Design and Analysis of Leaf Spring

Dr. Tankeshwar Prasad[1] | G Ram Kiran[1] | A Akilesh Gowd[1] | K G Pawan Kumar[1] | ChTharun Kumar[1]

[1]Department of Mechanical Engineering, Godavari Institute of Engineering and Technology(A), Rajahmundry.

Abstract: Increasing competition and innovation in automobile sector tends to modify the existing products by new and advanced material products.

A suspension system of vehicle is also an area where these innovations are carried out regularly. Leaf springs are one of the oldest suspension components that are being still used widely in automobiles.

Our aim is to design a Composite Leaf Spring which helps in reduction of weight and Better performance than Conventional Steel Leaf springs. Dimensions of the composite leaf spring are to be taken as same dimensions of the conventional leaf spring. The objective is to compare the bending stress, total deflection and percentage of weight saving of different types of composite materials such as steel, carbon epoxy, graphite epoxy, E-glass epoxy.

Modeling and analysis of a leaf spring is performed on Ansys workbench to determine total deflection and equivalent (von misses) stresses under loading conditions.

KEYWORDS:CAD/CAM, Ansys, Leaf spring,graphite epoxy, E-Glass epoxy, leaf springs, E-Glass epoxy ud

DOI of the Article: https://doi.org/10.46501/GIETME03

Available online at: http://ijmtst.com/vol7si05.html

As per UGC guidelines an electronic bar code is provided to seure your paper

To Cite this Article: Dr. Tankeshwar Prasad; G Ram Kiran; A Akilesh Gowd; K G Pawan Kumar and ChTharun Kumar. Design and Analysis of Leaf Spring. *International Journal for Modern Trends in Science and Technology* 2021, *7*, pp. 13-19. https://doi.org/10.46501/GIETME03

Article Info. Received: 12 June 2021; Accepted: 16 July 2021; Published: 20 July 2021

INTRODUCTION

Leaf springs also referred to as semi-elliptical springs or cart springs are one of the oldest forms of suspension used in vehicles, especially heavy vehicles. A leaf spring looks similar to a bow minus the string. It consists of a stack of curved narrow plates of equal width and varied length clamped together with shorter plates at the centre to form a semi-elliptical shape. The center of the arc provides location for the axle, tie holes are provided at either end for attaching to the body.

A leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles. Originally called alaminated or carriage spring, and sometime referred to as a semi elliptical spring or chart spring, it is one of the oldest forms of springing, dating backto medieval times. A leaf spring takes the form of a slender arc -shaped length offspring of rectangular cross-section. In the most common configuration, the center of the arc provides location for the Axle, while tie holes are provided at either end for attachingto 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.

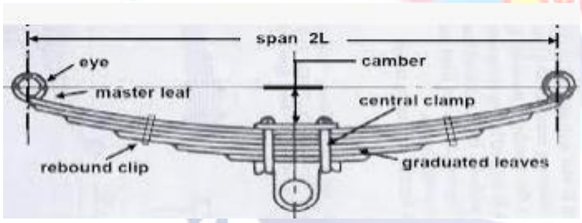


Fig 1 Schematic diagram of Leaf Spring

STRUCTURE OF PAPER

The paper is organized as follows in section 1 the introduction of the paper is provided along with the keywordsstructure, important terms, objectives and overall description.in section 2 we discussed related work.in section 3 we discussed design procedure of leaf spring.in section 4 we discussed analysis of leaf spring.in section 5 we discussed results of the analysis.in section 6 we discussed conclusion of analysi. In section 7 we discussed the references and websites used.

OBJECTIVES

The objective of the present work is to design, analyze and propose a method of fabrication of composite 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 composite leaf spring.

