Static Analysis of Leaf Spring with Heterogeneous Concept

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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. 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 caries 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. 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 elasticity material, this system is designed and modelled using PRO-E software, dimensions and loading data are taken from literature reviews. FEA based static analysis will be conducted to study the behaviours of existing and heterogeneous models and the effectiveness of new model will be evaluated.

Keywords: Leaf Spring, Synthetic Rubber, PRO-E Wildfire 4.0, ANSYS Workbench 13.0.

1. INTRODUCTION

The most common type of the leaf spring used in automobile is the semi-elliptical leaf spring. This spring consists of number of leaves, which are held together by U-clips. The long leaf fastened to the supports is called master leaf whose ends are bent to form an eye. Remaining leaves are smaller lever called graduated leaves. The perpendicular distance between the reference lines to the master leaf is called camber. The camber is provided so that even at the maximum load the deflected spring should not touch the machine member to which it is attached. The central clamp is required to hold the leaves of the spring The front end of the spring is connected to the frame with a simple pin joint, while the rear end of the spring is connected with a shackle. Shackle is the flexible link

which connects between leaf spring rear eye and frame. When the vehicle comes across a projection on the road surface, the wheel moves up, this leads to deflecting the spring. This changes the length between the spring eyes. The leaf spring should absorb the vertical vibrations and impacts due to road irregularities by means of vibrations in the spring deflection so that the potential energy is stored in spring as strain energy and then released slowly. So, the steel Leaf spring or composite leaf springs are easily damaged. In the present work, to increasing the energy storage capability of a leaf spring ensures a more compliant suspension system and then same time reduce the stress for flow to leafs and reduce the deformation of leafs.

2. SYSTEM MODEL

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 nerve 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 behaviour is called Hyper elastic, by introducing this Hyper elastic material between leaf spring members will absorb the loads and stress due them. The behaviours of this proposed heterogeneous model will be evaluated through static analysis and compared with the existing model.

3. PREVIOUS WORK

Malaga Anil Kumar et al. [1] describes that three different composite materials have been used for analysis of mono-composite leaf spring. They are E-glass/epoxy, Graphite/epoxy and carbon/epoxy. E-glass/epoxy composite leaf spring can be suggested for replacing the steel leaf spring both from stiffness and stress point of view. A comparative study has been made between steel and composite leaf spring with respect to reduce to weight and reduce to stress. Composite mono leaf spring reduces the stress by 475MPa for E-Glass/Epoxy, 1573MPa for Graphite/Epoxy, and 1061MPafor Carbon/Epoxy over conventional leaf spring.

M. Raghavedra et al [2] This paper describes design and analysis of laminated composite mono leaf spring. In the present work, the dimensions of an existing mono steel leaf spring of a Maruti 800 passenger vehicle is taken for modeling and analysis of a laminated composite mono leaf spring with three different composite materials namely, E-glass/Epoxy, S-glass/Epoxy and Carbon/Epoxy subjected to the same load as that of a steel spring. The design constraints were stresses and deflections. Static analysis of a 3-D model has been performed using ANSYS 10.0. Compared to mono steel leaf spring the laminated composite mono leaf spring is found to have 47% lesser stresses, 25%~65% higher stiffness, 27%~67% higher frequency and weight reduction of 73%~80% is achieved.

