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Design and Static Structural Analysis of Leaf Spring by Using Composite Materials for Light Vehicles

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ABSTRACT: In now a day the fuel efficiency and emission gas regulation of automobiles are two important issues. To fulfil this problem the automobile industries are trying to make new vehicle which can provide high efficiency with low cost. The best way to increase the fuel efficiency is to reduce the weight of the automobile. The weight reduction can be achieved primarily by the introduction of better material, design optimization and better manufacturing processes. The achievement of weight reduction with adequate improvement of mechanical properties has made composite a very good replacement material for conventional steel. To reduce vehicle weight, three techniques have been studied rationalizing the body structure, utilizing lightweight materials for parts and decreasing the size of the vehicles. In this approach by introducing composite materials into automobile industries, which is having low cost, high strength to weight ratio and excellent corrosive resistance can fulfil the requirement.

The automobile vehicles have number of parts which can be able to replace by composite material, but due to the improvement of mechanical properties of composite material. It has more elastic strength and high strength to weight ratio has compared with those of steel material. So, out of many components one of the components of automobile, the leaf spring which use for carried out the whole weight of the vehicle is best option for replacement of steel material by composite materials. Leaf springs are used in suspension systems. The automobile industry has shown increased interest in the replacement of steel leaf spring with composite leaf spring due to high strength to weight ratio.

Composite materials are one of the material families which are attracting researchers and being solutions of such issue. In this paper we describe design and

In this project we demonstrate the design and analysis of a Mahindra Jeep Commander 650 Di leaf spring is considered which is made up of coir reinforced polyester matrix composite and fibre reinforced polymer (S-glass/epoxy). The main objective of this project is to reduce the weight of an automobile by replacing its steel leaf spring with composite leaf spring when the load applied is constant and at the same defection compare its relative merits and demerits. The modelling of leaf-springs is done using NX -10.0 and analysis is done using ANSYS 18.1.

KEYWORDS: Key words: Stiffness, Composite Leaf Spring, E-Glass/Epoxy, ANSYS 18.1, NX10.0 – CAD.

I. INTRODUCTION

suspension system is one having springs and otherdevices that insulate the chassis of a vehicle from shocks transmitted through the wheels.

The main components of the suspension system are:

- Struts
- Shock absorbers
- Springs
- Tires

The automobile chassis is mounted by the axles, not directly but through some form of springs. This is done to isolate the vehicle body from the road shocks which may be in the form of bounce, pitch, roll or sway. These tendencies give rise to an uncomfortable ride and also cause additional stress in the automobile frame and body. All the part performs the function of isolating the automobile from the road shocks are collectively called a suspension system. Italsoincludes the spring device and various mountings. A suspension system consists of a spring and a damper. Theenergy of road shock causes the spring to oscillate. Theseoscillations are restricted to a reasonable level by thedamper, which is more commonly called a shock absorber.A spring isdefined as an elastic body, whose function is to distort when loaded and to recover its original shape whenthe load is removed. The different types of springs are:

1. Helical springs
2. Conical and volute springs
3. Torsion and spiral springs
4. Leaf springs
5. Disc or Belleville springs
6. Special purpose spring

1.1. LEAF SPRING

The leaf spring is main element of the suspension system. Itcan control for the wheels during acceleration, braking andturning, general movement caused by the road undulations.Leaf springs are designed in two methods: multi-leaf and mono leaf. The multi-leaf spring is made of several steelplates of different lengths stacked together. During normaloperation, the spring compresses to absorb road shock. Theleaf spring bends and slide on each other allowingsuspension movement. An example of a mono-leaf spring isthe tapered leaf spring. The leaf is thick in the middle andtapers towards the two ends. Many of these leaf springs are made of composite material, while others are made of steel.In most cases leaf springs are used in pairs mountedlongitudinally (front and back). However, there is anincreasing number of vehicle manufacturers using singletransverse (side to side) mounted leaf spring.

Three types of leaf springs are:
1. Laminated or Multi-leaf springs.
2. Single or Mono-leaf springs.
3. Tapered leaf springs.

The third type of leaf spring is the combination of the abovetwo. The multi-leaf springs are commonly used inthe automobile suspension system at the rear side and are stillin use for commercial vehicles suspension system. Itconsists of a number of steels
strips or leaves placed on thetop of each other and then clamped together. The type ofapplication and load carried determines the length andnumber of leaves. The top leaf is called as the main leaf and the ends of the leaf are rolled to form the eye of the spring.This is for attachment to the vehicle chassis or body. Thespring eye allows movement about the shackle and pin atthe rear.

