Design Simulation Comparison of Mono Leaf Spring Using SAE 1045 – 450– QT and E- Glass Epoxy materials for Automotive Performance

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Abstract – This paper presents comparative simulation results of E-Glass Epoxy mono composite leaf spring for different layup as well for different thickness condition. First, simulation results have been performed for SAE 1045-450-QT steel material from weight saving and stress reduction point of view. Secondly, comparative simulation analysis performed between [0-45-(-45)-90-0], [0-45-(-45)-0], [0-0-45-(-45)-0] and [0-45-90] layup with different thickness from 9 mm, 10 mm, 12 mm, 13mm and 15 mm , considered according to selection of each layup thickness. The design and comparative simulation analysis was done in ANSYS Software. Similar mechanical properties for E-Glass epoxy composite material were considered for all simulation procedure. The design constraints and meshing were also being similar for all conventional and composite models of leaf spring. Design and simulation results were predicted by considering linear static analysis and presented.

Keywords: E-Glass Epoxy Composite, Layup, Simulation, ANSYS

I. INRRODUCTION

As reducing weight and increasing strength of products are high research demands in the area of automotive, composite materials are getting to be up to the mark of satisfying these demands. As leaf spring contributes considerable amount of weight to the vehicle and needs to be strong enough, a mono E-glass/Epoxy leaf spring is designed and simulated following the design rules of the composite materials. Due to catastrophic failure nature of materials already used in automotive leaf spring, it is considerably replaced by high strength, high stiffness composite material.

For the suspension of three wheeler vehicle, usually single or mono leaf spring necessarily design for attempting to reduce the weight of the vehicle and also for improving comfort. Also it is emphasis on safety, cost and durability.

This paper covers design and simulation of mono E - Glass/Epoxy composite leaf spring for lightweight passenger three wheeler vehicles. The main objectives are:

1. Performance comparison of SAE 1045-450-QT Steel material with E-Glass Epoxy material
2. Simulation Comparison of E-Glass Epoxy material for different layup
3. Simulation Comparison of different layup composite materials for different thickness
4. Selection of better result produced layup of E-Glass Epoxy material.

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II. LITRATURE REVIEW

A single leaf with variable thickness and variable width for constant cross sectional area are analyzed in ANSYS software with different composite materials along with the steel. A comparative study has been made between different composite materials and with the steel in respect of weight, deflection and stress. It can be observed that Boron Aluminum is the best suitable material for replacing the steel in manufacturing of mono leaf spring. The savings in the weight is 90.3% [1]. Static, dynamic & shock analysis for two & five layered composite leaf spring essential in showing the comparative results. The leaf spring has to withstand a centre load of 1000kg. In static analysis the maximum displacement is observed in two layered i.e. 101.5mm compared to 83.23mm in five layered. Also during the static analysis Von-mises stress for the five layered is more than two layered i.e. 948Mpa for five layered compared to 795.4Mpa for two layered. The range of frequencies for two layers is 19.2 Hz to 1433 Hz and for five layers is 21.2 Hz to 1612 Hz [2]. Leaf spring have designed and modeled using Mild steel, E-glass, S-glass, and C-glass. As per the static analysis on 8-leafs, E-glass epoxy is having good yield strength and better than using Mild-steel as though stresses are little bit higher than mild steel. Leaf spring using 12 leafs; S-glass (Carbon reinforced fiber) is having better results while comparing with C- glass, E-glass and mild steel and also increased the number of leafs reduces the stress for structural stability [3].

Under the same static load conditions, deflection and stresses of steel leaf spring and composite leaf spring are found with the great difference. Deflection of Composite leaf spring is less as compared to steel leaf spring with the same loading condition [4]. Experimental results from testing the leaf springs under static loading containing the stresses and deflection shows the weight of the leaf spring is reduced considerably about 85 % by replacing steel leaf spring with composite leaf spring. Thus the reduction of unsprung mass is achieved to some extent [5]. The lay-up geometry has a strong influence on fatigue strength. 0° laminate results have values 1.5-1.8 times higher than +45°/0°/-45° and +30°/-30°/0° laminates which exhibit similar fatigue strengths (although +30°/ -30°/0° is 10-15% lower than the +45°/0°/-45° case) [6]. The fatigue life of a leaf spring can be calculated by using total life and crack initiation methods, to investigate the effect of mean stress on fatigue life [7].

