Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 5, May-2016

ANALYSIS AND SIZE OPTIMIZATION OF COMPOSITE LEAF SPRING USING FEA

AMIT KOTADIYA[a],

[a] **Government Engineering college, junagath, Gujarat, India.**

Abstract

The Automobile Industry has shown increased interest for replacement of steel leaf spring with that of composite leaf spring, since the composite material has high strength to weight ratio, good corrosion resistance and tailor-able properties. The paper describes a static analysis of steel leaf spring and laminated composite Multi leaf spring. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The dimensions of an existing conventional steel leaf spring of a Light design calculations. Static Analysis of a 3-D model of conventional leaf spring is performed using ANSYS 11.0 and hyper mesh. Same dimensions are used in composite multi leaf spring using carbon/Epoxy and Graphite/Epoxy unidirectional laminates. The load carrying capacity, and weight of composite leaf spring are compared with that of steel leaf spring. The design constraints are stresses and deflection. A weight reduction of 80 % is achieved by using composite leaf spring. And if consider Mono leaf spring then Weight reduction has achieved 88.57%. After size optimization thickness reduction in mono leaf spring 1 mm and mass reduction 88.97%.

Keywords: Steel, Carbon epoxy, Static Analysis, Size Optimization, FEA

Nomenclature

b	Width of leaf spring
t	thickness of leaf spring
L	Span of leaf spring
Greek symbols	
δ	Deflection (mm)
Ϭ	Bending stress (MPa)

1. INTRODUCTION

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturer in the present scenario. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the unsprung weight. This helps in achieving the vehicle with improved riding qualities. It is well known that springs, are designed to absorb and store energy and then release it. Hence, the strain energy of the material becomes a major factor in designing the springs. The relationship of the specific strain energy can be expressed as

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

Where,

σ is the strength,

ρ is density

E is the Young's modulus of the spring material.

It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. The introduction of composite materials was made it possible to reduce the specific weight of the leaf spring without any reduction on load carrying capacity and stiffness. Since the composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. Several papers were devoted to the application of composite materials for automobiles. The application of composite structures for automobiles and design optimization of a composite leaf spring has been studied by Rajendran. Great effort has been made by the automotive industries in the application of leaf springs made from composite materials.

The introduction of fiber reinforced plastics (FRP) made it possible to reduce the weight of a machine element without any reduction of the load carrying capacity. Because of FRP materials high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel, multi-leaf steel springs are being replaced by mono leaf FRP springs was described by the S. Vijayarangan [1]. Raghavedra and Syed Altaf Hussain described the design and analysis of laminated composite mono leaf spring. In their work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle are taken for modelling and analysis of a laminated composite mono leaf spring with three different composite materials namely, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. The three different composite mono leaf springs have been modelled by considering uniform cross-section, with unidirectional fiber orientation angle for each lamina of a laminate. Static analysis of a 3-D model has been performed using ANSYS 10.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found to have lesser stresses, higher stiffness, higher frequency and weight reduction of 73.80% is achieved.

Replacing steel leaf spring using a Genetic Algorithm optimization technique using composite material 93% weight reduction is achieved by the G.S. Shivashankar [2].

Experiments analysis work completed UTM and numerical analysis was done FEA using ANSYS software and material selected glass fibre reinforced plastic (GFRP) and the polyester resin and the weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf is described by the Jadhao and Dalu. [3].

2. LEAF SPRINGS

Leaf springs also known as flat spring is made out of flat plates. Leaf springs are designed two way multi-leaf and mono-leaf. The leaf springs may carry loads, brake torque, driving torque, etc. In addition to shocks, the multi-leaf spring is made of several steel plates of different lengths stacked together. During normal operation, the spring compresses to absorb road shock. The leaf springs bend and slide on each other allowing suspension movement.

Design Parameter of Leaf Spring

Leaf steel spring use in this work includes: total length (eye to eye), 1025 mm; arc height of axle seat (camber), 90.8 mm; width of leaves, 60mm; thickness of leaves, 16 mm: full bump loading 7500 kg. Even though the leaf spring is simply supported at the end.

