INVESTIGATION OF JUTE GLASS EPOXY LEAF SPRING EXPERIMENTALLY

Neelam Singh Rajput¹, Kashinath H. Munde²
¹PG Scholar, ²Associate Professor, Department of Mechanical Engineering
ABMSP’s Anantrao Pawar College of Engineering & Research, Pune, Maharashtra, India

ABSTRACT
The suspension leaf spring is one of the potential items for weight reduction in automobiles unsprung weight. The main aim of our project is to study and analyses the leaf spring of Bolero Vehicle which is made up of Steel and combination of Jute and glass epoxy material. Moreover, up to date there is no study carried out on the characterization of glass–jute fiber reinforced sandwich composites laminates with hand layup method. In leaf spring specific weight and specific stiffness ratios must be high so that material selection becomes vital problem. The 3 D model of leaf spring was drawn with the help of CATIA software. The analysis will be performed in ANSYS software with ACP tool post module to determine stress at each layer by selection of different layers. Prototype of Jute Glass Epoxy is being tested on UTM and with the help of FFT Analyzer.

Keywords—ACP tool post, Jute glass epoxy composite material, UTM, Composite leaf spring, FFT

I. INTRODUCTION
A leaf spring is a long, level, flimsy, and adaptable bit of spring steel or composite material that opposes twisting. The fundamental standards of leaf spring structure and get together are moderately basic, and leaves have been utilized in different limits since medieval occasions. Most substantial vehicles today utilize two arrangements of leaf springs per strong hub, mounted oppositely to the hub and supporting the vehicle's weight. This framework necessitates that each leaf set go about as both a spring and an on a level plane stable connection. Since leaf sets need inflexibility, such a double job is just appropriate for applications where load-bearing capacity is a higher priority than exactness in suspension reaction. More established cross over leaf spring courses of action mounted the solitary leaf set running corresponding to a live hub, yet utilized it both as a suspension interface and a spring component along these lines to the conventional plan. In vehicles with autonomous suspension and a cross over leaf spring course of action the leaf isn't utilized to control the wheel's area and acts just as a spring component. In this plan twofold wishbones act to find the wheel, while a solitary leaf or leaf set associated with the front or back sub-outline in the vehicle and the lower wishbone on each side gives...
the spring component. In certain applications two cross over leaf springs are utilized on a solitary hub with each giving separate springing activity to each wheel. In the past most cross over leaf springs courses of action utilized various steel components in a set like their customary longitudinal partners, yet most current applications utilize a composite (for the most part fiberglass) mono leaf component. In the current circumstance, to smooth out the utilization of vitality, weight decline got one of the basic central purposes of vehicle creators. Weight abatement can be cultivated by the introduction of better material. Leaf springs are generally used in suspension structures to hold paralyze stacks in vehicles like light motor vehicles, no-nonsense trucks and in rail systems. They pass on sidelong loads, brake force, driving force despite stagger holding. Leaf springs are having a favored position that the pieces of the deals may be guided along an unquestionable route as it evades. The use of composite materials for suspension leaf spring reduces the weight of common multi leaf steel leaf spring by practically 75%. A material with most prominent quality and least modulus of adaptability the longitudinal way is the most sensible material for a leaf spring. The composite materials have progressively adaptable strain vitality amassing limit, extraordinary disintegration check, high solidarity to weight extent as differentiated and those of steel. The leaf springs are continuously impacted in view of weariness loads, as they are a bit of the unstrung mass of the vehicle. The basic objective is to investigate their heap passing on cutoff, strength and weight venture assets of composite leaf spring. Weight decline is as of now the basic issue in vehicle adventures. Weight diminishing can be practiced essentially by the introduction of better material, plan progression and better collecting structures. The vehicle business has shown extended eagerness for the replacing of steel spring with fiberglass composite leaf spring in view of high solidarity to weight extent. The introduction of FRP material has made it possible to diminish the greatness of spring with no lessening on load passing on limit. Henceforth the purpose of this endeavor is to plan and production an absolute mono composite leaf spring.

