DESIGN ANALYSIS AND FAILURE MODES OF LEAF SPRING IN SUSPENSION SYSTEM

Yogesh Nikam[1], Dr.Avinash Badadhe[2]

[1]*Student, M.E Design Engineering, RSCOE Pune ,India*
[2] *Professor, Ph.D in Mechanical Engineering ,RSCOE Pune, India*

---***---

Abstract - *This research paper shows some of the general study on the design, analysis and fabrication of composite leaf spring. Leaf springs are one of the popular suspension components they are frequently used, especially in commercial vehicles. This paper literature has indicated a more interest in the replacement of steel spring with composite leaf spring. The suspension system included in a vehicle significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort and stability etc. These springs are commonly used in the vehicle suspension system and are subjected to billions of varying stress cycles leading to fatigue failure and a lot of research have been done for improving the performance of leaf spring. Many materials are used for leaf spring .but it is found that fiberglass material has good strength characteristic and lighter in weight as compare to steel for leaf spring. In this paper the author is reviewed few papers on use of different optional materials and effect of material on leaf spring performance.*
Key Words: GFRP, Steel Leaf Spring, Conventional Leaf Spring, Failure modes, Composites ,Fibres

1.INTRODUCTION

Leaf springs are widely used in suspension system of cars, railway carriages and other automobiles. Leaf springs are mainly used in suspension systems to absorb load shocks in automobiles like light motor vehicles, heavy duty trucks and in rail systems. The main function of leaf spring assembly as suspension elements is not only to support vertical loads, but also to isolate road-induced vibrations. The performance of leaf spring is complicated due to its clamping effects and inter-leaf contact etc. It carries lateral loads, brake torque in addition to shock absorb. Springs are crucial suspension elements on cars, necessary to decrease the vertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. The introduction of composites helps in designing a good 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 spring, strain energy becomes the major factor. In the present scenario the main focus of automobile manufacturers are to decrease weight of the automobile. Weight reduction can be achieved mainly by introducing better material, design optimization and better manufacturing processes. In automobile leaf spring is one of the crucial parts for weight reduction as it accounts for 15% - 20% of unsprung weight. Composite materials have made it possible to reduce the weight of leaf springs without any reduction in load carrying capacity and stiffness. Composite material are now used extensively in place of metal parts Several papers were devoted to the applications of composite materials for automobiles.

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. The main function of leaf spring assembly as suspension elements is not only to support vertical load, but also to isolate road-induced vibrations. The behaviour of leaf spring is complicated because of its clamping effects and inter-leaf contact etc. It carries lateral loads, brake torque, driving torque in addition to shock absorb. Springs are crucial suspension elements on car, necessary to minimize the vertical vibration, impacts and bumps due to road irregularities and create a comfortable ride.. The introduction of composites helps in designing the better suspension system with better ride qualities if it can be achieve without much increase in cost and decrease in qualities and reliabilities. In the design of springs, strain energy becomes the major factor. In the present scenario the main focus of automobile manufacturer is weight reduction of the automobile. Weight reduction can be achieved mainly by introducing the better material, design optimization and best manufacturing processes. Composite material have made it possible to reduce the weight of leaf springs without any reduction in load carrying capacity and stiffness. Composite materials are now used in various sectors in place of metal parts. Many papers were devoted to the application of composite material for automobiles.

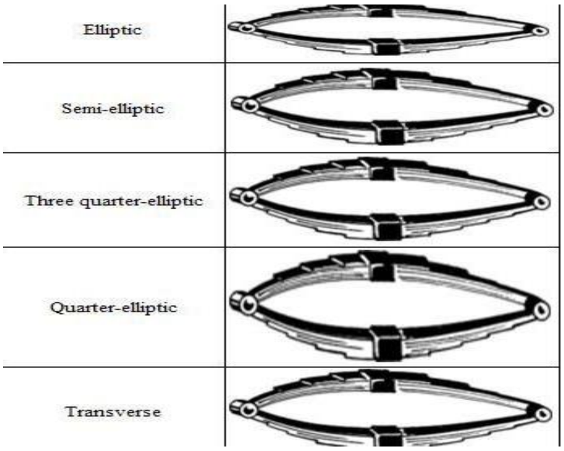


Figure-1: Types of leaf spring

This figure shows a laminated semi- elliptic spring. The top leaf is known as master leaf. The eye is provide for attaching the spring with another machine members. The amount of bend that is given to the springs from the central line, passing through the eyes, are known as camber. The camber is provided so that even at the maximum load the deflected spring not touch the machine member to which it is attached. The central clamp is require to catch the leaves of the spring.

