Design and Analysis of Wave Spring and compared with Coiled Spring for same Parameter

Prof. Dhruv Joshi , Santosh Srivastava S. , Bhautik Patel R. , Mehul Gohil M.

Abstract

The Spring which is one of the part of Suspension systems, Which is designed mechanically to handle shock impulse and dissipate kinetic energy. It decrease the amplitude of disturbances leading to increase in comfort and improved ride quality. The spring is compressed rapidly when the load impacting on it. The compressed spring rebound to its normal dimension or normal loaded length. The spring get compressed below its normal height when the load pushes the spring down. This causes the spring to rebound again. The spring bouncing process occurs over and over every less each time, until the up-and-down movement finally stops or the disturbance can be neglected. The system handling becomes very difficult and leads to uncomfortable operation when vibration become uncontrolled. Hence, the designing of spring in a suspension system is very crucial. The analysis is done by considering bike mass, loads, and no of persons seated on bike. Comparison is done by substituting coil spring by wave spring to verify the best dimension for the wave spring in shock absorber. Modeling and Analysis is done using Pro/ENGINEER and ANSYS respectively.

Key Words: *Shock Absorber, Coil Spring, Wave spring, Modified design, Stress analysis.*

I. Introduction

The Shock absorber which is one of the Suspension systems is designed mechanically to handle shock impulse and dissipate kinetic energy. It reduces the amplitude of disturbances leading to increase in comfort and improved ride quality. Hence, the designing of spring in a suspension system is very crucial. The Shock absorber coil spring is designed by using the modeling software Pro/ENGINEER Wildfire 4.0. Later this Pro/ENGINEER model is imported to ANSYS for the analysis work. The ANSYS software is used for analyzing the component by varying the load applied on it and the results are observed

Working of shock absorbers Spring:

Shock absorbers work in two cycles--the **compression cycle** and the **extension cycle**. The compression cycle occurs as the piston moves downward, compressing the hydraulic fluid in the chamber below the piston. The extension cycle occurs as the piston moves toward the top of the pressure tube, compressing the fluid in the chamber above the piston. A typical car or light truck will have more resistance during its extension cycle than its compression cycle. With that in mind, the compression cycle controls the motion of the vehicle's unsprung weight, while extension controls the heavier, sprung weight.

II. Objective

When a vehicle is travelling on a level road, the spring is compressed quickly when the wheel strikes the bump. The compressed spring rebound to its normal dimensions or normal loaded length which causes the body to be lifted. The spring goes down below its normal height when the weight of the vehicle pushes the spring down. This, in turn, causes the spring to rebound again. The spring bouncing process occurs over and over every less each time, until the up-and-down movement finally stops. The vehicle handling becomes very difficult and leads to uncomfortable ride when bouncing is allowed uncontrolled. The designing of spring in a suspension system is very crucial.

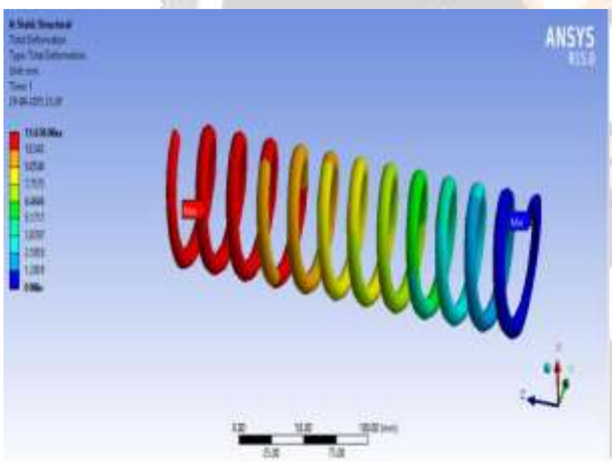
III. Modeling Dimesions of the spring:

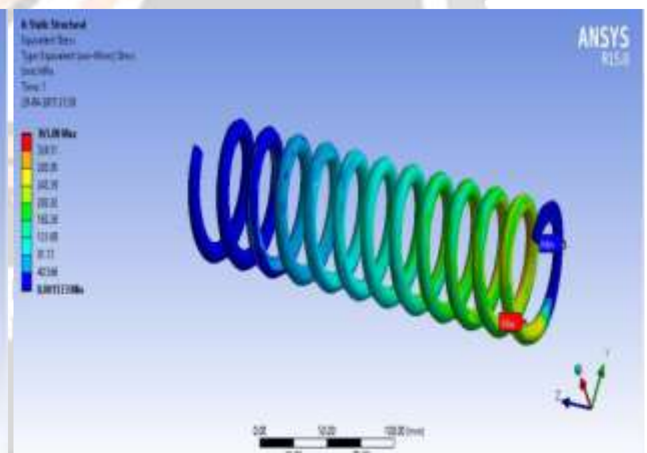
Modeling of the coil spring and wave spring is done using CRE-O modeling software.