II. MATERIALS FOR LEAF SPRINGS

composite is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material. (fibre Kevlar and whiskers). The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness, strong load carrying capacity and fatigue characteristics, which enables structural design to be more versatile.
Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. The reinforcement may be platelets, particles or fibres and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. In present work Leaf spring is made up of Three materials like conventional steel, CoconutFibreReinforced Polyester
Composite and Fibre reinforced polymer (S-glass/epoxy)

2.1.PROPERTIES OF THE MATERIAL

Table 1 Mechanical Properties of Steel

Property	value
Density	7850kg/m2
Tensile Yield Strength	250 MPa
Poisson's ratio	0.3
Young's modulus	210 Gpa

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Table 2 Properties of Coir composite

property	Value
Density	1380 kg/m^3
Tensile Yield Strength	25 MPa.
Poisson's ratio	0.3
Young's modulus	315Gpa

Table 3 Properties of S Glass/Epoxy composite

property	Value
Density	2480 kg/m^3
Tensile Yield Strength	4585 MPa.
Poisson's ratio	0.22
Young's modulus	86900Mpa

Figure: 2.1 Coir fibre

Figure: 2.2S Glass fibre

III. DESIGN AND MODELING OF LEAF SPRING

3.1. Model-Mahindra "Mahindra Jeep Commander 650 Di"

Leaf springs (also known as flat springs)are made out of flat plates. The advantage 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 device. Thus the leaf springs may carry lateral loads, brake torque; driving torque etc., in addition to shocks.

Let
t = Thickness of plate,
b= Width of plate,
2 L= Effective length of leaf spring
l = ineffective length of leaf spring
Nf = Number of full-length leaves
Ng = Number of graduated leaves
n = Total number of leaves = Nf + Ng
2W = Central load acting

FOS = factor of safety
δ f = Defection in full length leave

For reference and comparison sake a general leaf-spring of Model-Mahindra "Mahindra Jeep Commander 650 Di" was considered. The Dimensions of leaf spring as determined as follows.

Number of leaf springs = 10
Effective length of leaf spring = 1120 mm
Width of leaves = 50mm
Number of full-length leaves = 2
Number of graduated leaves = 8
Total number of leaves = 10
Central load acting = 2W=1910Kg
2W=1910X10X1.33(FOS)
= 25403 N
2W = 25403/4
= 6350.7

W = 3200 N

3.2.Material used for leaf spring: structural steel

Bending stress $= \frac{6WL}{nbt2}$

$= \frac{6X1600X560}{10X50X6\ 2}$

= 299 N/mm^2

Deflection in full length leave = $\frac{12WL3}{E\,b\,t\,3\,(2\,n\,G+3\,n\,F)}$

= (12X1600X560$^{3)}$
(207X(10)^{3}X50X6^3(2X8+3X2))

= 68.5 mm.

Lengthofleaf

$= \frac{\text{effectivelengt h}}{\text{number of leaves } -1} + \text{ineffctive length}$

Length of smallest leaf (leaf 1) = $\mathbf{\frac{1120}{10-1} + 90}$ = 214 mm

Length of second leaf $= \frac{1120}{10-1}X2 + 90 = 338$ mm

Length of third leaf= $\frac{1120}{10-1}X3 + 90 =$ 463 mm

Length of fourth leaf = $\frac{1120}{10-1}X4 + 90 =$ 588 mm

Length of fifth leaf= $\frac{1120}{10-1}X5 + 90 =$ 712 mm

Length of sixth leaf= $\frac{1120}{10-1}X6 + 90 =$ 837 mm

Length of seventh leaf = $\frac{1120}{10-1}X7 + 90 =$ 961 mm

Length of eight leaf= $\frac{1120}{10-1}X8 + 90 =$ 1085 mm

Length of nineth leaf = 1120 mm

Length of tenth leaf = 1120 mm

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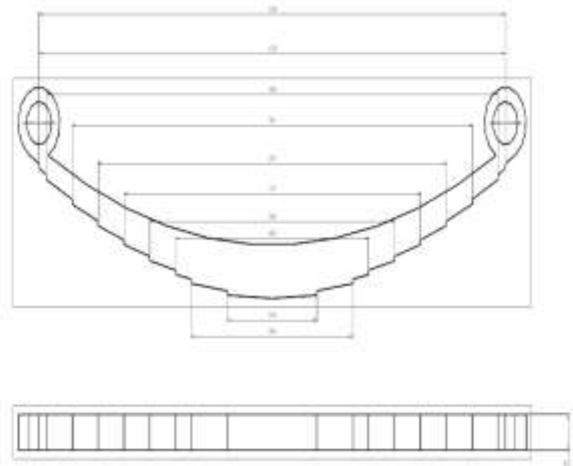

