# Design of Helical Spring Used in Two-Wheeler Rear Suspension

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***Abstract-*** *The helical spring used in a suspension system is a mechanical device designed to smooth out damp shock impulse, vibrations and dissipate kinetic energy. In a vehicle, the rough ground reduces the motion, leading to improved ride quality, and an increase in comfort due to substantially reduced amplitude of disturbances. A helical compression coil spring which used in transport is belonging to the medium price segment of the Indian automotive market. The use of different alloy steel materials is increasing in the design of automobile components due to their lightweight. 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 different alloy steel materials and then compared with each other, as spring materials to study their behaviors at the maximum loading conditions. The design of helical spring is to design 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 analyses are done on shock absorbers by varying materials for spring. The theoretical calculation is done to find out the load and deflection of the spring.*

***Keywords:*** helical compression spring, SOLIDWORKS, *ANSYS, alloy steel*

## I.INTRODUCTION

The shock absorbers have 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 from 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 is 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 an 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 unsprung 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, do 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, the "shock absorber" is reserved specifically for the hydraulic piston that absorbs and dissipates vibration.

## II. PROBLEM STATEMENT

The suspension system plays a very important role in the two-wheeler. It must damp, smooth out the shock and eliminate vibrations, impulse furthermore to absorb or dissipate energy so that the suspension system provides comfort for the passengers and vehicles. In this paper Optimization of the spring will be done by changing spring materials. As per the design, the experimental test was conducted. The static analysis using the finite element method has been done to find out the detailed load vs defection of the spring and the best helical spring with all suitable conditions are made

## III. LITERATURE SURVEY

**H.B. Pawar et al [2016]** reported that by reducing the total number of turns the weight can be reduced and stiffness can be increased. For that study, the material IS4454 is taken into consideration the actual coil number of turns is 14.the modified design has a total no. of turns are 12.5 the feed wire length required for modified spring is reduced by 10%. Due to the reduction in feed wire length the mass reduced by 10%. Due change in stiffness the load-carrying capacity of the modified spring was increased by 7%

**Tausif M. Mulla et al [2013]** The elastic behavior and the stress analysis of springs employed in the TWV's front automotive suspension have been presented and discussed in this paper. The results were obtained by a fully 3D FEA analysis. Relative errors on maximum shear stress ranging from 1.5 to 4 percent, concerning the applied loads, obtained when compared with the values calculated by using a 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 the same except for end turns. In such a case residual stress in every coil may be an important factor that influences the failure

**Ganesh Bhimrao Jadhav et al [2015]** studied and reported 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 is to be used in place of conventional spring steel. The cause of implementing a combination of steel and composite material is the low stiffness of a single composite spring, which limits its application to light vehicles. The fuel efficiency of automobiles can be maximized by lowering the weight of the vehicle. In regular vehicles combination of conventional steel and composite material can be used to overcome low stiffness

**Bhavesh R. Valiya et al [2015]** reported that for the present study 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. Experimental analysis is done to validate the strength and modal analysis is done to validate the displacements in different loading conditions. Modeling and analysis are done by using Pro/ENGINEER and ANSYS. 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 the coil and the number of turns to the life of the spring.

**Sangmesh Pattar et al [2014]** In the present work helical compression spring is material is stainless steel modeled and static analysis carried out by using ANSYS V14.5. it is observed that maximum stress is developed at the inner side of the coil. From the ANSYS and theoretical. At lower loads both theoretical and ANSYS results are within the range, but when load increases the ANSYS results are uniformly reduced compared to theoretical results.

