Comparative Analysis of Two-Wheeler Suspension Helical Compression Spring for Steel and Composite Material at Different Loading Conditions

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Abstract -The Springs are crucial suspension elements on automobiles which are necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. Helical Compression springs are most commonly used for vehicle suspension and some industrial applications. The present work attempts to study the feasibility to select composite materials in the design of helical compression spring used in automobile suspension systems. The use of composite materials is increasing in the design of automobile components due to their light weight and costs. The objective of this is to compare stresses, deflection and weights for both steel and composite material. In this research, steel helical spring related to light vehicle suspension system under the effect of a uniform loading has been studied and finite element analysis has been compared with analytical solution. Afterwards, steel spring has been replaced by composite helical spring glass/Epoxy. Spring weight, maximum stress and deflection have been compared with steel helical spring. According to the results, it was found that Compared to the steel spring, the composite spring has stresses that are much lower, the deflection is higher and the spring weight is nearly 75% lower.

Keywords: ANSYS, Composite materials, Conventional steel, Glass/Epoxy, Helical compression spring

1.INTRODUCTION

Springs are crucial suspension elements on automobiles which are necessary to minimize the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. Helical Compression springs are most commonly used for vehicle suspension and some industrial applications. The fuel efficiency and emission gas regulations of automobiles are two important issues in these days. The best way to increase the fuel efficiency is to reduce the weight of the automobiles by employing composite materials in the structure of the automobiles.

Composite springs has low weight, low Stresses and corrosion resistance hence steel springs are replaced by them. Steel springs cannot withstand high temperature. At high temperature where it is required to operate composite springs are used. Metal springs have several advantages, they are very cheap to produce and can be produced in almost all kinds of measures and in a very broad range of stiffness. The design and manufacture of composite springs are very difficult as composite materials are Anisotropic. Therefore, the uses of composite materials in springs are not yet popular. However, they are used in the suspension system of the automobiles. Because composite springs have some advantages over the metal springs, many researchers are actively involved in the study of composite springs. Abdul Budan and Manjunathathe [1] checked feasibility of replacing the metal coil spring with the composite coil spring. Three different types of springs were made using glass fiber, carbon fiber and combination of glass fiber and carbon fiber. The objective of the study was to reduce the weight of the spring. Mehdi Bakhshesh and Majid Bakhshesh [2] studied replacement of a helical steel spring by three different composite helical springs. Shokrieh and Rezaei [3] analyzed a four-leaf steel spring used in the rear suspension system of light vehicles.

The aim was to obtain a spring with lowest weight that is having capacity to carry given static external forces without failure. Compared to the steel spring, composite spring has stresses that are much lower and spring weight is nearly 80% lower.Chang et al. [4] have conducted the experiment on mechanical behavior of helical composite springs. They have made the springs with different material structures like, unidirectional laminates, rubber core unidirectional laminates, unidirectional laminates with a braided outer layer, and rubber core unidirectional laminate with a braided outer layer. Dolas and Jagtap [5] also analyze the performance of Shock absorber spring by varying stiffness, which is obtained by doing optimization using Genetic Algorithm as optimization technique to used maximum ride comfort.Goran and Marino [6] find out that due to frequent failures of coil springs on a specific type of motor vehicle, analysis of possible causes of failures was performed. Analysis was done on a single coil spring removed from a vehicle after failing in service. Choi [7] carried finite analysis method for simulating a camshaft cap punching bench test. Stiffness results of simulated camshaft cap component were correlated with the test data and validated the modal accuracy in terms of material and boundary conditions. Pawar et al. [10], In their paper, mathematical and finite element analysis methodology using the obtained the weight reduction of the helical compression spring. Jadhav and Gawande [11], in their paper, 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 and aching the weight of composite material.Youli et al. [9] find out that from bearing coil to first active coil in service, compression coil spring fractured at the transition position and for fully active coil the nominal stress here should always be much less than that at the inside coil position. Logavigneshwaran and Sriram [12] the objective of the studies was for comfortable rides vehicles by changing the wire diameter of coil spring and design to the shock absorber.

The literature survey has revealed that, only prototype composite springs were prepared and tested for the performance. Since the time consumed for the manufacturing of the composite springs is more, the standard and simple method of mass production of composite coil springs is required from the economical point of view. In this study a spring from two-wheeler is taken for replacement. Glass fibers are used for the manufacture of composite coil springs. The principal advantage of fiber reinforced polymer matrix composites for automobile parts is weight savings, part consolidation, and improvement in NVH (noise, vibration and harshness). The absence of corrosion problems, which lowers maintenance cost for automobile parts, enables the use of fiber reinforced polymeric composite. Springs were manufactured in this study with glass fibers GF. These springs were tested. The results show the feasibility of composite springs for light vehicle applications.

