Design and study of Parabolic composite Mono-leaf Spring

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ABSTRACT

In the recent days weight reduction of an automobile vehicle is one of the important issues in automobile industries. These automobile industries are open to any kind of modification and implementation which can reduce the weight of the vehicle. The suspension leaf spring has the great potential in weight reduction as it account for 10% to 20% of the unspring weight of the vehicle. The introduction of composite leaf spring made of E-glass fiber epoxy resin has made it possible to reduce weight without reducing its load carrying capacity and stiffness.
This work deals with the comparison of conventional steel leaf spring with mono composite leaf spring. The width of the mono leaf spring varies from Centre to the outer side in the parabolic pattern. The CAD modeling of composite spring is done in CREO 3.0 software and analysis is done in ANSYS 16.0 workbench. The output results of the process are maximum deflection, equivalent (Vonmises) stresses. Finally conclusions are drawn on the basis of the results.

Keyword: - *Mono-leaf spring , E-glass epoxy , Analytical solution , Creo 3.0, Ansys 16.0 ,experimental testing*

1. INTRODUCTION

Ever increasing demands of high performance together with long life and light weight necessitate consistent development of almost every part of automobile. Increasing competition and innovations in automobile sector tends to modify the existing products or replacing old products by new and advanced material products. A suspension system of vehicle is also an area where these innovations are carried out regularly. 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.

Leaf spring is a simple form of a spring, commonly used for the suspension in wheeled vehicles. It is also one of the oldest forms of springing, dating back to medieval times. Just for the common form of its conception in Italian language a leaf spring suspension is called “balestra” (cross bow).an advantages of a leaf spring over a helical spring is that the end of the leaf spring may be guided along a definite path. 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 introducion of better material, design optimization and better manufacturing processes.

2. COMPONENT STUDY

Name of Component – Leaf Spring
Material – E-glass epoxy
Thickness – 20 mm

Fig.1. composite Leaf spring Design

3. Principle of Leaf Spring:

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. 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. In the design of springs, strain energy becomes the major factor. The relationship of the specific strain energy can be expressed as

$$U=\sigma^2/\rho E$$

Where σ is the strength, ρ is the density and E is the Young's Modulus of the Spring material It can beeasily observed that material having lower modulus and density will have a greater specific strain energy capacity .The introduction of composite materials made it possible to reduce the weight of the leaf spring without reduction of load carrying capacity and stiffness due to the following factors of composite materials as compared to steel. Arrangement of leaf spring in a car Model An upturned spring eye is used to attach the front end of semi-elliptic leaf spring to the chassis frame, and a free end with a bracket constraining vertical motion to attach the back end of semi-elliptic leaf spring to the chassis frame.3.

4. Theory of Composite Material:

The material which is composed of two or more different kind of composites which are insoluble in each other and maintain their physical phases and they physically and chemically separated by a clear- cut interface or inter phases called composites. Composites are mixture of two substance in which one of the substance is known as the matrix phase is in the form of sheets, fibers, or particles and is implanted in the other substance say the reinforcing phase. Numerous composite materials propose a combination of strength and modulus that are either equivalent to or superior than any conventional metallic metals. Modulus to weight-ratios and the strength to weight-ratio of these composite materials are markedly higher to those of metallic materials Because of their low specific gravities. Fatigue damage tolerances and the fatigue strength weight ratios of several composite laminates are exceptional. For these explanations, fiber composite have emerged as a main class of structural substance and are either used or being considered as replacements for metal in many weight-critical parts in automotive, aerospace, and other industries. High internal damping capacity is another unique feature of numerous fiber reinforced composites. This leads to enhanced vibration energy inclusion within the material and results in reduced transmission of noise to adjacent structures.

5. Process Description:

Static Analysis Used to determine displacements stresses, etc. under static loading conditions linear static analyses. Nonlinearities can include hyper elasticity, contact surfaces, stress stiffening, plasticity, large deflection, large strain and creep.

