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Structural Analysis of Leaf Spring Using Composite Materials for Lightmotor Vehicle

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Abstract*— *Automobile industry has shown increased interest in the replacement of conventional materials with composites due to its property of high strength to weight ratio. In the present work, the dimensions of an existing laminated steel leaf spring of a LIGHT MOTOR VEHICLE is taken for modelling for steel and the structure is changed into simple mono leaf spring and the material is changed to composite material and it is analysed. To reduce the weight of the suspension system. To increase the fuel efficiency of vehicle. To provide better riding comfort. By introducing the composite material instead of conventional steel material

Keywords*— *Leaf spring.

I. Introduction

This project describes design and analysis of laminated leaf springs on various composite materials like glass fiber, boron fiber, and Buckminster fullerene T-300. Here the steel springs are compared with other composite materials with their stress, stiffness, frequency and its weight reduction.

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, tri biological and environmental applications, 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 the advantage of leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device. 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 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 with those of steel, multi- leaf steel springs are being replaced by mono- leaf composite laminated springs.

using SOLIDWORKS software is used for modeling and ANSYS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using ANSY

1.1 Application

The composite industry has begun to recognize that the commercial application of composite promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus the shift of composite application from aircraft to other commercial materials (e.g. steel), the properties composite materials can be designed considering the structural aspects. The design components using composites involves both materials and structural design. Composite properties (e. g. stiffness, thermal expansion etc.) can be varied continuously over a board range of values under the control of the designer. Careful selection of reinforcement type enables finished product characteristics to be tailored to almost any specific engineering requirement.

II. Literature Survey

Fatigue failure always starts with crack-growth. The crack can initiate from the surface or at a depth below the surface depending on the materials processing conditions. Evaluation of a Leaf Spring Failure‟ gives the determination of the point of failure during an accident sequence of a rear leaf spring in a sport utility vehicle is presented in terms of fracture surface analysis and residual-strength estimates. The point of failure of the spring was placed at the start of the accident sequence.

Fatigue life prediction is based on knowledge of both the number of cycles the part will experience at any given stress level during that life cycle and another influential environmental and use factors. The local strain-life method can be used pro-actively for a component during early design stage.

In the case of parabolic spring, this was representing by different road surface and driving condition of the vehicle. Using constant amplitude loading, test were performed in controlled condition. But in VAL, lot of parameter need to be consider like cycle range and sampling frequency.

Traditionally, fatigue life at variable amplitude is predicted by using material properties from constant amplitude laboratory test together with the Palmore-Miner damage accumulation hypothesis. The major reason for carrying out variable amplitude loading test is the fact that a prediction of fatigue life under this complex loading is not possible by any cumulative damage hypothesis. There is the demand for spring

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excellent in sag resistance and fatigue properties, along with the increase in loaded stress on the springs. Strengthening for spring material would be effective in improving fatigue property, from the point of fatigue limits.

Fatigue test using constant amplitude loading is a commonly practiced to predict the fatigue life properties of materials. Many models have been developed to predict the fatigue life of components subjected to variable amplitude loading. The earliest of these are based on calculations of the yield zone size ahead of the crack tip and are still widely used .The objective of the study carried by F.N. Ahmad Refngah, S. Abdullah, for their paper Life Assessment of a Parabolic Spring under Cyclic Strain Loading" is to simulate the variable amplitude loading for the fatigue life analysis. Service loading of parabolic spring has been collected using data acquisition system. The finite element method (FEM) was performed on the spring model to observe the distribution stress and damage.

The experimental works has been done in order to validate the FEM result. The origin of premature fracture in leaf springs used in Venezuelan buses is studied. To this end, common failure analysis procedures, including examining the leaf spring history, visual inspection of fractured specimens, characterization of various properties and simulation tests on real components, were used. It is concluded that fracture occurred by a mechanism of mechanical fatigue, initiated at the region of the central hole, which suffered the highest tensile stress levels.

