Design and Numerical Investigation of Static Loading characters of Heterogeneous Model Leaf Spring

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Abstract—Suspension system is a major unit in automotive design, especially leaf spring design. It absorbs payload and road loads to give comfort to vehicle. Leaf spring system is an assembly, contains arched leaves put together by “U” bolts. Loads travel through each leaf and produce contact stress with each contact members, this effectively reduces the life time of the spring system. Spring steels are majorly preferred as leaf spring material, but in practical nature vehicle carries loads that are much higher than designed limit and causes earlier failure to leaf spring, which is a catastrophic in a driving condition and should be avoided. Preferring composite materials is very costly even though they are far better than metals, so, it is evident to develop an economical, maintenance friendly design for the leaf spring system. In this project work, a heterogeneous model leaf spring system is developed and numerically tested for a better suitability for the existing model. This model will introduce synthetic rubber sleeves between spring leafs, which is a hyperrealist material in nature, this system is designed and modelled through CAD software, dimensions and loading data are arrived from literature reviews. FEA based static analysis will be conducted to study the behaviors of existing and heterogeneous models and the effectiveness of new model will be evaluated. The heterogeneous model is very economical alternative to many composite models proposed in the literature review and easy to manufacture, recyclable, and maintainable.

Keywords—CAD, FEA, Leaf Spring, Heterogeneous

I. INTRODUCTION

1.1 Suspension and Leaf Springs
Suspension can be considered as a link between the wheels and the body. It absorbs quick loadings and collects the elastic energy. Design fundamentals are based on the strength and comfort. The strength characteristics are usually determined according to the suspension type and loading. The comfort design fundamentals originate from the fluctuation and vibration point of view. The basic idea for the design is to generate the wanted elasticity and maintain the driving comfort. The leaf spring is one of the oldest suspension types. Nowadays it is widely used in heavy duty vehicles and work machines. Sometimes it is also called as a semi-elliptical spring; as it takes the form of a slender arc shaped length of spring steel (Fig.1.1) of rectangular cross section. The center of the arc provides the location for the axle, while the tie holes are provided at either end for attaching to the vehicle body.

Supports the chassis weight, controls chassis roll more efficiently-high rear moment center and wide spring base, controls rear end wrap-up, controls axle damping, controls braking forces and regulates wheelbase lengths (rear steer) under acceleration and braking.

Fig 1: Leaf Springs

1.2 Spring Material Property
The most common leaf spring material used is silicon steel and the properties of the same if given below.
Name : 65Si7 (Isotropic)
Young’s modulus (E) : 2.1e5 N/mm2
Poisson’s Ratio : 0.266
BHN : 400-425
UTS : 1940 MPa
Tensile strength Yield : 1450 MPa
Spring stiffness : 221.5 N/mm2
Density : 7850 Kg/m3

1.3 Mechanical Properties of Rubber
Rubber is a unique material that is both elastic and viscous. Rubber parts can therefore function as shock and vibration isolators and/or as dampers. Although the term rubber is used rather loosely, it usually refers to the compounded and vulcanized material. In the raw state it is referred to as an elastomer. Vulcanization forms chemical bonds between adjacent elastomer chains and subsequently impart dimensional stability, strength, and resilience. An unvulcanized rubber lacks structural integrity and will “flow” over a period of time. Rubber mechanical properties as follows,
Hardness, shore A : 10–90
The springs experience fluctuating loads with static loads under all loading conditions. These leaf springs absorb road loads and shocks. While in riding, continuous change in the road surfaces bumps and pot holes make fluctuation loads in the spring members, this decrease service life of the spring members and in turn the whole system. Minimization of the load absorption between leaf members or minimize contact will increase the life. But, the cost of the new or modified system must be economical and in terms of maintenance and replacement. So, there is a strong need for a new and innovative economical stress minimization system.

2.2 Proposed Solution
It is clear that, minimizing contact loading will yield improvement in the service life of the leaf spring system. The literature reviews provides enough guidance in leaf spring dimensional details, static loading details from experiment and finite element analysis. Most of the authors proposed composite material model as a better alternate for the leaf spring system, even though it has advantages in strength and fatigue life, it is serve an economical model for vehicles in the present situation, more over the manufacturing and serviceability is difficult for them. Considering all these factors, a Hyper elastic material (Synthetic Rubber) as an interleaf between leaf springs is proposed in this project work. Rubber can elongate several hundred times than its original shape and retain the same after loading, this behavior is called Hyper elastic, by introducing this Hyperelastic material.
between leaf spring members will absorb the loads and stress due them. The behaviors of this proposed heterogeneous model will be evaluated through static analysis and compared with the existing model.

III. MODELLING AND SIMULATION

3.1 Model
The following figures show the solid models of the leaf spring system that is taken for the analysis. The model dimensions are taken from the literature review [5] and tested with the given condition and compared with the experimental results. Since the eye diameter and U-bolt dimensions are not specified in any of the literature review, the FEA results may vary ±10% from the actual.

