Journal of Engineering Research and Application www.ijera.com
ISSN : 2248-9622, PP 65-70

RESEARCH ARTICLE OPEN ACCESS

Design, Analysis and Simulation of E-glass Fiber/Epoxy and Carbon Fiber/Epoxy Mono leaf Composite Spring for Light Commercial Vehicle.

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ABSTRACT : *The present study evaluates the use of composite material leaf spring to reduce the unsprung weight, minimize cost and improving the strength of leaf spring. In this present study Epoxy fiber resin composite and carbon fiber composite mono leaf spring models static load analysis by using Ansys software is done and compared with the conventional steel alloy multi leaf spring. Also Mathematical Simulation is carried out on E glass fiber and Carbon fiber mono leaf spring to understand the stability using MAT lab software. Finally All the results are compared to make the conclusion.*
Keywords *- Carbon Fiber Epoxy, E Glass Fiber Epoxy, Mono leaf Composites, Impulse Response Plot, Multi Leaf Steel Spring*

I. INTRODUCTION

Recently automobiles manufactures are trying to reduce the unsprung weight of automobiles for improving the fuel efficiency and finding alternative composite material with better mechanical property, stiffness and fatigue life.

Viability and potential of FRP (fiber reinforced plastic) in automobile structural application [1]. The introduction of composites helps in designing a better suspension system with better ride quality if it can be achieved without much increase in cost and decrease in quality and reliability [2].E Glass Fiber composite leaf spring have more flexibility and hardness and stresses, noise parameters are get reduced than conventional leaf spring [3].Fatigue life of composite leaf spring is more than the conventional spring [4].

II. PROBLEM DEFINATION

Lot of research is carried out for finding best suitable composites material for light commercial vehicle suspension system. Advanced computer aided analysis result with validation of experimental test shows that Graphite epoxy, Carbon fiber resin composite and E-Glass fiber epoxy resin are suitable. .The objective of this present work is to design ,analyze the composite mono leaf spring of E glass Fiber Epoxy, Carbon fiber epoxy with conventional multi leaf. Steel spring and Also dynamic simulation of both the composite material spring is carried out and compared to investigate its stability and ride quality.

III. PROBLEM DESCRIPTION

The leaf spring are designed to absorb and store energy and releases that energy slowly. This strain energy maximum value will give you comfortable suspension system. Strain energy plays very important role in the design of suspension system. Specific strain energy expressed as

$$U = \frac{\sigma^2}{2 \times \rho \times E} \qquad (1)$$

Where σ is the strength, ρ is the density and E is the Young's modulus of the Spring Material [5].

By observing above equation, material having less modulus of elasticity and less density has more specific strain energy. By replacing conventional steel material with E glass fiber Epoxy and Carbon Fiber Epoxy composite material without reduction in its load carrying capacity and stiffness and high strength to weight ratio. Mono Composite leaf Spring of E Glass Epoxy and carbon fiber epoxy are designed by taking reference of Mahindra Commander Suspension System. As per the design obtained 3 D solid models for composite Mono leaf spring a Static Load analysis of composite mono leaf spring of E Glass Fiber and Carbon Fiber epoxy has been carried out by using, Ansys R15 Software for meshing, solving Respectively. Dynamic Simulation of Multi leaf steel spring and Mono composites springs are carried out by Mat lab Simulink Software.re prepared on Auto desk inventor Software.

IV. MONOLEAF COMPOSITE LEAF SPRING

Carbon fiber epoxy resin composite have high specific strength and elasticity and higher fatigue life. The main drawbacks for carbon epoxy resin its cost, low impact resistance and high electrical conductivityEpoxy Glass fiber resin is having also high strength and elasticity than conventional hardened carbon steel alloy. E-glass Fiber Epoxy have lesser strength compared to Carbon Fiber Epoxy .Due to less cost E-Glass Fiber Epoxy is suitable for mass production

V. DESIGN SPECIFICATION

Here in this study Weight and Suspension system measurements of Mahindra "Model -Commander DI " light commercial vehicle is taken,
Gross Vehicle Weight = 2150Kg
Unsprung Weight =240Kg
Total sprung Weight = 1910 Kg
Factor of safety = 1.4
Acceleration due to gravity = 9.81m/s^2
Total weight (W)= 1910*9.81*1.4=26231.9 N
Weight acting on single leaf spring is one fourth of total load =F= 26231.9/4 = 6557.9 N
Design parameters for Multi leaf steel spring are as
Number of full length leaf = 02,
Number of graduated leaves = 08,
Dimension for the master leaf are shown in table 1

Table1: Specification of Master Steel Leaf Spring

Sr No	Parameters	Dimension
1	Full length of leaf	1120mm
2	Radius of curvature	961.11mm
3	Thickness	6mm
4	Width	50mm

Multi leaf Steel spring is modeled in Auto desk inventor software and imported in Ansys software for analysis by considering same load condition at its centre. Then following results are obtained Stress=453.92Mpa, Displacement=10.16mm [6].

