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"A Review on Design, Analysis, and Optimization of Composite Leaf Springs for Different Materials Using ANSYS Software"

Pradeep Kumar Mahobiya [1], Ruchika Saini [2],

1.Research Scholar, Department of Mechanical Engineering, JEC Jabalpur (M.P.)
2. Assistant Professor, Department of Mechanical Engineering, JEC Jabalpur (M.P.)

Abstract

In this paper a brief review of a leaf spring design for various materials has been addressed. This review is designed to be a comprehensive source for designing a leaf spring using various composites as the Automobile industries are showing keen interest for replacing steel leaf spring with that of a composite leaf spring to obtain reduction in weight, which is an effective measure for energy conservation as it reduces overall fuel consumption of the vehicle. In this paper, design model of existing leaf spring has been created and optimized using Ansys parametric optimization with a goal of reducing the weight of leaf spring, improving the life span of structure by reducing stress and increasing the natural frequency of the leaf spring. The optimum values of these parameters of the leaf spring were obtained. the leaf spring of composite materials performed better in terms of the stress level, stiffness and the natural frequency. At the same time, the weight of the composite leaf spring has significantly reduced. In summary, the study concluded that composite leaf spring is better efficient compared with conventional leaf spring from steel.

The aim of this paper is "To analyze the different types of materials which affect the mechanical and thermal load carring capacity of the leaf springs" on the basis of previous study.

Keywords: composite leaf springs, design, suspension, steering, structural integrity, ANSYS etc.

INTRODUCTION

A leaf spring is a component of some vehicles' suspension systems. Specifically, a leaf spring is composed of several (or occasionally just one) thin strips of metal, called leaves, arranged on top of each other to form a single curved piece. The bending of the leaves and the friction between them as they slide slightly over each other while bending, absorbs the vehicle's weight as well as any bumps. Most leaf springs are curved these are often called elliptical springs. The curvature helps the spring absorb impact. leaf springs in particular, help perform the first two of these functions: they support the weight of the vehicle while absorbing bumps. A leaf spring is usually attached to the body or frame of the vehicle at each end, while the wheel or axle assembly is fixed to the middle of the spring. Usually

each spring extends in the same direction as the vehicle, one on each side, with attachment points at the front and rear; a few suspension designs feature a single leaf spring attached at each side.

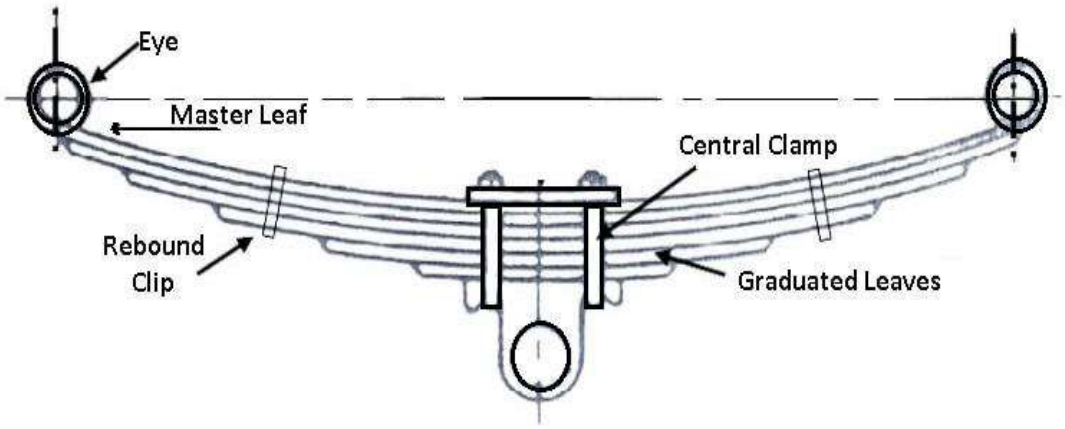

Figure.1 Diagram of the Leaf spring components.

Leaf spring consists of a number of leaves, made of steel plates, of increasing lengths from the centre. All the leaves are clamped by a centre bolt at the centre and side almost at the sides so that the leaves are in position. The main leaf is the longer one having bent ends, called the spring eyes. The spring eye is connected to the frame by a shackle. The centre portion of the spring is connected to the front axle by U-bolt.