## IV. DESIGN AND ANALYSIS OF HELICAL SPRING:

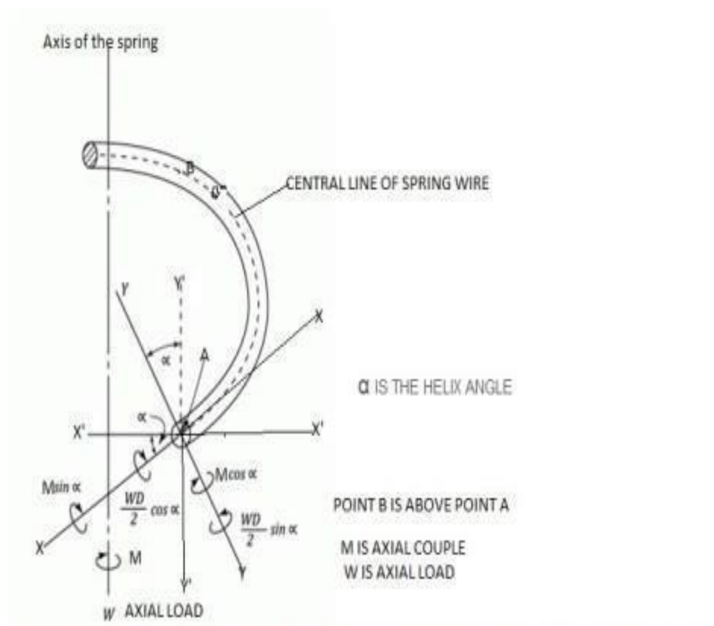



Fig.SECTION AB OF OPEN COILED HELICAL SPRING, DETAILS UNDER AXIAL LOAD 'W' AND AXIAL COUPLE 'M'

**Von mises stress:**

Let α be the angle of the helix
Then the length of n turns of spring L =πD n/cos α
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 a 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:**

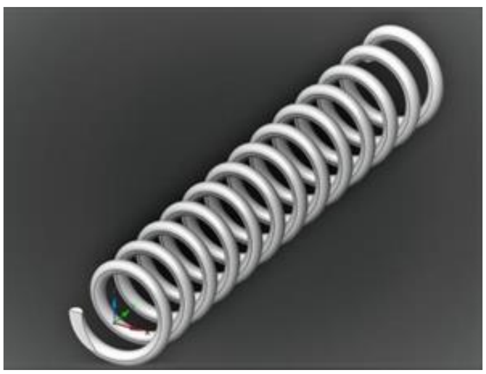
The component (WD Sin α)/2 will cause the bending stress in the spring wire.
$\sigma_b = 16WD \sin\alpha / \pi d3$

**Maximum Principal Stresses:**

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

**von mises stress:**
$\sigma_v = [((\sigma_1-\sigma_2)^2+\sigma_1^2+\sigma_2^2)/2]^{0.5}$

**DESIGN OF SPRING:**



**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
- Spring type: plain and grounded
- Number of active total coils: 15
- Total weight acting on spring: curb weight of bike+2 persons
- For testing assumed that damper is not present 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 steel. In addition, it has 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 0.03 |
| 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 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 steel. 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 |

PROPERTIES OF WORK MATERIALS

| | **Tensile yield strength (Mpa)** | **Young's modulus (Gpa)** | **Poison Ratio** | **Shear module (Gpa)** |
|---|---|---|---|---|
| **Music wire** | **2050** | **190** | **0.29** | **76.7** |
| **50cr23** | **1800** | **200** | **0.30** | **76.9** |
| **Stainless-steel S45500** | **1580** | **190** | **0.28** | **78** |

