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Design, Analysis and Fabrication of Mono Leaf Spring using S-Glass Composite

Mr. Rohit Vasant Rambade
UG Student
Department of Mechanical Engineering
MGM`S College of Engineering and Technology, Kamothe, Navi Mumbai

Mr. Naveen Sanjay Dudhale
UG Student
Department of Mechanical Engineering
MGM`S College of Engineering and Technology, Kamothe, Navi Mumbai

Mr. Siddhartha Kedar Valawalkar
UG Student
Department of Mechanical Engineering
MGM`S College of Engineering and Technology, Kamothe, Navi Mumbai

Mr. Pankaj Ramchandra Yadav
UG Student
Department of Mechanical Engineering
MGM`S College of Engineering and Technology, Kamothe, Navi Mumbai

Prof. Mr. Mahesh Murlidhar Patil
Assistant Professor
Department of Mechanical Engineering
MGM`S College of Engineering and Technology, Kamothe, Navi Mumbai

Abstract

Leaf spring is a device used in automotive vehicles to carry unexpected impact loads. These leaf springs are generally made of steels i.e. Mild steel, cast steel etc. Mono leaf springs are generally preferred for vehicles with low load carrying strength and Light weight vehicles. The advance Mono leaf springs are manufactured using GFRP which are light in weigh and have low load carrying capacity as compared to Glass Composites i.e. E Glass, S Glass, Carbon Fiber etc. In this project work, Objective is to design a Mono Leaf spring Using Advance S-Glass Series composite Materials which will results into absorbing high Impact shocks. In this project work, Mono Leaf spring of Mahindra Model of Commander 650 Di is considered for design and Analysis. Concept of Reverse engineering is used to measure all the design parameters of the mono leaf spring. Theoretical Designing is done using standard Mono Leaf Spring Design process and 3D modelling is done using Solid works 2015 software. Finite Element Analysis software ANSYS Workbench 18.0 is used to study the static and dynamic Behavior of the spring under standard working conditions. ACP Analysis is done for Composite leaf spring to find Load Carrying capacity. S-Glass Composite series is used to manufacture mono leaf spring and Tested experimentally for actual load Capacity using Experiment Setup. The finite Element Analysis will show that Mono Leaf Spring Made of S-glass Composite will perform better as compared E Glass Composites and All the convectional Metals series Materials in terms of load capacity, Life, Performance, Impact Strength, Flexibility, Cost, Wear and Corrosion.

Keywords- Mono Leaf Spring, S-Glass Composite, ACP Analysis, Design, Fabrication

I. INTRODUCTION

Leaf spring is a simple form of spring commonly used for the suspension in wheeled vehicles, originally called as laminated or carriage spring. A leaf spring takes the form of a slender arc-shaped length of spring steel of rectangular cross-section. In the most common configuration, the center of the arc provides location for the axle, while loops formed at either end provide for attaching to the vehicle chassis. 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 stiction in the motion of the suspension. For this reason, some manufacturers have used mono-leaf springs.

II. OBJECTIVE

- To Design a Mono Leaf Spring By the application of light weigh, High Impact strength advance composite material Application.
- To Replace Conventional Steel leaf springs used in automobile with S-Glass composite leaf spring.
- To compare different composite materials for their mechanical behavior when subjected to the same working condition as of an actual steel leaf spring.

III. PROBLEM DEFINITION

Weight reduction with enhanced performance of a vehicle has been the primary focus zone of the automobile industries eventually cost saving. This can be achieved by replacing the older materials with new advance materials for e.g. Fiber reinforced polymers (composite materials) new materials gives design engineers to explore and experiment all the new possibilities. One such possibility arises with the leaf springs used in automobiles.

IV. METHODOLOGY

- Obtaining design data of the existing mono leaf spring
- 3D Modelling of Existing Leaf spring using Solidworks
- Selection of S-Glass Composite Material Series
- Theoretical calculations for stress and deformation
- Designing of New Leaf Spring using S-Glass/Epoxy material
- FEA analysis of Original Leaf spring using ANSYS Workbench
- Analysis of Composite Leaf using ANSYS Composite Prep/Post (ACP).
- Fabrication of the model and Testing.