Fig:3.1 Drafting of steel leaf spring

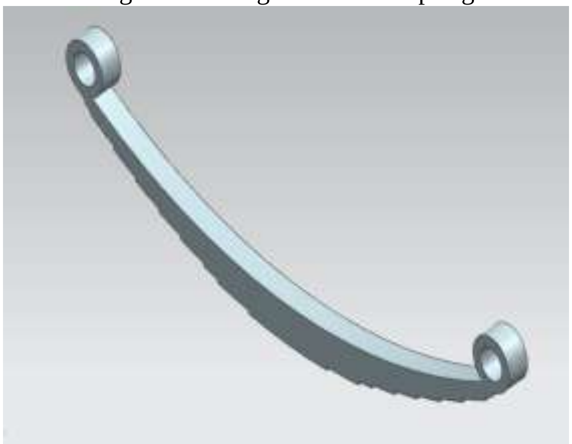

Figure: 3.2 CAD model of Steel leaf-spring.

3.3. Dimensions of Coconut Fibre Reinforced Polyester Composite Leaf-Spring and Fiber reinforced polymer (S-glass/epoxy):

The dimensions of composite leaf springs are set in such a way that, when 3200 N is applied, the deflection should be same as that of steel leaf-spring.

Deflection in full length leaves = $\frac{12WL3}{E\, b\, t3\, (2\, n\, G+3\, n\, F)}$

68.5=(12X1600X560^3)/(207X(10)^{3}XbX8^3(2X8+3X2))

b = 67 mm

Firstly, length of 1420 mm and thickness of 8 mm is fixed and width is calculated using above formula.

Lengthofleaf $=\frac{\text{effectivelengt h}}{\text{number of leaves } -1} + \text{ineffctive length}$

Length of smallest leaf (leaf 1) = $\frac{1420}{10-1} + 90$ = 247.7 mm

Length of second leaf $=\frac{1420}{10-1}X2 + 90 =$ 405.55 mm

Length of third leaf = $\frac{1420}{10-1}X3 + 90 = 563.33$ mm

Length of fourth leaf=$\frac{1420}{10-1}X4 + 90 = 721.11$ mm

Length of fifth leaf=$\frac{1420}{10-1}X5 + 90 = 878.88$ mm

Length of sixth leaf=$\frac{1420}{10-1}X6 + 90 = 1036.66$ mm

Length of seventh leaf=$\frac{1420}{10-1}X7 + 90 =$ 1194.4 mm

Length of eight leaf= $\frac{1420}{10-1}X8 + 90 = 1352.22$ mm

Length of nineth leaf= 1420 mm

Length of tenth leaf= 1420 mm

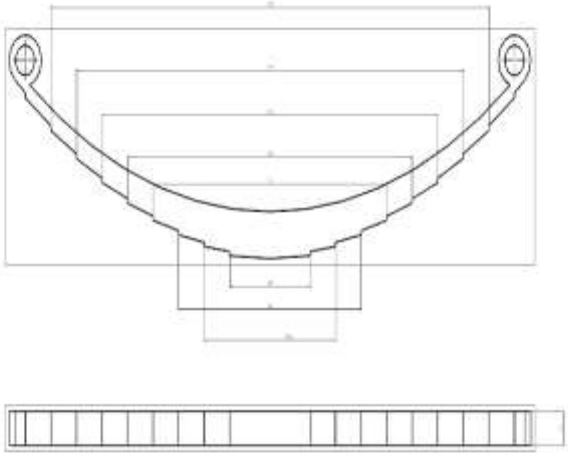

Fig:3.3Drafting of coconut fibre and S Glass fibre composite leaf springs

Figure:3.4CAD model of coconut fibre and S Glass fibre composite leaf springs

IV. ANALYSIS OF THE LEAF SPRING

ANSYS finite element analysis (FEA) is a computer basednumerical technique for calculating the strength andbehavior of engineering structures. It can be used tocalculate deflection, stress, vibration, buckling behavior andmany other phenomena. It can be used to analyze eithersmall or large-scale deflection under loading or applieddisplacement. It can analyze elastic deformation, orpermanently bent out of shape plastic deformation. Thecomputer is required because of the astronomical number ofcalculations needed to analyze a large structure. The powerand low cost of modern computers has made Finite ElementAnalysis available to many disciplines and companies.

