

Von Mises Stress Analysis of Carbon and E-Glass Epoxy Composite Materials

Dr. KVS Seshendra Kumar

Assistant Professor

Department of Industrial Engineering

GIT, GITAM University, Visakhapatnam, India

Corresponding Authors' email id: seshendravenkata.karri@gitam.edu

Abstract

This work is carried out on a multi leaf spring having nine leaves used by a commercial vehicle, each leaf length, deformation and bending stresses are theoretically designed. The finite element modeling and analysis of a multi leaf spring has been carried out. It includes two full length leaves in which one is with eyed ends and seven graduated length leaves. Different type of material has chosen like steel, aluminum, carbon epoxy and glass epoxy. The model of the leaf spring has been generated in pro/e 5.0 and imported in ANSYS-12 for finite element analysis, which are most popular CAE tools. The FE analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements and refining them under defined boundary condition. Bending stress and deflection are the target results. A comparison of different material results have been done to conclude the low weight optimum model.

Keywords: *Design, Leaf Spring, Composite Materials, Finite Element Analysis, FEM, CAE tools.*

I. INTRODUCTION

Leaf springs also known as flat spring are made out of flat plates. Leaf springs are designed two ways: 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.

In order to conserve natural resources and economize energy, weight reduction has been the main focus of automobile manufacturers 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 automobiles as it accounts for 10% - 20% of the unstrung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of composite materials was made it possible to reduce

the weight of 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 with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs. The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system.

Material properties

Table: 1

Parameter	Steel	Al	e-glass epoxy	Carbon -epoxy
E-X (Pa)	2E11	7e10	50e9	1.34e11
E-Y (Pa)	-	-	12e9	7e9
E-Z (Pa)	-	-	12e9	7e9
P-XY	0.266	0.3	0.3	0.3
P-YZ	-	-	0.3	0.3
P-ZX	-	-	0.3	0.3
G-XY (Pa)	-	-	5.6e9	5.8e9
G-YZ (Pa)	-	-	5.6e9	5.8e9
G-ZX (Pa)	-	-	5.6e9	5.8e9
ρ (Kg/M ³)	7860	2470	2000	1600

METHODOLOGY

The three dimensional model of the multi leaf spring is shown in the figure below. The multi leaf spring is modeled maximum deflection i.e. flat position reverse direction to attain its original shape i.e. semielliptical. The boundary condition is the collection of different forces, pressure, velocity, supports, constraints are required for complete analysis. As per specifications the spring is drawn at flat condition, therefore the load is applied in downward direction to achieve initial no load condition. As no load camber is 153° , a joint rotation of 27° is considered for both revolute joints, during static analysis. The boundary conditions for the experimental results are shown in the figure.

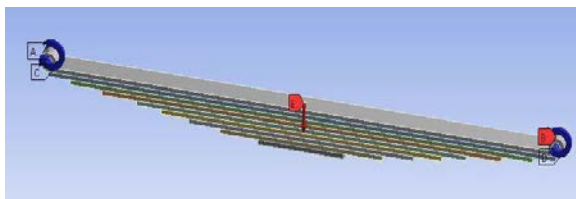


Figure: 1 Modeling and finite element analysis

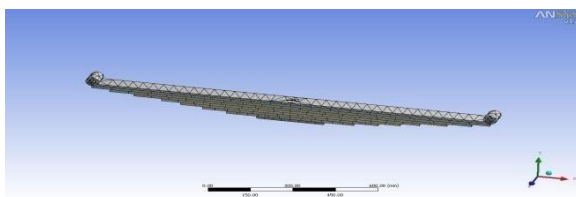


Figure: 2 Finite element model generated in ANSYS

CAD modeling software is dedicated for specialized job of 3 d modeling. The model of multi leaf structures are also include many complicated parts which are difficult to make by any other of CAD modeling as well as finite element software. CAD modeling of complete leaf spring structure is performed by using pro/e 5.0 software [7]. it is specialized software for create the part and all individual parts are assembled in pro/e [7] and which is imported in ansys 12.0 as iges file [2]

Numerical Example

A stress-deflection analysis is performed using finite element analysis (FEA). The complete procedure of analysis has been done using ANSYS-12 [2]. To conduct finite element analysis, the general process of FEA is divided into three main phases, preprocessor, solution, and postprocessor.

