

Finite Element Analysis of Composite Leaf Spring for Automotive Vehicle

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ABSTRACT: Reducing weight while increasing or maintaining strength of products is getting to be highly important. The Automobile Industry has great interest for replacement of steel leaf spring with that of composite leaf spring, The objective is to compare the stresses and weight saving of composite leaf spring with that of steel leaf spring since the composite materials has high strength to weight ratio, good corrosion resistance. The material selected was glass fibre reinforced polymer (E glass/epoxy), it is used against Conventional steel..

I.INTRODUCTION

Weight reduction has been the main focus of automobile manufacturers in the present scenario. 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 more fuel efficiency and improved riding qualities.

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.

According to the studies a material made with maximum strength and minimum modulus of elasticity in the longitudinal direction is the most suitable material for a leaf spring. The leaf springs are more affected due to fatigue loads, as they are a part of the unsprung mass of the automobile.

In the present work, a normal leaf steel spring used in passenger cars or light duty vehicles is replaced with a composite multi leaf spring made of glass/epoxy composites. The dimensions and the number of leaves for both steel leaf spring and composite leaf springs are considered to be the same.

II.OBJECTIVE

This project describes design and experimental analysis of composite leaf spring made of glass fibre reinforced polymer. The objective is to compare the load carrying capacity, stiffness and weight savings of composite leaf spring with that of steel leaf spring.

Finite element analysis with full load on 3-D model of composite multi leaf spring is done using ANSYS 14.5 and the analytical results are compared with experimental results. Compared to steel spring, the composite leaf spring is found to have 67.35% lesser stress, 64.95% higher stiffness frequency than that of existing steel leaf spring. A weight reduction of 66.8% is achieved by using optimized composite leaf spring.

III.LITERATURE SURVEY

LEAF SPRING:

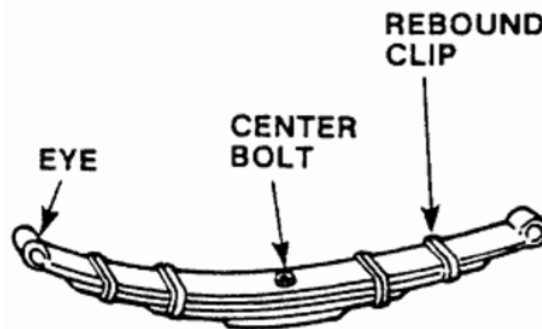
Leaf springs are mainly used in suspension systems to absorb shock loads in automobiles like light motor vehicles, heavy duty trucks and in rail systems. It carries lateral loads, brake torque, driving torque in addition to

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shock absorbing Leaf spring is a very crucial and important component used in automobile industry. In most cases during truck operation, spring leaves are subjected to five deformation modes such as tension, compression, bending, torsion and shear. Therefore, special requirements are imposed on the material and structure of this critical part of the truck chassis.



The main and auxiliary spring leaves, undergoes degradation over a certain time interval, due to which its physical-mechanical characteristics change with the material embrittlement occurring most intensely. This results in the initiation and propagation of fatigue cracks, which under heavy load conditions of truck operation cause early failure of this most critical part of the suspension assembly.

IV.MATERIAL PROPERTIES OF LEAF SPRING

The elements whose weight is not transmitted to the suspension spring are called the un-sprung elements of the automobile. This includes wheel assembly, axles, and part of the weight of suspension spring and shock absorbers. The leaf spring accounts for 10-20% Of the un-sprung weight.

Parameter	Value
Material selected	Structural steel
Young's Modulus, E	2.1×10^5 N/mm ²
Poisson's Ratio	0.266
BHN	400-425
Tensile strength Ultimate	1272MPa
Tensile strength Yield	1158MPa
Spring Stiffness	221.5N/mm
Normal Static loading	6388Kgf
Density	0.00000785Kg/mm ³
Behaviour	Isotropic

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DEMERITS OF CONVENTIONAL LEAF SPRING

- They have less specific modulus and strength.
- Increased weight.
- Conventional leaf springs are usually manufactured and assembled by using number of leaves made of steel and hence the weight is more.
- Its corrosion resistance is less compared to composite materials.
- Steel leaf springs have less damping capacity.

