International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 09 | Sep 2019 www.irjet.net p-ISSN: 2395-0072

Design, Analysis and Comparison between the Conventional Materials with Composite Material of the Leaf Springs

Girish h c [1] Dr K M Purushotama[2]

[1]Student, Master of Technology, Dr. Ambedkar Institute of Technology Bangalore, Karnataka, India
[2]Professor, Dept. of Mechanical Engineering Dr. Ambedkar Institute of Technology Bangalore, Karnataka, India

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Abstract – *Currently automobile suspension systems use a special kind of springs, which is Leaf spring. The added advantage of leaf spring over conventional springs is that the end of the spring can be guided along a definite path as it deflects to act as a structural member in addition to energy absorbing device.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. Further to reduce weight of structural steel leaf spring by using different materials and also to improve the deflection attributes of leaf spring. Finally compare the stresses, deformations and weight saving of composite leaf spring with that of steel leaf spring. The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. 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) and Kevlar 149. The design parameters were selected and analyzed with the objective of selecting the best material for leaf spring. Result shows that, the E – glass composite leaf spring has maximum strength to weight ratio and can undergo about more deflection than Kevlar 149 and conventional steel leaf spring. The leaf spring was modeled in ANSYS Design Molder and the analysis was done using ANSYS 14.0 software.*

***Key Words*:** leaf spring, ANSYS design of leaf spring, structural analysis, E-glass ANSYS workbench,

1. INTRODUCTION

The system which reduces the road shock and vibrations of the vehicles are termed as suspension system. Some of the basic components of suspension system are shock absorber, Torsion bar and springs. Uneven surfaces of the roads cause lot of vibrations during the vehicle run. Engine when it is running also contributes to the vibration. Hence in the absence of suspension system, these vibrations are transferred to the entire body of the car, which may lead to uncomfortable ride and can result in failure of some car body parts. Suspension system separates the vehicle body and wheel, so that when the wheels feel the vibration, they are absorbed by the springs of suspension system instead of being transferred to the vehicle body. Present day different types of suspension systems and springs are being used based on the load capacity and the comfort level. A multi-leaf spring or laminated spring is a very important component in automobile suspension system, it is essential elements in suspension system of vehicle including sport utility vehicles, trucks, and rail road vehicles. Semi-elliptical leaf springs are almost universally used for suspension. The laminated spring consists of number of leaves called blades. The blades are varying in length curvature so that they will tend to straighten under the load. The leaf spring is design is based upon the theory of beams of uniforms strength. The accurate modelling of leaf spring is evaluated by performing static structural analysis using ANSYS software and to compare the stress induced and deformation for different load

1.1 Suspension leaf spring

The leaf spring main purpose is to filter out the axle excitation before these disturbances reach the chassis. There are a variety of different suspensions used on vehicles. However, some types of suspensions have grown more popular than others. In the truck /car industry the overwhelming majority are leaf springs. Leaf springs are less expensive, simpler and more reliable than any other common suspension. In addition, they act as both spring and damper simultaneously, thus, reducing or eliminating the need for independent shock absorbers

1.2 Leaf Spring

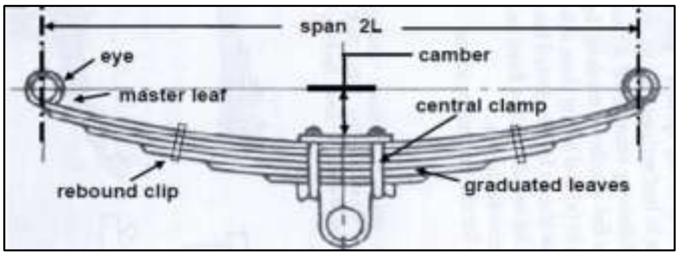

Figure 1: Leaf Spring 2D diagram

The leaf spring consists of a series of flat plates or leaves, usually of semi-elliptic shape, which are held together with the help of U-bolts and centre clip. Generally, two types of leaves may be observed in a multi-leaf spring i.e.