The development of a composite leaf spring having constant cross sectional area, where the stress level at any station in the leaf spring is considered constant due to the parabolic type of the thickness of the spring, has proved to be very effective. So, composites can be used for leaf springs for light weight vehicles and meet the requirements, together with substantial weight savings [8].

III. DESIGN DESCRIPTION OF MONO COMPOSITE LEAF SPRING

A. Dimensions of Mono Leaf Spring:

Total Length of the spring (Eye to Eye) = 1200 mm
Free Camber (At no load condition) = 120 mm
Design Thickness of Mono leaf = 8 mm
Width of leaf spring = 60 mm

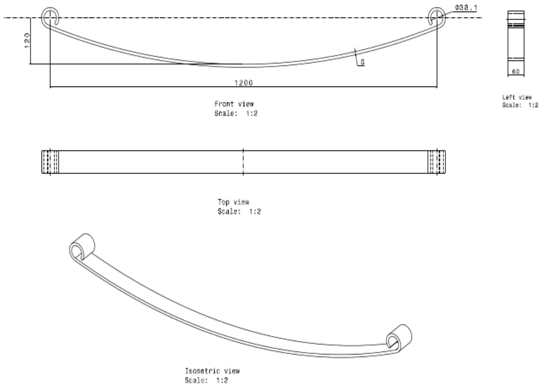

Fig.1 Model of Mono Leaf Spring for simulation

B. Material Description:

SAE 1045- 450 –QT Material:

Elastic Modulus (E) = 207×10^3 MPa
Yeild Tensile Strength = 1515 MPa
Ultimate Tensile Strength = 1584 MPa
Density = 7.7×10^3 Kg/m^3

E-Glass Epoxy Composite Material:

Tensile modulus along X-direction (Ex) = 34000 MPa
Tensile modulus along Y-direction (Ey) = 6530 MPa
Tensile modulus along Z-direction (Ez) = 6530 MPa
Tensile strength of the material = 900 MPa
Compressive strength of the material = 450 MPa
Shear modulus along XY-direction (Gxy) = 2433 MPa
Shear modulus along YZ-direction (Gyz) = 1698 MPa
Shear modulus along ZX-direction (Gzx) = 2433 MPa
Poisson ratio along XY-direction (υxy) = 0.217
Poisson ratio along YZ-direction (υyz) = 0.366
Poisson ratio along ZX-direction (υzx) = 0.217
Mass density of the material (ρ) = 2.6×10-6 kg/mm3

C. Boundary Conditions & Loads:

The Figure 1 illustrates the boundary condition of Mono leaf spring. Leaf is constrained in all directions except along X-Rotation at Eye Bolts and load of 3250 N is applied at centre.

Table.1 Boundary condition – Mono Leaf Spring

D.O.F. Constrained	Front Eye	Rear Eye
Translation Constrained	X, Y & Z direction	Y & Z direction
Rotation Constrained	X & Z direction	X & Z direction
Allowing	Free Y rotation	Free X translation

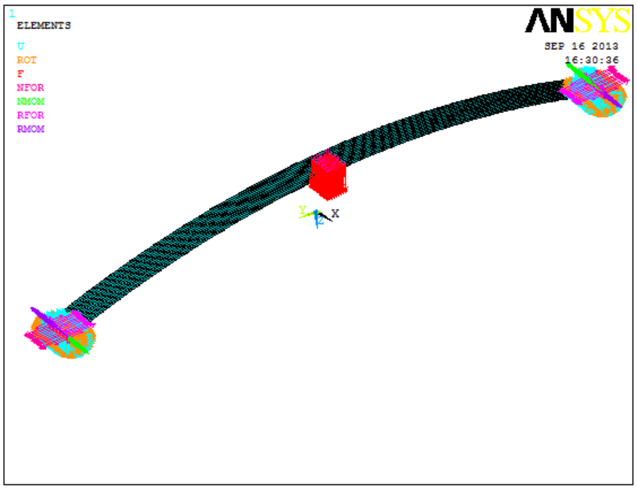

Fig.2 Model of Mono Leaf Spring for simulation

IV. SIMULATION RESULTS AND DISCUSSION

The objective of this paper is to evaluate performance of leaf spring using SAE 1045- 450 -QT steel material and E-Glass Epoxy Composite materials for different layup with respect to variation of thickness of leaf spring.
The three simulation cases are considered here for E –Glass Epoxy composite mono leaf spring:

