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Design and Analysis of Leaf Spring

Saurabh S. Rodge[1], Tushar P. Patil[1], Pavan Nikam[2]
[1]Student, Vishwatmak Om Gurudev College of Engineering, Shahapur, Maharashtra, India
[2]Professor, Vishwatmak Om Gurudev College of Engineering, Shahapur, Maharashtra, India

ABSTRACT

We know that the spring plays very essential part of every automobile for suspension point of view. Leaf spring is the main type of suspension system which is used in many light and heavy vehicles. Leaf spring used in many vehicles due to having some main characteristics which are shown below.

1. Uniformly load distribution
2. Lower cost
3. Rough used
4. Easier in Isolation and Tightly attached with working frame

Today every automobile company has been working on increasing the efficiency with reducing the weight without having any load carrying capacity. In this paper we would like to review some previous research work performed on the leaf spring by previous researchers for increasing the working condition and capacity with load reduction. The paper based on material composition, experimental testing and load (Steady, Dynamic) study etc.

Key words: Leaf Spring, Material Compositions, Mathematics, Experiments, ANSYS

I. INTRODUCTION

A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Leaf springs absorb the vehicle vibrations, shocks and bump loads (induced due to road irregularities) by means of spring deflections, so that the potential energy is stored in the leaf spring and then relieved slowly. Ability to store and absorb more amount of strain energy ensures the comfortable suspension system. Semi-elliptic leaf springs are almost universally used for suspension in light and heavy commercial vehicles. For cars also, these are widely used in rear suspension. The spring consists of a number of leaves called blades. The blades are varying in length. The blades are us usually given an initial curvature or cambered so that they will tend to straighten under the load. The leaf spring is based upon the theory of a beam of uniform strength. The lengthiest blade has eyes on its ends. This blade is called main or master leaf, the remaining blades are called graduated leaves. All the blades are bound together by means of steel straps. Springs are an important and frequently used component in mechanical engineering. Whilst most people are able to recognize a few standard spring configurations, the range of springs is actually much broader: they have many different forms and perform a number of quite separate and distinct functions, with one spring often combining several functions.

The spring is mounted on the axle of the vehicle. The entire vehicle load rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, leading to deflection of spring. This changes the length between the spring eyes. If both the ends are fixed, the spring will not be able to accommodate this change of length. So, to accommodate this change in length shackle is provided at one end, which gives a flexible connection. The front eye of the leaf spring is constrained in all the directions, where as rear eye is not constrained in X-direction. This rare eye is connected to the shackle. During loading the spring deflects and moves in the direction perpendicular to the load applied. When the leaf spring deflects, the upper side of each leaf tips slides or rubs against the lower side of the leaf above it. This produces some damping which reduces spring vibrations, but since this available damping may change with time, it is preferred not to avail of the same. Moreover, it produces squeaking sound. Further if moisture is also present, such inter - leaf friction will cause fretting corrosion which decreases the fatigue Strength of the spring.

II. LITERATURE REVIEW

In this section research papers are discussed related to the present work. Published papers are highlight in this section.

1) Mahmood M. shokrieh and Davood Rezaei 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 finite element results showing stresses and deflections verified the existing analytical and experimental solutions. Using the results of the steel leaf spring, a composite one made from fiberglass with epoxy resin is designed and optimized using ANSYS. Main consideration is given to the optimization of the spring geometry. In 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 units weights nearly 80% less than the steel spring. The natural frequency of composite leaf spring is higher than that of the steel leaf spring and is far enough from the road frequency to avoid the resonance.

2) E. Mahdi a, O.M.S. Alkoles et al. presented work on light composite elliptic springs for vehicle suspension. They worked on based study marries between an elliptical configuration and the woven roving composites. In this paper, the influence of ellipticity ratio on performance of woven roving wrapped composite elliptical springs has been investigated both experimentally and numerically. A series of experiments 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 and maximum failure increase with increasing wall thickness. In general, this present investigation demonstrated that composites elliptical spring can be used for light and heavy trucks and meet the requirements, together with substantial weight saving. The results showed that the ellipticity ratio significantly influenced the spring rate and failure loads. Composite elliptic spring with ellipticity ratios of a/b 2.0 displayed the highest spring rate.

3) Y. N. V. Santhosh Kumar, M. Vimal Teja et. al presented work on design and analysis of composite leaf spring . They also discussed the advantages of composite material like higher specific stiffness and strength, higher strength to weight ratio. This work deals with the replacement of conventional steel leaf spring with a Mono Composite 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 spring as compared to the steel leaf spring. For this they

selected the composite material was E-Glass/Epoxy. The leaf spring was modeled in Pro/E 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 spring for the analyzed stresses. So from result they proved that weight reduction obtained by using composite leaf spring as compared to steel was 60.48 %, and it was also proved that all the stresses in the leaf spring were well within the allowable limits and with good factor of safety. It was found that the longitudinal orientations of fibers in the laminate offered good strength to the leaf spring.