some graduated -length leaves and a few extra full-length leaves. The length of the leaves gradually decreases from top to bottom. The longest leaf in the top is known as master leaf which is bent at both the ends to form spring eyes. The extra full-length leaves are inserted between the master leaf and the graduated-length leaves to support the transverse shear force. In order to maintain proper alignment and to restrict the lateral shifting of leaves, rebound clips are used in practice, these springs rest on the axle of an automobile. Its front end is connected with the frame by means of a simple pin joint and the rear end is connected with the frame through a flexible link known as shackle

1.3 PARTS OF LEAF SPRING

Master leaf

Top side of the leaf is called a master leaf for this leaf eye is provided for linking the spring with the other mechanical member

Camber

The certain amount of bend is given to the spring from the central line, passing through the eyes, is known as camber

The camber is provided so that even at the maximum load the deflected spring should not touch the machine member to which it is attached.

Central clamp

The central clamp is required to hold the leaves of the spring.

Rebound clips

Rebound clips are used to hold the leaves together and to keep the leaf in aligned and avoid lateral shifting

Graduated leaves

Smaller leaves are called graduated leaves extra full-length leaf is provided to increase strength against shear force

2. LITERATURE REVIEW

Mahmood M. Shokrieh et. al [1], have replaced a steel leaf spring by a composite one. Primary aim of their study was to design a leaf spring that possess minimum weight and is capable of taking a given external static force without any undergoing failure. Numerical analysis was carried using ANSYS V5.4. The obtained deflection and stress results were compared with analytical results

Using the results obtained for steel leaf spring they designed a composite leaf spring made of fibreglass with epoxy resin. Further numerical analysis was carried out for the composite leaf spring using ANSYS V5.4 with displacement and stress as design constraints. Composite leaf spring weighed about 80% less and comparatively less stress as compared to steel springs.

Pozhilarasu V. [3] carried out the comparative analysis of conventional steel and composite leaf spring. The composite material chosen was GFRP – Glass Fibre Reinforced Plastic. Numerical analysis was carried out using ANSYS software and the experimental analysis was carried out in Universal Testing Machine. Both methods of analysis showed large differences in results for conventional leaf spring and composite leaf spring.

Aishwarya A.L [4] in their study carried out free vibration analysis of composite leaf springs. Modelling and analysis were done using ANSYS. Effect of relative movements of the leaves, variation of width and friction between the leaf spring was studied. They found that friction co efficient had no effect on the results.

3.1 PROBLEM IDENTIFICATION

- Weight of the structural steel leaf spring is comparably high.
- Deflection attributes are poor in case of structural steel.
- Poor ride properties due to the noise and friction

3.2 OBJECTIVES

- To find the replacement of the structure
- To analyze the behavior of springs under varying loads.
- To reduce weight of structural steel leaf spring by using other materials.
- To improve the deflection attributes of leaf spring
- To reduce the failure of leaf spring under various loading

3.3 METHODOLOGY

A structural analysis is used to calculate deformations stress and strain on model in response to specified conditions

- A static analysis gives certain information about model i.e. Stress analysis: tells us amount of stress that material can withstand
- Strain analysis: tells us amount of strain that material can withstand i.e. part will break
- Deformation analysis: tells us how much the shape of the model changes
- The leaf spring is designed by using ANSYS 14.0 software with specified dimension
- The 3D leaf spring model is imported to the ANSYS work bench
- The analysis is carried out by specifying material properties and meshing
- Application of boundary conditions for static structural model
- Interpretation of solution and results

3.4 MATHEMATICAL ANALYSIS

For the purpose of analysis, the leaves are divided in two groups as master leaf along with graduated length leaves forming one group and the extra full-length leaves forming the other group.

