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# Design and Analysis of Helical Compression Spring of IC Engine

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**Abstract:** Helical spring made of spring steel often have high yield strength which enables them to return to their original form after a significant force is applied. Specific application of steel spring in automotive is ruled by industrial guideline, like, Japanese industrial standard(JIS),Daewoo Engineering standard(DES) and Daihatsu Technical Standards(DTS). This project attempts to investigate the characteristics of a helical spring type by using Steel alloy and CFRC materials approach was done systematically by using Ansys. The Helical springs were intended to verify the steel alloy spring material properties (spring constant, Yield strength and tensile strength) for standards of CFRC spring. To successfully reduce a vehicle weight by replacing steel with composite materials, it is essential to optimize the material parameters and design variables of the structure. On the other hand, finite element results show that the spring meets the customer requirements within small deviation. In the present study investigated for numerical cycles to determine the ply angles and wire diameter of carbon fiber/epoxy composite coil springs to attain a spring rate equal to that of an equivalent steel component. The spring was modeled in CATIA and the analysis is performed in ANSYS.

**Keywords:** “CATIAV5 R20”,” MODAL ANALYSIS”,”ANSYS”,”MODES”,”STABILITY”

## 1. INTRODUCTION

The helical springs are made up of a wire coiled in the form of a helix and are primarily intended for compressive or tensile loads. The cross-section of the wire from which the spring is made may be circular, square or rectangular. 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 degree. The major stresses produced in helical springs are shear stresses due to twisting. The load applied is parallel to or along the axis of the spring. In 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. It is as an elastic machine element, which deflects under the action of loading and returns to its original shape when the load is removed. It can take any shape and form depending upon its application. The important functions and applications of springs are as follows:

(1) Springs are used to absorb shocks and vibrations, e.g. vehicle suspension springs, railway buffer springs.
(2) Springs are used to store energy, e.g. springs used in clocks, toys, circuit breakers and starters
(3) Springs are used to measure the force e.g. springs used in weighing balances and scales.
(4) Springs are used to apply force and control motion.

## 2. GEOMETRIC MODELING OF SPRING

We can create solid bodies by sweeping sketch and non-sketch geometry to create associative features or Creating primitives for the basic building blocks, then adding more specific features (for example, holes and slots). Sweeping sketch and non-sketch geometry lets us to create a solid body with complex geometry. This method also gives us total control over the editing of the body. Editing is done by changing the swept creation parameters or by changing the sketch. Editing the sketch causes the swept feature to update to match the sketch. Creating a solid body using primitive’s results in a simple geometry solid body. Making changes to primitives is more difficult, because primitives cannot always be parametrically edited. We can use primitives when we do not need to be concerned with editing the model. Generally, however, it is to our advantage to create the model from a sketch. The geometric model of the spring is shown in Figure1.

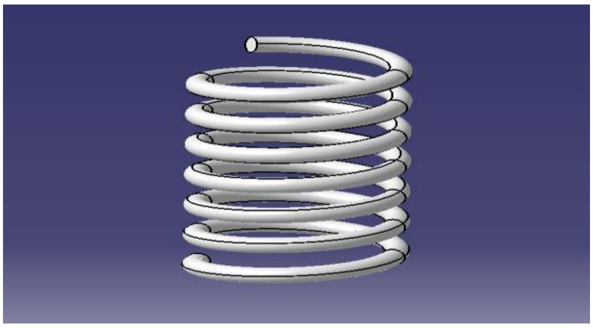

Fig.1: Geometric Model of spring

## 3. FINITE ELEMENT MODELING OF SPRING

The model created in CATIA software is imported through the IGES file in to Hyper mesh software then geometry clean up is carried out. Using the ANSYS library of elements the cards are prepared. The element selected for meshing the spring is a 10 nodded 3D sold element which is having 3dof/node and 24dof/element, the element has shown in Figure2. After checking the convergence norms the meshed model is shown in Figure3.