4) Pankaj Saini, Ashish Goel, Dushyant Kumar et al. 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 is used against conventional steel. The design parameters were selected and analyzed with the steel leaf sprin 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 results 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, 91.95% for Graphite/Epoxy, and 90.51 % for Carbon/Epoxy over steel leaf spring. Hence it is concluded that E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring from stress and stiffness point of view.

5) Manas Patnaik, Narendra Yadav, et al worked on study of a parabolic leaf spring by finite element method & design of experiments. Main objective of this study was the behavior 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 spring of a mini loader truck, which has a loading capacity of 1 Tonnes. The modelling of the leaf spring has been done in SOLID WORK 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 they 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 stress.

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 spring can be achieved by studying the various plots obtained from Design of Experiments.

6) Malaga. Anil Kuma, T. N. Charyulu, et al. presented work on design optimization of leaf spring. The automobile industry has shown increased interest in the replacement of steel spring with composite leaf spring. Main purpose of this paper is to replace the multi-leaf steel spring by mono composite leaf spring for the same load carrying capacity and stiffness.Composite materials have more elastic strain energy storage capacity and high strength-to-weight ratio as compared to those of steel. It is possible to reduce the weight of the leaf spring without any reduction on load carrying capacity and stiffness. The design constraints were limiting stresses and displacement. Here the dimensions of a leaf spring of a light weight vehicle are chosen and modeled using ANSYS 14. 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 spring. They are Eglass/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.

7) Prahalad Sawant Badkar et al. 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 distribution 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.

8) H.A.AI-Qureshi et al. 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 mechanical 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 frequency is higher and the spring weight without eye units is nearly 80% lower.

9) Ashish V.Amrute, Edward Nikhil karlus et al. presented work on design & assessment of leaf spring. Main objective of this work is to compare the load carrying capacity, stresses and weight savings of composite leaf spring with that of steel leaf spring. Here the multi leaf spring consist 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 leaf spring using E-glass/Epoxy. Dimensions of the composite leaf spring are to be taken as same dimensions 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 25.05% in composite leaf spring means less stress induced with same load carrying conditions. The conventional multi leaf spring weights about 10.27kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus the weight reduction of67.88% is achieved by using composite material rather than using steel material.

III. GEOMETRY & FORMULAES

The top leaf is known as the master leaf. The eye is provided for attaching the spring with another machine member. The amount of bend that 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. The camber shown in the figure is known as positive camber. The central clamp is required to hold the leaves of the spring. However, the bolt holes required to engage the bolts to clamp the leaves weaken the spring to some extent. Rebound clips help to share the load from the master leaf to the graduated leaf. In order to carry heavy load few more additional full length leaves are placed below the master leaf for heavy loads. Such alteration from the standard laminated leaf spring, what we have learnt above, does not change the stress value, but deflection equation requires some correction.

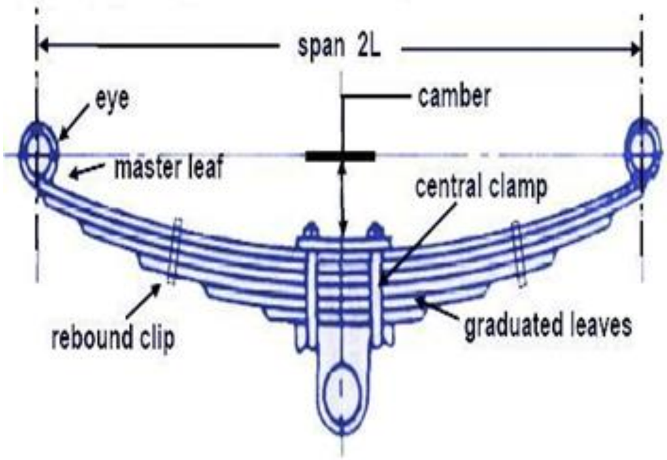

Figure 1. Leaf Spring

$$\delta_{max} = \frac{\delta_c Q f L^3}{E N b_N h^3}$$

Where, correction in deflection, δ is given as,

$$\delta_c = \frac{1.0 - 4m + 2m^2\{1.5 - \ln(m)\}}{(1.0 - m)^3}$$

Where,

$m = N_f / N$

N_f = Number of full length leaves

N = Total number of leaves in the spring

IV. RESULT AND ANALYSIS

ANSYS is the name commonly used for ANSYS mechanical, general-purpose finite element analysis (FEA) computer aided engineering software tools developed by ANSYS Inc. ANSYS mechanical is a self contained analysis tool incorporating pre-processing such as creation of geometry and meshing, solver and post processing modules in a unified graphical user interface. ANSYS is a general-purpose finite element-modeling package for numerically solving a wide variety of mechanical and other engineering problems. These problems include linear structural and contact analysis that is non-linear. Among the various FEM packages, in this work

ANSYS is used to perform the analysis. The following steps are used in the solution procedure using ANSYS.