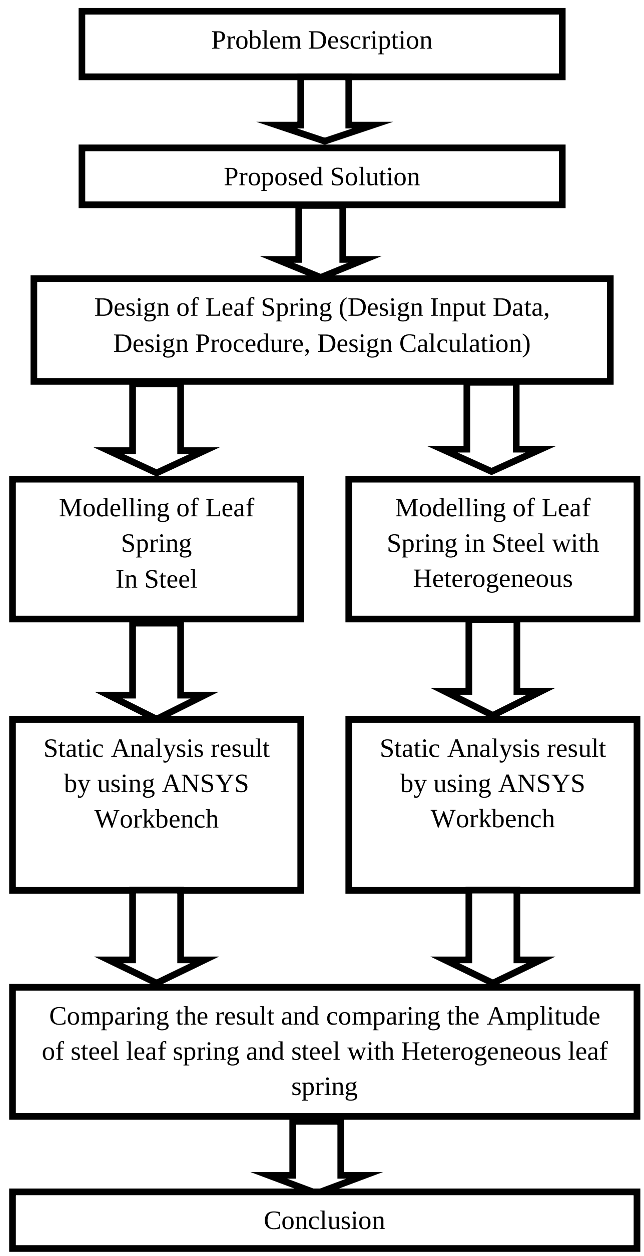
B.Vijaya Lakshmi et al [3] The objective of this paper is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring. The design constraints are stresses and deflections. The dimensions of an existing conventional steel leaf spring of a Heavy commercial vehicle are taken Same dimensions of conventional leaf spring are used to fabricate a composite multi leaf spring using E-GLASS/EPOXY, C-GLASS/EPOXY, S- GLASS/EPOXY unidirectional laminates. Pro/Engineer software is used for modeling and COSMOS is used for analysis. Static & Dynamic analysis of Leaf spring is performed using COSMOS.

Harinath Gowd, G. et al [4] carried out a work to analyze the safe load of the leaf spring, which will indicate the speed at which a comfortable speed and safe drive is possible. A typical leaf spring configuration of TATA-407 light commercial vehicle is chosen for study. Finite element analysis has been carried out to determine the safe stresses and pay loads.

N.P.Dhoshi et al [5] This paper describes to Analysis and Modification of Leaf Spring of Tractor Trailer Using Analytical and Finite Element Method. On reducing the number of leaf spring from 17 to 13will further reduce the weight by approximately 6kg and the production cost by nearly 20%. stress and deflection on leaf Spring is 446 Mpa.

Manjunath H.N. et al [6] In this research work, Eigen value, harmonic and random vibration analysis for steel and various composite leaf springs(EGlass/Epoxy, Graphite/Epoxy, Boron/Aluminum,Carbon/Epoxy and Kevlar/Epoxy) is carried out using ANSYS 10. Boron/Aluminium possesses more vibration capacity than conventional steel leaf spring. And also it has good performance characteristics as compared with other materials.