Types of Leaf springs:-

1. Semi-elliptical spring
2. Quarter-elliptical spring
3. Three-quarter elliptical spring
4. Transverse spring
5. Full elliptical spring
6. Platform type spring

1. **Semi-elliptical spring:** The Semi-elliptical springs are usually used in all the vehicle. Particularly in trucks, semi-elliptical springs are fitted in front and rear axles. But in cars, they are fitted on the rear axle only and the independent suspension is fitted on the front axle. Semi-elliptical springs are cheaper and require less repairing. They increase the range of spring action and last for a long time.
2. **Quarter-elliptical spring:** Quarter-elliptical springs were used in old small cars, like Chrysler cars. This type of spring consists only a quarter portion of the full elliptical spring and fitted with the frame by the bolt.
3. **Three-quarter elliptical spring:** Three quarter elliptical spring is the combination of semi-elliptical and quarter elliptical springs. These types of springs were used in old cars.
4. **Transverse spring:** Transverse spring in just like the semi-elliptical spring but inverted in shape. One end of the spring in joined with chassis frame by shackle, and the other end with the axle. It is also fixed with frame by the bolts at the centre.
5. **Full elliptical spring:** Full elliptical springs are consists of two semi-elliptical springs joined together oppositely. This type of spring was used in old cars. They do not maintain correct axle alignment.

6. **Platform type spring:** Platform type springs consist of two semi-elliptical springs. They are fitted with chassis frame by shackle at one side and the other side is fitted with an inverted semi-elliptical spring. In this arrangement, the weight of the car is divided into three points.

The applications of leaf springs

Leaf springs are relatively simple to make and have been used on carts and carriages since long before cars and trucks came into existence. Many of the first cars, including the Ford Model T, employed leaf springs. Leaf springs are appropriate for spreading heavy loads over a large area (because they are attached to the vehicle at the ends, which may be several feet apart) and for suspension designs that incorporate a "solid" axle rather than independent suspension for each wheel, which was common on cars up through the 1970s and is still the norm on heavy vehicles such as trucks. These factors render leaf springs appropriate for trucks and other heavy vehicles but less so for cars, as such designs tend to have undesirable effects on a vehicle's handling. As independent (as opposed to solid axle) rear suspensions have become increasingly common on cars, leaf springs are now found primarily on trucks and vans.

Literature Review

K.S. Ashraff Ali et al; presents in this research work reveals the modeling and investigation of composite leaf spring delivered utilizing polymers strengthened with glass fiber. The plan and investigation of composite leaf spring created utilizing polymers reinforced with glass fiber. The modeling constraints are strains, stresses and deflection. Measurements of the present standard steel leaf spring of a light commercial vehicle. Using E-Glass/ Epoxy unidirectional covers, indistinguishable measurements from customary leaf spring are used to make a composite multi leaf spring. The 3-D model of traditional leaf spring is also dynamically analyzed using ANSYS 12 Workbench and contrasted with the analytical results [1].

Bathuka Mallesh and Balaji Gupta et al; reported in this assignment we're going to create fallen leave spring for the goods Mild Steel and additionally composite fabric Glass Carbon by means of the use of various support attitudes . A purpose of report is modeling in addition to lay out a leaf spring consistent with the loads carried out. Currently utilized cloth for leaf springtime is solid metal. A fallen depart spring is a fundamental kind of springtime; usually it is most important in the interruption in automobiles. The leaf springs are prolonged and additionally slender sheets related to a framework of teaser enjoyment upper or lower the axle. The single-leaf spring times, or unmarried-leaf springs, it involved to honestly a sheet springtime metal. Those were normally heavy size within center & equal inside a direction of the give up, and they do not typically give an excessive amount of quantity of energy & interruption of lugged motors. The operators are trying the find out to how bigger hundreds usually using the couple of leaf springs; these contain different types of leaf springs of numerous periods advanced in the pinnacle to the particular. A great deal smaller of a fallen leave springtime, in a direction of the lowest it is misting likely to be, presenting it the very same semielliptical kind a solitary fallen go away spring obtains from being thicker inside the center Springs will forestall running from exhaustion due to the duplicated smoothness of spring.The calculating of layout is providing Finite Element Analysis Structural Evaluation was finished at leaf springtime through used to specific substances Mild Steel as well as Glass Carbon. Modal in addition to fatigue Evaluation is likewise done [2].