COMPOSITE LEAF SPRING

The composite materials made it possible to reduce the weight of machine element without any reduction of the load carrying capacity. Because of composite material's high elastic strain energy storage capacity and high strength-to-weight ratio compared with those of steel .FRP springs also have excellent fatigue resistance and durability.



It can be easily observed that material having lower modulus and density will have a greater specific strain energy capacity. Hence, composite material becomes a very strong candidate for such applications. The introduction of composite materials has made it possible to reduce the weight of leaf spring without any reduction on load carrying capacity. Hence, steel leaf springs are being replaced by composite leaf springs.

The replacement of steel with optimally designed composite leaf spring can provide 92% weight reduction. Moreover the composite leaf spring has lower stresses compared to steel spring. All these will result in fuel saving which will make countries energy independent because fuel saved is fuel produced composite leaf springs.

MERITS OF COMPOSITE LEAF SPRING

- Reduced weight.
- Due to laminate structure and reduced thickness of the mono composite leaf spring, the overall weight would be less.
- Due to weight reduction, fuel consumption would be reduced.
- They have high damping capacity; hence produce less vibration and noise.
- They have good corrosion resistance.
- They have high specific modulus and strength.
- Longer fatigue life

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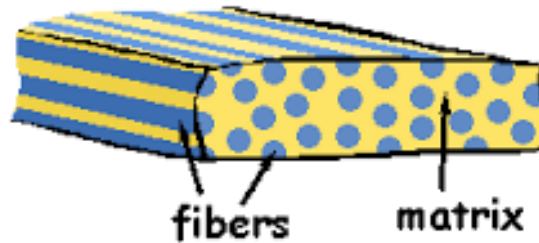
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COMPOSITES:

Composites are one of the most widely used materials because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and exhibit desirable properties.

The strength-weight ratio is higher than other materials. Their stiffness and cost-effectiveness offered, apart from easy availability of raw materials, make them the obvious choice for applications in surface transportation.

a close-up of what
a composite might
look like



MATERIAL PROPERTIES OF E-GLASS/EPOXY:

Material properties of e-glass/epoxy

The most crucial parameter is weight reduction as it directly affects efficiency, payload and the economy. Durability is the chief factor as these vehicles are normally realizations of capital investments.

The matrix material used with fibre glass, however, limits its use to low temperatures, usually below 121°C, although it is not a debilitating limitation for the fibre, as its properties can still be used and maintained at temperatures beyond 426 to 482°C.

The principal design criterion for transport vehicles involves conditions that the structural weight must be minimized to conserve raw material, tribological factors and at the same time remain the least polluting. The lifetime should be long and reliable. Reliability should be considerably improved to conserve materials and reduce maintenance costs. Designs should be considered giving importance to fatigue and fracture resistance.

Sl.N	Properties	Value
1	(Ex), MPa	34000
2	(Ey), MPa	6530
3	(Ez), MPa	6530
4	Tensile strength Mpa	900
5	Compressive strength, Mpa	450
6	(Gxy), Mpa	2433
7	(Gyz), Mpa	1698
8	(Gzx), Mpa	2433
9	(Nuxy)	0.217
10	(NUyz)	0.366

FIBER REINFORCED POLYMER (FRP) COMPOSITES:

Fibre reinforced plastic (FRP) (also fibre-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibres. The fibres are usually glass, carbon, aramid, or basalt. Rarely, other plastic material without fibre reinforcement is known as the matrix. The matrix is a tough but relatively weak plastic that is reinforced by stronger stiffer reinforcing filaments or fibres.

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Composite & steel leaf springs

Highly aggressive environmental conditions have a significant effect on the durability and structural integrity of steel. Corrosion of steel rods is a potential cause for the structural damage of the leaf springs. In a new approach, FRPs are now being used as alternative for steel the mechanism of FRP confinement is explained in the following section.

