View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by International Journal of Innovative Technology and Research (IJITR)

N Nagabhushana Ramesh * et al.
(IJITR) INTERNATIONAL JOURNAL OF INNOVATIVE TECHNOLOGY AND RESEARCH
Volume No.5, Issue No.6, October - November 2017, 7698-7704.

Static And Transient Analysis Of Composite Leaf Spring

Dr. N. NAGABHUSHANARAMESH
Professor, Department of Mechanical Engineering, Anurag Group of Institutions

B. JHANSY RANI
PG student, Department of Mechanical Engineering, Anurag Group of Institutions

Dr. R. VENKAT REDDY
Professor and Head of Department, Anurag Group of Institutions

Dr. P. RAVIKANTH RAJU
Associate Professor, Department of Mechanical Engineering, Anurag Group of Institutions

Abstract: **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. This work deals with finding a suitable composite material that can be a replacement for conventional steel leaf spring. The stress and displacements have been calculated using theoretically as well as using ANSYS for steel leaf spring and composite leaf spring. The model is designed in CREO software for the vehicle Mahindra "Model - commander 650 di". Analysis is done in ANSYS software for different materials (Steel, Kevlar and E-Glass Epoxy). The static analysis is done to determine the deformation, stress and strain for different materials. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Transient analysis is done to determine the deformation, stress with respect to time for different materials. Fatigue analysis is done to determine the fatigue life for steel, E glass epoxy and Kevlar leaf spring.**

Keywords: **Leaf Spring; Composite Material; CREO Parametric; Static; Transient Analysis;**

I. INTRODUCTION

1.1 INTRODUCTION AND HISTORY OF LEAF SPRING

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called a laminated or carriage spring, and sometimes referred to as a semi-elliptical spring or cart spring, it is one of the oldest forms of springing, appearing on carriages in England after 1750 and from there migrating to France and Germany.

There were a variety of leaf spring types, usually employing the word "elliptical". "Elliptical" or "full elliptical" leaf springs referred to two circular arcs linked at their tips. This was joined to the frame at the top center of the upper arc, the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailing arms, would be needed for this design, but not for "semi-elliptical" leaf springs as used in the Hotchkiss drive. That employed the lower arc, hence its name. "Quarter-elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over their differentials that were curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non-metallic sheets in between the metal leaves, such as wood.

1.2 CHARACTERISTICS OF LEAF SPRING

The leaf spring acts as a linkage for holding the axle in position and thus separate linkages are not necessary. It makes the construction of the suspension simple and strong. Because the positioning of the axle is carried out by the leaf springs, it is disadvantageous to use soft springs i.e. springs with low spring constant. Therefore, this type of suspension does not provide good riding comfort. The inter-leaf friction between the leaf springs affects the riding comfort. Acceleration and braking torque cause wind-up and vibration. Also wind-up causes rear-end squat and nose-diving. The inter-leaf friction damps the spring's motion and reduces rebound, which until shock absorbers were widely adopted was a great advantage over helical springs.

1.3 MATERIALS FOR LEAF SPRING

The material used for leaf springs is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel products greater strength and therefore greater load capacity, greater range of deflection and better fatigue properties.

Glass fiber

The main advantage of Glass fiber over others is its low cost. It has high strength, high chemical resistance and good insulating properties. The disadvantages are low elastic modulus poor adhesion to polymers, low fatigue strength and

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

high density, which increase leaf spring weight and size. Also crack detection becomes difficult.

Materials constitute nearly 60%-70% of the vehicle cost and contribute to the quality and the performance of the vehicle. Even a small amount in weight reduction of the vehicle, may have a wider economic impact. Composite materials are proved as suitable substitutes for steel in connection with weight reduction of the vehicle. Hence, the composite materials have been selected for leaf spring design.

The material of the spring should have high fatigue strength, high ductility, high resilience and it should be creep resistant. It largely depends upon the service for which they are used i.e. severe service, average service or light service.

1.4 SUMMARY

This chapter gives the introduction and history of leaf spring along with applications, characteristics and materials used.

II. LITERATURE SURVEY

This literature review includes technical reports, journal publications and textbooks. In addition various engineering and mathematical analysis tools were investigated for utilization in this paper. From the literature survey of the past researchers it can be seen that the weight reduction is very common issue to increase the fuel efficiency and reduce the air pollution in automobile industries in now a days. The reduction of the weight is achieved by replacing composite material in place of steel leaf spring. Also the composite materials have much lower stresses and deflection and higher fatigue life.

