International Journal of Emerging Trends in Engineering and Development Issue 4, Vol.4 (June-July 2014)
Available online on http://www.rspublication.com/ijeted/ijeted_index.htm ISSN 2249-6149

Finite Element Analysis of Mono Composite Leaf Spring under the Static Load Condition

JAGBHOOSHAN PATEL[a], VEERENDRA KUMAR[b]

[a] Research Scholar, Department of Mechanical Engineering,
Jabalpur Engineering College Jabalpur -482011, (M.P), India.
[b] Professor, Department of Mechanical Engineering,
Jabalpur Engineering College Jabalpur -482011, (M.P), India.

ABSTRACT: - Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this paper we describe design and analysis of composite leaf spring. The objective is to compare the stresses deflection and weight saving of composite leaf spring with that of steel leaf spring. The design constraint is deflection. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, since the composite materials has high strength to weight ratio, good corrosion resistance. The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and kevlar epoxy is used against conventional steel. The design parameters were selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring.

Keywords: leaf spring, E-Glass/Epoxy, carbon/epoxy Kevlar/epoxy composites, weight reduction and strength, finite element simulation.

INTRODUCTION

Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to shock absorbing. 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 unsprung 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. For weight reduction in automobiles as it leads to the reduction of un-sprung weight of automobile.

The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% 0f the un-sprung weight. The composite materials made it possible to reduce the weight of machine element without any reduction of the load carrying capacity. Because of composite material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel. FRP springs also have excellent fatigue resistance and durability. But the weight reduction of the leaf spring is achieved not only by material replacement but also by design optimization. Weight reduction has been the main focus of automobile manufacturers in the present scenario. The replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction. Moreover the composite leaf spring has lower stresses compared to steel spring. All these will result in fuel saving which will make countries energy independent because fuel saved is fuel produced. [5]

LITERATURE SURVEY

Investigation of composite leaf springs in the early 60's failed to yield the production facility because of inconsistent fatigue performance and absence of strong need for mass reduction. Researches in the area of automobile components have been receiving considerable attention now.[1] Many industrial visits, past recorded data shows that steel leaf springs are manufactured by EN45, EN45A, 60Si7, EN47, 50Cr4V2, 55SiCr7 and 50CrMoCV4 etc. These materials are widely used for production of the parabolic leaf springs and conventional multi leaf springs and extensively tested for fatigue life and on Road comfort performances. [7]

The introduction of composite materials made it possible to reduce the weight of the leaf spring without any reduction on the load carrying capacity and stiffness. Studies were conducted on the application of composite structures for automobile suspension system. Leaf springs absorb the vehicle vibrations, shocks and bump loads (Induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. Efforts were taken for Finite Element Analysis of multi leaf springs. These springs were simulated and analyzed by using ANSYS 14.5. Replacement of the steel leaf spring with a Genetic Algorithm based optimally designed composite leaf spring. Study is also done on numerical analysis of large deflection of prismatic Cantilever beams for various types of materials by using MATLAB so as to find out displacements. [2] A double tapered beam for automotive suspension leaf spring has been designed and optimized. Optimization of steel leaf spring in design is also done for many of vehicles. Premature failure in leaf springs was also studied so as to suggest remedies on application of composite leaf springs. [1]

METHOD AND SOFTWARE USED

FEA

The finite element analysis (FEA) is a computing technique that is used to obtain approximate solutions to the boundary value problems in engineering. It uses a numerical technique called the finite element method (FEM) to solve boundary value problems. FEA involves a computer model of a design that is loaded and analyzed for specific results. [6]

ANSYS

ANSYS is being used by designers across a broad spectrum of industries such as aerospace, automotive, manufacturing, nuclear, electronics, biomedical, and many more. ANSYS provides simulation solutions that enable designers to simulate design performance directly on desktop. In this way, it provides fast, efficient and cost-effective product development from design concept stage to performance validation stage of the product development cycle. ANSYS package help to accelerate and streamline the product development process by helping designers to resolve issues related to structural deformation, heat transfer, fluid flow, electromagnetic effects, a combination of these phenomena acting together, and so on. [6]