a) Mono leaf spring with five layup [0-45-(-45)-90-0] - thickness of 10 mm, 13 mm and 15 mm
b) Mono leaf spring with four layup [0-45-(-45)-0] - thickness of 8mm, 10 mm and 12mm
c) Mono leaf spring with five layup [0-0-45-(-45)-0] - thickness of 10 mm, 13 mm and 15 mm
d) Mono leaf spring with three layup [0-45-90] - thickness of 9 mm. 10 mm and 12 mm

a) Static simulation results for five layup [0-45-(-45)-90-0] of leaf spring with thickness of 10mm, 13mm and 15mm respectively are as follows:

1. Thickness = [2mm-2mm-2mm-2mm-2mm] = 10mm

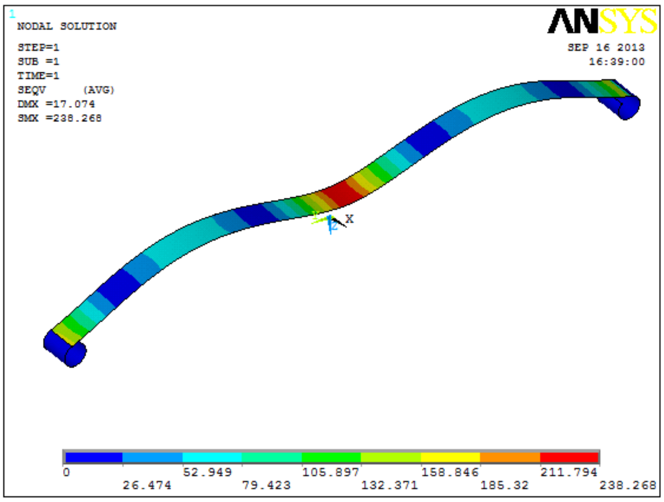

Fig.3 Stress Plot - [0-45-(-45)-90-0] Lay up 10 mm thickness

2. Thickness = [2mm-3mm-3mm-3mm-2mm] = 13mm

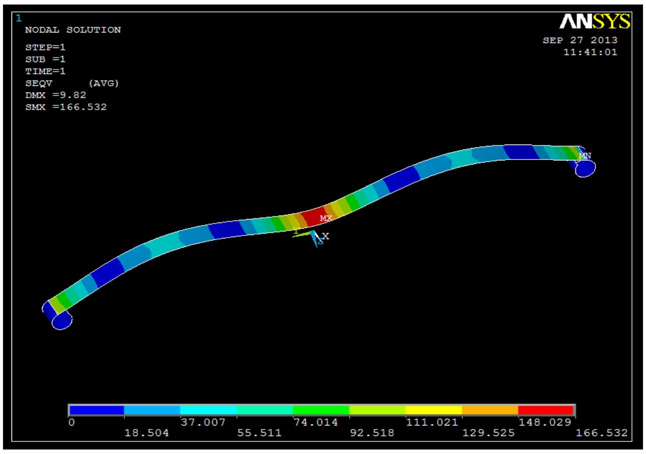

Fig.4 Stress Plot - [0-45-(-45)-90-0] Lay up 13 mm thickness

