DESIGN AND ANALYSIS OF COMPOSITE LEAF SPRING

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ABSTRACT

The present paper deals with the Design and analysis of composite leaf spring. The analysis has been conducted by using ANSYS-12 software with the help of static structural tool. A three-layer composite leaf spring with full length leave made of E-Glass/epoxy composite material has been used. The results of Conventional steel leaf spring have been compared with the present results obtained for composite leaf spring. E-glass/epoxy material is better in strength and lighter in weight as compared to the conventional steel leaf spring. Lot of work has been done and is shown in this paper in an interest of justifying the title of the paper.

Key words: Leaf spring, Finite element analysis, Fatigue analysis CAE tool.


1. INTRODUCTION

Leaf spring is widely used in automobiles and is one of the important components of suspension system. It consists of one or more leaves. As a general rule, the leaf spring is regarded as a safety component as its failure could lead to severe accidents. The leaf spring might carry loads, brake torque, driving torque, etc. In addition to shock absorbers, the multi-leaf spring is made of several steel plates of different lengths stacked together. During normal operation, the spring compresses to absorb the shock.

The leaf springs bend and slide on each other thereby allowing suspension movement. Fatigue failure is the predominant mode of in-service failure of many automobile components. This is due to the fact that the automobile components are subjected to variety of fatigue loads like shocks caused due to road irregularities, the sudden loads due to the wheel traveling over the bumps etc. The leaf springs are more affected due to fatigue loads as they are a part of the un sprung mass of the automobile. In this paper, the analysis of eight-leaf steel spring is presented. The leaf spring was analysed over its full operating range from 1kN to 10 kN. Bending stress and deflection are the target results. Finally, fatigue life of the steel leaf spring is also predicted.

The main objective of this work is to perform finite element analysis of multi leaf spring. experimental results have been taken on a full scale static load testing machine, in which leaf spring is held under an axial load at centre till maximum deflection. These experimental results will be compared with FEA results for validation.
2. MATERIAL AND METHODS

Material properties and Design parameters below is showing the different parameters related to material properties;

Design parameters of the multi leaf spring used in this work are:
Total span length (eye to eye): 1450mm
Number of full length leaves: 02
Length of full length leaves (L-1 and L-2): 1450 mm each
Width of all leaves: 70mm
Thickness of all leaves: 12mm
Number of graduated length leaves: 07
Length of graduated length leaves;
(L-3, L-4, L-5, L-6, L-7, L-8 and L-9): 1320mm, 1140mm, 940mm, 800mm, 640mm, 464mm & 244mm respectively.

3. MATERIAL PROPERTIES

Material properties of E glass/ Epoxy (GFRP): The different parameters related to GFRP leaf springs are tabulated in the table below:

<table>
<thead>
<tr>
<th>Properties of E-Glass/ Epoxy composite leaf spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sr. No</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

It is obvious that the composite material have better mechanical properties than conventional steel as the energy storage capacity of composite material is much higher than steel therefore it is the best material
for application selected. Also from eq.1 the material with maximum strength and minimum modulus of elasticity is the most suitable material for leaf spring application

4. STATIC ANALYSYS
The aim of this analysis is to study the multi-leaf steel leaf spring and verification of the results within the desirable limits. ANSYS software is used to analyse the stresses by performing static analysis for the given leaf spring specification and to determine the deflection in leaf springs. Analysis involves discretization called meshing, boundary conditions, loading.

4.1. Elements Type
SOLID45- 3-D Structural Solid.
CONTA174 - 3-D 8-Node Surface-to-Surface Contact.

4.2. Meshing
Meshing involves division of the entire model into small pieces called elements. It is convenient to select the free mesh because the leaf spring has sharp curves, so that shape of the object will not alter. To mesh the leaf spring the element type must be decided first. Here, the element type is solid 45. The element edge length is taken as 5 mm. The numbers of elements are taken 2225 and the total numbers of nodes are 8099.