RELATED WORK

There were a variety of leaf springs, usually employing the word "elliptical". "Elliptical" or "full elliptical" leaf springs referred to two circular arcs linked at their tips. This was joined to the frame at the top center of the upper arc; the bottom center was joined to the "live" suspension components, such as a solid front axle. Additional suspension components, such as trailingarms, would usually be needed for this design, but not for "semi-elliptical" leaf springs as used in the Hotchkiss drive. That employed the lower arc, hence its name. "Quarter-elliptic" springs often had the thickest part of the stack of leaves stuck into the rear end of the side pieces of a short ladder frame, with the free end attached to the differential, as in the Austin Seven of the 1920s. As an example of non-elliptic leaf springs, the Ford Model T had multiple leaf springs over its differential that were curved in the shape of a yoke. As a substitute for dampers (shock absorbers), some manufacturers laid non-metallic sheets in between the metal leaves, such as wood.

Leaf springs where very common on automobiles, right up to the 1970s in Europe and Japan and late 1970s in America when the move to front wheel drive, and more sophisticated suspension design saw automobile manufacturers use coil springs instead. Today leaf springs are still used in heavy commercial vehicles such as vans and trucks, SUVs and railway carriages. For heavy vehicles, where as coil spring transfer it to a single point. unlike coil springs, leaf spring also locate the rear axle, eliminating the need for trailing arms and a pan hard rod, thereby Saving cost and weight in a simple live axle rear suspension. A further advantage of a leaf spring over a helical spring is that the end of the leaf spring may be guided along a definite path.

A more modern implementation is the parabolic leaf spring. This design is characterized by fewer leaves whose thickness varies from centre to ends following a parabolic curve. In this design, inter-leaf friction is unwanted, and therefore there is only contact between the springs at the ends and at the centre where the axle is connected.

ANSYS Workbench Overview

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.
ANSYS Workbench is comprised of five modules:

- Simulation for performing structural and thermal analyses using the ANSYS solver.
- CFX-Mesh for generating a CFX-Premesh for the CFX-5 solver.
- Design Modeler for creating and modifying CAD geometry to prepare the solid model for use in Simulation or CFX-Mesh.
- DesignXplorer and DesignXplorer VT for investigating the effect of variations input to the response of the system.
- FE Modeler for translating a Nastran mesh for use in ANSYS.

Design parameters of leaf spring:

Leaf NO.	Full leaf length in mm (2L)	Half leaf length in mm (L)	Radius of curvature R in mm
1.	1076	538	1601
2.	890	445	1609
3.	672	336	1671

Table 1

After drawn first leave select "extrude" then give depth 60mm (width),change operation in add frozen, change direction in reverse and change its type from face<ok.select on generate to form solid view then changes its plane and draw the similarly ten leaves one over another depend on different plane and sketch. So that it is individually assemble one over another leaves. Save the name as leaf spring. Finally the design procedure is completed.