3.5 DIMENSION OF EACH LEAF

Table 1: length of each leaf spring

Length of smallest leaf	275 mm
Length of 2nd leaf	550 mm
Length of 3rd leaf	775 mm
Length of 4th leaf	1050 mm
Length of 5th leaf	1250 mm

3.6 DESIGN SPECIFICATION

Table 2: design specification

Geometric variable	Design implications
Leaf length	2L=1250mm
Number of leaves (n)	n=5
Leaf thick ness (t)	t=12mm
Leaf width (b)	b=80mm
Load acting at the centre of the spring	20000 N,15000 N,10000 N, 5000 N,

Table 3: variation of maximum bending stress and deformation

Load in N	Stress in Pa	Deformation in m
5000	2.0304×10^{08}	0.02047
10000	3.997×10^{08}	0.037941
15000	6.581×10^{08}	0.05541
20000	8.8215×10^{08}	0.071852

4. LEAF SPRING CAD MODEL

Leaf spring for the current analysis was created using ANSYS Design Modeller software.

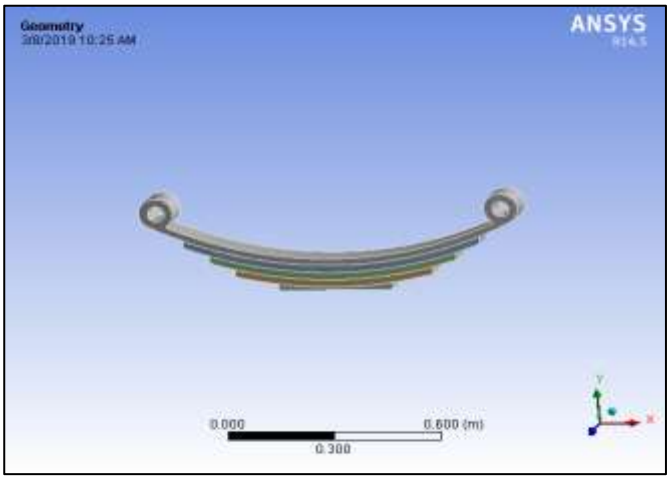

Figure 2: Leaf Spring Isometric view

Leaf spring is modelled in ANSYS design modeller software by taking dimension of each leaf spring first master leaf is designed, next graduated leaf spring is designed All the model is assembled is as shown in fig with all dimension are in mm

4.1 LEAF SPRING MESH DETAILS

Mesh generation process is important process in finite element analysis. Meshing discretise entire model into very small elements. In this work "fine mesh" is selected for meshing the 3D model of the leaf spring.

Meshing of the leaf spring CAD model was carried out using ANSYS meshing platform. Care was taken to see that the meshing error is as minimal as possible

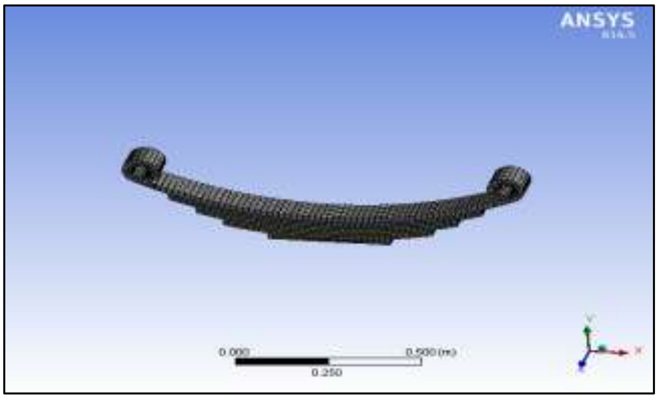

Figure 3: Meshed Leaf Spring

Grid independency test was carried out to make sure that the results do not vary with the mesh size. In total there are 16240 and 2502 nodes and elements respectively.