Coil spring:
Mean diameter: 60mm Free Length: 300mm pitch: 24mm
Wire diameter :12mm number of turns: 10

Wave Spring:
O.D. : 54mm I.D:47mm free length: 300mm
Number of waves per turn: 2 number of turns: 10 Thickness: 0.54mm

Structural analysis coil spring:





a. Deformation, mm b. Equivalent stress, MPa
Fig:1 Fig:2

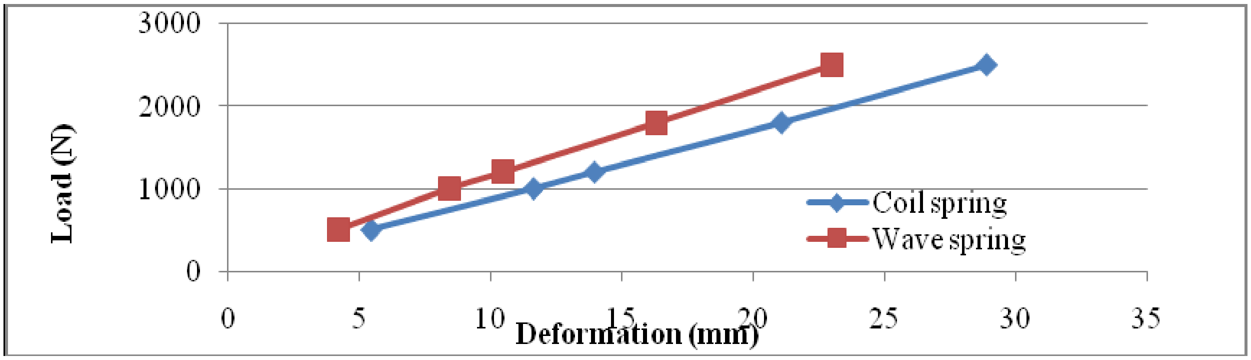


Figure3: Variation of deformation with increasing load of coil and wave spring

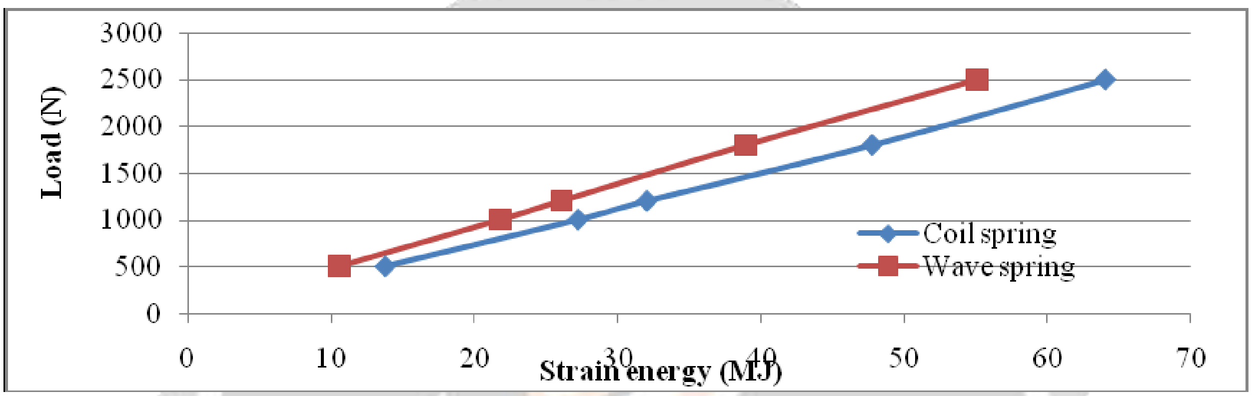
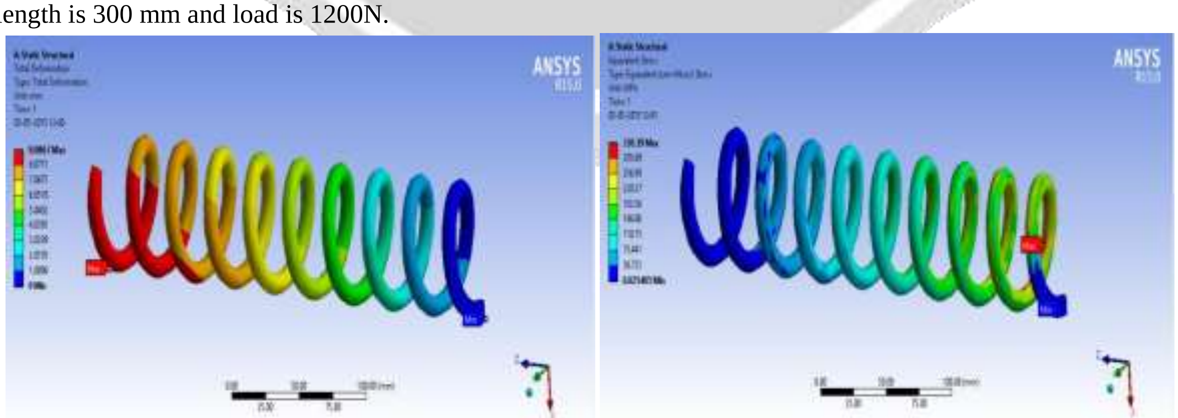


