
ABSTRACT

In today's scenario, the main weightage of investigation is to reduce the weight of product while upholding its strength. To solve that problem, this work is carried out for the design and analysis of mono composite materials leaf spring and entire new design criteria of mounting. The automobile vehicles have number of parts which can be able to replace by composite material. The foremost component of the suspension system of vehicle is leaf spring. It has substantial amount of weight, and it would have ample strength because it needs to resist vibrations and jolts during its working. The design considerations for this study are stress and deflection. Materials used for comparison are conventional, composite E-Glass/Epoxy, and E-glass fiber. In the present work deflection and bending stresses induced in the two leaf springs are compared. The solid modelling of leaf spring is done in CATIA V5 and analysed using ANSYS 14.5. From the static analysis results, Graphite Epoxy is better over other materials. It is found that there is a maximum displacement of 5.12 mm for Graphite Epoxy. Also, the Vonmises stress in the Graphite epoxy is 434.43 MPa.

KEYWORDS: Composite leaf spring, Suspension, Leaf spring suspension, Mono leaf spring.

INTRODUCTION

Suspension system of any vehicles contains leaf spring to absorb jolts. The vehicles must have a good suspension system that can deliver a good ride and good human comfort. It is observed that the failure of steel leaf springs is usually catastrophic. According to studies made for leaf spring the material with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material. In order to reduce the accidents, arising out of such failures conventional steel leaf spring can be replaced with gradually failing composite leaf springs. By doing this, the weight of the vehicle may also be reduced while maintaining the strength of the leaf spring.[1]

A composite material is nothing but permutation of two materials that produce an effect so that the combination produces combined properties that are different from any of those of its constituents. This is done purposefully in today's scenario to achieve different design, manufacturing as well as service advantages of product. In this paper leaf spring is representative of those products, for which automobile manufacturers are working to get best composite material that meets the current requirement of strength and weight reduction in one, to replace the existing steel leaf spring.

A suspension system of vehicle is also an area where these innovations are carried out regularly. More efforts are taken in order to increase the comfort of user. Appropriate balance of comfort riding qualities and economy in manufacturing of leaf spring becomes an obvious necessity.

To improve the suspension system, many modifications have taken place over the time. 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. Inventions of parabolic leaf spring, use of composite materials for these springs are some of these latest modifications in suspension systems. [2]

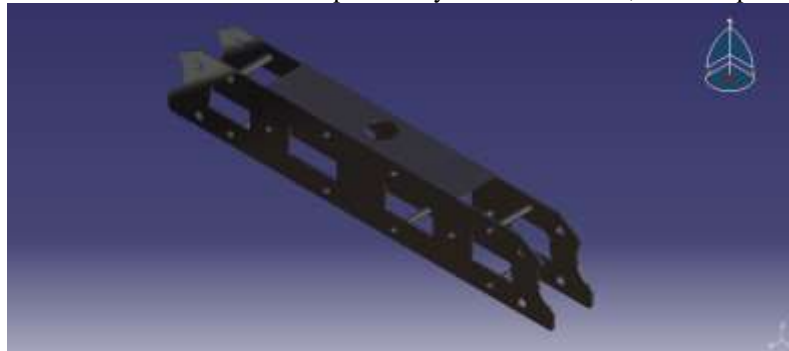
A spring is defined as an elastic body, whose function is to distort when loaded and to recover its original shape when the load is removed. Springs are elastic bodies that can be twisted, pulled or stretched by some force. They can return to their original shape when the force is released.

Leaf spring (also known as flat springs) is made out of flat plate. The advantage in leaf spring over helical spring is that the ends of the spring may be guided along a definite path as it deflects to act as a structural member in addition the energy absorbing device. Thus the leaf springs may carry lateral loads, brake torque, driving torque etc., in addition to shocks. [3]

MODELING OF SUSPENSION AND PARTS

Modelling of hub

Figure below shows a CAD model of hub of the suspension system. On the hub, all other parts are to be mounted.



Hub of suspension system

Modelling of leaf spring

Figure below shows a CAD model of leaf spring. Different materials of leaf spring are used for analysis.



Leaf spring of composite material

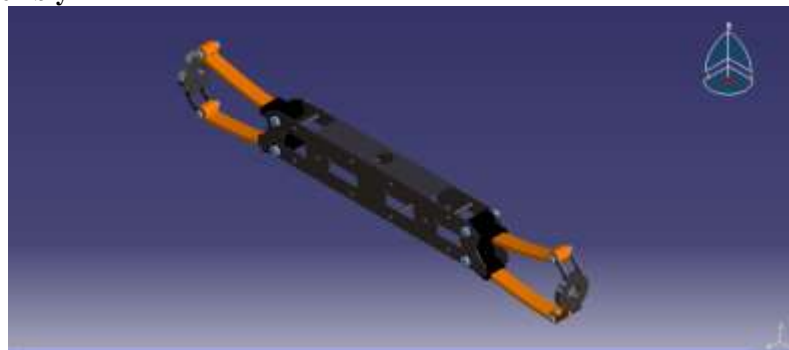


CAD model of wheel mounting

Modelling of wheel mounting

Figure shows a CAD model of wheel mounting on which wheel is to be mounted.