V. VEHICLE SELECTION AND THEORETICAL CALCULATION

A. Selection of Vehicle and Its Specifications

Table 1: Mahindra model "Commander 650 di" is being considered

Parameters	*Dimensions in mm*
Total length	*1120*
Camber	*180*
Thickness	*30*
Width	*50*
Diameter of the eye	*23*

For Loading Conditions

- Gross weight of vehicle 2150 Kg
- Unsprang weight 240Kg
- Total sprung weight 1910 Kg
- Factor of safety 1.2
- Acceleration due to gravity 9.8m/s2
- Therefore, total weight = 1910 x 10 x 1.2
  = 29740 N
- Since the vehicle is a four wheeler , a single leaf spring corresponding to one wheel will take 1/4th of the weight , hence
  F=26740 / 4 = 6685 N
- For analysis purpose, only half spring is considered as the spring is symmetrical about vertical transverse plane.

B. 3D Modelling using Solidworks

1) Full Leaf Spring

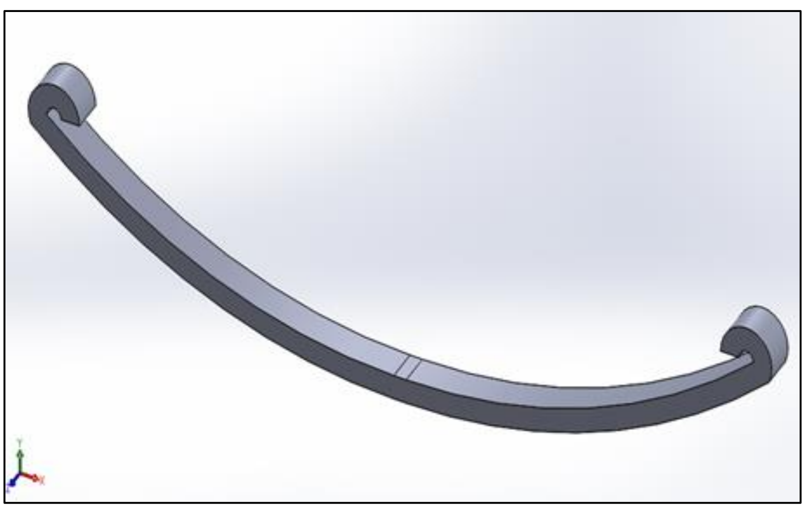

Fig. 1: Solidworks-Full Leaf Spring

2) *Half Leaf Spring*

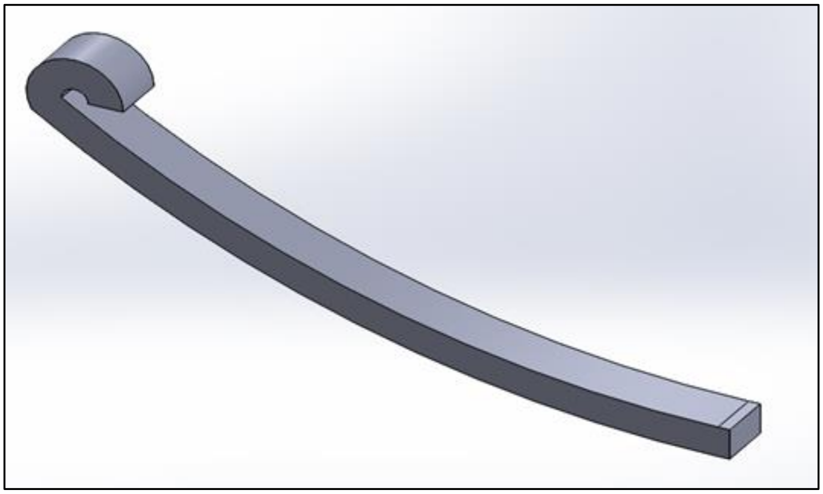

Fig. 2: Half Leaf Spring

C. Theoretical Design Calculation

- Deflection in the spring is given

$$\delta = \frac{WL^3}{3EI}$$

Where,
δ ⟶ Static deflection.
W⟶ Load in N.
L ⟶ Length of Spring in mm.
E ⟶ Young's modulus in MPa.
I ⟶ Moment of Inertia in mm^4