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2. Body of Paper

- **DESIGN CALCULATION OF HELICAL SPRING-**

Specification of spring

Spring wire diameter (d) = 8 mm

Mean coil diameter (D) = 40 mm

Free length of spring (Ls) = 160 mm

No of turns (n) = 11

Spring Index (C) = $\boldsymbol{D/d}$ =40/8=5

Wahl's stress factor (K) = 4 C−1/4C−4 + 0.615/C K = 4 x 5−1/4 x 5−4 + 0.615/5 = 1.31

Deflection (y) =8FnD3/Gd4

Maximum shear stress (τmax) =K8FD/πd3

The Design of a helical compression spring currently used in the suspension system of a two wheeler is analyzed in this work.

Load considerations:

Weight of bike= 131 kg

Let weight of first person= 70 kg

Weight of bike and first person= 131+70=201 kg

Weight of first and second person= 140 kg

Weight of first and second person and bike=131+140=271 kg

W1=201 kg and W2=271 kg

Suspension is 65 %

Hence 65% of 201= 201 X 65/100 = 130.65 kg

Similarly, 65% of 271 = 271 X 65/100 = 176.15 kg

Consideration of dynamics load it will be double Therefore W1= 130.65 X 2 = 261.3 kg

And W2 = 176.15 X 2 = 352 kg

Now load - F=Wx9.81

F1=W1x9.81 = 261.3x 9.81 = 2563.35 N

F2=W2x9.81 = 352x9.81 = 3453.12 N

For single shock absorber, F1=2563.35/2 = 1281.7 N

F2 = 3453.12/2 = 1726.6 N

For this load considerations,

Table -1: Design Calculation for Stress and Deflection Values at Various Loads

(Conventional Steel Helical Spring)

Sr. No.	Load applied on conventional Helical spring (N)	Maximum shear stress (τmax) in MPa	Deflection (y)occurred in (mm)
1.	1281.7	334.03	22.02
2.	1726.6	450	29.67

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➢ MATERIAL SELECTION-

Table -2: Properties of Materials (For Steel Spring)

Sr.No	Specification	Value
1	Density(g/cm3)	7.85
2	Allowable shear stress (MPa)	480
3	Modulus of rigidity (MPa)	80000
4	Modulus of elasticity (MPa)	210000
5	Ultimate Tensile strength (MPa)	505
6	Yield tensile strength (MPa)	215
7	Poisson's Ratio	0.3

Table -3: Properties of Materials (For Composite Glass/ Epoxy Spring).

Sr. No	Properties		Value
1	Young modulus(E)	EX(MPa)	43000
		EY(MPa)	6500
		EZ(MPa)	6500
2	Poisson's ratio	PRXY	0.27
		PRYZ	0.06
		PRZX	0.06
3	Shear modulus(G)	GX(MPa)	4500
		GY(MPa)	2500
		GZ(MPa)	2500
4	Density	ρ(kg/m m^3)	0.000002

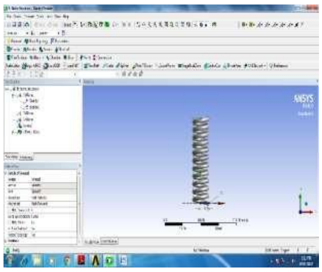
➢ ANALYSIS OF SPRINGS-

Assumptions:

- **Software to be used for ANSYS 18**
- Model simplification for FEA.
- **Meshing size is limited to computer compatibilities.**
- Static analysis is considered.
- Material used for steel Helical spring analysis is isotropic

4.1Modeling of Steel helical spring

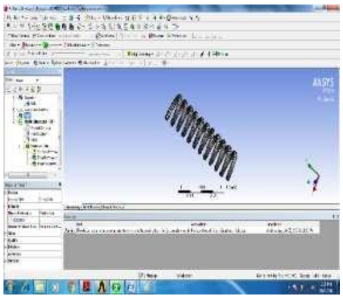
Fig -1: Drawing of Steel helical spring



Number of elements used are 5841 & and number of node used are 30840.

- Type of meshing: 3D
- Type of elements: Automatic

Fig -2: Modeling of Steel helical spring (Meshed body)



4.2 Defining force

Apply boundary condition-

Boundary condition one end remote displacement for component Y free, X and Z fixed and rotation Z free, X and Y fixed and other end remote displacement for component Y free, X and Z fixed and rotation Z free, X and Y fixed. Loading conditions involves applying a load lower side of spring.