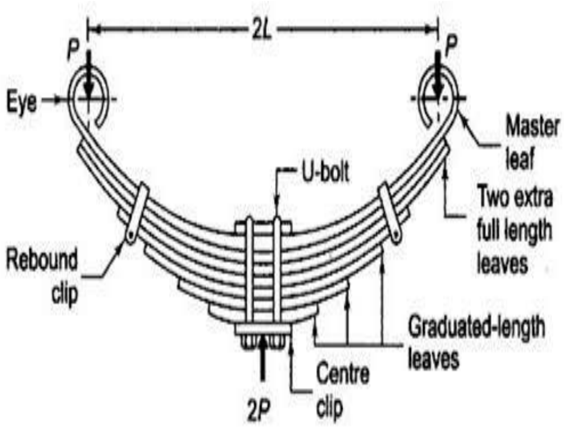


Figure-2: Main parts of Leaf Spring

2. LITERATURE REVIEW

In this sections research papers of different Authors are discussed related to the present work. Also Published papers are highlighted in this section.

M.M.Shokrieh and D.Rezaei[1]presented work on design, analysis and optimization of leaf spring. The aim of this review paper was steel leaf spring was replaced with an optimized composite one. Main objective of this paper was to obtain a spring with minimum weight that is capable of carrying given static external forces without failure. Here the work is carried out of a four-leaf steel spring which used in the rear suspension system of light vehicles & heavy duty vehicles. The four-leaf steel spring is analyzed by using ANSYS V5.4 software. The FEM results showing stress and deflection verified the existing analytical and experimental solutions. Using the result of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimize using ANSYS. Main consideration is given to the optimizations of the spring geometry. n this study stress and displacements were used as design constraint. The experimental results are verified with the analytical data and the finite element solutions for the same dimensions. Result shows that stresses in the composite leaf spring are much lower than that of the steel leaf spring. Compared to the steel leaf spring the optimized composite leaf spring without eye unit weights nearly about 80% less than the steel spring. The natural frequencies of composite leaf spring are higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance.

E. Mahdi a, O.M.S. Alkoles[2]etc presented work on light composite elliptic springs for vehicle suspension. They worked on based study marries between the elliptical configuration and woven roving composites. In this paper, the influence of ellipticity ratios on performance of woven roving wrapped composites elliptical springs has been investigated both experimentally and numerically. A series of experiment was conducted for composite elliptical springs with ellipticity ratios (a/b) ranging from one to two. Here they were also presented history of their failure mechanism. Both spring rate (K) and maximum failure increase with increasing wall thickness. In general, this present investigation demonstrated that composite elliptical spring can be used for light as well as heavy trucks and meet the requirement, together with substantial weight saving. The result showed that the ellipticity ratio is significantly influenced the spring rate and failure loads. Composite elliptic spring with ellipticity ratio of a/b 2.0 displayed the highest spring rate.

Y. N. V. Santhosh Kumar, M. Vimal Teja[3]etc presented work on design and analysis of composite leaf spring . They also discussed that the advantages of composite materials like higher specific stiffness and strength, higher strength to weight ratio. This work deals with replacement of conventional steel leaf spring with a Mono Composites leaf spring using E-Glass/Epoxy. For this they selected design parameters and analysis of it. Main objective of this work is minimizing weight of the composite leaf springs as compared to the steel leaf spring. For this they selected the composite material was E-Glass/Epoxy. The leaf spring was designed in ProE and the analysis was done using ANSYS Metaphysics. From results they observed that the composite leaf spring weighed only 39.4% of the steel leaf springs for the analyzed stresses. So from result they proved that weight reduction obtained by using composite leaf springs as compared to steel was 60.48 %, and it was also proved that all the stresses in the leaf springs were well within the allowable limits and with good factor of safety. It was found that the perpendicular orientation of fibers in the laminate offered good strength to the leaf spring.