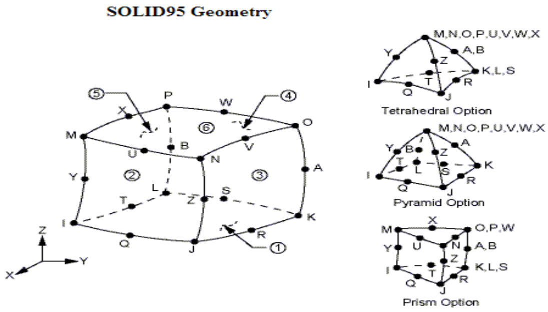


Fig.2: SOLID95 Geometry

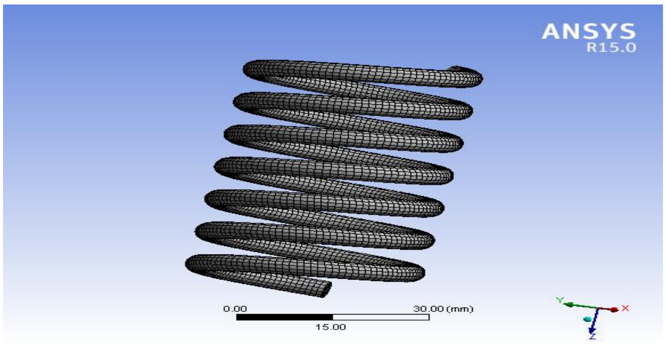


Fig.3: Meshed Model of Spring

## 4. MATERAL PROPERTIES

The materials selected for springs are steel and CFRC Composites. The properties of these materials are given as here under. Mechanical Properties of steel: Young's modulus: 73 GPa, Poisson's ratio: 0.33.

Mechanical Properties of CFRC Composites are Young's modulus $=E_x$ = 180GPa, $E_y$= l0Gpa $=E_z$, Poisson's ratio $nu_{xy}$ = 0.28, Shear modulus $=G_{xy}$ = 7. 1 GPa, Mass density =1600 kg/m$^3$, Damping co-efficient = 0.018.

## 5. RESULTS AND DISSCUSSIONS

**5.1 Static Analysis:** From the Figure 4a. Shows the variation of deformation in the spring due to a torque of 20 N-m is applied, the maximum deformation is observed is 4.11 mm for the Steel alloy material.

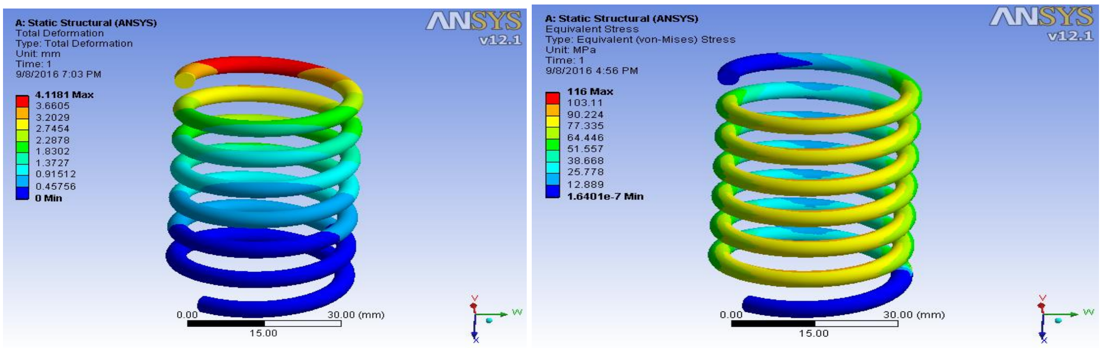


Fig-4(a) Deformed shape, mm  Fig.4(b). Vonmises stress induced, MPa

**Fig.4: Deformation and Vonmises stress induced in the spring made of steel alloy with a torque of 20 N**

The Vonmises stress induced in the spring made of steel with a torque of 20 N-m is 1.64e$^{-7}$N/mm$^2$ , which is seen from the Figure4b.From the Figure 5a shows the variation of deformation in the spring due to a torque of 20 N-m applied, then maximum deformation observed is 4.11 mm for the CFRC material and the corresponding Vonmises stress induced in the spring is 1.312e$^{-7}$N/mm2, which is observed from Figure5b.