III. Composite Materials

A composite material is defined as a material composed of two or more constituents combined on a macroscopic scale by mechanical and chemical bonds. Composites are combinations of two materials in which one of the material is called the “matrix phase” is in the form of fibres, sheets, or particles and is embedded in the other material called the “reinforcing phase”. Many composite materials offer a combination of strength and modulus that are either comparable to or better than any traditional metallic metals. Because of their low specific gravities, the strength to weight-ratio and modulus to weight-ratios of these composite materials are markedly superior to those of metallic materials.

The fatigue strength weight ratios as well as fatigue damage tolerances of many composite laminates are excellent. For these reasons, fibre composite have emerged as a major class of structural material and are either used or being considered as substitutions for metal in many weight-critical components in aerospace, automotive and other industries. Another unique characteristic of many fibre reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced transmission of noise to neighbouring structures. High damping capacity of composite materials can be beneficial in many.

3.1. Classification of Composites

The composites are classified as follows:

3.1.1 Organic – Matrix Composites (OMCs)

3.1.2 Polymer- Matrix Composites

3.1.3 Carbon – matrix Composites

TABLE 1.1. Examples of polymers best suited for the process.

Reinforcing Material	Most Common Matrix Materials	Properties Improved
Glass Fibres	UP, EP, PA, PC, POM, PP, PBT, VE	Strength, Elasticity, heat resistance
Wood Fibres	PE, PP, ABS, HDPE, PLA	Flexural strength, Tensile modulus, Tensile Strength
Carbon and Aramid Fibres	EP, UP, VE, PA	Elasticity, Tensile Strength, compression strength, electrical strength.

Metal Matrix Composites (MMCs)

3.1.5 Ceramic – matrix Composites (CMCs)

3.1.6 Fiber-reinforced composites

IV. Selection of Composite Material

As mentioned earlier, the ability to absorb and store more amount of energy ensures the comfortable operation of a suspension system. However, the problem of heavy weight of spring is still persistent. This can be remedied by introducing composite material, in place of steel in the conventional leaf spring. Research has indicated that the results of GLASS FIBER were found with good characteristics for storing strain energy. So, a virtual model of leaf spring was created in Pro-E. Model is imported in ANSYS and then material is assigned to the model. These results can be used for comparison with the conventional steel leaf spring.

TABLE 1.2. Fiber unidirectional epoxy composite properties.

Property	ASTM Standard	75°F	22°C
Elastic Constants		Msi	GPa
Longitudinal Modulus, E_L	D3039	7.7 - 8.5	53 - 59
Transverse Modulus, E_T	D3039	2.3 - 2.9	16 - 20
Axial Shear Modulus, G_{LT}	D3518	0.9 - 1.3	6 - 9
Poisson's Ratio, ν_{LT}	D3039	0.26 - 0.28	0.26 - 0.28
Strength Properties		ksi	MPa
Longitudinal Tension, F^{tu}_L	D3039	230 - 290	1590 - 2000
Longitudinal Compression, F^{cu}_L	D3410	100 - 180	690 - 1240
Transverse Tension, F^{tu}_T	D3039	6 - 12	41 - 82
Transverse Compression, F^{cu}_T	D3410	16 - 29	110 - 200
In-Plane Shear, F^{su}_{LT}	D3518	9 - 24	62 - 165
Interlaminar Shear, F^{sbs}	D2344	8 - 15	55 - 103
Longitudinal Flexural	D790	180 - 250	1240 - 1720
Longitudinal Bearing	D953	68 - 80	469 - 552
Ultimate Strains			
Longitudinal Tension, ϵ^{tu}_L	D3039	2.7 - 3.5%	
Longitudinal Compression, ϵ^{cu}_L	D3410	1.1 - 1.8%	
Transverse Tension, ϵ^{tu}_T	D3039	0.25 - 0.50%	
Transverse Compression, ϵ^{cu}_T	D3410	1.1 - 2.0%	
In-Plane Shear, γ^{u}_{LT}	D3518	1.6 - 2.5%	
Physical Properties			
Fiber Volume (%)	D2734	57 - 63%	57-63%
Density	D792	lb/in^3 0.071 - 0.073	g/cm^3 1.96 - 2.02

4.1. Types of Fiber

In the fiber reinforced composite materials the fibers are playing major role since the fiber properties influence more in the composite properties. Hence the selection of fiber is important. There are large number of fibers available in the commercial usage such as

- Glass fiber
- Boron fiber
- Buckminsterfullerene
- E-Glass
- S-Glass
- Carbon (graphite)
- Aramid (Kevlar 49)

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V. DESIGN OF MONO LEAF SPRING

TABLE 1.3. Design parameters of steel leaf spring.