Pankaj Saini, Ashish Goel, Dushyant Kumar[4]etc. studied on design and analysis of composite leaf spring for light vehicles. Main objective of this work is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring. Here the three materials selected which are glass fiber reinforced polymer(E-glass/epoxy), carbon epoxy and graphite epoxy used against conventional steel. The design parameters were selected and analyzed with the steel leaf spring From results, they observed the replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction and also the composite leaf spring has lower stresses compared to steel spring. From the static analysis result it is found that there is a maximum displacement of in the steel leaf spring. From the result, among the three composite leaf springs, only graphite/epoxy composite leaf spring has higher stresses than the steel leaf spring. From results its proved that composite mono leaf spring reduces the weight by 81.22% for E-Glass/Epoxy, 91.90% for Graphite/Epoxy, and 90.50 % for Carbon/Epoxy over steel leaf spring. Hence it is concluded that E-glass/epoxy composite leaf spring can be suggested as replacing the steel leaf spring from stress and stiffness point of view.

cManas Patnaik, Narendra Yadav,[5]etc worked on study of a parabolic leaf spring by finite element method & design of experiments. Main objective of this study was the behaviour of parabolic leaf spring, design of experiment has been implemented. For DOE, they selected input parameters such as Eye Distance & Depth of camber. This work is carried out on a mono parabolic leaf springs of a mini loader truck, which has a loading capacity of 1 Tonnes. The modelling of the leaf spring has been done in CATIA V5 R20 Max Von Mises stress and Max Displacement are the output parameters of this analysis. In DOE Eye Distance & Depth of camber have been varied and their affect on output parameters have been plotted. The variation of bending stress and displacement values are computed. From design of experiments observed following a) If The camber is increased there is a decrease in the average amount of displacement. b) If the eye distance is increased there is an increase in the average amount of displacement. c) If the camber is increased there is an increase in the average amount of von misses stresses. d) If the eye distance is increased there is an increase in the average amount on von misses stress. Hence from results it is conclude that the optimum setting of dimensions pertaining to parabolic leaf springs can be achieved by studying the various plots obtained from Design of Experiments.

Malaga. Anil Kuma, T. N. Charyulu,[6]etc presented work on design optimization of leaf spring. The automobile industry has shown increase interest in the replacement of steel springs with composite leaf spring. Main purpose of this paper is to replace the multi-leaf steel springs by mono composite leaf springs for the same load carrying capacity and stiffness. Composite material have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. It is possible to minimize the weight of the leaf spring without any reduction on load carrying capacity and stiffness. The design constraints were limiting stresses and displacements. Here the dimensions of a leaf spring of a light weight vehicles are chosen and modeled using ANSYS 9.0. As the leaf spring is symmetrical about the axis, only half part of the spring is modeled by considering it as a cantilever beam. Three different composite materials have been used for analysis of mono-composite leaf springs. They are E-glass/epoxy, Graphite/epoxy and carbon/epoxy. Static and model analysis has been performed. From results it is concluded that E-glass/epoxy has lower stresses among using three materials. So they suggested E-glass/epoxy composite material for replacement of steel leaf spring.

Prahalad Sawant Badkar[7]worked on Design improvements of leaf Spring of BEML Tatra 815 VVNC 8 X 8 Truck. Main objective of this work is increase the PL carrying capacity of BEML Tatra by 5000 kg. by incorporating the necessary changes in suspension system(Leaf Spring) of the vehicle. The distributions of gross vehicle weight (GVW) on the front and rear tandem axles are Front axle weight is 2 x 6500 kg , Rear axle weight is 2 x 7500 kg , Gross vehicle weight is 28,000kg. Here they do some changes in design so they distributed weight of of Fifth wheel load (FWL) on the front and rear tandem axle is Front axle weight is 2 x 6750 kg, Rear axle weight is 2 x 9750 kg ,Gross vehicle weight is 33,000 kg . The new design of rear leaf spring, stress vehicles for rated load and maximum load are well within the yield stress of material. The new design rear leaf spring also gives the higher fatigue life this is most important in design of any leaf spring, this helps in measure the life of spring. Results showed that finite element analysis (FEA) on rear leaf spring verifies that, design were adequate. The material 60Cr4V2 is better for design of new leaf spring, which fulfills the requirement.