VI. MODELING AND ANALYSIS

Composite material mono leaf spring manufacturing is considered by Hand lay technique. For accommodation of Continuous reinforced fiber and mass production cross section of mono leaf spring selected is constant width and constant thickness. By Considering Master leaf design Specifications of steel leaf the dimension and for same load of 6557.9 N Composite mono leaf spring dimensions are shown in table 2.

Table2: Composite Monoleaf Specification

Material	Full length (mm)	Width (mm)	Thickness(mm)	Radius of curvature (mm)
E glass Epoxy	1120	50	22	961.11
Caron Epoxy	1120	50	14	961.11

Mono leaf spring of E glass epoxy and carbon Epoxy are modeled according to given dimension in Auto desk inventor software. The material properties for Carbon Fiber Epoxy and E Glass Epoxy monoleaf spring are considered orthotropic mentioned in the Table 3.

Table3: Orthographic Properties Of Monoleaf Composites

Sr No	Properties	E-Glass /Epoxy	Carbon Fiber/ Epoxy
1	E_X(MPa)	43000	177000
2	E_Y(MPa)	6500	10600
3	E_Z(MPa)	6500	10600
4	PRXY	0.27	0.27
5	PRYZ	0.06	0.02
6	PRXZ	0.06	0.02
7	G_X(MPa)	4500	7600
8	G_Y(MPa)	2500	2500
9	G_z(MPa)	2500	2500
10	ρ(Kg/mm^3)	2*10^{-6}	1.6*10^{-6}

Mono leaf composites spring model carried out in Autodesk inventor software converted into IGES Cad drawing format IGES Cad files then imported into Ansys R15 Software. The element is 8 node solid element is considered and meshing is done. The monoleaf is considered as simply supported beam fixed at both the ends and the force load of 6557.5 N. is applied at the centre of monoleaf composites spring in upward direction.

Table 4: Result Analysis of Ansys Software

Sr No	Material	Stress (Mpa)	Displacement (mm)
01	E glass Epoxy	58.61	3.86
02	Carbon Epoxy	58.72	2.72

For the above mentioned material mono leaf models analysis is carried out using Ansys R15 software. For Fig 1 and Fig 2 shows Von- Mises stress analysis for E glass Fiber/Epoxy and Carbon Fiber/Epoxy Monoleaf Spring Models . The results obtained are tabulated in the table no 4. The analysis results obtained shows that values of maximum Von-Mises stresses for E Glass fiber /Epoxy and Carbon Fiber Epoxy are which less than the multileaf steel spring is. Maximum Displacement of monoleaf composites for the above mentioned material is found as 3.86 mm and 2.72mm respectively .These values are also within the safer limits58.61 Mpa and 58.72Mpa respectively.

