A Review on Design and Optimization of Composite Leaf Spring

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ABSTRACT:
Automobile industry has shown increased interest in the replacement of steel spring with composite one because of high strength to weight ratio. Due to which 50% or more than that weight and cost reduction is achievable. The material of Glass Fiber Reinforced Plastic (GFRP) is suitable for manufacturing of leaf spring. The strength of this composite depends on volume to weight ratio of reinforcement, L/D ratio of fiber, orientation angles etc. The proposed design finds to reduce the weight of vehicle as well useful to reduce the cost. It gives a high level of comfort. Therefore, analysis of the composite material becomes equally important to study the behavior of Composite Leaf Spring. The aim is to review the paper about fabrication and analysis of composite leaf spring.

Keywords: E-glass Epoxy, High Strength to Weight Ratio, Finite element analysis, Weight reduction, Optimum Cost.

I. INTRODUCTION

In order to conserve natural resources and economize energy, the weight reduction and optimum cost is the main focus of automobile manufacturers in the present. Composite materials play an important role in automotive as well as industrial applications. Weight reduction is achieved by the introduction of better material, manufacturing processes and design optimization. The suspension leaf spring is one of the products in which weight reduction is possible. As it accounts 10%-20% of the unsprung weight [1]. This achieves the vehicle with more fuel efficiency as well as improved ride qualities. As the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared to steel, the composite material offer opportunities for substantial weight saving. The paper is focusing on the implementation of composite materials by replacing steel in conventional leaf springs of a suspension system. Composite materials have made it possible to reduce the weight of leaf spring without any reduction in load carrying capacity.

Composite materials are now used extensively in place of metal parts. It can find the application of composite materials in several automobile applications [2, 3]. The automobile-sector is showing an increased interest in the area of composite material-leaf springs due to their high strength to weight ratio [2]. Therefore analysis of composite material leaf springs has become essential in showing the comparative results with conventional leaf springs [4]. Dara Ashok, et al, In his work they give the information about design and structural analysis of composite leaf spring made of glass fiber reinforced polymer (GFRP) [1]. Sachin Kr, et al, in the work a general study on the design, analysis and fabrication of composite leaf spring is done. They reviewed some papers on the use of alternate materials, effect of material on leaf spring performance and fatigue life prediction of leaf spring. They focus on the performance of epoxy glass fiber reinforced materials used in leaf spring [2]. Vinkel Arora, et al, The paper is focused on determination of better eye end design of single leaf spring used in light motor vehicle [3]. The objective of the work is to carry out computer aided design and analysis of a conventional leaf spring, with experimental and computational design considerations and loading conditions using CATIA and ANSYS. M. M. Patunkar, et al, In his paper a comparison analysis of steel leaf spring is done with a virtual model of a composite leaf spring under the same static load condition. Deflection and stresses of steel leaf spring and composite leaf spring are to be analyzed [4]. M. Raghavedra, et al, The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. From the results, it is observed that the laminated composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications [5]. M.Venkatesan and D. Helmen Devaraj, The paper gives design and experimental analysis of composite leaf spring made of glass fiber reinforced polymer. The main objective is to compare the stiffness, load carrying capacity and weight of composite leaf spring with that of steel leaf spring. The dimension of the light commercial vehicle is used. The design constraints are stresses and deflections. In which finite element analysis with full load on the 3-D model of composite multi leaf spring is done using ANSYS 10 and the analytical results are compared with experimental results. After studying the above paper, it is seen that the study in present topic will find new era in this sector.

II. PARAMETERS CONSIDERED

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A. Material selection:
The material selection criteria are so much important in design of leaf spring. It is depends on the parameters such as High strength, Economy, Versatility & flexibility, Corrosion resistance, Weight advantages of material.

B. Proposed material for leaf spring:
The proposed material for the leaf spring is Composite material of Glass Fiber Reinforced Plastic. The material offer following advantages over the other materials are: It offers high strength as compared to conventional materials of leaf spring. It is having lowest cost of manufacturing as compare to conventional. It has high corrosion resistance property as well as lower weight to strength ratio.

C. Properties of Composite Material:
The material E-glass / epoxy composite with 65% fiber volume is selected for Composite leaf spring. E-Glass fibers are selected as they have low cost compared to either Carbon / Graphite fibers. It has high strength, high chemical resistance. But, the density is high compared to the other fibers. Fibers – E-glass high quality fiber, which is used as a standard reinforcement and has good mechanical property requirements. Resins– Epoxy resin and solvent is used. Hardener–PVA which is a low viscosity polyamine is selected. The specimen testing is done according to ASTM standards.

