A Review on Composite Materials of Leaf Spring for the Weight Optimization

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Abstract - The leaf spring is a common automotive component and the main part of the suspension system. The spring is prepared to experience jerks and vibrations when moving over rough surfaces. Given that the suspension leaf spring makes up between 10 and 20 per cent of the unsprung weight of a car, it is an attractive target for weight reduction in automobiles. The weight reduction benefits are to increase fuel efficiency and improve riding quality. A review of the literature on composite leaf spring materials has been done in order to determine how they affect the way that they function.

***Key Words*:** Composite materials, Glass Fiber, Carbon Fiber, Static analysis, Weight optimization, Leaf Spring.

1. INTRODUCTION

The leaf spring suspension system are considered to be one of the oldest designs. Spring is characterized as an elastic object whose purpose is to deform under the influence of an external load and restore its initial form once the load is eliminated. By utilizing spring deflections, leaf springs absorb the vehicle's shocks, impact loads, and vibrations. Potential energy is stored in the leaf spring before being gradually released. [1]. It was invented in the 18th century. The leaf spring is made up of several leaves, or blades. Although the blades often vary in length, they are all the same length in this instance. The graded leaves are the blades below the master leaf, which is the longest blade and has eyes on its ends. It has been used sizably in both passenger cars and trucks due to its high stiffness, strength, and load-carrying ability. In addition to transverse, full, and platform-type springs, there are also semi-elliptical, quarter-elliptical, three-quarters elliptical, and other forms of leaf springs.

The leaf spring structure is shown in the figure, it has two U-bolts and a central clamp or central pin which are used to hold the leaves together. Additionally, rebound clips serve the purpose of maintaining the alignment of the leaves and preventing lateral shifting of the plates during operation [2].

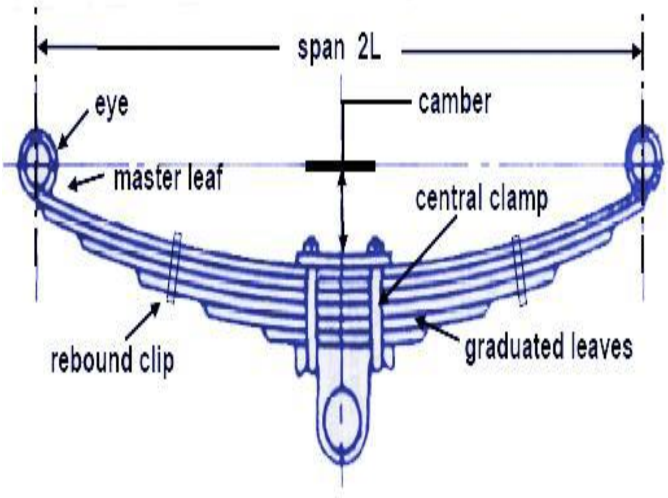

Fig.1 Dimensions of Leaf Spring [1]

The automobile's axle contains a spring that is ascending. The spring's front end is coupled to the structure through a pin connection, while the spring's back end is joined using a shackle. The rear eye and body of the leaf spring are linked together via a shackle. A flexible link serves as a shackle. The wheel shakes as a result of the automobile reaching a point on the road, which causes the spring to deflect. This alters the length between the spring eyes [2]. The spring cannot adjust this modification in length as both of its ends are stationary. Consequently, a flexible attachment is provided at the end of each shackle which has been designed to accommodate this variation in length. The leaf spring's front eye is restricted in every orientation, but its unusual rear eye linked to the shackle has no limitations throughout the X-direction. The spring experiences deflection and displacement when the load is applied, moving in a direction at right angles to the force.

Composite Material

A composite material consists more than one material, each of which has unique features. Composite materials are utilized in industries like aerospace, automotive, and many others. Composite materials are made of two or more constituents that combine to form a single unit. The mechanical and chemical bond is used for combination. Each constitutes has its significance and characteristic.

Composites can be employed to form more robust configurations than their non-composite companion at comparable expenditure due to their intrinsic strength-to-weight ratio. A leaf spring that is manufactured using composite material can be an option for the traditional steel leaf spring. Composite leaf springs have several advantages over steel leaf springs, like as lightweight, strong materials, high stiffness-weight ratio, flexibility, etc. Composite materials are produced in different shapes such as flat or round bars with different cross sections including circular shapes with rounded corners or square bars with sharp edges. So, they can be applied to automotive applications.

The price of production of composite material leaf springs is substantially lower in comparison to steel and other materials. It furnishes weight reduction, high stiffness, as well as strength at a minimum price. The primary justification for the composite material is that you can use a considerable number of composite materials of the exact length without altering their weight or stiffness which would influence the cost of production.