Shishay Gebremeskel et al. [1] in this diary it presents leaf spring amazing proportion of weight to the vehicle and ought to be adequate, a singular E-glass/Epoxy leaf spring is arranged and reproduced keeping the structure rules of the composite materials considering static stacking. This particular setup is made expressly for light weight three-wheeler vehicles. As decreasing weight and extending nature of things are high exploration demands on the planet, composite materials are finding the opportunity to be adequate of satisfying these solicitations. As leaf spring contributes noteworthy proportion of weight to the vehicle and necessities to be adequate. Additionally, it is shown that the coming about arrangement and stresses are a great deal underneath the quality properties of the material satisfying the most extraordinary weight disappointment standard. It has achieved a good exhaustion life of 221.16*10^3 cycles.

Fig.1 A traditional leaf spring arrangement
Originally called laminated or carriage spring, a leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. It is one of the oldest forms of springing, dating back to medieval times.

Mayur Teli et al. [2] in this article present exploration on glass fiber to look at the use of leaf spring for weight reduction in electric vehicle. Weight advancement of 67.70% for GFRP is found interestingly with EN 46 material. For redirection 3.93%, for firmness 4.06%, for vitality acclimatized 3.94% and for ordinary recurrence is 5.25% qualification. The part regards from test meet with need of BS 970:1991 standard Grade EN 46. 3-point pressure procedure is used on UTM with consistence to ASTM D790-03 norm for composite material. Trial and FEA result are taken a gander at for endorsement of this examination. It is presumed that % qualification in values for redirection 3.93%, for firmness 4.06%, for vitality ingested 3.94% and for ordinary recurrence is 5.25%, which are adequate characteristics. Weight differentiate between EN 46 leaf spring and GFRP leaf spring is 67.70%. From above centers, it is found that Glass Fiber Reinforced Plastic (GFRP) leaf spring is better material and reasonable trade instead of EN 46 for electric vehicle with plenitude battery weight for static conditions.

Malaga Kumar et al. [3] in this examination it presents the replacement of multi-leaf steel spring with mono composite leaf spring. As the leaf spring is even about the rotate, simply half bit of the spring is exhibited by thinking about it as a cantilever column. The cutoff conditions are UY, UZ at the front eye end and UX, UZ in the middle. A heap of 3300N was applied at the base in the leaf spring in the Y-heading. From the static assessment results it is found that there is a most outrageous misshapening of 92.591mm in the steel leaf spring and the E-glass/epoxy, graphite/epoxy, and carbon/epoxy are 89.858mm, 80.369mm and 82.662mm and furthermore the von-mises stress in the steel is 596.047MPa. Correspondingly, E-glass/epoxy, Graphite/epoxy and Carbon/epoxy is 475.606MPa, 1556MPa and 1061MPa. The firmness of steel leaf spring is 35.60N/mm and similarly solidness of E-glass/epoxy, graphite/epoxy and carbon/epoxy composite leaf springs are 36.72N/mm, 39.92N/mm and 41.06 N/mm independently. Composite mono leaf spring diminishes the weight by 85% for E-Glass/Epoxy, 94.18% for Graphite/Epoxy, and 92.94 % for Carbon/Epoxy over normal leaf spring.
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M. Raghavendra et al. [4] in this writing it presents structure and assessment of overlaid composite mono leaf spring with three various composite materials to be explicit, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy presented to a comparable burden as that of a steel spring. Appeared differently in relation to mono steel leaf spring the overlaid composite mono leaf spring is found to have 47% lesser tensions, 25%–65% higher solidness, 27%–67% higher recurrence and weight lessening of 73%–80% is cultivated. By using a composite leaf spring for a comparable burden passing on limit, there is a reduction in weight of 73%–80%, trademark recurrence of composite leaf springs is 27%–67% higher than steel leaf spring and 23–65% stiffer than the steel spring. Considering the results, it was understood that carbon/epoxy overlaid composite mono leaf spring has overwhelming quality and solidness and lesser in weight stood out from steel and other composite materials considered in this assessment. From the results, it is seen that the overlaid composite leaf spring is lighter and more functional than the standard steel spring with similar arrangement points of interest.

