Modelling and Experimental Studies on Mechanical Properties of E-Glass Fiber Reinforced Polyester Composite to evaluate its Suitability to use as a Leaf Spring Material

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Abstract : This paper aims mechanical behavior of the e-glass epoxy laminates which are fabricated as per ASTM-D 790, ASTM-D 882, ASTM-D 785 standards by varying fiber orientation of (0^0, 45^0, 90^0) using hand lay-up and press molding techniques. The specimens of E-glass epoxy laminated composites are examined experimentally. Experiments have been carried out on these laminated composite specimens to find the tensile, flexural and hardness strengths. Using Abaqus software with different orientations of laminates are modelled and solved analytically. Comparing the results with both experimental and analytical and evaluate the unknown values of composites by using artificial neutral network in MATLAB. The properties of laminated composite are applied to a designed multi leaf spring for analysis in ANSYS workbench. The objective of this analysis is to compare the stresses, deformation & strain energy of composite leaf spring with the properties of steel leaf spring.

Keywords: Hand lay-up technique, fiber orientation, Abaqus, ANSYS, MATLAB

I.INTRODUCTION

The introduction of composite materials was made it possible to reduce the weight of leaf spring without any reduction of load carrying capacity and stiffness[1].Leaf springs are mainly used in suspension systems to absorb shocks loads in automobiles like light motor vehicles and heavy duty trucks. It carries lateral loads, brake torque, driving torque in addition to stock absorbing[2].This paper is mainly focused on the implementation of composite materials of replacing steel in convectional leaf springs of a suspension system to reduce weight, improving the safety, comfort and durability. The composite materials having more elastic strain energy storage capacity due to low young's modulus and low density than steel.

II.FABRICATION DETAILS

The reinforcement material employed was E-glass fiber (610 GSM). The matrix material are epoxy resins LY 556 and hardener HY 951 mixed in appropriate ratio 1:10 with room temperature curing cycle of 24 hours duration. The glass/Epoxy composite is fabricated using simple hand layup technique. The procedure consists of placing the glass fibers, layer by layer and applying liquid epoxy mixed with hardener on the glass fibers until the desired thickness is obtained. The layup assembly is pressed with the help of roller so that excess air between the layers is expelled out.

The tensile test was carried out using a universal testing machine. The testing specimen is prepared according to ASTM-D 882 standard. The specimen were clamped at ends and tests were performed. The tests were closely monitored and conducted a room temperature. In flexural test specimen is prepared according to ASTM-D 790 standard. The load acts at center of the specimen and ends are simply supported. The hardness test was conducted using Rockwell M scale machine. The test specimen is prepared according to ASTM_D 785.

III.LEAF SPRING DESIGN

The spring consists of a number of leaves called blades. The blades are varying in length. The blades are usually straight so that they will tend to initial curvature or cambered under the load. The spring is mounted on the axle of the vehicle. The entire vehicle load is rests on the leaf spring. Multi leaf spring carries lateral loads, brake torque, driving torque in addition to shock absorbing. Advantage of leaf spring over helical spring are that the ends of the springs are guided along a definite path and it is act as a structural member. It is well known that springs, are designed to absorb and store energy and then release it slowly. Ability to store and absorb more amount of stair energy ensures the comfortable suspension system. Hence, the strain energy of the material becomes a major factor in designing the springs.

3.1 Design parameters

The specification of the multi leaf spring.

Parameter		Value
Total Length of the spring, (L)	-	1150mm
No. of full length leave	-	2
Number of graduated length leaves	-	8
Total number of leaves	-	10
Thickness of leaves, (t)	-	12mm
Width of leaves, (b)	-	50mm
Load, (w)	-	3200

The length of graduated length leaves L8, L7, L6.... are 1085,961, 837,712,588,463,338 & 214mm respectively.

3.2 Multi leaf spring boundary conditions

Constraint

-fixed both end

Forces

-Apply forces at center in (downward) y-direction.

Analysis

-Linear static type

-Maxi. Design load (w) = 3200 N

The multi leaf spring is modeled in the position having maximum deflection i.e. in the flat position and will be loaded in reverse direction to attain its original its original shape. Loading conditions involves applying a load at the center of a main leaf. As per the specification the spring is drawn at flat condition, therefore the load is applied in downward direction to achieve initial no load condition.

IV.MODELLING AND FINITE ANALYSIS METHOD

4.1 CATIA modelling

Using CATIA software leaf spring is modelled by given specification.