H.A.AI-Qureshi[8]studied on automobile leaf spring from composite materials. The aim of this paper is design, analysis & fabrication of composite spring. For this compact car is taken as prototype. A single leaf, variable thickness spring of glass fiber reinforced plastic with similar mechanicals and geometrical properties to the multileaf steel spring was designed, fabricated and tested. Here they performed experiment in laboratory & was followed by road test. Field testing to determine ride characteristics were also carried out on a number of GFRP spring which were mounted in place of conventional steel spring on jeep. This test were limited to ride quality and sound observation on different road condition. From result it is observed that GFRP spring were more flexible then steel leaf spring. From test ride they observed that harshness & noise also reduced then steel leaf spring. Compared to the steel spring, the optimized composite spring has stresses that are much lower, the natural frequencies are higher and the spring weight without eye units is nearly 80% lower.

AshishV.Amrute, Edward Nikhil karlus,[9]presented work on design & assessment of leaf spring. Main objective of this work is to compare the load carrying capacity, stresses and weight saving of composite leaf spring with that of steel leaf spring. Here the multi leaf spring consist of three full length leaves in which one is with eyed ends used by a light commercial vehicle. For analysis of leaf spring Tata ace ex vehicle taken as prototype. This work deals with replacement of conventional steel leaf spring of a light commercial vehicle with composite leaves spring using E-glass/Epoxy. Dimensions of the composite leaf spring are to be taken as same dimension of the conventional leaf spring. The Theoretical and CAE results are compared for validation. From results it is proved that the bending stresses are decreased by 25.07% in composite leaf spring means less stress induced with same load carrying condition. The conventional multi leaf spring weights about 10.27kg where the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus the weight reduction of 67.88% is achieved by using composite material rather than using steel material.

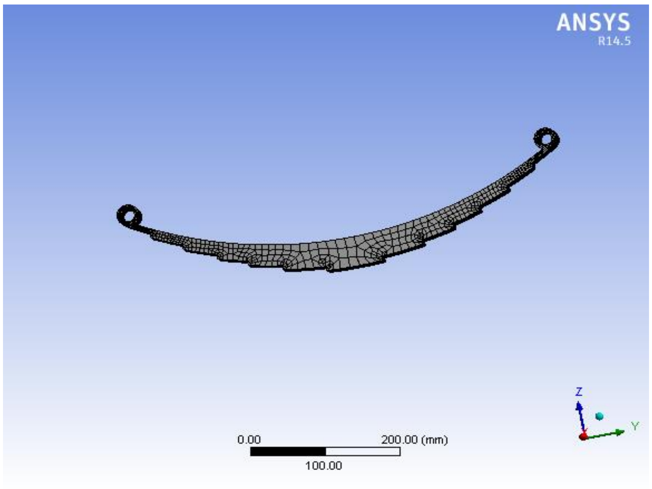
3. DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING

We know that Flexural rigidity is most important parameter in the leaf spring design, and it should increase from two ends of the spring to its center .This idea gives different types of design possibilities, such as constant cross section design, constant width with varying thickness design is selected due to its capability for mass production, and to accommodate continuous reinforcement of fibre.The design of composite leaf spring aims at the replacement of seven leaf steel springs of an automobile with a mono-leaf composite spring. The design requirements are taken to that of the steel leaf spring:

- Design load ,W=4500N
- Maximum allowable vertical deflection ,δmax=160
- Distance between eyes in straight condition,L=1220mm
- Spring rate, K= 28-31N/mm.

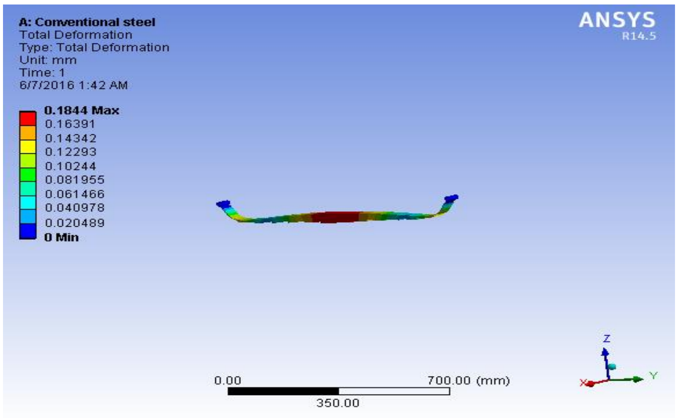
The composite leaf spring is designed to cater the above requirements based on the design procedures given above. Whatever the geometry of leaf spring, it is necessary that it is designed to have minimum weight. The leaf spring modeled in Catia V5 was imported to ANSYS in IGES format. Since composite leaf spring was modeled as a solid, solid element named and was used to mesh the model .This element is a higher order 3-D, 10-node element. Also the element is defined as 10 node and every node has three degree of freedom in the x, y, and z directions .

