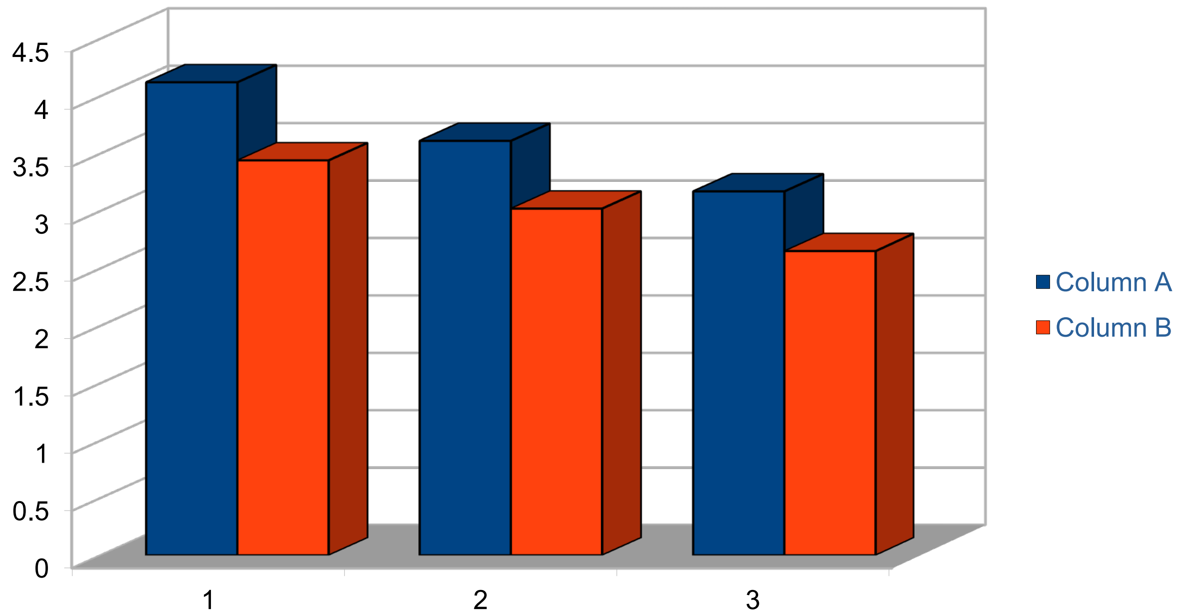


Fig:Theoretical F.O.S vs Analytical F.O.S

CONCLUSIONS:

The following are the conclusions made from the above analysis based on static structural analysis.

- Design optimization of helical spring profile results shows that, the FOS of the music wire is 3.44 and the FOS for the 50cr1v23 and stainless steel s45500 is 3.02 and 2.65 for the load of 1200 N.
- From the static analysis results it is found that spring stiffness for the music wire,50cr1v23 and the stainless steel is 25.48 , 25.98 and 25.686

- Comparing all three helical spring materials as the stiffness of the materials are almost similar but the FOS of the music wire is high , so the best helical spring from the above material is music wire

Future scope

- In the future, there is growing opportunities use of composite materials for helical spring.

- Transient analysis,Modal analysis of helical spring can be performed and tested in spring cases.