Pankaj Saini et.al [5] In this paper it presents structure and assessment of composite leaf spring. The material picked was glass fiber fortified polymer (E-glass/epoxy), carbon epoxy and graphite epoxy are used against customary steel. From the static examination results it is found that there is a most outrageous disfigurement of 10.16 mm in the steel leaf spring and the relating migrations in E-glass/epoxy, graphite/epoxy, and carbon/epoxy are 15.mm, 15.75mm and 16.21mm and von-mises in the steel is 453.92 MPa with the von-mises stress in E glass/epoxy, Graphite/epoxy and Carbon/epoxy is 163.22MPa, 653.68 MPa and 300.3 MPa independently. Composite mono leaf spring reduces the weight by 81.22% for E-Glass/Epoxy, 91.95% for Graphite/Epoxy, and 90.51 % for Carbon/Epoxy over standard leaf spring.

Asheesh Kumar et al. [6], in this examination it presents epoxy material and Jute fiber-epoxy composite with hand lay-up methodology. Thus, an open leaf spring made of delicate steel plate has been used. It is revealed that the jute epoxy composite demonstrated better bendable and compressive quality. Pliable and compressive quality augmentations with Jute fiber support. Resulting to investigating the properties of Jute fiber sustained Epoxy composite the going with end is drawn. From the above results, it revealed that the jute epoxy indicated better malleable and compressive quality. Gathering nature of strands reduces with increase in number of filaments in a Bundle. Unbending nature increases with Jute fiber support. Bowing quality augmentations with increase in pace of Jute fiber. Compressive quality augmentations with increase in pace of Jute fiber. Impact quality has no unmistakable change after extension of fiber. These sorts of composites can be significant for advancement reason, portion sheets, divider, floor, window and door frames, housetop tiles, flexible or pre-made structures which can be used amidst normal catastrophes, for instance, floods, rough breezes, tremors, etc.

R. Lalitha Narayana et al. [7], Automobile world has an increased interest in reduction of weight by the replacement of steel by natural fiber reinforced composites. Moreover, the composite materials have more elastic strain energy storage capacity and high strength capacity and high strength to weight ratio compared to steel. Natural fibers are emerging as low cost, lightweight and apparently environmentally superior alternatives to glass fibers in composites. The aim of present work is to compare the Glass-Fiber-Reinforced - Composite (GFRC) leaf spring with a Natural-Fiber-Reinforced Composite/Jute-Fiber – Reinforced – Composite (NFRC/JFRC) leaf spring. Fabrication is carried by hand lay-up technique and tested. The present work carries analytical and simulated results comparison of both types of composite leaf springs. The testing was performed experimentally with the help of Universal Testing Machine (UTM) and by Finite Element Analysis (FEA) using ANSYS. Stresses and Deflection were verified with analytical and experimental results. Compared to the GFRC leaf spring, the NFRC Composite material spring has stresses much lower to steel and the spring weight is also

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reduced nearly to 60-70%. The NFRC leaf spring resulted reduction in deflection and stresses without compromising stiffness as experimentally and analytically.

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I.1 PROBLEM STATEMENT

Nowadays, it is observed that use of composite material in automobile sector is increasing due to its low weight and high strength carrying capacity. In present research combination of natural and synthetic fibre is used to study on existing leaf spring with modification in design and development.

I.2 OBJECTIVES

- Design and development of modified composite material leaf spring in CATIA software.
- To increase the breaking strength of automobile mono leaf spring.
- To understand effect of characterization of glass–jute fiber reinforced sandwich composites laminates using ANSYS
- To determine stresses at each layer using ACP tool post along with deformation.
- To manufacture composite jute glass epoxy leaf spring by hand layup method.
- Experimental testing using three point bent test.
- Validation of experimental and FEA results.

