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Fatigue Life Prediction of Composite Semi-elliptical Leaf Spring for Heavy vehicle

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ABSTRACT

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— **Composite material, Fatigue life, Finite Element Analysis,Geometrical Modeling,Leaf spring, optimized design.**

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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.

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 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.

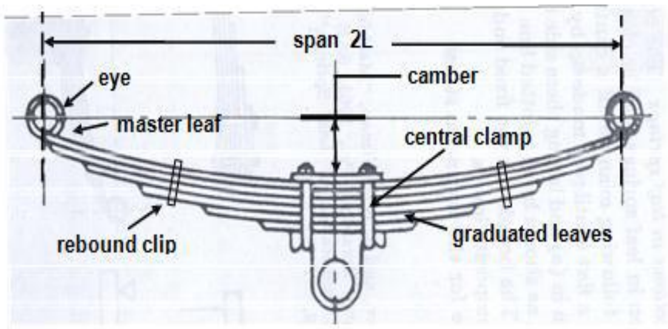

Fig 1.1 Laminated semi-elliptic leaf spring

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.

A. 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.

B.NeedFor 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 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.

C.ObjectivesOf 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.

II. LITERATURE REVIEW

Saelemet al.[1]simulated a leaf springs model. An experimental leaf springs model was verified by using a leaf springs test rig that could measure vertical static deflection of leaf springs under static loading condition.The results showed a nonlinear relationship between the applied load and the leaf springs deflection for both directions of loading, in form ofa hysteresis loop. Refngah et al. [2] worked on the possibility and capability of replacing the multi-leaf with the parabolic spring in suspension system.He performed the finite element analysis to analyze the stress distribution and behavior of both the springs. Then, time histories service loading data was analyzed and damage area was simulated to predict the fatigue life of the components. The simulation results are compared and validated with the experimental results. Fuentes et al. [3] studied the origin of premature failure analysis procedures, including examining the leaf spring history.The visual inspection of fractured specimens and simulation tests on real components were also performed. It was concluded that fracture occurred by a mechanism of mechanical fatigue initiated at the region of the central hole, which suffered the highest tensile stress levels. Aggarwal et al. [4] evaluated the axial fatigue strength of En45a spring steel sample experimentally as a function of shot peening in the circumstances used.curves of the samples were correlated with leaf springs curve in vehicles. Aggarwal et al. [5] concluded that influence of high contact pressure and An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it.Patunkar and Dolas [6] worked on nonlinear force displacement of each leaf spring as well as the spring characteristics of a pack consisting of two to four leaves using ansys. The results from ansys were compared with those from the test, which showed a fairly good agreement with each other. Kumar and Vijayarangan [7] described static and fatigue analysis of steel leaf springs and composite multi-leaf springs made up of glass fibre reinforced polymer using life data analysis. The dimensions of an existing conventional steel leaf spring of a light commercial vehicle were taken and verified by design calculations. Staticanalysis of 2-D model of conventionalleaf springs was also performed using ANSYS 7.1. G HarinathGowd, E VenugopalGoudet. al [8] attempts typical leaf spring configuration of TATA-407 light commercial vehicle 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. Kumar KrishanAndAgarwal M.L et. al [9] finite element analysis and modeling was carried out on a multi leaf. spring 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.Mr.V.K.Aher, Mr.P.M.Sonawane et.al [10] '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. 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.U.S. RamakanthAnd K. Sowjanya et. al [11] 'Design and analysis of automotive multi leaf springs using composite materials 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. B vijaylakshmiet. al [12] 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.Rajendran, S.Vijayaranganet. al [13] 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 Qureshiet. al [14] has described a single leaf, variable thickness spring of glass fibre reinforced plastic (GFRP) with similar mechanical and geometrical properties to the multi-leaf steel spring was designed, fabricated and tested.M.senthilkumar&S.vijayarangan et.al [15],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 made up of glass fibre reinforced polymer using life data analysis.