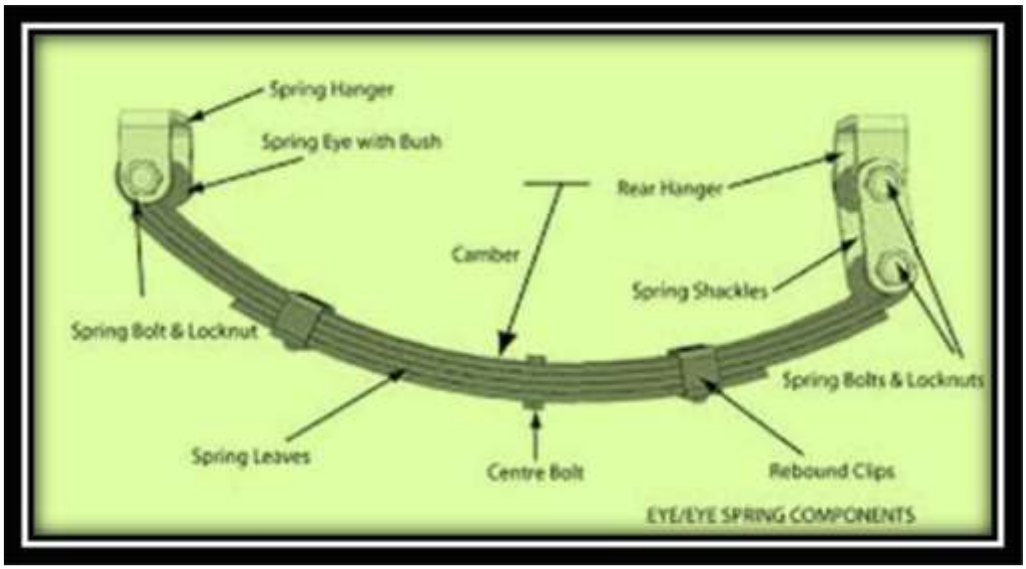

Figure.2 Schematic diagram of the Leaf spring.

K. Krishnamurthy and P. Ravichandran et al; proposed in this work the weight of the leaf spring is reduced by replacing conventional steel material by various composite materials. Its parameters were evaluated experimentally, Using ANSYS. A leaf spring is a type of spring, which is commonly used for suspension system in automobiles. For light commercial vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. The leaf spring is designed using modeling software and FEA is done to find stress and deflection. Values are also compared both experimentally and numerically. From this, it is found that the newly proposed material is more economical and has less weight when compared to conventional material [3].

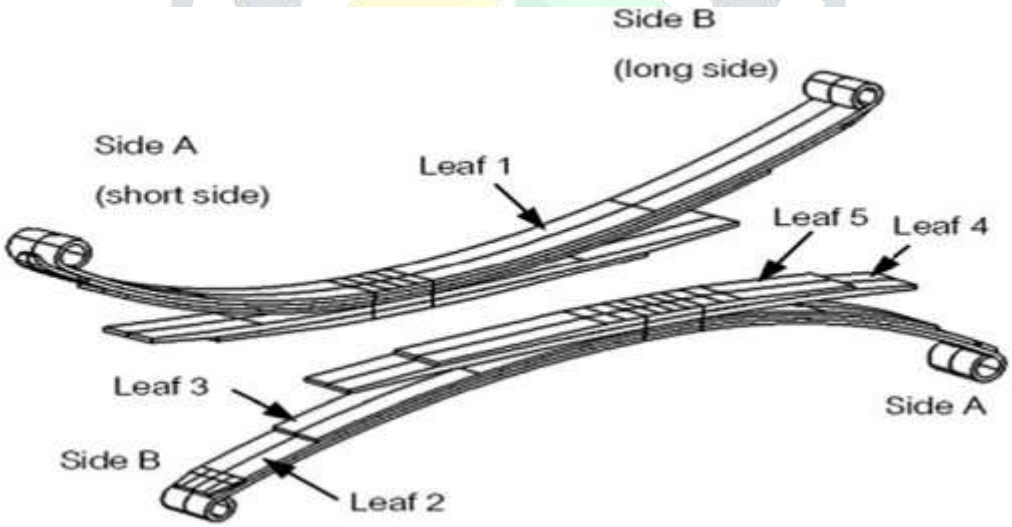

Figure.3. Two Stages of Leaf Spring Design.

Chirag D. Bhatt and Mukesh Nadarajan et al; Proposed the study to analyze the suspension plays most important aspects in heavy automobile vehicles the optimization of suspension, the leaf spring is introduced with new material selections in this paper. Leaf spring is a simple form of spring, it is widely used for the suspension in wheeled vehicles. Leaf spring is long narrow plates attached to the body of the trailer axle. Leaf spring plays major role in automobile industries. Multi leaf spring in Indian Automobile Industries are very large automobile industries in Indian manufacturing companies majorly producing multi leaf spring for heavy load vehicles because this leaf spring it acts

as an energy absorbing material on the virtue of its deflection. In this paper the study includes, the version of leaf spring is created in stable works of different materials FRP, Titanium Alloy, Super Bainite and Structural Steel. The 3D modeling of leaf spring is carried out using SOLIDWORKS 2013 and the analysis is done using ANSYS 17.2 software [4].

