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Finite Element Analysis and Optimization of Composite Leaf Spring for Light Passenger Vehicle

[1]Mr. Sunil Gowda K J, [2]Dr.Chetan Byrappa
[1]PG Scholar, [2]Assistant Professor,
Department of Mechanical Engineering, Bangalore Institute of Technology, Bangalore-564, Karnataka, India
***Email:** chetbk@gmail.com*

Abstract

In the making of fuel efficient vehicle gross weight of the vehicle is biggest enemy for automotive vehicle designers. The engineer's to way to reduce gross weight of the vehicle is opting a modern engineering material with better material properties such as fiber reinforced polymer composites. When there is need for weight reduction along with better material properties composites are better potential candidates. There are numerous automotive parts which can be with composite. In this present study the simplest part called leaf spring which is responsible for absorb road shocks and vehicle stability has been considered. In this present work initially reverse engineering to be carried out on existing metal leaf spring to record dimensions and type of leaf sprig. In next steps there type of composite material has been considered for leaf spring namely E glass epoxy, carbon epoxy and graphite epoxy. The composite optimization has been carried out using optistruct® to find optimal composite material system and after optimizing again stress analysis has been carried out to find stress and displacement. The obtained results good in agreement.

***Keywords:** Leaf spring, Fuel efficiency vehicle, E Glass Epoxy, Composite Axial.*

INTRODUCTION

The leaf springs (also known as laminated springs) usually found in automobiles suspension system. The leaf springs are energy absorbing devices that absorb the energy dissipated on wheel axels due to bad road condition and vehicle dynamics. The main objectives of the providing leaf springs in automobile suspension system are as follows,

- Supports weight of the chassis.
- Controls chassis roll more efficiently-high rear moment center and wide spring base.
- Controls rear end wrap-up.
- Controls axle damping.
- Controls braking forces.

The contemporary automobile industry have been constantly searching out higher strength absorbing leaf spring fabric with minimum particular modulus, as want for fuel green automobile has turn out to be main goal of automobile region. The FRP composite cloth might be better replacement for the prevailing leaf spring substances, as it satisfies each minimum weight and greater energy absorbing design objectives. The efficiency of the leaf springs lies at capacity to absorb more strain energy due to shock loads since strain energy relationship with density expressed as shown in Eq. 1

$$\boldsymbol{U = \frac{1}{2} * \frac{\sigma^2}{\rho E}}$$

It clearly says that lower density and modulus will have a greater specific strain energy capacity, hence choice of the composite material will achieve the objectives mentioned

Leaf Springs

This section onwards explanation give not only about the design, construction and materials used regarding leaf spring since area of interest of this study is leaf spring. A leaf spring is an elastic body which is intended to distort when it is under shock load and sprung back to original position when load has been removed.

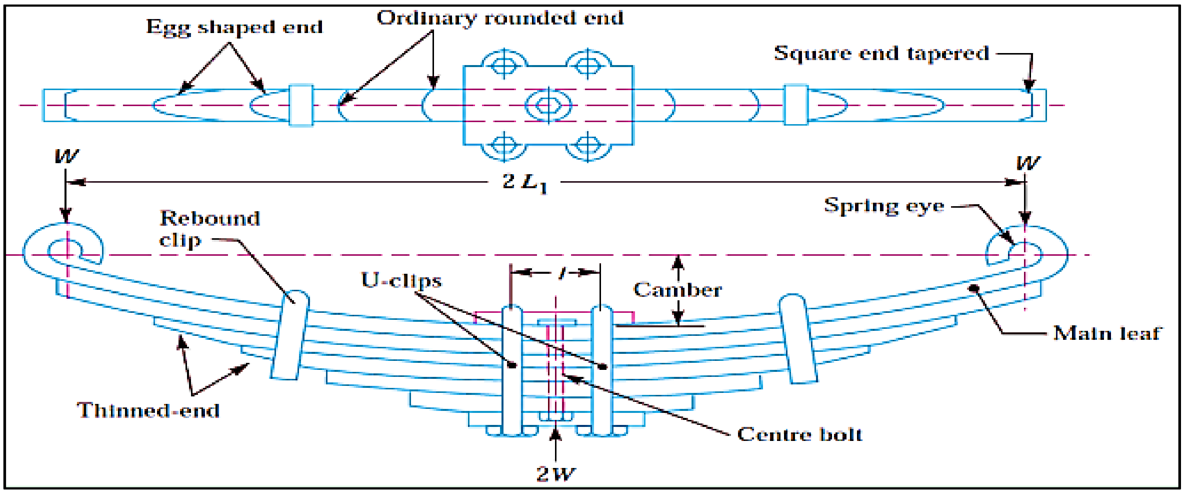

Fig. 1: *Details of Semi elliptic leaf spring*

Forces on leaf spring

A leaf spring have to guide various kinds of outside forces proven in Figure 2 but the maximum vital task is to face up to the variable vertical forces.

