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FEA Analysis of Composite Leaf Spring Using Ansys

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ABSTRACT: Leaf spring is the most preferred and widely used kind of suspension system in automobiles. The leaf springs employed in the vehicle should have greater and safer working stress and deflection. This is to provide the driver with the necessary comfort while riding the vehicle and to limit or reduce the jerks and shocks which get transmitted from roads to the body during the vehicle movement. This present work examines the induced stresses, deflections & deformations produced within the springs under static load. Different materials differing in their mechanical characteristics have been selected for the study. The analysis is being carried out in commercially available analysis software and results shows that in comparison to steel leaf spring, composite leaf springs show less stresses, deformations and weight is comparatively reduced.

KEYWORDS: Suspension System, Composite Leaf spring, Working Stress, Static Load, FEA Analysis.

I. INTRODUCTION

Leaf springs are known to be the earliest suspension system in the automobile business. They are initially termed as laminated spring or the carriage springs. Leaf spring has an advantage in comparison to helical springs that its ends can be guided over a definite path.

A leaf spring appears as a slim circular segment moulded length of spring steel of rectangular cross-segment. The focal point of the curve gives area to the pivot, while tie gaps are given at either end to appending to the vehicle body. For overwhelming vehicles, a leaf spring can be produced using a few leaves stacked on top of each other in a few layers, frequently with logically shorter takes off. Leaf springs can serve finding and to some degree damping and in addition springing capacities. While the interleaf contact gives a damping activity, it is not very much controlled and results in station in the movement of the suspension. Thus a few producers have utilized mono-leaf springs.

FINITE ELEMENT ANALYSIS:

Finite element analysis (FEA) is a computer based numerical procedure for ascertaining the quality and conduct of building structures. It can be utilized to ascertain redirection, push, vibration, clasp conduct and numerous other marvels. It additionally can be utilized to break down either little or vast scale avoidance under stacking or connected uprooting. It utilizes a numerical system called the finite element strategy (FES). In limited component strategy, the real continuum is spoken to by the limited components. These components are thought to be joined at determined joints called hubs or nodal focuses. As the genuine variety of the field variable (like relocation, temperature and weight or speed) inside the continuum is not known, the variety of the field variable inside a limited component is approximated by a basic capacity. The approximating capacities are likewise called as introduction models and are characterized as far as field variable at the hubs. At the point when the balance conditions for the entire continuum are known, the questions will be the nodal estimations of the field variable.

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OBJECTIVES OF THE WORK:

- To construct a leaf spring model of 'Mahindra Commando 650Di' using a modelling software and to carry out analysis in analysis software.
- Steel leaf considering different thickness has been analyzed.
- Later, composite materials considering three different materials with three different thickness has been analysed.
- The obtained results of composite leaf spring are then compared with steel leaf springs.

II. LITERATURE SURVEY

Pankaj Saini et al, [1] displayed the leaf spring considering it as a cantilever bar with consistently conveyed stack in. They chose three unique materials (E-glass/Epoxy, carbon epoxy and graphite epoxy) for their examination and thought about for stresses and weight sparing of a composite leaf to that of customary leaf with plan imperative as firmness. A relative report demonstrates that E-glass/epoxy composite leaf spring can be proposed for supplanting the steel leaf spring from the anxiety and firmness perspective.

Composite multi leaf spring using E-glass/Epoxy as the material was subjected to static analysis by **Ashish.V. Amrute et al**, [2]. From their study they concluded that deflection and stresses in composite leaf springs was found to be much lesser than that of steel leaf spring.

Parkhe Ravindra et al, [3] experimentally investigated composite mono leaf spring for static loading. The result shows that the stresses induced in Carbon/Epoxy composite leaf spring was nearly 42% less than that of steel leaf spring. Hence, they finally concluded that composite material can be used efficiently for light weight vehicles to meet the requirements, along with considerable weight reduction.

Dynamic analysis of a composite leaf spring has been carried out by **Manjunath.H et al**, [4] considering five different composite materials (E-glass/epoxy, Graphite/epoxy, Boron/Aluminum, Carbon/epoxy and Kevlar/epoxy) respectively. Results showed that Boron/Aluminum was having the highest natural frequency compared to other composite materials.