UNIGRAPHICS

NX Mold Design software delivers a state-of-the-art solution that enables mold manufacturers to shrink their lead times and tighten their cost controls. By combining industry knowledge and best practices with process automa- tion, NX Mold Design streamlines the entire mold development process from part design to tool assembly layout, tool design and tool validation. NX Mold Design excels at even the most challenging mold designs, providing advanced functionality, step-by-step guidance and associativity with part designs to ensure fast response to design changes and quality mold

SPECIFICATION OF PROBLEM:

The objective of the present work is to design the Carbon/Epoxy composite leaf spring for automobile Suspension system and analyze it. This is done to achieve the following. To the replace conventional steel leaf springs with Carbon/Epoxy composite leaf spring. To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with composite leaf spring. A virtual model of both steel and mono composite leaf spring was created in unigraphics. Model is imported in ANSYS 14.5 for analysis by applying normal load conditions. After analysis a comparison is made between exisisting conventional steel leaf spring and laminated mono composite leaf spring in terms of deflections and stresses.

SPECIFICATION OF THE CONVENTIONAL LEAF SPRING

The test steel leaf spring used for experiment is made up of 55Si2Mn90. The composition of material is 0.56 C%, 1.80 SI%, 0.70 Mn%, 0.045 P%, 0.045 S%. Following are the parameters for the 55Si2Mn90.

Table No.1 Specification of Existing Leaf Spring

Parameters	Value
Total Length of the spring (Eye to Eye)	1060mm
Free Camber (At no load condition)	95mm
No. of full length leave(Master Leaf)	01
Thickness of leaf	10mm
Width of leaf spring	70mm
Maxm Load given on spring	500N
Young's Modulus of the spring	2.1×10^5 N/mm^2
Weight of the leaf spring	7.6kg

Table No.2 Properties of Carbon/Epoxy material [5]

Sr.no.	Properties	value
1	Tensile modulus along X-direction (Ex), MPa	177000
2	Tensile modulus along Y-direction (Ey), MPa	10600
3	Tensile modulus along Z-direction (Ez), MPa	10600
4	Shear modulus along XY-direction (Gxy), MPa	7600
5	Shear modulus along YZ-direction (Gyz), MPa	2500
6	Shear modulus along ZX-direction (Gzx), MPa	2500
7	Poisson ratio along XY-direction (NUxy)	0.27
8	Poisson ratio along YZ-direction (NUyz)	0.02
9	Poisson ratio along ZX-direction (NUzx)	0.02
10	Mass density of the material (ρ), Kg/mm3	0.0000016

CALCULATIONS:

Tensile modulus of composite material along X-axis= E1= (Ef.Vf) + (Em.Vm)

Where, f = fiber, m = matrix, V = volume in composite. [2]

E1 = 177GPa

Table No.3 Calculation of stress and deflection

Sr No.	Parameter (For uniform width)	Formulae	Steel	Composite
1	Maximum stress induced, σmax (MPa)	$\sigma = \frac{3FL}{bt^2}$	114.23	75.35
2	Maximum deflection, δmax (mm)	$\delta = \frac{2FL^3}{Ebt^3}$	10.2	8.4

Issue 4, Vol.4 (June-July 2014)
ISSN 2249-6149

THREE-DIMENSIONAL FINITE ELEMENT ANALYSIS

To design composite leaf spring, a stress and deflection analysis was performed using the finite element method done using ANSYS software.

