Analysis and Experimental Validation For Fatigue Behavior of Composite Material Helical Compressive Spring used for Four Wheeler Suspension System

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ABSTRACT

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. Metal coil springs can be replaced by composite springs because of high strain energy, less weight and high corrosion resistance. Carbon pre-peg epoxy based composite spring is the best alternate to metallic springs and e-glass epoxy based composite springs. A composite helical spring is developed using mould making process and experimental fatigue testing are carried out on E-Glass fiber based spring. The results indicate that E-Glass fibers are superior in structural parameters compared to metallic springs.

Keywords: helical spring, composite material, ANSYS.

1.INTRODUCTION

Spring are crucial suspension element on automobiles which is necessary to minimize the vehicle vibrations, impacts and bumps due to road irregularities and create a comfortable ride. coil spring are commonly used for automobiles suspension and industrial application the fuel efficiency an emissions gas regulations of automobiles are two important issues in this days. the best way to increase the fuel efficiency is to reduce the weight of the automobile by employing composite material in the structure of the automobile . metal coil spring can be replaced by composite spring because of weight reduction and corrosion resistant .metal coil springs cannot withstand at high temperature .Therefore the application of composite material spring purpose of saving energy and improving the performance of shock absorber with high weight and high quality .composite spring have to be used for today's vehicle with the more no of electric vehicle and hybrid vehicles are entering into the market in the present scenario it has become essential to go for the light component for improving the efficiency because composite springs have some advantage over the metal spring many researches are actively involved in the world in the study in the study of composite spring

2. Material and Method

Composite coil springs have many advantages over the conventional. there light and have better performance in fatigue and dynamic response in addition to the structural benefits compose it springs can be designed to render the optimal Mechanical properties by orientation and content of reinforcing fibres they have been typically manufactured by mould making process although this process can be cost effective maybe Limited which results in the strength and stiffness also from three different types of spring material glass fibre ,Carbon fibre and combination of glass fiber and carbon fiber we select E-glass fiber for make helical spring. This E-glass fibre contain epoxy resin, binder powder, cobalt hardner and glass fiber.

(E-glass fiber composite material spring)

LITERATURE REVIEW

Manish Dakhore et.al. [1]

He has studied value of stress found to be more at the critical section of the spring as indicated by red colour. Hence possibility of failure is more at that section compared to other section of spring. This paper is discusses about locomotive suspension coil springs, their fundamental stress distribution and materials characteristic. The analysis of locomotive spring is carried out by considering cases, when the locomotive at the straight path, curved path and on uphill. This paper also discusses the Experimental analysis of a helical suspension spring by using strain gauge. The stress analysis for the forces obtained and for modal and harmonic response has been carried out by FEA using ANSYS.

Md. Mustak et.al. [2]

Studied the used of E-poxy glass materials for the design of helical suspension spring. The metal coils of helical spring are replaced by e-poxy carbon. In this work finite element analysis of helical spring is analyzed by using ANSYS, and in out the values of all parameters.

Aamir A. Waghade et.al. [3]

Have carried out the works on harmonic analysis of helical suspension spring. In this paper they have introduced the method for rectangular cross section helical spring. This paper discusses the experimental analysis of ahelical suspension spring by using strain gauge. The stress analysis for the forces obtained and for modal and harmonic response has been carried out by FEA analysis.

Achyut P. Banginwar et.al. [4]

He carried out work on the design and analysis of shock absorber using finite element analysis in this paper; he discussed about shock absorbing system by using 3D Pro-

Engineering Software and validates the design, he has done structural analysis, modal analysis on the shock absorber system.

Mehdi Bakhsheshet.al. [5]

Hehavestudied result found by comparing steel spring with composite helical spring it has been found to have lesser stress and has the most value when fiber position has been considered to be in direction of loading. Also weight of spring has been reduced shown that changing percentage of fiber, especially at Carbon/Epoxy composite, does not affect spring weight.