II. COMPOSITES

- COMPOSITE MATERIALS

The choice of the material for leaf springs depends on both engineering design requirements and economies of the application. A study made on JUTE/E-GLASS/EPOXY reveal that the specific stored energy coefficient (SEC), used as design criterion, is advantageous compared to conventional steel leaf springs. Considerations for fatigue of JUTE/E-GLASS/EPOXY can be grouped under the heading of material, processing, and design.
JUTE/E-GLASS/EPOXY leaf springs are generally designed as a mono-leaf beam. The mono-leaf design is possible with JUTE/E-GLASS/EPOXY, since the material can be designed for high strength as well as good deflection characteristics. JUTE/E-GLASS/EPOXY leaf springs are extensively made using of unidirectional glass fiber because of its good combination of mechanical properties and of its low cost. Fatigue characteristics of composites are different from that of metals. For simple tension unidirectional composites, the fatigue limits are generally of higher percentages of tensile strength. Thus the durability of composite leaf spring is superior to that of conventional leaf springs under fatigue loading.

Unlike the conventional multi-leaf springs, the spring’s eyes for composite leaf springs are separately made and joined to the JUTE/E-GLASS/EPOXY leaf spring because of different material are used for spring and eyes. The eyes are made in metal and joined to the composite leaf springs either by adhesive bonding or mechanical fastening. Since the unidirectional JUTE/E-GLASS/EPOXY system is sensitive for fiber discontinuity, the joint design becomes very critical.

Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composites, whereas in alloys, constituent materials are soluble in each other and form a new material which has different properties from their constituents.

II.1 ADVANTAGES OF COMPOSITES OVER THE CONVENTIONAL MATERIALS

- High strength to weight ratio
- High stiffness to weight ratio
- High impact resistance
- Better fatigue resistance
- Improved corrosion resistance
- Good thermal conductivity
- Low coefficient of thermal expansion. As a result, composite structures may exhibit a better dimensional stability over a wide temperature range.

II.2 APPLICATIONS OF COMPOSITES

The common applications of composites are extending day by day. Nowadays they are used in medical applications too. The other fields of applications are,

- Automotive: Leaf springs, Drive shafts, clutch plates, engine blocks, push rods, frames, Valve guides, automotive racing brakes.

III. DESIGN & CALCULATION

- Initially research paper relevant to the topic is gathered and after going through research papers, composite leaf spring is examined.
- A 3-D CAD model will be prepared by studying the conventional design of leaf spring.
- Prepared 3-D model will be transferred to ANSYS software and proper meshing will be created on the model for further analysis.
- To determine stress at each layer will be provided and performed in ANSYS software using ACP tool post.
- A prototype of the model will be manufactured.
- FFT analysis will be performed on the oil damper setup to determine acceleration at respective grade oil.
III.1 CALCULATIONS

Weight of vehicle = 1615 Kg (TATA SUMO)
Maximum load carrying capacity = 535 Kg
Total weight = 1615 + 535 = 2150 Kg
Taking F.S. = 2 and acceleration due to gravity = g = 10 m/s²
Total Weight = W = 2150*2*10 = 43000N
Since the vehicle is 4-wheeler a single leaf spring corresponding to one of the wheels takes up \( \frac{1}{4} \) th of the total weight.
F = 43000/4 = 10750 N
IV. FINITE ELEMENT ANALYSIS

FEA: The finite element analysis (finite element method) is a numerical technique for finding approximate solutions of partial differential equations as well as of integral equations. The solution approach is based on either eliminating the differential equation completely (steady state problems) or rendering the partial differential equation into an approximating system of ordinary differential equations, which are then numerically, integrated using standard techniques such as Euler’s method etc.

In the finite element method, a structure is broken down into many small simple blocks or elements. The behavior of an individual element can be described with a relatively simple set of equations. Just as the set of elements would be joined together to build the whole structure, the equations describing the behaviors of the individual elements are joined into an extremely large set of equations that describe the behavior of the whole structure.