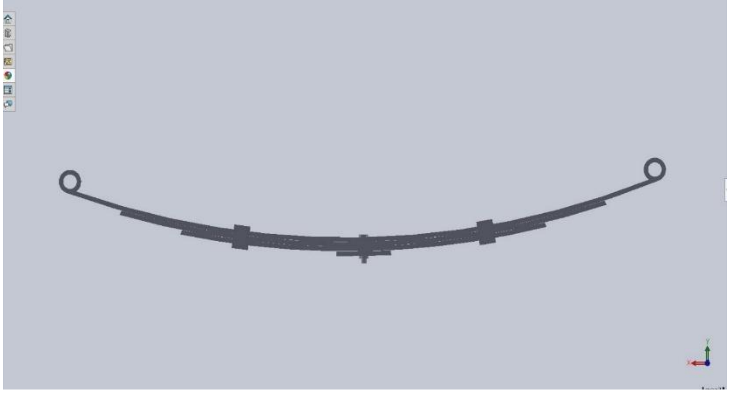


Fig2:Front View of Leaf Spring

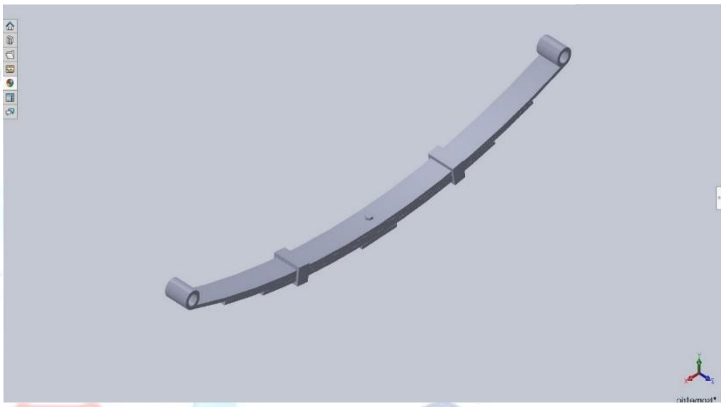


Fig 2: Isometric View of Leaf Spring

PROPOSED METHODOLOGY

DESIGN OF LEAF SPRING

The aim of this work is to develop a 3D modeling of leaf spring and to study the Leaf springs functionality, design parameters effecting on an automobile vehicle suspension system.

MATERIALS USED IN LEAF SPRINGS

The material used for leaf spring is usually a plain carbon steel having 0.90 to 1.0% carbon. The leaves are heat treated after the forming process. The heat treatment of spring steel produces greater strength and there for greater load capacity, greater range of deflection and better fatigue properties.

According to Indian standards, the recommended materials are:

1. For automobiles: 50 Cr 1, 50 Cr 1 V 23, and 55 Si 2 Mn 90 all used in hardened and tempered state.
2. For rail road springs: C 55 (water-hardened), C 75 (oil-hardened), 40 Si 2 Mn90 (water hardened) and 55 Si 2 Mn 90 (oil-hardened).

Physical properties of some of these materials are given in following table.

Materials	condition	Ultimate tensile strength (Mpa)	tensile yield strength (Mpa)	Brinell hardness No.
50 Cr 1	Hardened	1680-2200	1540-1750	461-601
50Cr 1 V 23	And	1900-2200	1680-1890	534-601
55 Si 2Mn 90	tempered	1820-2060	1680-1920	534-601

Table 2

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 kgTotal 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

DESIGN PROCEDURE OF LEAF SPRING

1) Click start button and open Ansys workbench 2021R1

2) Double click on static structural from toolbox then static structural toolbox is disappearing.

3) In that toolboxes double click on "geometry" and select the desired unit length "mm"<ok.

4) Select on sketching and draw as per given dimensions by using command like (line, arc by 3point, arc by center, circle).

5) Take centre point on the y-axis and draw the radius of curvature 961.11 mm, give the half length 560 mm right and left side from the centre point of the curvature.

6) Similarly draw the remaining 9 curves with 6 mm thickness one by one.

Design parameters of leaf spring:

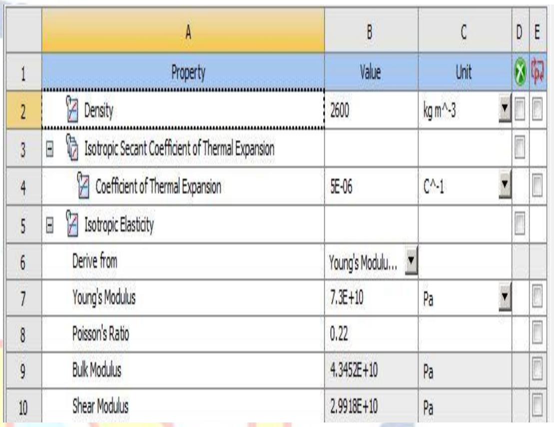
Leaf NO.	Full leaf length in mm (2L)	Half leaf length in mm (L)	Radius of curvature R in mm
1.	1076	538	1601
2.	890	445	1609
3.	672	336	1671

Table 3

7) After drawn first leave select "extrude" then give depth 60mm (width),change operation in add frozen, change direction in reverse and change its type from face<ok.

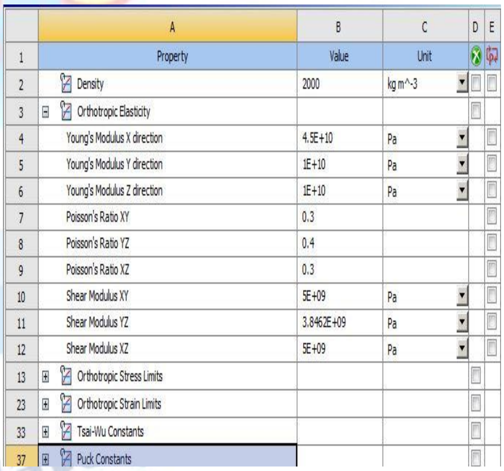
8) select on generate to form solid view then changes its plane and draw the similarly ten leaves one over another depend on different plane and sketch. So that it is individually assemble one over another leaves.

