Review of Composite Material Mono Leaf Spring

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Abstract—Weight reduction has been the main focus of automobile manufacturers. Weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The suspension leaf spring is one of the potential items for weight reduction in automobiles as it accounts for 10% - 20% of the unsprung weight. This achieves the vehicle with more fuel efficiency and improved riding qualities. The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity and stiffness. Since, the composite materials have more elastic strain energy storage capacity and high strength to weight ratio as compared with those of steel, multi-leaf steel springs are being replaced by mono-leaf composite springs. The composite material offer opportunities for substantial weight saving but not always are cost-effective over their steel counter parts. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of variations in the spring deflection so that the potential Energy is stored in spring as strain energy and then released slowly. So, increasing the energy storage capability of a leaf spring ensures a more compliant suspension system.

The material selected was glass fiber reinforced polymer (E-glass/epoxy), carbon epoxy and graphite epoxy is being used for making an mono leaf spring. Here we are selected and analyzed with the objective of minimizing weight of the composite leaf spring as compared to the steel leaf spring.

Keywords— Composite Material, Leaf Spring, Suspension, Automobile

I. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other engineered composite materials include:

- Composite building materials such as cements, concrete.
- Reinforced plastics such as fiber-reinforced polymer.
- Metal Composites.
- Ceramic Composites (composite ceramic and metal matrices).

1.1 Advantages & properties that can influence the different parameters of automobile design by selecting composite material are:-

1) High strength to wear ratio.
2) Corrosion resistance.
3) Wear resistance.
4) Stiffness.
5) Fatigue life.
6) Temperature depending behavior.
7) Thermal insulation.
8) Thermal conductivity.
9) Low electrical conductivity.

Naturally, not all of these properties are improved at the same time nor is there usually any requirement to do so. In fact, some of the properties are in conflict with one another, e.g., thermal insulation versus thermal conductivity. The objective is merely to create a material that has only the characteristics needed to perform the design task. Modern composites using fiber-reinforced matrices of various types have created a revolution in high-performance structures in recent years. Advanced composite materials offer significant advantages in strength and stiffness coupled with light weight, relative to conventional metallic materials. Along with this structural performance comes the freedom to select the orientation of the fibers for optimum performance. Modern composites have been described as being revolutionary in the sense that the material can be designed as well as the structure.

II. CHARACTERISTICS OF COMPOSITE MATERIALS

10) High fatigue strength, fatigue damage tolerance, high specific strength and modulus.
11) Anisotropic.
12) Production of both material and structure or component in a single operation - manufacturing flexible, net-shape, complex geometry.
13) Corrosion resistance and durable. Other unique functional properties - damping, low CTE (coefficient of thermal expansion).

Generally leaf spring used in suspension systems to absorb shocks in light motor vehicle, trucks, rail systems etc. Suspension system consists of a spring and a damper. The energy of road shock. Causes the spring to oscillate. These oscillations are restricted to a reasonable level by the damper which is more commonly called a shock absorber.
III. OBJECTIVE OF SUSPENSION SYSTEM

1) To obtain the stability of the vehicle in rolling, while in vehicle in running condition [4].
2) To safety the occupants from road shocks.
3) To prevent the road shocks from being transmitted to the vehicle components.

3.1 Basic occurrence for vertical loading:

When the rear wheel comes across a bump or pit on the road, it occurs vertical forces, tensile or compressive depending upon the road irregularity. These are absorbed by the elastic compression, shear, bending or twisting of the spring [3]. When the front wheel strikes a bump it starts vibrating. These vibrations die down exponentially due to damping present in the system. The rear wheel however, reaches the same bump after certain time depending on the wheel base and the speed of the vehicle. When the rear wheel reaches the bump, it experiences similar vibrations as experienced by the front wheel some time ago. It is seen that to reduce pitching tendency of the vehicle, the frequency of the front springing system be less than that of the rear springing system[4]. From human comfort point also it is seen that it is desirable to have low vibration frequencies. The results of the studies of human beings have shown that the maximum amplitude which may be allowed for a certain level of discomfort decreases with the increase of vibration frequency.

3.2 The leaf serves several functions that other suspension systems might need additional hardware to serve. The leaf does the following:

1. Supports all of the chassis weight.
2. Controls chassis roll more efficiently by utilizing a higher rear moment center and a wide spring base.
3. Controls rearend wrap-up when not mounted with birdcage-type mounts.
5. Controls lateral forces much the same way a Panhard bar does, but with very little lateral movement.
6. Controls braking forces when not mounted with birdcage-style mounts.
7. Better at maintaining wheelbase lengths (reduced rear steers) under acceleration and braking.