The leaf spring modeled in creo 3.0 was imported to ANSYS in IGES format. Leaf spring was modeled as a solid part, SOLID187 solid element was used to mesh the model. SOLID186 element is10- node and higher order 3-D element. SOLID186 has a quadratic displacement behavior and is well suited to modeling irregular. The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The SOLID186 element has creep, stress stiffening, plasticity, hyper elasticity, large deflection, and large strain capabilities; the element input data also includes the orthotropic or anisotropic material properties.

6 Composite Leaf Spring Geometric Specifications:-

The tables below shows the complete geometrical and mechanical properties of the composite leaf spring.

Sr. No.	Parameters	Dimensions in mm
1	Total length of the spring	1000
2	Free camber (at no load condition)	130
3	Total number of leaves	01
4	Thickness of leaf	20
5	Width of the leaf near the centre	55
6	Width of the leaf near the eye	100

Table 1: Mechanical properties of the material

Property	Magnitude
Young's modulus	40000 MPa
Poisson's ratio	0.217
Tensile strength	900 MPa
Compressive strength	450 MPa
Density (Kg/m^3)	2.16×10^5

Calculations:

for TATA ACE light commercial vehicles:

GVW(gross vehicle weight)	=	**1200kg**
Maximum load carrying capacity	=	**1000kg**
Total load	=	**12000+1000**
	=	**2200kg**
	=	**21582 N**
Load in a single leaf	=	**21582/4=5395.5N**
Span length (2L)	=	**1000mm**

But 2 F = 5395.5 N So F = 2697 N

Now equation for maximum stress and maximum deflection due to applied force in the leaf spring is given by

$$\sigma_{max} = \frac{6WL}{bt^2}... = \frac{6\times2697.5\times500}{55\times20^2} = 367.87 \text{ N/m } m^2..............$$

$$\delta_{max} = \frac{4WL^3}{Ebt^3} = \frac{4\times2697\times500^3}{40000\times55\times20^3} = 76.64\ mm$$

Where,

E -Modulus of elasticity,

L -The characteristic length of the spring -

W -Force applied to the leaf spring b

-Width of the leaf spring

t -Thickness of the leaf

7 Static Analysis of Composite leaf spring

ANSYS software is used to analyze the stresses by performing static analysis for the given leaf spring specification and to determine the deflection in leaf springs. Analysis involves discretization called meshing, boundary conditions, loading.

- Advantages of FEA :-

Visualization increases

- Design cycle time reduces
- No. of prototypes reduces
- Testing reduces
- Optimum design

- The process of performing ANSYS can be broken down to three Main steps.

1) Pre-processing
2) Solver
3) Post-processing

A. ELEMENTS TYPE

- Solid 186 (3-D BRICK ELEMENT with 20 Nodes)
- CONTA174 - 3-D 8-Node Surface-to-Surface Contact.