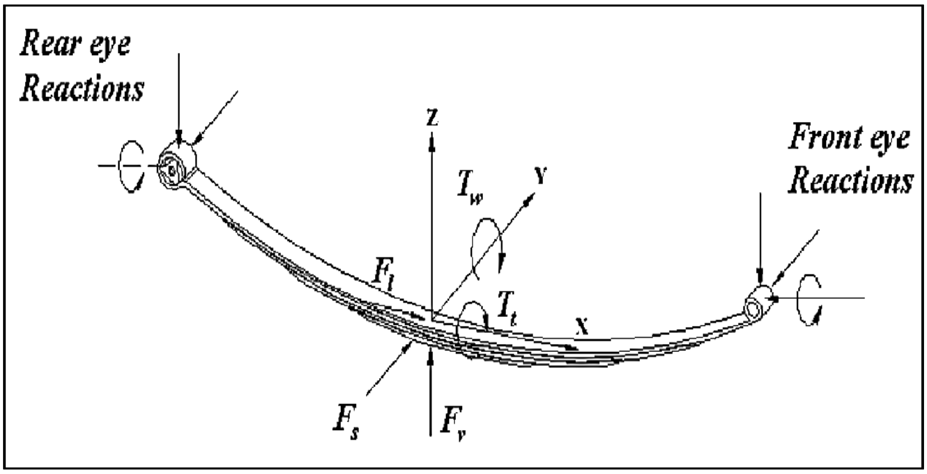

Fig. 2: *Forces on leaf spring*

Composite material as substitute for steel

Over the last three decade's composite materials has become strongest competitor due the better material properties over the conventional metal alloys. The composite materials known for the good strength to weight ratio due to this it has got a candidate material place in all maximum all structural packages. The contemporary undertaking in composite fabric enterprise is value of production. The efforts to produce economically appealing composite additives have ended in numerous revolutionary manufacturing techniques presently getting used inside the composite industry.

Further, the need of composite for lighter production materials and extra seismic resistant systems has placed excessive emphasis at the use of latest and superior materials that no longer best decreases useless weight but also absorbs the surprise & vibration. Composites are actually drastically getting used for rehabilitation/ strengthening of pre-existing systems that need to be retrofitted to cause them to seismic resistant, or to restore harm caused by seismic activity.

Design of MultiLeaf Spring
Conventional metal leaf spring design method based on the equations derived from principle of beams of uniform strength and few empirical relations that available in literature. In present study leaf spring of Force motors light passenger vehicle called "**Trax Cruiser**" has been considered**.**

Table 1: *Vehicle and leaf spring specifications*

Vehicle and leaf spring specifications		
Existing leaf spring material with material properties		Steel(50 Cr 1 V 23) σ_t=1900MPa, σ_y=1800MPa, E=210GPa ρ=7.85x10^{-6} Kg/mm^3
Mass of vehicle,kg	W_v	2850
Payload capacity,kg	W_p	No payload case
Number of leaf springs	k	4
Total number of leaf	n_f	6
Number of full leaf	n_g	2
Number of graduated leaf	n	4
Eye to eye length,mm	$2L_1$	1200
Ineffective length,mm	l	110
Breadth of leaf,mm	b	60
Thickness of leaf,mm	t	8
Factor of safety considered	FOS	1.5

RESULT AND DISCUSSION
Following section explains stress and displacement result for existing leaf spring using Design equations and FEA.