3.3 General Design Parameter of Steel Leaf Spring[7]:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material selected</td>
<td>Steel 55Si2Mn90</td>
</tr>
<tr>
<td>Tensile strength (N/mm²)</td>
<td>1962</td>
</tr>
<tr>
<td>Yield strength (N/mm²)</td>
<td>1470</td>
</tr>
<tr>
<td>Young’s modulus E (N/mm²)</td>
<td>2.1·10⁷</td>
</tr>
<tr>
<td>Design stress (σb) (N/mm²)</td>
<td>653</td>
</tr>
<tr>
<td>Total length (mm)</td>
<td>1190</td>
</tr>
<tr>
<td>The arc length between the axle seat and the front eye (mm)</td>
<td>595</td>
</tr>
<tr>
<td>Arc height at axle seat (mm)</td>
<td>120</td>
</tr>
<tr>
<td>Spring rate (N/mm)</td>
<td>32</td>
</tr>
<tr>
<td>Normal static loading (N)</td>
<td>3850</td>
</tr>
<tr>
<td>Available space for spring width (mm)</td>
<td>60 – 70</td>
</tr>
<tr>
<td>Spring weight (kg)</td>
<td>26</td>
</tr>
</tbody>
</table>

3.4 General Material properties of composite Leaf Spring [7]:

<table>
<thead>
<tr>
<th>Properties</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile modulus along X-direction (Ex), MPa</td>
<td>34000</td>
</tr>
<tr>
<td>Tensile modulus along Y-direction (Ey), MPa</td>
<td>6530</td>
</tr>
<tr>
<td>Tensile modulus along Z-direction (Ez), MPa</td>
<td>6530</td>
</tr>
<tr>
<td>Tensile strength of the material, MPa</td>
<td>900</td>
</tr>
<tr>
<td>Compressive strength of the material, MPa</td>
<td>450</td>
</tr>
<tr>
<td>Shear modulus along XY-direction (Gxy), MPa</td>
<td>2433</td>
</tr>
<tr>
<td>Shear modulus along YZ-direction (Gyz), MPa</td>
<td>1698</td>
</tr>
<tr>
<td>Shear modulus along ZX-direction (Gzx), MPa</td>
<td>2433</td>
</tr>
<tr>
<td>Poisson ratio along XY-direction (NUxy)</td>
<td>0.217</td>
</tr>
<tr>
<td>Poisson ratio along YZ-direction (NUyz)</td>
<td>0.366</td>
</tr>
<tr>
<td>Poisson ratio along ZX-direction (NUzx)</td>
<td>0.217</td>
</tr>
<tr>
<td>Mass density of the material (ρ), kg/mm³</td>
<td>2.6-106</td>
</tr>
<tr>
<td>Flexural modulus of the material, MPa</td>
<td>40000</td>
</tr>
<tr>
<td>Flexural strength of the material, MPa</td>
<td>1200</td>
</tr>
</tbody>
</table>
IV. INTRODUCTION OF FINITE ELEMENT SOFTWARE FOR ANALYSIS

The finite element method (FEM) is the dominant discretization technique in structural mechanics. The basic concept in the physical interpretation of the FEM is the subdivision of the mathematical model into disjoint (none overlapping) components of simple geometry called finite elements or elements for short. The response of each element is expressed in terms of a finite number of degrees of freedom characterized as the value of an unknown function, or functions, at a set of nodal points.

4.1 Objectives of FEM:

1) Understand the fundamental ideas of the FEM
2) Know the behavior and usage of each type of elements covered in this course.
3) Be able to prepare a suitable FE model for structural mechanical analysis problems.
4) Can interpret and evaluate the quality of the results (know the physics of the problems).
5) Be aware of the limitations of the FEM (don't misuse the FEM a numerical tool).

4.2 Required basic information to operate the finite element analysis software:

1) Nodal point spatial locations (geometry).
2) Elements connecting the nodal points.
3) Mass properties.
4) Boundary conditions or restraints.
5) Loading or forcing function details.
6) Analysis options.

4.3 FEM Solution Process Procedures:

1. Divide structure into pieces (elements with nodes) (discretization/meshing).
2. Connect (assemble) the elements at the nodes to form an approximate system of equations for the whole structure (forming element matrices).
3. Solve the system of equations involving unknown quantities at the nodes (e.g., displacements).
4. Calculate desired quantities (e.g., strains and stresses) at selected elements.

V. CONCLUSION

1) In this paper we have understand it is possible to easy manufacturing a leaf spring using E glass epoxy glass fiber.
2) As per the point of weight reduction it is possible by using composite material.
3) Ride comfort and life of Composite Leaf Springs are also more when compared to Steel Leaf Springs.

REFERENCES