9) Save the name as leaf spring. Finally the design procedure is completed.



	A	B	C
1	Property	Value	Unit
2	Density	2600	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
4	Coefficient of Thermal Expansion	5E-06	C^-1
5	Isotropic Elasticity		
6	Derive from	Young's Modulu...	
7	Young's Modulus	7.3E+10	Pa
8	Poisson's Ratio	0.22	
9	Bulk Modulus	4.3452E+10	Pa
10	Shear Modulus	2.9918E+10	Pa

Fig 3 Epoxy E Glass properties



	A	B	C
1	Property	Value	Unit
2	Density	2000	kg m^-3
3	Orthotropic Elasticity		
4	Young's Modulus X direction	4.5E+10	Pa
5	Young's Modulus Y direction	1E+10	Pa
6	Young's Modulus Z direction	1E+10	Pa
7	Poisson's Ratio XY	0.3	
8	Poisson's Ratio YZ	0.4	
9	Poisson's Ratio XZ	0.3	
10	Shear Modulus XY	5E+09	Pa
11	Shear Modulus YZ	3.8462E+09	Pa
12	Shear Modulus XZ	5E+09	Pa
13	Orthotropic Stress Limits		
23	Orthotropic Strain Limits		
33	Tsai-Wu Constants		
37	Puck Constants		

Fig 4: Epoxy E Glass UD properties

10. Analysis of leaf spring

1) After design click on "modeling"

2) Model A4<click on geometry <select ten solid parts and changes its material properties.

3) Double click on assignment and select the new materials. Click on engineering data sources then go through general materials < click on structural steel and modify the structural steel into steel like small changes its properties

a) Young's modules of steel 210000 Mpa

b) Poisson's ratio of steel 0.3

4) Select the composite material from the Engineering data source.

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	2600	kg m^-3		
3	Isotropic Secant Coefficient of Thermal Expansion				
4	Coefficient of Thermal Expansion	5E-06	C^-1		
5	Isotropic Elasticity				
6	Derive from	Young's Modulu...			
7	Young's Modulus	7.3E+10	Pa		
8	Poisson's Ratio	0.22			
9	Bulk Modulus	4.3452E+10	Pa		
10	Shear Modulus	2.9918E+10	Pa		

Fig 5: Epoxy E Glass properties

	A	B	C	D	E
1	Property	Value	Unit		
2	Density	2000	kg m^-3		
3	Orthotropic Elasticity				
4	Young's Modulus X direction	4.5E+10	Pa		
5	Young's Modulus Y direction	1E+10	Pa		
6	Young's Modulus Z direction	1E+10	Pa		
7	Poisson's Ratio XY	0.3			
8	Poisson's Ratio YZ	0.4			
9	Poisson's Ratio XZ	0.3			
10	Shear Modulus XY	5E+09	Pa		
11	Shear Modulus YZ	3.8462E+09	Pa		
12	Shear Modulus XZ	5E+09	Pa		
13	Orthotropic Stress Limits				
23	Orthotropic Strain Limits				
33	Tsai-Wu Constants				
37	Puck Constants				

Fig 6: Epoxy E Glass UD properties

	A	B	C	D	E
1	Property	Value	Unit		
2	Material Field Variables	Table			
3	Density	7200	kg m^-3		
4	Isotropic Secant Coefficient of Thermal Expansion				
5	Coefficient of Thermal Expansion	1.1E-05	C^-1		
6	Isotropic Elasticity				
7	Derive from	Young's Modulu...			
8	Young's Modulus	1.1E+11	Pa		
9	Poisson's Ratio	0.28			
10	Bulk Modulus	8.3333E+10	Pa		
11	Shear Modulus	4.2969E+10	Pa		
12	Tensile Yield Strength	0	Pa		
13	Compressive Yield Strength	0	Pa		
14	Tensile Ultimate Strength	2.4E+08	Pa		
15	Compressive Ultimate Strength	8.2E+08	Pa		

Fig 7: Grey Cast Iron properties

6) After enter the properties click ok and select on return to the project. Then double click on mesh < generate mesh. Finally entire body will take meshed.