Figure4: Variation of strain energy with increasing load of coil and wave spring.

The Fig.1 and 2 shows deformation, equivalent stress of coil spring.
The Fig.3 shows variation of Deformation with Load.
For same Parameters wave spring has less deformation compared to coil spring.

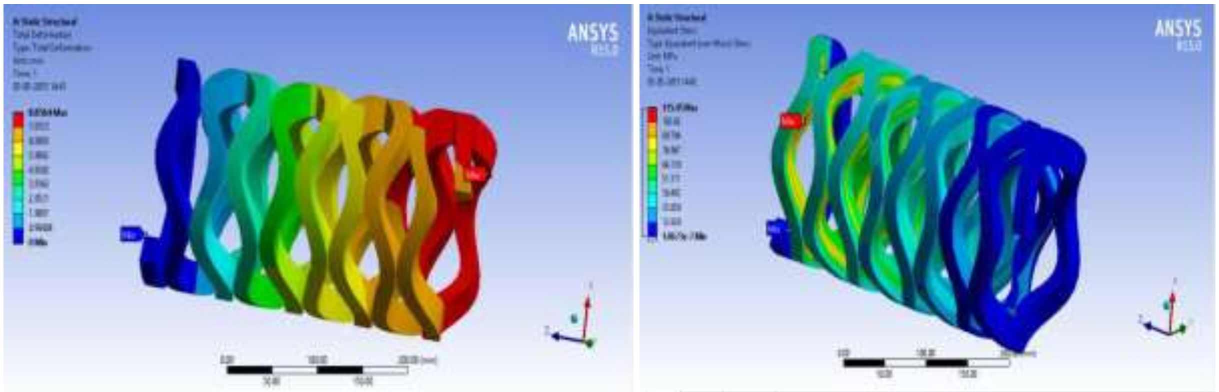
From Fig.4 it is observed that as load increases strain energy increases and the strain energy of wave spring is less than coil spring. The average percentage variation is 21.3%.

Analysis of coil and wave spring: The Fig.5 show deformations and equivalent stress of coil spring when number of turns is 8 and load is 1200N. The Fig.6, shows deformations and equivalent stress of Wave spring when free length is 300 mm and load is 1200N.



a. Deformation , mm b. Equivalent stress, M-Pa

Fig:5



a. Deformation, mm b. Equivalent stress, MPa

Fig:6

By comparison wave spring has less deformation. As number of turns increases deformation increases, but in case of coil and wave spring as number of turns increases there is an average percentage variation of (7%) between coil and wave springs.