**Design procedure of the spring:**

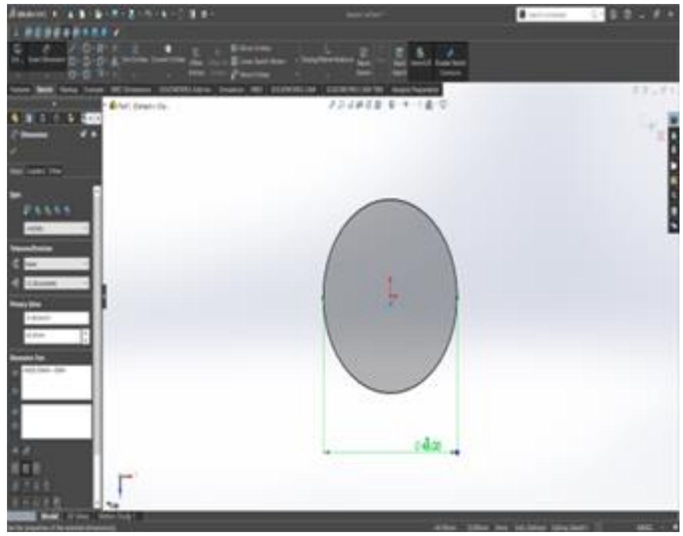
**SOLIDWORKS:**

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.

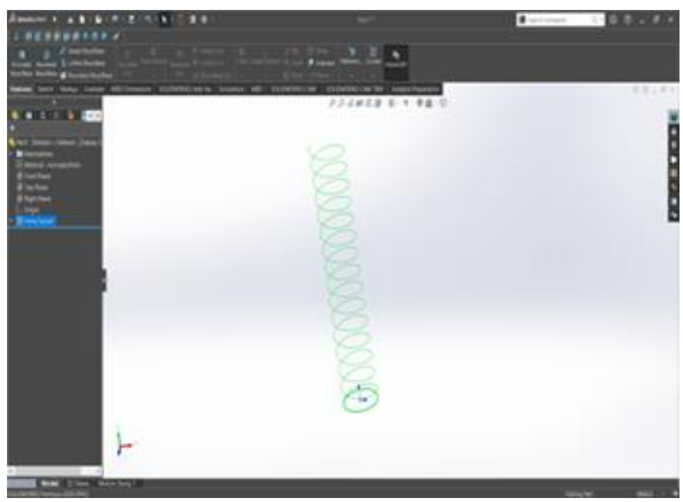
A SOLIDWORKS model consists of 3D geometry that defines its edges, faces, and surfaces. The SOLIDWORKS software lets you, design models, quickly and precisely.

SOLIDWORKS uses a 3D design approach. As you design apart, 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

Step1: Select the top plane select the sketch and make one circle of mean diameter

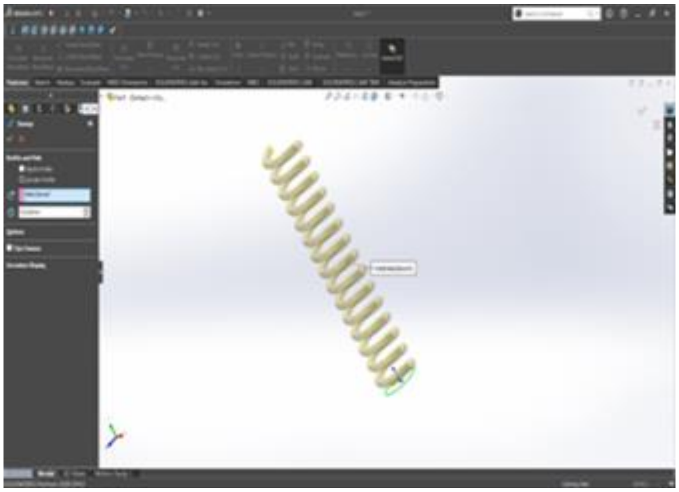


Step 2:
Go to features---> Curve ---> Helix. Adjust the parameters like Pitch, No of revolution