3. Thickness = [3mm-3mm-3mm-3mm-3mm] = 15mm

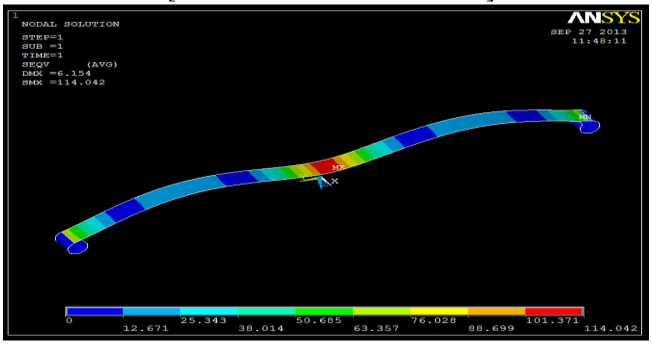

Fig.5 Stress Plot - [0-45-(-45)-90-0] Lay up 15 mm thickness

b) Static simulation results for four layup [0-45-(-45)-0] of leaf spring with thickness of 8mm, 10 mm and 12mm

1. Thickness = [2mm-2mm-2mm-2mm] = 8mm

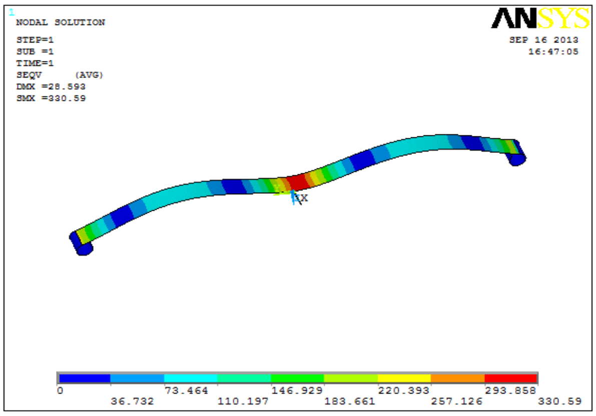

Fig.6 Stress Plot - [0-45-(-45)-0] Lay up 8 mm thickness

2. Thickness = [2mm-3mm-3mm-2mm] = 10 mm

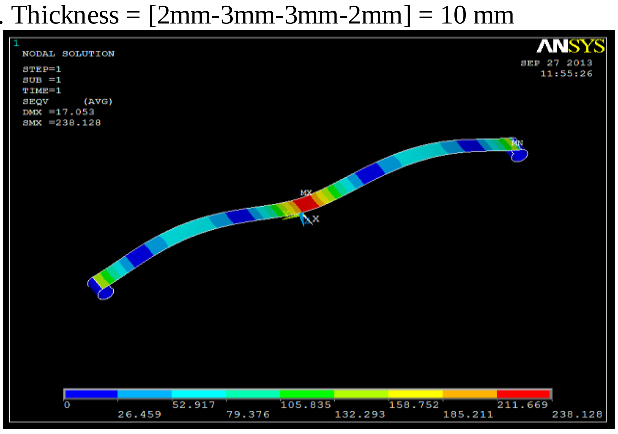

Fig.7 Stress Plot - [0-45-(-45)-0] Lay up 10 mm thickness

3. Thickness= [3mm-3mm-3mm-3mm] = 12mm

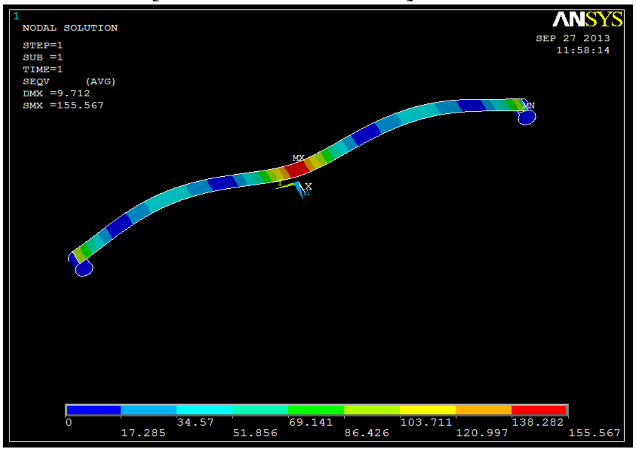

Fig.8 Stress Plot - [0-45-(-45)-0] Lay up 12 mm thickness

c) Static simulation results for five layup [0-0-45-(-45)-0] of leaf spring with thickness of 10 mm, 13 mm and 15 mm

