VIRTUAL ANALYSIS OF COMPOSITE MATERIAL LEAF SPRING

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Abstract—*Structural analysis of leaf spring using different composite materials in light commercial vehicle. Leaf springs are unique kind of springs used in vehicle suspension systems. The benefit of 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 to energy absorbing machine. The main function of leaf spring is not only to bear vertical load but also to isolate road induced vibrations. A typical leaf spring configuration of TATA-ACE light commercial vehicle is chosen for study. Finite element analysis has been carried out to find out the safe stresses and pay loads. The prologue of composite materials has made it likely to diminish the weight of the leaf spring without any diminution in load carrying capability and stiffness. Leaf spring is modeled in CATIA V5 R20 software and it is imported in ANSYS workbench 14.5. The conventional steel leaf spring and the composite leaf spring were examined under parallel conditions using ANSYS software and the outcome are Stresses, deflection and strain energy results for both steel and composite leaf spring material were obtained..*

Key Words: **composite materials, leaf spring, steel, stresses, deflection**.

1. INTRODUCTION

A leaf spring is a plain type of spring generally used for the suspension in wheeled automobiles. Initially called a laminated or carriage spring, and occasionally referred to as a semi-elliptical spring or cart spring, it is one of the oldest types of springing, dating back to medieval times.

The shape of leaf spring is the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most general pattern the center of the arc provides location for the axle, either end for joining to the automobile body is provided with tie holes. For weighty vehicles, a leaf spring can be made from several leaves piled on top of each other in several layers, often with progressively smaller leaves. Leaf springs can serve locating and to some extent damping as well as bouncing purposes. While the interleaf friction provides a damping action, it is not well controlled and results in stiction in the motion of the suspension. For this reason some companies have used mono-leaf springs.

A leaf spring can either be joined directly to the frame at both ends or attached directly at one end, usually the front, with the other end joined through a shackle, a short swinging arm. The shackle takes up the leaning of the leaf spring to stretch when compressed and thus makes for flexible springiness. To carry a swiveling member some springs terminated in a concave end, called a spoon end.

Finite Element analysis tools offer the marvelous advantage of enabling design teams to consider essentially any casting option without incurring the expenditure associated with built-up and machine time. The capability to try new designs or models on the computer gives the chance to reduce problems before initiating production. Additionally, designers can rapidly and with no trouble find out the sensitivity of specific molding constraints on the quality and production of the ultimate part. The leaf spring replica is formed by CatiaV5R20, pro-E or any of the modeling software and it is imported in to the analysis software and the boundary conditions, the loading conditions are given to the imported model and result are calculated by post processor. The results of steel leaf spring and composite leaf spring are obtained to forecast the advantages of composite leaf spring for an automobile.

The leaf spring should take up the vertical vibrations and impacts due to road abnormality by means of differences 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 potential of a leaf spring ensures a more yielding suspension system. For a leaf spring material with minimum modulus of elasticity and maximum strength and in the longitudinal direction is the most appropriate. Luckily, composites have this distinctiveness. Fatigue failure is the major mode of in-service breakdown of many vehicle elements. This is due to the reality that the vehicle parts are subjected to mixture of fatigue loads like shocks caused due to road abnormality traced by the road wheels, the sudden loads due to the wheel moving over the bump etc. The leaf springs are more influenced due to fatigue loads, as they are a part of the unstrung mass of the vehicle..

2. MATERIALS

The materials commonly used for designing a leaf spring are, chromium vanadium steel, chromium-nickel-Molybdenum steel, plain carbon steel, silicon-manganese steel. The materials selected for steel leaf spring is 65Si7.