Displacement and Stress Result For existing Metallic leaf Spring
In this section stress result for existing metallic leaf spring using the design equations. The metallic leaf spring results shown in Table 2

Table 2: *Displacement and stress for existing metallic leaf spring*

Parameter	Magnitude
Stress(Mpa)	698
Displacement(mm)	142

Stress and Displacement for e-Glass/Epoxy

Stress and displacement contour for E-glass/epoxy with all ° layers. The maximum of stress and displacement observed along center of leaf spring where the load from axel has been applied. The center on bending region doesn't show any stress and displacement maximum because it will be supported by axel sea through center U-Bolt.

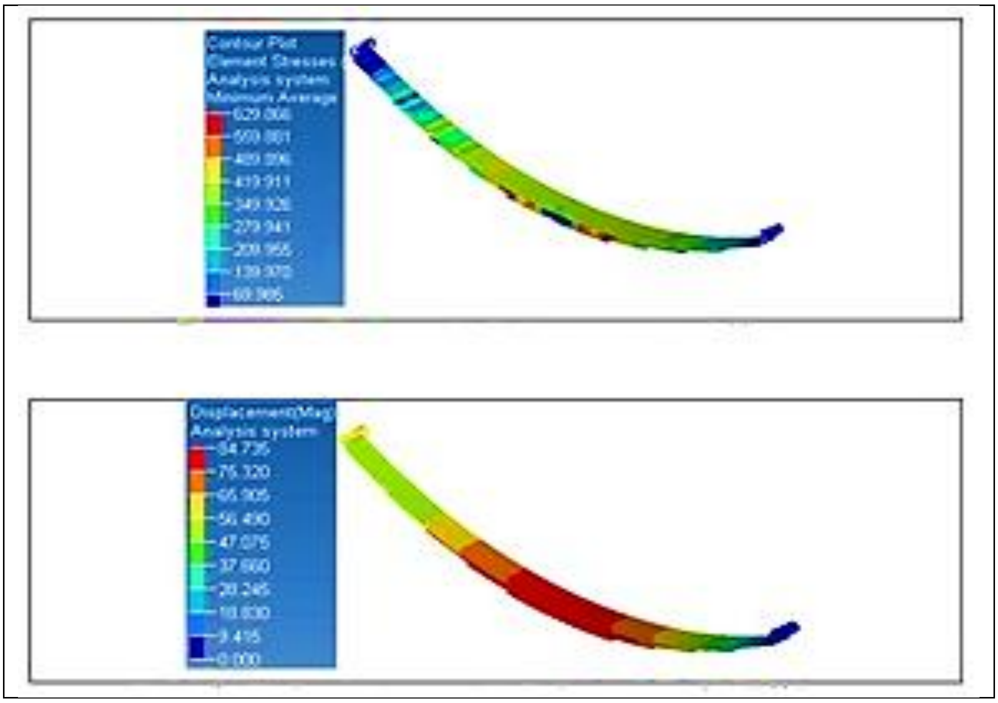

Fig. 3: *Stress and Displacement for e-Glass/Epoxy*

Summary Of stress and Displacement results before optimization (All Layers)

Table 3: *stress and displacement before optimization*

Material	Displacement(mm)		Stress(Mpa)	
	Value	% Reduction	Value	% Reduction
Steel	118	NA	760	NA
E Glass/Epoxy	84	28.8	629	17.2
Carbon/Epoxy	73	38.1	509	33.0
Graphite/Epoxy	55	53.4	503	33.8

Composite optimization Of E-Glass/Epoxy leaf Spring

The colour code given below Figure shows optimal plysequence for given loading condition with various manufacturing constraints as discussed. With objective function is to minimize the mass and displacement as constraint. The optistrcuts gives the best possible ply sequence after running various iterations, here it has converged at 4th iteration.

Iteration 0	Iteration 1	Iteration 2	Iteration 3
1	3	20	20
2	2	3	3
3	1	2	2
4	4	9	9
5	6	1	1
6	7	8	8
7	8	6	6
8	5	7	7
9	10	13	13
10	11	12	12
11	9	4	4
12	12	5	5
13	15	10	10
14	14	11	11
15	16	16	16
16	13	15	15
17	18	14	14
18	19	17	17
19	17	18	18
20	20	19	19