![Figure 1. Specimen for testing and tensile testing machine](image)

Now, the material used is E-glass epoxy fibre whose properties are as follows: [4]

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Properties of E-glass epoxy fiber</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Tensile modulus along X-direction (Ex)</td>
<td>34000 MPa</td>
</tr>
<tr>
<td>2.</td>
<td>Tensile modulus along Y-direction (Ey)</td>
<td>6530 MPa</td>
</tr>
<tr>
<td>3.</td>
<td>Tensile modulus along Z-direction (Ez)</td>
<td>6530 MPa</td>
</tr>
<tr>
<td>4.</td>
<td>Ultimate Tensile strength of the material</td>
<td>900 MPa</td>
</tr>
<tr>
<td>5.</td>
<td>Ultimate Compressive strength of the material</td>
<td>450 MPa</td>
</tr>
<tr>
<td>6.</td>
<td>Poisson ratio along X-Y direction (NUxy)</td>
<td>0.217</td>
</tr>
<tr>
<td>7.</td>
<td>Poisson ratio along Y-Z direction (NUyz)</td>
<td>0.366</td>
</tr>
<tr>
<td>8.</td>
<td>Poisson ratio along Z-X direction (NUzx)</td>
<td>0.217</td>
</tr>
<tr>
<td>9.</td>
<td>Mass density of the material (ρ)</td>
<td>2.6x10⁴ kg/mm³</td>
</tr>
</tbody>
</table>

D. Design related theory:
In this constant cross section design is considered cause of following reasons. In which both thickness and width are kept constant throughout the leaf spring. Due to which,
1. Capability for mass production and accommodation of continuous reinforcement of fibers.
2. Since the cross-section area is constant throughout the leaf spring, same quantity of reinforcement fiber and resin can be fed.

E. Design calculations:
In design of composite multileaf spring the light motor vehicle is considered. Total load taken is the sum of the weight of the vehicle and extra luggage. It is assumed that the total load is equally shared by each of the four leaf springs of a vehicle. The calculation of stress and deflection is done by considering spring as a cantilever beam. The specification is as per follow,
Span length (eye to eye) 2L = 900 mm, Full bump load, P = 2800 N, Camber height = 87 mm, Thickness of each leaf, t = 18 mm, Width of each leaf, b = 80 mm, Design stress without considering sudden impact, f = 725 N/mm². Ineffective length, IL = 60mm, Effective length, EL = 840mm. Modulus of Elasticity for steel=2.1x10¹¹ N/mm², Master leaf =980 mm, d =Diameter of eye end = 20 mm.
F. Procedure:
Lay up selection: For fabrication of leaf spring hand lay-up technique is used. The lay-up is selected to be bi-directional along the longitudinal direction of the spring. The pattern is made up of plywood. The mixture is applied on the mould and the resin is applied again. This is continued for 32 layers. After the lay-up is finished, it is kept undisturbed for 24 hrs at room temperature.

III. MODELING OF CFRP LEAF SPRING
The modeling of composite leaf spring is done with CAD software. CATIA V5 modeling software is used and virtual model of the multilayer composite leaf spring is done considering all dimensions and tolerances.

IV. ANALYSIS
For this purpose ANSYS 12.1 FEA software is selected due to its simplicity and quick results. The model generated in the above section is imported in the analysis software and the static structural analysis of composite leaf spring is done. The boundary condition used for analysis is as follow,
1. Translational motion of one of the two eyes along X-axis as free and other fixed.
2. Translational motion along Y-axis as free.
3. Translational motion along Z-axis as fixed.
V. RESULTS OF ANSYS

The following graphs are generated by using data obtained by analysis.

![Load vs. Deflection curve of Composite Leaf Spring](image1)

**Figure 6. Load vs. Deflection curve of Composite Leaf Spring**

![Load vs. Stress of Steel and Composite Leaf Spring](image2)

**Figure 7. Load vs. Stress of Steel and Composite Leaf Spring (computational results)**

VI. CONCLUSIONS

E-glass/epoxy mat is used as the material and epoxy as resin. The fabrication method used for composite leaf spring is hand lay-up method and it is cost effective. So the cost reduction for the manufacturing process is achievable. Analysis of composite and steel leaf spring is done by using ANSYS and the results are obtained. The load vs. deflection in composite leaf spring is studied. It is observed that 0° orientations have minimum deformation as compare to the bi-directional orientation. The reduction in weight of composite for E-glass / Epoxy leaf spring is nearly 70%. So the weight reduction is also achieved. In the experiment on Composite leaf spring, load is applied till the deformation value is same as that of the steel spring is obtained.

REFERENCES