Failure Analysis of Springs used in tractor seat application and Optimization using FEA

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ABSTRACT

One of the major problems faced by automobile industries in few decades is the efficiency which is related to the weight of the product. This has given us to more research in lightweight materials without changing mechanical properties. The composite materials are giving this to industries. In this Paper the helical compression steel springs are replaced with that of composite materials. The composite materials used are E-glass/Epoxy and Carbon fiber/Epoxy. Spring analysis is done with FEA and results are compared with Existing Spring. The spring are manufactured and the experimental deflections are also measured. The study shows that the weight reduction achieved with composite spring. Thus, indicating that the composite material springs can be effectively used as replacement for heavy.

Index Terms**:** Composite, FEA, Helical Spring

1. INTRODUCTION

THE main function of these springs is to absorb the shock and vibrations and provide comfort to the driver. Current research work in Agriculture and automobile industries is largely focused in use of alternative materials in place with lightweight. Composite materials are the mixture of two or more materials. The use of composite materials reduces the weight of components but showing the same mechanical properties compared to the conventional materials. This leads to solve the problem of weight reduction faced in few decades by the spring manufactures. The helical springs are one of those components where the composite material can be implemented. The present work showcases the effective implementation of composite materials for helical compression spring in tractor seat in place of steel spring. The performance characteristics of the composite helical spring are compared with a randomly selected steel spring of a tractor helical compression springs are used in the Tractor seat.

2. Problem Statement

[A] In tractor seat, spring steel is used but weight of the seat is too much. So, optimize seat's existing spring and suggest good spring.

[B] Objective:-

1. To Design the Tension and Compression Springs for tractor seat application.

2. To investigate life cycles of Tension and Compression springs using Analytical and FEA technique and suggestion of best spring.

3. COMPOSITE MATERIALS

Composite material consists of two parts one matrix and the other reinforcement (Fibers). Thus the properties of composite are mixture of the two constituents. According to lamina the properties and behavior of composite changes. For unidirectional lamina the behavior is anisotropic [2] [3]. E-Glass/Epoxy and Carbon fiber/Epoxy (Where epoxy is matrix and E-glass, carbon are fibers) are two selected composites for helical spring with uni-directional lamina. The main parameters considered for selection are Mechanical properties, cost of materials and availability of material. The properties of the selected material prove to be appropriate for the selected application and the materials are available readily. Due to these factors these materials are selected.

4. DESIGN OF SPRING

After the selecting a suitable material and a safe stress value for a given spring, designer should next determine the type of end coil formation best suited for the particular application.

The parameters were selected by inserting values of d, D and N is the following equation

$$\delta = \frac{8PD^3N}{Gd^4},$$

$$\tau = K\left(\frac{8PD}{\pi d^3}\right)$$

- For steel Spring–
  Consider force on spring -1471.5 N

  - 1500 N for Design Purpose

Wire diameter = 7.5 mm

Mean Diameter = 57.5 mm

S_{ut}=1000 N/mm^2

Spring Index (C) = D/d =57.5/7.5=7.66

The permissible stress is given by,

τ= 0.5 S_{ut} =0.5(1500) =500 N/mm2

$$K = \left(\frac{4C - 1}{4C - 4} \right) + \left(\frac{0.615}{C} \right)$$
$$K = \left(\frac{4x7.66 - 1}{4x7.66 - 4} \right) + \left(\frac{0.615}{7.66} \right) \quad = 1.19$$

$$\tau = K\left(\frac{8PD}{\pi d^3} \right)$$
$$\tau = 1.19\left(\frac{8x1500x57.5}{\pi x7.5^3} \right) = 619 \text{ N/mm}^2$$

$$\delta = \frac{8PD^3N}{Gd^4} = \frac{8x1500x57.5^3x35}{87500x7.5^4} = 272.5mm$$

Stiffness = Load /Deflection = 1500/272 =7.79 N/mm

- For E-glass Epoxy Spring –

C=4.5

d= 15mm

D=67.5mm

N=24

$$\delta = \frac{8PD^3N}{Gd^4} = \frac{8x1500x67.5^3x13}{3700x15^4} = 256mm$$

$$K = \left(\frac{4C - 1}{4C - 4} \right) + \left(\frac{0.615}{C} \right)$$
$$K = \left(\frac{4x4.5 - 1}{4x4.5 - 4} \right) + \left(\frac{0.615}{4.5} \right) \quad = 1.26$$

$$\tau = K\left(\frac{8PD}{\pi d^3}\right)$$
$$\tau = 1.26\left(\frac{8x1500x67.5}{\pi x15^3}\right) = 76.38 \text{ N/mm}^2$$

The Design is safe as design stress is lower than allowable and the deflection results are satisfactory for the application.