III. DESIGN CALCULATIONS OF LEAF SPRING

The functions of springs are absorbing energy and release this energy according to the desired functions to be performed. So leaf springs design depends on load carrying capacity and deflection.

Weight and initial measurements of Mahindra “Model - commander 650 di” light vehicle are taken.

Gross vehicle weight = 2150 kg
Unsprung weight = 240 kg
Total sprung weight = 1910 kg
Taking factor of safety (FS) = 1.4
Acceleration due to gravity (g) = 10 m/s²
There for; Total Weight (W) = 1910*10*1.4
= 26740 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight.

$$2W = \frac{26740}{4} = 6685 \text{ N}$$

$$W = 3342.5 \text{ N}$$

Length of leaf = $\frac{\text{effective length}}{\text{np.of leafs}-1}$ +in effective length ………(eq. 3.1)

Effective length =1120 mm, ineffective length =90 mm, no of full length leafs =2 , gradual length leafs =8, Total leafs =10.

Length of smallest leaf $= \frac{1120}{10-1} + 90 = 214$ mm

Leaf no.	Full leaf length (2L)	Half leaf length (L)	Radius of curvature R (mm)
1	1120	560	961.11
2	1120	560	967.11
3	1085	542.5	973.11
4	961	480.5	979.11
5	837	418.5	985.11
6	712	356	991.11
7	588	294	997.11
8	463	231.5	1003.11
9	338	169	1009.11
10	214	107	1015.11

Table 3.1 shows the Design Parameters of Leaf Spring

S.NO.		
1	Total Length of the spring (Eye to Eye)	1120mm
2	Free Camber (At no load condition)	180mm
3	No. of full length leaves	2
4	No. of graduated leaves	8
5	Thickness of leaf	6 mm
6	Width of leaf spring	50mm
7	Maximum Load given on spring	6685 N

Table 3.2 shows the Specifications of Leaf Spring

IV. DESIGN OF LEAFSPRING

4.1 INTRODUCTIONTO CREO

PTC CREO, formerly known as Pro/ENGINEER, is 3D modeling software used in mechanical engineering, design, manufacturing, and in CAD drafting service firms. It was one of the first 3D CAD modeling applications that used a rule-based parametric system. Using parameters, dimensions and features to capture the behavior of the product, it can optimize the development product as well as the design itself.

The name was changed in 2010 from Pro/ENGINEER Wildfire to CREO. It was announced by the company who developed it, Parametric Technology Company (PTC), during the launch of its suite of design products that includes applications such as assembly modeling, 2D orthographic views for technical drawing, finite element analysis and more.

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

4.2 MODELING OF LEAF SPRING

Fig. 4.1 3D Model of Leaf Spring

4.3 INTRODUCTION TO ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

4.4 MATERIAL PROPERTIES OF STEEL 55 Si 2 Mn 90

Table 4.1 Material properties of steel

Parameter	values
Material selected	55 Si 2 Mn 90
Young's modulus	$2*10^5$MPa
Passion's ratio	0.3
BHN	534-601
Tensile strength ultimate	1962 MPa
Tensile strength yield	1470 MPa
Density	7850 Kg/m^3

4.5 STATIC ANALYSIS OF STEEL LEAF SPRING

Static structural analysis for bending stress and deflection for steel leaf spring are shown in Figure 4.2 and 4.3 respectively. Figure 4.2 shows that maximum deformation contours at the centre portion of leaf spring and minimum is at the eye ends. Figure 4.3 shows that maximum stress contours at the eye ends of the leaf spring and minimum at centre portion of leaf spring.

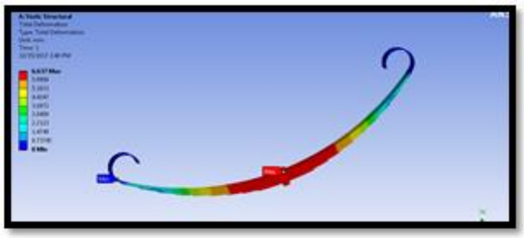

Figure4.2 Maximum deformation contours for steel leaf spring

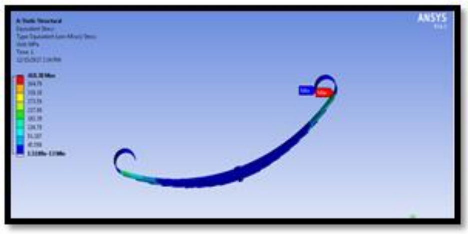

Figure 4.3 Von mises stress contours for steel leaf spring

4.6 RESULT ANALTSIS OF STEEL LEAF SPRING

Below Table shows that static analysis fairly matches with the theoretical results but it also shows that static analytical results underestimate the results.