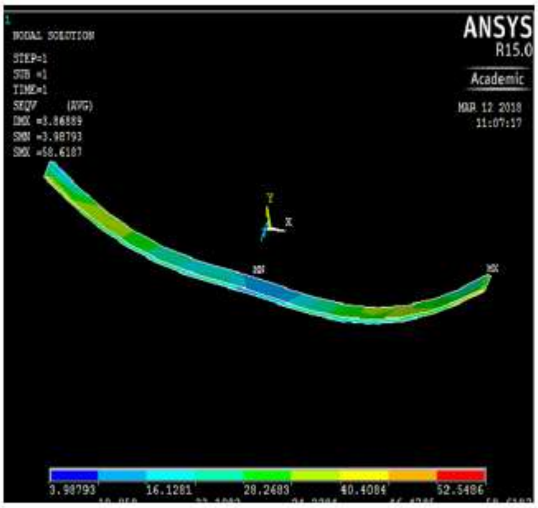

Figure 1: Von-Mises Stresses for E Glass /Epoxy

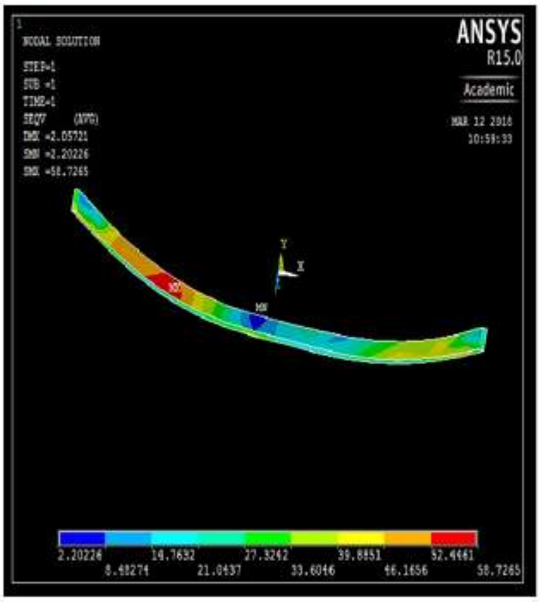

Figure 2: Von-Mises Stresses for Carbon Epoxy

which is less than the multileaf steel spring. Maximum Displacement of monoleaf composites for the above mentioned material is found as 3.86 mm and 2.72mm respectively .These values are also within the safer limits.

VII. DYNAMIC SIMULATION MODEL

The governing equation for the dynamic simulation of a composites monoleaf spring is given by,

$$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{f\} \qquad (2)$$

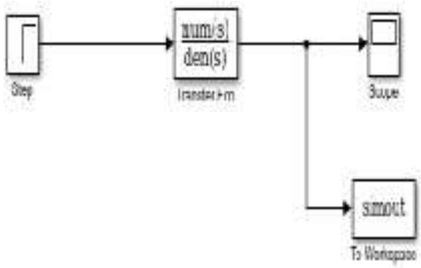

Figure 3: Dynamic Model

Specification of steel leaf spring, Carbon epoxy and E-Glass epoxy are taken and Damping coefficient and stiffness is calculated theoretically for validation of dynamic simulation result.Results obtained are shown in table 5.

Table 5: Design Specification

Variables	Steel	Carbon Epoxy	E-Glass Epoxy
Mass(Kg)	17.89	2.1	6.5
Damping Coefficien t(NS/m)	0.11	0.43	0.95
Stiffness (N/mm)	38.72	46.09	32.72

VIII. DYNAMIC SIMULATION MODEL

Fig 4 ,5 and 6 shows the step impulse plot response for Multileaf steel spring, E Glass Epoxy and Carbon Fiber Epoxy Mono-leaf Composite Spring Respectively.

Fig 7, Fig 8 and Fig 9 shows the impulse response plot for multi leaf steel spring, E- Glass Fiber /epoxy mono leaf spring and Carbon fiber Epoxy Composites mono leaf spring respectively

After observing the step response and impulse response of Mat lab simulation for multi leaf steel spring, E glass Epoxy composite and Carbon epoxy composites the results for the peak amplitude are shown in table 5and table 6 respectively.

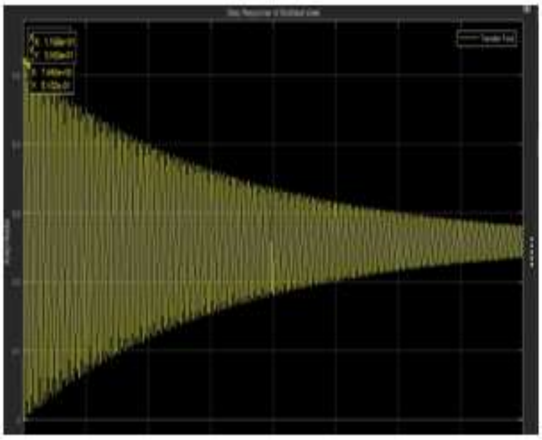

Figure 4: Step Respose for Multileaf Spring

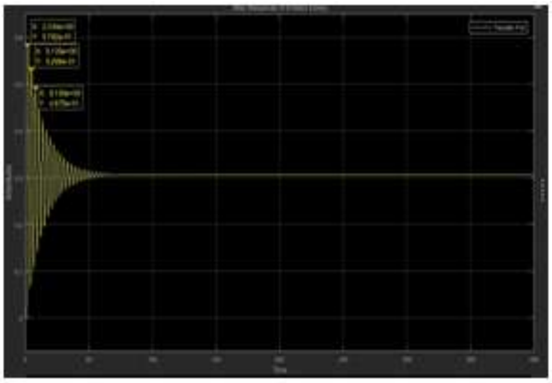

Figure 5: Step Response for E Glass Epoxy

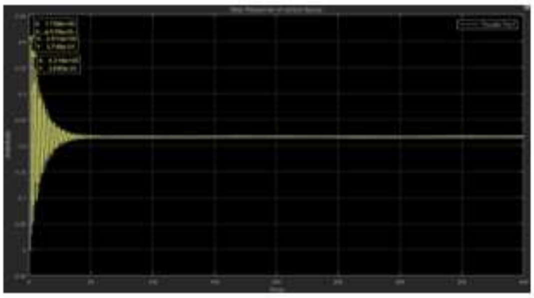

Figure6: Step Response for Carbon Epoxy

From the above result peak amplitude for composite mono leaf spring of Carbon Fiber Epoxy and E Glass Epoxy composites and multi leaf steel spring are. almost the same. Settling time is different for all the three material spring. As per the plot and amplitude settling time for mono leaf spring of carbon epoxy is less than Glass epoxy mono leaf spring and multi leaf steel spring. So the dynamic simulation result indicates that Carbon and E glass epoxy composite mono leaf spring are more stable than multi leaf steel leaf spring.