2.5. APPLICATIONS:

Fibre reinforced plastics are best suited for any design program that demands weight savings, precision engineering, finite tolerances, and the simplification of parts in both production and operation. A moulded polymer artefact is cheaper, faster, and easier to manufacture than cast aluminium or steel artefact, and maintains similar and sometimes better tolerances and material strengths.

V.METHODOLOGY

The suspension leaf spring is one of the potential items for weight reduction in automobile as it accounts for ten to twenty percent of the unsprung weight. The introduction of composites helps in designing a better suspension system with better ride quality if it can be achieved without much increase in cost and decrease in quality and reliability

More elastic strain energy storage capacity and High strength-to-weight ratio. Considering various factors related with leaf spring, the literature was studied. The data generated by various researchers was collected and various factors were analysed. Testing of leaf spring was done in order to get the practical performance result of leaf spring. Bending stress, deflection, safety factor, fatigue strength were studied.

VI.MODELING

DESIGN SELECTION:

The leaf spring behaves like a simply supported beam and the flexural Analysis is done considering it as a simply supported beam. The simply supported beam is subjected to both bending stress and transverse shear stress.

Constant Thickness, Varying Width Design: In this design the thickness is kept constant over the entire length of the leaf spring while the width varies from minimum at the two ends to a maximum at the centre.

Constant Width, Varying Thickness Design:

In this design the width is kept constant over the entire length of the leaf spring while the thickness varies from minimum at the two ends to a maximum at the centre.

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Constant Cross-Selection Design:

In this design both thickness and width are varied throughout the leaf spring such that the cross section area remains constant along the length of the leaf spring. Since the cross-section area is constant throughout the leaf spring, same quantity of reinforcement fibre and resin can be fed continuously during manufacture

The constant cross section design method is selected due to its capability for mass production and accommodation of continuous reinforcement of fibres.

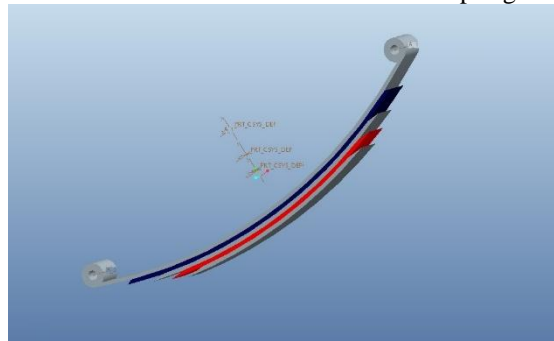
ASSUMPTIONS

- All non-linear effects are excluded.
- The stress-strain relationship for composite material is linear and elastic; hence Hooke's law is applicable for composite materials
- The load is distributed uniformly at the middle of the leaf spring.
- The leaf spring has a uniform, rectangular cross section.

GEOMETRY MODELING

In this study the design was done and the model was prepared in the PRO-E 5.0 software. The three dimensional model was exported in the ANSYS workbench 14.5. The model was fixed to its boundary condition. The meshing was done on the model. The model was loaded with the load at its central point, the stressed parts of the leaf spring which is subjected under the full load shows equivalent stress. The assembled model of leaf spring is shown below

Total Length of the sprin	830 mm
Free Camber (At no load)	83mm
No. of full length leave (01
Thickness of leaf	8mm
Width of leaf spring	60mm
Maximum Load given on	4900N
Weight of the leaf spring	15.6372



Assembly model of leaf spring

DIMENSIONS OF THE LEAF SPRING

The assembly model is imported into ansys workbench

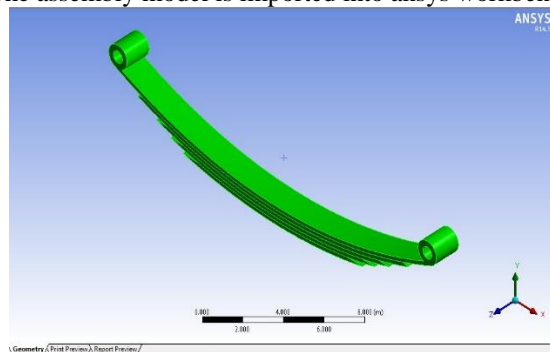


Fig 7: Imported geometry

Setting up contact points & boundary conditions:

Contact points & boundary conditions are set for the leaf spring model

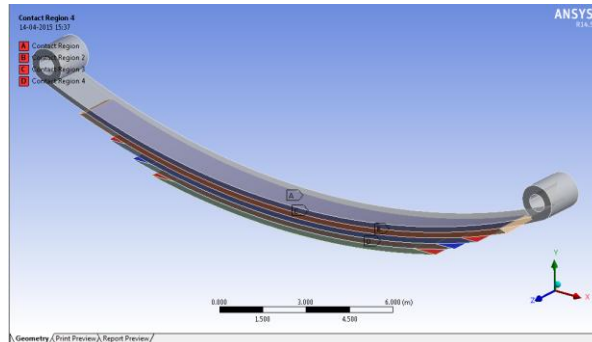


Fig 8: Contact points

MESHING:

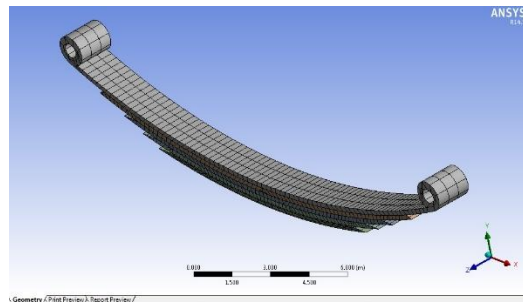


Fig 9: meshing of leaf spring

POST PROCESSING

In order to validate the design parameters, FEA is performed using ANSYS Workbench 14. One side of the model is completely fixed (cantilever) and the free end is subjected to a force of in vertically downward direction. A maximum load of 4900N is applied at the central point on the final layer of leaf spring.

Leaf no	Full leaf length (mm) 2L	Half leaf length(mm) L	Radius of curvature R (mm)
1	830	415	1078
2	714	357	1086
3	578	286	1094
4	490	245	1102
5	412	206	1110

Equivalent (von- misses) stress:

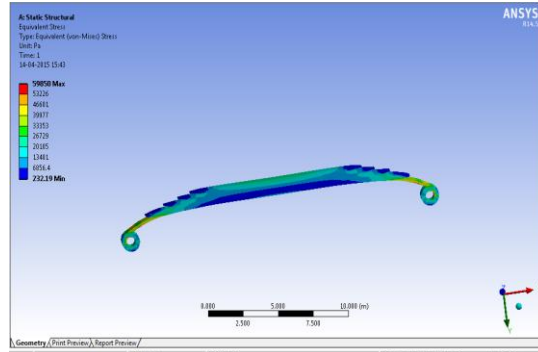


Fig 10: Equivalent (von- misses) stress

Equivalent elastic strain

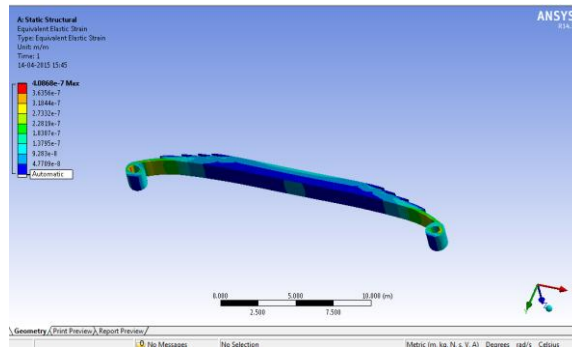
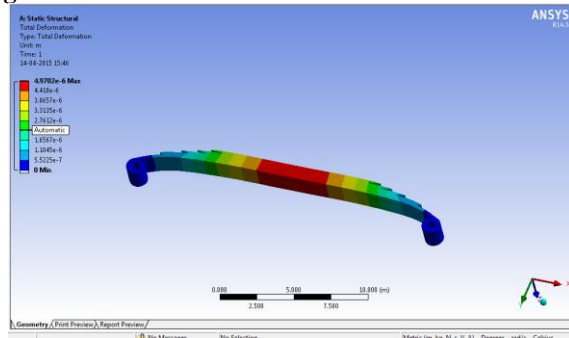