![Geometry](image)

**Fig. 5 Geometry imported in ANSYS**

<table>
<thead>
<tr>
<th>Table 1 Material Properties of glass epoxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<tr>
<td>Property</td>
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<tr>
<td>Density</td>
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<tr>
<td>Orthotropic Elasticity</td>
</tr>
<tr>
<td>Tensile X direction</td>
</tr>
<tr>
<td>Tensile Y direction</td>
</tr>
<tr>
<td>Compressive X direction</td>
</tr>
<tr>
<td>Compressive Y direction</td>
</tr>
<tr>
<td>Shear XZ</td>
</tr>
<tr>
<td>Shear YZ</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2 Material Properties of jute epoxy</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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<tr>
<td>Property</td>
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<tr>
<td>Tensile X direction</td>
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<td>Shear XZ</td>
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<tr>
<td>Shear YZ</td>
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<tr>
<td>Shear KZ</td>
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</tbody>
</table>

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Mesh

ANSYS Meshing is a general-purpose, intelligent, automated high-performance product. It produces the most appropriate mesh for accurate, efficient Multiphysics solutions. In ANSYS after importing geometry in module meshing is performed also known as discretization process. In meshing whole component is breakdown or discretized into small elements to solve finite element equation at nodes. In present hexahedral mesh is used for analysis. A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model.
In boundary condition round eye section is fixed as per existing boundary condition and calculated force is applied at center.
Fig. 10 Equivalent stress for layer 1

Fig. 11 Equivalent stress for layer 6

Fig. 12 Equivalent stress for layer 20
V. PROTOTYPE TESTING

A. Compression Test:
Compression test is one of the simple and fundamental test methods. In order to obtain values of deflection, stiffness and energy absorbed of JGP composite leaf spring prototype experimentally, bend / compression test is carried out. Leaf spring is prepared for the test as per standard. For reinforced plastics 3-point compression test on universal testing machine is conducted with regulation of ASTM D790 standard. As per standard leaf spring is measured for its length end to end and then mounted on universal testing machine at the center in c-channel as per the boundary conditions. Boundary conditions for test: both eye ends of JGP leaf spring prototype are hinged supported i.e. rested on cylindrical support in a c-channel to guide the motion. As per the standard span length is measured and located centrally on UTM as shown in fig. 16. The load is applied gradually with constant speed and at room temperature. The load vs displacement graph is plotted autonomously as observed in graph 2. The load applied on JGP leaf spring is more than the rated load of conventional leaf spring.

Table 3 Compression Test Report

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value</th>
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<tbody>
<tr>
<td>Test</td>
<td>Compression Test</td>
</tr>
<tr>
<td>Method</td>
<td>3-Point Compression</td>
</tr>
<tr>
<td>Standard</td>
<td>ASTM D790 – 03</td>
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<tr>
<td>Specimen</td>
<td>Leaf Spring Assembly</td>
</tr>
<tr>
<td>Material</td>
<td>Glass Fiber Reinforced Plastic</td>
</tr>
<tr>
<td>Load Cell</td>
<td>9800 N (1000 Kg)</td>
</tr>
<tr>
<td>Temperature</td>
<td>25°C</td>
</tr>
<tr>
<td>Speed</td>
<td>10 mm/min</td>
</tr>
<tr>
<td>Peak Compression</td>
<td>22.3 %</td>
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</tbody>
</table>
Fig. 13 JGP Composite Leaf Spring curing on mould set up

Fig. 14 Trimmed final prototype of E-glass/Epoxy composite leaf spring

Fig. 15 Untrimmed E-glass/Epoxy composite leaf spring prototype
B. Vibration Test:
Vibration test is observed by introducing the external force to the object to be tested. Fast Fourier Transform FFT analyzer is used to convert the signal from original time domain to frequency domain. From this conversion the natural frequency of object can be observed and checked to avoid the resonance with system. The value of natural frequency is in compliance with ISO 2631. The test setup is as observed in fig. 8.