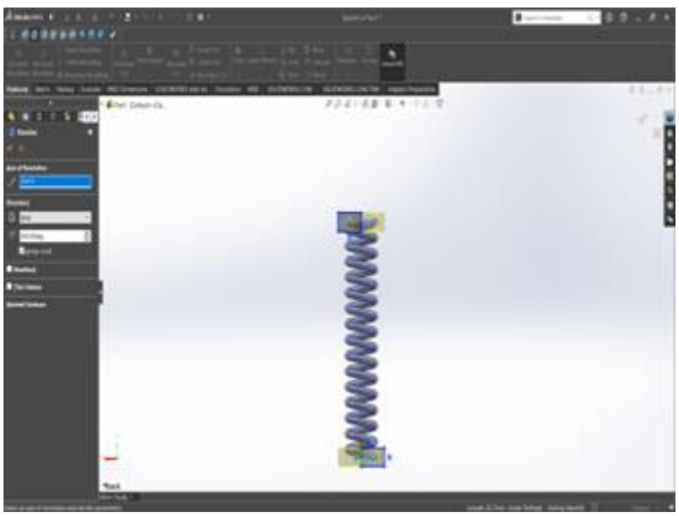
Step 3:

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

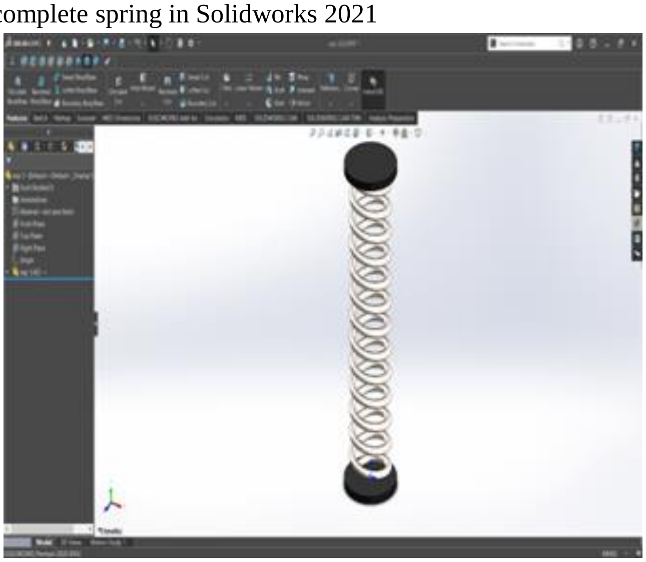


Step 4:

For equal distribution of load and fixed link merge two circular plates on top and bottom



Step5:
complete spring in Solidworks 2021



## 3. ANALYSIS OF THE SPRING

**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 IGES(igs) format the design is analyzed 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 evaluation after the evaluation the results are displayed the equivalent stress, the displacement, the principal stresses are displayed.

**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.

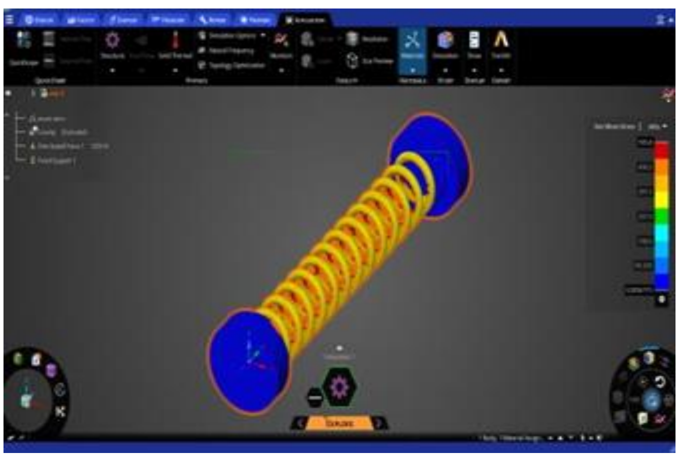
**Obtain Solution**

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

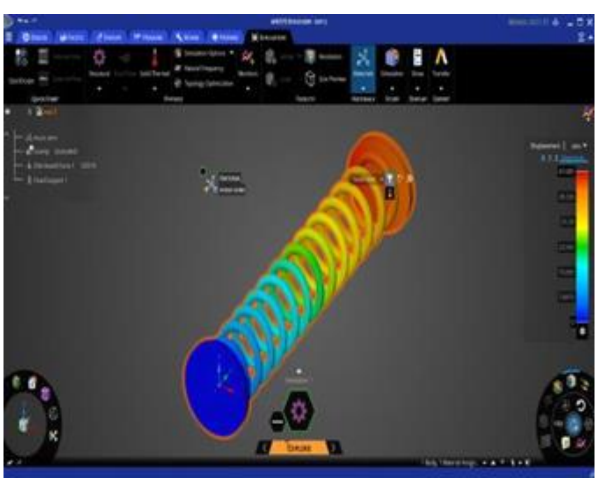
**Present the Results**

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.

