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FATIGUE LIFE PREDICTION OF COMPOSITE SEMI-ELLIPTICAL LEAF SPRING FOR HEAVY VEHICLE

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ABSTRACT
A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Leaf Springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. There are mono leaf springs, or single-leaf springs, that consist of simply one plate of spring steel. These are usually thick in the middle and taper out toward the end, and they don't typically offer too much strength and suspension for towed vehicles. Drivers looking to tow heavier loads typically use multi leaf springs, which consist of several leaf springs of varying length stacked on top of each other. The shorter the leaf spring, the closer to the bottom it will be, giving it the same semielliptical shape a single leaf spring gets from being thicker in the middle.

The objective of this paper is to Predict the fatigue life cycle for crack initiation at maximum stress location in the Leaf spring.. The design constraints are stresses and deflections. The aim of this project is to study existing semi elliptic leaf spring and optimize the critical part like eye, bolt etc. to minimize the overall weight of the assembly without hampering its structural strength. It also involves geometrical and finite element modeling of existing design and optimized design. Geometrical modeling is carried out by using CATIA V5 and finite modeling in ANSYS14.0. Results of Static, and fatigue analysis of existing design and optimized design are compared. The optimization is carried out by changing the material for semi elliptic leaf spring. The material used semi-elliptic leaf spring is a composite material such as E GLASS EPOXY.

KEYWORDS: Fatigue life, structural strength, semi-elliptical leaf spring, optimized design, weight reduction, composite material, FEA.

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

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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 spring deflects and moves in the direction perpendicular to the load applied. The main objective of this work is to perform static and fatigue analysis of multi leaf spring used in heavy vehicles.

The objectives of suspension are, 1) to prevent the road shocks from being transmitted to the vehicle components.2) to safeguard the occupants from road shocks. 3) To preserve the stability of the vehicle in pitting or rolling, while in motion

TYPES OF LEAF SPRING

1) Elliptical Leaf spring
2) Semi-Elliptical Leaf spring
3) Three Quarter elliptical Leaf spring
4) Quarter Elliptical Leaf spring
5) Transverse Leaf spring

A laminated semi-elliptic spring .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.

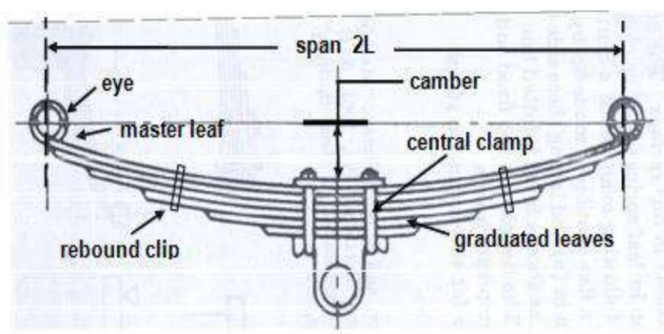

Fig 1.1 Laminated semi-elliptic leaf spring

The leaf spring involves two full length leaves and seven graduated leaves, four packing which are made of 65Si7 material. This conventional leaf spring model consists of 37 parts which, includes two full length leave, seven graduated leaves. The remaining part involves four rebound clips of MS, four shim pipes of C.D.S.T/ERW, centre nut & bolt and bush of bronze.

Problem defination

In the current work, the component considered is the Rear Leaf Spring Used in the Suspension System of Heavy Vehicles during ride; all springs will eventually fail from fatigue caused by the repeated flexing of the spring. Once the spring life limit is reached a fatigue failure will occurs due to various factors such as Overloading, Decarburization of steel, Maintenance and other. In order to predict the Life of Leaf Spring Fatigue Analysis is carried.

Need for analysis

The load rate and fatigue life (under specified stress range) are to be determined theoretically. The process of experimental fatigue life prediction of leaf springs is a time consuming process; that is, for the fatigue life of 100000 cycles, the experimental procedure will consume approximately 2-3 days. The leaf spring is mounted in the machines by simulating the condition of the vehicle the fatigue test stroke is determined, and the leaf spring is tested from maximum stress to minimum or initial stress. As there are a number of factors responsible for fatigue life enhancement like material processing, loading, surface, size, and environmental factor, it is mandatory that the fatigue life should

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be determined by considering these factors. The engineers working in the field of leaf springs design are facing a challenge to devise a fatigue life assessment method which is reliable and consumes less with the past experience of the Service provider in this field, modeling in catia -v5 and analysis in ANSYS -14 appears as a competent tool to pursue Analysis for this Project Work.