Modelling of an assembly



CAD modelling of an assembly

We've converted it to a dual-cantilever thermoplastic spring in the rear. It's very similar to double-wishbone geometry. Front-wheel-drive car shed more than 45 kg by replacing its all-steel rear suspension with a configuration featuring of composite leaf springs and upper control arms attached to a steel sub frame.

CALCULATIONS OF DEFLECTION AND BENDING STRESS

- Step (1): Material of leaf spring

Material selected steel: 50 Cr 1 V 23,

Composition of material: 0.45% C, 0.1-0.3% Si, 0.6-0.9 % Mn, 0.9-1.2 % Cr.

- Step (2): Basic data of vehicle

Gross vehicle weight: 2090 kg,

Load carrying capacity: 480 kg,

Factor of safety taken: 1.5,

Acceleration due to gravity: 9.81 m/s²,

Wheel track (L): 1346 mm.

- Step (3): Basic requirement of load

Maximum capacity = 2090+480 Kg

$$= 2570 \text{ Kg}$$

$$= 2570 \times 9.81 \times 1.5$$

$$= 37817 \text{ N}$$

So, load acting on each wheel = 37817/4 = 9454 N.

- Step (4): Calculation of dimensions of leaf spring

Thickness of Leaf (t) = 10 mm,

The effective length of leaf for this design is given by,

Wheel track of Mahindra Thar (L) = 1346 / (2 × 2) = 336.5 mm,

In this design there are no graduated leaves so n_g = 0,

No. effective total spring (n) = 2,

Width of leaf spring (b) = 70 mm.

- Step (5): Calculation of the load and effective length of leaf spring

Consider the leaf spring is cantilever beam. So the load acting on each assembly of the leaf spring is acted on the two ends of the leaf spring. Load acted on the leaf spring is divided by the two because of consideration of the cantilever beam. [13]

$$2 \times W = 9454$$

$$W = 9454/2 = 4727 \text{ N.}$$

- Step (6): Calculations of the stress generated in the leaf spring are as under

Material of the leaf spring is 50 Cr 1 V 23,

Properties of the material are as under:

$$\text{Tensile strength } (\sigma_t) = 190 - 240 \text{ Kgf/mm}^2 = 1900 - 2400 \text{ N/mm}^2,$$

$$\text{Yield strength } (\sigma_y) = 180 \text{ Kgf/mm}^2 = 1800 \text{ N/mm}^2,$$

$$\text{Modulus of elasticity } (E) = 200000 \text{ N/mm}^2,$$

By considering the factor of safety for the safety purpose of the leaf spring is 1.5 for Automobile leaf spring. So, the allowable stress for the leaf spring is as under:

$$\text{Tensile strength } (\sigma_t) = 1900 / 1.5 = 1266.66 \text{ N/mm}^2,$$

$$\text{Yield strength } (\sigma_y) = 1800 / 1.5 = 1200 \text{ N/mm}^2,$$

Bending stress generated in the leaf spring is as under:

$$\sigma = \frac{6WL}{n \cdot b \cdot t^2} = \frac{6 \times 4727 \times 336.5}{2 \times 70 \times 10^2} = 681.70 \text{ N/mm}^2$$

So, the stress generated in the leaf spring is lower than the allowable design stress. So design is safe.

- Step (7): Calculations of the deflection in the leaf spring are as under

$$\delta = \frac{4WL^3}{n E \cdot b \cdot t^3} = \frac{4 \times 4727 \times 336.5^3}{2 \times 200 \times 10^3 \times 70 \times 10^3} = 25.73 \text{ mm [4]}$$

STATIC ANALYSIS OF STEEL LEAF SPRING

Assumptions[5]

- Software to be used for ANSYS 14.5,
- Model simplification for FEA,
- Meshing size is limited to computer compatibilities,
- Static analysis is considered,
- Material used for steel leaf spring analysis is isotropic.

