DESIGN AND ANALYSIS OF A COMPOSITE LEAF SPRING

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Abstract

A leaf spring is a simple form of spring, commonly used for the suspension in wheeled vehicles. Leaf springs are long and narrow plates attached to the frame of a trailer that rest above or below the trailer's axle. For safe and comfortable riding, to prevent the road shocks from being transmitted to the vehicle components and to safeguard the occupants from road shocks it is necessary to determine the maximum safe stress and deflection. The objective is to find the stresses and deformation in the leaf spring by applying static load on it. Here for design model Mahindra “Model - commander 650 di” light vehicle are taken. Different materials with different mechanical properties are considered for the structural static analysis. Therefore in the present work, leaf spring is designed by considering static load on vehicle. The model of leaf spring is created in solid works with three different thickness 4mm, 5mm and 6mm and analysis is done using ansys 14.5 workbench with three different materials such as Carbon epoxy, Carbon steel E-glass epoxy. Thus the structural analysis is carried out at 6685N force and stress, strain, maximum shear stress and total deformation values found out.

Key words: leaf spring, solid works, ansys workbench 14.5, carbon steel, carbon epoxy, E glass epoxy.

1. INTRODUCTION:

A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. The center of the arc provides location for the axle, while tie holes are provided at either end for attaching to the vehicle body. For very heavy vehicles, a leaf spring can be made from several leaves stacked on top of each other in several layers, often with progressively shorter leaves. Leaf springs can serve locating and to some extent damping as well as springing functions. While the interleaf friction provides a damping action, it is not well controlled and results in station in the motion of the suspension. For this reason some manufacturers have used mono-leaf springs.

Figure 1. Leaf spring

2. OBJECTIVE

- The objective of the present work is to design, analyze and propose a method of fabrication of composite mono-leaf spring for automobile suspension system. This is done to achieve the following
- this design helps in the replacement of conventional steel leaf springs with composite mono-leaf spring with better ride quality.
- To achieve substantial weight reduction in the suspension system by replacing steel leaf spring with mono composite leaf spring.

3. LITERATURE REVIEW

G.h. goud and e V. Goud explained the modeling and design of leaf spring, used in automobile suspension systems. Static analysis determines the safe stress and corresponding pay load of the leaf spring and also to study the behavior of structures under practical conditions. The present work attempts 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. In computer-aided design, geometric modeling is concerned with the computer compatible mathematical description of the geometry of an object. Static analysis is performed to find the von-mises stress by using ansys software and these results are compared with bending stresses calculated in mathematical analysis at various loads. It is concluded that for the given specifications of the leaf spring, the maximum safe load is 7700n. It is observed that the maximum stress is developed at the inner side of the eye sections, so care must be taken in eye design and fabrication and material selection. The selected material must have good ductility, resilience and toughness to avoid sudden fracture for providing safety and comfort to the occupants.

4. TRANSVERSE LEAF SPRING AND SOLID AXLE FRONT SUSPENSION OF EARLY CARS

The configuration consists of a one-piece axle (solid front axle), to the ends of which the steerable front wheels are mounted. The axle receives its vertical and transverse support from a transverse leaf spring (leaf springs were often used for support in more than one direction), and its longitudinal support from fore-aft links sometimes called "radius rods" which are attached (via pivots) to the ends of the axle at their forward end and to the sides of the chassis (again via pivots) at their aft end. The ends of the transverse leaf spring can either tie to the top of the rods, or to the top of the solid axle. The transverse leaf spring is attached at its center to the center of the chassis's front cross member.

Advantages and disadvantages:

In addition to simplicity lightness and compact shape, at least in some directions, since only the small end of the spring was attached to the wheel, it gave low un sprung weight. In addition to its contribution to ride and handling, this reduced wheel bearing loads and therefore allowed smaller cheaper bearings.

5. WEIGHT TRANSFER IN LEAF SPRING SUSPENSION SYSTEM

Weight transfer during cornering, acceleration or braking is usually calculated per individual wheel and compared with the static weights for the same wheels.

The total amount of weight transfer is only affected by four factors: the distance between wheel centers (wheelbase in the case of braking, or track width in the case of cornering) the height of the center of gravity, the mass of the vehicle, and the amount of acceleration experienced.