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4.1.Meshing:

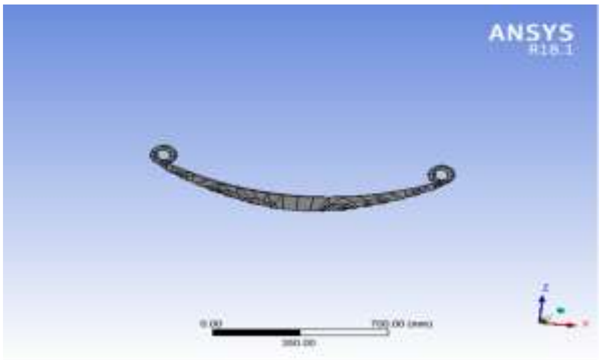


Fig 4.1: Mesh generation for steel leaf spring

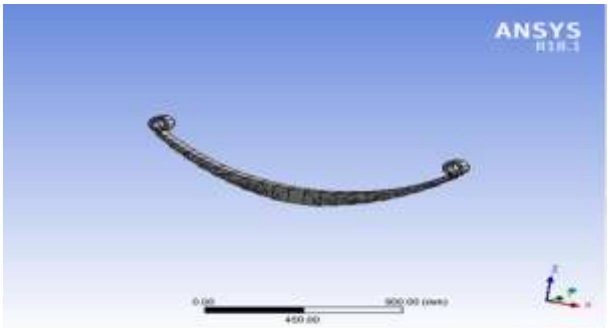


Fig 4.1: Mesh generation for coconut fibrecomposite leaf spring

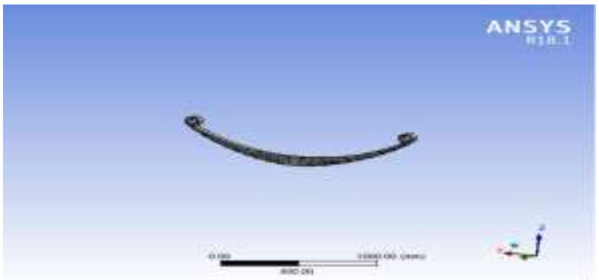
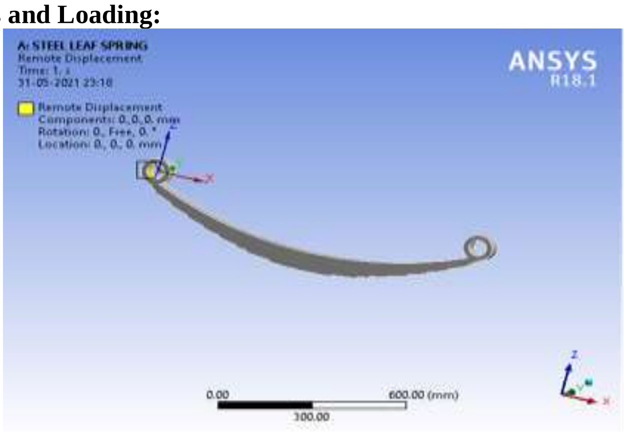