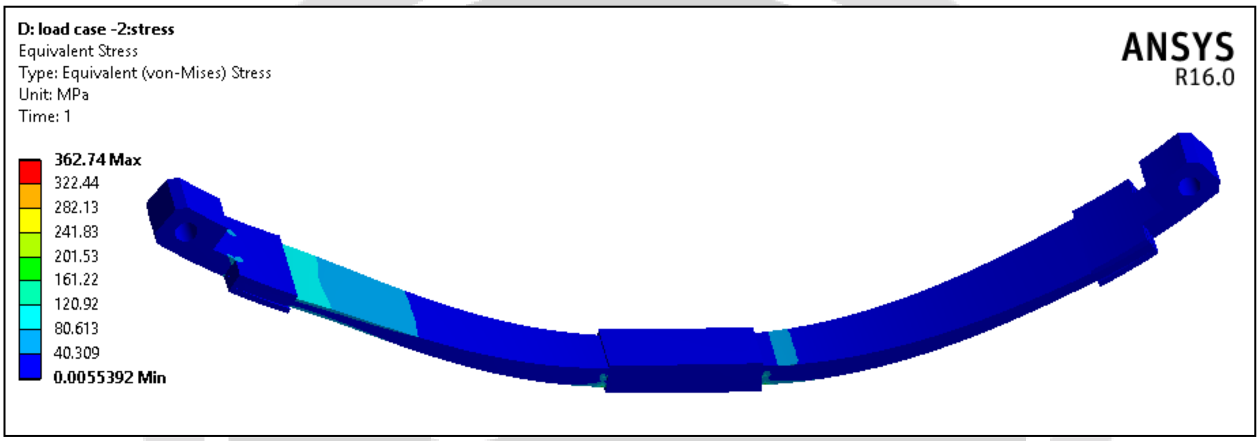
B. MESHING :-

Meshing involves division of the entire of model into small pieces called elements. It is convenient to select the free mesh because the leaf spring has sharp curves ,so that shape of the object will not alter. Hex dominant meshing method is used to have brick elements in the meshing To mesh the leaf spring the element type must be decided first. Here, the element type is solid 186.The numbers of elements are taken 296603 and the total numbers of nodes are 69882.

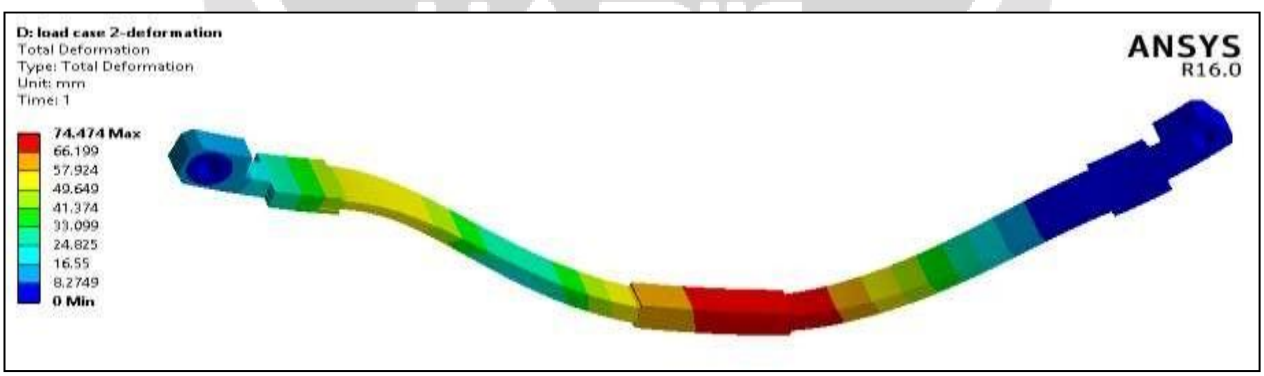
C. BOUNDARY CONDITIONS-

Boundary conditions for steel and composite material are same one end has given degree of translation and other end fixed. At the midpoint vertically upward force applied because in TATA ACE there is support at midpoint, acceleration due to gravity in downward direction.