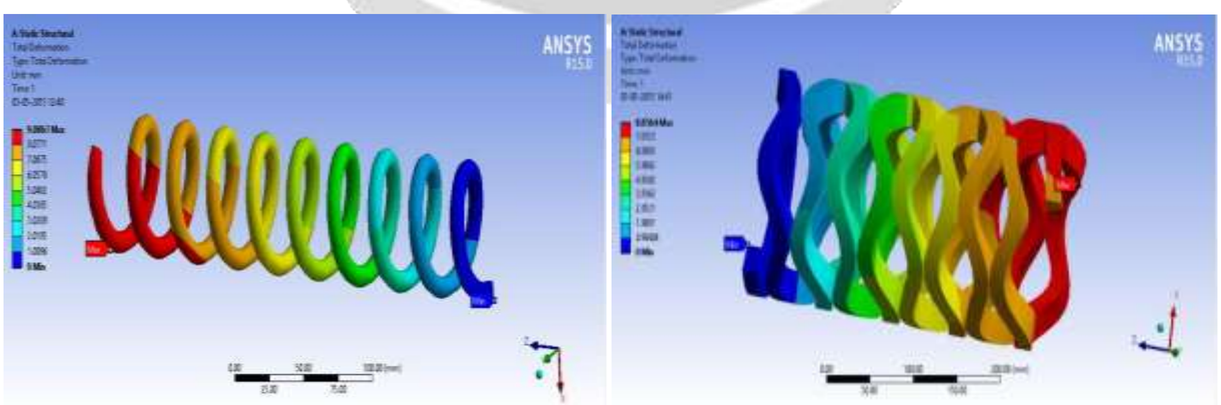
From this analysis when number of turns increases, compared to coil spring wave spring has less deformation.

Table 1: Variation of deformation and stress of coil and wave spring

No. of Turn	**Coil Spring**		**Wave Spring**	
	Deformation , mm	**Eq. Stress , MPa**	**Deformation , mm**	**Eq. Stress , MPa**
8	**9.08**	**330**	**8.8**	**130.45**
10	**9.97**	**340**	**9.81**	**138.89**
12	**11.45**	**350**	**10.91**	**142.55**

8.2 Comparison of coil and wave spring when free length varying

The Fig.8 shows variation of deformations when free length changes by keeping number of turns constant. By comparison for less number of turns coil spring is better than wave spring.



a. Coil spring b. Wave spring

Figure8: Deformation of coil and wave springs

Table2: Variation of deformation of coil and wave spring with free length

	Deformation in , mm	
Free Length ,mm	**Coil Spring**	**Wave Spring**
300	**9.08**	**8.85**
250	**8.34**	**8.63**

8.4 Comparison of Coil and Wave spring when twisting moment varying

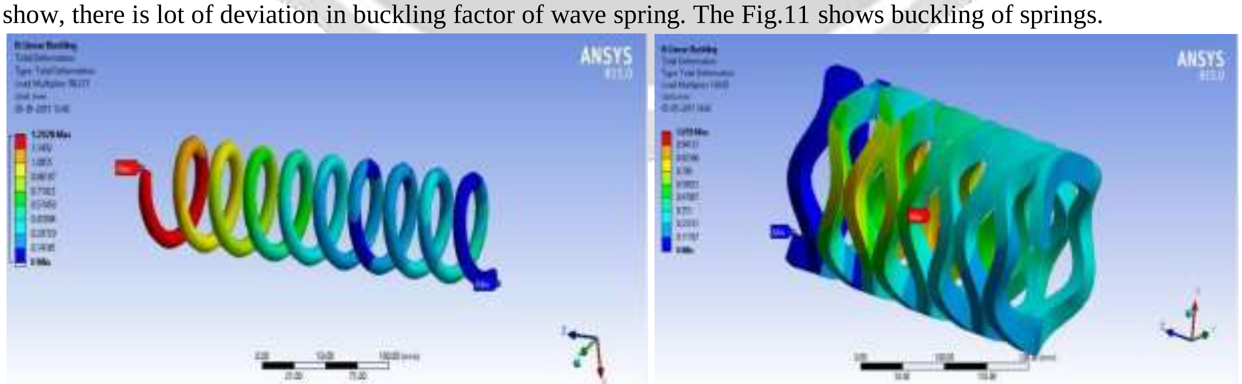
When a spring is subjected to twisting moment shear stress is developed and also strain energy is stored. From Table3 as twisting moment increases shear stress also increases. From Table3, it is observed that as twisting moment increases shear stresses of both springs‟ increases but as compared to coil spring there is lot of deviation in shear stress for same parameters. Since in applications where twisting moment acting wave spring gives better results compared to coil spring. It is also observed that equivalent stress for coil spring is high compared to wave spring therefore coil spring fails easily. From results, as twisting moment increases strain energy increases. The strain energy variation with twisting moment is observed that Wave spring possess more elastic strain energy compared to coil spring.