4.2 PROPERTIES OF THE MATERIAL CHOSEN FOR ANALYSIS

1. **E Glass**

Table 4: Mechanical Properties of E Glass

Mechanical	Symbols	Units	Values
Young's modulus	E	Pa	$8.5x10^{10}$
Shear modulus	G	Pa	$3.4553x10^{10}$
Bulk modulus	K	pa	$5.2469x10^{10}$
Poisson's ratio	μ	-	0.23
Density	p	Kg/m^3	2600
Tensile Yield strength	S_y	Pa	$1.95x10^{10}$
Compressive yield strength	S_{cy}	Pa	$4x10^{09}$
Compressive ultimate	S_{cy}	Pa	$5x10^{09}$

2. **Kevlar 149**

Table 5: Mechanical Properties of Kevlar 149

Mechanical	Symbols	Units	Values
Young's modulus	E	Pa	$1.86x10^{05}$
Shear modulus	G	Pa	$6.8889x10^{10}$
Bulk modulus	K	Pa	$2.0667x10^{11}$
Poisson's ratio	μ	-	0.35
Density	p	$g\ cm/m^3$	1.45
Tensile Yield strength	S_y	MPa	3440

3. **Structural steel**

Table 6: Mechanical Properties of Structural Steel

Mechanical	symbols	units	values
Young's modulus	E	Pa	$2x10^{05}$
Shear modulus	G	Pa	$7.6923x10^{10}$
Bulk modulus	K	Pa	$7.6923x10^{10}$
Poisson's ratio	μ		0.3
Density	p	Kg/m^3	7850

4.3 BOUNDARY CONDITIONS

X, Y and Z component of remote displacement is set to zero for one end, indicating that there is no displacement on that end. For the other end the X component is assigned free type boundary condition while the other two components are set to zero.

For both the ends the X and Y component of rotation are set to zero, while Z component is allowed to rotate freely. Different loads are applied in the positive Y direction at the bottom of the leaf spring.

RESULTS AND DISCUSSION

5.1 LEAF SPRING ANALYSIS

Leaf spring analysis was carried out at 5000 N, 10000 N, 15000 N and 20000 N. Below figures shows the analysis carried out at 20000 N for E Glass, Kevlar 149 and Structural Steel.

5.2 ANALYSIS OF E-GLASS LEAF SPRING AT 20000N

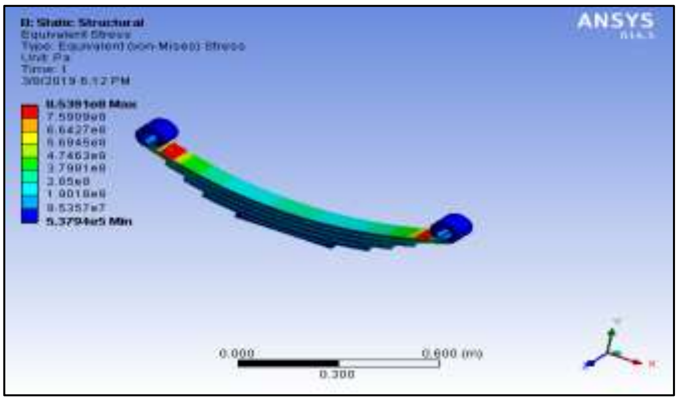

Figure 4: Equivalent Stress for E Glass at 20000 N

Figure 4 shows the stress acting on the leaf spring at a load of 20000 N. The maximum value of the stress is found to be occurring near to eye region Maximum stress is $8.5391 x10^8$ Minimum stress is $5.3794 x10^5$

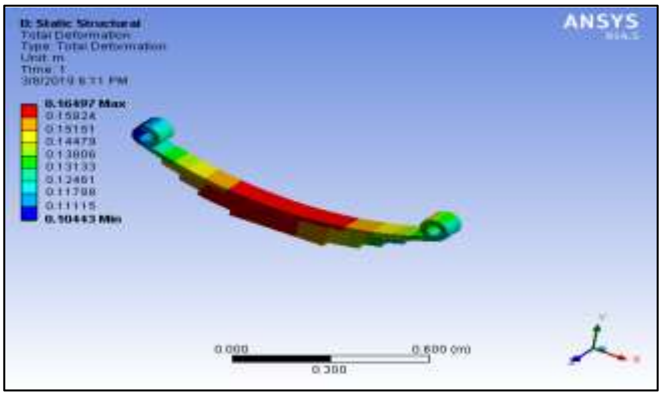

Figure 5: Total Deformation for E Glass at 20000 N

Figure 5 shows the total deformation of the leaf spring during application of load, the deformation is progressing from centre at a maximum value