P.S.Valsange [6]

He have been presented the review of fundamental stress distribution, characteristic of helical coil springs. An in depth discussion on the parameters influencing the quality of coil springs is also presented. Factors affecting strength of coil spring, F.E.A. approaches by the researchers for coil spring analysis are also studied. Reduction in weight is a need of automobile industry. Thus the springs are to be designed for higher stresses with small dimensions. This requires critical design of coil springs. This leads to critical material and manufacturing processes. Decarburization that was not a major issue in the past now becomes essential, to have better spring design.

Vladimir Kobelev [7]

He presented research work on Shape Optimization for Helical Compression Springs.This work is concentrated for reducing impact events in railroad cars, primarily, and some heavy trucks, helical, or coil, springs are used.In some vehicles, torsion bars are used instead of the coil springs. The reduction of weight of the suspension springs causes the decrease of unsprung mass of the axle, and has a positive influence on the comfort, traction and steering properties of the car.

4.0 Terms used in Compression Springs

a. Specific Strain Energy

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

$$U = \frac{1}{2} \text{x W x } \sigma$$

b. Solid Length

When the compression spring is compressed until the coils come in contact with each other, then the spring is said to be *solid*. The solid length of a spring is the product of total number of coils and the diameter of the wire. Mathematically, Solid length of the spring,

$LS = n'.d$

c. Free Length

The free length of a compression spring, as shown in Fig.1.2 is the length ofthe spring in the free or unloaded condition. It is equal to the solid length plus the maximum deflectionor compression of the spring and the clearance between the adjacent coils (when fully compressed).Mathematically,

Free length of the spring,

LF = Solid length + Maximum compression + Clearance betweenadjacent coils (or clash allowance).

$LF = n'.d + \delta max + 0.15\ \delta max$

The following relation may also be used to find the free length of the spring, i.e. $LF = n'.d + \delta max + (n' - 1) \times 1\ mm$

In this expression, the clearance between the two adjacent coils is taken as 1 mm.

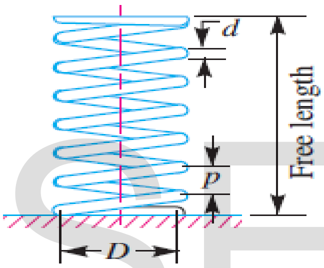


Fig.1.2.Free Length of Spring

d. Spring Index

The spring index is defined as the ratio of the mean diameter of the coil to the diameter of the wire. Mathematically,

Spring index,

$C = D / d$

e. Spring Rate

The spring rate (or stiffness or spring constant) is defined as the load required per unit deflection of the spring. Mathematically,

Spring rate,

$k = W / \delta$

Where,

W = Load,

δ = Deflection of the spring.

K = Stiffness or spring rate.

f. Pitch

p = Free length/n'-1

The pitch of the coil may also be obtained by using the following relation, i.e.

Pitch of the coil,

$$P = \frac{\text{Free Length of Coil}}{n' - 1}$$

5.0 Design Calculation for Existing & composite spring,

Mean Diameter of spring=90 mm

Wire Diameter=10mm

Nos.of Active Coils=07

Modulus of Rigidity for Steel=80 KN/mm^2=80 x 10^3 N/mm^2

Axial Loading =200 N

- Spring Index=C=$\frac{D}{d} = \frac{90}{10} = 9$
- Shear Stress Factor=$K_s = 1 + \frac{1}{2C} = 1 + \frac{1}{2 \text{ x} 9} = 1.05$
- **Maximum Deflection of steel Spring**

$$\sigma = \frac{8WD^3n}{Gd^4} = \frac{8 \text{ x } 200 \text{ x } 90^3 \text{x} 7}{80 \text{ x } 10^3 \text{ x } 10^4} = 9.47\text{mm.}$$

- **Stiffness of steel Spring**

$$\text{Stiffness} = \frac{Gd^4}{8DN^4} = 21.10\text{N/mm}$$

- **Maximum Deflection of composite Spring**

$$\sigma = \frac{8WD^3n}{Gd^4} = \frac{8 \text{ x } 200 \text{ x } 90^3 \text{x} 7}{32 \text{ x } 10^3 \text{ x } 10^4} = 21.66 \text{ mm}$$

- **Stiffness of composite Spring**

$$\text{Stiffness} = \frac{Gd^4}{8DN^4} = 9.49\text{N/mm}$$

So considering above stiffness and deflection calculations we decide as per springs in series (K1+K2+K3=K) .we have to select 3 spring composite material glass fiber against steel spring.