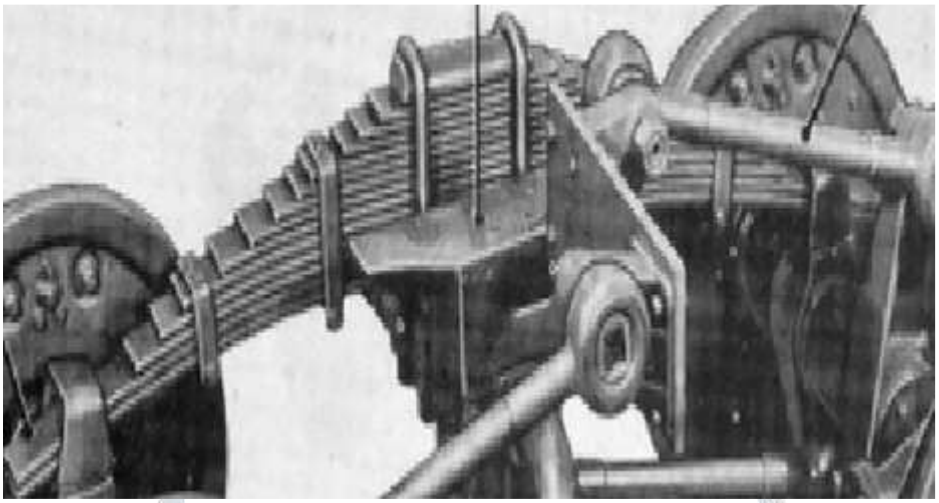

Figure.4. Basic leaf spring model.

Pradip Kumar et al; carried out in this paper analysis is done for leaf spring whose thickness varies from the centre to outer end in parabolic nature followed by mathematical equation of a parabola, hence it is named as parabolic leaf spring (PLS). The modeling and analysis of the leaf spring has done in CATIA V5 R20 and ANSYS 15. The finite element analysis of the leaf spring has been carried out by initially discretising the model and then applying the relevant boundary conditions under the static loading conditions. The results from FEA indicated that the red area close to shackle was undergoing maximum value of stress which may lead to failure of mono parabolic leaf spring. A comparison between the different materials of leaf spring has also been performed to study the influence of mechanical properties of different material of PLS, in order to find out the amount of maximum stress for different material. During the analysis of all the materials boundary condition and applied load are same [5].

Kaul Pulkit solanki and Ajay Kumar Kaviti et al; carried out in this paper we present our work on two types of leaf springs (i.e. Semielliptical and parabolic). The main intention of introducing this paper is to achieve modification in the design. We use input parameters like span length (distance between eyes to eyes), camber length (Arc height at axle seat) and Ratio. The model of leaf spring prepared with the help of ANSYS design modular software and Structural steel and stainless steel were used as a Material. Here in this paper we focused on output results like deflection, stresses, factor of safety in stress and factor of safety in strain term. Over all simulations of semi-elliptical and parabolic leaf springs have been done on ANSYS software and under the application of constant amplitude load. Our work concluded that whenever we change the length of span and camber we found that the semi-elliptical leaf spring produce maximum deflection and maximum stresses than the parabolic leaf spring under the same boundary condition. Our paper gives the detailed information and process with fine results [6].

Temesgen Batu and Hirpa G. Lemu et at; studies in this paper design model of existing master leaf spring has been created and optimized using SolidWorks parametric optimization with a goal of reducing the weight of leaf spring, improving the life span of structure by reducing stress and increasing the natural frequency of the leaf spring. The constraint used was limiting stress and natural frequency with the leaf spring's thickness and width as optimization variables. Optimum values of these parameters of the leaf spring were obtained. Again, using parametrically optimized

leaf spring model static and modal analysis was studied under two different composite materials, Epoxy Carbon UD Prepreg and Epoxy E-Glass UD, aiming to get minimum weight and improved life span compared to steel material (55SiMn90). The result shows that the leaf spring of composite materials performed better in terms of the stress level, stiffness and the natural frequency. At the same time, the weight of the composite leaf spring has significantly reduced. In summary, the study concluded that composite leaf spring is better efficient compared with conventional leaf spring from steel [7].

