WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Analysis and Optimization of Steel Leaf Spring Replaced By Composite Leaf Spring

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ABSTRACT

In the look for to care for natural resources and financial energy. Weight decline has been the heart of auto-manufactures and the aerospace industry in the present day. Weight reduce can be archived mostly by introduce better design optimization, better material, and improved manufacturing processes. This approach by introducing composite materials into automobile industries, which has high strength to weight ratio and excellent corrosive resistance, can accomplish the condition. This review paper investigates the use of composite materials in the design of leaf springs for automotive vehicles. The paper emphasizes the correctness of composite materials planned for leaf spring in automobiles and expands a new leaf spring design that optimizes weight decrease and strength. The review provides particularsconcerningbefore efforts perform on the design of leaf springs while outlining the knowledge gap areas. This review originates with an introduction to leaf springs and a short history of their advance. Follow by the properties that construct an outstanding leaf spring, this assist narrow down the information required for additional increase provides that avenues for possible future investigate.

Keywords: Leaf steel, Fibre Glass Epoxy, Fuel efficiency of vehicle

Introduction

Leaf springs are important element in the suspension systems of vehicles with activity value vehicles, trucks, SUVs, and railway carriages. The principle of leaf springs is to divide and keep the vehicle chassis from vibrations that it occurrence as it movements above uneven and bumpy terrain [1]. Additionally, they support in give manage to the wheels all through braking acceleration and common vehicle practised in road undulation [2]. Existing, the automobile and aerospace industries face quickly increasing resistance to development active products [3]. Their search aim at conserve natural income and economizing energy through weight reduction. Weight decrease can be achieve mainly by the beginning of better designs that save on material utilize, improved manufacturing processes and improved materials. Focused by the goal to decrease vehicle weight, interest has been drawn into the development of composite leaf springs, which have a higher strength to weight ratio than the conventional materials on the market. This paper studies assorted composite materials and geometries to recover the top material and geometry that performs improved than several active leaf springs.

Leaf Springs

Leaf springs were initially coined laminated or carriage springs. They are one of the oldest spring designs to ever exist, date back to the 17th century [4] The design of leaf springs is moderately separate in that it does not bring the distinctive helical/ coil shape but quite a thin rectangular cross-section that spans down an arch-shaped length, see figure 1 below.

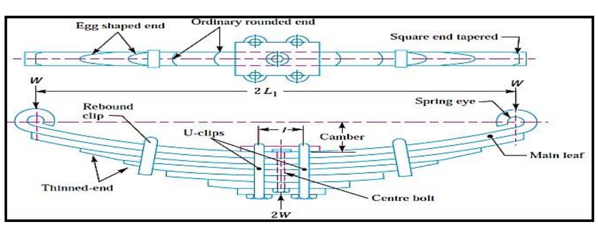

Fig. 1. Leaf springs

To date, a variety of designs of leaf springs have been developed, scope beginning the elliptic design, three-quarter elliptic, quarter-elliptic and transverse, to the added recent designs, like the semi-elliptic, the parabolic leaf spring and ultimately the mono-leaf spring . All these designs had their pros and cons; still, this segment will only divide the modern designs.

2.1 Multi-leaf semi-elliptic

This is the mainly common design in the account of leaf springs. It use some layers of leaves stack jointly, through the longest one on top and gradually shorter leaves next. The longest leaf spring is word the master leaf, looped at both ends to permit for its addition to the chassis. The loops are identified as the eye; following the master leaf, the second leaf is called the second master leaf. The rest of the other leaves are coined accommodate leaves. The leaves are held jointly by what is not as U- clip; this allows for the sharing of stress amongst the leaves and stops other leaves from buckling. This design was beneficial in the sense that it also provides damping action for the vehicle. In addition, interleaf friction reduce the continued oscillation of the car. However, this design had a drawback; the interleaf friction cannot be controlled and would at times result in unwanted place in the motion of the suspension. For this cause, a fresh design was execute, the parabolic leaf spring.

3.Materials

Leaf spring’s material concern is one of the centre areas of hub in this paper. The material use gives the spring its exclusive properties, which are essential, intended for its function. Such properties are greatest tensile strength and smallest amount modulus of elasticity. These properties give, for higher specific strain energy (equation 1) one of the central properties for a leaf spring [13]. $S=1/2\ (\sigma 2\ /\rho E)$ (1) this property means that the spring can stock up more strain energy and keep the chassis from undulations. The review will only centre on composite materials since the growth is base on composite materials

3.1Composite Materials

Composites materials (composites) are shaped by merge two or more materials to form one . The combined materials do not counter but in its place, keep a familiar interface. The growth of these materials is forced by the detail that there is no available homogenous material with the desired characteristics for a given application [15]. For example, fiber materials are used in leaf springs because of the following properties: 1 High strength to weight ratio, 2 Lightweight, 3 Fire Resistance, 4 Chemical and weathering resistance, 5 Design Flexibility, and 6, Manufacturing Economy. Additionally, composite has superior fatigue properties [13], they are even used to repair metallic frames with fatigue damage [14]. In as much as composites are valuable, they have limits that consist of high raw material costs and frequently high fabrication and assembly costs. Still, the benefits that composites present are distant better than their deficit.