Table 4 Vibration Test Report

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Test</td>
<td>Vibration (Natural Frequency)</td>
</tr>
<tr>
<td>Standard</td>
<td>ISO 2631 (For Test Values)</td>
</tr>
<tr>
<td>Specimen</td>
<td>Leaf Spring Assembly</td>
</tr>
<tr>
<td>Material</td>
<td>Glass Fiber Reinforced Plastic</td>
</tr>
<tr>
<td>Temperature</td>
<td>250°C</td>
</tr>
<tr>
<td>Sampling Mode</td>
<td>8 Channel</td>
</tr>
<tr>
<td>First Natural Freq.</td>
<td>36.62 Hz</td>
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</table>
Fig. 17 FFT Analyzer Test Rig

The test process begins with FFT spectrum with 2 channels out of which two are used, one for sensor to capture time domain signal and other for hammer to create minute impact on leaf spring. The composite leaf spring is mounted in between the two-bench vice with the help of cylindrical shaft support so as to create a hinged support boundary condition. The FFT is connected to output screen via USB port and software is installed so as the signals from impact are visualized in real time. A small impact with the use of hammer is created and the vibrations are captured with help of sensor attached on leaf spring. This time domain signal is converted to frequency domain by FFT spectrum and displayed on output screen in the form of force vs frequency graph. The first peak denotes the first natural frequency/mode shape of the leaf spring.
Table 5 Excess Load Condition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>EXP</th>
<th>FEA</th>
<th>Error</th>
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<tr>
<td>Deflection</td>
<td>mm</td>
<td>33.73</td>
<td>35.11</td>
<td>3.93</td>
</tr>
<tr>
<td>Stiffness</td>
<td>N/mm</td>
<td>104.9</td>
<td>100.8</td>
<td>4.06</td>
</tr>
<tr>
<td>Energy absorbed</td>
<td>kJ</td>
<td>59.71</td>
<td>62.16</td>
<td>3.94</td>
</tr>
<tr>
<td>Natural frequency</td>
<td>Hz</td>
<td>36.63</td>
<td>38.66</td>
<td>5.25</td>
</tr>
</tbody>
</table>

From above table the values of deflection, stiffness, energy absorbed and natural frequency are obtained from finite element analysis and experimental testing on glass fiber leaf spring prototype, which has same specifications that of EN 46 leaf spring except for thickness parameter. The percentage error observed for validation between experimental testing and finite element analysis is between 3 to 6% range which is satisfactory value. The values observed in above table are in according to following standards: 1. Deflection- SAE HS 788 2. Stiffness - SAE HS 788 3. Natural frequency – ISO 2631

VI. CONCLUSION

Composite materials are getting to be up to the mark of satisfying these demands. In this project reducing weight of vehicles and increasing the strength of their spare parts is considered. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials. And it is shown that the resulting design and simulation stresses are much below the strength properties of the material satisfying the maximum stress failure criterion. It has achieved an acceptable fatigue life of 221.16*10^3 cycles. This particular design is made specifically for light weight three wheeler vehicles. Its prototype is also produced interested researcher has to go through this project and do the dynamic analysis of the design, since only the static loading case is considered here.

As automobile world demands research of reducing weight and increasing strength of products, composite material should be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a single Jute Glass/Epoxy composite leaf spring is designed and analysed. From static analysis of composite Jute glass fiber mono-leaf spring using FEA, we found that deflection and max. stress in composite mono leaf spring is lesser than conventional leaf spring hence conventional leaf spring can be easily replaced by composite mono leaf spring. In the present work, composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness as that of steel leaf spring.

Jute/E-glass/Epoxy hybrid composite leaf spring is found to be more economical than E-glass/Epoxy composite leaf spring as the cost of jute fiber is very much less as compared to E-glass fiber and it is abundantly available in nature. In present research natural and synthetic material hybrid combination is used to study the effect on existing steel material. It is observed that stress and deformation are very low for existing boundary condition. As reducing weight and increasing strength of products are high research demands in
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