Fig 4.2: Mesh generation for S glass/Epoxy composite leaf spring

4.2. Boundary Conditions and Loading:



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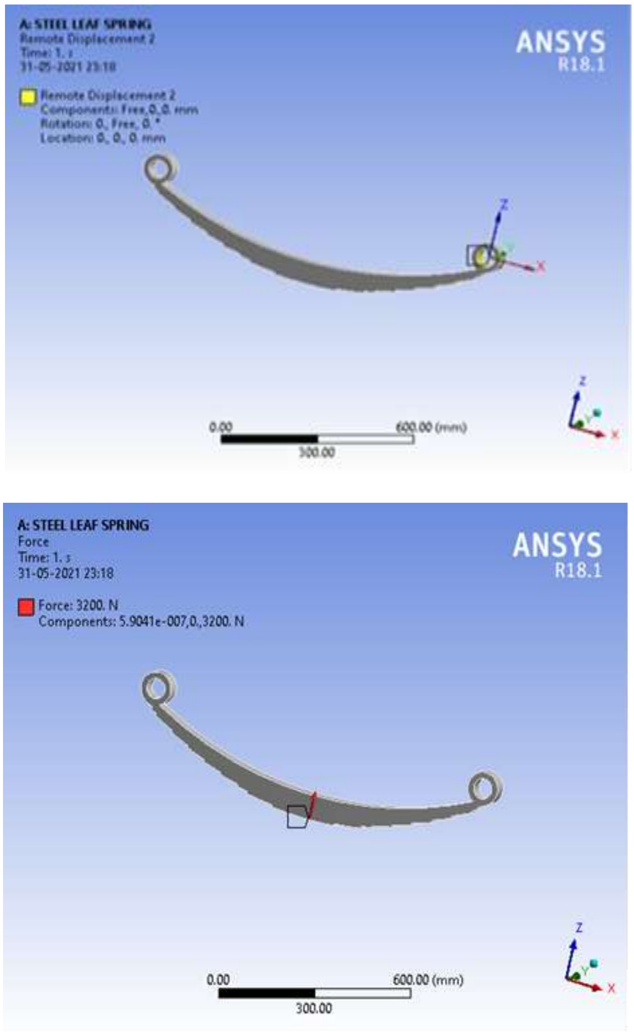


Fig 4.3: Boundary conditions for three leaf spring

V. RESULTS AND DISCUSSIONS

The steel leaf-spring,coconut fibre composite leaf-spring and S Glass/Epoxy composite leaf-springs areanalysed by giving constraints and the results obtained are asfollows.