Maximum deformation: 0.16497 Minimum deformation: 0.10443

5.3 ANALYSIS OF KEVLAR LEAF SPRING AT 20000 N

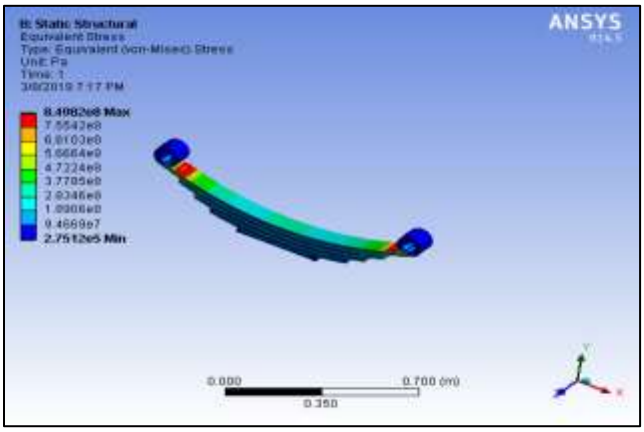

Figure 6: Equivalent Stress for Kevlar 149 at 20000 N

Values of stress

Maximum stress: 8.4982 x10^8

Minimum stress: 2.7512 x10^5

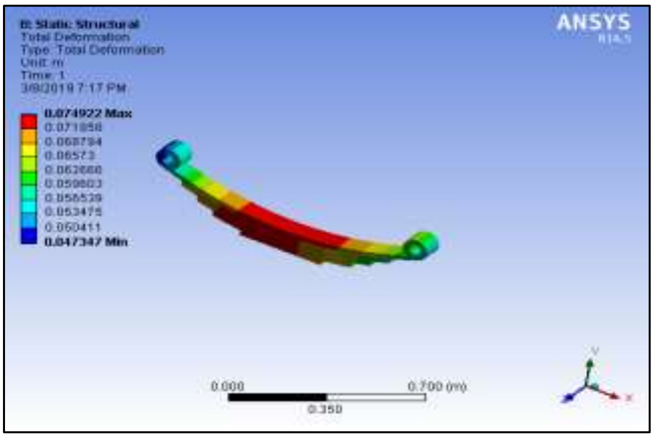

Figure 7: Total Deformation for Kevlar 149 at 20000 N

Values of deformation

Maximum deformation: 0.074922

Minimum deformation: 0.047347

5.4 ANALYSIS OF STRUCTURAL STEEL LEAF SPRING AT 20000N

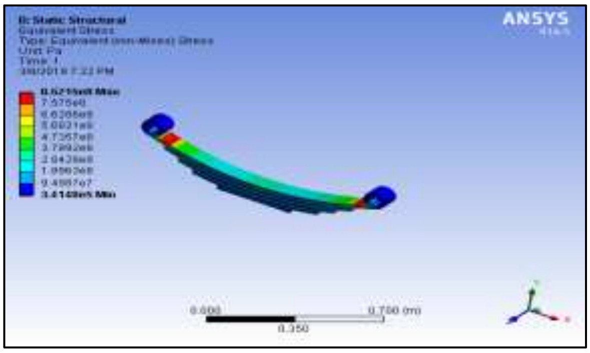

Figure 8: Total Deformation for Structural Steel Leaf spring at 20000 N

Values of stress

Maximum stress: 8.5215x10^8

Minimum stress: 3.4148 x10^5

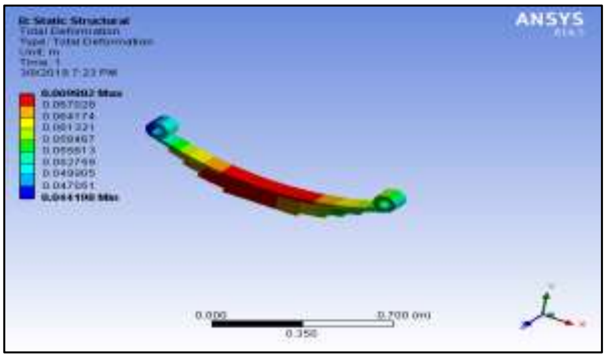

Figure 9: Total Deformation for Structural Steel Leaf spring at 20000 N

Values of deformation

Maximum deformation: 0.069882

Minimum deformation: 0.044198

Table 7: Comparison of deformation between theoretical and ANSYS based results

Load in N	Maximum deformation	Maximum deformation
	Theoretical	ANSYS based
5000	0.0247	0.01747
10000	0.037941	0.034941
15000	0.05541	0.05241
20000	0.071852	0.069882

It is seen that the software-based results almost match with the theoretical solutions and hence, it validates the concept of mathematical formulations for maximum deformation and bending stress in different leaves.

Figure 10: variation of max. deformation v/s load

The results obtained by the analysis of E – Glass, Structural Steel and Kevlar 149 respectively at loads of 5000 N, 10000 N, 15000 N, and 20000 N. From the above analysis figures, it is clear that in all the cases the maximum stress appears to be near the eye region. The value of stress increases with increase in loading for all the cases. E – Glass leaf spring undergo more deformation than other two materials at all the loading condition.

In the figure 10, it is observed that when varying load the maximum deformation of the leaf spring for the steel material and the composite material are compared. E-Glass material shows more deflection then structural steel

7. CONCLUSIONS