Objectives of the work

The main objective is to predict life of the semi-elliptical leaf spring of composite material for weight optimization. The following are important points regarding this objective of study

1. Study existing semi-elliptic leaf spring and its design.
2. Geometric modeling of existing leaf spring.
3. To carry out static, fatigue analysis and optimization of existing semi-elliptic leaf spring by using ANSYS 14.0 Workbench software.
4. Finding the maximum stress location and its magnitude in Semi-elliptic leaf Spring Leaf Spring.
5. To carry out Analysis of Modified design for same loading condition.
6. Recommendation of new fatigue life prediction for semi-elliptic leaf spring.

LITERATURE REVIEW

G Harinath Gowd, E Venugopal Goud et. al [1] 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. A typical leaf spring configuration of TATA-407 light commercial vehicle on this Finite element analysis has been carried out to determine the safe stresses and pay loads. 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 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 selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.

Kumar Krishan And Agarwal M.L et. al [2] finite element analysis and modeling was carried out on a multi leaf spring having nine leaves used by a commercial vehicle. It includes two full length leaves in which one is with eyed ends and seven graduated length leaves. The material of the leaf spring is SUP9. The FE model of the leaf spring has been generated in CATIA V5 R17 and imported in ANSYS-11 for finite element analysis of the leaf spring has been performed by discretization of the model in infinite nodes and elements refining them and under defined boundary condition. A comparison of both i.e. experimental and FEA results have been done to conclude that. When the leaf spring is fully loaded, a variation of 0.632 % in deflection is observed between the experimental and FEA result, which validates the model and analysis. On the other hand, bending stress in both the cases is also close to the experimental results. The maximum value of equivalent stresses is below the Yield Stress of the material that the design is safe from failure.

.Mr.V.K.Aher, Mr.P.M.Sonawane et.al [3] 'Prediction of Fatigue life of multi leaf spring used in the suspension system of light commercial vehicle' along with analytical stress and deflection calculations. This present work describes static and fatigue analysis of a modified steel leaf spring of a light commercial vehicle (LCV). The non-linear static analysis of 2D model of the leaf spring is performed using NASTRAN solver and compared with analytical results. The preprocessing of the modified model is done by using HYPERMESH software. The simulation results are compared with analytical results. The fatigue life of the leaf spring is also predicted using MSC Fatigue software. They finally conclude that, the fatigue life prediction is performed based on finite element analysis and fatigue life simulation method. FEM gives the prediction of critical area from the viewpoint of static loading. The stiffness of the leaf spring is studied by plotting load versus deflection curve for whole working load range which shows the linear relationship. Using the constant amplitude loading, the fatigue damage and life of the spring has been predicted. From the damage contour, the highest damage value is in acceptable range.

U.S. Ramakanth And K. Sowjanya et. al [4] 'Design and analysis of automotive multi leaf springs using composite materials'.This work is carried out on multi leaf springs having nine leaves used by a commercial vehicle. The semi-elliptic leaf spring model is generated using solid works and and by importing it into ansys analysis is done by finite element approach. The material of the leaf springs is 65Si7 (SUP9), composite leaf springs and hybrid leaf springs. Fatigue analysis of leaf springs is carried out for steel leaf springs, and Static analysis for steel leaf springs, composite leaf springs and hybrid leaf springs. They finally concluded that, under the same static load conditions the stresses in leaf springs are found with great difference. Stresses in composite leaf springs is found out to be less as compared to the conventional steel leaf springs, also a new combination of steel and composite leaf springs (hybrid leaf springs) are given the same static loading and is found to have values of stresses in between that of steel and composite leaf springs. The cost of the GFRP composite is very high when compared to conventional steel leaf springs, while the cost of hybrid leaf springs may be lesser when compared to GFRP composite leaf springs. The fatigue analysis of the steel leaf springs are carried with four approaches, Soderberg's approach is found out to give better results for the analysis of life data for leaf springs

B vijaylakshmi et. al [5] designed and modeled a leaf spring using in pro-engineering for the material Mild steel, E-glass, S-glass, and C-glass. static analysis on 8-leafs concluded that E-glass epoxy is better than using Mild-steel as though stresses are little bit higher than mild steel, E-glass epoxy is having good yield strength value (5e+008N/m2) and also epoxy material components are easy to manufacture and this having very low weight while comparing with traditional materials and analysis leaf spring using 12 leafs for S-glass is having better results while comparing with C-glass, E-glass and mild steel. So better to use S-glass epoxy (Carbon reinforced fiber) and by increasing the number of leafs to reduce the stress for structural stability. While comparing with the weight it is having less weight than traditional leaf spring (Mild steel). After static analysis they analyzed frequency analysis. Model analysis is mainly used to match the frequency of previous leaf spring model. So finally we can conclude that S-glass epoxy is the best material to manufacture leaf spring because of good structural stability low production cost and good efficiency.