Table 4.2 Comparison of theoretical and analysis results for steel leaf spring.

parameters	Analytical results	ANSYS Results
Von-mises stress (M Pa)	398.25	410.38
Deflection (mm)	6.129	6.637

4.7 ANALYSIS OF COMPOSITE LEAF SPRING

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. So, a virtual model of leaf spring was created in CREO. Model is imported in ANSYS and then material is assigned to the model. These results can be used for comparison with the steel leaf spring.

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

S.NO.	Properties	E-glass/epoxy	Kevlar
1	EX (MPa)	43000	45960
2	EY (MPa)	6500	9300
3	EZ(MPa)	6500	9300
4	PRXY	0.27	0.37
5	PRYZ	0.06	0.33
6	PRZX	0.06	0.33
7	GXY(MPa)	4500	3800
8	GYZ(MPa)	2500	3500
9	GZX(MPa)	2500	3500
10	ρ (kg/mm³)	0.000002	0.0000014

Table 4.3 shows the orthotropic properties of E glass epoxy, Kevlar materials.

4.8 STATIC ANALYSIS OF COMPOSITE LEAF SPRING

Below Figures (5.1 to 5.4) shows the maximum deflection and stress values evaluated at the given load for the materials Kevlar and E glass epoxy. Figure 5.1, 5.3 shows that maximum deformation contours at the centre portion of leaf spring and minimum is at the eye ends. Figure 5.2, 5.4 shows that maximum stress contours at the eye ends of the leaf spring and minimum at centre portion of leaf spring.

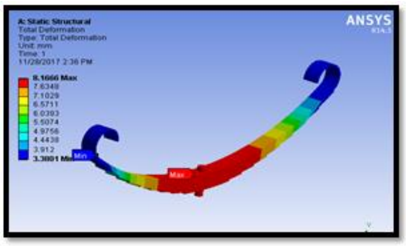

Figure 4.4 Maximum deflection contours of Kevlar

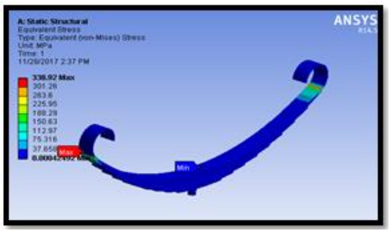

Figure 4.5 Von mises stress contour of Kevlar leaf

4.9 COMPARISION OF STEEL AND COMPOSITE LEAF SPRING ANLAYSIS DATA

Materials	Displacements (mm)	Stress (MPa)	Weight (Kg)
Steel	6.637	410.38	17.53
E glass epoxy	11.079	368.89	4.57
Kevlar	8.166	338.92	3.65

Here, from comparison of steel leaf spring with composite leaf spring as shown in Table 4.4, it can be seen that deflection is 6.637 mm on steel leaf spring and corresponding deflection in E-glass/epoxy and Kevlar are 11.079 mm, 8.166 mm. Also the von-misses stress in the steel leaf spring 410.38 MPa while in E- glass/epoxy and Kevlar the von-misses stresses are 368.89 MPa, 338.89 MPa respectively. From the results Kevlar leaf spring is having minimum stress compared to steel and E glass epoxy.

V. TRNSIENT ANALYSIS OF LEAF SPRING

A transient dynamic analysis is used to determine the response of a structure subjected to a time-dependent loading considering inertia and damping effects. It is often referred to as a time-history analysis. The full method in ANSYS uses the full system matrices to calculate the transient response at each solution point. The model-superposition method scales the mode shapes and sums them to capture the dynamic response.

Below Figures 5.1 to 5.3 shows the deformation of the leaf spring at 10, 20 and 30 sec respectively for the given load.

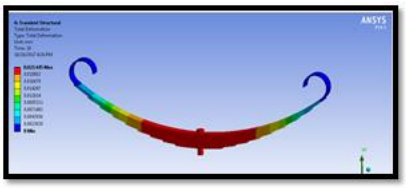

Figure 5.1 Deformation of leaf spring at 10 seconds.

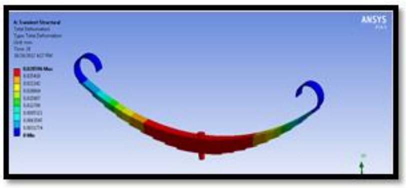

Figure 5.2 Deformation of leaf spring at 20 seconds.

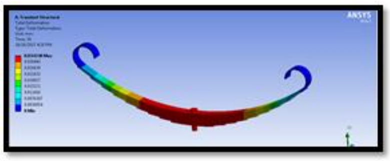

Figure 5.3 Deformation of leaf spring at 30 seconds.