5.1 Analysis of steel Leaf Spring

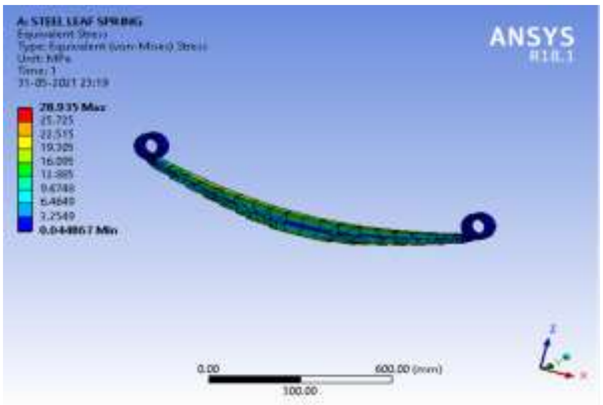


Fig.5.1.Max. Stress distribution

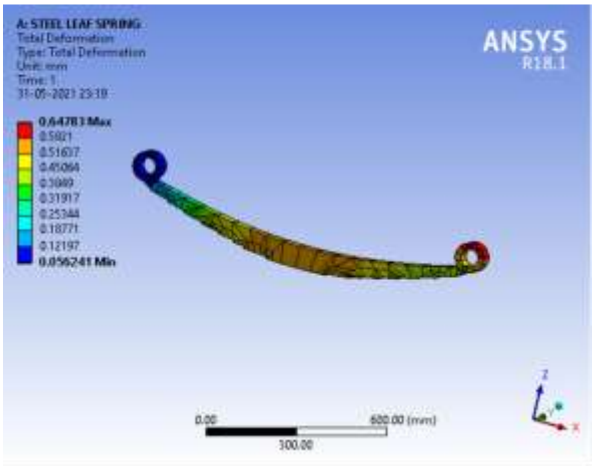


Fig.5.2.Max. Deformation

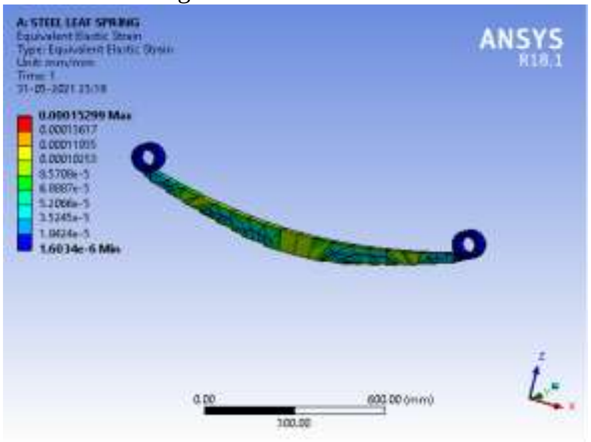
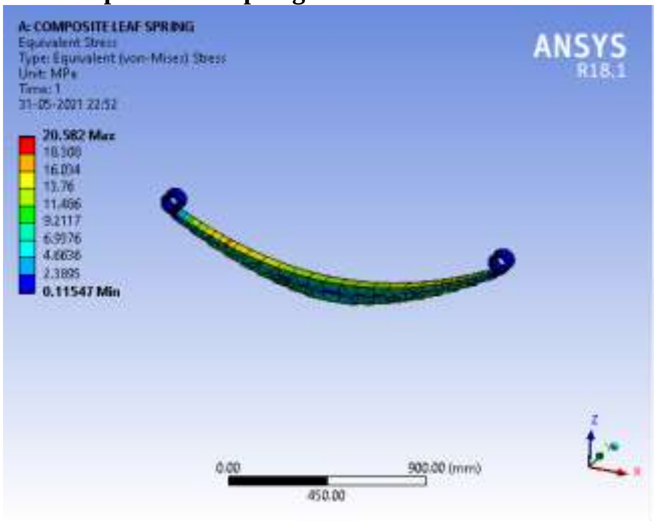


Fig.5.3.Max. strain distribution

5.2 Analysis of coconut fibre composite LeafSpring



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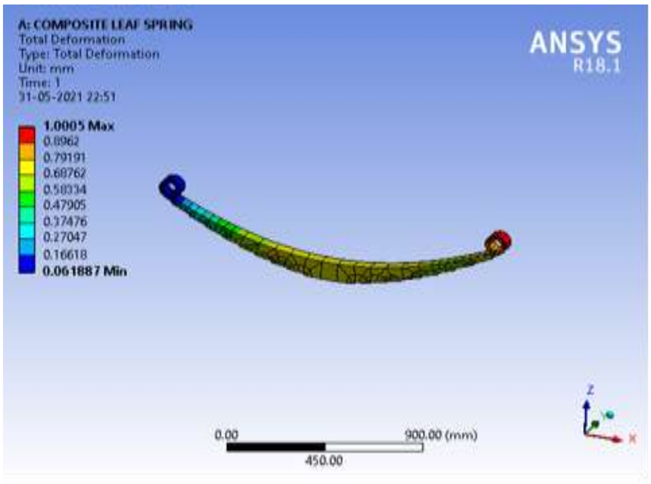