- Moment of Inertia for a rectangular cross section is given as

I=(bd3)/12

Where,
b ⟶width of section in mm.
d ⟶Depth of section in mm

- Deflection in steel Leaf Spring

δ=(WL3) / 3EI
δ = (3342.5 x (560)3) / (3 x 210000 x 112500)
δ=8.28 mm
≈ 9 mm

Since our deflection is to be restricted to 09 mm, and keeping the width constant (i.e. 50 mm), we can calculate the required thickness of the leaf spring made of S-Glass/Epoxy.

S-Glass/Epoxy has E_x= 50000 MPa.

Hence,

δ=(WL3) / 3EI
I =(WL3) / 3$E\delta$
I = (3342.5 x (560)3) / (3 x 50000 x 9)
I = 434812.20 mm4

Also,
I=(bd3) / 12
d3=12I / b
d=∛ ((12 x 434812.20) / 50)
d=47.08 mm.

Hence an approximate value of 47 mm is selected for design.

VI. SELECTION OF COMPOSITE MATERIAL

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. The individual components remain separate and distinct within the finished structure. Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, racing car bodies, shower stalls, bathtubs, storage tanks, imitation granite and cultured marble sinks and countertops.

Table 2: Mechanical Properties of E-Glass and S-Glass and S2-Glass

Properties	E-glass	S-glass	S2-glass
Young's modulus (GPa)	72	86	86
Poisson's ratio	0.21	0.21	0.21
Density (Mg/m^3)	2.55	2.485	2.48
Tensile strength (MPa)	1520	4700	4800
Specific heat (J/kg.K)	800	735	740

Table 3: Weighted Residual Method for Material Selection

Properties	E-glass	Points	S-glass	Points	S2-glass	Points
Young's modulus (GPa)	72	3	86	5	**86**	5
Poisson's ratio	0.21	5	0.21	5	**0.21**	5
Density (Mg/m^3)	2.55	3	2.485	4	**2.481**	5
Tensile strength (MPa)	1520	2	4700	5	**4800**	5
Total Points		**13**		**19**		**20**

A. Properties of Steel Leaf Spring Materials

Properties	Alloy steel
Young's modulus (GPa)	210
Poisson's ratio	0.28
Density (Kg/m3)	7700
Yield strength (MPa)	620.42
Ultimate strength (MPa)	723.83

VII. FEA SIMULATION ON LEAF SPRING

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed. It is called analysis, but in the product development process, it is used to predict what is going to happen when the product is used