III. LEAF SPRING DESIGN PARAMETER

To design semi-elliptical leaf spring, the terms like span, no load assembly camber, loaded camber, stack height, opening, seat length, are used, these are also called design parameters.Span= 1600 mm,Camber =240mm,Thickness =13 mm,Width = 80 mm, Inside Eye Diameter =35mm,Outside Eye diameter =55mm,Number of full length leaves F = 5,Number of graduated leaves G= 11 and Total Number of leaves n = 16,Ineffective length=200mm,Total Height =200mm,Distance b/w U-clamps at the centre =240mm,Length of sixth leaf = 1500 mm ,Length of seventh leaf =1500mm ,Length of Eighth leaf =1400 mm Length of ninth leaf=1300 mm, Length of tenth leaf =1100 mm,Length of eleventh leaf=950 mm,Length of twelvethleaf=800mm,Length of thirteenth leaf=650mm,Length of fourteenth leaf=550mmLength of fivteenth leaf= 410mm,Length of sixteenth leaf=330mm,Max load =10tons ,Working load=5tons aprrox.(50KN),This leaf spring is used in ASHOK LEYLAND LORRY(model:ley5655) . Material used for steel leaf spring is 55Si2Mn 90 steel.

A. Composite Material Selection

Material selected should have ability to store more energy in the semi-elliptical leaf spring Specific elastic srain energy given by-$S=1/2(\sigma^2/\rho E)$.where σ is allowable stress, ρ density, E modulus of rigidity.E glass epoxy is selected for composite material cause of its mechanical properties modulus of elasticity E-38.6 GPa, modulus of shearG-4.14GPa, poisson ratio 0.24, tensile strength-1062MPa, compressive strength-662MPa, shear strength-110MPa

B. Solid Modelling of Steel

Catia V5 is a 3Dmechanical CAD (computer-aided design) program that runs on Microsoft Windowsand is being developed by Dassault Systems Solidworks Corp ,Building a model in Catia usually starts with a 2D sketch (although 3D sketches are available for power users). The sketch consists of geometry such as points, lines, arcs, conics (except the hyperbola), and splines. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity.

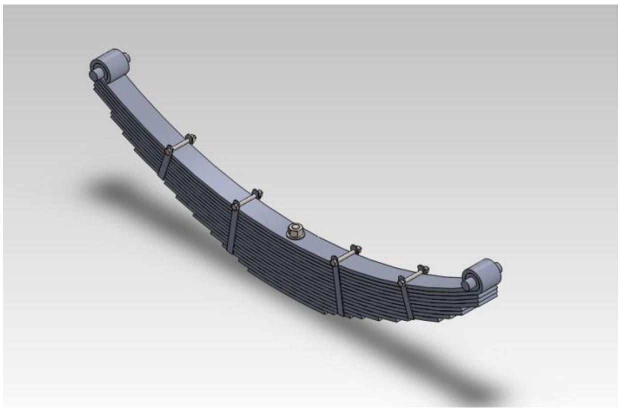

Fig No.1-Solid Modelling of Semi-elliptical leaf spring.

means that the dimensions and relations drive the geometry, not the other way around. The dimensions in the sketch can be controlled independently, or by relationships to other parameters inside or outside of the sketch.In an assembly, the analog to sketch relations are mates. Just as sketch relations define conditions such as tangency, parallelism, and concentricity with respect to sketch geometry, assembly mates define equivalent relations with respect to the individual parts or components, allowing the easy construction of assemblies. Catia V5 also includes additional advanced mating features such as gear and cam follower mates, which allow modeled gear assemblies to accurately reproduce the rotational movement of an actual gear train.

C. FEA of Steel.

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.

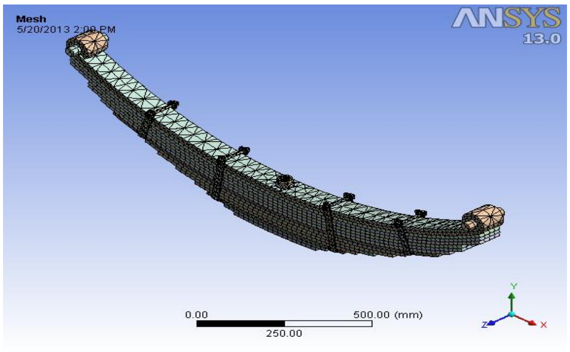

Fig no.2- Mesh view of steel.