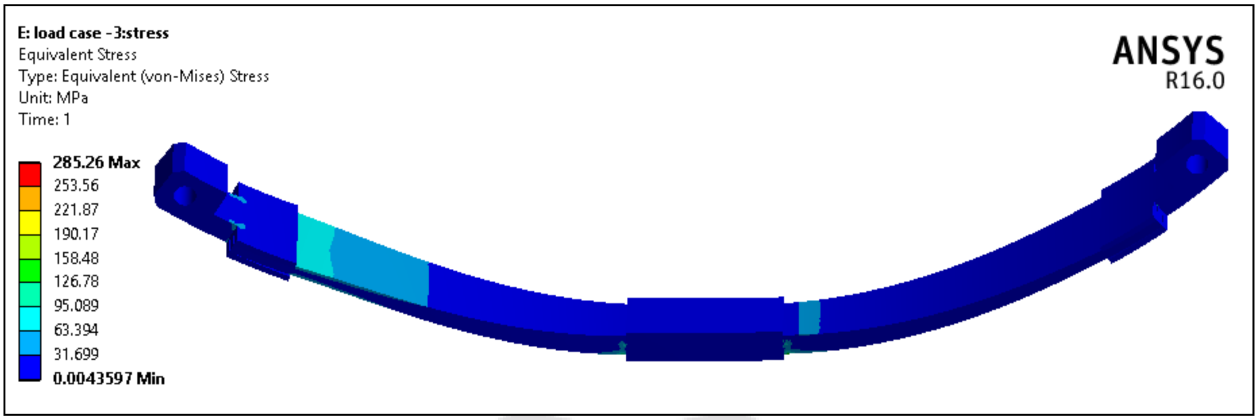
7.1 FEA Analysis Result :-



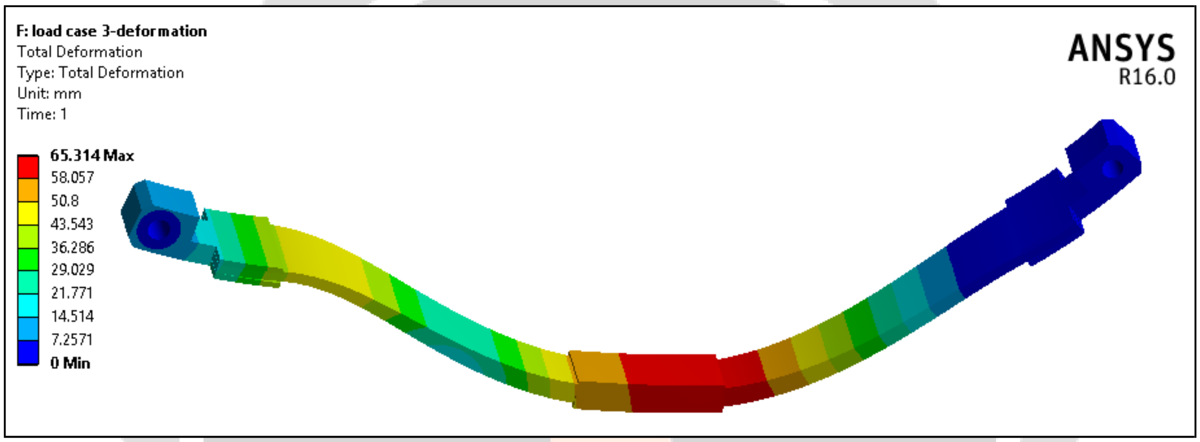
Maximum Bending stress of composite leaf spring At load 2697 N



Maximum deformation of Composite Leaf spring At Load 2697 N



Maximum Bending stress of composite leaf spring At load 2140 N



Maximum Deformation of composite leaf spring At Load 2140 N

8 EXPERIMENTAL SET UP:-

8.1 Testing Procedure :-

1) Arrange the holding clamp of UTM machine as per the size of leaf spring.

2) Switch on the CPU of computer and the UTM machine.

3) Reset the UTM machine as per our requirement.

4) The variation in deflection with respect to applied load is selected on the software.

4) Apply the load gradually from starting with 0 KN to maximum load spring sustain.

5) Observe the deflection for that applied load.

6) When inner surface of the leaf spring will get touch to the workbench of UTM machine, stop the load.