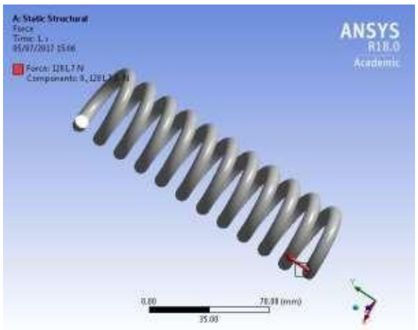


Fig -3: Modeling of Steel helical spring (Defining Force)

4.3 FEA-Result Analysis of Steel helical spring.

Application of Load on spring = 1281.7 N

Maximum shear stress contour of steel helical spring at 1281.7 N.

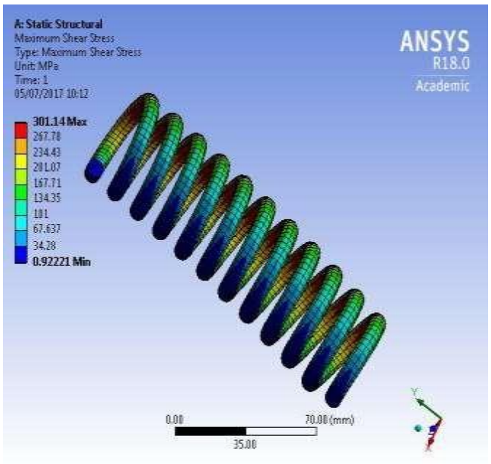


Fig -4: Maximum shear stress contour of steel helicalspring at 1281.7 N.

Maximum deflection contour of steel helical spring at 1281.7 N.

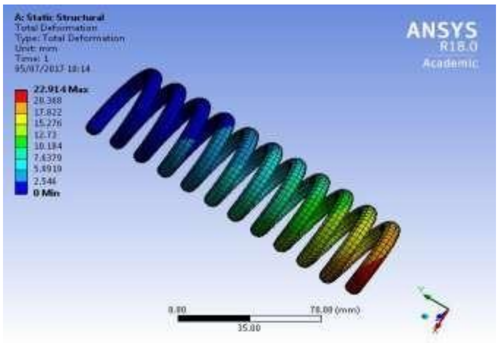


Fig -5: Maximum deflection contour of steel helical springat 1281.7 N.

Table -4: Results of FEA for Stress and Deflection Values at Various Loads (Steel Helical Spring)

Sr. No.	Load applied on conventional Helical spring (*N*)	Maximum shear stress (τmax) in *MPa*	Deflection (y) occurred in (*mm*)
1.	1281.7	301.14	22.91
2.	1726.6	426.62	30.55

4.4 FEA Result Analysis of Composite helical spring. Application of Load on spring = 1281.7 N

Maximum shear stress contour of composite helical spring at1281.7 N.

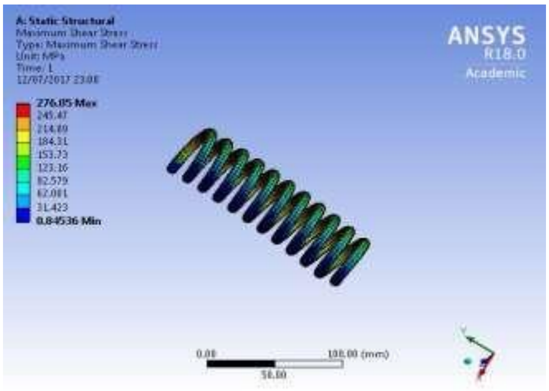


Fig -6: Maximum shear stress contour of compositehelical spring at 1281.7 N

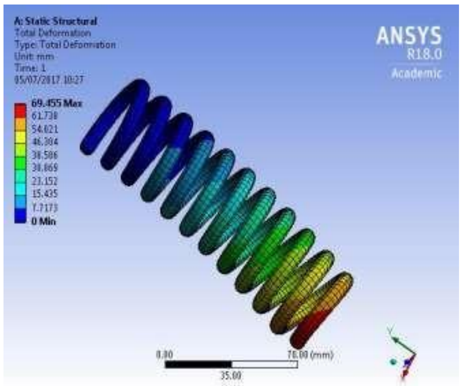


Fig -7: Maximum deflection contour of composite helicalspring at 1281.7 N

Table -5: Results of FEA for Stress and Deflection Values at Various Loads (Composite Helical Spring)

Sr. No.	Load applied on conventional Helical spring (*N*)	Maximum shear stress (τmax) in *MPA*	Deflection (y) occurred in(*mm*)
1 .	128 1.7	276.05	69.46
2	172 6.6	391.48	92.61

➢ EXPERIMENTAL VALIDATION

For tests, the existing helical spring designed by the Sponsoring firm for vendors is put to test. The helical spring would ordinarily experience gradually applied load. For reasons of safety, `sudden load' is considered during its design stage. As such, existing steel helical spring is tested for mechanical strength, while a trial is taken.