Preprocessor: The preprocessor is a program that processes the input data to produce the output that is used as input to the subsequent phase (solution). Following are the input data that needs to be given to the preprocessor: i. Type of analysis ii. Element type iii. Real constants iv. Material properties v. Geometric model vi. Meshed model vii. Loading and boundary conditions.

Solution: Solution phase is completely automatic. The FEA software generates the element matrices, computes nodal values and derivatives, and stores the result data in files. These files are further

used by the subsequent phase (postprocessor) to review and analyze the results through the graphic display and tabular listings.

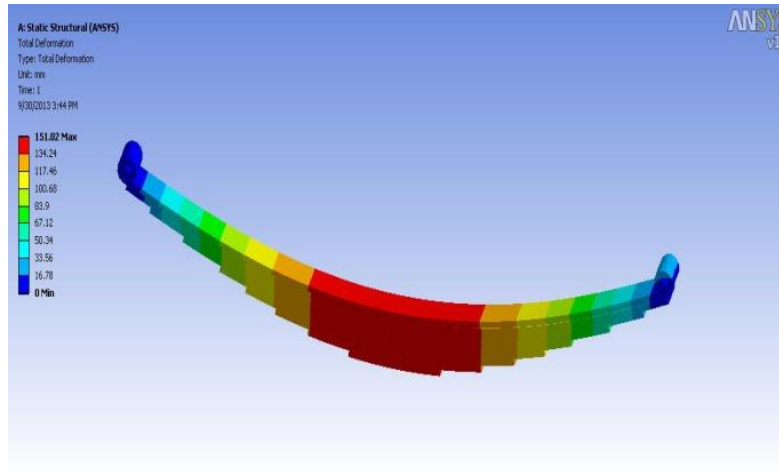


Figure: 3 Deformation of Steel Bending Stress of Steel

$$totaldeflection = \frac{12 w l^3}{E X B X t^3 (2 ng+3 nf)} [6]$$

$$totaldeflection = \frac{12 \times 17500 \times 725^3}{2.1 \times 10^5 \times 70 \times 12^3 (2 \times 7 + 3 \times 2)}$$

$$= 157.5 \text{ mm}$$

$$bendingstress = \frac{6 w l}{n t^2} [6]$$

Table: 2 Natural frequencies of steel and aluminum materials

Parameter	Steel	Al
Deformation (theoretical)	157.5	465
Deformation (ANSYS)	151	294
Bending Stress (theoretical)	839.1	839.1
Bending Stress (ANSYS)	904	992.3