Legend
90.0 degrees
45.0 degrees
0.0 degrees
-45.0 degrees

Fig. 4: *optimal plysequence*

Stress and Displacement after Optimization

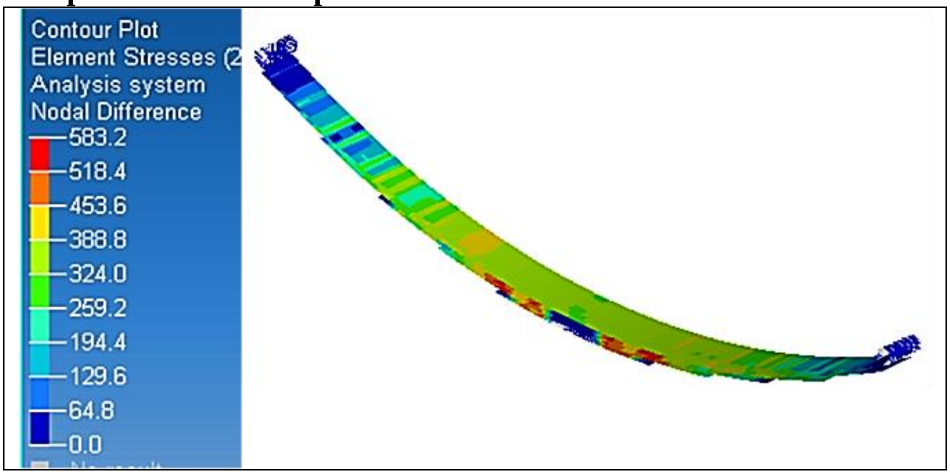

Fig. 5: *Stress after optimization for E glass epoxy*

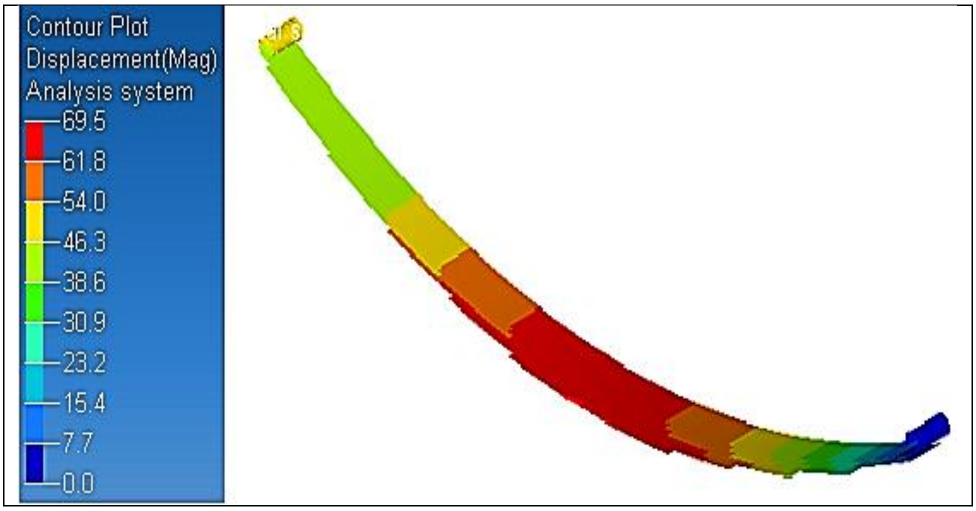

Fig. 6: *Displacement after optimization for E glass epoxy*

Summary Of stress and Displacement results after optimization (All Layers)

Table 4: *stress and displacement after optimization*

Material	Displacement(mm)		Stress(Mpa)		Weight(Kg)	
	Value	% Reduction	Value	% Reduction	value	% Reduction
Steel	118	NA	760	NA	20.4	
E Glass/Epoxy	69.5	41	583.2	23	5.2	75

CONCLUSIONS

The conclusions of the every study considered as heart of the study and it must be short and effective. Following are other few conclusions from this study:A FEA based stress analysis on composite leaf spring of various ply orientations and to compute the weight advantage over the metallic leaf spring has been carried out successfully.

- The design calculations using classical design equations to find displacement and stress value in existing metallic leaf spring has been carried out successfully.
- The linear static contact analysis on existing metallic leaf spring to extract displacement and stress value has been carried out successfully.
- The modal analysis on leaf spring models to extract the natural frequency.
- A FEA based composite optimization for composite leaf spring by considering various constraints and design objectives has been carried out successfully.
- Stress and displacement of composite leaf spring found to be lesser 23% and 41% from steel leaf spring.
- 75% of weight reduced after optimization.

  The outcomes of these studies have been compared successfully and results are in good agreement

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