Table -1: STEEL (65SI7)

Density(ρ) Kg/m3)	7860
Young's modulus, Mpa	2.1e5
Poisons ratio	0.266
Tensile strength (Mpa)	500
Tensile ultimate strength (Mpa)	800

2.1 Composite Materials

A composite material is defined as a material created of two or more ingredients combined on a macroscopic level by mechanical and chemical bonds. Composites are mixture of two substance in which one of the substance is known as the matrix phase is in the form of sheets, fibers, or particles and is implanted in the other substance say the reinforcing phase. Numerous composite materials propose a combination of strength and modulus that are either equivalent to or superior than any conventional metallic metals. Modulus to weight-ratios and the strength to weight-ratio of these composite materials are markedly higher to those of metallic materials Because of their low specific gravities. Fatigue damage tolerances and the fatigue strength weight ratios of several composite laminates are exceptional. For these explanations, fiber composite have emerged as a main class of structural substance and are either used or being considered as replacements for metal in many weight-critical parts in automotive, aerospace, and other industries. High internal damping capacity is another unique feature of numerous fiber reinforced composites. This leads to enhanced vibration energy inclusion within the material and results in reduced transmission of noise to adjacent structures.

Table -2: carbon fiber/E-poxy material properties:

S. N	Properties	Valve
1	Tensile modulus along X-direction(EX), Mpa	62000
2	Tensile modulus along Y-direction(EY), Mpa	48000
3	Tensile modulus along Z-direction(EZ), Mpa	48000
4	Tensile strength of the material, Mpa	1830
5	Shear modulus along XY-direction(Gxy),Mpa	3270
6	Shear modulus along YZ-direction(Gyz),Mpa	3270
7	Shear modulus along ZX-direction(Gzx),Mpa	1860
8	Poisson ratio along XY-direction(NUxy)	0.22
9	Poisson ratio along YZ-direction(NUyz)	0.22
10	Poisson ratio along ZX-direction(NUzx)	0.30
11	Mass density of the material (ρ),Kg/mm3	1580

Table -3: Material properties of E-glass /E-poxy

S. N	Properties	Valve
1	Tensile modulus , Mpa	40000
2	Tensile strength of the material, Mpa	900
3	Compressive strength,Mpa	450
4	Poisson ratio	0.217
5	Mass density of the material (ρ),Kg/m3	2600

AlBeMet (Beryllium aluminum):

AlBeMet is the trade name for a beryllium and aluminum metal matrix composite derived by a powder metallurgy process.

AlBeMet is produced by hot consolidating gas atomized prealloyedfine particles. Each powder particle includes aluminum between beryllium dendrites producing a homogeneous microstructure. Aluminum-beryllium metal matrix composite merged the fabrication and mechanical property behaviors of aluminum with the high modulus and low density characteristics of beryllium.

In aerospace and satellite applications Be-Al alloys are used due to weight advantage.

Physical properties:

AlBeMet have High modulus-to-density ratio 3.8 times that of aluminum or steel reduces the chance of mechanically induced failure and minimizes flexure.

Thermal conductivity of just about 210 W/mK exceed by about 25% that of general aluminum metal matrix composites such as Al 6061.

The composite structure of Polished AlBeMet displays considerable surface scatter inherent and it cannot be removed by optical polishing. (Usual surface roughness from an AlBeMet polished surface is in the 200-250 angstroms finish.) An amorphous coating such as electro less nickel is essential.

Table -4: AlBeMet

Density(ρ) Kg/m3)	2071
Young's moduls,Gpa	193
Poisons ratio	0.17
Tensile yield strength (Mpa)	332
Tensile ultimate strength (Mpa)	447

3. DESCRIPTION

Static Analysis Used to determine displacements stresses, etc. under static loading conditions linear static analyses. Nonlinearities can include hyper elasticity, contact surfaces, stress stiffening, plasticity, large deflection, large strain and creep.

The leaf spring modeled in CATIA V5 R20 was imported to ANSYS in IGES format. Leaf spring was modeled as a solid part, SOLID187 solid element was used to mesh the model. SOLID187 element is10-node and higher order 3-D element. SOLID187 has a quadratic displacement behavior and is well suited to modeling irregular. The element is defined by 10 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z directions. The SOLID187element has creep, stress stiffening, plasticity, hyper elasticity, large deflection, and large strain capabilities; the element input data also includes the orthotropic or anisotropic material properties.