Analytical calculation

Bending stress

$$\sigma = \frac{6WL}{nbt^2}$$

= 197.683 MPa

Deflection:

$$\delta = \frac{6PL^3}{(3n_f + 2n_g)Ebt^3}$$

= 6.60 mm

3. FINITE ELEMENT ANALYSIS OF STEEL LEAF SPRING

The basic requirements of a leaf spring steel are that the selected grade of steel must have the sufficient harden ability for the size involved to ensure a full martenstic structure throughout the sentire leaf section. In general terms the higher the alloy content is mandatory to ensure the adequate harden ability when the thick leaf sections are used. The material used for the experimental work is SUP 9. Its chemical compositions are given below in Table 1.

Table 1 Chemical composition of steel

International Journal of Advance Research in Engineering, Science & Technology (IJAREST)

Volume 3, Issue 5, May 2016, e-ISSN: 2393-9877, print-ISSN: 2394-2444

% C	%Si	%Mn	%S&P	%Cr
.50/.60	.15/.35	.65/.95	.035	.65/.95

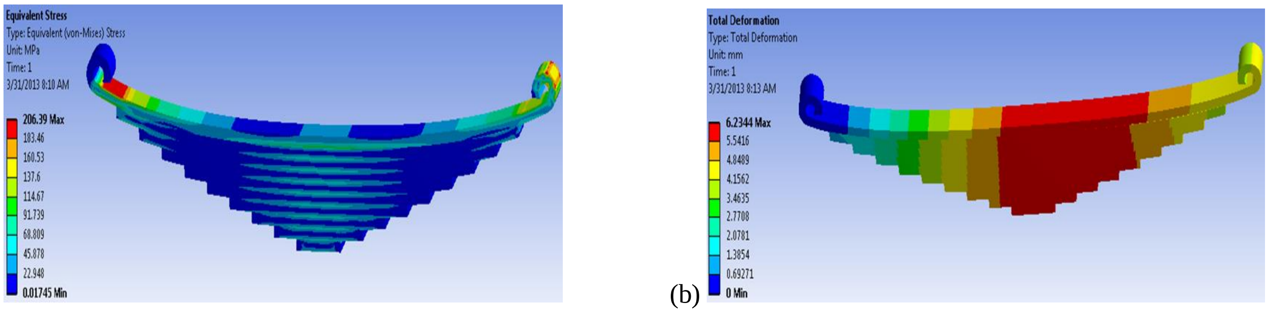
Finite Element analysis using ANSYS and Hyper Works

The CAD model of leaf spring imported into ANSYS 11 and hyper mesh, the boundary conditions and material properties are specified as for the standards used. The material used for the leaf spring for analysis is structural steel, which have approximately been isotropic behaviour and properties are SUP 9.

The output from the solution phase is in the numerical form and consists of nodal values of the field variable and its derivatives. For example, in structural analysis, the output is nodal displacement and stress in the elements. The postprocessor processes the result data and displays them in graphical form to check or analyze the result. The graphical output gives the detailed information about the required result data. The mono leaf spring with all boundary conditions and material properties is imported in ANSYS-11 and hyper mesh.

Meshing is the process in which your geometry is spatially discredited into elements and nodes. This mesh along with material properties is used to mathematically represent the stiffness and mass distribution of the structure. The automatically meshed at solve generated. The default element size is determined based on a number of factors including the overall model size, the proximity of other topologies, body curvature, and the complexity of the feature. If necessary, the fineness of the mesh is adjusted up to four times (eight times for an assembly) to achieve mesh.

The boundary condition is the collection of different forces, pressure, velocity, supports, constraints and every condition required for a complete analysis. Applying the boundary condition is one of the most typical processes of analysis. A special care is required while assigning loads and constraints to the elements. Boundary condition of the spring involves the one end fix and other end X and Y axis displacement and rotation about the Z axis. Loading conditions involve applying a load at the centre of the bottom leaf.



(a) (b)

Fig.1: (a)Von misses stress in steel leaf spring using Ansys (b)Displacement in steel leaf spring using Ansys

Using Ansys Fig.1(a) shows maximum Von-miss stress 206.1 MPa and Fig 1(b)shows maximum deflection 6.23 mm.

Result

The comparison of analytical result and FEA result of leaf spring with steel material as described in Table 2. The percentage difference between these two values is in the range of 5 to10 %.

Table 2 Comparison of Analytical and FEA result.