Properties of steel

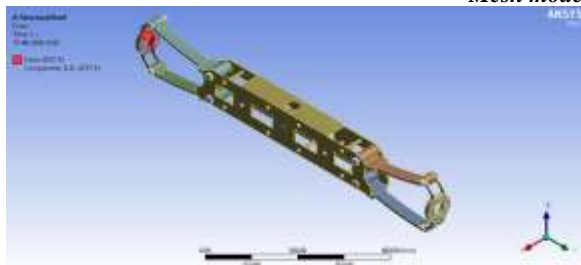
Table 1. Properties of steel material

Parameter	Values
Material selected	50Cr1V23
Young's modulus	2*105 MPa
Poisson's ratio	0.3
BHN	534-601
Tensile strength ultimate	2000 MPa
Tensile strength yield	1800 MPa
Density	7850 Kg/m ³

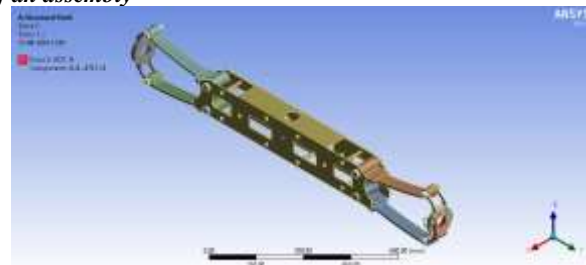
Meshing is the process in which your geometry is spatially discretized into elements and nodes. This mesh along with material properties is used to mathematically represent the stiffness and mass distribution of the structure. The mesh has been generated automatically. The default element size is determined based on a number of factors including the overall model size, the proximity of other topologies, body curvature, and the complexity of the feature. As shown in figure below, number of elements used are 55454 & number of nodes used are 103575.



Mesh model of an assembly



Load applied at left hand side of wheel mounting



Load applied at right hand side of wheel mounting

Boundary condition one end remote displacement for component X free, Y and Z fixed and rotation Z free, X and Y fixed and other end remote displacement for component X, Y and Z fixed and rotation Z free, X and Y fixed. Loading conditions involves applying a load upper side at the centre of the bottom leaf spring.

STATIC ANALYSIS OF COMPOSITE SPRING

As mentioned earlier, the ability to absorb and store more amount of energy ensures the comfortable operation of a suspension system. However, the problem of heavy weight of spring is still persistent. This can be remedied by introducing composite material, in place of steel in the conventional leaf spring. Research has indicated that the results of E-glass/epoxy, and Graphite epoxy were found with good characteristics for storing strain energy. So, a virtual model of leaf spring was created in CATIA. Model is imported in ANSYS and then material is assigned to the model. These results can be used for comparison with the steel leaf spring.

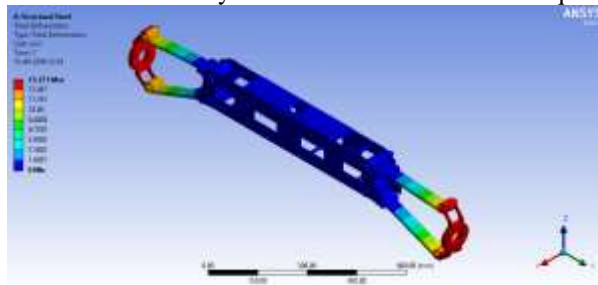
Table 2. Properties of composite material

Sr. No.	Properties	E-glass/Epoxy	Graphite Epoxy
1	EX (MPa)	43000	294000
2	EY (MPa)	6500	6400
3	EZ (MPa)	6500	6400
4	PRXY	0.27	0.023
5	PRYZ	0.06	0.01
6	PRZX	0.06	0.01
7	GXY (MPa)	4500	4900
8	GXY (MPa)	2500	3000
9	GXY (MPa)	2500	3000
10	ρ (kg/mm ³)	0.000002	0.00000159

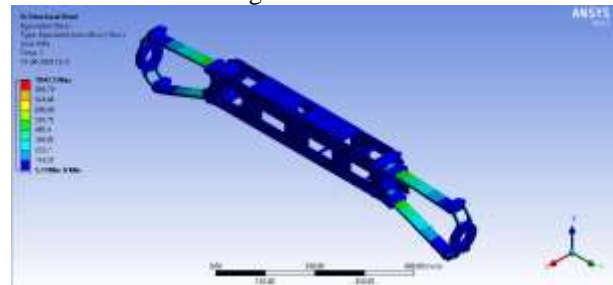
RESULTS

Result of steel leaf spring

Static structural analysis for total deformation and equivalent stress as shown in figures below.



Total deformation in the spring (Structural steel)



Equivalent stress in the spring (Structural steel)

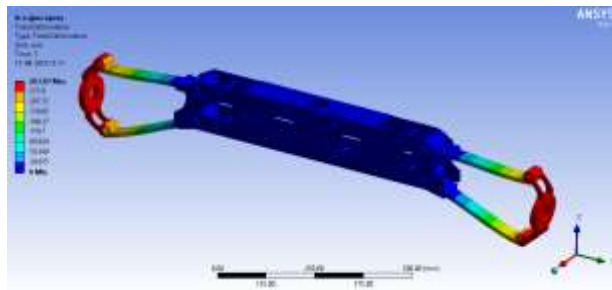
Table 3 shows that static analysis fairly matches with the analytical results but it also shows that static analytical results underestimate the results. For the optimization of leaf spring, accurate prediction of stress and deflection is necessary for that reason we have to perform model and transient analysis of leaf spring.