4 Review of past studies based on the analyses of different leaf spring designs

In one of the newstudycomplete by Mahanthi and Murali , they made a comparative study between eight materials, four alloys and four composite materials to make sure which of the eight materials carry outimproved when it come to strength to weight ratio. Mahanthi and Murali used Computer Aided Three-Dimensional Interactive Application (CATDIA) to develop similar 3D models for each material and did the analyses using ANSYS's finite element analysis submission. The study they made concernedbe relevant loads from 1000N to 4000N. Each material was bare to these four loads and total deformation and equivalent stresses were noted. Based on the results of static analyses of both steel and composite leaf springs like EN47, KEVLAR, S-Glass Epoxy & E-Glass Epoxy, the conclusion they 3 MATEC Web of Conferences 347, 00031 (2021) SACAM2020 https://doi.org/10.1051/matecconf/202134700031 drew was that Kevlar (composite material) do best since it had the smallest amount weight and perform improved in terms of strain energy, total deformation and equivalent stress. In another study conduct by Prakash [17] in 2017, he limited his analysis to only two materials, steel 65Si7 representing the alloys and E-glass/Epoxy representing the composite materials. Prakash's design imperatives were stresses and deflections, again like Mahanthi and Murali. He did not build the designs but used CATIA (Computer Aided Three-dimensional Interactive Application) to model designs and ANSYS finite constituent analysis to carry out static analysis on the models. The investigation finished that steel leaf springs are approximately 70% heavier than composite leaf springs and that they are they are muh more resilient to stressors than steel springs of the equal design. Another significant outcome drawn from Prakash's investigation is that composite materials are 5 times more durable than conventional steel springs. In the paper "design and analysis of composite leaf springs" by Pinaknath [18], he investigates the effectiveness of composites leaf springs limiting his materials to only two, E glass /Epoxy (GFRP) for composites and 65Si7 steel for alloys just like Prakash [17]. He made the E-Glass/Epoxy design into a three-layered structure and performed both static and dynamic analyses on the models. He then evaluates his judgmentbeside the conventional leaf spring design. The results obtained concluded that composite materials are much stronger as they have less stress and a deflection when bare to loads, the material also possesses useful specific strain energy. Pinaknath also observes that composite materials are 67.88% lighter in weight than steel leaf springs and are an sufficient substitute for both stiffness and stress. alike to the study approved by Pinaknath, Vivek Rai [19] in the paper he in print on the development of composite leaf springs for lightweight commercial vehicles, in place of 65Si7 steel like Pinaknath he uses, EN47 steel. He also used dissimilar software to behavior his study, Pro-E wildfire 4.0 for 3D modeling and ANSYS for static analyses. Vivek's object was to restore the multi-leaf steel spring with a mono composite leaf spring for the similar load carrying ability and stiffness. To perform this, he evaluates EN 47 steel and composite materials (not specified). The finite element analysis results obtained are shown in Table 2 below.

Table 1. Finite element analysis results [19]

Parameter EN47 Composite	**Parameter EN47 Composite**	**Parameter EN47 Composite**
Load (N)	**2445**	**2445**
Max stress (MPa)	**738**	**569**
Max Deformation (mm)	**23.4**	**22.6**
FoS	**1.14**	**1.52**

First by numerical simulation then followed by an experimental test. The materials investigated were the glass fiber reinforcement with epoxy From the results he obtained in table 2, Vivek concluded that transitioning from conventional steel springs to composite leaf springs was necessary. It is clear from the table that the yield stress and deformation of composite material have no significant difference from that of steel but, the use of composites contributes to a considerable reduction in vehicles weight; the benefits of the composite leaf springs outweigh its shortfalls. Three years later, after Vivek's study, et al. [20] published a review on the design of composite leaf springs for railway vehicles; their focus was to design and optimize the Railway leaf springs done resin for composite materials. The material was modeled into the same shape and size as that of a conventional leaf spring.

Four years ahead of the work published by Sedlacek et al., Venkatesan and Devaraj [21] conduct a similar study with additional specified elements. The study focused on the materials in contrast study, which focused on geometry instead. The investigation ofVenkatesan and Devaraj compared leaf springs made from steel with 0.9 to 1% carbon to those made from a composite material made from Glass/Epoxy reinforcements. Their study more examines the effect of shape, using uniform cross-section leaf springs and those that are non-uniform (thicken as they approach the middle). The investigation was done by means of simulative software, 3D modeller for 3D drawing and ANSYS 10.0 for the finite element analyses.Venkatesan and Devaraj drew two finishes from their study; 1) the geometry of the leaf springs plays a significant role; it affects the performance of the leaf spring.