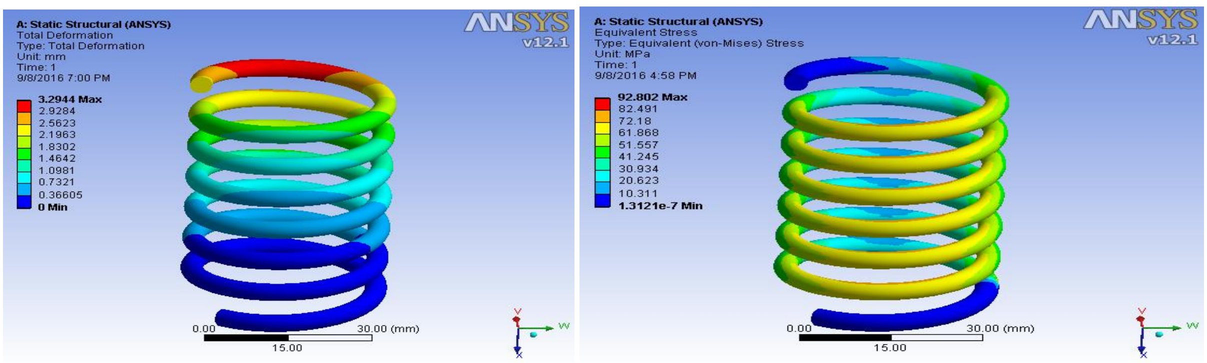


Fig.5 a. deformed shape, mm  Fig.5 b. Vonmises stress induced, MPa

**Fig.5: Deformation and Vonmises stress induced in the spring made of CFRC composite with a torque of 20 N-m**

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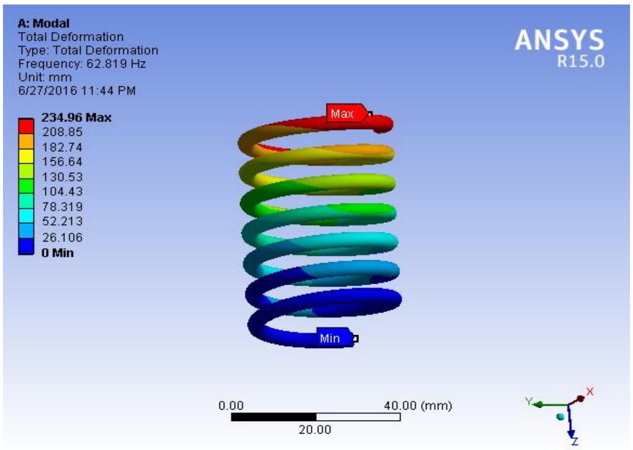
**5.2 Modal Analysis of spring**

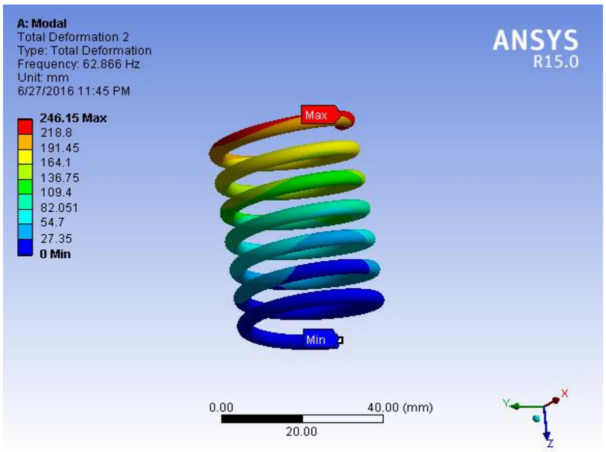
Modal analysis is carried out for structural steel and CFRC Composite Spring. Eigen value analysis is carried out by using Block Lanczo's method.

Six natural frequencies are obtained for structural steel is given in Figure6.

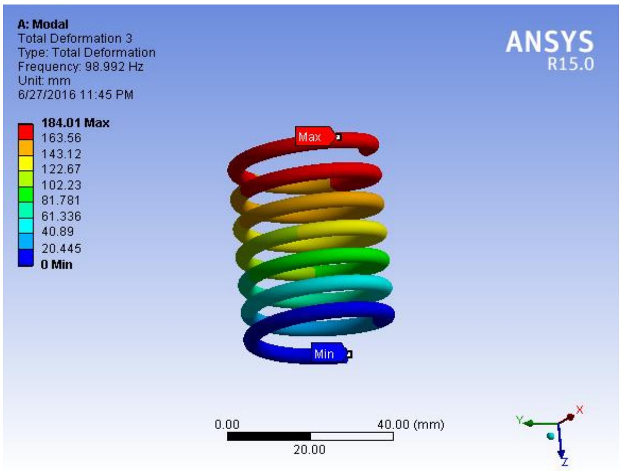
Whereas Figure7shows the natural frequencies of steel made of CFRC composite materials.