1. Thickness= [2mm-2mm-2mm-2mm] = 10mm

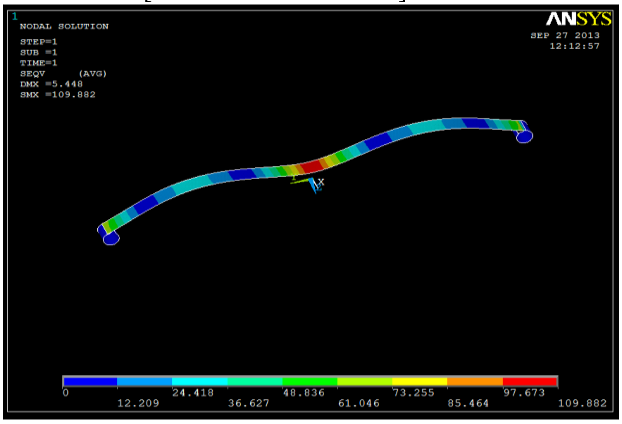

Fig.9 Stress Plot - [0-0-45-(-45)-0] Lay up 10 mm thickness

2. Thickness= [2mm-3mm-3mm-3mm-2mm] = 13mm

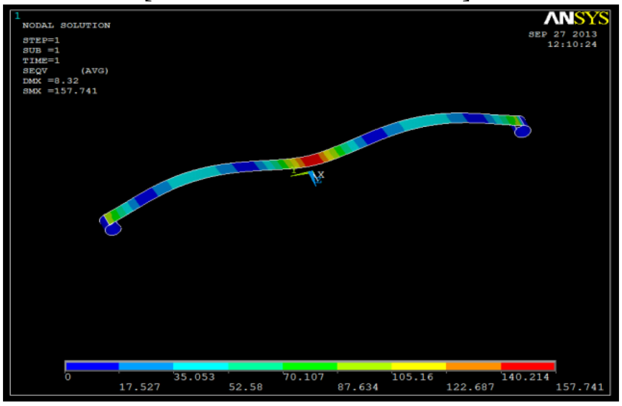

Fig.10 Stress Plot - [0-0-45-(-45)-0] Lay up 12 mm thickness

3. Thickness = [3mm-3mm-3mm-3mm-3mm] = 15mm

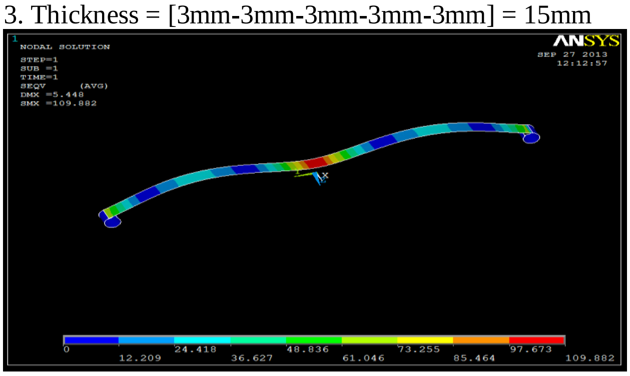

Fig.11 Stress Plot - [0-0-45-(-45)-0] Lay up 15 mm thickness

d) Static simulation results for three layup [0-45-90] of leaf spring with thickness of 9 mm, 10 mm and 12 mm