UN sprung weight transfer

Un sprung weight transfer is calculated based on the weight of the vehicle's components that are not supported by the springs. This includes tires, wheels, brakes, spindles, half the control arm's weight and other components. These components are then (for calculation purposes) assumed to be connected to a vehicle with zero sprung weight.

Sprung weight transfer

Sprung weight transfer is the weight transferred by only the weight of the vehicle resting on the springs, not the total vehicle weight. Calculating this requires knowing the vehicle's sprung weight (total weight less the un sprung weight), the front and rear roll center heights and the sprung center of gravity height (used to calculate the roll moment arm length). Calculating the front and rear sprung weight transfer will also require knowing the roll couple percentage.

Demerits of conventional leaf spring ([1], [4],][5],[7]..)

They have less specific modulus and strength.

- Increased weight.
- Conventional leaf springs are usually manufactured and assembled by using number of leafs 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.

Merits of composite leaf spring [1-13]

- 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.

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 leaf spring is assumed to be in vacuum.
- The load is distributed uniformly at the middle of the leaf spring.
- The leaf spring has a uniform, rectangular cross section

6. Basic concepts of composite materials

Composite materials are basically hybrid materials formed of multiple materials in order to utilize their individual structural advantages in a single structural material. The constituents are combined at a macroscopic level and are not soluble in each other. The key is the macroscopic examination of a material wherein the components can be identified by the naked eye.

Fibers:

Fibers are the principal constituent in a fiber-reinforced composite material. They occupy the largest volume fraction in a composite laminate and share the major portion of the load acting on a composite structure. Proper selection of the type, amount and orientation of fibers is very important, because it influences the following characteristics of a composite laminate.

- Specific gravity
- Tensile strength and modulus
- Compressive strength and modulus
- Fatigue strength and fatigue failure mechanisms
- Electric and thermal conductivities
- Cost

The various types of fibers currently in use are

- Glass Fibers
- Carbon Fibers
- Aramid Fibers
- Boron Fibers

7. MODELING OF LEAF SPRING

Specifications Of Design Data

- Here Weight and initial measurements of Mahindra “Model - commander 650 di” light vehicle are taken.
  Gross 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/s^2
  There for; Total Weight (W) = 1910*10*1.4 =26740N
  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
- Here we modeled leaf spring of three different thickness values they are 4mm, 5mm, 6mm.

Design parameters of leaf spring:

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

Design parameters of leaf spring:

Leaf no.	Full leaf length (mm) 2L	Half leaf length(mm) L	Radius of curvature R (mm)
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

Fig 2. Design parameters of leaf sprigs

Design model of leaf spring by using various features in solid woks part modeling