6.0 Operation Of The Spring Stiffness Testing Machine

Spring testing machine are used for Spring stiffness testing this include spring testers which are commonly used to test stiffness of disc springs, ware springs, coil springs, and spring type components .

1) The spring testing machine consists of two plates, two side pillars, a base, a mechanism .

2) The assembly consists of an upper plate and a lower plate. Spring is attached between these two plates. Upper plate is adjustable according to the height of spring and lower plate is connected to base of machine.

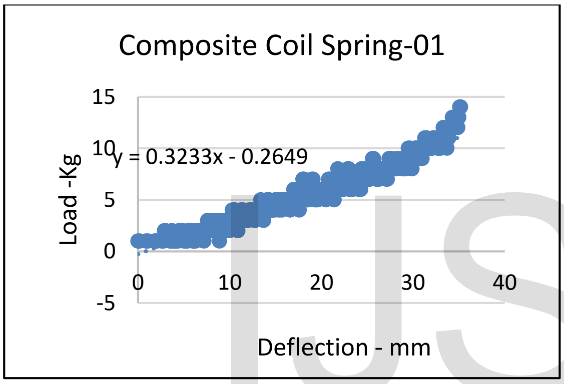
3) Our 3 spring fixed in between two plates Some initial force is produced by the upper plate so that it can hold the spring between these two plates. When the force is applied on the spring by the upper plate, the lower plate is taken as the zeroth level.

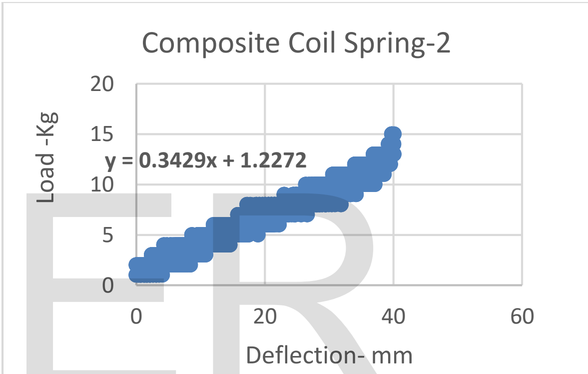
4) When the machine is started loading with the help of Displacement sensors or amplitude measuring instruments) record the readings and are displayed on the screen. Readings are recorded to calculate the stiffness.

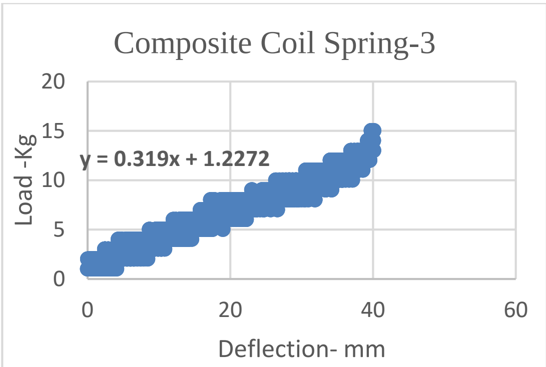
5) We get observed data of spring stiffness before and after testing

	Observed Spring Stiffness before testing	**Observed Spring Stiffness after testing**
Sample 01	0.32 Kg/mm	0.30 Kg/mm
Sample 02	0.36 Kg/mm	0.34Kg/mm
Sample 03	0.31 Kg/mm	0..29 Kg/mm

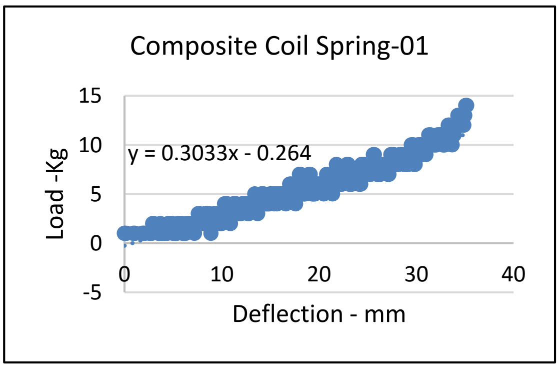
Annexure 1 (spring Stiffness before testing)