Y.S. Kong and S. Abdullah et al; presented in this paper analyzing the forces exerted on the spring eye are simulated under extreme load cases, such as braking, cornering, and pothole striking.This paper analyzes the capability of various leaf spring eye designs to prevent failure under braking, cornering, and pothole striking loading conditions. A leaf spring is a vital suspension component of heavy trucks, such that the failure of leaf spring eyes could cause fatal accidents.The magnitudes of the different loadings were extracted from a multibody dynamics model and were used as the load inputs to the finite element explicit simulation. The principal surface stresses of four different spring eye designs were obtained and compared to the material yield and the ultimate tensile strengths to evaluate the sustainability of the spring eye during extremeload cases. Results show that a minimum thickness of 17 mm is sufficient for the leaf spring eye design to prevent failure under extreme torsional loadings. This research provides insightful analysis of leaf springs to prevent the occurrence of failure during engineering design [8].

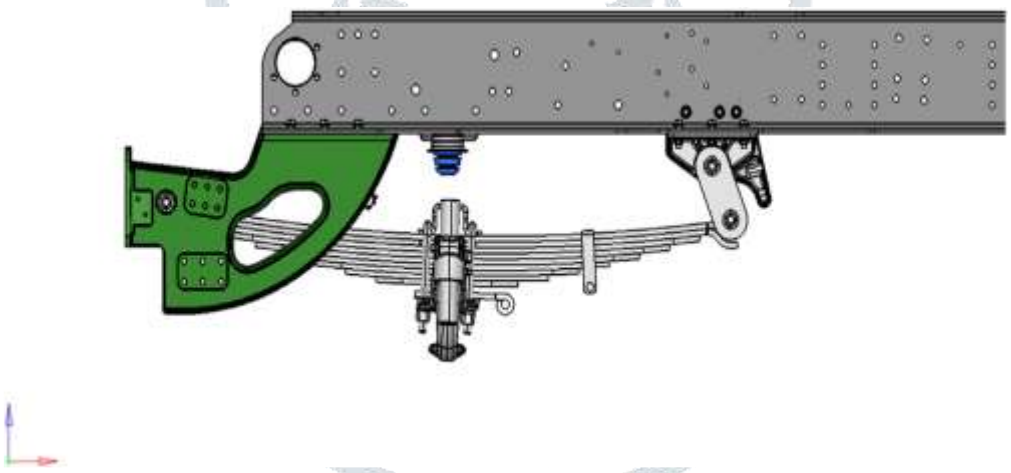

Figure. 5 Suspension leaf spring configuration of the truck.

Michail Malikoutsakis et al; In this study carried out The present paper presents the design and optimization procedure for parabolic leaf springs for truck axle payloads of 7.5 and 8.0 tons. The requirements to be met in such a process cover the kinematic behavior of the spring (the conformation of the trajectory of the wheel joint connected to the spring with the trajectory of the steering arm), the spring rates, as well as strength and, most importantly, durability criteria. Therefore, a multi-disciplinary optimization has been performed aiming at the fine tuning between the vehicle's wheel joint kinematics, the leaf stress response and damage for certain multiaxial load spectra. Optimized kinematics have been calculated using proper design parameters. The springs' durability has been theoretically assessed based on (a) FEM-calculated stresses at pure vertical loading and braking events, which have been identified to cause the highest stresses in operation, and (b) analytical damage calculations for certain multiaxial load sequences based on the Miner's elementary linear damage accumulation rule. The vehicle's kinematics behaviour has been verified experimentally by driving prototypes at test tracks. Straight-driving, cornering, comfort and steering behaviour have been quantitatively evaluated by 7 different expert drivers. The developed springs were found to

perform equivalently to (in case of the 8.0to spring) or significantly better (in case of the 7.5to spring) than the respective serial springs [9].

CONCLUSION

On the basis of previous research study, this study review outline involves the proposed work for the weight of the leaf spring is reduced by replacing conventional steel material by various composite materials to reduce the time and the cost of the development procedure of a new designed leaf spring. The most efficient way to reach this goal is to correlate the results of the testing and simulation. The leaf spring under static load condition is studied and results like stresses and deflection are obtained with the help of its parameters were evaluated Using ANSYS. The leaf spring is designed using modeling software and finite element analysis (FEA) is done to find stress and deflection, so that, it would be possible to release new designs mostly depending on the simulation which is the fastest and the reasonable way to reach a final evaluation. A new designed leaf spring, with two leaves, is simulated in finite element analysis (FEA) with the loads from multi body simulations in order to reach a fatigue life assessment is tested in the test bench with the pre-defined loads from the rough road is mounted to a complete truck structure to run a full rough road truck program to reach the final evaluation. In this paper, these three durability assessment techniques are compared and correlated with each other as a main scope.The structure of the test bench and the procedure of the rough road testing are given in details. From this, it is found that the newly proposed material is more economical and has less weight when compared to conventional material. Hence the effective design of leaf spring along with the suitable material is made and various analysis are done for the effective results. The further research can be gone in this direction.

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