A. Boundary Condition- Steel Leaf Spring

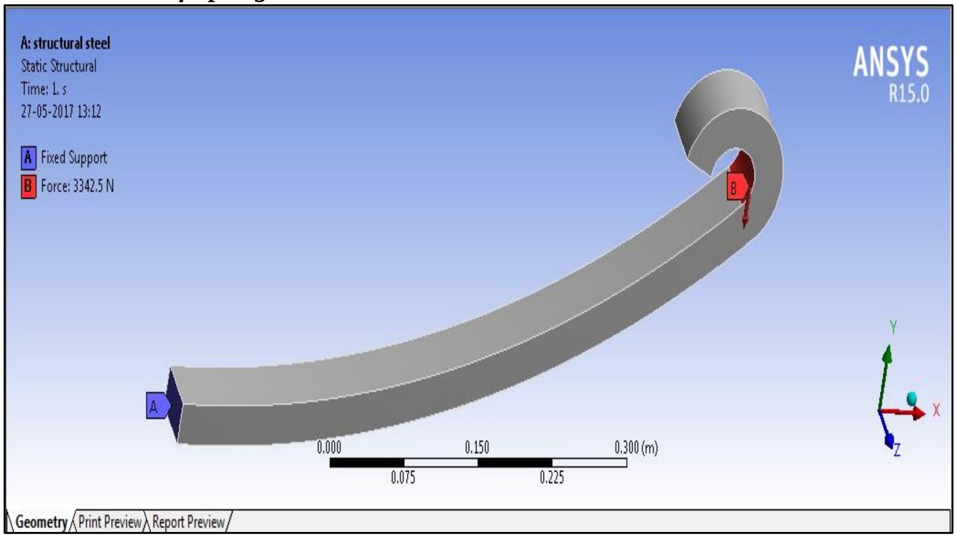

Fig. 1: Loading conditions applied

B. Equivalent Stress- Steel Leaf Spring

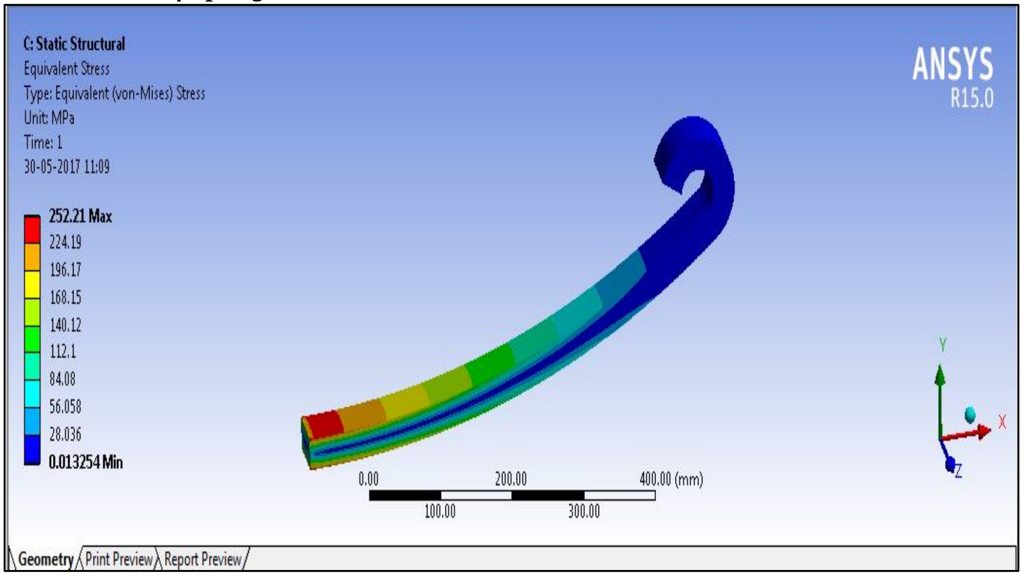

Fig. 2: Equivalent Stress of steel leaf spring

C. Deformation- Steel Leaf Spring

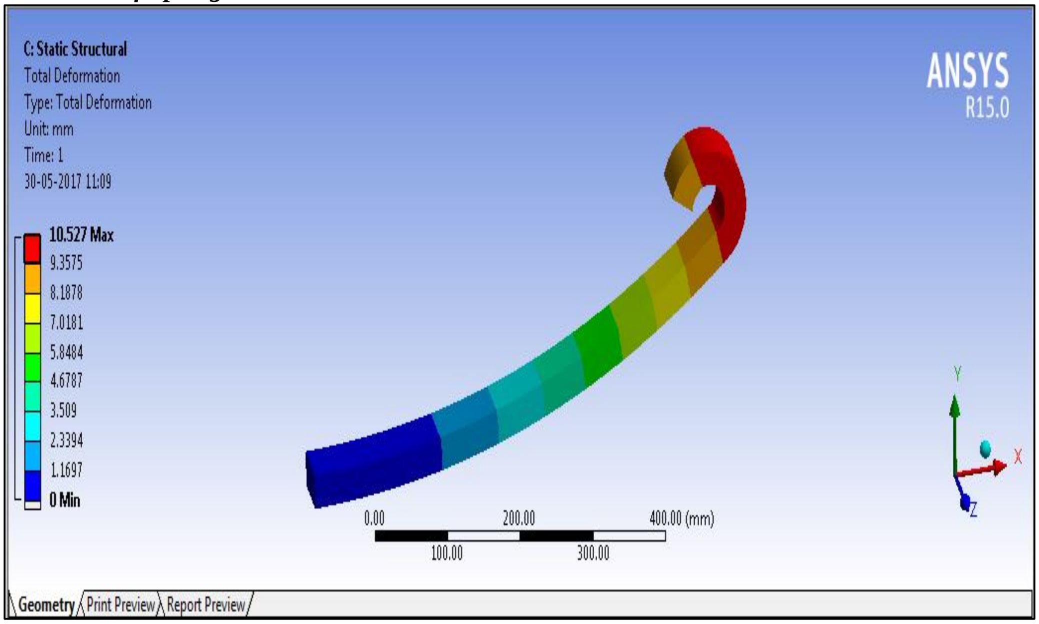

Fig. 5: Deformation- Steel leaf spring

D. Composite Leaf Spring using ACP

ANSYS Composite PrepPost software provides all the necessary functionality for the analysis of layered composite structures. An intuitive interface efficiently defines materials, plies and stacking sequences.

ANSYS Composite PrepPost is an add-on module dedicated to the modelling of layer composite structures.

ANSYS Composite PrepPost is used by Engineers for designing and analysing layered composites. The simulation focuses on correct and