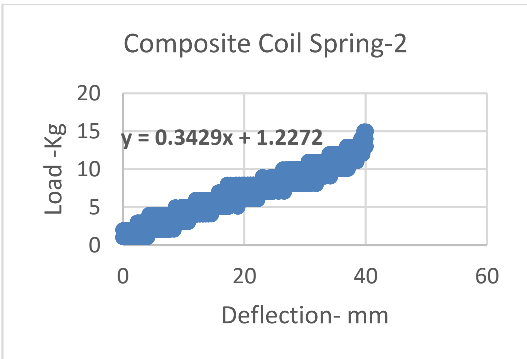


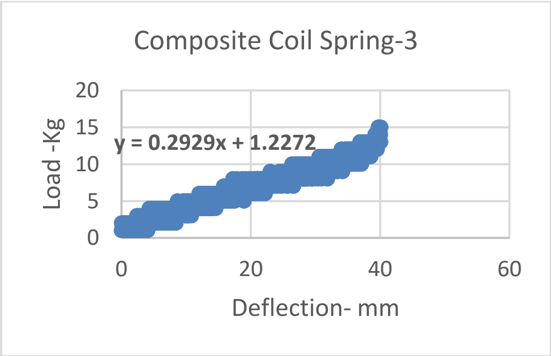




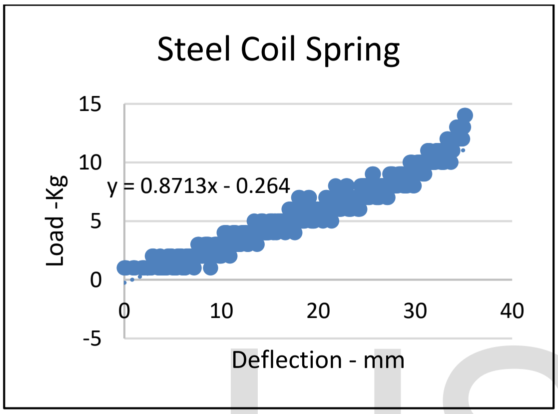
Annexure 2 (spring Stiffness after testing)



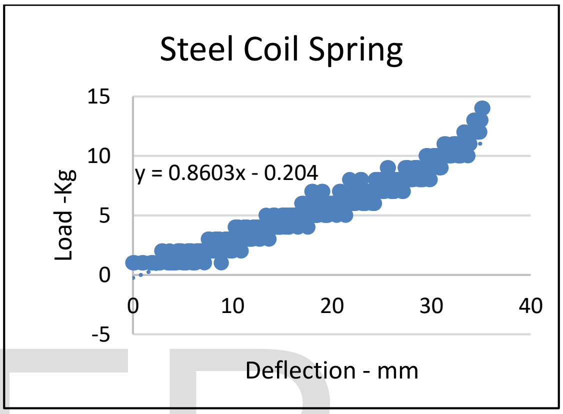




Annexure 3 (steel spring Stiffness before testing)



Annexure 4 (steel spring Stiffness after testing)



	Observed Steel Spring Stiffness Before Testing	Observed steel Spring Stiffness after Testing
Sample 01	0.87 Kg/mm	0.86 Kg/mm

6.0 Operation of the spring fatigue testing machine

Fatigue test experimentation is carried out on the fatigue test machine for conventional and composite helical compression spring for design validation. The test setup is a special purpose fatigue testing machine on which the samples of the springs are tested.

Objective of the Test: To carry fatigue test for a given conventional and composite helical spring.