Below Figures from 5.4 to 5.6 shows the maximum stress evaluated in leaf spring at 10,20 and 30 sec for a given load.

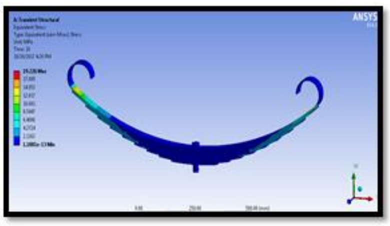

Figure 5.4 Maximum stress of leaf spring at 10 seconds.

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

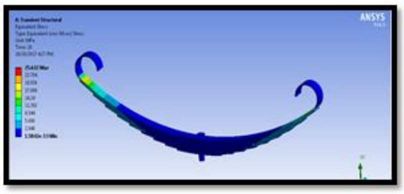

Figure 5.5 Maximum stress of leaf spring at 20 seconds.

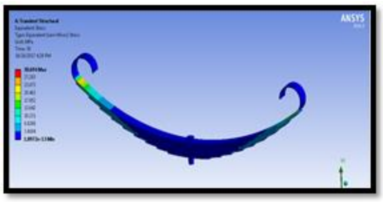

Figure 5.6 Maximum stress of leaf spring at 30 seconds.

Below Table5.1 shows the transient analysis results of leaf spring. From the results Table it can be seen that the deformation increases with respect to time and the difference in deformation value reduces with respect to time. Also the stress value increases with respect to the time and the difference in stress value decreases with respect to the time.

Table 5.1 Transient analysis results

MATERIAL	TIME (sec)	DEFORMATION (mm)	STRESS (MPa)
Steel	10	6.6325	410.32
	20	7.1394	420.86
	30	10.836	429.21
E glass epoxy	10	11.061	368.73
	20	12.492	379.25
	30	14.547	388.96
Kevlar	10	8.1119	338.16
	20	9.6606	348.83
	30	11.062	361.14

VI. FATIGUE ANALYSIS OF LEAF SPRING

6.1FATIGUE LIFE ESTIMATION BYGRAPHICAL METHOD

Load Calculations

Kerb weight of the vehicle = 1450 kg

Gross Vehicle Weight = 2150 kg

Out of this, 40% acts on the front leaf springs and60% acts on the rear leaf springs.

Minimum Load acting on two rear leaf springs= 0.6 x 1450 = 870 kg

Therefore minimum load acting on a single rear leaf spring = $\frac{870}{2}$ = 435 kg = 4350 N

Hence minimum load (2W) acting on the leaf spring considered is taken as 4350 N

Maximum Load acting on two rear leaf springs = 0.6 x 2150= 1290 kg

Therefore maximum load acting on a single rear leaf spring = $\frac{1290}{2}$= 645 kg

Hence maximum load (2W) acting on the leaf spring considered is taken as 6450 N

6.2 THEORETICAL CALCULATIONS OF LEAF SPRING

Mean stress(σ_m) = $\frac{\sigma_{min}+\sigma_{max}}{2}$ ……….(Eq 6.2)

Alternating stress(σ_a) = $\frac{\sigma_{max}-\sigma_{min}}{2}$ ……….(Eq 6.3)

$\sigma_{max}=\frac{18W_{max}L}{bt^2(3n_F+2n_G)}=\frac{18\times3225\times530}{50\times6^2(3\times2+2\times8)}$ …….(Eq 6.4)

= 776.9 MPa

$\sigma_{min}=\frac{18W_{minL}}{bt^2(3n_F+2n_G)}=\frac{18\times2125\times530}{50\times6^2(3\times2+2\times8)}$ …….(Eq 6.5)

= 523.977 MPa

6.3 FATIGUE LIFE CALCULATION FOR STEEL

S_{ut} (ultimate tensile stress)= 1962 MPa

S_y (yield stress)= 1470 MPa

$S^1_e = 0.5S_{ut}$= 981MPa

S_a = 126.46 MPa

S_m = 650.4 MPa

$S_e = K_{load}\times K_{surface}\times K_{temp}\times K_{reliability}\times K_{size}\times S_e^1$

K_{load}= Load factor for bending = 1

$K_{surface}$ = 1

K_{temp}=1,if T≤450°C

$K_{reliability}$=0.80 , assuming 99% reliability

$K_{size}=1.24\times d^{-0.107}=1.24\times(883.413)^{-0.107}=0.60$

S_e(endurance stress)=$K_{load}\times K_{surface}\times K_{temp}\times K_{reliability}\times K_{size}\times S_e'$

=1×1× 1×0.80×0.60×981 =470.88Mpa

Figure 6.1 shows an alternating stress versus mean stress plot for the steel leaf spring. Point I indicates the intersection of alternating stress and mean stress. The equivalent alternating stress as determined by joining the point of intersection I

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

and ultimate strength point with the alternating stress axis is found to 190 MPa.