Table 3. Comparison of analytical and analysis result for steel leaf spring

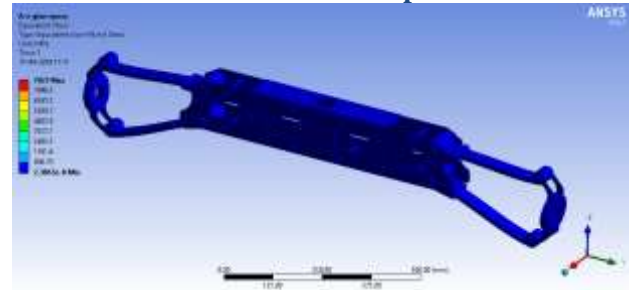
Parameters	Analytical Results	Static analysis Results	Percentage variations
Von-mises stress (MPa)	681.70	1047.01	53.58
Maximum Deflection(mm)	25.73	15.12	41.23

Result of composite leaf spring

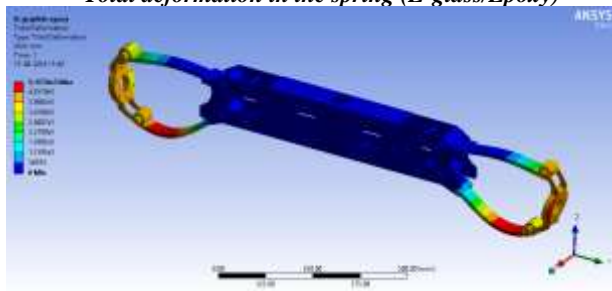
Static structural analysis for total deformation and equivalent stress for E-glass/ epoxy as shown in figures and static structural analysis for total deformation and equivalent stress for graphite epoxy as shown in figures.



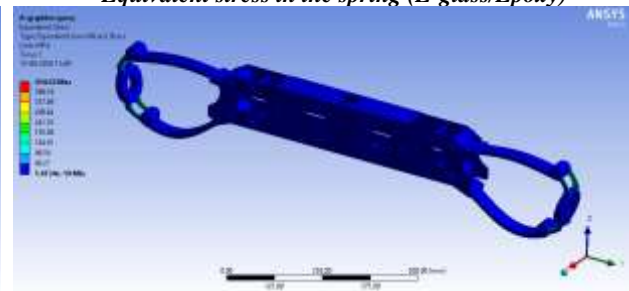
Total deformation in the spring (E-glass/Epoxy)



Equivalent stress in the spring (E-glass/Epoxy)



Total deformation in the spring (Graphite Epoxy)



Equivalent stress in the spring (Graphite Epoxy)

Table 4. Comparison of analysis result for steel and composite leaf spring

Materials	Deflection (mm)	Stress (MPa)
Steel	15.12	1047.01
E-glass/ Epoxy	267.07	7927
Graphite Epoxy	5.12	434.43

Here, from comparison of steel leaf spring with composite leaf spring as shown in table 6. It can be see that the maximum deflection 15.12 mm on steel leaf spring and corresponding deflection in E-glass/epoxy, and Graphite epoxy are 267.07 mm, and 5.12 mm respectively. Also, the von-misses stress in the steel leaf spring 1047.01 MPa while in E-glass/epoxy, and Graphite epoxy the von-misses stress are 7927 MPa, and 434.43 MPa respectively.

CONCLUSION

The design and static structural analysis of leaf spring has been carried out. Two different materials were taken for analysis, steel and composite. Comparison has been made between steel leaf spring and composite leaf spring having same design and same load carrying capacity. The stress and displacements have been calculated using analytically as well as using ANSYS for steel leaf spring and composite leaf spring. From the static analysis results, it is found that there is a maximum displacement of 15.12 mm in the steel leaf spring. For E-glass/ epoxy and Graphite epoxy maximum displacement were 267.67 mm and 5.12 mm respectively.

From the static analysis results, it also seen that the von-mises stress in the steel leaf spring is 1047.01 MPa and in E-glass/epoxy, and Graphite epoxy are 7927 MPa, and 434.43 MPa respectively. Graphite epoxy composite leaf spring has lower displacements and stresses than that of existing steel leaf spring. E-glass/ epoxy composite leaf spring has higher displacements and stresses than that of existing steel leaf spring.

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