4. PROPOSED METHODOLOGY



5. SIMULATION RESULTS

Permissible stress(σ_b) =Yield Stress / Factor of Safety

$\sigma = 6PL / nbt^2$

Maximum Deflection $Y_{max}=12P L^3 / Ebt^3(3n_e + 3n_g)$

Camber = 0.5 × Maximum deflection

Radius of Curvature $R = L^2 / 2y$

Load on pin $P_b = P / \cos 45^0$

Bending moment, M = Load on pin ×b'/ 4

Moment arm length = b + 2 × clearance

By equating the bending moment to the resisting moment of the pin,

$M = \sigma_t(\pi / 32)d_p^2$

Shear failure τ = Load on pin / 2 × Area of Length

Length of leaves

$L1 = (L / (n - 1)) + x$

$L2 = (L / (n - 1))\, 2 + x$

$L3 = (L / (n - 1))\, 4 + x$

$L4 = (L / (n - 1))\, 6 + x$

$L5 = (L / (n - 1))\, 8 + x$

$L6 = (L / (n - 1))\, 10 + x$

$L7 = (L / (n - 1))\, 12 + x$

$L8 = (L / (n - 1))\, 14 + x$

Lm = Length of Master leaf + Allowance for eye

$= L + 2\pi (d + t)$

Specification of leaf spring

Suspension : rear leaf

Length of master of leaves : 1525mm

Width of spring leaves : 70mm

Thickness of spring leaves: 10mm

Radius of curvature : 2070mm

Diameter of center bolt : 18mm

Camber : 55mm

Ineffective length : 100mm

Total no.Of leaves : 9

No. of full length leaves : 2

No. of graduated leaves : 7

Geometric Properties of leaf spring

Width of spring leaves : 70mm

Thickness of spring leaves: 10mm

Radius of curvature : 2070mm

Camber : 55mm

Maximum Deflection : 110mm

Length of leaves : 185,270,355,606,775,943, 1112,1281mm

(L2,L3,L4,L5,L6,L7,L8)

Length of master of leaves : 1525mm

Model

Fig.1.Steel leaf spring Assembly

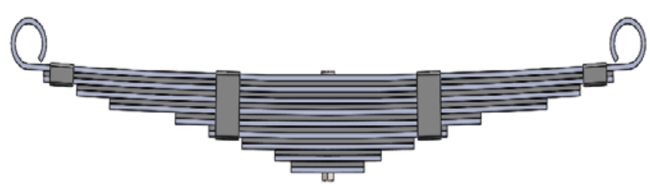


Fig.2.Steel with Heterogeneous Concept of leaf spring Assembly

Boundary Conditions

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

Static Analysis for steel eaf spring

Spring Material properties

Material selected in Manganese Silicon Steel (Steel 55Si2Mn90)

Young'sModulus E = 2.1E5 N/mm^2

Density = 7.86E-6 kg/mm^3

Poission's ratio = 0.3

Tensile stress = 1962 N/mm^2

Yield stress = 1470 N/mm^2

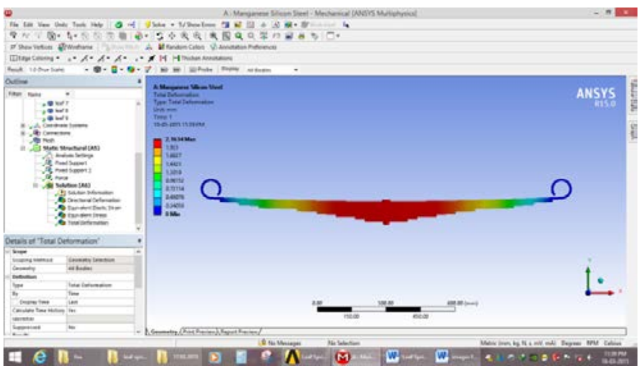


Fig.3. Directional Deformation – Y axis

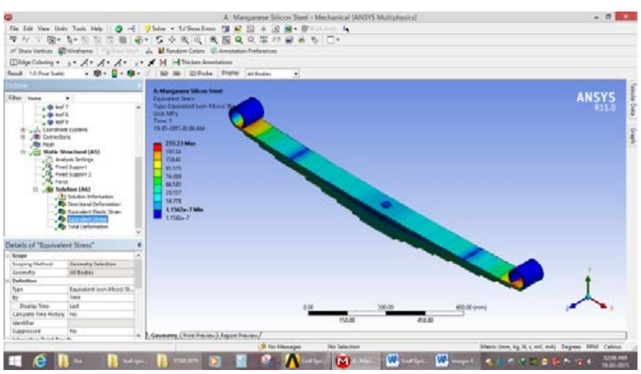


Fig.4. Maximum Stress developed

Static Analysis for Heterogeneous leaf spring

Object Name	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress
Minimum	-1.2107e-003 mm	1.551e-013 mm/mm	2.6677e-008 MPa
Maximum	0.31569 mm	7.7434e-004 mm/mm	263.66 MPa
Minimum Occurs On	leaf 9 _ master leaf		
Maximum Occurs On	leaf 7	leaf 9 _ master leaf	rubber 8