Mode No	Steel hz	Al hz
1	4.06	36
2	23	92
3	29	136
4	87	168
5	146	171

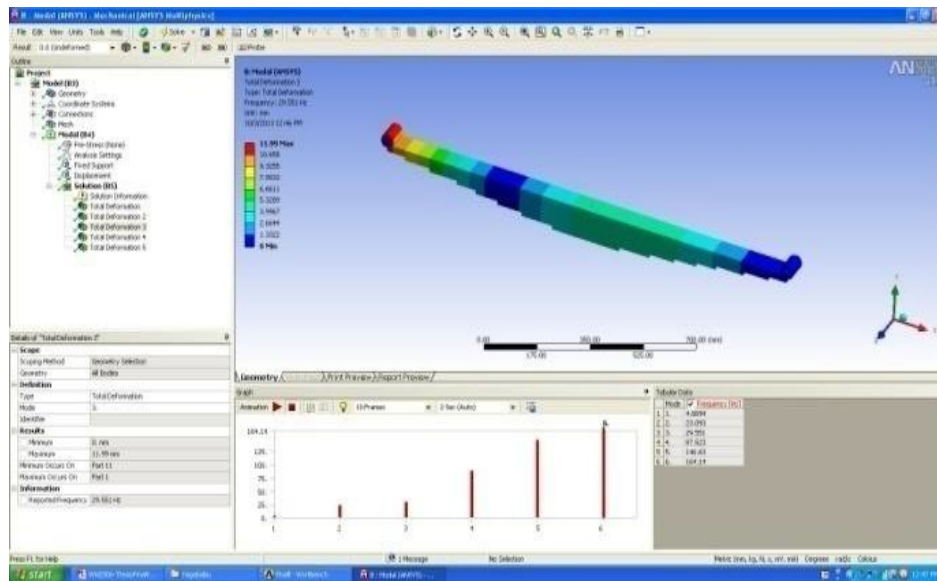
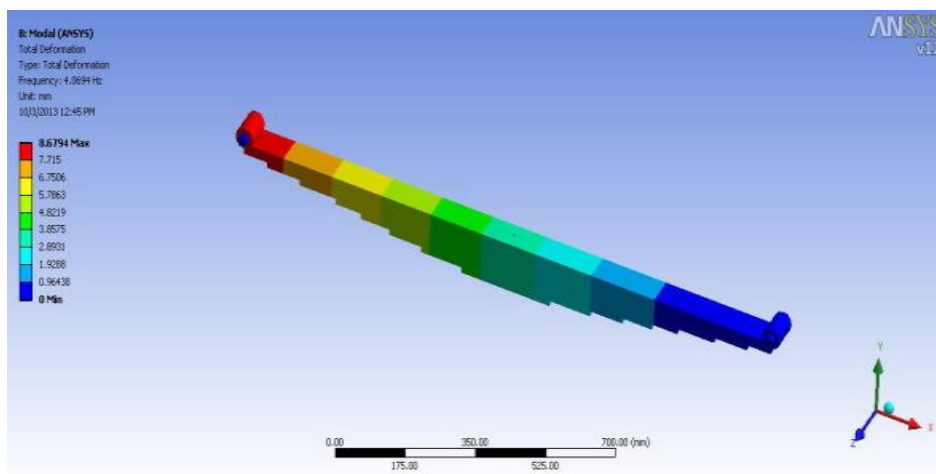
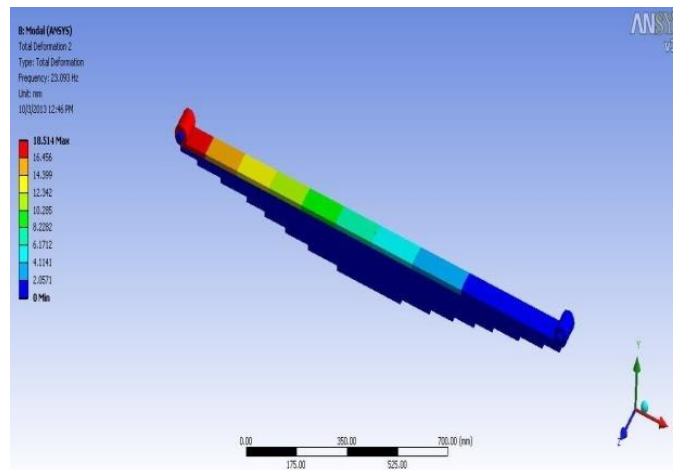