4.2 Finite element analysis

A stress, deflection and strain energy analysis is performed using finite element analysis (FEA). The complete procedure of analysis has been done using ANSYS workbench-15.

4.3 MAT lab

An artificial neutron network (ANN) is a computational model based on the structure and functions of biological neutrals networks. Information that flows through the network affects the structure of the ANN because a neural networks changes or learns, in a sense-based on that input and output.

V. RESULTS AND DISCUSSIONS

5.1 Experimental and ABAQUS result in tensile test

Table 5.1:

S. No	Orientation	Loads (N)	Maximum stress(Mpa)	
			Experimental	ABAQUS
1	0^0	4062.49	203.12	206.44
2	45^0	4630.34	123.84	128.52
3	90^0	4241.25	113.07	117.30

From the table 5.1 comparison between experiment and Abaqus is done for tensile test. The results obtained from ABAQUS have been compared with experimental result for E-glass/ epoxy composite. Generally, from 0^0 to 90^0 the maximum stress values are decreasing. The experimental values for 0^0 orientation at load 4062.49 (N), the maximum stress obtained is 203.12 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 206.44 (Mpa). After comparing the percentage errors is 1.6% for 0^0 orientation. Thus, the experimental values for 45^0 orientation at load 4630.34 (N), the maximum stress obtained is 123.84 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 128.52 (Mpa). After comparing the percentage errors is 3.6% for 45^0 orientation. Finally, the experimental values for 90^0 orientation at load 4241.25 (N), the maximum stress obtained is 113.07 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 117.30(Mpa). After comparing the percentage errors is 3.6% for 90^0 orientation. From the comparison it is observed that for percentage of 0^0,45^0,90^0 are less. Thus, experimental and Abaqus values for maximum stress is nearly same.

5.2 Experimental and ABAQUS result in flexural test

Table 5.2:

S.No	Orientation	Loads(N)	Maximum stress(Mpa)	
			Experimental	ABAQUS
1	0^0	121.51	46.66	49.00
2	45^0	342.65	131.58	133.12
3	90^0	165.33	63.49	64.77

From the table 5.2 comparison between experiment and Abaqus is done for flexural test. The results obtained from ABAQUS have been compared with experimental result for E-glass/ epoxy composite. The experimental values for 0^0 orientation at load 121.51 (N), the maximum stress obtained is 46.66 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 49.00 (Mpa). After comparing the percentage errors is 4.7% for 0^0 orientation. Thus, the experimental values for 45_0 orientation at load 342.65 (N), the maximum stress obtained is 131.58 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 133.22(Mpa). After comparing the percentage errors is 1.1% for 45^0orientation. Finally, the experimental values for 90^0 orientation at load 165.33 (N), the maximum stress obtained is 63.49 (Mpa) and at the same load condition for ABAQUS the maximum stress value is 64.77(Mpa). After comparing the percentage errors is

1.9% for 90^0 orientation. From the comparison it is observed that for percentage of 0^0,45^0,90^0 are less. Thus, experimental and Abaqus values for maximum stress is nearly same.

5.2 Experimental result in hardness test

Table 5.3:

	Specimen Label	Experimental Values
1	0001(flx)/1	48
2	0001(flx)/2	54
3	0001(flx)/3	62

From above table 5.3 orientation 0^0 to 90^0 hardness values are increasing. Thus, for 0^0, 45^0,90^0 the hardness values are 48, 54, 62.Thus the maximum hardness attains at 90^0.