Table 3: Variation of shear stress, equivalent stress and strain energy

Twisting Moment	**Coil Spring**			**Wave Spring**		
	Shear Stress	**Eq Stress**	**Strain Energy**	**Shear Stress**	**Eq Stress**	**Strain Energy**
130	**118.43**	**230.71**	**6.4**	**48.11**	**94.15**	**20.59**
150	**130.28**	**253.78**	**7.73**	**58.52**	**108.65**	**27.41**
180	**148.24**	**288.39**	**9.99**	**69.61**	**130.38**	**38.48**
200	**165.81**	**323.01**	**12.53**	**81.02**	**145.02**	**45.42**

5.5 Linear buckling analysis

Pre bucking analysis gives buckling factor values for different modes. When number of turn's changes, free length varies buckling factor varies for both coil and wave spring. Buckling occurs when slenderness ratio is greater than 4.Buckling is mainly depends upon their geometrical properties rather than their material properties. The results show, there is lot of deviation in buckling factor of wave spring. The Fig.11 shows buckling of springs.



a. Coil spring b. Wave spring

Figure11: Buckling of coil and wave spring when free length =300mm

The Table 4 shows variations of buckling load with free length of both coil and wave spring. Buckling factor is higher for wave spring in comparison. As free length increases buckling factor decreases. The buckling factor for coil spring is an average 26 % less compared to wave spring.

Free length in mm	**Bucking factor**	
	Coil spring	**Wave spring**
320	**96.04**	**125.03**
300	**98.21**	**128.02**
280	**100.11**	**129.78**
250	**102.48**	**131.08**

5.6 Modal analysis The mode shapes are given in Fig.12. Modal analysis gives natural frequencies of both Coil and Wave spring in different modes. Natural frequency for springs is given by

The natural frequency equations are for springs fixed at both ends. If only one end of the spring is fixed, it behaves like a fixed-fixed spring of twice its length. Thus, for a spring with only one end fixed, the frequency is 1/2 the value given by the above equations. The Table5 gives natural frequencies for different springs of coil and wave. Wave spring has less natural frequency for different modes. At mode 5 the natural frequency of coil spring is 79 Hz whereas wave spring has 38Hz; hence it is observed that the natural frequency in wave spring is average 44.24% less than coil spring.