1. The geometry of the gear to be analyzed is imported from solid modeller Pro/Engineer in IGES format this is compatible with the ANSYS.
2. The element type and materials properties such as Young's modulus and Poisson's ratio are specified.
3. Meshing the three-dimensional gear model. Figure1 shows the meshed 3D solid model of gear.
4. The boundary conditions and external loads are applied.
5. The solution is generated based on the previous input parameters.
6. Finally, the solution is viewed in a variety of displays.

Table 1

Sr. No.	Geometry Name	Gear 1
1.	No. of leaf	6
2.	Weight	10kg
3.	Material type	Steel

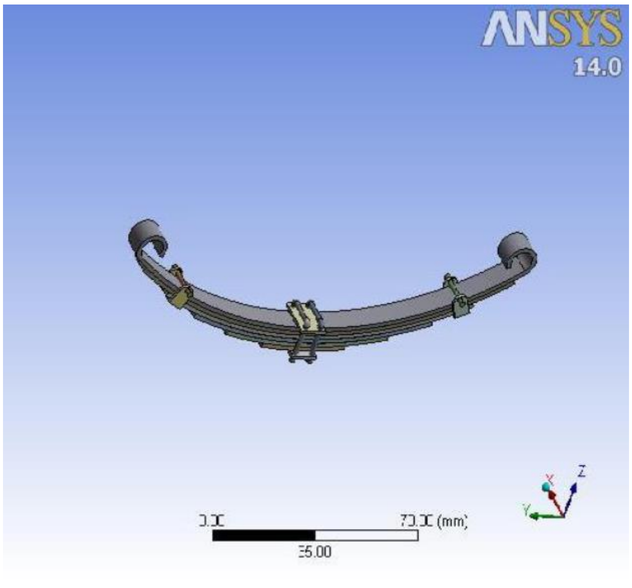

Figure 2. solid model of leaf spring generated by Pro/Engineer (imported on ANSYS)

Figure 3. Mesh of leaf spring

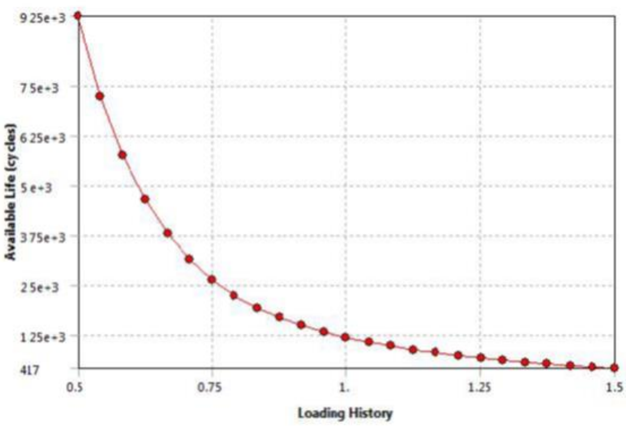

Figure 4. Fatigue sensitivity plot of leaf spring

V. EXPECTED ADVANTAGES

1. The main advantage of using a composite material is to increase strength to weight ratio and they also have a higher corrosive resistance.
2. The composite materials are more elastic then the conventional material (Steel).
3. The comparison results show that the composite spring has lower stresses and much lower weight. Then the automotive dead weight is reduced.
4. Increasing the working condition and capacity with load reduction.
5. Totally weight reduction take place to increase the efficiency in vehical.
6. Lower cost. Rough used.
7. Easier in Isolation and Tightly attached with working frame.

VI. CONCLUSION

The study done by us here gives a review on previous paper and journals based on different ideas and modifications with the help of mathematics, experiments, and computational methods. Now in this portion we concluded here the main parameters analyze by us from the study of these previous papers.

1. The main area focuses about the material used for manufacturing of leaf spring. Now a day's composite material is used in heavy manner as a leaf spring material in place of steel.
2. The main components used for manufacturing of composite leaf springs are E-Glass/Epoxy, C-Glass/Epoxy, and S-Glass/Epoxy for reduction of weight as compare to conventional steel leaf spring.
3. The main advantage of using a composite material is to increase strength to weight ratio and they also have a higher corrosive resistance.
4. The composite materials are more elastic then the conventional material (Steel).
5. The papers also shows the heavy amount of work with the help of computational software's because of saving time and cost with great

accuracy. The papers used here focus on different computational software's like ANSYS, N-code design, and COMSOL for analysis and software's like CATIA, CAD, and PRO-E for design purpose.

6. The study here presents a method named hand layup for quick and desired results with minimum time.

VII. 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 Research Vol.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 V. 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). 1532