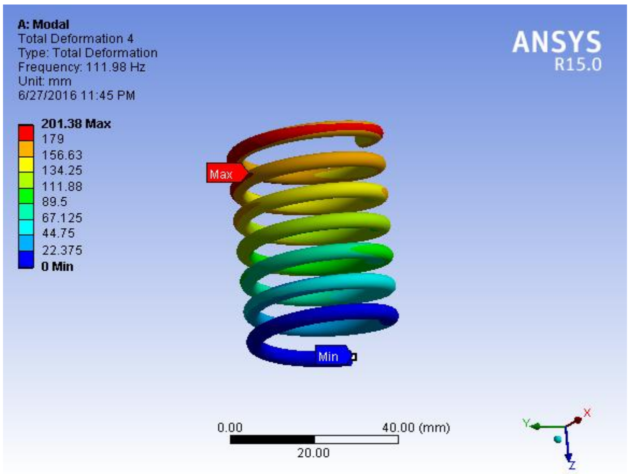

a. First mode (fn1=62.819Hz)



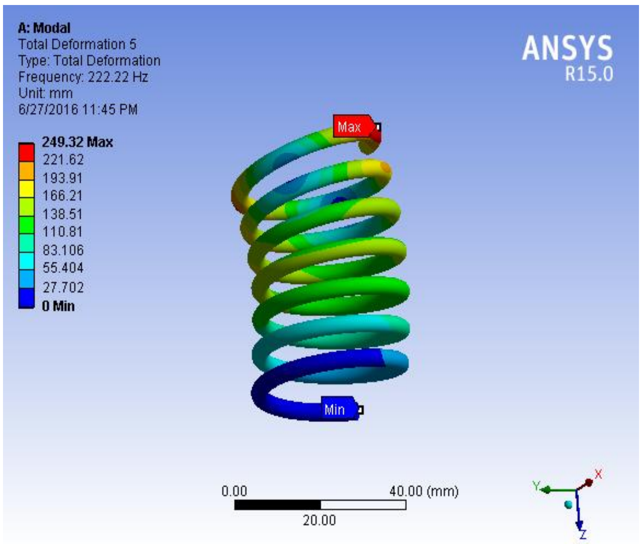

b. 2nd Mode (fn2=62.866Hz)



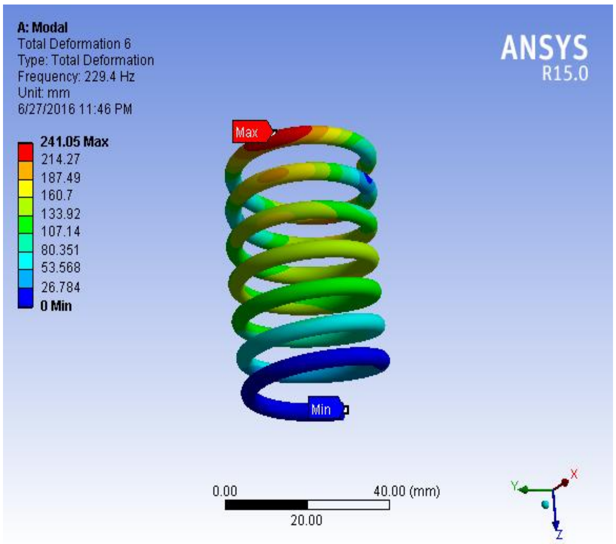

c. 3rd Mode (fn3=98.992Hz)




d. 4th Mode (fn4=111.98 Hz)




e. 5th Mode (fn5=222.22 Hz)




f. 6th Mode (fn6=229.4 Hz)

