

Design analysis of helical spring of suspension system

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Abstract – Helical spring has been widely used in the suspension system of the machines. This conventionally used spring was purely manufactured with the help of steel, which as a result increased the weight of the entire working machine, which was the hindrance in increasing its efficiency. Hence our project demonstrates the feasibility of adopting composite material for design of helical coil suspension system. In this project the design analysis of combination of steel and composite material will be performed. This will result into greater stiffness with reduced weight of the spring which will be the prime advantage of this project.

Keyword - helical spring, suspension system, composite material.

I. INTRODUCTION OF SPRINGS

There are innumerable areas wherein the use of springs is inevitable. There are many types of springs which can be used for various purpose as per the requirements. Spring can be defined as follows:

“An elastic body whose function is to recover its original shape and dimensions after the removal of load is said to be a spring.”

Various applications:

To obtain cushioning effect in automobiles, like railway buffers, trains, buses etc. and absorb shocks along with vibrations.

It can also be used in clutches, brakes, etc.

The control of motion between two or more elements like cams sliding over followers. Spring balances use springs for the measurement of forces. Storage of energy can be done with the help of springs. There are number of kinds of springs as follows:

- 1) Helical springs
- 2) Conical and volute springs

Out of the above mentioned springs, the most commonly used springs for suspension system are helical springs and leaf springs.

Suspension system

A system in which the elements like tyres, air, springs, various linkages work collectively for helping in holding the road and braking so that safety can be increased and a better driving can be obtained.

Helical springs

The springs in which the coiling of wire is done in helix form and the intension is to work for compressive or even tensile loads. It may have different cross sections like circular, square or even rectangular.

Types of helical springs:

- Compression springs
- Tension springs.

Problem Summary

In the present scenario, due to the danger of non-availability of conventional fuels in near future, it has become very important to reduce the use of fuels.

This is possible only if the development of some alternate fuel takes place. This development is taking place at quite a good pace since recent times.

But this may take a lot of time to develop an alternate by which the use of conventional fuels like petroleum can totally be exempted.

Hence due to this reason, it is very necessary to utilize the conventional fuel as judiciously as possible.

For achieving this objective, it is inevitable to improve the efficiency of the vehicles. The efficiency of any vehicle is highly dependent on the weight of the vehicle.

The suspension system of an automobile is a very crucial segment of automobile vehicle. Till date, the leaf springs and helical compression springs are widely used in automobile suspension systems by most of the manufacturers.

It has been studied that a suspension system plays a very important role in smooth and jerk free ride. So it is very important to design springs with high precision.

The use of conventional steel as spring material increases the overall weight of the automobile suspension system and hence, the weight of entire assembly or vehicle.

Due to this reason, the efficiency of the vehicle reduces as a result of which more fuel is consumed which is a big reason to worry having studied the non-availability of resources in near future.



Fig.1.1

II. AIM AND OBJECTIVES OF THE PROJECT

This project demonstrates the study of use of helical springs in suspension systems. Helical springs which are widely used for suspension systems are generally manufactured with high carbon steel spring like EN 47.

This conventionally used material has all the properties which are suitable for springs of suspension system and it also possess some properties which are the prime requirements for suspension systems.

The steel spring possess all such properties. Even then, there are some major drawbacks of this material which may be stated as high weight, irrisistance to corrosion, conductor of electricity, etc.

Hence due to this reason, the idea of design of a new composite material satisfying the above drawbacks arose.

Aim

To reduce the weight of the suspension system by some means so as to meet the solution of the problem mentioned earlier and To obtain higher stiffness.

To obtain additional advantages like corrosion resistance, non-conductance to heat and electricity.

The highest potential of reducing weight of suspension system lies in the reduction of weight of suspension spring. The manufacturers are interested in replacing the steel springs with light weight composite materials.

Hence the objective of this project is to carry out designing of spring with a light weight composite materials.

Objectives

Composite materials are those materials which are light in weight and has good stiffness properties along with some additional beneficial properties like corrosion resistance and it can also withstand high temperature.

But manufacturing composite materials is very costly. So, these materials can be utilized only if the efficiency of the vehicle can be increased to such an extent that the cost of the material can be overcome.

Objectives can be summarized as follows

To provide better riding as well as better performance of handling.

To provide reliable steering control at the time of maneuvering by maintaining wheels in proper position.

To ensure better control over forces during braking acceleration, etc. for this suspension system should be so designed to reduce or prevent squat, dive and rolling of the body of vehicle.

To ensure reduction in high frequency vibration achieved due to tire excitation.