The second benefit of composite is that when compared with different materials like steel, it does not require any remarkable maintenance during the manufacturing procedure so there is no possibility of deteriorating due to exposure to the transportation or storage period, etc., which helps us to lower maintenance cost.

There are two types of composite material:

I. Matrix type
II. Reinforcement type
   - Aramid Fiber
   - Glass Fiber
   - Natural Fiber
   - Carbon Fiber

2. LITERATURE REVIEW

Numerous research publications on the examination and optimization of leaf springs have been released. An overview of a few identified exploration studies on this work is then provided in this section:

1. A study by Trivedi Achyut and Bhoraniya R.M. compared the weight savings and load-enhancing capabilities of composite leaf springs to conventional ones [3]. The measurement of an original steel leaf spring is used for lightweight design estimations. Using analytical commercial software, static analysis is performed on a 3D model of a typical leaf spring. The exact same measurements are also used to make composite multi-leaf springs from composite materials such as graphite and carbon fiber. Stress, weight, and the distortion of composite leaf springs in comparison to conventional leaf springs are impediments Static analysis is carried out for static conditions, whereas dynamic analysis is utilized for a real-time situation. After comparing leaf springs with composite leaf springs, it exhibits that composite leaf springs have a high strength to weight ratio, nearly 400% less weight than traditional leaf spring. Model analysis of this work state that composite leaf spring is safe because it doesn’t show a resonance effect
2. Amrut Rao, R Reji Kumar, and Achamyeleh Kassie collaborate to reduce vehicle weight by 68.14% while preserving or improving component strength [4]. The leaf spring, a significant contributor to vehicle weight, needs to be robust enough. By considering only static loading, he applied the design principles of composite materials to create a sole leaf spring using E-glass. This particular design is primarily intended for lightweight cars. Leaf springs cross-sectional design is used to streamline the manufacturing process and design analysis. The outcome shows that design stresses below the material's strength properties comply with the maximum stress defect norm.
3. S-glass/epoxy, E-glass/epoxy, and carbon/epoxy are three distinct composite materials applied to create a laminated composite mono-leaf spring-examined by M. Raghavendra, K. Palani Kumar, Syed A. Hussain and V. Pandurang [5]. These composite materials are loaded at a rate equivalent to that of a steel leaf spring. The deflections and stresses are design discretions in the investigation. The three separate composite mono-leaf springs were created by assuming an invariant cross-section with a unidirectional fiber exposing angle for each lamina of a laminate. ANSYS 10.0 is used to do a static analysis. The laminated composite mono leaf spring outperformed the mono steel leaf spring in terms of stress reduction (47%), stiffness increase (25–65%), frequency increase (27–67%), and weight reduction (73–80%). Additionally, the actual evidence suggests that the laminated composite leaf spring is lightweight and more affordable.
4. By using composite materials, Vasan, T. & Shibi, S.M. & Tamilselvan, C.K. attempt to lighten leaf springs. Materials like aramid fibers, epoxy resin, carbon, and glass were utilized in the experiment. [6]. By employing the Manual layup method, the different samples were prepared and these samples take for three tests i.e., Flexural, tensile, and Impact tests. The stress distribution and deformation are obtained by deeming interleaf contact. The research paper offers a single-leaf spring as a case study to compare the performance of GFRP and steel leaf springs. According to the study's findings, the composite spring has lower stresses and is lighter, which contributes to reducing the dead weight of automobiles
5. Through static and dynamic analysis of three models, Basavaraj Kabanur and Prof. P.S. Patil compare a novel leaf spring model to a traditional elliptical leaf spring. [7]. The study aims

to reduce the frictional stress produced between the leaves by modifying the traditional leaf spring design. The study involved creating three distinct leaf spring designs: Model 1, which was the standard leaf spring, Model 2, featuring a leaf spring with a variable radius of curvature, and Model 3, having a U-shaped bend at the centre. The study found that Models 2 and 3 exhibited minimum frictional stress due to a reduction in the contact area between the leaves, resulting in improved riding comfort and increased strain energy when compared to the standard leaf spring, i.e., Model 1