- For carbon Epoxy spring –

G = 3900 N/mm^2

S_{ut}=1149 N/mm^2

Assume,

Spring Index (C) = 4.5,

d= 15mm

D=67.5mm

N=13

$$\delta = \frac{8PD^3N}{Gd^4} = \frac{8x1500x67.5^3x13}{3700x15^4} = 256mm$$

$$K = \left(\frac{4C-1}{4C-4}\right) + \left(\frac{0.615}{C}\right)$$
$$K = \left(\frac{4x4.5-1}{4x4.5-4}\right) + \left(\frac{0.615}{4.5}\right) = 1.26$$

$$\tau = K\left(\frac{8PD}{\pi d^3}\right)$$
$$\tau = 1.26\left(\frac{8x1500x67.5}{\pi x15^3}\right) = 76.38 \text{ N/mm}^2$$

The design is safe as design stress is lower than permissible and the deflection results are satisfactory for the application. Thus, this design is selected.

Specification	E-Glass Epoxy	Carbon Epoxy
Coil diameter(d) mm	15	15
Mean Diameter(D) mm	67.5	67.5
Spring constant(C)	4.5	4.5
Number of turns(N)	13	13
Total number of turns(Nt)	15	15
Length(L) mm	440	440
Pitch(p) mm	20	20
Shear modulus(G) N/mm^2	3704	3940

Table-1 Selected Values For Springs

4. FINITE ELEMENT ANALYSIS

Modelling:-

The modeling of spring is carried in CREO. In CREO Part Modelling feature is used for modeling the spring of desired dimensions. The selected reference steel spring had square.

Material:

The material properties of composites are not present in default material list of ANSYS, hence the properties have to be entered in the directory.

Meshing and loading conditions:-

After meshing the loading and boundary conditions are applied. The ends which are seated in the suspension system of helical spring are fixed and at the other end axial load are applied. As the spring is considered for Seat the loads are calculated accordingly. The average weight of Human is 80kg and along with two person the total weight becomes 160kg. And again the load is distributed between two struts at rare side. Thus approximately 80kg load will act upon each strut. Hence the analysis is carried for 1500N, 1000N and 750N load.

Static analysis:-The linear static analysis is carried out to determine the total deformation and shear stress. The deformation and stress analysis is carried for each 750N, 1000N and 1500N load.