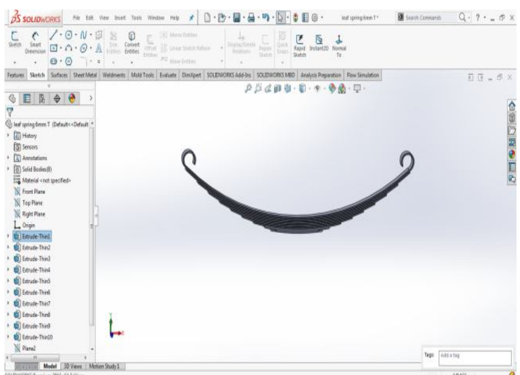


Fig 3. Leaf spring model 6mm

5mm thickness model

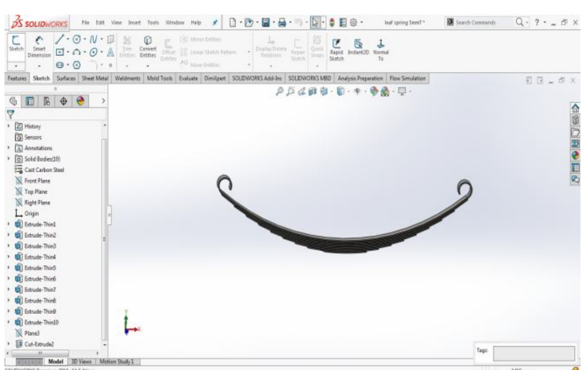


Figure4. Leaf spring model 5mm

4m thickness model

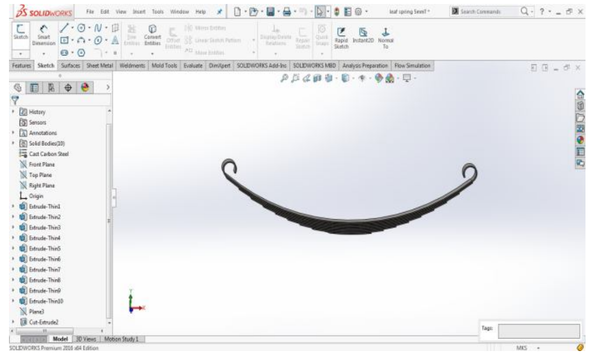


Figure5. Leaf spring model 4 mm

MATERIAL PROPERTIES

Material	Density(kg/m^3)	Young's modulus(MPa)	Poison's ratio	Tensile yield strength(MPa)
Carbon epoxy	1600	1.4e005	0.3	1900
Carbon steel	7840	2.1e005	0.33	8.e-004
e-glass epoxy	2600	0.8e005	0.23	2050

Figure 6. Material properties

8. FINITE ELEMENT ANALYSIS

Introduction

finite element analysis (fea) is a computer-based numerical technique for calculating the strength and behaviour of engineering structures. It can be used to calculate deflection, stress, vibration, buckling behaviour and many other phenomena. It also can be used to analyze either small or largescale deflection under loading or applied displacement. It uses a numerical technique called the finite element method (fem). In finite element method, the actual continuum is represented by the finite elements. These elements are considered to be joined at specified joints called nodes or nodal points. As the actual variation of the field variable (like displacement, temperature and pressure or velocity) inside the continuum is not known, the variation of the field variable inside a finite element is approximated by a simple function. The approximating functions are also called as interpolation models and are defined in terms of field variable at the nodes. When the equilibrium equations for the whole continuum are known, the unknowns will be the nodal values of the field variable.

Static analysis

Static analysis deals with the conditions of equilibrium of the bodies acted upon by forces. A static analysis can be either linear or non-linear. All types of non-linearity's are allowed such as large deformations, plasticity, creep, stress stiffening, contact elements etc. This chapter focuses on static analysis. A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those carried by time varying loads.

9. STRUCTURAL ANALYSIS ON LEAF SPRING

First leaf spring solid works part is converted to igs file to import in ansys software

Thus the analysis is carried out with three different materials for leaf spring containing three different thicknesses

The model is fixed at bottom surface of the leaf spring

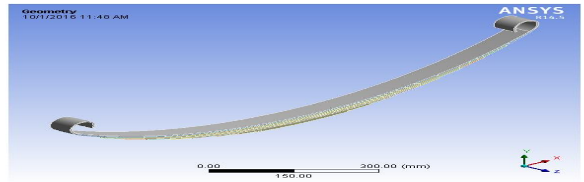


Figure7. Fixed support model

Fine mesh is applied on the leaf spring model

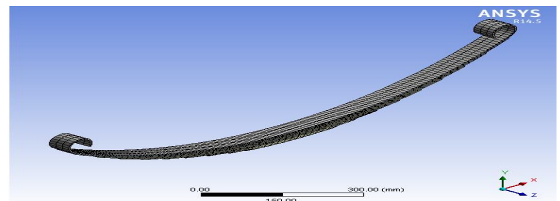
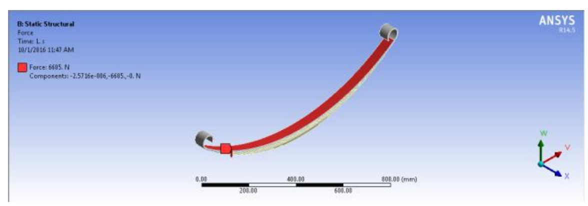


Figure8. Mesh support

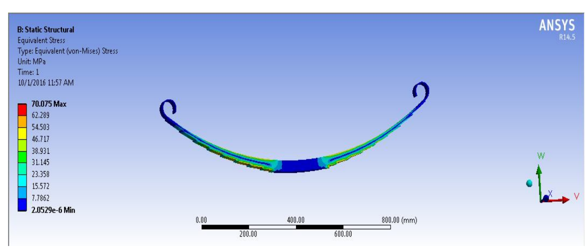
Compressive loads are applied on the leaf spring