To obtain reduction in road noise which is transmitted to the body of vehicle.

III. LITERATURE REVIEW

Due to the feasibility of application of composite material in automotive suspension system, many researchers are involved in study of composite material.

Chang-Hsuan Chiu, Chung-Li Hwan, Han-Shuin Tsai and Wei-Ping Lee have conducted the experiment on mechanical behavior of helical composite springs. They have made the springs with different material like, unidirectional laminates, rubber core unidirectional laminates, unidirectional laminates with a braided outer layer, and rubber core unidirectional laminate with a braided outer layer.

Henry and c. Robert has tried treplace the metal coil spring of a Rover saloon car using carbon fiber.

P.K. Mallick has fabricated and conducted the performance test for the composite elliptic spring. The composite leaf springs are successsfully used in the suspension of the light vehicles. The fibers used in these are unidirectional E-glass due to their high extensibility, toughness and low cost. The composite leaf spring is designed and analyzed using ansys. The results showed that an optimum spring width decreases hyperbolically and the thickness increases linearly from the spring eye towards the axle seat.

Compared to steel springs the optimized composite spring has strength that are much lower, the natural frequency is high and the spring weight is nearly 80% lower.

D. Abdul Budan and T.S. Manjunatha has investigated the use of different composite material in helical coil spring of suspension system and other automotive applications. In all of the above research papers it has been observed that the application of composite materials has been limited to light weight vehicles. An effort has been made by the author to prepare a solution for application of composite materials in regular vehicle.

Materials Required

Spring steel high carbon EN47

E-Glass/Epoxy (glass fiber reinforced polymer)

Kelvar Epoxy

Carbon Epoxy

Graphite Epoxy

MACHINES REQUIRED

Spring coiling machine

A machine used to produce springs, spring washers and the collar springs from wire and rods in known as spring coiling machine. There are both, automatic and semi- automatic machines. Helical, cylindrical, conical and contoured springs are made by either hot or cold coiling on spring coiling machine.

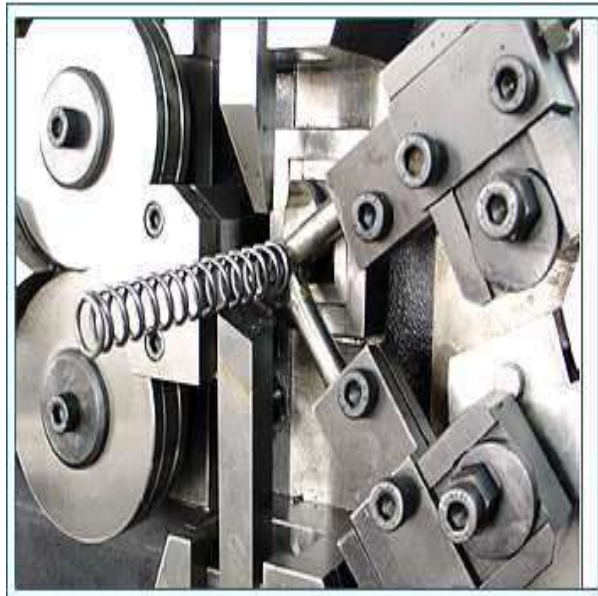


Fig.1.2

Grinder

A grinder is used to provide closed or ground ends to the springs by using grinding operation. Several grinders like automatic grinders which can carry out grinding of more number of springs.





Fig.1.3

Furnace

Furnace is a device used for high temperature heating. Furnace is used to heat treatment process of spring.



Fig.1.4

Spring deflection Tester



Fig.1.5

Main Aims of the project

To decrease the weight of the spring

To increase the stiffness of the spring with lesser mass of material.

Possible solution

The objective of increasing the stiffness can be achieved by various heat treatment processes on the steel spring. By heat treatment, properties like hardness, ductility, toughness, etc. can be changed which would be an aiding factor for varying stiffness of spring.

The industries have been widely using this method practically for improving the deflection parameters of the spring. This heat treatment process is done in an electric furnace.

Heat treatment

The process in which the heating and cooling has to be done on a metal or an alloy so that desired properties or conditions can be obtained.

Hence, various specific methods like Annealing, Normalizing, Hardening and Tempering can be used.



Fig.1.6

Normalizing

Normalizing is the process of heating the material to a suitable temperature, holding for appropriate period of time, so that residual stresses can be relieved, and then slowly cooling to minimize the generation of new residual stresses.