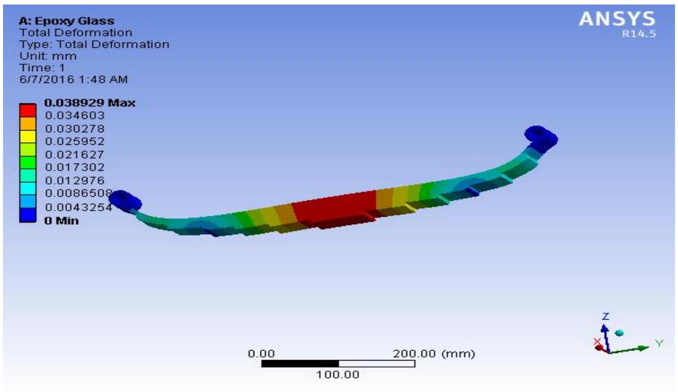
4. MESHING OF LEAF SPRING

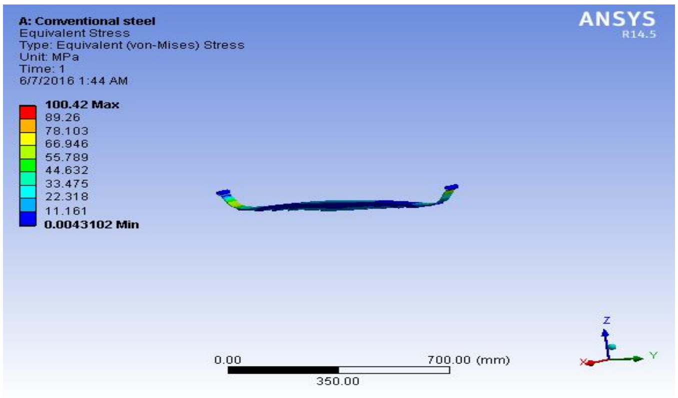


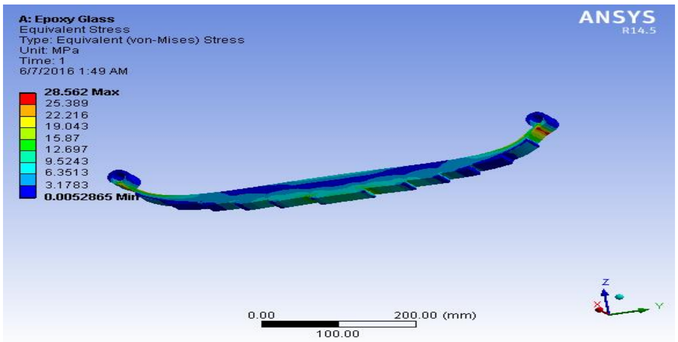
5. RESULTS

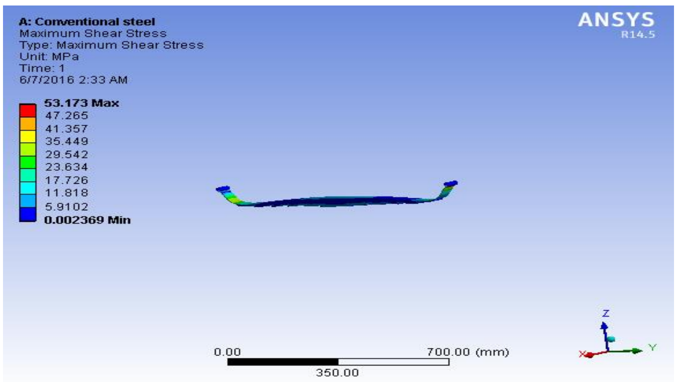
From the results it can be observed that the total deformation for Epoxy Glass material is less compared to conventional steel leaf spring material. Equivalent stress generated in the composite Epoxy Glass leaf spring is less compared to steel leaf spring. Less maximum shear stress and maximum principal stress have been found in E-Glass/Epoxy material compared to conventional steel leaf spring.