The results obtained of deflection for specified loads are discussed in compared to both that of steel and composite helical springs.

Fig -8: Experimental testing.

RESULTS AND DISCUSSION

For conventional steel and composite helical spring at different loading conditions for load F1 and F2, the comparison of maximum stresses can be seen in table VI. It can be seen that maximum stresses induced in composite springs are comparatively less than that of steel springs

Table -6: Comparison of Static Analysis (FEA) Results for Conventional

Steel Helical Spring and Composite Material.

Sr. No.	Load applied on spring (N)	Maximum shear stresses in MPa (steel spring)	Maximum shear stresses in MPa (composite spring)
1.	1281.7	301.14	276.05
2.	1726.6	426.62	391.48

From tables 7 and 8 shows the comparison for theoretical, FEA and experimental results for steel and composite materials resp. with percentage variation. It can be seen that deflection obtained in steel helical spring is more than that of composite spring and the stiffness of composite coil springsis less than that of steel spring having same dimensions; hence the use of the composite coil springs can be limited to light vehicles, which requires less spring stiffness.

Table -7: Comparison of Theoretical, Static Analysis (FEA) And Experimental Results for

Conventional Steel Helical Spring

Sr. No .	LOAD (N)	Deflection (y)(mm)			
		Theoretical Result	Static Analysis Results (FEA)	Experimental Results (UTM Machine)	Percentage Variation observed
1	1281.7	22.06	22.91	19.9	0.1 %
2	1726.6	29.67	30.55	29.6	0.03 %

Table -8: Comparison of Theoretical, Static Analysis (FEA) And Experimental Results

Sr. No	LOAD (N)	Deflection (y)(mm)			
		Theoretical Result	Static Analysis Results (FEA)	Experiment l Results (UTM Machine)	Percentage Variation observed
1.	1281.7	70.49	69.46	67.7	0.02 %
2.	1726.6	94.46	92.61	90.2	0.03 %

Table 9 shows the weight comparison for both steel and composite material spring. It can be seen that the weight of helical spring is reduced by about 75% by replacing steel helical spring with composite helical spring.

Table -9: Weight Reduction

Sr.no	Weight (Kg)	% Material required compared to present design	% Material saved as compare to present design
Present material (Steel)	0.770	100	---------------
Optimized(Composite Material)	0.186	24.16	75.84

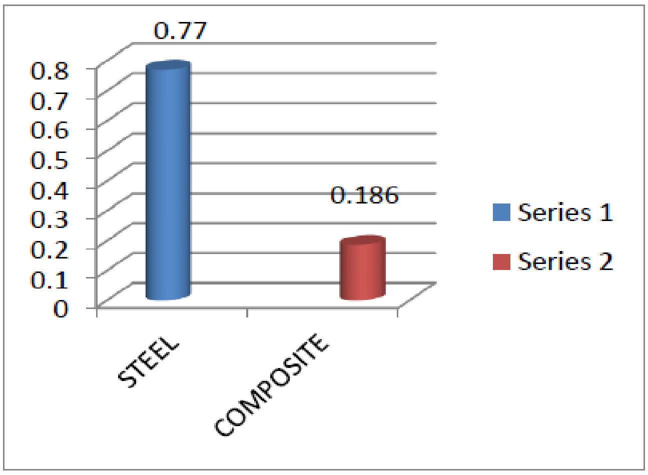


Fig -9: Comparison graph result of weights in steel HelicalSpring and composite helical spring.

3. CONCLUSIONS

The composite helical spring overcomes the current challenge that automobile industries is facing that of reduction in weight as composite helical springs have less weight than that of conventional steel helical spring with same design specifications but until now it is not financially effective over steel springs. Strain energy capacity and strength to weight ratio of composite material as compared to those of steel material is high. In this manner, it is concluded that composite materials are feasible in design of helical compression used in automobile suspension system and composite helical spring is effective replacement for the current steel helical spring in automobile industries.

1. The composite materials are feasible to be used in design of helical compression spring used in automobile suspension system.
2. The weight of helical spring is reduced by about 75% by replacing steel helical spring with composite helical spring.
3. The stresses in composite helical spring are reduced by 50-80% as compared to that in steel helical springs.
4. The stiffness of composite coil springs is less than that of steel spring having same dimensions; hence the use of the composite coil springs can be limited to light vehicles, which requires less spring stiffness.
5. The criteria of selection of composite material for springs depends upon the cost and use of the spring which can be compensated by saving the fuel from weight reduction as composite materials are costly than that of steel and its manufacturing is difficult.

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