Load 6685N

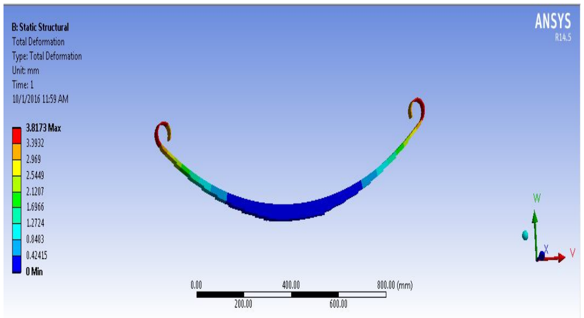


Material: carbon epoxy, thickness 6mm

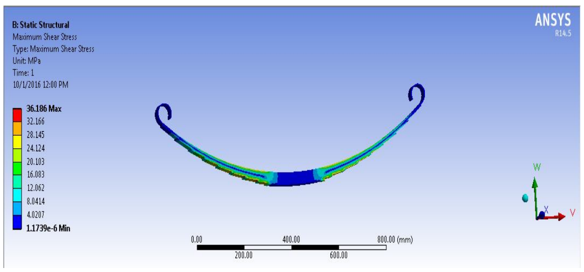
Maximum stress



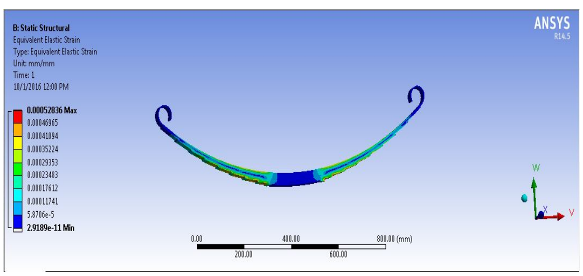
Total deformation



Maximum shear stress

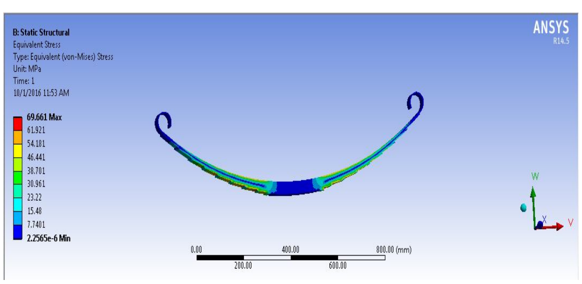


Maximum strain

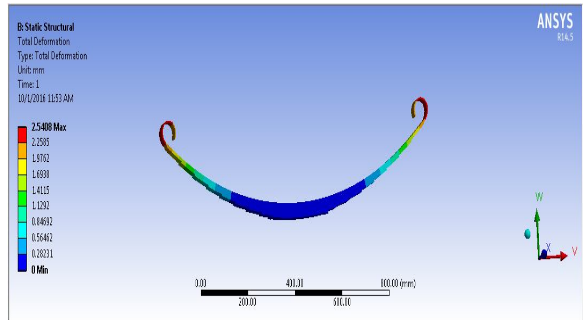


Material: carbon steel

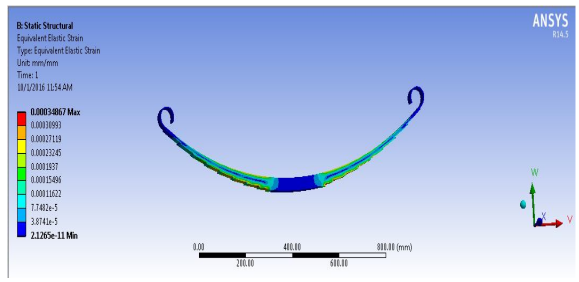
Max stress



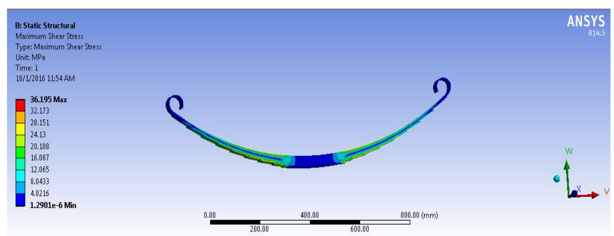
Total deformation



Maximum strain

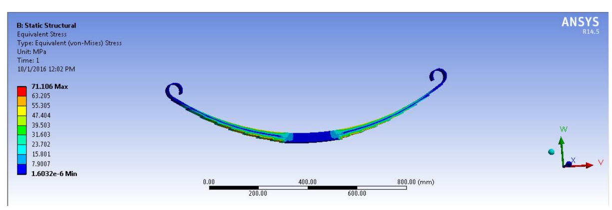


Maximum shear stress

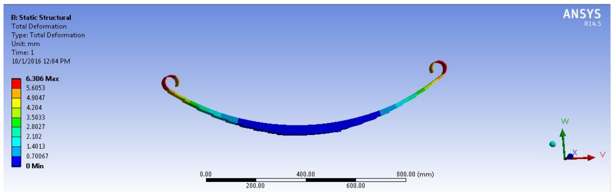


Material: e-glass epoxy

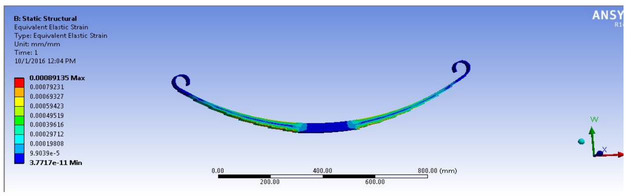
Maximum stress



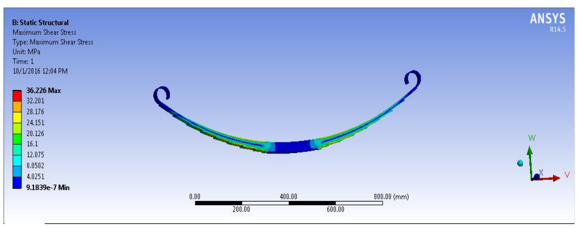
Total deformation



Maximum strain



Maximum shear stress



10. RESULTS

Structural analysis tables results for 4mm thickness model

Material	Max stress	Total deformation	Max strain	Max shear stress
Carbon epoxy	70.075	3.8173	0.00052836	36.186
Carbon steel	69.6661	2.5408	0.00034867	36.195
E-glass epoxy	71.106	6.306	0.00089135	36.226

Table1. Analysis results for 4mm thickness model

5mm thickness model

Material	Max stress	Total deformation	Max strain	Max shear stress
Carbon epoxy	43.53	1.9667	0.0003263	22.556
Carbon steel	43.373	1.3091	0.00021515	22.438
E-glass epoxy	44.959	3.2485	0.00055131	22.888

Table2. Analysis results for 5mm thickness model

6mm thickness model

Material	Max stress	Total deformation	Max strain	Max shear stress
