A Review Paper on Design & STATIC Analysis of Leaf Spring

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Abstract--This paper reviews some of the general study on the design, analysis and fabrication of composite leaf spring. Leaf springs are one of the oldest suspension components they are still frequently used, especially in commercial vehicles. 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. Static analysis determines the safe stress and corresponding pay load of the leaf spring and also to study the behavior of structures under practical conditions. The present work attempts to analyze the safe load of the leaf spring, which will indicate the speed at which a comfortable speed and safe drive is possible. The literature has indicated a growing interest in the replacement of steel spring with composite leaf spring.The suspension system in a vehicle significantly affects the behavior of vehicle, i.e. vibration characteristics including ride comfort, stability etc. Leaf springs are commonly used in the vehicle suspension system and are subjected to millions of varying stress cycles leading to fatigue failure. In this paper the author is reviewed few papers on use of alternate materials and effect of material on leaf spring performance.

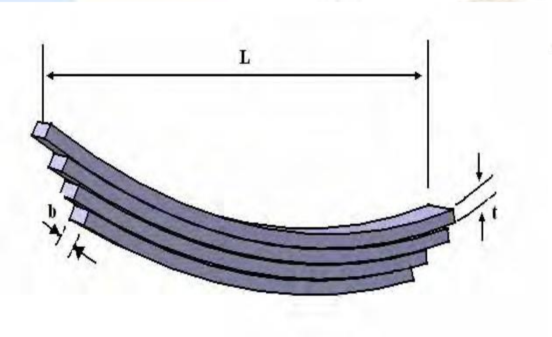
Keywords: steel leaf spring, ANSYS, PRO-E software, Geometric modeling, Static analysis.

1. 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.

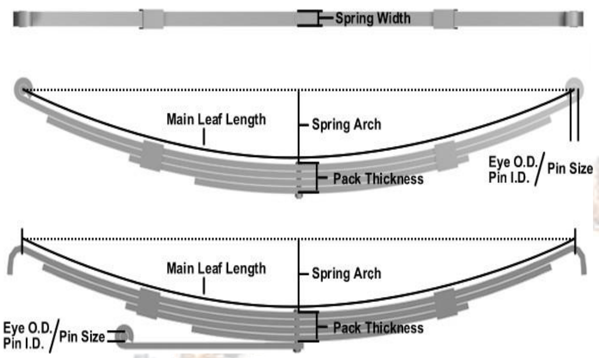
The spring is mounted on the axle of the vehicle. The entire vehicle load rests on the leaf spring. The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, leading to deflection of the 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, whereas rear eye is not constrained in X-direction. This rare eye is connected to the shackle. During loading the springdeflects and moves in the direction perpendicular to the load applied.

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 element is not only to support vertical load, but also to isolate road-induced vibrations. The behaviour of leaf spring is complicated due to 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 cars, necessary to minimize thevertical vibrations, impacts and bumps due to road irregularities and create a comfortable ride. The suspensionleaf spring is one of the potential items for weight reduction inautomobile as it accounts for ten to twenty percent of the unsprung weight.



Elements of Leaf Spring

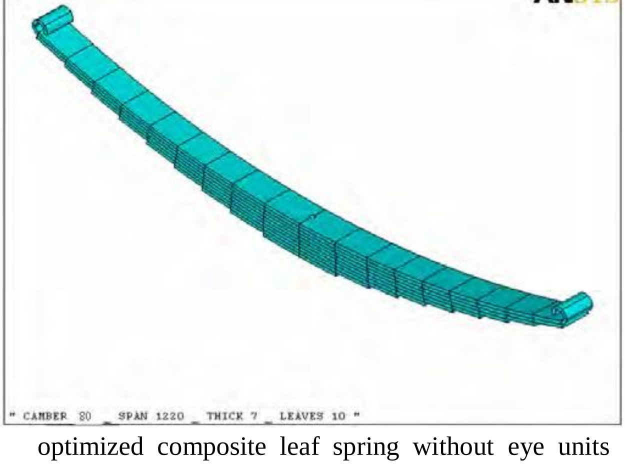
The introduction of composites helps in designing a better suspension system with better ride quality ifit can be achieved without much increase in cost and decrease in quality and reliability. In the design of springs, strain energy becomes the major factor. In the present scenario the main focus of automobile manufacturers is weight reduction of the automobile. Weight reduction can be achieved mainly by introducing the better material, design optimization and better manufacturing processes. In automobiles, leaf spring is one of the potential parts for weight reduction as it accounts for 10% - 20% of the unsprung weight. Composite materials have made it possible to reduce the weight of leaf spring without any reduction in load carrying capacity and stiffness. Composite materials are now used extensively in place of metal parts. Several papers were devoted to the application of composite materials for automobiles.