Sl.no	Parameter	Length in mm
1	Length of leaf spring from eye end to eye end	1270
2	Width at both end	120
3	Width at center	60
4	Thickness at both end	10
5	Thickness at center	30
6	Diameter of eye end	50

5.1 Isotropic Properties of Epoxy

Young's modulus = 240gpa
Poisons ratio = 0.34

5.2. Modelling of Leaf Spring

Once you have created the model it is necessary to produce the multi view drawings of the model. It is a guideline that shows the key steps to create drawing with Solid w

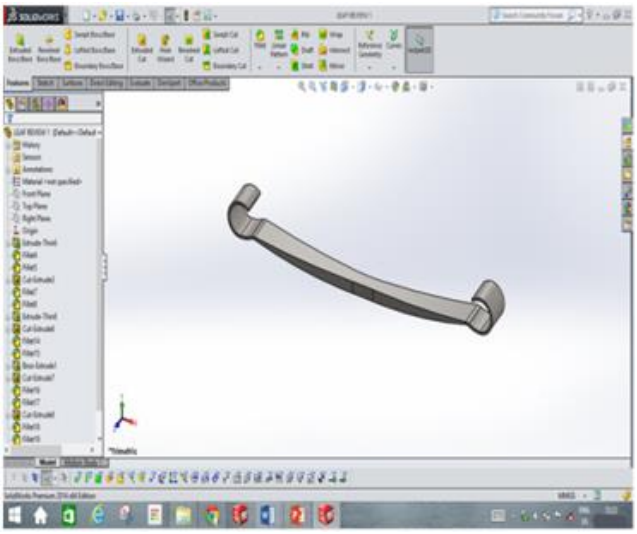

Fig. 1.1. Model of leaf spring.

VI. ANALYSE BY USING ANSYS

Step 1: Main menu > preferences
Click on structural and give ok.
Step 2: Main menu > preprocessor > element type > add/edit/delete
Add an element type
Structural brick 8 node 85
Ok to apply the element type and close the dialog box.
Step 3: Main menu > preprocessor > material props > material models
Double click on structural, linear, elastic, and isotropic
For steel leaf spring
Enter 2.1 10^{*5} for EX
Enter 0.313 for PRXY
Ok to define material property set and close the dialog box
Material > exit.
Step 4: File > import> IGES form solid works

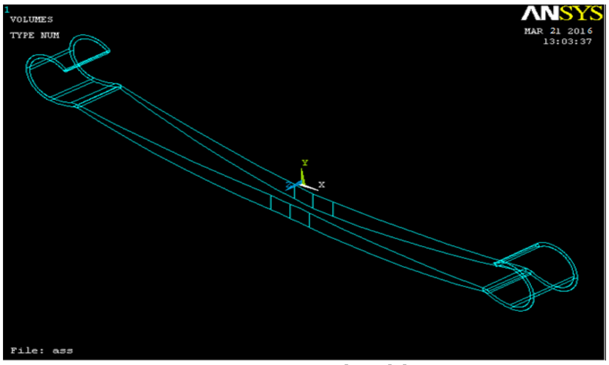

Fig. 1.2. Imported model.

Step 5: Main menu > preprocessor > meshing > mesh tool Mesh tool window will appear, line set select the front line of the leaf and give ok. Area set select front area of the leaf and give ok. Volume select and select the object and give ok.