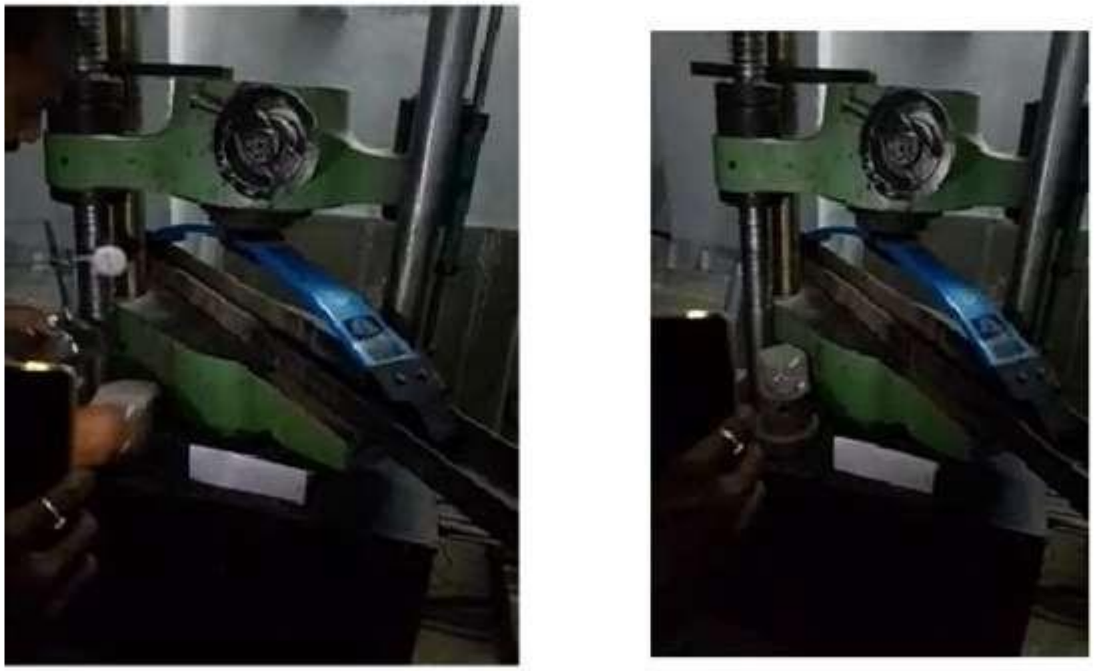


Fig.2. Testing of Composite Leaf spring on UTM

7) Observe the maximum deflection occurred in the spring at specific load.

8) Take all the readings of the load vs deflection from the software.

9) Remove the load applied gradually till the spring regains its mean position.

10) Remove the leaf spring from holding clamp fixture.

9 Results :-

According to that we have tested composite leaf spring upto load 2140 N result as follow

	Steel Leaf	Composite Mono Leaf spring		
	Anaylatical	**Anaylatical**	**Experimental**	**FEA**
Load (N)	**2140**	**2140**	**2140**	**2140**
Deflection(mm)	**33.96**	**60.79**	**60.69**	**65.31**
Stress (N/mm^{2})	**428**	**291.8**	**290.34**	**285.40**
Mass (Kg)	**13.27**	**4.3**		

Table.2. tested composite leaf spring upto load 2140 N

By the comparison of results between steel leaf spring and the composite leaf spring from analytical and experimental the deflection is increased by 45 % in composite leaf spring that is within the camber range. The bending stresses are decreased by 33.05% in composite leaf spring means less stress induced with same load carrying conditions. The conventional multi leaf spring weights about 13.27kg whereas the E- glass/Epoxy multi leaf spring weighs only 4.3 kg. Thus the weight reduction of 67.88% is achieved.

10. Conclusion:

The composite parabolic leaf spring is lighter and more economical than the conventional steel spring with similar design specifications. A mono composite leaf spring for the vehicular suspension system was designed using E-Glass/Epoxy with the objective of minimizing weight of the leaf spring. And it is shown that the resulting design stresses are much below the strength properties of the material satisfying the maximum stress failure criterion. The deflection of the leaf spring along its transverse direction, which is very small compared to the considered maximum deflection.

Future Scope :

The future work can be performed as

1) Now a day's composite leaf spring is convenient to use only on expressways vehicles. After improving the quality of roads it can be used in rural area's vehicle also.

2) Now a day there is need of weight reduction in Light Utility Vehicle, So by using composite leaf spring in these vehicles we will get sophisticated design.

3) By modifying the properties of material and design parameters composite leaf spring can be use in the Heavy Duty Vehicle also.

4) This world is now replacing conventional accessories by deriving new composites and nano material in metallurgical research.

5) With tremendous improvement in all the accessories of vehicle, new generation of automotives will be capable to reach customer's satisfaction.

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