Sagar.B. Mahajan et al, [5] presented a research work at static loading conditions. By varying thickness, stress and deflection of glass fibre reinforced composite (GFRP) was found having difference as compared to conventional leaf spring. They compared analytical results with FEA for design of composite with varying thickness and found that FEA results shows good agreement with stress and deflection. Their study demonstrated that composites can be used for leaf springs to meet the requirements

Replacement of a conventional spring with composite leaf spring was taken up by **Rupesh.N. Kalwaghe et al**, [6] due to its high strength to weight ratio for the same load carrying capacity and stiffness with same dimensions as that of leaf spring. They found that with use of composite material the weight of spring was reduced by 67.88%. Based on their research they suggest that E-glass/epoxy composite leaf spring can replace steel leaf spring both from stress and stiffness point of view.

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III. METHODOLOGY AND DISCUSSIONS

FEA Method:

FEA analysis comprises a computer generated model of any material or any design which needs to be stressed and analysed. The manipulation of the existing design is much easier in FEA analysis than any analytical approach. The results help to determine the appropriate values for new models to be designed. FEA comprises of the following steps

1. Building the Geometry
2. Assigning the Material Properties
3. Creating the Mesh
4. Describing The Boundary Conditions
5. Application of the Forces
6. Obtaining the Required Solution
7. Presentation of the Result

DESIGN SPECIFICATIONS:

Weight and starting estimations of Mahindra “Model - commander 650 Di” light vehicle are considered.

Net vehicle weight = 2150 kg

Un sprung weight = 240 kg

Total sprung weight = 1910 kg

Taking factor of safety (FS) = 1.4

Acceleration due to gravity (g) = 10 m/s²

There for; Total Weight (W) = 1910*10*1.4 = 26740 N

Since the vehicle is 4-wheeler, a single leaf spring corresponding to one of the wheels takes up one fourth of the total weight.

$F = 26740/4 = 6685$ N

6685+1315(considering average persons load) = 8000N

Here we modelled leaf spring of three different thickness values they are 4mm, 5mm, 6mm.

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Table 1. Parameters of Leaf Spring

Leaf no	Full length (mm)	Half length (mm)	Radius of curvature
1	1120	560	961.11
2	1120	560	967.11
3	1007	503.5	973.11
4	894	447	979.11
5	780	390	985.11
6	667	333.5	991.11
7	554	277	997.11
8	440	220	1003.11
9	327	163.5	1009.11
10	214	107	1015.11

Weight Measurements (for steel)

- 1) 1st leaf weight = volume x density x acceleration due to gravity = $1120 \times 50 \times 6 \times 0.00000786 \times 10 = 26.40\text{N}$
- 2) 2nd leaf weight = $1120 \times 50 \times 6 \times 0.00000786 \times 10 = 26.40\text{N}$
- 3) 3rd leaf weight = $1007 \times 50 \times 6 \times 0.0000786 \times 10 = 23.74\text{ N}$
- 4) 4th leaf weight = $894 \times 50 \times 6 \times 0.0000786 \times 10 = 21\text{N}$
- 5) 5th leaf weight = $780 \times 50 \times 6 \times 0.00000786 \times 10 = 18.39\text{N}$
- 6) 6th leaf weight = $667 \times 50 \times 6 \times 0.00000786 \times 10 = 15.72\text{N}$
- 7) 7th leaf weight = $554 \times 50 \times 6 \times 0.00000786 \times 10 = 13.06\text{N}$
- 8) 8th leaf weight = $440 \times 50 \times 6 \times 0.00000786 \times 10 = 10.3\text{N}$
- 9) 9th leaf weight = $327 \times 50 \times 6 \times 0.00000786 \times 10 = 7.71\text{N}$
- 10) 10th leaf weight = $214 \times 50 \times 6 \times 0.00000786 \times 10 = 5.04\text{N}$

Total weight = $26.40 + 26.40 + 23.74 + 18.39 + 15.72 + 13.06 + 10.3 + 7.71 + 5.04 = 167.76\text{N}$

Similarly,

- a) Total weight of chromium vanadium steel = 120.448N
- b) Total weight of carbon graphite leaf = 80.14N

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c) Total weight of S2 glass leaf = 62.14N

Table 2. Leaf Spring Specifications

Straight length of the leaf	1120mm
Number of leaves	10
Full leaves	2
Half leaves	8
Leaf thickness	50mm
Leaf width	6mm
Working load	8000N
Weight of steel leaf	167.76N
Weight of chromium vanadium leaf	120.448N
Weight of carbon graphite leaf	80.14N
Weight of S2 glass leaf	62.14N