TATA ACE light commercial vehicle:

GVW (weight) = 1550 kg

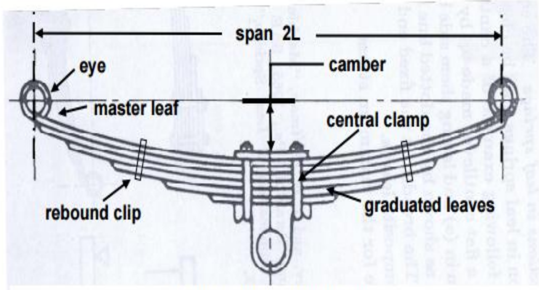
Maximum load capacity= 1000 kg

Total weight = 2550 kg

In single leaf = 25015.5 /4 = 6253.875 N

Span length 2L = 1540 mm

Uniform width leaf spring equation



Laminated semi-elliptic spring

Uniform width leaf spring:

$$\sigma_{max} = \frac{6FL}{bh^2}$$

E – The modulus of elasticity

L – The characteristic length of the spring.

F – Force applied to leaf spring

b - Width of leaf spring

h - Height or thickness of leaf spring

$$\delta_{max} = \frac{4FL^3}{Ebh^3}$$

Length of Leaf Spring Leaves:

The length of the leave springs are calculated by using the formulas given below. n = 5

Length of (n-1) the leaf = (Effective length /n -1) *(n-1) +Ineffective length

Where 2L1 = Length of span or overall length of the spring,

l=distance between centers of U-bolts (ineffective length (I.L) of the leaf spring),

nF= Number of full length leaves,

nG = Number of graduated leaves,

n = Total number of leaves = nF + nG,

E.L = Effective length of the spring = 2L1 – (2/3) l,

d = Inside diameter of eye and

t = Thickness of master leaf.

Table -5: Geometric properties of leaf spring:

S l.No .	Parameters	Dimensions (mm)
1	Total length of spring (eye to eye)	1540
2	Free camber (at no load condition)	136

3	No. of full length leave (master leaf)	1
4	Thickness of leaf	13
5	Width of leaf spring	70

4. ANALYSIS

4.1 Meshing

Mesh generation is one of the most vital aspects of engineering simulation. in addition many cells may result in elongated solver runs, and too few may lead to incorrect outcome. ANSYS Meshing tool supplies a way to balance these necessities and obtain the right mesh for each recreation in the most programmed way possible. ANSYS Meshing tools have been built on the strengths of stand-alone, class-leading meshing tools. The strongest aspects of these separate tools have been brought together in a single setting to generate some of the most dominant meshing obtainable.

The extremely automated meshing setting makes it easy to produce the subsequent mesh types:

- Cut cell Cartesian
- Body fitted Cartesian
- Hexahedral
- Hexahedral inflation layer
- Prismatic inflation layer
- Tetrahedral
- Hexahedral core

Constant user controls make toggling methods very directly forward and various methods can be used within the same replica. Mesh connectivity is maintained automatically.

Various physics need special meshing approaches. Fluid dynamics simulations want extremely high-quality meshes in both element shape and smoothness of sizes modify. Structural mechanics replication desires to use the mesh efficiently as run times can be prejudice with high element counts. ANSYS Meshing has a physics favorite setting make sure the correct mesh for each replication.

4.2 Boundary Conditions

The leaf spring is build up on the axle of the automobile; the ends of the leaf spring are in eye shape and the frame of the vehicle is linked to that ends. The front eye of the leaf spring is attached with a pin to the structure therefore the eye can spin freely concerning that pin but translation of front eye does not take placed. The shackle is fixed to the frame of vehicle and on that restrict the rear eye of the leaf spring is linked means this linkage is permanent.