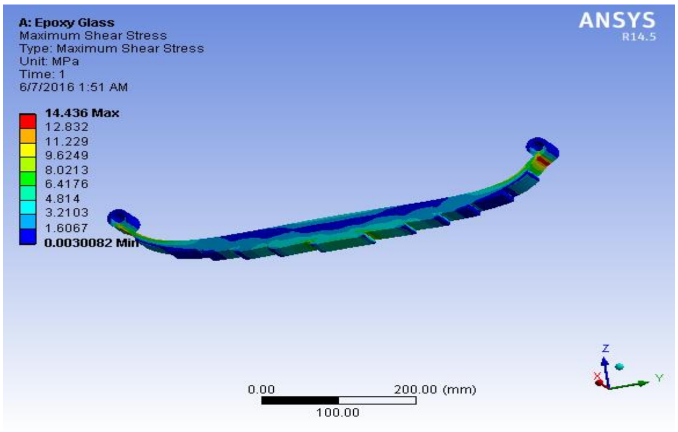


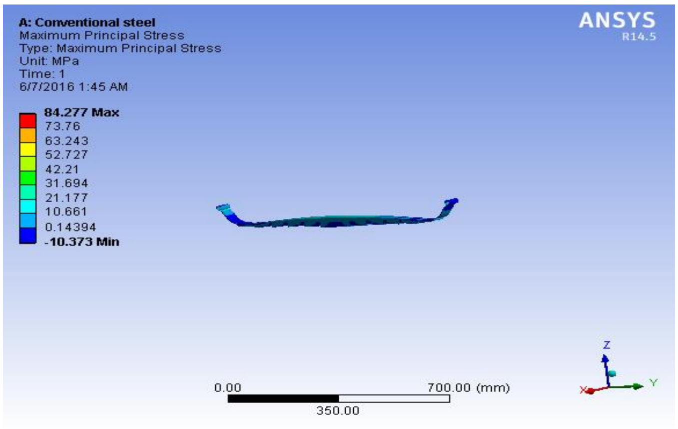

A: Epoxy Glass
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
6/7/2016 1:48 AM
0.038929 Max
0.034603
0.030278
0.025952
0.021627
0.017302
0.012976
0.0086508
0.0043254
0 Min
ANSYS
R14.5
0.00
200.00 (mm)
100.00

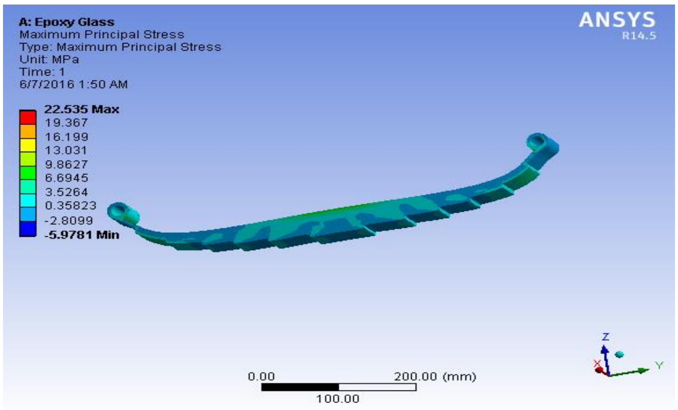

A: Conventional steel
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
6/7/2016 1:44 AM
100.42 Max
89.26
78.103
66.946
55.789
44.632
33.475
22.318
11.161
0.0043102 Min
ANSYS
R14.5
0.00
700.00 (mm)
350.00


A: Epoxy Glass
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
6/7/2016 1:49 AM
28.562 Max
25.389
22.216
19.043
15.87
12.697
9.5243
6.3513
3.1783
0.0052865 Min
ANSYS
R14.5
0.00
200.00 (mm)
100.00


A: Conventional steel
Maximum Shear Stress
Type: Maximum Shear Stress
Unit: MPa
Time: 1
6/7/2016 2:33 AM
53.173 Max
47.265
41.357
35.449
29.542
23.634
17.726
11.818
5.9102
0.002369 Min
ANSYS
R14.5
0.00
700.00 (mm)
350.00