efficient use of this technology for the purpose of overcoming some of the inherent challenges in composite modelling, such as capturing fiber orientation, model inspection, failure analysis and parameterization.

This also Covers, how to make high fidelity models, gain time savings at the post-processing stage, and integrate global - local models for detailed design and more.

E. Modelling

In order to carry out the ANSYS Composite Prep Post (ACP) analysis, a surface model of the spring is required which was modelled in Solid Works 15.

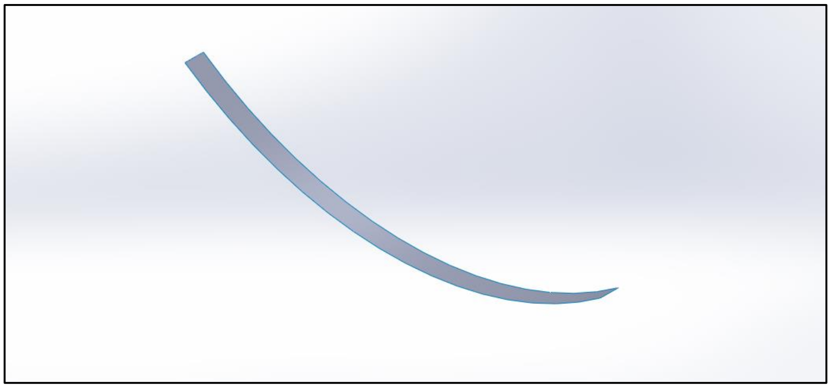

Fig. 6: Surface model of mono leaf spring

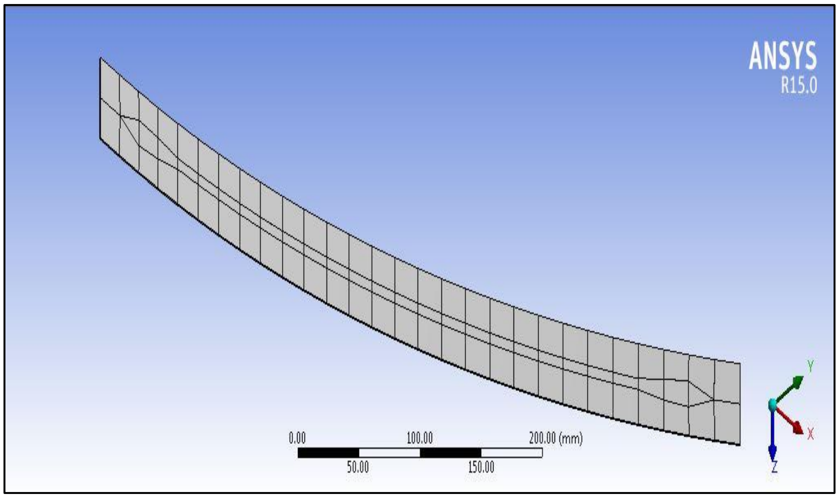

Fig. 7: Shell meshed model

F. Fiber Orientation

The fiber direction was now specified. Green arrows indicate fiber direction whereas pink is the direction of drop off matrix material.