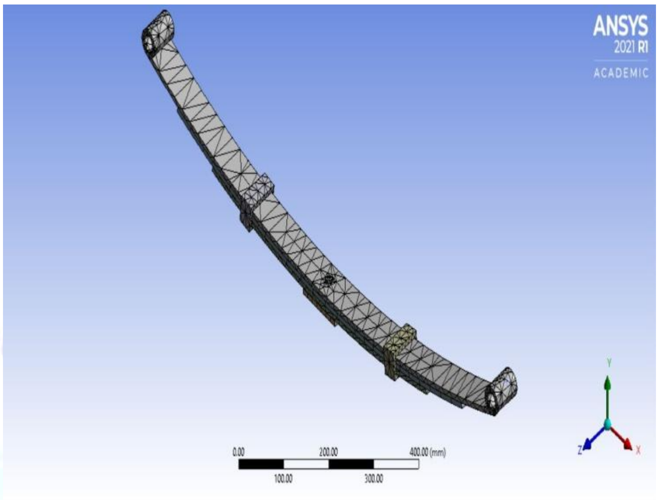


Fig 8: Mesh view of the leaf spring

7) Right click on static structural insert fixed support. There is select the face which we have to fixed the area and then apply through geometry.

10) Insert force in Y –direction 20000N at middle of the leaf spring.

The picture of static structure as shown in below.

11) Right click on solution < insert what we have to find out from leaf spring after applied load

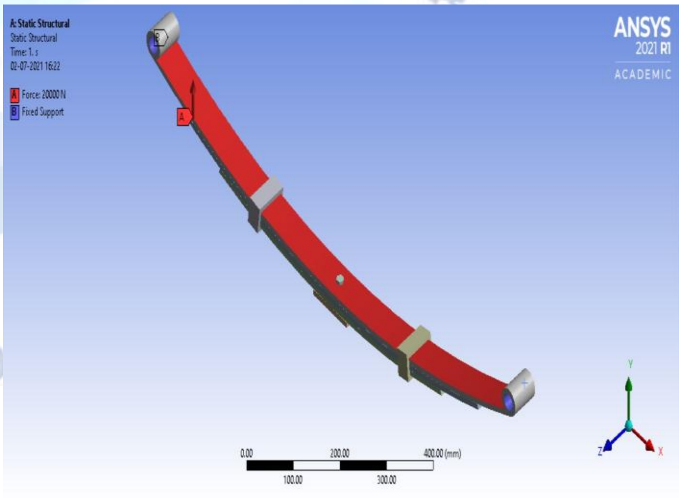


Fig 9: Loading condition of leaf spring

12) We have found

a) Total deformation of leaf spring

b) Equivalent stress (or) bending stress

13) Right click on solution and select solve (finally we get the results of all above)

V.RESULTS

From the analysis of structural steel leaf spring and E- composite E-glass/epoxy leaf spring is less compared to glass/epoxy, it observed that the total deformation of for structural steel leaf spring. Maximum shear stress and E-glass/epoxy material is less compared to conventional maximum principal stress is less in composite E-glass/epoxy steel leaf spring material. Equivalent stress generated in the as compared to conventional structural steel material.