Fig 11: Equivalent elastic strain

Total deformation of leaf spring:



VII.CALCULATIONS

Design of Leaf Spring

Considered Data:

Material: structural steel

Leaf Spring Length (L) = 830mm

Leaf Spring Width (b) = 060mm

Leaf Spring Thickness (t) = 08mm

Unladen Weight = 655Kg (approx.)

Laden Weight = 1000kg (approx.)

Factor of Safety (FOS) = 2

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No. of Leaf = 1
Acceleration Due To Gravity (g) = 9.8m/s

Analytical Calculation:

Load Calculation:

Maximum Load (F) = Laden Weight x FOS x g ÷ No. of Wheels
= 1000 x 2 x 9.8 ÷ 4
Maximum Load (F) = 4900 N

Stress Calculation:

Maximum Stress (σ_{max}) = $6FL \div nbt^2$
[From PSG Design Data Book Page No: 7.104]
= $(6 \times 4900) \times 830 \div (1 \times 60 \times 8^2)$

Maximum Stress (σ_{max}) = 700.5 N/mm²

Weight Calculation:

Let us consider the weight of single leaf

Mass = Density x (n x Length x Width x Thickness) kg

Weight of steel spring = 7850 (0.830 x 0.060 x 0.008) = 3.12744 kg

Weight of E-Glass/Epoxy spring = 2600 (0.965 x 0.045 x 0.030) = 1.03584kg

% of Less Weight = $100 - \left(\frac{\text{Wt. of E-Glass/Epoxy Leaf Spring}}{\text{Wt. Of Steel Leaf Spring}} \right) \times 100$
= $100 - (1.0358 \div 3.12744) \times 100 = 66.87\%$

VIII.RESULTS

To design composite leaf spring, a stress analysis was performed using the finite element method done using ANSYS software. Modelling was done for every leaf. Also, analysis is carried out for composite leaf spring with bonded end joints for Glass/Epoxy.

It is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications. The maximum and shear stresses along the bonded adhesive layer for glass/epoxy were measured and plotted

Table 5: Comparison of Steel and Composite structure

Parameter	FEA results for steel	FEA results for composite	Variation %
Load (N)	4900	4900	Nil
Deflection (mm)	21.774	16.30797	-25.10%
Bending stress	116.4196	41.8194	-64.07%
Stiffness (N/mm)	57.4388	76.695	25.11%
Mass (Kg)	15.6372	5.1792	-66.87%

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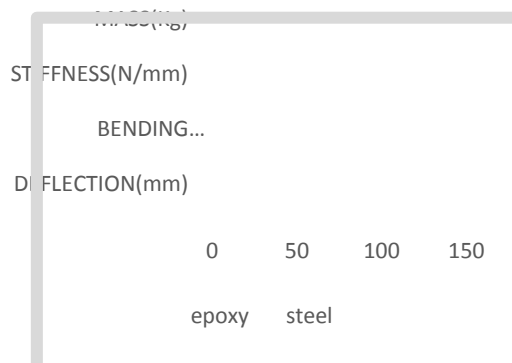


Chart 1: Comparison of results

IX.CONCLUSION

The development of a composite leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective.

The study demonstrated that composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings.

The 3-D modelling of composite leaf spring is done and analysed using ANSYS A comparative study has been made between composite and steel leaf spring with respect to weight, cost and strength.

From the results, it is observed that the composite leaf spring is lighter and more economical than the conventional steel spring with similar design specifications. Composite leaf spring reduces the weight by 67 % for E-Glass/Epoxy, over conventional leaf spring.

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