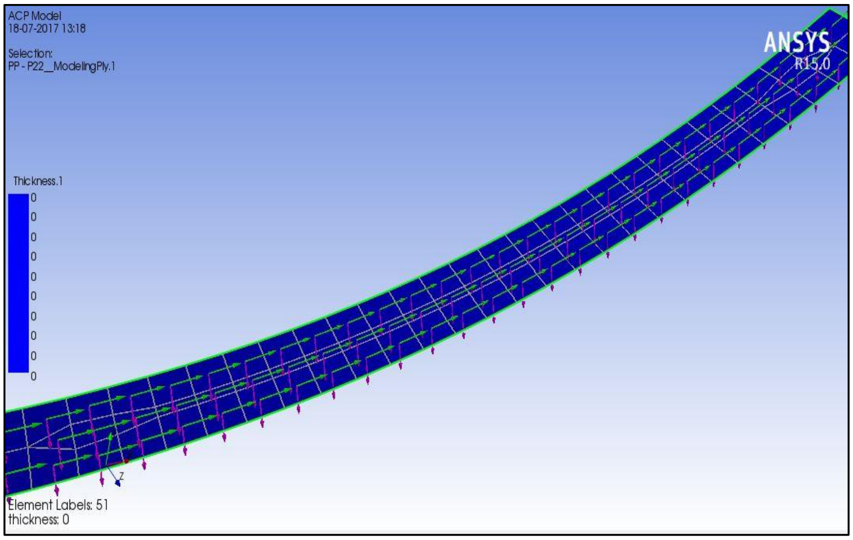

Fig. 8: Fiber orientation

O degree fiber orientation has been considered in the current project. Fiber being S-Glass fibers and drop off matrix material is Epoxy resin. Now 45 layers of fiber was added each of 1mm thickness to obtain a solid model.

The following model has been showed and also a solid model with fiber direction has been shown