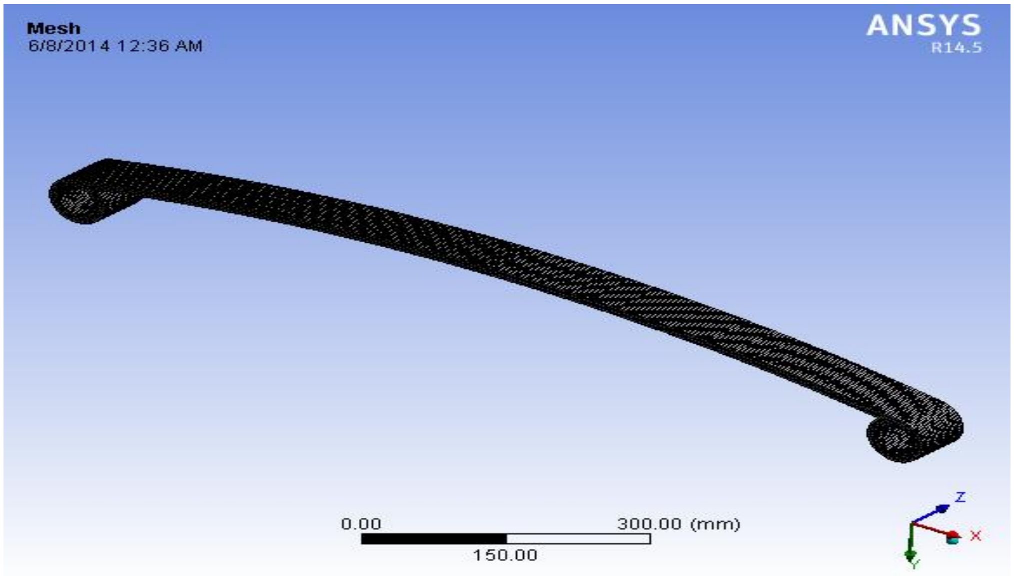

Fig. 1 mesh model of monocomposite leaf spring**.**

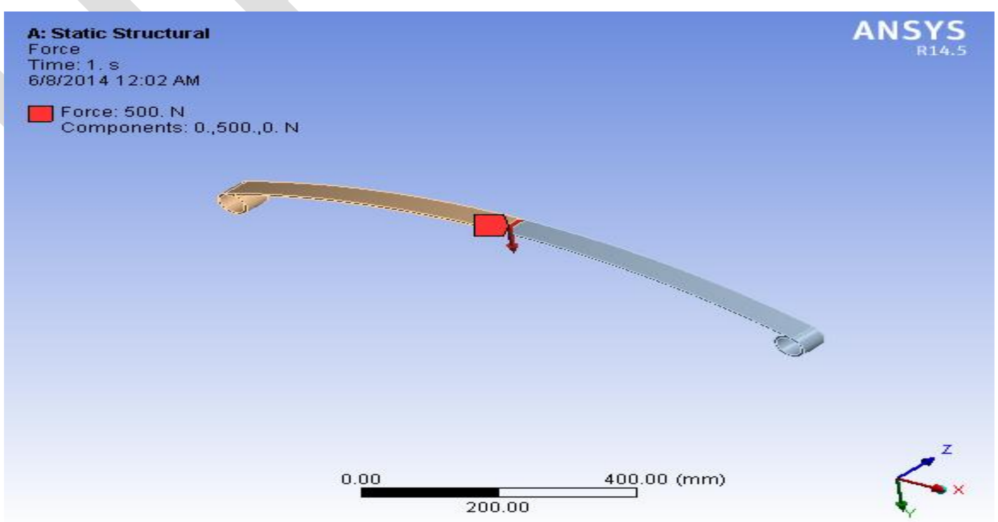

Fig. 2 Solid Modeling of Composite Leaf Spring

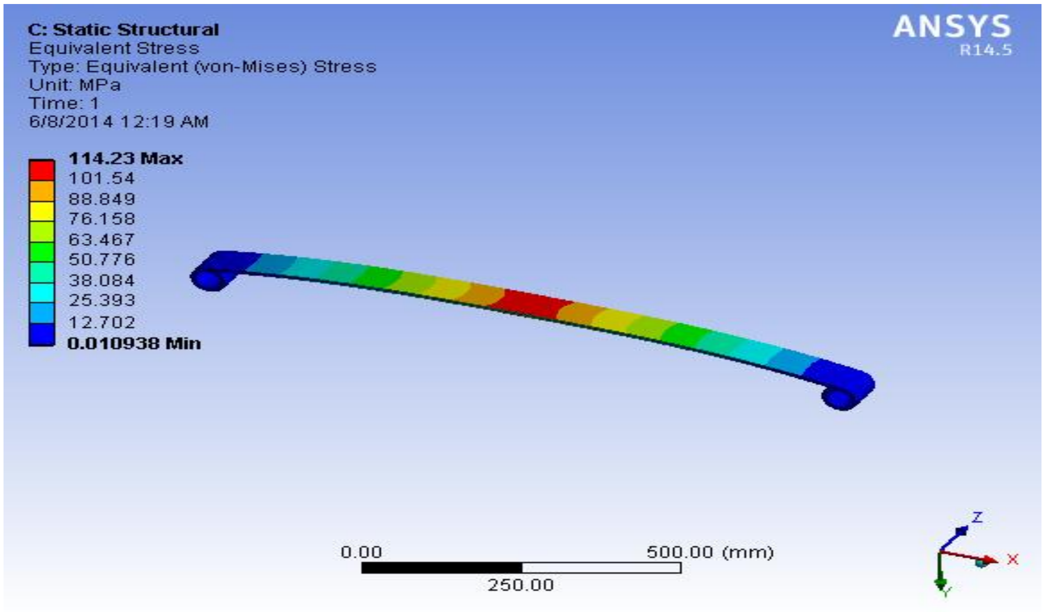

Fig. 3 Von-mises stresses of steel leaf spring

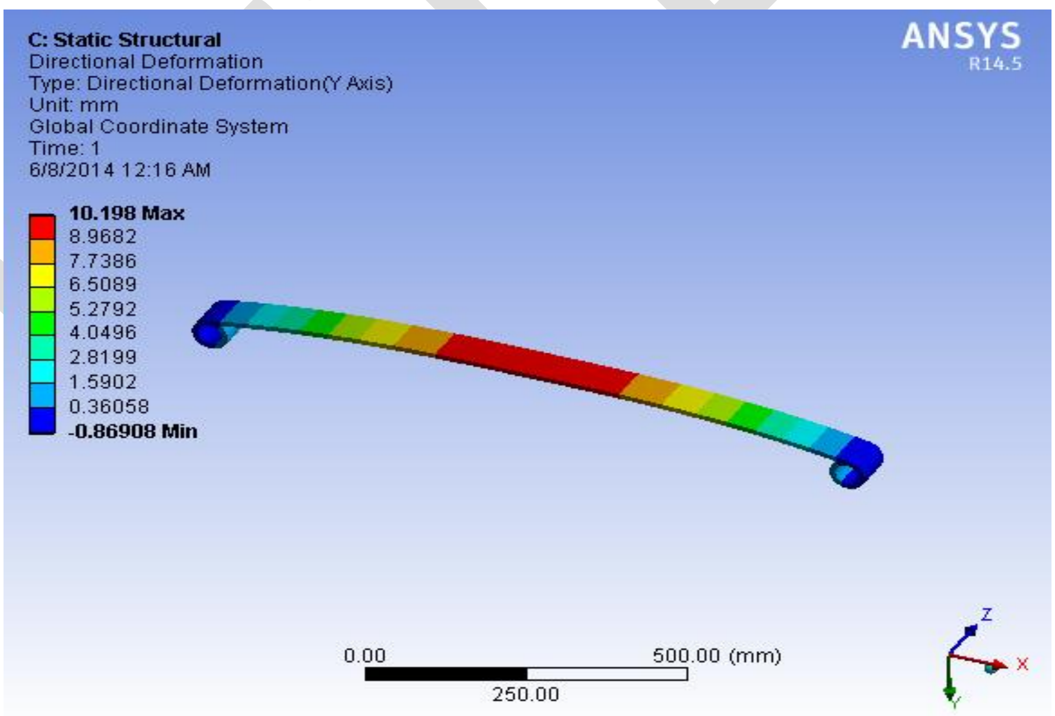

Fig. 4 Deflection Analysis of steel Leaf Spring

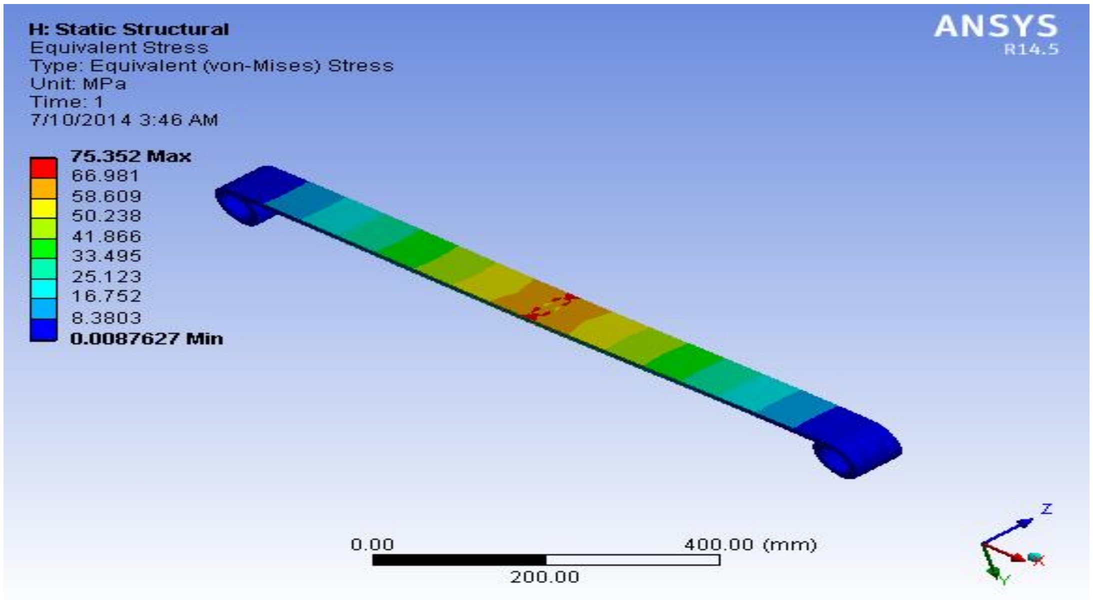

Fig. 5 Von-mises stresses of carbon/epoxy leaf spring

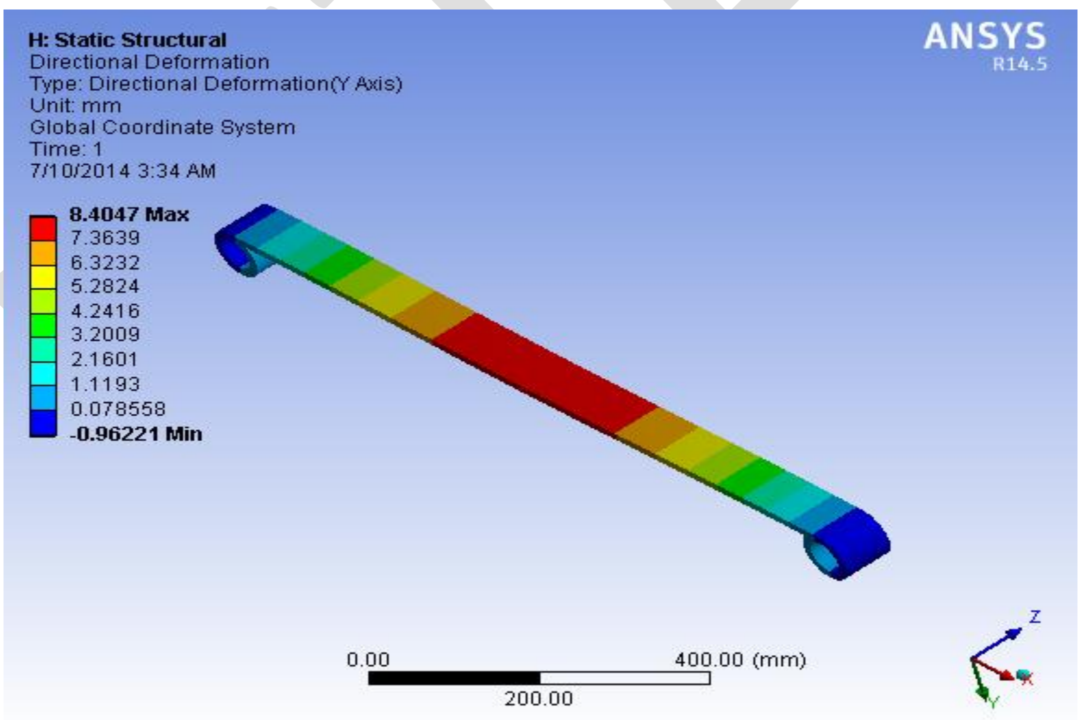

Fig. 6 Deflection Analysis of carbon/epoxy Leaf Spring

RESULTS AND DISCUSSION

Table No.4 Comparison results of stresses, deflection and weight saving

Sr no.	Materials	Stress(MPa)		Deflection(mm)		Thick-ness (mm)	Weight (Kg)	% Reduc-tion in weight
		Analytical	FEM	Analytical	FEM			
1	Steel	113.57	114.23	10.12	10.198	10	7.6	
2	Glass/ Epoxy	35.053	36.355	9.998	8.617	18	3.6	52%