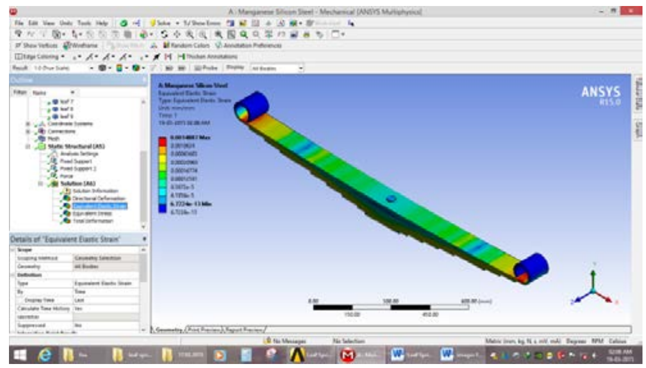


Fig.5.Maximum Strain developed

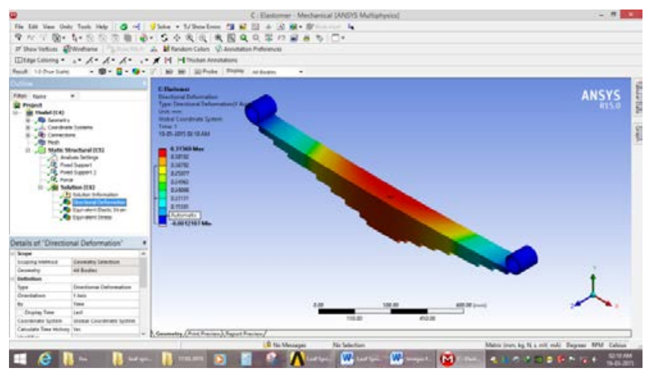


Fig.6.Directional Deformation – Y axis

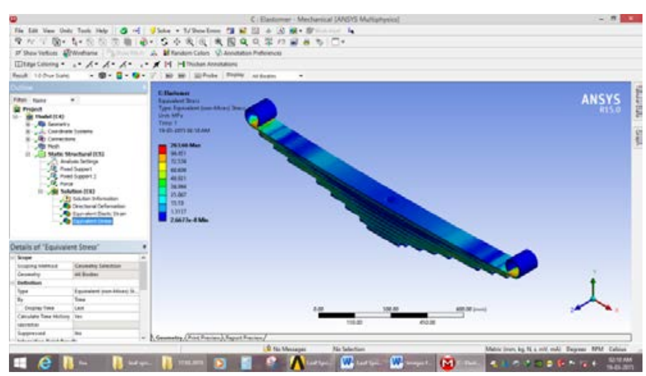


Fig.7.Maximum Stress developed

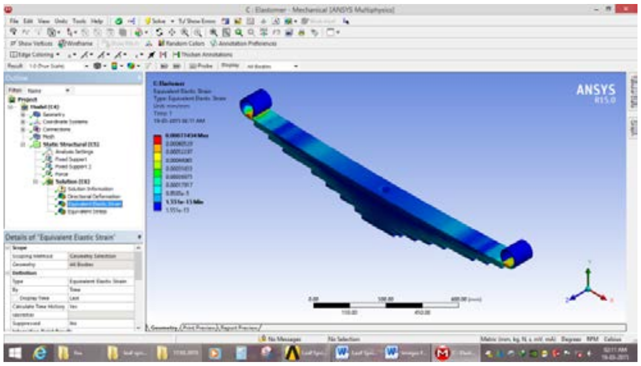


Fig.8.Maximum Strain developed

Table-1: Static Analysis Result for Steel Leaf Spring

Object Name	Directional Deformation	Equivalent Elastic Strain	Equivalent Stress
Minimum	-2.809e-003 mm	6.7224e-013 mm/mm	1.1562e-007 MPa
Maximum	2.1634 mm	1.4887e-003 mm/mm	255.23 MPa
Minimum Occurs On	leaf 9		
Maximum Occurs On	leaf 8	leaf 9	

Table-2: Static Analysis Result for Heterogeneous Leaf Spring

6. CONCLUSION

In this research work the design and mode of Silicon Manganese Steel Leaf spring and Heterogeneous Leaf spring by using Pro/E wildfire 4.0.As per Static Analysis on Silicon Manganese Steel and Heterogeneous leaf spring, In Steel leaf spring the Maximum stress is 255.23MPa occurs on Leaf 9. In Heterogeneous leaf spring, Maximum stress is 263.33MPa occurs on Rubber 8. In this, we get the reduced stress flow to the leafs and deformation. Finally, conclude that Heterogeneous leaf spring is better than Steel leaf spring.

7. FUTURE SCOPES

In the future work, leaf spring material could be replaced alternative material to improve their mechanical properties and to improve durability and to reduce the stress flow to leaf.

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