**Fig.6: First 6 Natural Frequencies in the Gyroscope made of Structural steel Material**

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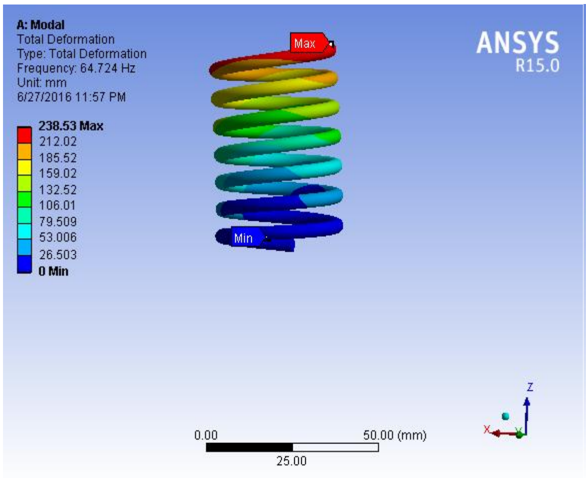
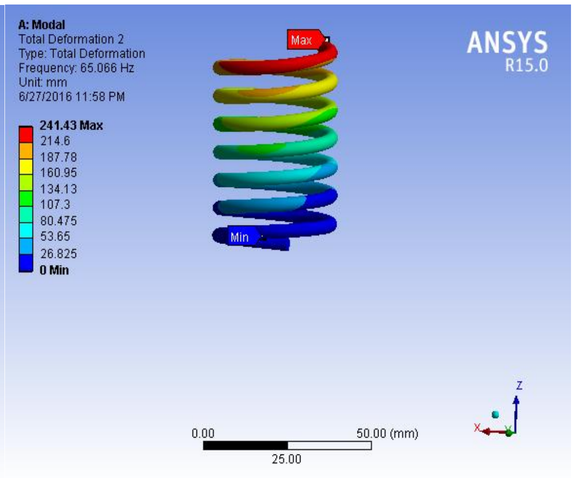
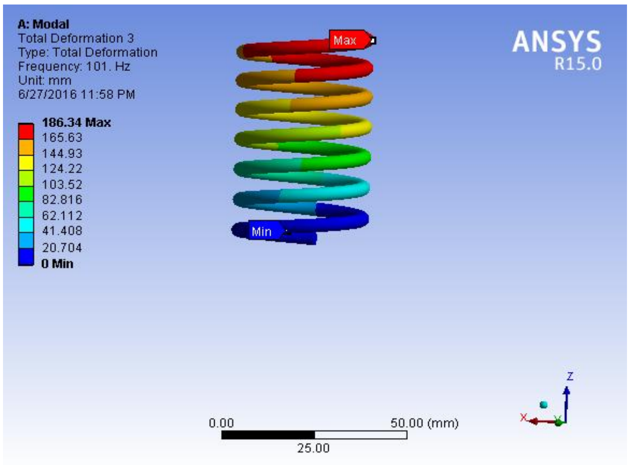


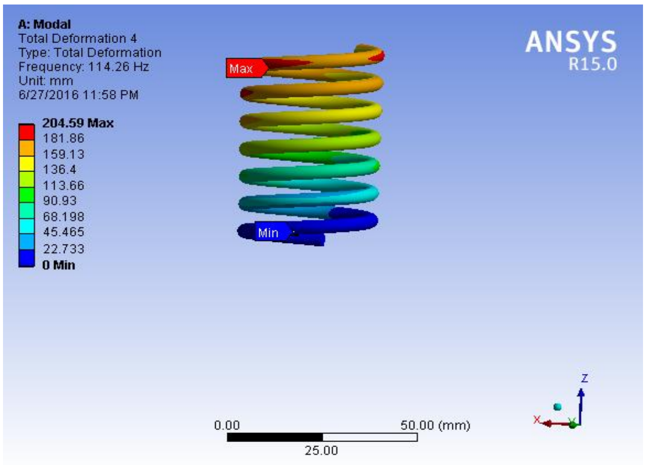

a. 1st Mode (fn1=64.724 Hz)