**Von Mises stress of Music wire**



**Axial displacement of music wire**



**Von Mises stress of 50cr1v23**

**Axial displacement of 50cr1v23**

**Von Mises stress of Stainless steel S45500**

**Axial displacement 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:**

- $\sigma_v = [((\sigma_1-\sigma_2)^2+\sigma_1^2+\sigma_2^2)/2]^{0.5}$
- $\sigma_v = [(327241.2+104329.7+61692.624)/2]^{0.5}$
- $\sigma_v = 496.62$ Mpa

## V. RESULTS

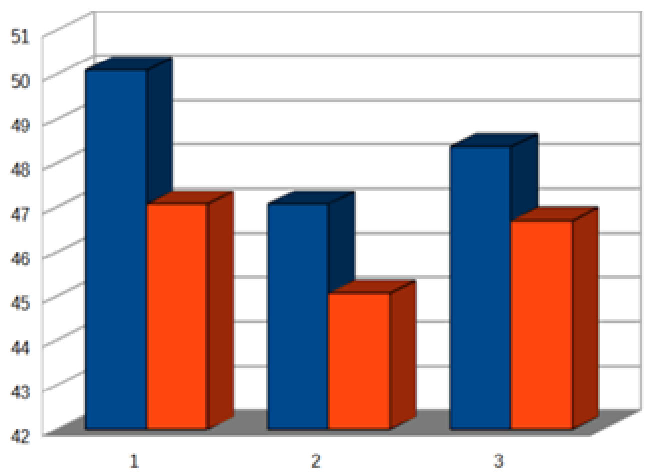
**Theoretical displacement vs Analytical displacement**

| | 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 |

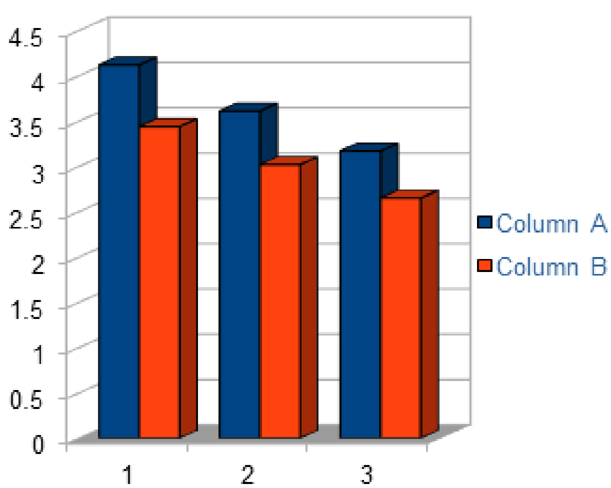
**Theoretical equivalent stresses vs analytical equivalent stresses:**

| Material | Yield stress | Theoretical equivalent stress (Mpa) | Theoretical F.O.S | Analytical equivalent stress (Mpa) | Analytical F.O. S |
|---|---|---|---|---|---|
| Music wire | 2050 | 497.6 | 4.12 | 595.7 | 3.44 |
| 50cr1v23 | 1800 | 497.6 | 3.61 | 595.7 | 3.02 |
| Stainless steel S45500 | 1580 | 497.6 | 3.17 | 595.8 | 2.65 |

**comparing theoretical and analytical displacement:**




**comparing theoretical and analytical equivalent stress:**




## VI. CONCLUSION

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

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