Hardening

It is a metallurgical process in which the springs are heated to the temperature of about 850°C so that the conversion to austenite takes place. These springs are then taken out of the furnace and are placed in the bath of water so that rapid cooling takes place.

IV. DESIGN AND EXPERIMENTAL RESULTS**Experimental Results**

The improvement in stiffness of spring can be noted by the following comparison

Table 1



Raymond® LIGHT DUTY DIE SPRINGS					JIS B 5012 Series Blue					
Outer Dia. (mm)	Inner Dia. (mm)	Free Length (mm)	Catalog Number	Load at 1mm Def. (kgf)	LOAD DEFLECTION TABLE					
					For Maximum Operating Def. (40% of free length)		For Long Life (30% of free length)		For Optimal Life (12% of free length)	
A	B	C			Deflection (mm)	Load (kgf)	Deflection (mm)	Load (kgf)	Deflection (mm)	Load (kgf)
8	8	10	ASL 8 X 10	3.50	4.0		3.6		3.2	
		15	ASL 8 X 15	1.67	6.0		5.4		4.8	
		20	ASL 8 X 20	1.25	8.0		7.2		6.4	
		25	ASL 8 X 25	1.00	10.0		9.0		8.0	
		30	ASL 8 X 30	0.83	12.0		10.8		9.6	
		35	ASL 8 X 35	0.71	14.0		12.6		11.2	
		40	ASL 8 X 40	0.63	16.0	10 (98.1)	14.4	9 (88.3)	12.8	8 (78.5)
		45	ASL 8 X 45	0.56	18.0		16.2		14.4	
		50	ASL 8 X 50	0.50	20.0		18.0		16.0	
		55	ASL 8 X 55	0.46	22.0		19.8		17.6	
10	6	60	ASL 8 X 60	0.42	24.0		21.6		19.2	
		20	ASL 10 X 20	1.81	8.0		7.2		6.4	
		25	ASL 10 X 25	1.43	10.0		9.0		8.0	
		30	ASL 10 X 30	1.21	12.0		10.8		9.6	
		35	ASL 10 X 35	1.03	14.0		12.6		11.2	
		40	ASL 10 X 40	0.90	16.0		14.4		12.8	
		45	ASL 10 X 45	0.80	18.0		16.2		14.4	
		50	ASL 10 X 50	0.73	20.0	14.5 (142.2)	18.0	13 (127.5)	16.0	11.5 (112.9)
		55	ASL 10 X 55	0.68	22.0		19.8		17.6	
		60	ASL 10 X 60	0.60	24.0		21.6		19.2	
12	6	65	ASL 10 X 65	0.55	26.0		23.4		20.8	
		70	ASL 10 X 70	0.51	28.0		25.2		22.4	
		75	ASL 10 X 75	0.48	30.0		27.0		24.0	
		80	ASL 10 X 80	0.45	32.0		28.8		25.6	
		20	ASL 12 X 20	2.53	8.0		7.2		6.4	
		25	ASL 12 X 25	2.10	10.0		9.0		8.0	
		30	ASL 12 X 30	1.75	12.0		10.8		9.6	
		35	ASL 12 X 35	1.50	14.0		12.6		11.2	
		40	ASL 12 X 40	1.32	16.0		14.4		12.8	
		45	ASL 12 X 45	1.17	18.0	21 (206)	16.2	19 (186.3)	14.4	17 (166.7)
14	7	50	ASL 12 X 50	1.05	20.0		18.0		16.0	
		55	ASL 12 X 55	0.96	22.0		19.8		17.6	
		60	ASL 12 X 60	0.88	24.0		21.6		19.2	
		65	ASL 12 X 65	0.81	26.0		23.4		20.8	
		70	ASL 12 X 70	0.75	28.0		25.2		22.4	
		75	ASL 12 X 75	0.70	30.0		27.0		24.0	
		80	ASL 12 X 80	0.66	32.0		28.8		25.6	
		25	ASL 14 X 25	2.80	10.0		9.0		8.0	
		30	ASL 14 X 30	2.34	12.0		10.8		9.6	
		35	ASL 14 X 35	2.00	14.0		12.6		11.2	
14	7	40	ASL 14 X 40	1.75	16.0		14.4		12.8	
		45	ASL 14 X 45	1.56	18.0		16.2		14.4	
		50	ASL 14 X 50	1.40	20.0		18.0		16.0	
		55	ASL 14 X 55	1.27	22.0		19.8		17.6	
		60	ASL 14 X 60	1.17	24.0	28 (775)	21.6	25 (245)	19.2	22 (216)
		65	ASL 14 X 65	1.08	26.0		23.4		20.8	
		70	ASL 14 X 70	1.00	28.0		25.2		22.4	
		75	ASL 14 X 75	0.92	30.0		27.0		24.0	
		80	ASL 14 X 80	0.87	32.0		28.8		25.6	
		90	ASL 14 X 90	0.77	36.0		32.4		28.8	