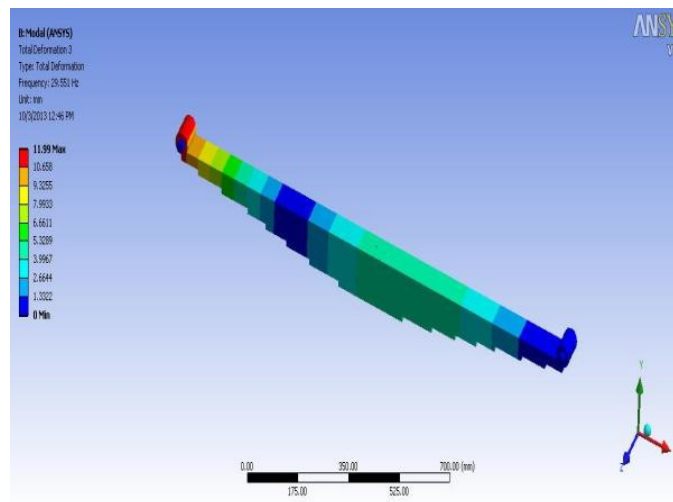
Figure: 4 Natural frequencies for steel



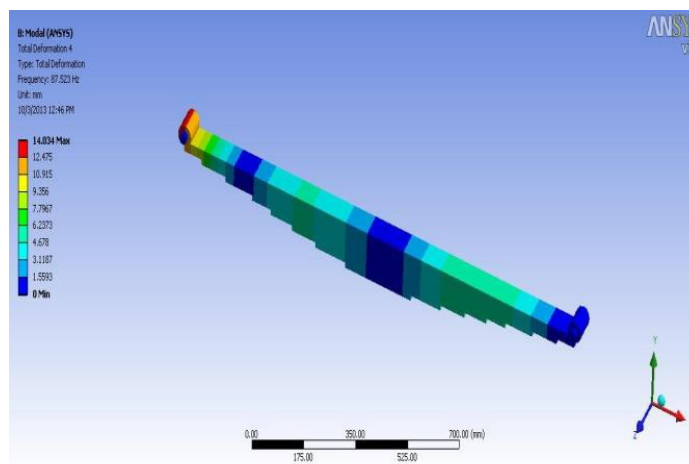
1 st mode shape of steel leaf



2 nd mode shape of of steel leaf



3 rd mode shape of of steel leaf



4 th mode shape of of steel leaf

Composite materials [4] like glass epoxy, carbon epoxy are considered in this work , it having orthotropic properties , each leaf are manufactured by using latupsequency technique.

In carbon epoxy material, 13 layers [1] are considered as 45,-45,0,90,90,90,90,90,90,0,-45,45 and each having constant thickness and finally form as 12 mm thick leaf flat plate. And glass epoxy contains 23 layers [1] like 45,-

45,45,-45,45,-45,45,-45,0,0,0,0,0,0,-45,45,-45,45,-45,45,-45,45. each having constant thickness and finally form as 12 mm thick leaf flat plate.

In this present work static, modal and harmonic analysis are performed in steel, aluminum, glass epoxy and carbon epoxy materials [3]. Considering with same boundary condition and loading. Static analysis Results are shown in below table

Table: 3

Parameter	Steel	Al	e-glass	Carbon epoxy
Deformation (mm)	66	189	713	233
Bending Stress (M.Pa)	618	618	856	920

Modal analysis [5] are used for finding the natural frequencies of total spring, it is totally depending up on weight and shape of spring .due to which we can find out where the resonance will occur.

Modal analysis natural frequencies are shown in blow table

Table: 3

Mode No.	Steelhz	Alhz	e-glasshz	Carbon epoxyhz
1	0.992	1.062	1.921	1.019
2	3.307	3.538	1.928	2.688
3	3.31	3.542	2.01	3.604
4	3.37	3.61	2.398	3.886
5	3.988	4.266	3.5	3.987

CONCLUSION

- 1) Total individual leaf length and number of leafs are designed theoretically.
- 2) Total deformation and bending stresses have found as per design calculations.
- 3) Using different lengths each leaf are modeled in PRO/E modeling software and assembled as single product.
- 4) analysis are performed by considering boundary conditions like fixed joint, revolve joint and sliding in x directions. Loading 35000 N has taken in to consideration at centre of entire leaf spring.
- 5) After post processing design results and ANSYS analysis results are compared for steel and aluminum.
- 6) Same model imported in to ANSYS APDL and static, model and harmonic analysis are performed for four different materials.
- 7) All material results are compared and steel material having less deformation and minimum bending stresses as compared to remaining materials. Even composite materials are having large deformation, according to weight; we can reduce 79% of mass as compared to steel. And carbon epoxy material having bending stresses near to steel material.
- 8) By using model analysis natural frequencies have found it can gives where the resonance will occur. Harmonic analysis also performed in that we applied the load and found that what maximum deformation at which natural frequency is.
- 9) From all above results composite material carbon epoxy is in design limit and low cost, less weight as compared to remaining materials. And which is optimum leaf spring for light weight vehicles where weight concentration is more.

REFERENCES

- I. Comparison of Static, Dynamic & Shock Analysis for Two & Five Layered Composite Leaf Spring by K.A. Sai Anuraag & Bitragunta Venkata Sivaram

- II.** ANSYS Inc: ANSYS Users Manual, Rev. 1995, 5.2-Vol.I – IV, Houston, PA.

- III.** Rajendran I. and Vijayarangan S., Design and Analysis of a Composite Leaf Spring, Institute of Engineers, India, 82,180–187

- IV.** Jones, R. M. Mechanics of Composite Materials. 2e, McGraw-Hill Book Company, 1990

- V.** M.Venkatesan, D. Helmen Devaraj, “Design & analysis of composite leaf spring in light vehicle”, IJMER, Vol.2, Issue.1, Jan-Feb 2012 pp-213-218 ISSN: 2249-6645

- VI.** R.S. Khurmi, J.K. Gupta. A text book of Machine Design, 2000.

Pro/Engineer Wildfire Release 2.0 for Engineers & Designers, Prof. Sham Tickoo, dreamtech press, Reprint 2006