Rajendran , S.Vijayarangan et. al [6] has presented an artificial genetics approach for the design optimization of composite leaf spring. The design variable (thickness and width) of steel and composite leaf springs are optimized by making use of GA (Genetic Algorithm).
Optimization using GA has contributed to a reduction of 8% of the steel spring weight and 23.4% of the composite spring weight.

H.A. Al Qureshi et. al [7] has described a single leaf, variable thickness spring of glass fiver reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi-leaf steel spring was designed, fabricated and tested.

M.L Aggarwal,V.P. Agrawal, R.A. Khan et. al [8] has calculated fatigue strength of shot peening leaf spring from laboratory samples of EN45A spring steel specimen. A lot of research has been done to improve fatigue strength of material by creating compressive residual stress field in their surface layers through shot peening.
W. Hufenbach & F. Adam et. al [9] has presented a method to adjust the spring rate of a leaf spring element. For dimensioning of this system a strategy was developed and validated. The tests of manufactured leaf spring elements with different reinforcements show a good agreement between the calculation and the measured characteristic.

M.senthil kumar & S.vijayarangan et.al [10], carrying out design and experimental analysis of composite leaf spring using glass fibre reinforced polymer. Composite leaf spring has lesser stress, higher stiffness, and higher natural frequency than steel leaf spring. Conventional leaf spring weighs more than composite leaf spring, thereby weight reduction was occurred. Fatigue life of composite leaf spring is predicted to be higher than that of steel leaf spring.

Mouleeswaran et al.[11] describes static and fatigue analysis of steel leaf springs and composite multi leaf spring made up of glass fibre reinforced polymer using life data analysis. The dimensions of existing conventional steel leaf springs of a light commercial vehicle are taken and are verified by design calculations. Static analysis of 2-D model of conventional leaf spring is also performed using ANSYS 7.1and compared with experimental results.
A. strzat and T.Paszek et al [12] 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.

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Zhi'an Yang and et al. [13] studied the cyclic creep and cyclic deformation. Efforts were taken for Finite Element Analysis of multi leaf springs. These springs were simulated and analyzed by using ANSYS [5].

SOFTWARE FOR DESIGN AND ANALYSIS

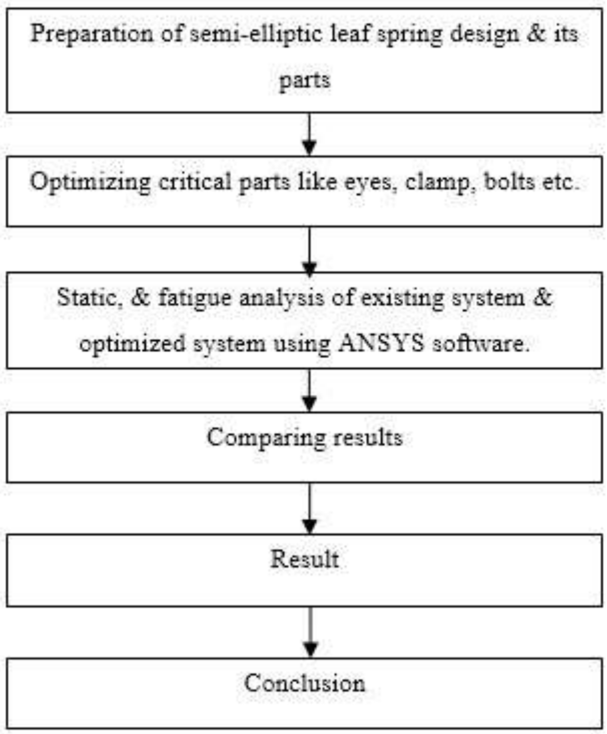
Catia V5

Catia V5 is the design software which provides basic platforms for designing any machine parts that can be used for the advanced design engineering companies that require product, process, and resource modeling and for the high-end design, where high quality surfacing or Class-A surfacing is used for designing. A good feature is that any change made to the external data is notified to user and the model can be updated quickly.

ANSYS workbench 14.0

The general purpose FEA software Workbench is used to develop the model for a wide range of engineering problem-solving requirements (e.g., static, dynamic, nonlinear behavior, transient analysis, or optimization). It is a compressive general purpose finite element analysis program for structures.

PROPOSED FLOW OF WORK AND METHODOLOGY



CONCLUSION

The automobile chassis is mounted on the axles, not direct but with some shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stresses in the automobile frame and body. All the parts which perform the function of isolating the automobile from the road shocks are collectively called a suspension system.

Composite Leaf spring is advice 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 maximum safe load and maximum fatigue life cycle of leaf spring. Therefore in the present work composite leaf spring is modeled static analysis and fatigue analysis is to find out using ANSYS software. Finding the maximum stress developed at leaf spring, care must be taken in that

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part by material selection and manufacturing. The selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comport to the occupants.

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