Fig.5.4. Max.Stressdistribution
Fig.5.5.Max. Deformation

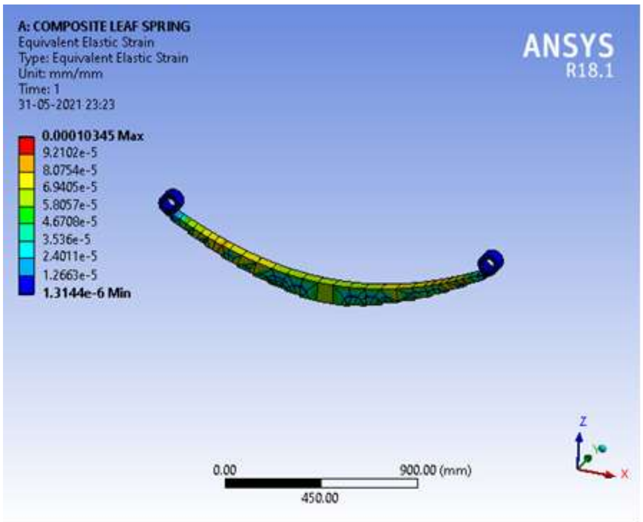

Fig.5.6.Max. strain distribution

5.3 Analysis of S GLASS/EPOXY composite Leaf Spring

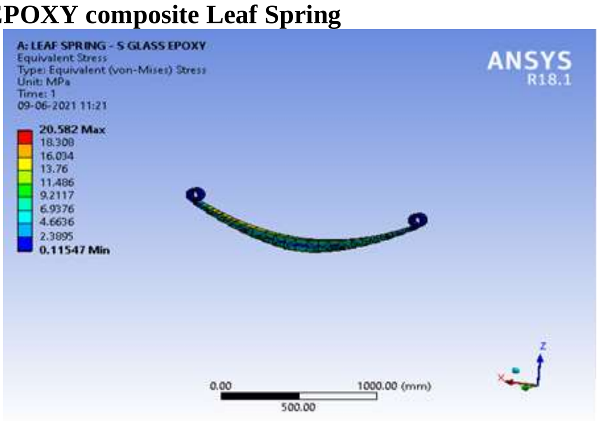

Fig.5.7.Max. Stress distribution

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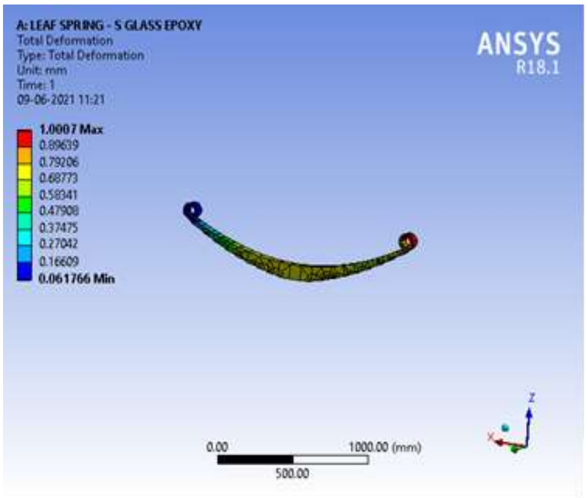

Fig.5.5.Max. Deformation

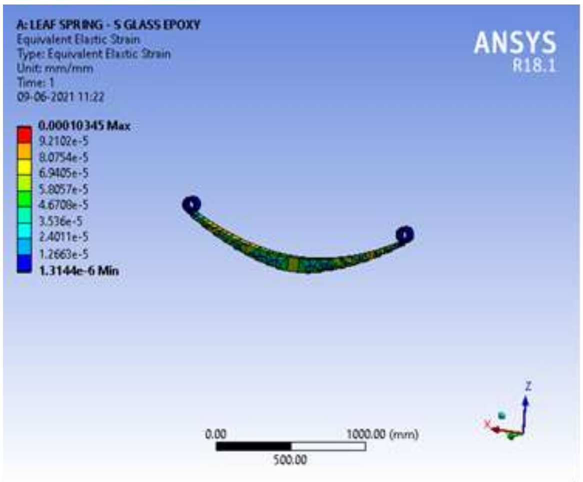

Fig.5.6.Max. strain distribution

Table 5.1. Comparison of Analysis Results of steel leaf and composite leaf springs

S. No	Material for leaf spring	Max stress (Mpa)	Max Deformation (mm)	Max. straindistribution	Weight (Kg)
1	Steel leaf spring	28.935	0.64783	0.00015299	**28.2727**
2	SGlass/ Epoxy composite leaf spring	20.582	1.0007	0.00010345	**17.9988**
3	Coconut fiber Composite leaf spring	20.582	1.0005	0.00010345	**10.0155**

Percentage of Weight saved (coconut fibrecomposite leaf spring) = 64.575%

$$= \frac{(28.2727 - 10.0155)}{28.2727}$$

Percentage of Weight saved (S Glass/Epoxy composite leaf spring)

$= \frac{(28.2727-17.9988)}{28.2727}$

$=$ 36.338%

From the results it can be observed that Equivalent stress generated in the Coconut Fiber Reinforced Polyester Composite leaf spring is less compared to S Glass/Epoxy composite leaf spring and steel leaf spring. Less maximum strain and acceptable deformation have been found in Coconut Fiber Reinforced Polyester Composite leaf spring compared to S Glass/Epoxy composite leaf spring and conventional steel leaf spring.

VI. CONCLUSIONS

Under the same static load and deflection conditions, both composite and steel leaf springs show great difference in their weights. The weight of steel leaf spring is very high compared to that of composite leaf springs. The weight of steel spring is 28.2727 kgs whereas weight of S Glass/Epoxy composite leaf spring is 17.9988Kg and weight of coconut fibre composite leaf spring is 10.0155 kgs. The induced stress of coconut fibre composite leaf spring is 20.582 MPa which is equal to the S Glass/Epoxy composite leaf spring less than that of steel leaf spring 28.935 MPa. The results obtained for deflection of steel leaf spring and composite leaf springs are in acceptable range. Composite leaf spring can be used in light weight vehicles, where weight is an important factor, whereas steel spring can be used in budget cars for its low cost of manufacturing.

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