4.3 SOLID186 Element Description:

SOLID186 is a advanced order 3-D 20-node solid element that display quadratic displacement performance. The element is distinct by 20 nodes having three degrees of freedom per node: translations in the nodal x, y, and z directions. The element supports hyper elasticity, creep, stress stiffening, large deflection, plasticity, and large strain ability. It also has miscellaneous formulation capability for replicate deformations of nearly incompressible elastoplastic materials, and entirely incompressible hyper elastic materials.

5. RESULT AND DISCUSSION

5.1.1 STEEL (60SI7) under 2000N load

Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 2000N is shown below in figure (1)

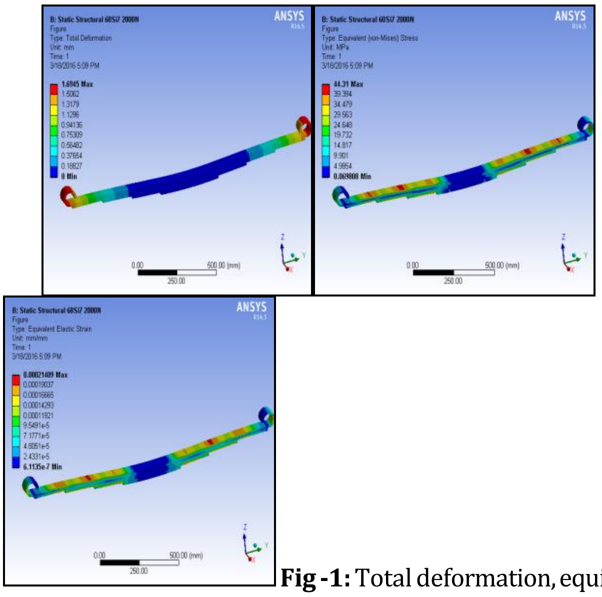


Fig -1: Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 2000N.

5.1.2 STEEL (60SI7) under 4000N load

Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 4000N is shown below in figure (2)

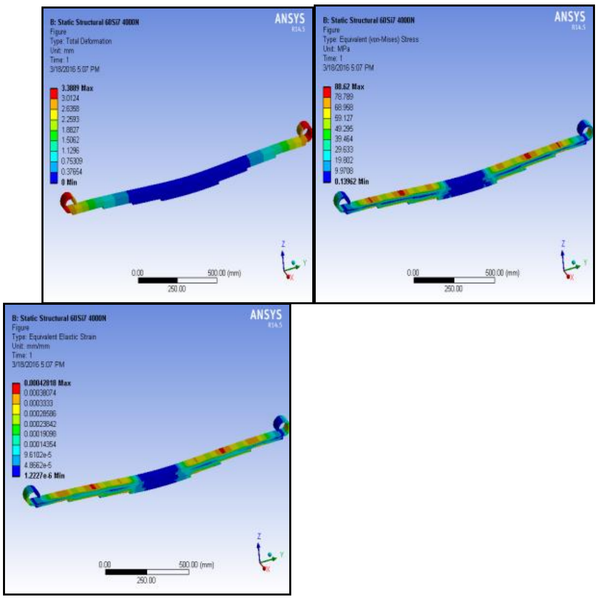


Fig -2: Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 4000N.

5.1.3 STEEL (60SI7) under 5000N load

Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 4000N is shown below in figure (3)