Technical Specifications of Fatigue Testing Machine

Test Condition: A random 3 sample springs was taken for testing

1. Working Temperature: Room temperature (25 degree Celsius)
2. Frequency: 1 cycle/sec

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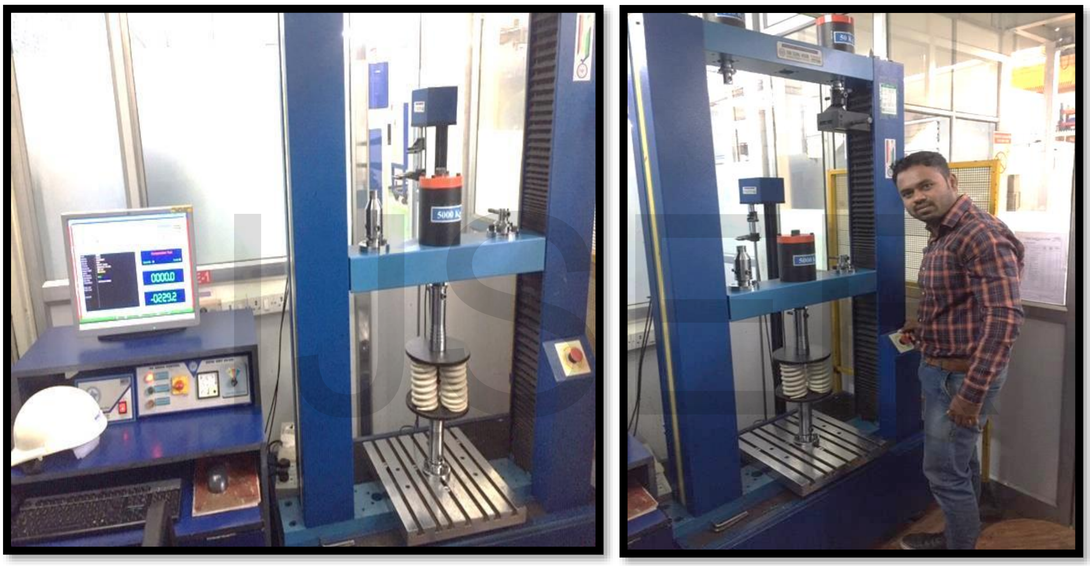
Operation	Automatic
Maximum load	2500 kg
Min load	0.5 kg
Stroke length	5 mm to 45 mm
Frequency	1 HZ
Max speed	12000cycles/hr
Machine weight	1200 kg

(Specification of fatigue testing machine)



Test set up for stiffnes and fatigue (Tata Motors)

Experimental fatigue study of suspension spring

Test Procedure

1. The experimental study was carried out for design validation. Physical testing on the spring in compression is done as accordance to Compression Testing.

2. The testing was done by 2.5 ton spring testing machine, STM along with load cell having load carrying capacity 2500kg. It was made by Star Testing Systems, India and is computerized and software based.

3. Number of coil springs that are used for testing is three pieces. The 3 spring was tested at a time.

4. The tested springs were mounted both on top and bottom, at specially made seats. After this testing done by compressing coil spring from 5mm to 40mm full solid condition which simulates vehical operating condition.

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5. Results produced from the testing i.e. all 3 samples having no failure until 1.5 lack cycles

	Cycles covered	Remarks
Sample 01	157976	Test stopped. Passed 1.5 lacs cycles, 1.5 times life compared to steel spring
Sample 02	158975	
Sample 03	155870	

Result discussion

Performance measurement done on 2.5T (2.5 Tones) Actuator make M/s Star Testing machine. Testing done by compression loading data points collected thru machine software. Three spring tested and results are consistent. Post durability testing stiffness loss found less than 5% which is acceptable as per vehicle norms.

Fatigue testing done on 2.5T (2.5 Tones) Actuator make M/s Star Testing machine. Testing done by compressing coil spring from 5 mm to 40 mm full solid condition, which simulates vehicle-operating condition. No failure reported until 1.5 lakhs cycles. (Literature reference 1 lakh cycle life for steel spring)

CONCLUSION

1. All 3Composite coil springs samples successfully completed 1.5 lakhs durability cycles which is 1.5times higher than exiting steel coil spring.
2. Stiffness loss well within 5% range which is acceptable as per vehicle norms.

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