Table 3. Composite Material Specifications

Material	Young's Modulus (Mpa)	Poisson's Ratio	Bulk Modulus (Mpa)	Shear Modulus (Mpa)	Density (kg/mm ³)
Medium Carbon Steel	2×10^5	0.29	1.587×10^5	310	0.00000786
Chromium Vanadium	2.1×10^5	0.29	1.667×10^5	81395	0.00000564
Carbon Graphite	27600	0.23	17037	11220	0.00000345
S2 Glass	86900	0.23	53642	35325	0.00000284

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IV. EXPERIMENTAL RESULTS

The designing and modeling of the composite leaf spring has been carried out considering three different composite materials i.e. Chromium Vanadium, Carbon Graphite and S2 glass. The dimensions of the ‘Mahindra Commando 650 Di’ were taken into account for this study. The composite leaves were designed w.r.t the same existing dimensions but with varying thicknesses. The modeling has been done in SOLIDWORKS and FEA analysis is being processed in ANSYS WORKBENCH. Three different thicknesses have been taken into consideration for the study i.e. 4mm, 5mm and 6mm respectively. The leaves have been subjected to a working load of 8000N. The various results have been discussed here.

Table 4: Static Analysis for Medium Carbon Steel

Parameters	Thickness		
	4mm	5mm	6mm
Stress (N/Mm ²)	27.702	23.979	23.423
Strain	0.00015354	0.00012928	0.00010797
Deformation (Mm)	0.045699	0.033378	0.024974

The FEA analysis result for medium carbon steel has been tabulated in the table 4. The above table shows that of all the different thicknesses, leaf made up of 6mm thicknesses has the least stress, deformation and strain values.

Table 5: Static Analysis for Chromium Vanadium Steel

Parameters	Thickness		
	4mm	5mm	6mm
Stress (N/Mm ²)	27.702	23.979	20.423
Strain	0.00014622	0.00012313	0.00010283
Deformation (Mm)	0.0435323	0.031788	0.023785

The static analysis carried out for chromium vanadium steel leaf spring is presented in the table 5. The table shows that chromium vanadium steel leaf spring of 6mm thickness bears minimum values for induced stress, strain and deformations.

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Table 6: Static Analysis for Carbon Graphite

Parameters	Thickness		
	4mm	5mm	6mm
Stress (N/Mm ²)	27.519	23.798	20.258
Strain	0.0011107	0.00093421	0.00077956
Deformation (Mm)	0.33149	0.24224	0.18124

The FEA result for static analysis of carbon graphite leaf has been tabulated in the above table 6. From the table, it can be seen that stresses, deformations and strain are minimum in leaf made of 6mm thickness rather than the other two.

Table 7: Static Analysis for S2 Glass

Parameters	Thickness		
	4mm	5mm	6mm
Stress (N/Mm ²)	27.519	23.798	20.250
Strain	0.00035276	0.00093421	0.00024759
Deformation (Mm)	0.10528	0.24224	0.057563

The results through FEA analysis for static analysis of S2 glass leaf is shown in the above table7. The table shows that S2 glass leaf of 6mm thickness has better results for stress, strain and deformations than its contour parts.

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V. CONCLUSION

From the study we came to the following conclusion:

- The structural analysis is successfully carried out in ANSYS WORKBENCH taking three different composites i.e. carbon graphite, S2 glass and chromium vanadium. Working load of 8000N was applied on varying thickness of spring for 4mm, 5mm & 6mm respectively.
- The three composite leaves were compared with that of existing steel leaf spring.
- From the above results we can conclude that leaf made of chromium vanadium composite of 6mm shows less stress compared to its counter-parts selected for the study.
- Even though the S2 glass shows less stress concentrations, it underwent for maximum strain and deformation than that of other materials.
- Though 4mm leaf has less weight but it underwent for maximum stress compared to other leaf springs. 5mm leaf got the values closer to 6mm leaf and it also has less weight than 6mm leaf spring.
- Dynamic analysis is been carried out under given loading condition.
- Deformation on different modes based on frequencies has been carried out.
- Chromium vanadium steel showing less deformation on dynamic load condition followed by S2 glass composite.

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