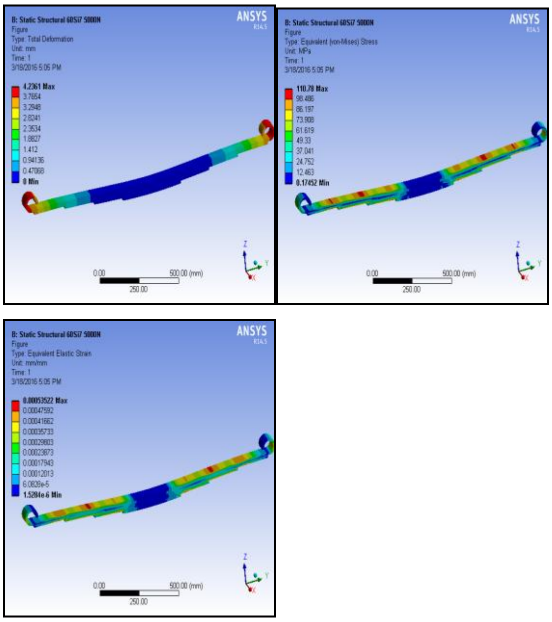


Fig -3: Total deformation, equivalent stress, equivalent elastic strain of steel (60SI7) for load equal to 5000N.

5.2.1 AlBeMet under 2000N load

Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 2000N is shown below in figure (4)

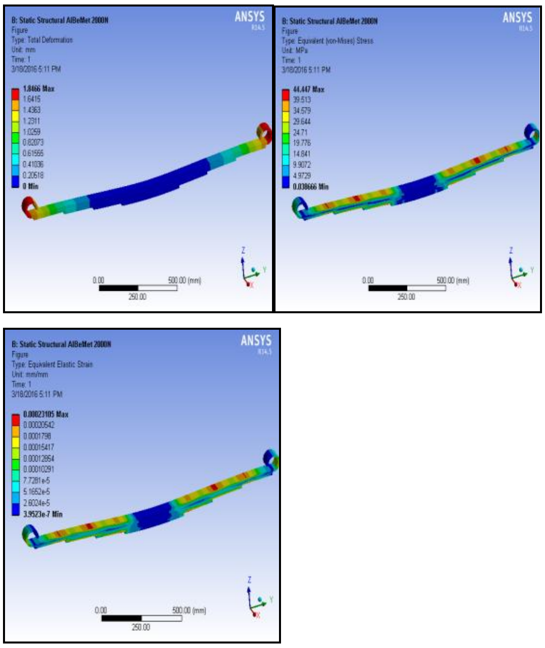


Fig -4: Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 2000N.

5.2.2 AlBeMet under 4000N load

Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 2000N is shown below in figure (5)

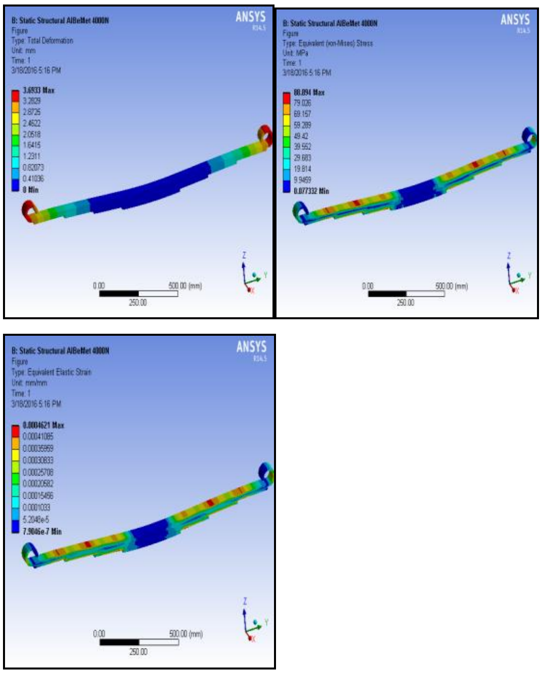


Fig -5: Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 4000N.