Laminated semi-elliptical leaf spring

2. LITERATURE REVIEW:

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

I, S. Vijayarangan A formulation and solution technique using genetic algorithms (GA) for design optimization of composite leaf springs is presented here. *J.P. Hou et al.* explained the design evolution process of a composite leaf spring for freight rail application. *A.strzat and T.Paszek* performed a three dimensional contact analysis of the car leaf spring. They considered static three dimensional contact problem of the leaf car spring and the solution is obtained by finite element method performed in ADINA 7.5 professional system. The maximum displacement of car spring is chosen as reliability criterion. Different types of mathematical model were considered starting from the easiest beam model and ending on complicated three dimensional non-linear model which takes into consideration large displacements and contact effects between subsequent spring leaves. The static characteristics of the car spring was obtained for different models and later on, it is compared with one obtained from experimental investigations. *Fu-Cheng Wang* performed a detailed study on leaf springs. Classical network theory is applied to analyze the behavior of a leaf spring in an active suspension system. *I.Rajendran and S.Vijayarangan* performed a finite element analysis on a typical leaf spring of a passenger car. Finite element analysis has been carried out to determine natural frequencies and mode shapes of the leaf spring by considering a simple road surface model. Further more literatures areavailable on concepts and design of leaf springs The dimensions and the properties of the materials are taken from the spring manufacturing companies catalogues

3. MODELING & ANALYSIS OF LEAF SPRING

In computer-aided design, geometric modeling is concerned with the computer compatible mathematical description of the geometry of an object. The mathematical description allows the model of the object to be displayed and manipulated on a graphics terminal through signals from the CPU of the CAD system. The software that provides geometric modeling capabilities must be designed for efficient use both by the computer and the human designer.

To use geometric modeling, the designer constructs the graphical model of the object on the CRT screen of the ICG system by inputting three types of commands to the computer. The first type of command generates basic geometric elements such as points, lines, and circles. The second type command is used to accomplish scaling, rotation, or other transformations of these elements. The third type of command causes the various elements to be joined into the desired shape of the object being created on the ICG system. During this geometric process, the computer converts the commands into a mathematical model, stores it in the computer data files, and displays it as an image on the CRT screen. The model can subsequently be called from the data files for review, analysis, or alteration. The most advanced method of geometric modeling is solid modeling in three dimensions.

Full model of leaf spring

Modeling Procedure for Leaf Spring

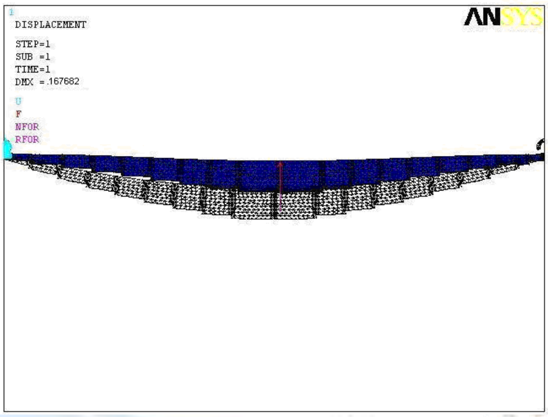
1. First create the key point 100 at origin, i.e. x ,y, z = (0, 0, 0).
2. Create another key point 200 at some arbitrary distance in Z-direction, say x, y, z = (0, 0, 200).
3. Join the above two key points 100 and 200 to get the reference axis.
4. By using data from mathematical analysis Create the key point1 with a distance of radius of curvature R_1in vertically down-ward direction, i.e. x, y, z = (0, $-R_1$, 0).
5. Similarly key points 2 and 3 correspond to R_2, i.e. x, y, z = (0, $-R_2$, 0) and key points 4 and 5 correspondsto R_3, i.e. x, y, z = (0, $-R_3$, 0).
6. Key point 20 corresponds to R_{11}. i.e. x, y, z = (0, -R11, 0).
7. Join the pair of key points sequentially as follows Key points 1 and 2, 2 and 3, 3 and 4...and 19 and 20.
8. Then line1 formed by the key points 1 and 2, line2 formed by the key points 2 and 3 and line10 formed by the key points 19 and 20.
9. Extrude the above lines with respect to reference axis stated in step3 as follows: Extrude line1 with an angle Φ_1, will get area1
   Extrude line2 with an angle Φ_2, will get area2,………andExtrude line10 with an angle Φ_{10}, will get area10.
10. After extruding all the lines, the semi area of the spring without eye will form on XY- plane with significant degeneracy.
11. To avoid degeneracy, extend the right side line of smallest area i.e. area 10 to some extent such that it cross the top most area i.e. area1.Now divide area by line. For this, select the areas left to extended line1and divide with that line. Similarly, extend the right side line of second smallest area i.e. area9 to some extent such that it cross the top most area i.e. area1. Again divide area by line.
    For this select the areas left to extended line2 and divide with that line.
12. The above process is to be done up to extension of line of area9 and divide area area by extension line9.
13. Now perfect half area of leaf spring without eye will form.
14. Eye construction:
    Extend the right side line of top most area i.e. area1 to the length equal to the radius of eye. Delete lines only, so that key point of that line will remain. Shift the origin to that key point. Create another key point say some key point300 in Z-direction. Join the above two key points to get reference axis to rotate the right side line of area1. Extrude the line with respect to reference axis to an angle 275^0 to 280^0. Delete all reference lines. So half area of leaf spring with eye is formed.
15. To get the full area of the leaf spring. Shift the origin to the top left most area key point i.e. key point1. Reflect the entire area with respect to YZ – plane.
16. To get the solid model of the leaf spring, extrude the area by Z-offset to a length equal to the width of the leaf spring.
17. To make a cylindrical hole at centre of the leaf spring to provide bolting for all the leaves, so that all the leaves are in perfect alignment: Create centre key point of the leaf spring on the top view i.e. XY-plane, by using key points between key points' command. Shift the origin to that key point. Choose the proper work plane by using work plane Create a cylinder along Z-axis in vertically downward direction. Subtract the cylinder from the solid leaf spring. So that leaf spring with hole to provide bolt will obtain.