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Table 2

Raymond® LIGHT DUTY DIE SPRINGS ISO SPECIFICATION SERIES METRIC DIMENSIONS GREEN										
Hole Dia. (mm)	Rod Dia. (mm)	Free Length (mm)	CATALOG NUMBER	Load at 1 mm Def. (N)	LOAD DEFLECTION TABLE					
					For Optimum Life (25% of free length)		For Long Life (30% of free length)		Maximum Operating Def. (25% of free length)	
					Load (N)	Deflection (mm)	Load (N)	Deflection (mm)	Load (N)	Deflection (mm)
A	B	C								*Maximum Deflection (mm)
10	5	25	203-104	10.0	62.5	6.3	75.0	7.5	87.5	8.8
		32	203-105	8.5	68.0	8.0	81.6	9.6	95.2	11.2
		38	203-106	6.8	64.6	9.5	77.5	11.4	90.4	13.3
		44	203-107	6.0	66.0	11.0	79.2	13.2	92.4	15.4
		51	203-108	5.0	63.8	12.8	76.5	15.3	89.3	17.9
		64	203-110	4.3	68.8	16.0	82.6	19.2	96.3	22.4
		76	203-112	3.2	60.8	19.0	73.0	22.8	85.1	26.6
12.5	6.3	305	203-148	1.1	83.9	76.3	100.7	91.5	117.4	106.8
		25	203-204	17.9	111.9	6.3	134.3	7.5	156.6	8.8
		32	203-205	16.4	131.2	8.0	157.4	9.6	183.7	11.2
		38	203-206	13.6	129.2	9.5	155.0	11.4	180.9	13.3
		44	203-207	12.1	133.1	11.0	159.7	13.2	186.3	15.4
		51	203-208	11.4	145.4	12.8	174.4	15.3	203.5	17.9
		64	203-210	9.3	148.8	16.0	178.6	19.2	208.3	22.4
16	8	76	203-212	7.1	134.9	19.0	161.9	22.8	188.9	26.6
		89	203-214	5.4	120.2	22.3	144.2	26.7	168.2	31.2
		305	203-248	1.4	106.8	76.3	128.1	91.5	149.5	106.8
		25	203-304	23.4	146.3	6.3	175.5	7.5	204.8	8.8
		32	203-305	22.9	183.2	8.0	219.8	9.6	256.5	11.2
		38	203-306	19.3	183.4	9.5	220.0	11.4	256.7	13.3
		44	203-307	17.1	188.1	11.0	225.7	13.2	263.3	15.4
20	10	51	203-308	15.7	200.2	12.8	240.2	15.3	280.2	17.9
		64	203-310	10.7	171.2	16.0	205.4	19.2	239.7	22.4
		76	203-312	10.0	190.0	19.0	228.0	22.8	266.0	26.6
		89	203-314	8.6	191.4	22.3	229.6	26.7	267.9	31.2
		102	203-316	7.8	198.9	25.5	238.7	30.6	278.5	35.7
		305	203-348	2.5	190.6	76.3	228.8	91.5	256.9	106.8
		25	203-404	55.8	348.8	6.3	418.5	7.5	488.3	8.8
25	12.5	32	203-405	45.0	360.0	8.0	432.0	9.6	504.0	11.2
		38	203-406	33.3	316.4	9.5	379.6	11.4	442.9	13.3
		44	203-407	30.0	330.0	11.0	396.0	13.2	462.0	15.4
		51	203-408	24.5	312.4	12.8	374.9	15.3	437.3	17.9
		64	203-410	20.0	320.0	16.0	384.0	19.2	448.0	22.4
		76	203-412	16.0	304.0	19.0	364.8	22.8	425.6	26.6
		89	203-414	14.0	311.5	22.3	373.8	26.7	436.1	31.2
30	15	102	203-416	12.0	306.0	25.5	367.2	30.6	428.4	35.7
		115	203-418	10.9	313.4	28.8	376.1	34.5	438.7	40.3
		127	203-420	9.5	301.6	31.8	362.0	38.1	422.3	44.5
		139	203-422	8.4	291.9	34.8	350.3	41.7	408.7	48.7
		152	203-424	7.5	285.0	38.0	342.0	45.6	399.0	53.2
		305	203-448	4.0	305.0	76.3	366.0	91.5	427.0	106.8
		25	203-504	100.0	625.0	6.3	750.0	7.5	875.0	8.8
35	17.5	32	203-505	80.3	642.4	8.0	770.9	9.6	899.4	11.2
		38	203-506	62.0	589.0	9.5	706.8	11.4	824.6	13.3
		44	203-507	52.9	581.9	11.0	698.3	13.2	814.7	15.4
		51	203-508	44.0	561.0	12.8	673.2	15.3	785.4	17.9
		64	203-510	35.2	563.2	16.0	675.8	19.2	788.5	22.4
		76	203-512	28.0	532.0	19.0	638.4	22.8	744.8	26.6
		305	203-548	1.1	418.5	381.3	520.7	463.5	660.4	609.6