5.2.3 AlBeMet under 5000N load

Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 2000N is shown below in figure (6)

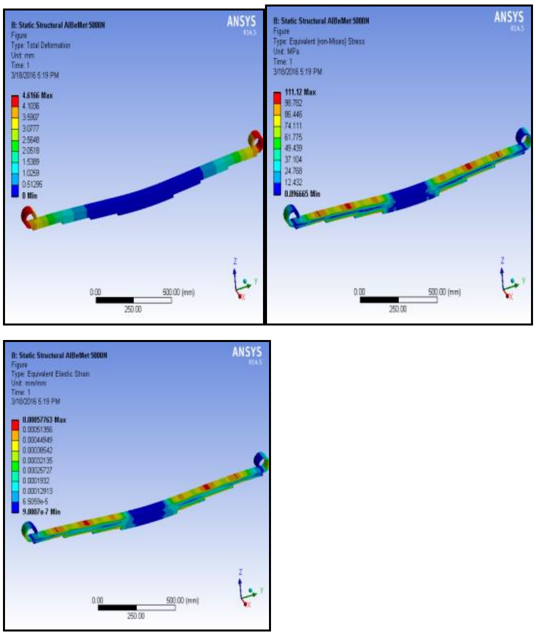


Fig -6: Total deformation, equivalent stress, equivalent elastic strain of AlBeMet for load equal to 5000N.

5.3.1 EGLASS/EPOXY under 2000N load

Total deformation, equivalent stress, equivalent elastic strain ofE-glass/Epoxy for load equal to 2000N is shown below in figure (7)

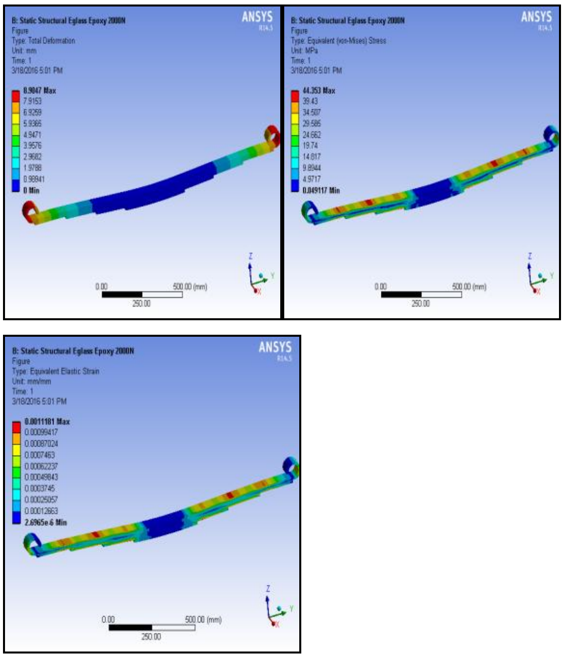


Fig -7: Total deformation, equivalent stress, equivalent elastic strain of E-glass/Epoxy for load equal to 2000N.

5.3.1 EGLASS/EPOXY under 4000N load

Total deformation, equivalent stress, equivalent elastic strain of E-glass/Epoxy for load equal to 4000N is shown below in figure (8)

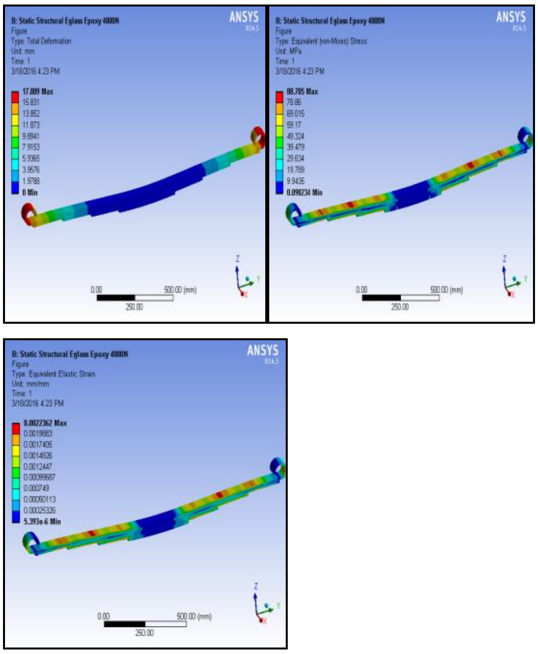


Fig -8: Total deformation, equivalent stress, equivalent elastic strain of E-glass/Epoxy for load equal to 4000N.