Structural analysis of leaf spring with Grey Cast Iron

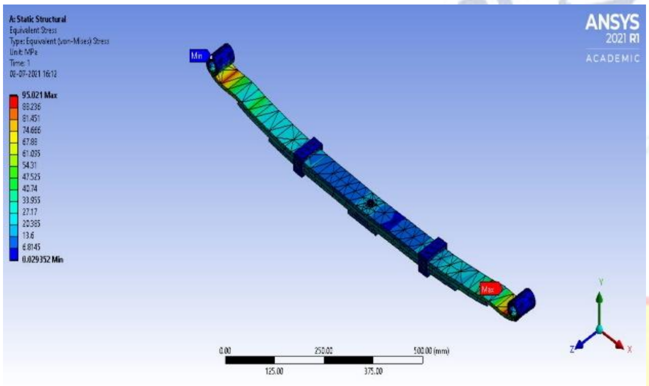


Fig 10: Stress distribution of leaf spring

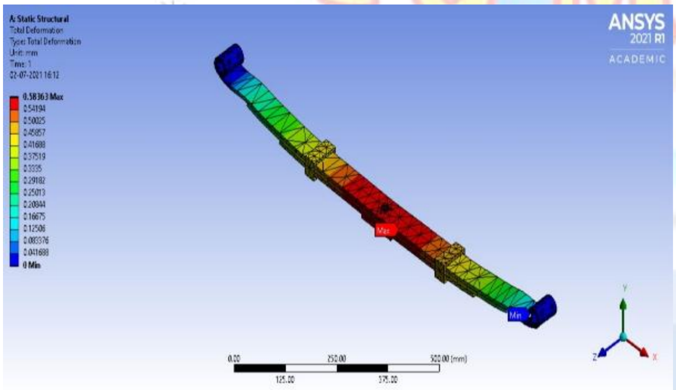


Fig 11: Deformation of leaf spring

Structural analysis of leaf spring with Epoxy E Glass:

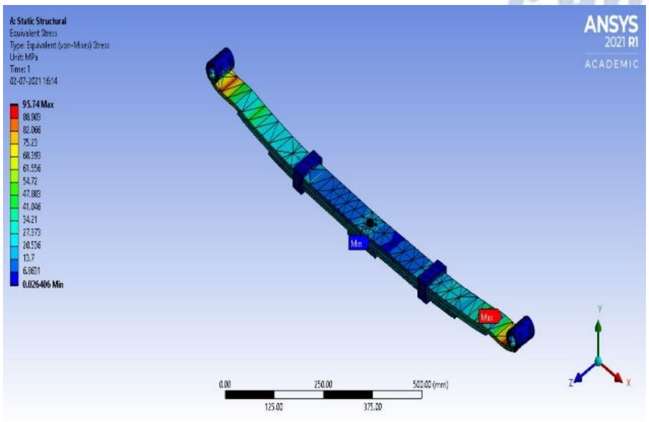


Fig 12: Stress distribution of leaf spring

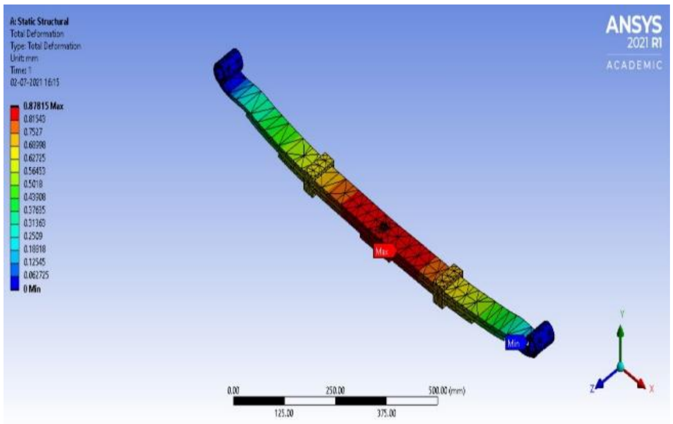


Fig 13: Deformation of leaf spring

Structural analysis of leaf spring with Epoxy E Glass UD:

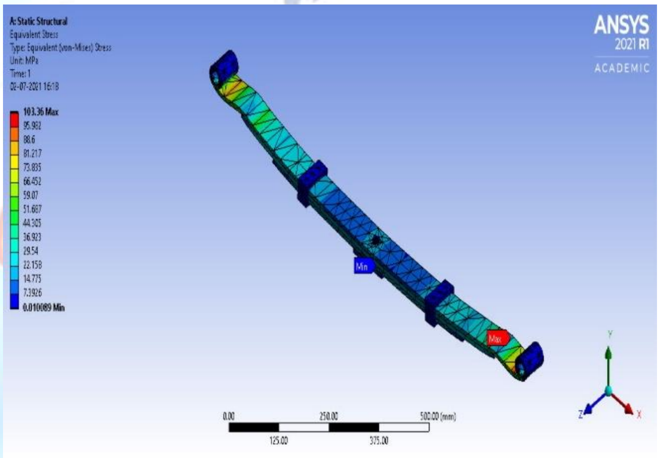


Fig 14: Stress distribution of leaf spring

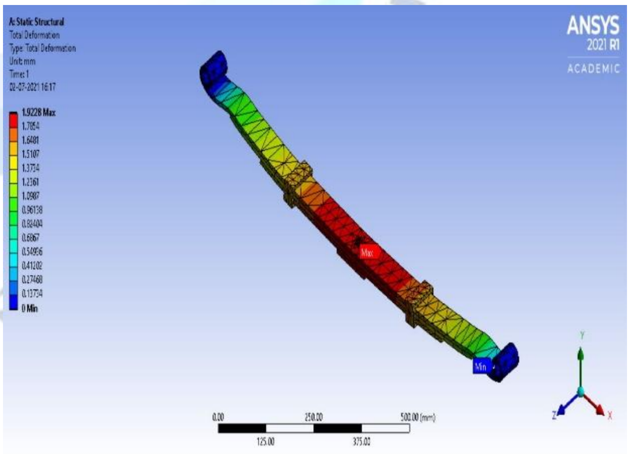


Fig 15: Deformation of leaf spring

CONCLUSION

In the present work, a steel leaf spring was replaced by a composite leaf spring due to high strength to weight ratio for the same load carrying capacity and stiffness with same dimension as that of steel leaf spring.

But when compare with Grey Cast Iron (GCI) the standard Epoxy E Glass Material and Epoxy E Glass UD material is not performing well but when compare with the weight of leaf spring grey cast iron has very high density when compare with the composite material. The stress and deformation values shown below

Material	Stress Mpa	Deformation mm
Grey Cast Iron	95.021	0.58363
Epoxy E Glass	95.74	0.87815
Epoxy E Glass UD	103.36	1.9

Above all the results shows that GCI giving better results when compare to Composite materials.

Epoxy E Glass material giving very clos values to the GCI material and Epoxy E Glass is very light weight when compare to GCI. So, Epoxy E Glass is the best suitable material for leaf spring.

REFERENCES

1. "A Textbook of Machine Design" by R.S.KHURMI_AND_J.K.GUPTA.
2. William D Callister. "Fundamentals of Material Science and Engineering". Fifth Edition. John Wiley & Sons, Inc 1985
3. Mikell P. Groover, "Fundamentals of Modern Manufacturing" Second Edition. John Wiley &Sons.Inc.
4. Metals Handbook. Volume 1 Microsturcture
5. Heat Treatment Principle and Technique by T.V Rajan, C.P Sharma, Ashok Sharma 6.Steel and Its Heat Treatmentby K.E Theling
6. Mr. V. Lakshmi narayana, "design and analysis of mono composite leaf spring for suspension in automobiles" ijert 2278-0181, vol. 1 Issue 6, august – 2012
7. Shishayamaregebremeskel, "design, simulation, and prototyping of single composite leaf spring for light weight vehicle", global Journals inc. (usa) 2249-4596, volume 12 issue 7, 21- 30, 2012
8. Manaspatnaik, narendrayadav, "study of a parabolic leaf spring by finite element method & design of experiments" ,ijmer 2249- 6645, vol.2, 1920-1922, july-aug 2012
9. Kumar krishan, aggarwalm.l, "computer aided fea comparison of mono steel and mono grp leaf spring", ijaers 2249–8974, vol. 1 issue 2, pp. 155-158, jan- march 2012
10. Mr. V. K. Aher *, mr. P. M. Sonawane , static and fatigue analysis of multi leaf spring used in the suspension system of lcv, (ijera)