Fig. 2 – Leaf Spring with Rubber Insert Model

Fig. 3- Steel Spring Model

3.2 Leaf Dimension
Length of full length leaves
(L-1 and L-2) : 1450 mm each
Width of all leaves : 70mm
Thickness of all leaves : 12mm
No. of extra full length leaf : 1
No. of graduated length leaves : 07
(L-3, L-4, L-5, L-6, L-7, L-8 and L-9) : 1320, 1140, 940, 800, 640, 464, 244 mm

3.3 Boundary Conditions
The eyes of the leaf springs are fixed and a static loading of 35000 N, will be applied for static analysis.

3.4 Static Analysis
The following figure shows the imported model of the leaf spring assembly for performing static analysis.

Fig. 4 - Leaf Spring Assembly
The assembly contains 9 leaves, two of them are master leaves and other seven are graduated leaves.

Fig. 5 - Mesh

The above figure shows the meshed model of the leaf assembly. It contains 193313 nodes and 47666 elements made of tetra and Hexa type 3d elements. The following figure shows the boundary condition. The master leaf eyes are fixed.

Fig. 6 - Boundary Condition

The following figure shows the loading condition of the model, the static loading of 35000 N is applied on the master leaf spring.

Fig. 7 - Loading Condition
The static loading condition is arrived from the literature reviews, for the same model the load is applied at the master’s leaf’s top face. When the model is taken cambered the load must be applied at the bottom leaf to simulate the real situation. Here the un-cambered model is taken and applied at the top. The following figure show the maximum deflection that the leaf assembly experience under static loading condition. The maximum value is 156.85 (153 + 3.85) mm.

Fig. 8- Total Deformation
The following figure shows the VonMises stress of the leaf assembly, it is maximum (1054.1 MPa) at the leaf eyes and it is understandably so, because of the one fixed and one movable ends.

Fig. 9 - VonMises Stress
The Tensile stress of the spring material is 1470 MPa which is much higher than the induced VonMises stress.
3.5 Heterogeneous Model Analysis
The following figure shows the heterogeneous model, the model consists of 9 steel leafs, which are interleaved with synthetic rubber. The thickness of the rubber sleeves are same thickness (12 mm) as steel leafs.

![Fig. 10 – Heterogeneous Model](image)

The following figure shows the meshed model, contains 101616 nodes and 118608 elements.

![Fig. 11 – Meshed Model](image)

3.6 Boundary Condition
The following figure shows the boundary condition, fixed ends and loading of 35000 N.

![Fig. 12 – Fixed Eye](image)

![Fig. 13 – Loading](image)

3.7 Results
The following figure shows the VonMises stress. The maximum value shows 146.30 MPa.

![Fig. 14 – VonMises Stress](image)

The following figure shows the maximum shear stress in the model. The value shows 77.722 MPa.

![Fig. 15 – Shear Stress](image)

IV. RESULT AND DISCUSSION

4.1 Static Analysis
The static analysis of the steel leaf model shows the following results

<table>
<thead>
<tr>
<th>Description</th>
<th>Experimental [5]</th>
<th>FEA</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load (N)</td>
<td>35000</td>
<td>35000</td>
<td>0</td>
</tr>
<tr>
<td>Max. Stress (MPa)</td>
<td>1018.00</td>
<td>1054.1</td>
<td>+ 10</td>
</tr>
<tr>
<td>Deflection (mm)</td>
<td>158.00</td>
<td>156.85</td>
<td>0.7</td>
</tr>
</tbody>
</table>

The result shows that the value gives acceptable nearer results to the experimental result.

4.2 Heterogeneous Model Static Analysis
The following table shows the comparison results of the normal steel and heterogeneous model.

<table>
<thead>
<tr>
<th>Description</th>
<th>Steel</th>
<th>Heterogeneous</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load (N)</td>
<td>35000</td>
<td>35000</td>
<td>0</td>
</tr>
<tr>
<td>Max. Stress (MPa)</td>
<td>1054</td>
<td>146.30</td>
<td>86.15</td>
</tr>
</tbody>
</table>

Experience a maximum of 1057.3 MPa. The induced is below the yield limit of 1470 MPa.

V. CONCLUSION
Static analysis of steel and heterogeneous leaf springs was numerically investigated and the results show effectiveness of heterogeneous model. From the literature review static loading with specification of leaf spring were extracted and the same is used for modeling the leaf spring. Steel leaf spring is modeled followed by heterogeneous; both were undergone static analysis which shows heterogeneous is far better than steel. The heterogeneous is modeled using silicon rubber leafs inserted between steel leafs provides best result in reducing stress, rubber leafs absorbed around 86% of stress in static loading.

The present research can be extended for experimental investigation to establish a better relationship between analytical, numerical and experimental results. This can be used to form empirical relation among the design parameters of leaf spring.

VI. REFERENCES