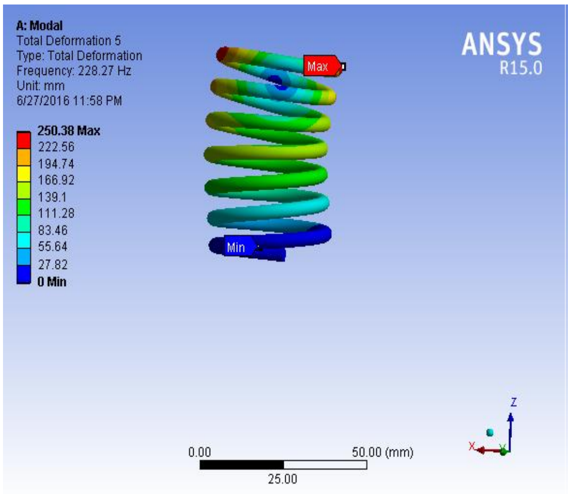

b. 2nd Mode (fn2=65.066 Hz)



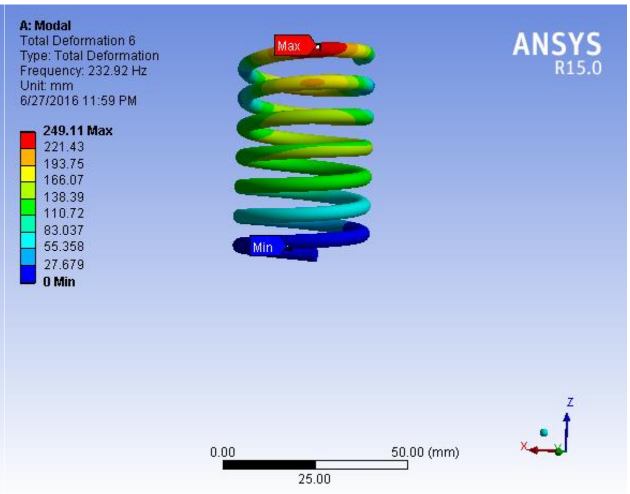

c. 3rd Mode (fn3=101.0 Hz)




d. 4th Mode (fn4=114.26 Hz)




e. 5th Mode (fn5=228.27 Hz)




f. 6th Mode (fn6=232.92Hz)

**Fig.7: First 6 Natural Frequencies in the spring made of CFRC composite Material**

The maximum deformation and vonmises stress induced in the spring made of steel and CFRC material is given table2 and it is observed that deformations and stress induced is more in steel material.

### 5.3 Fatigue Analysis of spring

Fatigue analysis is carried out for structural steel and CFRC Composite Spring. Whereas Figure shows the life and Factor of safety of steel and CFRC composite materials.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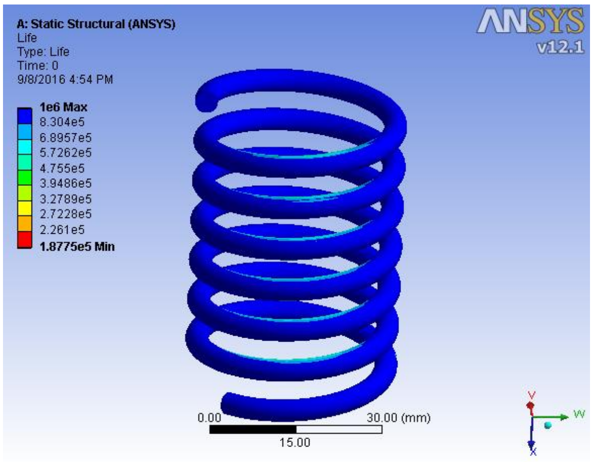