*Tabulated deflections shown represent near solid and are for design information

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Spring terminology

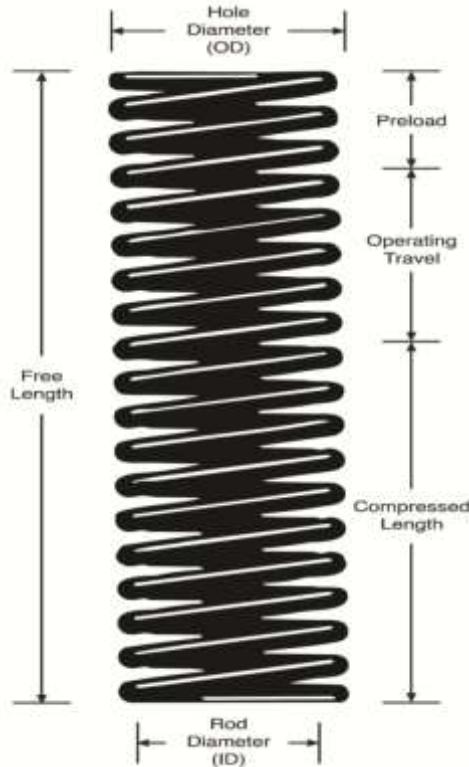


Fig.1.7

Outer Diameter
Inner Diameter
Free length
Preload
Deflection
Solid height
Load
Stiffness

Conventionally used spring material

Springs are generally manufactured from plain carbon steel or simply carbon steel.

Carbon steel has properties mainly due to its carbon content and does not contain more than 0.5% of silicon and 1.5% of manganese.

The plain carbon steels varying from 0.06% carbon to 1.5% carbon are divided into following types depending upon the carbon content.

1. Dead mild steel
2. Low carbon or mild steel.
3. Medium carbon steel.
4. High carbon steel.

Carbon steels which are used for spring materials have following properties useful for spring materials:

1. Allowable shear stress: 420 MPa (average service)
2. Modulus of rigidity G : 80 kN/mm²
3. Modulus of elasticity E : 210 kN/mm²

After studying the properties of various materials which make them suitable for manufacturing springs, E- Glass is selected for design and analysis of new spring.

Proposed material suitable for preparation of spring

E-glass

Usually the glass fiber can be made from silica alone, but some other materials are added to increase its work area which was limited due to high temperature and it will also give some extra properties which will be useful in other applications.

E-glass which is the example of the glass fiber with advanced properties of glass fiber.

E-glass was made to use in electrical application with the composition including:

- 1) Silicon dioxide (SiO_2)
- 2) Alumina (Al_2O_3)
- 3) Lime (CaO)

4) Magnesium oxide (MgO)

This was the original mixture which was found to compose the E-glass later Boron oxide was added to increase the difference between the temperature at which the e-glass melt and it formed the crystalline structure to prevent clogging of the nozzles used in fabrication.

V. FUTURE APPLICATION

To general trends are generally seen glass fiber industry:

One is upward which shows the enormous growth and second is downward which shows lower cost. And the country like china has both in control.

The glass fiber is used mainly where the cost is not the concern due to its high price. It is mostly used in making of parts of aircrafts (both commercial and passenger aircraft), turbine blade and the parts of wind mill.

Properties

- Properties of E-glass are as mentioned in the table below.
- E- glass does not have a well defined yield strength because the stress- strain relationship is typical.
- Hence the yield strengths of this material are taken as 70% of ultimate strengths.