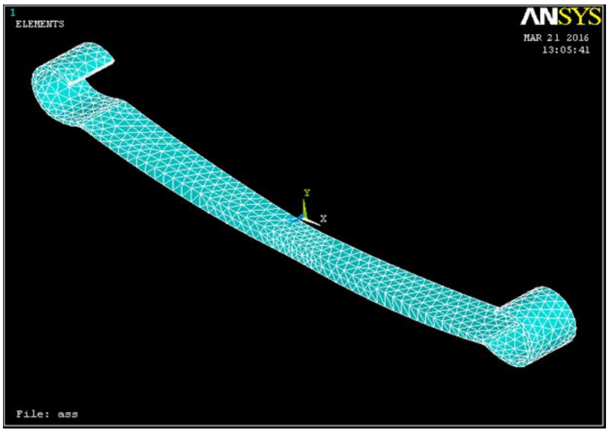

Fig. 1.3. Meshing.

Step 6: Main menu > solution > define load > apply > structural > displacement on area and select end area on the leaf.

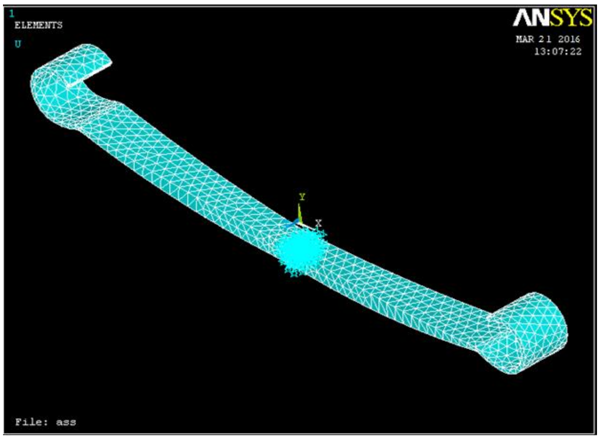

Fig. 1.4. Displacement.

Main menu > solution > define load > apply > structural > force/moment > on node
Pick bottom of the leaf and select the FY direction for both steel and composite leaf spring.
Enter the force value 1500N

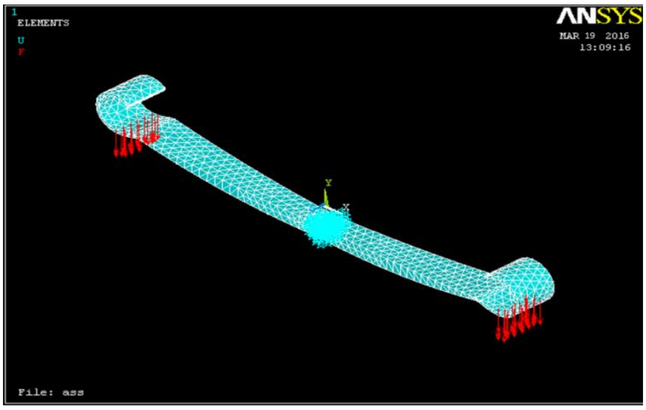

Fig. 1.5. Force applied.

Step 7: Main menu > solution > solve > current Ls-ok

#post processer

Step 8: Main menu > general postoroc> plot results > deform shape

Choose def + undeformed and give Ok

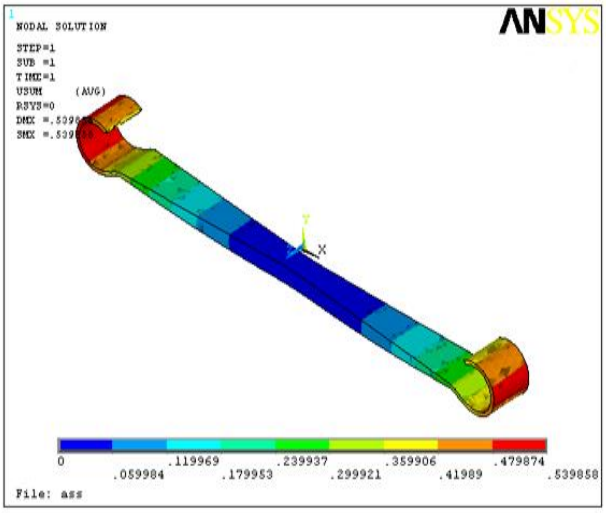

Fig. 1.6. Total Deformation of steel leaf spring.