The material selected as a replacement for conventional structural steel was glass fiber reinforced polymer (E-glass/epoxy) and Kevlar 149. The leaf spring was modeled in ANSYS Design Molder and the analysis was done using ANSYS 14.0 software.

The design parameters were selected and analyzed with the objective of selecting the best material for leaf spring. Result shows that. E – glass composite leaf spring has maximum strength to weight ratio and can undergo about more deflection than Kevlar 149 and conventional steel leaf spring.

Hence E – glass can be preferred as the material for the fabrication of leaf spring over Kevlar 149 and conventional structural steel.

8. REFERENCES

[1] Mahmood M. Shokrieh , Davood Rezaei " Analysis and optimization of a composite leaf spring " Composite Structures, 60 (2003) pp- 317–325, Vol.2.

[2] A Skrtz, T.Paszek,(1992) "Three dimensional contact analysis of the car leaf spring", Numerical methods in continuum mechanics, 2003, Zilina, Skrtz republic, pp-234-256, Vol.4.

[3] Cheng Wang, (1999) "Design and Synthesis of Active and Passive vehicle suspensions, pp-137-207, Vol.2.

[4] I Rajendran, S. Vijayarangan, "Design and Analysis of a Composite Leaf spring", Journal of Institute of Engineers India, 82, 2002, pp-180-187, Vol.2

[5] M. Venkatesan , D. helmen devaraj (2012) , Design And Analysis Of Composite Leaf Spring In Light Vehicle int. jr. of modern engineering research, pp-213-218, Vol.2.

[6] H.S. Manjunath, Maqsood Ali, Dr. L. Chandra sager "Computational fluid dynamic analysis and structural analysis of ribbed panel structure using FEA International Research Journal of Engineering and Technology (IRJET) oct 2017, pp-975-981, Vol.4,

[7] S. Venkatesh, Dr. S. S. Mohamed Nazirudeen, Dr. A. K. Shaik Dawood, R. Karthikeyan IRACST – Engineering Science and Technology: An International Journal (ESTIJ), ISSN: No. 4 August 2012, pp-2250-3498, Vol.2,

[8] G. Harinath Gowda & E Venugopal Goud "Static Analysis Of Leaf Spring" International Journal of Engineering Science and Technology (IJEST), ISSN: 0975-5462, No.08 August 2012, pp-, Vol. 4.