A: Epoxy Glass
Maximum Shear Stress
Type: Maximum Shear Stress
Unit: MPa
Time: 1
6/7/2016 1:51 AM
14.436 Max
12.832
11.229
9.6249
8.0213
6.4176
4.814
3.2103
1.6067
0.0030082 Min
ANSYS
R14.5
0.00
200.00 (mm)
100.00


A: Conventional steel
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: MPa
Time: 1
6/7/2016 1:45 AM
84.277 Max
73.76
63.243
52.727
42.21
31.694
21.177
10.661
0.14394
-10.373 Min
ANSYS
R14.5
0.00
700.00 (mm)
350.00


A: Epoxy Glass
Maximum Principal Stress
Type: Maximum Principal Stress
Unit: MPa
Time: 1
6/7/2016 1:50 AM
22.535 Max
19.367
16.199
13.031
9.8627
6.6945
3.5264
0.35823
-2.8099
-5.9781 Min
ANSYS
R14.5
0.00
200.00 (mm)
100.00

6. COMPARISON OF STEEL AND EPOXY GLASS RESULTS

Parameters	Conventional Steel Leaf Spring	Epoxy Glass Composite Leaf Spring
Total Deformation (maximum)	0.1844 mm	0.0389 mm
Equivalent Stress(maximum)	100.42 MPa	28.562 MPa
Maximum Shear Stress(maximum)	53.173 MPa	14.436 MPa
Maximum Principal Stress(maximum)	84.277 MPa	22.535 MPa

7. CONCLUSION

From above results it is clearly seen that the objective was to obtain a spring with minimum weight and is capable of carrying given static external forces by constraints limiting stresses and displacements. For this the steel leaf spring is replaced by composite leaf spring. This is better than using steel leaf spring. The performance of steel leaf spring was compared with the composite leaf spring using analytical and experimental results. FEA are used for prediction about the total life cycle and fatigue life of composite and steel leaf spring. Results show that the composite leaf spring is 80% lighter than conventional steel leaf spring with similar design parameters. The natural frequency of composite leaf spring is higher than that of the conventional steel leaf spring and is far from the road frequency to avoid the resonance. The stresses in the composite leaf spring are much lower than that of the steel spring. Than steel leaf spring Composite spring have more elastic strain energy storage capacity and also have high strength to weight ratio as compared with those of steel therefore, it is clearly seen that composite leaf spring is an better replacement for the existing steel leaf spring in automobile.

REFERENCES

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

[2] E. Mahdi a, O.M.S. Alkoles a, A.M.S. Hamouda b, B.B. Sahari b, R. Yonus c, G. Goudah"Light composite elliptic springs for vehicle suspension " Composite Structures, 75 (2006) 24–28.

[3] Y. N. V. Santhosh Kumar, M. Vimal Teja "Design and Analysis of Composite Leaf Spring" Dept. of Mechanical Engineering, Nimra College of Engineering & Technology, Ibrahimpatnam, Vijayawada. (2012)

[4] Pankaj Saini, Ashish Goel, Dushyant Kumar " Design and analysis of composite leaf spring for light vehicles " International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 5, May 2013.

[5] Manas Patnaik, Narendra Yadav, Ritesh Dewangan" Study of a Parabolic Leaf Spring by Finite Element Method & Design of Experiments "International Journal of Modern Engineering ResearchVol.2, Issue 4, July-Aug 2012 pp-1920-1922.

[6]Malaga. Anil Kumar ,T.N.Charyulu, Ch.Ramesh" Design Optimization Of Leaf Spring " International Journal of Engineering Research and Applications Vol. 2, Issue 6, November- December 2012, pp.759-765.

[7]Prahalad Sawant Badkar, Prahalad Sawant Badkar" Design Improvements of Leaf Spring of BEML Tatra 815 VVNC 8 X 8 Truck " International Journal of Emerging Technology and Advanced Engineering ,Volume 3, Issue 1, January 2013.

[8]H.A.AI-Qureshi" automobile leaf spring from composite materials "Journal of materials processing technology, 118(2001).

[9]Ashish Amrute, Edward Nikhil karlus, R.K.Rathore"design and assessment of multi leaf spring'' International journal of research in aeronautical and mechanical engineering, ISSN :2321-3051. November (2013).