Fig.8 a. Life of spring

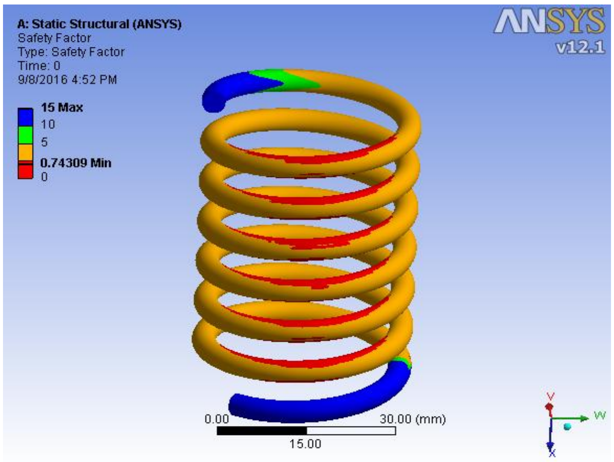


Fig.8 b. Factor of safety

**Fig.8: Life of spring & factor of safety of the spring made of Structural steel Material**

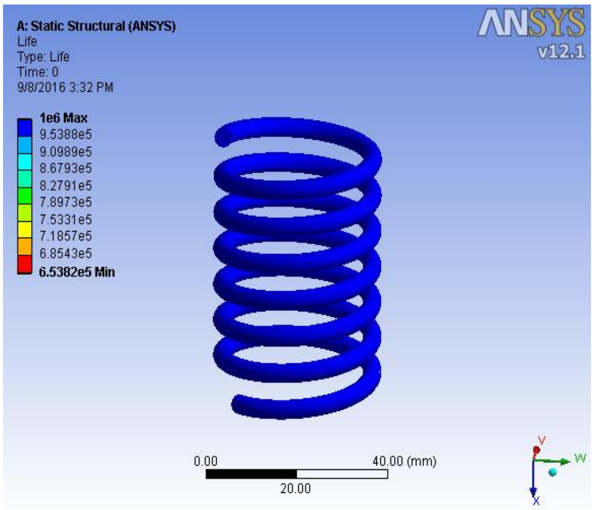


Fig.9 a. Life of spring

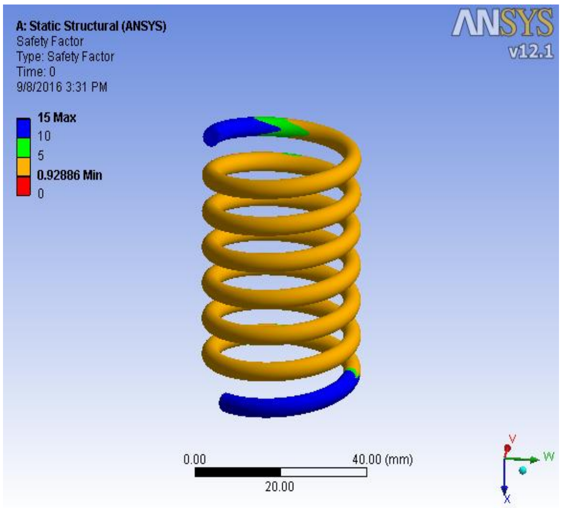


Fig.9 b. Factor of safety

**Fig.9: Life of spring & factor of safety of the spring made ofCFRC Material**

**Table 1: Comparison of Static Analysis Results**

| | Aluminum Alloy | CFRC |
|---|---|---|
| Deformation(mm) | 4.11 | 3.29 |
| Vonmises stress (MPa) | 1.64e-7 N/mm2 | 1.312e-7 N/mm2 |

Results of modal analysis of spring is shown in table2. It is observed that the natural frequencies are high in CFRC material as compared to the steel spring. Hence the dynamic stability is good in CFRCspring as compared to steel spring.

**Table 2: Comparison of Modal Analysis Results**

| Mode shapes | SteelAlloy Spring Frequency(Hz) | CFRCSpringFrequency(Hz) |
|---|---|---|
| First mode | 62.819 | 64.724 |
| Second mode | 62.866 | 65.066 |
| Third mode | 98.992 | 101.0 |
| Fourth mode | 111.98 | 114.26 |
| Fifth mode | 222.22 | 228.27 |
| Sixth mode | 229.4 | 232.92 |

**Table 3: Comparison of Fatigue Analysis Results**

| | Steel Alloy | CFRC |
|---|---|---|
| Life | $1.87E^5$ | $6.5E^5$ |
| Factor of safety | 0.74 | 0.92 |

## 6. CONCLUSIONS

The deflection in Spring made of Steel material is found to be 4.11 mm where as for the CFRC composite material spring is 3.29 mm, which is much less than that of steel alloy spring. Hence composite material spring is stiffer than steel spring.Modal analysis results showed that the natural frequencies of composite spring were higher than steel spring, which indicates that the dynamic response of composite spring is much superior to steel spring. Static stresses induced in the CFRC Composite spring is less than that of spring made of steel material. The life of spring is $1.87e^5$ for steel where as for CFRC is $6.5e^5$ which is more than the steel alloy. Factor of safety of both steel and CFRC are less than 1 within the limits. However the stresses induced in both springs are well within the allowablerange. Hence the design of the spring is satisfying the rigidity and strength criteria's.

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