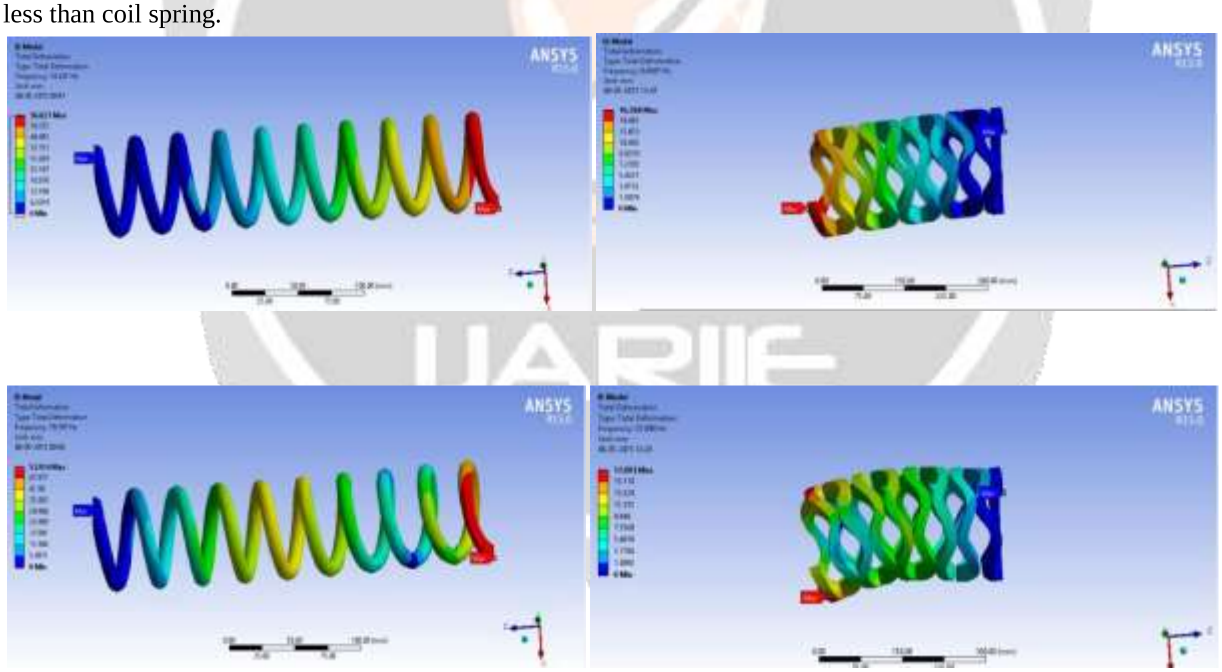


Figure12:. Natural frequency of coil and wave spring for Mode 1 and mode5

Table 5: Variation of natural frequencies for different modes

Mode No	**Natural frequency, Hz**		
	Coil spring	**Wave spring**	**% Variation**

1	**14.24**	**8.45**	**40.66**
2	**14.40**	**8.55**	**40.63**
3	**24.98**	**15.98**	**36.12**
4	**43.09**	**23.21**	**46.13**

Natural frequency is indirectly proportional to number of turns .As number of turns increases natural frequency decreases so that vibrations are more. From comparison coil spring has less vibration effect than wave spring since wave spring has less natural frequency compared to coil spring. Since for higher number of turns coil spring has a natural frequency of 40.05 Hz and wave spring has 21.88 Hz.

Table 6: Variation of frequency with No. of turns

No. of turns	**Natural frequency, Hz**	
	Coil spring	**Wave spring**
8	**79.03**	**35.89**
10	**65.72**	**31.52**
12	**56.18**	**27.89**
14	**40.05**	**21.88**

5.7 Fatigue analysis The main factors that contribute to fatigue failures include number of load cycles experienced, range of stress and mean stress experienced in each load cycle and presence of local stress concentrations. IC engine valve spring and automobile horn are subjected to high fatigue loads. In fatigue analysis I vary number of turns and free length of both coil and wave spring and results are tabulated. Life of spring varies with number of turns. From results it is observed that as free length increases minimum life to failure decreases, but wave spring has high fatigue life compared to coil spring.

Conclusions

Analysis on wave spring has been done by structural mechanics approach and results were validated and compared with the coil spring of the shock absorber. The deflection induced in the wave spring is average 25.88% less than the coil spring. The equivalent stress of wave spring is an average 58.32% less than coil spring. The strain energy of wave spring is an average 21.3% greater than coil spring. For less number of turns and free length Wave spring has a deformation of 8.63 whereas coil spring has 8.34, so if we use 8 number of turns and free length of 250mm coil spring is best suitable but as we increase free length or number of turns wave spring is better. The strain energy increases with increase in torque and it is an average 60% greater in wave spring compared to coil spring. From Buckling analysis buckling factor decreases with increase free length. The buckling factor in wave spring is an average 26% greater than coil spring. From Modal analysis coil spring produces less vibration effect about an average 44.24% compared to wave spring. As number of turns increases natural frequency decreases, coil spring has an average 52.55% less vibrations compared to wave spring. By performing Fatigue analysis, wave spring has high fatigue life is an average 15 % compared to coil spring. As free length increases fatigue life decreases and wave spring is better life compared to coil spring about 30%.

References:

[1] Rajkumar V. Patil; Dr. P. Ravinder Reddy; Dr. P. Laxminarayana, Buckling Analysis of Straight Helical Compression Springs Made Of ASTMA229 Gr-II, ASTM A 313 Materials (Type 304 & 316*). International journal of engineering research & technology (IJERT), Vol.2. Issue 6*, June-2013.

[2] Rajkumar V.Patil, P. Ravinder Reddy and P. Laxminarayana, „Comparison of cylindrical and conical helical springs for their buckling load and deflection", International Journal of Advanced Science and technology, vol.73 ,pp-33-50, 2014, http://dx.doi.org/10.14257/ijast.2014.73.03.This journal is from Science and Engineering Research Support Society , KOREA.

[3] James M. Meagher and Peter Altman (1996), "Stresses from flexure in composite helical implantable leads".

[4] M.T. Todinov (1999), "Maximum principal tensile stress and fatigue crack origin for compression springs, international journal of mechanical sciences", vol. 41, pp. 357-370.

[5] Watanabe Kotaro, Tamura Masashi, Yamaya Ken &Takahiko Kunoh (2001), "Development of a new-type suspension spring for rally cars", Journal of materials processing technology, pp. 132-134.

[6] Fakhreddine Dammak, Mohamed Taktak, Said Abid, Abderrazek Dhieb & Mohamed Haddar (2005), "Finite element method for the stress analysis of isotropic cylindrical helical spring", journal of mechanics and solids, vol.24, pp. 1068-1078.