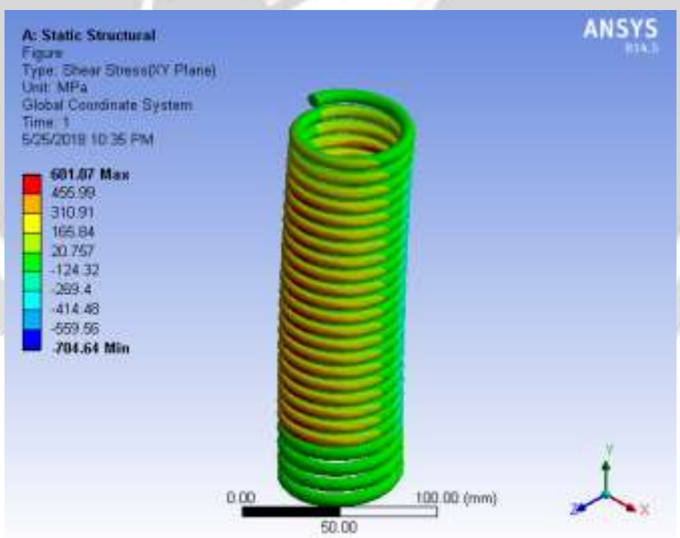

Fig No.1: Stress For Spring Steel 1500 N

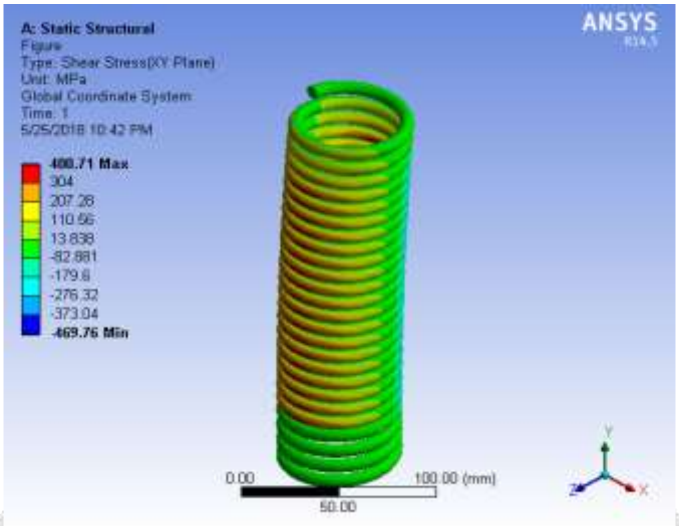

Fig No.2:Stress For Spring Steel 1000N

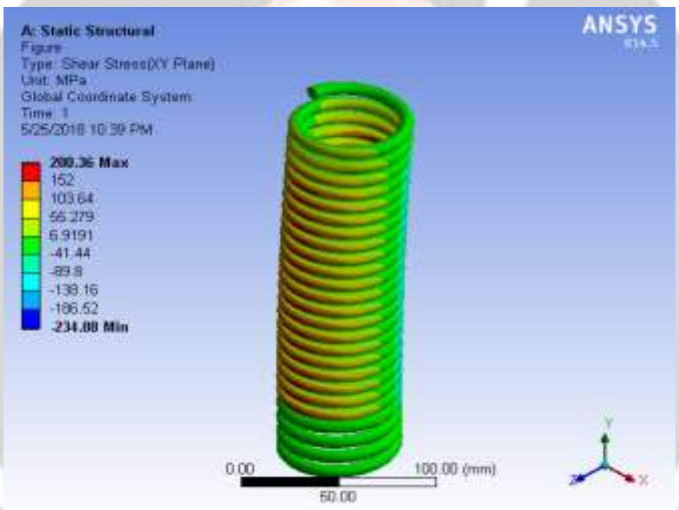

Fig No.3: Stress For Spring Steel 750 N

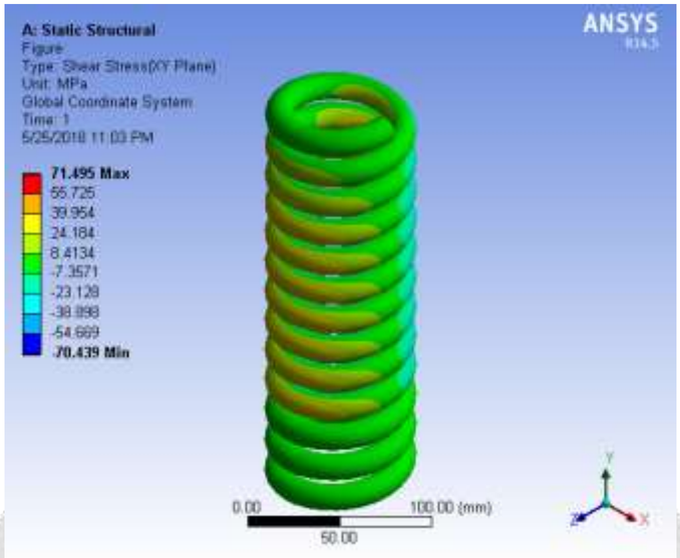

Fig No.4: Epoxy Glass And Epoxy Carbon Stress 1500 N

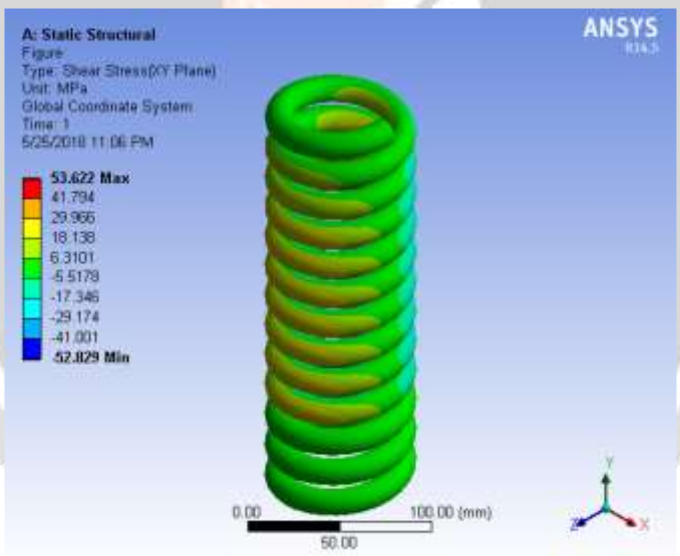

Fig No.5: Epoxy Glass And Epoxy Carbon Stress 1000 N

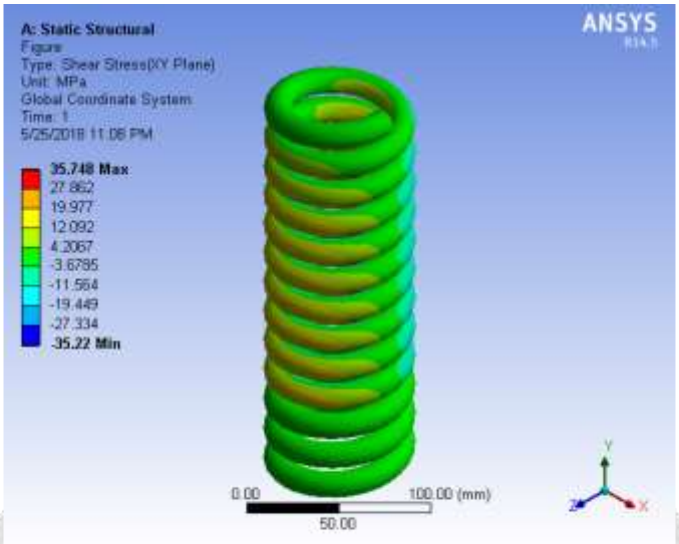

Fig No.6: Epoxy Glass And Epoxy Carbon Stress 750 N

4. RESULT AND ANALYSIS

Load in N	Deflection in mm		
	Steel	E-glass/Epoxy	Carbon/Epoxy
750	179	170	172.1
1000	222.1	210	208.6
1500	272.14	256	256.5

Table 3 FEA Deflections

Load in N	Deflection in mm		
	Steel	E-glass/Epoxy	Carbon/Epoxy
750	169	172	178
1000	200	201.2	199.3
1500	259	249	249

The ANSYS results of deflection indicated that the deflection for load 500N, 750N and 1000N are almost near for all the three springs, i.e., Steel spring, E-glass/Epoxy

Table 4 Theoretical Shear Stress Values

Load in N	Shear stress in N/mm^2		
	Steel	E-glass/Epoxy	Carbon/Epoxy
750	173	38.5	40.1
1000	520	52.3	54.5
1500	614	76.68	76.88

Table 5 FEA Shear Stress Results

Load in N	Shear Stress in N/mm^2		
	Steel	E-glass/Epoxy	Carbon/Epoxy
750	162.22	35.74	35.74
1000	543.33	53.62	53.62
1500	602	71.45	71.45

Table 6 Stiffness Results

	Stiffness in N/mm		
	Steel	E-glass/Epoxy	Carbon/Epoxy
Theoretical	7.79	25.35	26.75
FEA	8.2	19.03	22.07

The stiffness results shows that the steel and carbon/epoxy springs are the stiffest with E-glass and Carbon/Epoxy are Stiffer than spring.

Table 7 Weight Results

Steel (Average)	E-glass/Epoxy	Carbon/Epoxy
1064 grams	602 grams	436 grams

The weight of composite spring is very small as compared of steel spring. The E-glass/Epoxy spring with 600 gram weight is almost 40% lighter than steel spring while carbon/Epoxy spring with 436 gram is almost 60% lighter.

The theoretical and FEA results have deviations within the allowable range.

6. CONCLUSIONS

1. FEA and optimization techniques can be used for effective performance and weight reduction of spring with better strength.
2. Final optimized model showed stress and deformation values within safe limit and Carbon Epoxy having suitable alternative to existing material.
3. Optimized spring design shows 50% less weight compared to existing design and 22.48% less stress than existing.
4. Error between FEA and Experimental testing deformation results is small i.e.,15%.

5. ACKNOWLEDGEMENT

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