D. Fatigue analysis approach.

The element edge length is taken as 15 and is refined the area of centre bolt to 2. Fig2 shows the meshed model of the leaf spring.Fatigue analysis is conducted with two approaches namely Goodman's approach & Gerber's approach, by applying a load of 100000N, with a loading condition constant Amplitude load Fully Reversed and from history data – SAE Transmission.

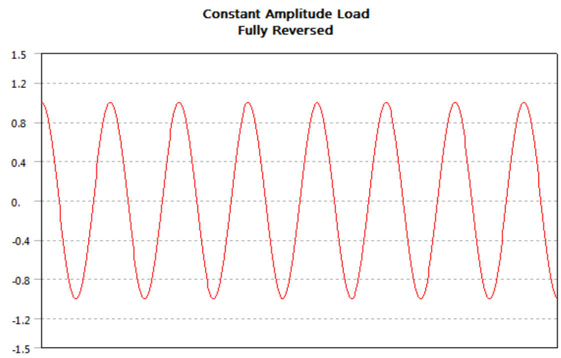

Fig. 3Constant amplitude loading

From the above said approaches it is seen that Gerber's approach shows a maximum value of life 1.061*106 cycles which is represented in blue color in the life data figure and the least value of life is shown in red color. And from the Gerber's approach we find that the red colored region is greater it shows less life compared to other approaches, hence it is most preferred in the analysis so the designer can increase the safety of the leaf springsConstant amplitude, proportional loading is the classic, "back of the envelope" calculation describing whether the load has a constant maximum value or continually varies with time. Loading is of constant amplitude because only one set of FE stress results along with a loading ratio is required to calculate the alternating and mean values. The loading ratio is defined as the ratio of the second load to the first load (LR = $L2/L1$). Loading is proportional since only one set of FE results are needed (principal stress axes do not change over time). Common types of constant amplitude loading are fully reversed (apply a load, and then apply an equal and opposite load; a load ratio of −1) and zero-based (apply a load and then remove it; a load ratio of 0). Since loading is proportional, looking at a single set of FE results can identify critical fatigue locations.

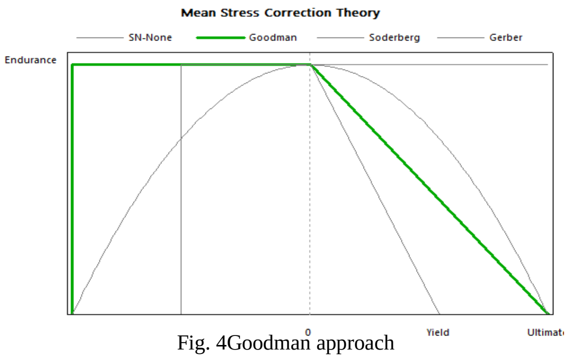

Fig. 4Goodman approach

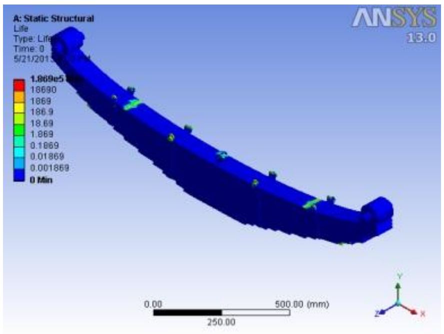

Fig. 5Isometric view for Goodman approach

IV. RESULT DISCUSSION

Present work is successfully done on steel material, now further proposed work is on composite material for better result.

To Provide the Ride comport to passenger, natural frequency of the leaf spring is designed such away that is should be less than road frequency. The road irregularities having maximum frequency 12Hz[4], to avoid the resonance natural frequency should be away from it.Range stress and mean stress apply in load cylces and presence of local stress concentrations in the leaf spring cause to fatigue failure of it.

SR NO	Theoretical result	
	parameters	**steel**
1	load	100000
2	Cycles	$1.06*10^6$ Cycles
SR NO	**FEA Result**	
	parameters	**steel**
1	load	100000
2	cycles	$1.26*10^6$ Cycles

V.CONCLUSION

Theautomobile 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 proposed 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 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.conclusion section is recommended as it helps the readers to check the relevance. Conclusion may the scope of the work presented in the paper.

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