Picture of E-Glass



Fig.1.8

Comparison of properties for carbon steel and E-Glass

Table 3

	Steel	E-glass
Density (g/cm ³)	7.85	2.4
Allowable shear stress (MPa)	420	71.7
Modulus of rigidity (kN/mm ²)	80	25
Modulus of elasticity (kN/mm ²)	210	72.4
Ultimate tensile strength (MPa)	505	3445
Yield tensile strength (Mpa)	215	2415
Poisson ratio	0.3	0.27

Specific strain energy

The main factor to be considered in the design of spring is the strain energy of a material used. Specific strain energy in the material can generally be expressed as

$$U = \frac{\sigma^2}{\rho E}$$

Where U = strain energy

σ = stress

ρ = density

E = young's modulus

This indicates that a material with lower young's modulus or density will have higher specific strain energy under the same stress condition. Thus we can say that E-Glass offers high strength and light weight.

Design for E-glass spring

The design of helical spring made of E-Glass is carried out considering the following parameters

Maximum Weight $W = 1000\text{N}$
 Maximum Deflection $\delta = 25\text{mm}$
 Permissible shear stress $\tau = 71.7\text{MPa}$
 Spring index (D/d) $C = 5$ (D= Mean diameter of spring, d = wire diameter of spring)
 Modulus of rigidity $G = 25\text{GPa}$

From the above data following results obtained

$$\text{Wahl factor } K = \frac{4C-1}{4C-4} + \frac{0.615}{C} = 1.31$$

Diameter of spring wire $d = 15.25\text{mm}$

$$(\tau = K \frac{8WC}{\pi d^2})$$

Mean diameter of spring $D = 76.26\text{mm}$

$$(D = Cd)$$

Outer diameter of spring $D_0 = 91.51\text{ mm}$

$$(D_0 = D + d)$$

Number of turns $n = 10$ turns

$$(\delta = \frac{8Wc^3n}{Gd})$$

Free length = 245.5mm

$$(n'd + \delta + .15\delta)$$

Pitch $P = 22.31\text{mm}$

$$(\frac{\text{free length}}{n'-1})$$

Design of spring in CREO Parametric

The design of spring having the values of dimensions as obtained by the analytical calculations is carried out in CREO Parametric.

The command used is helical sweep with the help of which a .prt file is generated which is later converted into .stp file for exporting it to ANSYS for analysis.

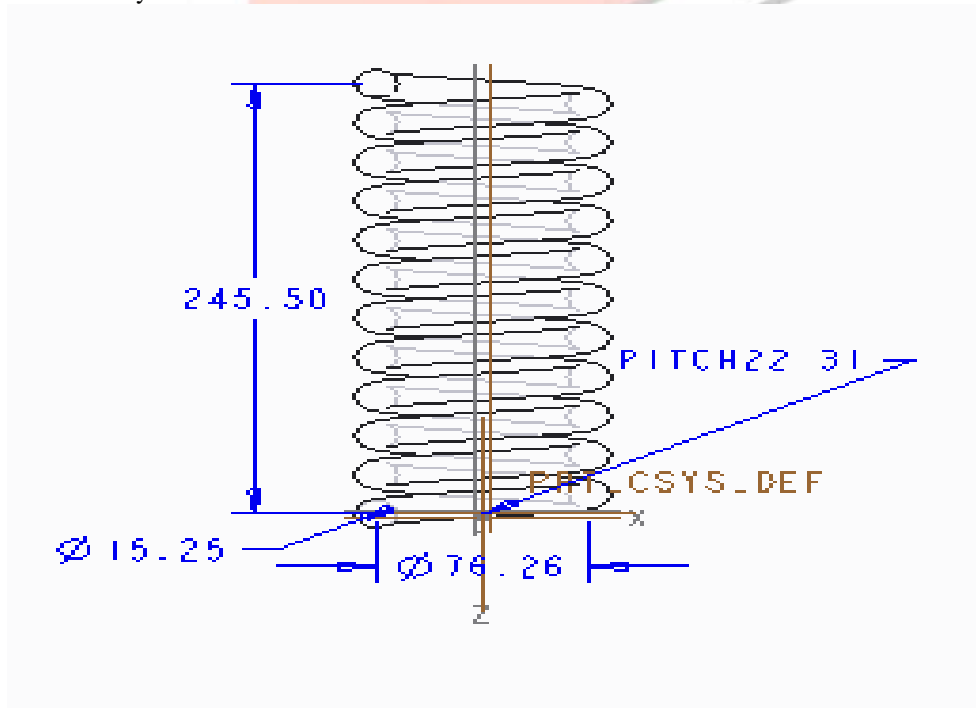


Fig.1.9

Static structural analysis

The file so generated in CREO parametric was imported to ANSYS for analysis.