Carbon epoxy	30.852	1.1587	0.00026096	16.25
Carbon steel	30.444	0.77134	0.00017186	15.99
E-glass epoxy	31.799	1.9134	0.00044223	16.845

Table3. Analysis results for 6mm thickness models

11. CONCLUSION

- Design and analysis of leaf spring is done
- Modeling of leaf spring is done in solid works 2016 design software
- First 4mm thickness leaf spring then 5 and 6 mm thickness are modeled
- The models are saved as igs files to import in ansys
- Structural analysis is carried out in ansys by applying three different materials such as carbon epoxy, carbon steel and e-glass epoxy at load 6685n force is applied on leaf spring for three different thickness leaf springs
- The material properties of the above materials are studied

- From the results we can conclude that already 6mm thickness is existing by we reduced it to 5mm and 4mm by varying the thickness reduction in weight occurred from the analysis carbon steel material for 5mm thicknesss is showing less stress compared to 4mm thickness leaf spring

- Leaf spring containing 4mm thickness undergone maximum stress though the weight reduction is maximum but stability to oppose the load is low but 5mm thickness leaf spring got the values nearer to 6mm and it has low weight compared to 6mm leaf spring

- Hence we can conclude that the leaf spring containing 5mm thickness applied with carbon steel material is showing best results.

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