6. The performance of steel EN45 leaf springs and those composed of composite materials such as isotropic aluminium 6061, carbon epoxy, and Kevlar is being compared in a study by Noronha, B., Yesudas, S., and Chacko. [8]. The deformation, load-bearing capacity, stresses, weight reduction, strain energy-storing capacity, natural frequencies, fatigue life, resistance to corrosion and affordability of the various materials were calculated using static and dynamic analysis. The usage of Kevlar/epoxy in leaf springs leads to a weight reduction of 82.14%, which lowers the vehicle's unsprung mass and improves the ride, handling, and mechanical effectiveness. Kevlar has a longer life cycle than any other material because of its exceptional material qualities. In summary, composite leaf springs made of Kevlar/epoxy outperform steel EN45 leaf springs in terms of all properties mentioned earlier like load-carrying capacity, deformation, weight reduction etc. Thus, it is recommended to utilize Kevlar/epoxy in leaf springs to enhance vehicle performance
7. A carbon/epoxy composite leaf spring is employed to change the typical steel leaf spring of a light commercial vehicle in a study by Mayur H. Karpe, Shubham P. Korde, Tushr S. Shinde, and Surekha S. Sangale. [9]. The composite leaf spring will have the alike size as the typical leaf spring. This study compares the steel leaf spring and composite leaf spring in terms of their weight savings, load-carrying capability, stresses, deformation, and other factors. The purpose of this study is to lessen deformation and stress in a carbon/epoxy leaf spring relative to a conventional leaf spring. This design enables the substitution of conventional steel leaf springs with composite mono leaf springs, which offer a better ride quality because analysis demonstrates that the composite mono leaf spring exhibits a decrease in deflection and stress during bending than the usual steel leaf spring for the equivalent load-carrying abilities. Additionally, substituting composite mono-leaf springs for steel leaf springs, this replacement reduces the weight of the suspension system.
8. A comparison study of the various materials used in parabolic leaf springs (PLS) was undertaken by Edward Nikhil Karlus, Rakesh L. Himte, and Ram Krishna Rathore [10]. Based on their research, it is possible to lower the stress generated in the leaf spring by substituting 55Si2Mn90 steel with a composite material. Additionally, they believe that this swap will increase spring comfort and concentrate the leaf spring's overall deflection. The weight is another important factor that is greatly reduced in carbon-epoxy composite leaf springs, improving the design of the leaf spring material. Compared to typical spring, the composite material makes up 80% of the total weight. It follows that carbon composites are appropriate for leaf springs in lightweight automobiles because they satisfy the requisite standards while obtaining a significant weight reduction. Additionally, because they are lighter and under less stress than steel leaf springs, also they have a longer fatigue life than steel leaf springs, which supports the idea that the newly proposed composite material is possibly employed to create lightweight suspension systems with better ride quality and fatigue life.
9. The study's goal was to replace a multi leaf steel spring in an LCV with a composite mono leaf spring in order to increase carrying capacity and stiffness while adhering to design restrictions regarding limiting stresses and displacement, according to Gulshad Karim Pathan, Prof. R.K. Kawade, and Prof. N. Jamadar [11]. Analysis and modelling of the steel and composite leaf springs were done by ANSYS 14.5 to achieve this. The results of the analysis indicated that the composite material spring could replace the TATA ACE leaf spring without compromising its strength. This is because the composite spring was designed to have equal stiffness as the steel leaf spring and was capable of withstanding the static load. However, one of the major drawbacks of the composite spring was its susceptibility to chipping. Despite this drawback, replacing the steel leaf spring with the composite leaf spring could reduce the weight of the leaf spring by approximately 50%, which significantly reduces the unsprung mass. This is a desirable objective and makes the composite leaf spring a viable alternative to the conventional steel leaf spring for applications that require similar design specifications
10. In their work, Kabariya Kanubhaii and Shyam Gupta, use 65si7 material to replace the rectangular steel leaf spring in a lightweight commercial automobiles cross-section with one that has a trapezoidal shape per leaf and an overall trapezoidal cross-section [12]. Various materials were used for both the trapezoidal cross-section per leaf and the trapezoidal cross-section, and their performance was compared. PRO-E was utilized to model the leaf spring, and ANSYS 14.5 was employed for carrying out a finite element analysis on the leaf spring. The output

parameters of this analysis were the maximum Von Misses stress and the maximum displacement. The research findings indicate that utilizing a trapezoidal cross-sectional design per leaf made of steel results in a weight reduction of 7.67%. However, when composite material is utilized, weight is reduced by 11.244%.

3. CONCLUSIONS

Currently, the primary concern within the automotive industry revolves around reducing the weight of vehicles. Consequently, the industry is actively exploring various modifications and implementations to achieve this objective. Among the prospective options for weight reduction in automobiles is the leaf spring. Different composite materials like carbon fiber, Glass fiber, Armide fiber, Kevlar etc. have been utilized separately in the manufacturing of composite leaf springs. Based on the findings, it is evident that there have been numerous research studies conducted on both glass fiber and carbon fiber composite materials. These studies were conducted independently, with a focus on exploring the properties and applications of each material. However, considering the potential advantages that can be gained from combining these materials, it may be beneficial to optimize leaf spring design by using a combination of both glass fiber and carbon fiber composites

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