Parameter	Analytical	FEA	Difference
Deflection	6.60	6.34	5.56 %
Bending Stress	197.683	206.1	9.06%

4. FINITE ELEMENT ANALYSIS (FEA) OF COMPOSITE LEAF SPRING

The dimensions of the composite leaf spring are taken as that of the conventional steel leaf spring. The number of leaves is also the same for composite leaf spring. The material selected for composite is carbon epoxy because it has lesser weight as compared to other materials.

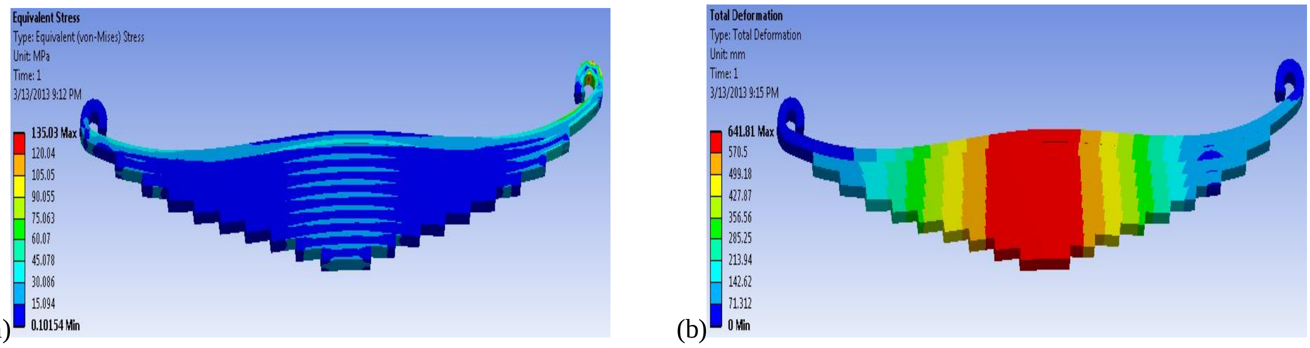
Material Properties for Carbon Epoxy

Material Properties of carbon epoxy composite material like Young's modulus, poison's ratio, modulus of rigidity and density is given in table 3.

Table 3 Material properties of carbon epoxy

Parameter	Value
E_{xx}	206.84 Mpa
E_{yy}	517.1 Mpa
E_{zz}	517.1 Mpa
M_x	0.25
M_y	0.25
M_z	0.25
G_{xy}	258.5 Mpa
G_{yz}	258.5 Mpa
G_{zx}	258.5 Mpa
Density	1600 Kg/mm^3

Using Ansys in composite material with carbon epoxy material having above material properties, Von-mises stress produced 135.03 MPa as shown in fig.(a). The displacement plot for the same as shown in the fig. (b).



(a) (b)

Fig.2: (a)Von misses stress in multi composite leaf spring using ANSYS (b)Displacement plot in multi composite leaf spring using ANSYS

If we consider only mono leaf spring and taken same dimension as steel leaf spring only thickness is varies by considering same deflection and same von-mises stress. Mono composite leaf spring weight reduction is achieved 90.09%. And if we consider 10 leaves composite leaf spring then weight reduction is achieved 80%.

Using HyperMesh considering mono leaf spring fig.3(a) described maximum Von-misses stress 206.1 MPa and fig.3(b) described maximum deflection 6.34 mm. And thickness is 36 mm achieved.

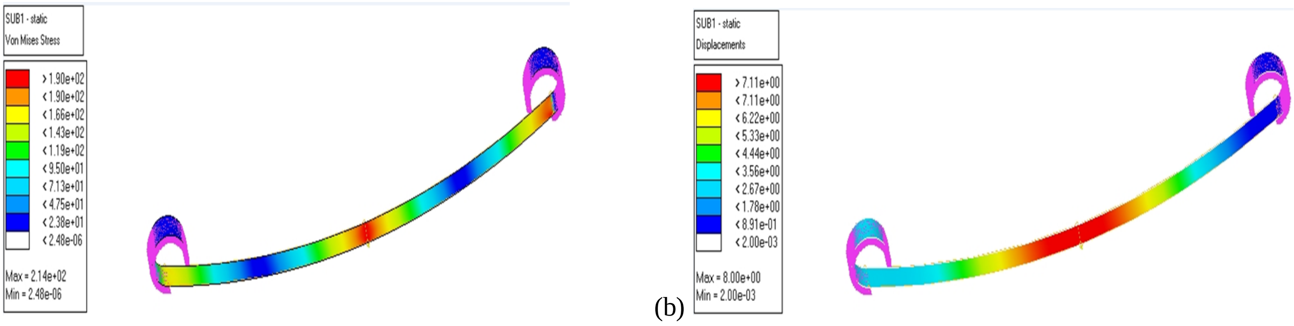


Fig.3(a) Von-misses stress in mono composite leaf spring using hyper mesh(b)Displacement in mono composite leaf spring using hyper Mesh.