1. Thickness= [3mm-3mm-3mm] = 9 mm

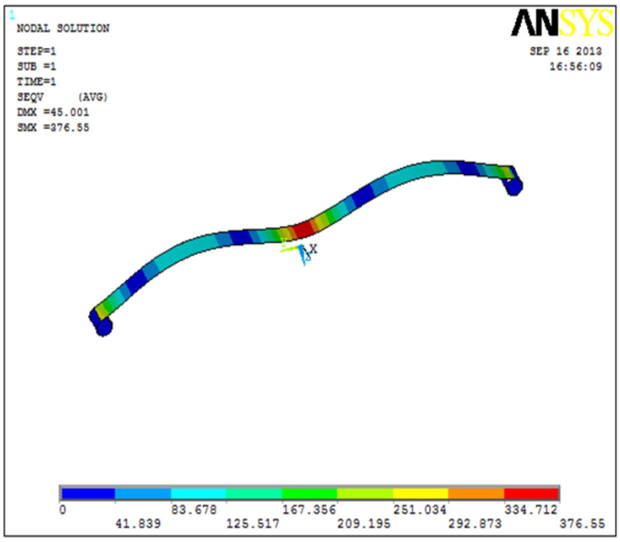

Fig.12 Stress Plot [0-45-90] Lay up 9 mm thickness

2. Thickness= [3mm-4mm-3mm] = 10 mm

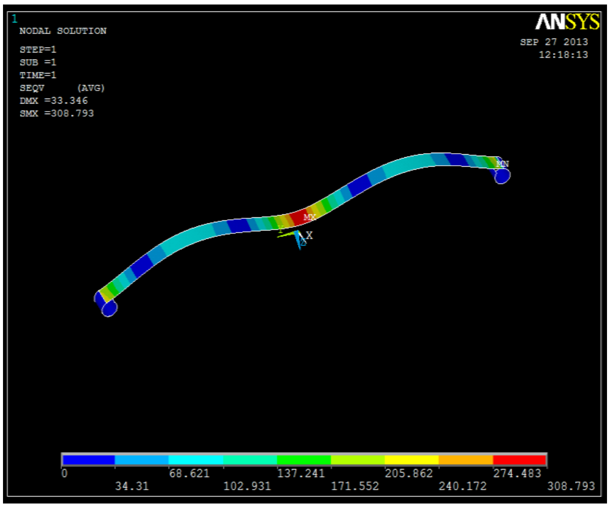

Fig.12 Stress Plot [0-45-90] Lay up 10 mm thickness

3. Thickness= [4mm-4mm-4mm] = 12 mm

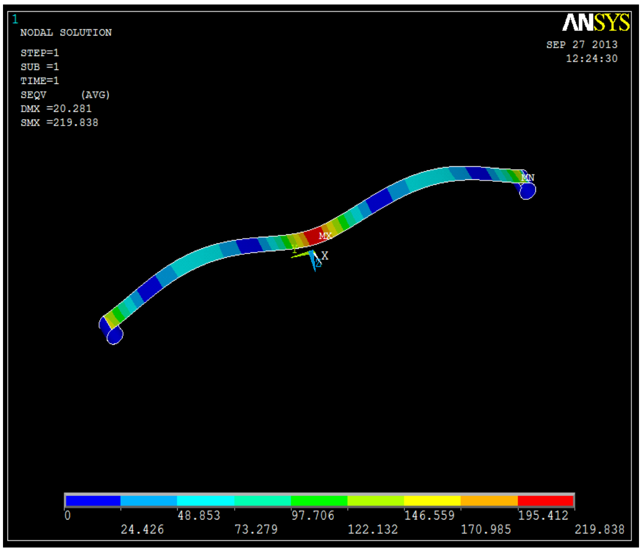

Fig.12 Stress Plot [0-45-90] Lay up 12 mm thickness

The Simulation result of leaf spring using SAE 1045- 450 - QT steel material is as follows with comparison to E- Glass Epoxy composite material for different layup with different thickness.