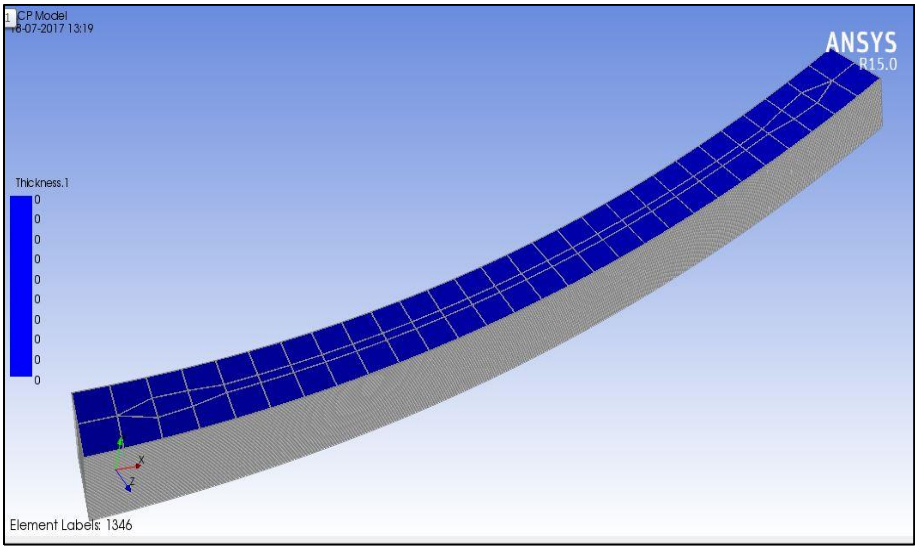

Fig. 9: Solid model of leaf spring

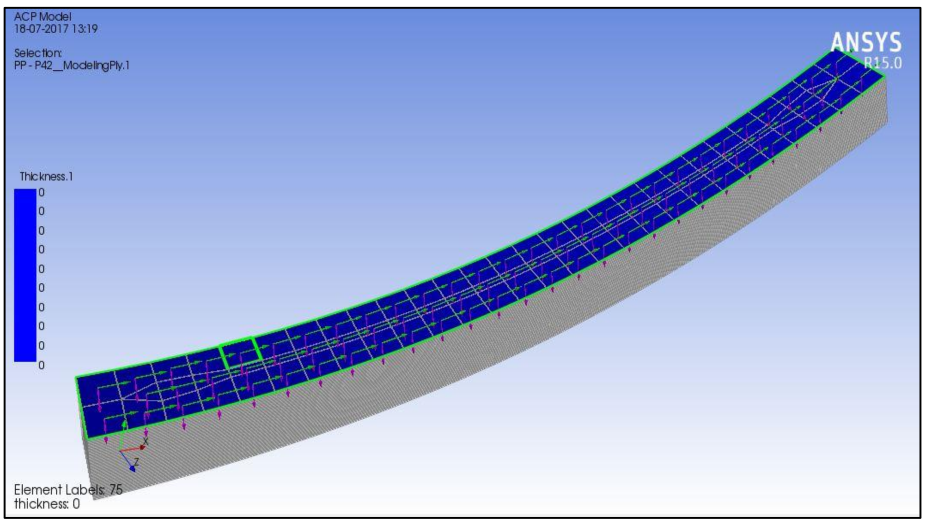

Fig. 10: Solid model with fiber orientation

G. Boundary Condition-Composite Leaf Spring

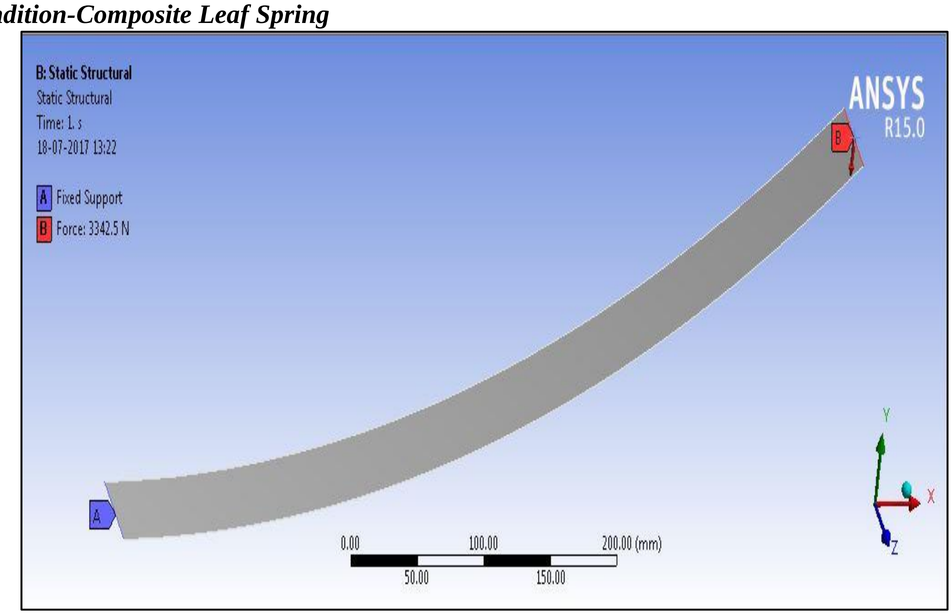

Fig. 11: Applied loading conditions

H. Stress- Composite Leaf Spring

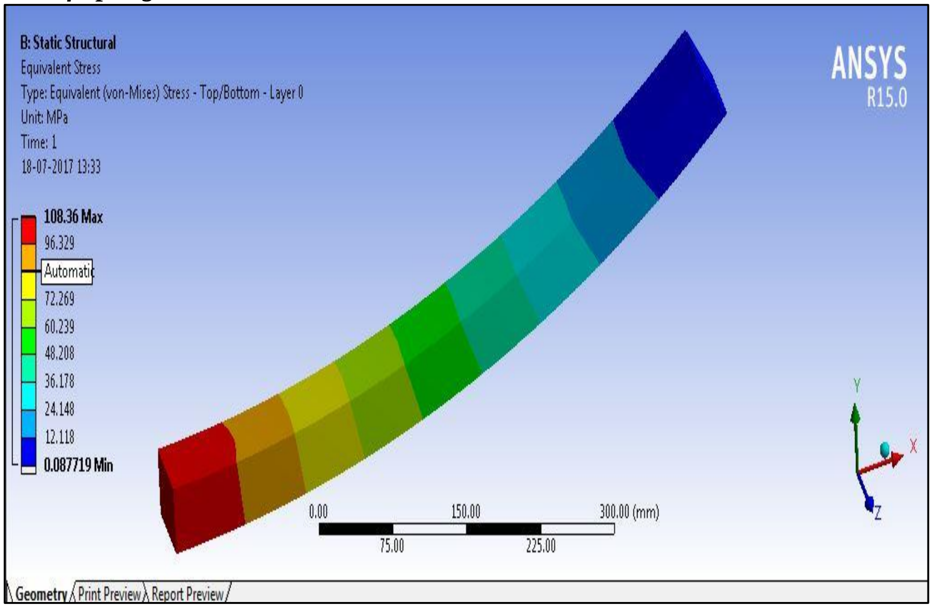

Fig. 12: Stress- Composite leaf spring

I. Deformation- Composite Leaf Spring

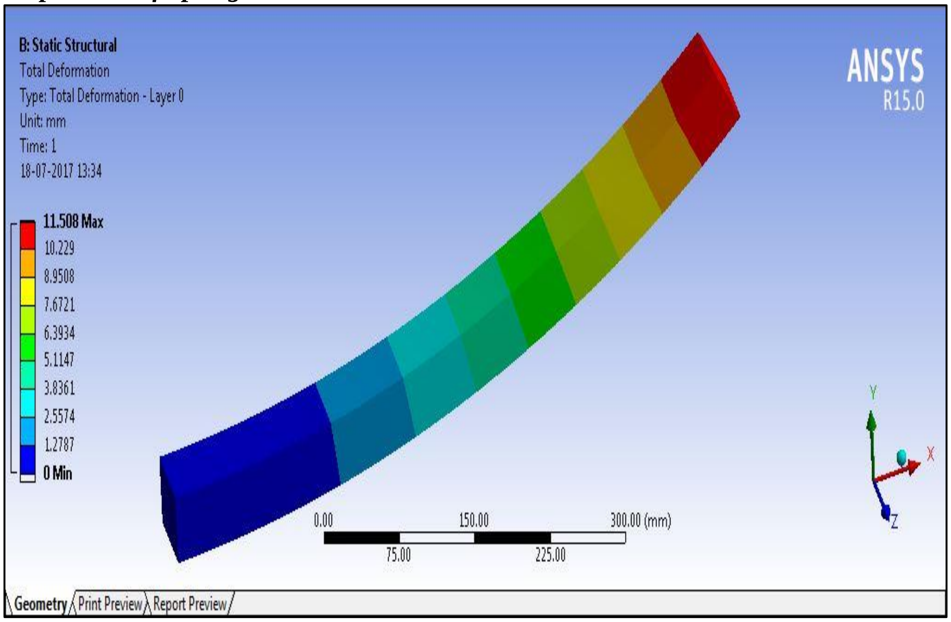

Fig. 13: Deformation- Composite leaf spring

VIII. RESULTS

Table 4: Results

Sr. No	*Material*	*Mass, Kg*	*Stress, (MPa)*	*Deformation, (mm)*
1	*Steel leaf spring*	*16.464*	*252.21*	*10.52*
2	*Composite leaf spring (S-glass)*	*8.842*	*108.36*	*11.50*

IX. CONCLUSION

The finite Element Results on Leaf spring made of Steel and Composite shows that, both the leaf springs perform better on actual loading conditions. Compared to steel leaf spring, Stress produced in the composite leaf spring is very low, that of its yield strength of the material. It has the tendency to carry higher loads than existing one.

If the composite is used to manufacture the leaf spring, it will result into large amount of weight saving i.e. 46.29% of weight of vehicle can be reduced. This amount of weight reduction will increase the efficiency of the vehicle.

This method of producing the leaf springs will also increase the driving and passenger comfort.

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