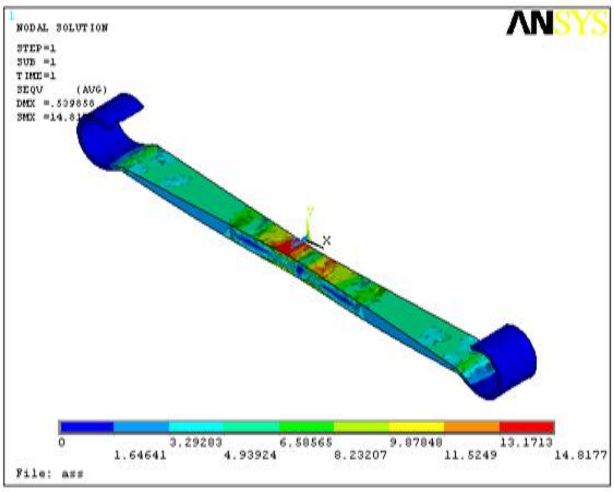

Fig. 1.7. Equivalent stress of steel leaf spring.

Step 9: Main menu > general post proc> plot results > contour plot > nodal solution > DOF solution > DOF sum of vector

Step 10: Main menu > general post proc> plot results > contour plot > nodal solution > Plot the von mises equivalent stress

VII. GRAPHS

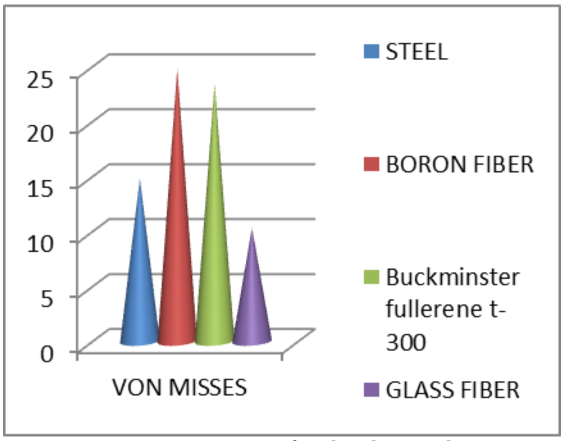

Fig. 1.8. Von misses of analyzed materials.

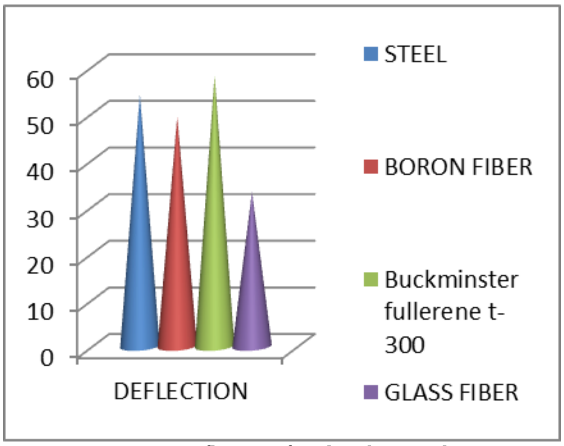

Fig. 1.9. Deflection of analyzed materials.

VIII. RESULT AND CONCLUSION

The Analyze of steel and composite leaf spring were carried analytically. Thus the steel and composite leaf spring load withstand capacity are tested at universal testing machine. The load withstand capacity of composite leaf spring is better than steel leaf spring. Thus the weight of steel and composite leaf spring are tested at electronic weight testing machine. The weight of the composite leaf spring is less than steel leaf spring. Using Ansys the total deformation equivalent stress & strain for both steel & composite materials has been found out.It is found that the composite within boron is having good material property than other materials. It is found that the boron mix composite can be used for automotive suspension. Which will be weight less and cost effective

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