Composite leaf springs with a thicker centre outperformed the ones with a uniform cross-section for strength.2) From the comparative study they carried out between composite and steel leaf springs concerning weight and strength, it was experiential that composite leaf springs are much lighter and have greater strength to weight ratio than steel leaf springs. Another similar study was approved out by Saini et al. [23] in 2013; their objective was to evaluate the stresses and weight-saving capabilities of three composite leaf springs made from different materials against steel made leaf springs. Saini et al. used Auto-CAD 2012 for 3D modelling, and the statistical analysis (stress and deformation) was done using ANSYS 9.0 software. The record of the materials and their presentation are listed in the table below

Table 2. [23]. Displacements and Von Misses stresses for the same loading conditions

Materials	**Displacements (mm)**	**Stress (MPa)**
Steel	**10.16**	**453.92**
Graphic epoxy	**15.75**	**653.68**
Carbon epoxy	**16.21**	**300.3**
E-glass epoxy	**15.89**	**163.22**

starting the results get from their study, only graphite-epoxy has higher Von-Misesstresses than steel, sense only graphite-epoxy can put back steel from the stress stiffness point of view. A comparative study was also complete on the strength to weight ratio. The results they obtained are listed in the table below.

Table 3. % saving of weight by using composites instead of steel [23].

Sr.No	**Materials**	**% Weight saving**
1	**Steel**	-

2	**Graphic epoxy**	**81.72**
3	**Carbon epoxy**	**90.51**
4	**E-glass epoxy**	**91.91**

Table 4 illustrate the percentage weight-saving deliberate against steel. Using either E-glass epoxy or Carbon epoxy of Graphite epoxy, there is 81.72, 90.51, 91.91 cuts in weight, in that order. The conclusion drawn from their results was that composite materials perform improved when weight decrease is considered than steel, with graphite-epoxy having the highest Performance. The above review covered the comparison of materials between composite materials and conventional steel materials extensively for leaf springs. The following reviews take a unique route. First, Papacz et al. [24] studied the aptitude of composite leaf springs to suppress vibrations. Amplitude and reactions of props were measured and recorded. Using these parameters, intended the coefficients of vibration for composite leaf springs and steel leaf springs. From the analyses they complete, they finished that leaf springs

made from composite materials have a more remarkable ability to suppress vibrations than steel springs. They also figured that composite materials are more comfortable to shape into any geometry and can be made into shapes with higher vibration suppression capabilities. one more exclusive approach was taken by Sam Varghese et al. They discussed the effects of shapes in the performance of leaf springs. They modelled two composite leaf springs made of glass fiber and with a polymer matrix, which was rectangular shaped (conventional); the other was trapezoidal. 3D models were drawn using solid works software, and the finite Element one analysis was done using ANSYS 16.0.

Table 5 shows the results of the investigation.

Cases	**Deformation(m)**	**Equivalent Stress (Pa)**
Conventional steel leaf spring	**0.0004301**	**1.6757 × 10**
E-glass/Epoxy leaf spring	**0.0023004**	\ **1.3896 × 10 8**

Conclusion

A significant review of the growth of composite leaf springs has been obtainable. The review in the end bring to a close that composites are a appropriate substitute for conventional steel. This is since of the single properties those composites possess. The review has also exposed ways to assess the performance of leaf springs both experimental and computational ones. The review, however, is subject to limitations in that, most of the work presented focused on computational analysis and less on experimental analysis. Grandson argue that simulations do not exactly simulate real-life events as a great deal as they are necessary and precise. Real-life experiments must be approved out to verify the results obtain by the simulation. Though, there were other unique approaches, one carried out by Frankovský, where they investigate the vibration suppression capabilities of composite materials in comparison to other materials. This study calls for the investigation of shapes and the leaf springs' material properties, which is a single approach to what most researchers are focusing on. Additionally, the review did not discuss much the vibration absorption properties of the springs an effect directly affected by specific strain energy of the material. This calls for further work to be carried out on the shape and other composite material compositions. The simplify establish in this review makes most of the work subject to limits, for example, studying one composite material and making conclusion based on the assumption that all composite materials are the similar. This study aims to contribute to this rising area of investigate by discover these gaps.

- The presentation of other composite materials, since there is diversity.
- The study of different shapes of leaf springs and appear into their performances
- (Optimization).
- Study the vibration amalgamation means of the leaf spring specifically focusing on strain energy for both dynamic loads and statistical loads.

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