The static structural analysis of the designed spring was carried out for tests under deformation and stress.

The properties of E-Glass were defined in the engineering materials.

The hex dominant method of was adopted for the generation of mesh for more accurate results.

A fixed support was inserted at the bottom part and force was applied axially from the top end.

Later the solution of the desired parameters was obtained.

The results of deformation and stress thus obtained are as under.

Total deformation results

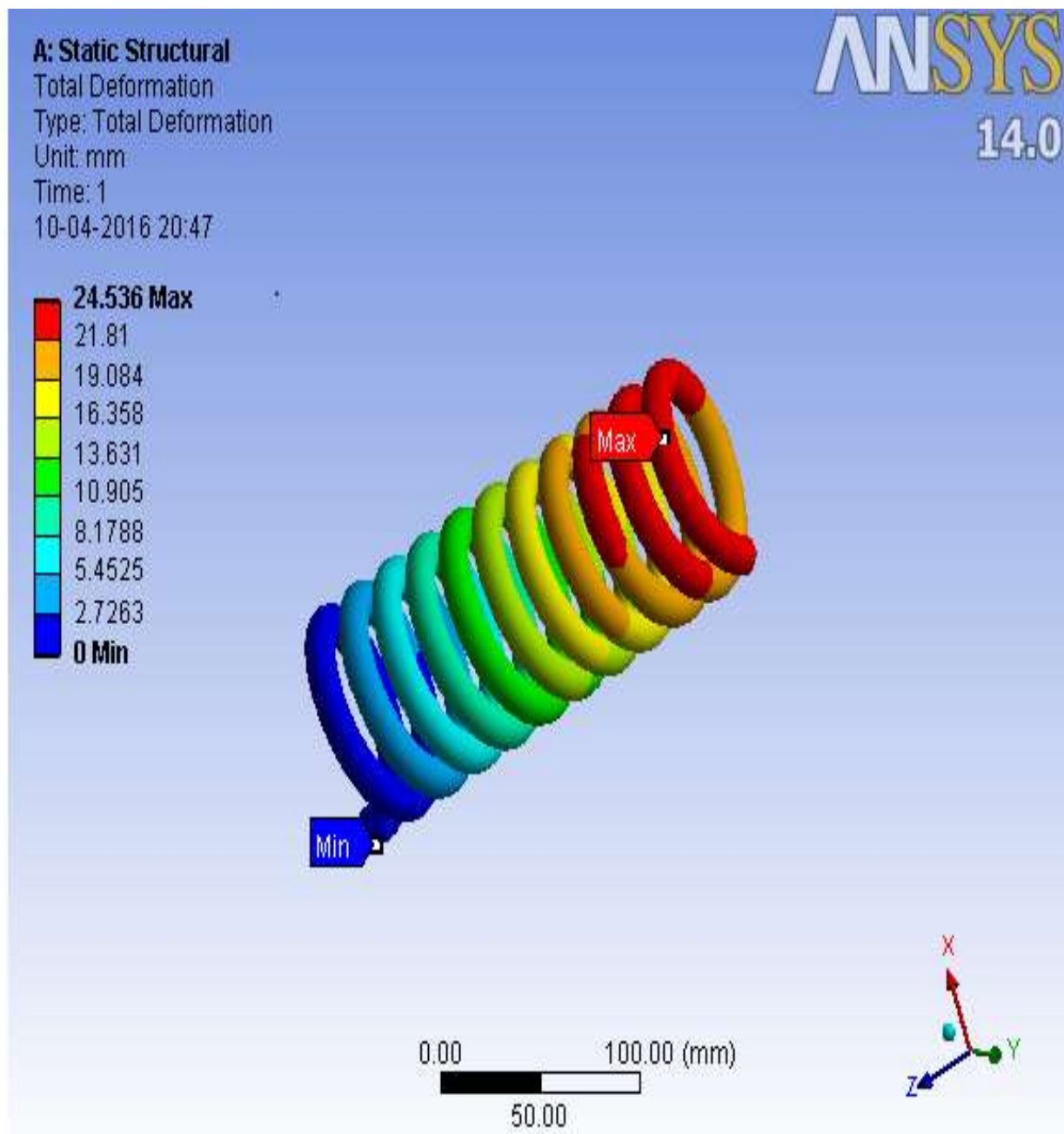


Fig.1.10

Equivalent stress results