4.3. Boundary Conditions
The front eye of the leaf spring is coupled directly with a pin to the frame so that the eye can rotate freely about the pin but no translation is occurred. The rear eye of the spring is connected to the shackle which is a flexible link the other end of the shackle is connected to the frame of the vehicle. The force 4169N applied at both the eye end of leaf spring. The both eyes of the leaf spring have the flexibility to slide along the X-direction when load applied on the spring and also it can rotate about the pin in Z-direction. The link oscillates during load applied and removed. So the displacement at the both eye is constrained along the X and Z directions

![Meshed Model of Steel Leaf Spring with Boundary Conditions](image)

**Figure 1** Meshed Model of Steel Leaf Spring with Boundary Conditions
Figure 2 Bending Stress of Steel Leaf Spring

Figure 3 Bending Stress of Steel Leaf Spring

Figure 4 Bending Stress of Composite Leaf Spring
5. RESULTS

From the results of static analysis of steel leaf spring, it is seen the displacement of leaf spring is 53.159 mm which is well below the camber length of leaf spring shown in fig. 4. It is seen that the maximum bending stress is about 450.73 MPa, which is less than the yield strength of the material shown in fig. 3. The FEA results are compared with the theoretical results and found that the theoretical result and FEA result are nearer to each other.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Theoretical Results for steel leaf spring</th>
<th>FEA Results for steel leaf spring</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load, N</td>
<td>4169</td>
<td>4169</td>
<td>NIL</td>
</tr>
<tr>
<td>Bending Stress, MPa</td>
<td>466.84</td>
<td>450.73</td>
<td>3.04 %</td>
</tr>
<tr>
<td>Total Deflection, mm</td>
<td>51.24</td>
<td>53.159</td>
<td>3.06 %</td>
</tr>
</tbody>
</table>

After that the multi leaf spring with E-Glass/Epoxy material is analyzed in ANSYS-12 with same dimension and same boundary condition as that of conventional leaf spring, showing bending stress and deflection under load in figures.5 & 6.

The comparison between steel leaf spring and composite leaf spring for deflection and bending stress results from the ANSYS is shown in the Table-V.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>FEA Results for steel leaf spring</th>
<th>FEA Results for composite leaf spring</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load, N</td>
<td>4169</td>
<td>4169</td>
<td>NIL</td>
</tr>
<tr>
<td>Bending Stress, MPa</td>
<td>450.73</td>
<td>338.03</td>
<td>- 25.05 %</td>
</tr>
<tr>
<td>Total Deflection, mm</td>
<td>53.159</td>
<td>34.676</td>
<td>- 34.76 %</td>
</tr>
</tbody>
</table>
By the comparison of results between steel leaf spring and the composite leaf spring from ANSYS-12 the deflection is decreased by 34.76% in composite leaf spring that is within the camber range. The bending stresses are decreased by 25.05% in composite leaf spring means less stress induced with same load carrying conditions.

The conventional multi leaf spring weights about 10.27 kg whereas the E-glass/Epoxy multi leaf spring weighs only 3.26 kg. Thus, the weight reduction of 67.88% is achieved. By the reduction of weight and the less stresses, the fatigue life of composite leaf spring is to be higher than that of steel leaf spring. Totally it is found that the composite leaf spring is the better than that of steel leaf spring.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Weights</th>
<th>% weight saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional Steel</td>
<td>10.27 kg</td>
<td>----</td>
</tr>
<tr>
<td>E-glass/epoxy</td>
<td>3.26 kg</td>
<td>67.88%</td>
</tr>
</tbody>
</table>

6. CONCLUSION

In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring. A semi-elliptical multi leaf spring is designed for a four wheel automobile and replaced with a composite multi leaf spring made of E-glass/epoxy composites. Under the same static load conditions the stresses and the deflection in leaf springs are found with great difference. Stresses and deflection in composite leaf springs is found out to be less as compared to the conventional steel leaf springs. All the FEA results are compared with the theoretical results and it is found that they are within the allowable limits and nearly equal to the theoretical results. A comparative study has been made between steel and composite leaf spring with respect to strength and weight. Composite leaf spring reduces the weight by 67.88% for E-Glass/Epoxy. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view. Totally it is found that the composite leaf spring is the better that of steel leaf spring. Therefore, it is concluded that composite multi leaf spring is an effective replacement for the existing steel leaf spring in vehicles.

REFERENCE


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