5. Size Optimization

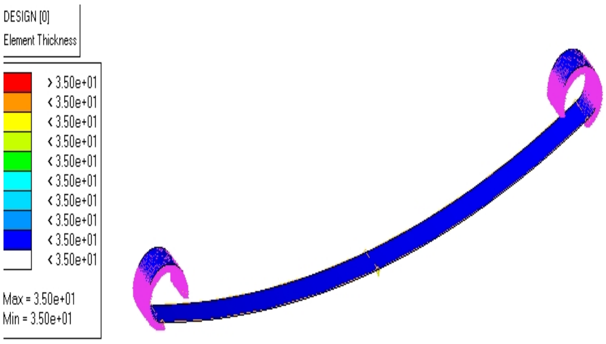


Fig.4 Size optimization of mono composite leaf spring using HyperMesh.

After size optimization mono leaf spring thickness has 35 mm. So thickness reduction 1 mm. And the mass of mono leaf spring has 5.01 mm. So mass reduced 88.97%.

6. Fatique Analysis

Life caclusion three approach used.

(1) Morrow Approach (2)Mean Approach (3)Smith-Watson-Topper Approach

FEA result of life calculation leaf spring:

(a) (b) (c)

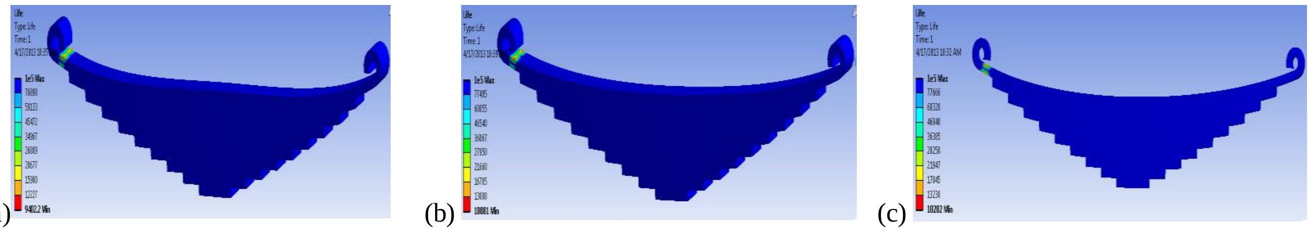


Fig.4(a)life calculation using mean Approach(b) life calculation using morrow Approach(c) life calculation using SWT Approach

Result Table:

Approach	Analytical(life calculation)	FEA (life Calculation)	%Difference
Mean	8.9e4	9.4e4	5.31
Morrow	1.2e4	1.008e4	16
SWT	1.15e4	1.2e4	13

7. Modal Analysis

Different mode shape having different natural frequencies as shown in fig.5 Here first five shapes has been found.