4. STATIC ANALYSIS

For the above given specification of the leaf spring, the static analysis is performed using ANSYS to find the maximum safe stress and the corresponding pay load. After geometric modeling of the leaf spring with given specifications it is subjected to analysis. The Analysis involves the following discritization called meshing, boundary conditions and loading. However modal analysis does not need loading.

Meshing

Meshing involves division of the entire of



model into small pieces called elements. This is done by meshing. It is convenient to select the free mesh because the leaf spring has sharp curves, so that shape of the object will not alter. To mesh the leaf spring the element type must be decided first. Here, the element type is solid 72. The element edge length is taken as 15 and is refined the area of centre bolt to 2. Fig 7.2 shows the meshed model of the leaf spring.

The following are the material properties of the given leaf spring.
Material = Manganese Silicon Steel, Young's Modulus E = 2.1E5 N/mm^2, Density ρ = 7.86E-6 kg/mm^3, Poisson's ratio = 0.3 and Yield stress = 1680 N/mm^2.

Boundary Conditions

The leaf spring is mounted on the axle of the automobile; the frame of the vehicle is connected to the ends of the leaf spring. The ends of the leaf spring are formed in the shape of an eye. The front eye of the leaf spring is coupled directly with a pin to the frame so that the eye can rotate freely about the pin but no translation is occurred. The rear eye of the spring is connected to the shackle which is a flexible link; the other end of the shackle is connected to the frame of the vehicle. The rear eyes of the leaf spring have the flexibility to slide along the X-direction when load applied on the spring and also it can rotate about the pin. The link oscillates during load applied and removed. Therefore the nodes of rear eye of the leaf spring are constrained in all translational degrees of freedom, and constrained the two rotational degrees of freedom. So the front eye is constrained as UX, UY, UZ, ROTX, ROTY and the nodes of the rear eye are constrained as UY, UZ, ROTX, ROTY. Figure 4 shows the boundary conditions of the leaf spring.

Loads Applied

The load is distributed equally by all the nodes associated with the center bolt. The load is applied along Fy direction as shown in Figure 4. To apply load, it is necessary to select the circumference of the bolthole and consequently the nodes associated with it. It is necessary to observe the number of nodes associated with the circumference of the bolt hole, because the applied load need to divide with the number of nodes associated with the circumference of the center bolt.

5. RESULTS AND DISCUSSIONS

Deformed and undeformed shape of leaf spring

The deformed and undeformed shape of the leaf spring gives the Von-Mises stress at various loads.

6. CONCLUSIONS

The automobile chassis is mounted on the axles, not direct but with some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies giifications of the leaf spring, the maximum safe load is 7700N. It is observed that the maximum stress is developed at the inner side of the eye sections, so care must be taken in eye design and fabrication and material selection. The selecteve rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the part which performs the function of isolating the automobile from the road shocks are collectively called a suspension system. Leaf spring is a device which is used in suspension system to safeguard the vehicle and the occupants. For safe and comfortable riding i.e, to prevent the road shocks from being transmitted to the vehicle components and to safeguard the occupants from road shocks it is necessary to determine the maximum safe load of a leaf spring. Therefore in the present work, leaf spring is modeled and static analysis is carried out by using ANSYS software and it is concluded that for the given specd material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.

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