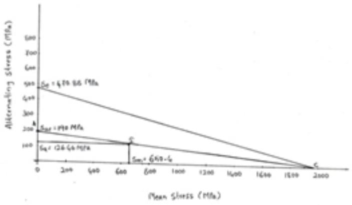

Figure 6.1 Alternating stress versus mean stress plot for steel

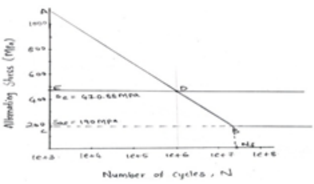

Figure 6.2 shows the S-N diagram for steel. Point A represents the alternating stress at which the spring will sustain 1000 cycles. Point D represents the endurance limit, that is, 470.88 MPa. The line CB represents the equivalent alternating stress. The intersection of alternating stress at point B will give the number of cycles to fatigue failure.

From Figure 6.2, S-N plot, it is observed that ∆ABC is similar to ∆ADE.

Fatigue analysis result table:

Table 6.1 shows the fatigue analysis results.

	Steel	**E glass epoxy**	**Kevlar**
Life	32.406-e^{6}	32.427-e^{6}	32.436-e^{6}

From the Table 6.1 the analysis results of fatigue life for steel is more, compared to E glass epoxy and Kevlar leaf spring.

Theoretical fatigue life results table:

Table 6.2 shows the theoretical fatigue life results.

	Steel	**E glass epoxy**	**Kevlar**
Life	10.47×10^{8}	53703.179	1.584×10^{11}

From Table 6.2 fatigue life estimated by graphical method is more for Kevlar when compared with steel and E glass epoxy leaf spring.

VII. CONCLUSIONS AND FUTURE SCOPE OF WORK

7.1 CONCLUSIONS

The design and static structural analysis of steel leaf spring and composite leaf spring has been carried out. Comparison has been made between composite leaf spring with steel leaf spring having same design and same load carrying capacity. The stress and displacements have been calculated using theoretically as well as using ANSYS for steel leaf spring and composite leaf spring. From the static analysis results it is found that the displacement is 6.637 mm in the steel leaf spring and the corresponding displacements in E-glass/epoxy and Kevlar are 11.079 mm and 8.166 mm. From the static analysis results, it also seen that the von-mises stress in the steel leaf spring is 410.38 MPa corresponding in E-glass/epoxy and Kevlar are 368.89 MPa and 338.92 MPa respectively. The two composite leaf springs have lower stresses than that of existing steel leaf spring.

A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 74.54% for E-glass/epoxy and 79.77% for Kevlar over the steel leaf spring.

From the transient analysis results, it is seen that the two composite leaf springs have the lower stress value than that of steel leaf spring. The stress value occurred is minimum for Kevlar leaf spring compared to E glass epoxy and steel leaf spring.

From the fatigue analysis results, it is seen that the fatigue life estimated is more for Kevlar leaf spring compared to E glass epoxy and steel leaf spring.

It can be concluded that Kevlar composite material can be a replacement for the conventional steel leaf spring.

7.2 FUTURE SCOPE OF WORK

- Analysis can be done on leaf spring by changing the fiber orientation of composite material.
- It can be obtained by doing the analysis with metal matrix composite leaf spring.

VIII. REFERENCES

[1] Design and analysis of composite leaf spring for light vehicles Pankaj Saini[1],Ashish Goel[2], Dushyant Kumar[3]

[2] Design and Analysis of Leaf Spring of an Automobile Using Composite Materials Naveen S 1 , Natarajan R2

[3] Design and Analysis of a Leaf Spring for automobile suspension system: A Review

 @ 2013-2017 http://www.ijitr.com All rights Reserved.

Baviskar A. C. 1 , Bhamre V. G. 2 , Sarode S. S. 3

[4] Design and analysis of aotomobile leaf spring using ansys Dev Dutt Dwivedi1, V. K. Jain2

[5] Design and Analysis of Leaf Spring with Composite materials Mr. Tharigonda Niranjan Babu * ,Mr P. Bhaskar, Mr. S. Moulali

[6] Design and Analysis of Composite Leaf Spring Y. N. V. Santhosh Kumar & M. Vimal Teja

 @ 2013-2017 http://www.ijitr.com All rights Reserved.