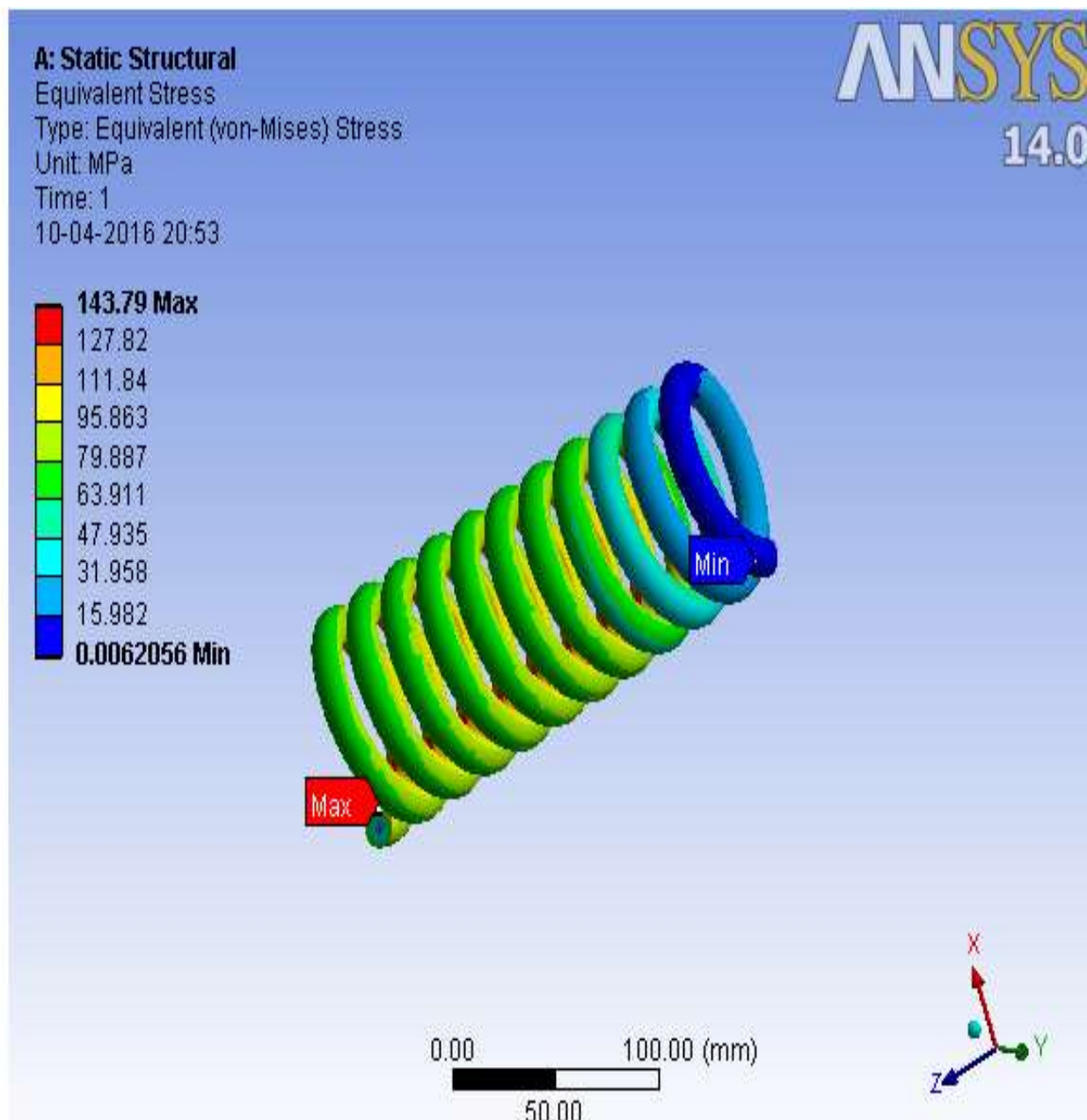


Fig.1.11

VI. CONCLUSION

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 maximum value of deflection obtained is 24.536mm which is less than 25mm. hence the design is safe under deflection.

The maximum value of equivalent stress obtained is 143.79Mpa which is well within the permissible limit i.e. 756MPa (yield strength in compression for E-Glass).

HENCE WE CAN SAY THAT THE DESIGN IS SAFE AND THUS THE HELICAL SPRINGS MADE OF E-GLASS CAN BE USED FOR THE APPLICATIONS OF SUSPENSION SYSTEM UNDER 1000N AXIAL FORCE.

VII. ACKNOWLEDGMENT

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