5.3.1 EGLASS/EPOXY under 5000N load

Total deformation, equivalent stress, equivalent elastic strain of E-glass/Epoxy for load equal to 5000N is shown below in figure (9)

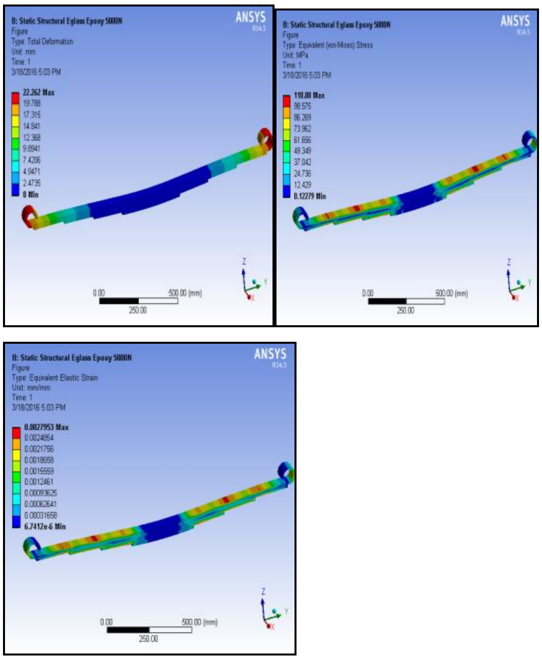


Fig -9: Total deformation, equivalent stress, equivalent elastic strain of E-glass/Epoxy for load equal to 5000N.

Result comparison of steel (60SI7), AlBeMet and E-Glass fiber epoxy under 2000N, 4000N and 5000N is shown in table 6, table 7 and table 8 respectively.

Table -6: Result comparison of steel (60SI7), AlBeMet and E-Glass fiber epoxy under 2000N.

	Steel (60Si7)	AlBeMet	E-Glass fiber epoxy
Load (N)	2000	2000	2000
Deflection (mm)	1.6945	1.8466	8.9047
Equivalent (von-mises) Stress(Mpa)	44.31	44.447	44.353
strain	0.00021409	0.00023105	0.011181
Mass (Kg)	41.59	10.9	13.759

Table -7: Result comparison of steel (60SI7), AlBeMet and E-Glass fiber epoxy under 4000N.

	Steel(60Si7)	AlBeMet	E-Glass fiber epoxy
Load (N)	4000	4000	4000
Deflection(mm)	3.3889	3.6933	17.809
Equivalent(von-mises)Stress(Mpa)	88.62	88.894	88.705
strain	0.00042818	0.0004621	0.0022362

Table -8: Result comparison of steel (60SI7), AlBeMet and E-Glass fiber epoxy under 5000N.

	Steel(60Si7)	AlBeMet	E-Glass fiber epoxy
Load (N)	5000	5000	5000
Deflection(mm)	4.2361	4.6166	22.262
Equivalent(von-mises)Stress(Mpa)	110.78	111.12	110.88
strain	0.00053522	0.00057763	0.0027953

6. CONCLUSION

The study verified that composites can be used for leaf springs for light weight vehicles and meet the necessities, together with significant weight savings. The 3-D modeling of both steel and composite leaf spring is done and analyzed. A relative study has been made between composite and steel leaf spring with respect to Deflection, strain energy and stresses. The 3-D modeling of composite leaf spring is done and analyzed using ANSYS. A relative study has been made between composite and steel leaf spring with respect to weight and strength. Under the same static load conditions the deflection and the stresses in the composite leaf springs and conventional steel leaf spring are found with huge variation. Deflection and Stresses in conventional steel leaf springs is found out to be more than composite leaf springs.

7. REFERENCES

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