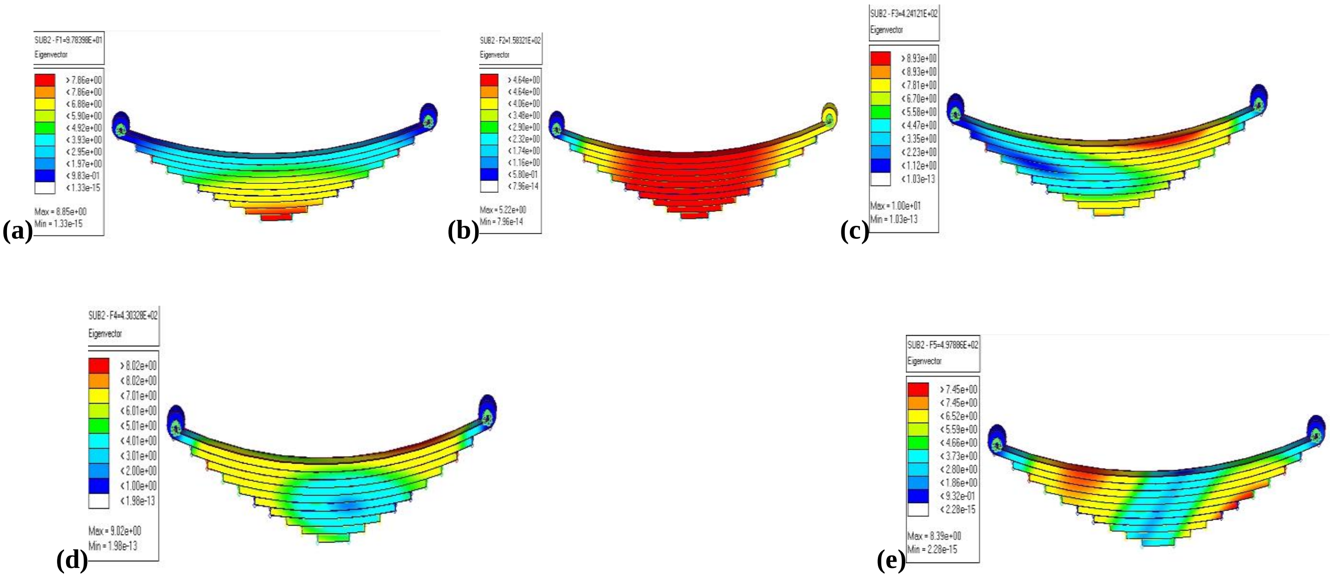


Fig.5(a)First mode shape natural frequency using HyperMesh(b)second mode shape natural frequency using HyperMesh(c)Third mode shape natural frequency using HyperMesh(d)Fourth mode shape natural frequency using HyperMesh(e)Fifth mode shape natural frequency using HyperMesh.

8. CONCLUSION

The design and static structural analysis of steel leaf spring and laminated composite leaf spring has been carried out. Comparison has been made between laminated composite leaf spring with steel leaf spring having same design and same load carrying capacity. From that 80 % mass reduction in composite material has been achieved for the same number of leaves. The fatigue life has been calculated using analytically as well as using ANSYS for steel leaf spring. The size optimization has been carried out for further mass reduction of composite leaf spring. From that 88.97 % mass reduction has been achieved using mono composite leaf spring compared to steel multi leaf spring.

9. REFRENCESES

[1] S. Vijayarangan I Rajendran. Design and Analysis of a Composite Leaf spring. Journal of Institute of Engineers India, 2002.

[2] D. Rajiv R. Pradeep G.S. Shivashankar, S. Vijayarangan. Genetic Algorithm Based Optimal Design of Mono Composite Leaf Spring and Testing. International Journal of Modern Engineering Research (IJMER) www.ijmer.com Vol.2, Issue.4, 2007.

[3] DR. R.S Dalu K. K. Jadhao. Experimental investigation and numerical analysis of composite leaf spring. International Journal of Engineering Science and Technology (IJEST), 2006.

[4] Sabapathy Vijayarangan Mouleeswaran Senthil Kumar. Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi-leaf Spring for Light Passenger Vehicles Using Life Data Analysis. ISSN 1392-1320 materials science, 2007.

[5] Sambagam Vjayarangan Gulur Siddaramanna Shiva Shankar. Mono Composite Leaf Spring for Light Weight Vehicle Design, End Joint Analysis and Testing Materials Science. International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.4, 2006.

[6] I. Nairne b G. Jeronimidis a R.M. Mayer J.P. Hou a, J.Y. Cherruault b. Evolution of the eye-end design of a composite leaf spring for heavy axle loads" Composite Structures. Composite Structures 78 (2007) 351358, 18 April 2006.

[7] I. Venkata Naga Sri Harsha B. Karthic. Comparative study of cambered leaf spring and laminated composite straight leaf spring. ISSN 1392-1320 materials science, 2005.

[8] Kumar Krishan and Aggarwal M.L. A Finite Element Approach for Analysis of a Multi Leaf Spring using CAE Tools. Research Journal of Recent Sciences Vol.1 (2), 92-96, February 2012.

[9] Mouleeswaran Senthil Kumar and Vijayarangan Sabapathy. Analytical and Experimental Studies on Fatigue Life Prediction of Steel and Composite Multi leaf Spring for Light Passenger Vehicles Using Life Data Analysis. International Journal of Modern Engineering Research (IJMER) Vol.2, Issue.4, 2007.