3	Kevlar/ Epoxy	67.2	67.5	10.52	10.2	16	2.45	67%
4	Carbon/ Epoxy	72.68	75.35	10.26	8.4	12.5	1.93	72%

Experimental results from testing the leaf springs under static loading containing the stresses and deflection are listed in the Table 4. These results are also compared with FEA in Table 4. Testing has been done for unidirectional Carbon/Epoxy mono composite leaf spring only. Since the composite leaf spring is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the conventional leaf spring by composite leaf spring. Since, the composite spring is designed for same stiffness as that of steel leaf spring, both the springs are considered to be almost equal in vehicle stability. The major disadvantages of composite leaf spring are chipping resistance. The matrix material is likely to chip off when it is subjected to a poor road environments (that is, if some stone hit the composite leaf spring then it may produce chipping) which may break some fibers in the lower portion of the spring.

This may result in a loss of capability to share flexural stiffness. But this depends on the condition of the road. In normal road condition, this type of problem will not be there.

Composite leaf springs made of polymer matrix composites have high strength retention on ageing at severe environments.

The steel leaf spring was replaced with a composite one. The objective was to obtain a spring with minimum weight which is capable of carrying given static external forces by constraints limiting stresses (Tsai-Wu criterion) and displacements. The weight of the leaf spring is reduced considerably about 72 % by replacing steel leaf spring with composite leaf spring. Thus, the objective of the unsprung mass is achieved to a larger extent. The stresses in the composite leaf spring are much lower than that of the steel spring.

CONCLUDING REMARKS

- The development of a composite mono leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered.
- Constant due to the parabolic type of the thickness of the spring, has proved to be very effective.
- The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight Savings;
- The 3-D modeling of both steel and composite leaf spring is done and analyzed using ANSYS.
- A comparative study has been made between composite and steel leaf spring with respect to weight, cost and strength.
- The analytical results were compared with FEA and the results show good agreement with test results.
- From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications.
- Composite mono leaf spring reduces the weight by 72% for Carbon/Epoxy, 52 % for Glass/Epoxy, and 65 % for Kevlar/Epoxy over conventional leaf spring.

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