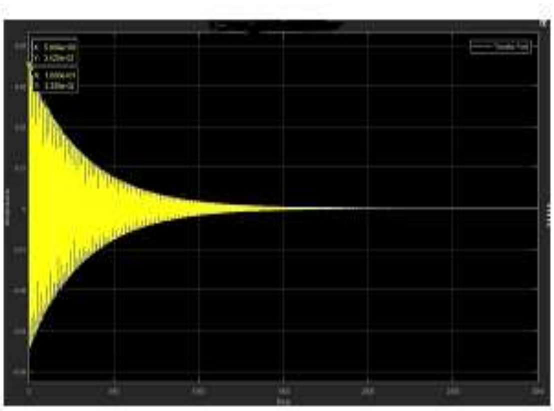

Figure 7: Impulse response plot for multi leaf spring

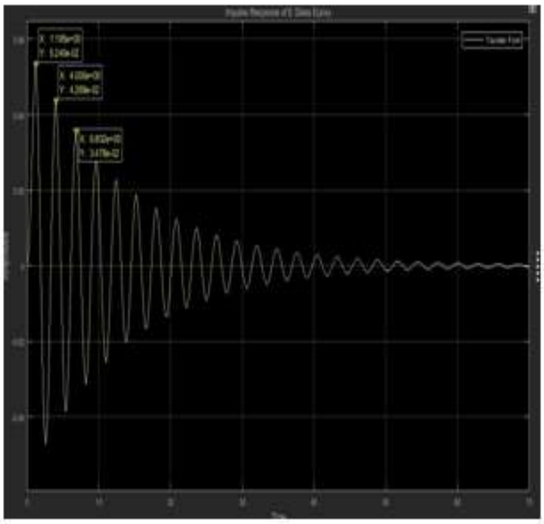

Figure 8:Impulse response plot for E Glass Epoxy

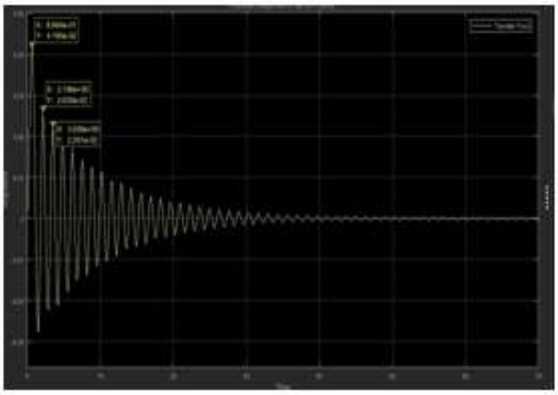

Figure 9: Impulse response plot for Carbon Epoxy

Table 6: Step Response Result

Plot	Specification	Steel multi-leaf spring	E glass Epoxy mono leaf spring	Carbon Epoxy mono leaf spring
Step Response	Peak Amplitude (mm)	0.5	0.5	0.4
	Rise time (S)	0.432	0.51	0.08

Table 7: ImpuseResponse Result

Plot	Specification	Steel multi leaf spring	Glass Epoxy mono leaf spring	Carbon Epoxy mono leaf spring
Impulse Response	Peak Amplitude (mm)	0.03	0.05	0.04
	Rise time (S)	0	0.10	0.14

IX. CONCLUSION

The deflection and stress result obtained by Ansys software analysis for carbon Epoxy composite and E Glass epoxy composites are within safer limits than multi steel leaf spring. Dynamic simulation is carried out for multi leaf steel spring as well as for composites of carbon epoxy and E Glass Epoxy using Mat lab simulink tool. Peak amplitude magnitude is checked for step and impulse response which is almost equal for all the three material. Which means carbon and E glass Composites mono leaf are more stable than steel spring. Hence we can conclude that Carbon epoxy composite better in strength point of view and but economical point of view preferable is E glass epoxy composite mono leaf spring to replace conventional multi leaf spring.

Hence among Multileaf Steel Spring, Carbon Fiber Epoxy and E Glass Fiber/Epoxy Monoleaf Composite springs E Glass Fiber Monoleaf Composite spring is preferable.

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