The Stress and deflection plotted can be shown in Fig. 13 and Fig. 14

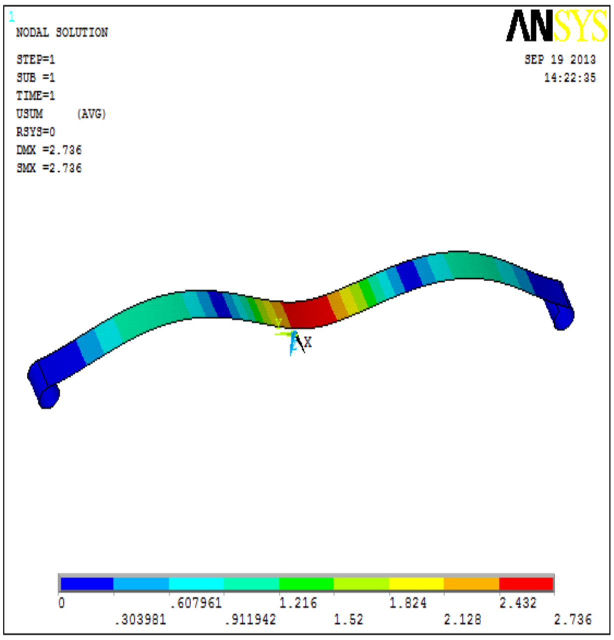

Fig.13 Deflection Plot for SAE 1045- 450 -QT steel material

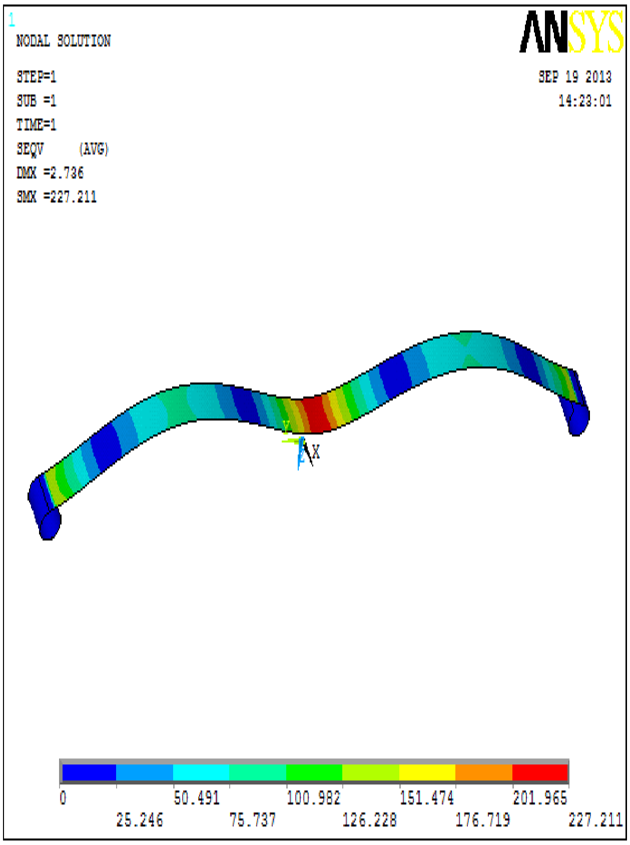

Fig.14 Stress Plot for SAE 1045- 450 -QT steel material

The comparative simulation results are formulated in tabular form as follows for E –Glass epoxy material in comparison to SAE 1045 – 450 – QT steel material.

Table 2: Comparison of stress simulation results

Lay Up / Thickness	[0-45-(-45)-90-0]	[0-0-45-(-45)-0]	[0-45-(-45)-0]	[0-45-90]
8 mm		------	330.59	------
9 mm	------	------	------	276.55
10 mm	238.268	231.622	238.128	308.793
12 mm	-------	------	155.567	219.838
13 mm	166.532	157.741	------	------
15 mm	114.042	109.882	------	------

Table 3: Comparison of deflection simulation result (mm)

Lay Up / Thickness	[0-45-(-45)-90-0]	[0-0-45-(-45)-0]	[0-45-(-45)-0]	[0-45-90]
8 mm	------	------	28.593	------
9 mm	------	------	------	45.0
10 mm	12.074	15.408	17.053	33.346
12 mm	-------		9.712	20.281
13 mm	9.82	8.32	------	------
15 mm	6.154	5.448	------	------

V. CONCLUSION

E- Glass Composite leaf springs with varying thickness and layup have been developed. On this leaf spring, simulation done for stresses using ANSYS software with different layup composite material along with SAE 1045 – 450 – QT steel material. A comparative simulation study has been made here helpful to designer with respect to different layup and thickness variation. This will helpful for researcher for selecting proper layup according to application. According to above study, the variation in thickness with layup has effect on stress and deflection parameter. This study will helpful in future for selecting proper layup condition along with thickness according to weight saving and increased stiffness point of view. The layup, thickness, weight and stiffness parameter should consider in design of mono leaf spring of automotive.

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