Figures and Tables

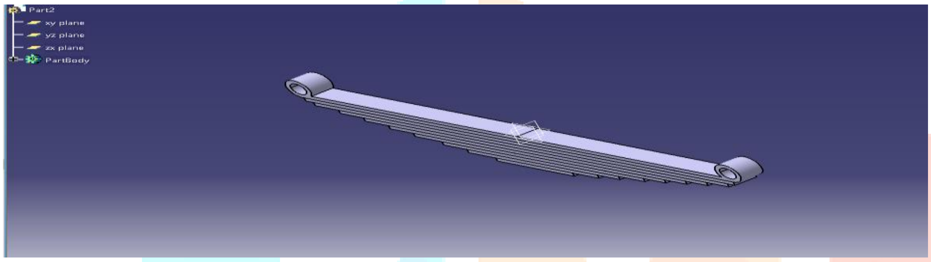


Fig 1: multi leaf spring assemblies

Tensile strength's using ABAQUS

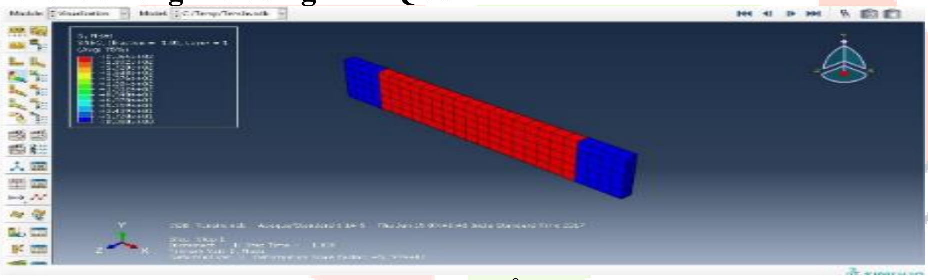


Fig2: tensile strength 0^0

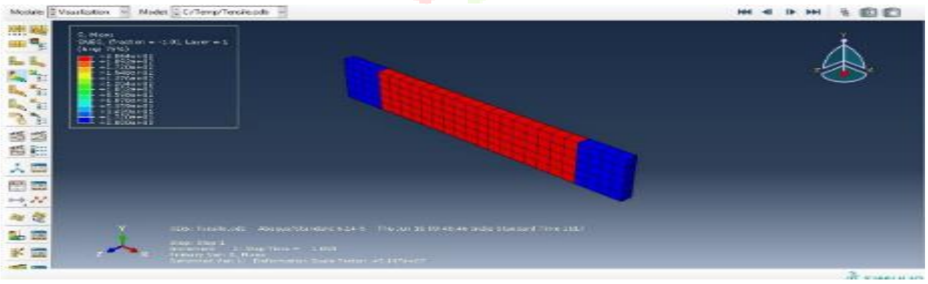


Fig3: tensile strength 45^0

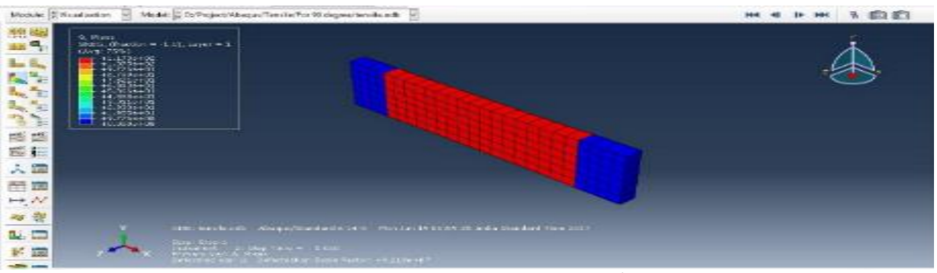


Fig4: tensile strength 0^0

Flexural strength's using ABAQUS

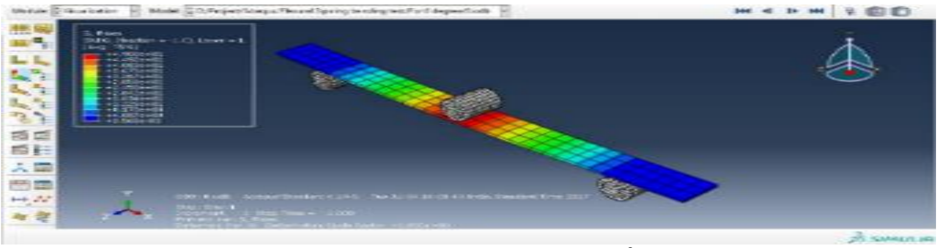


Fig5: flexure strength 0^0

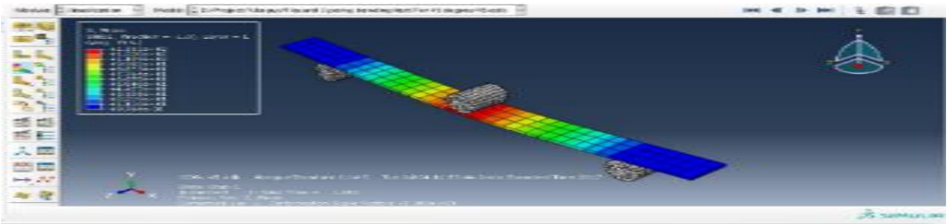


Fig6: flexure strength 45^0

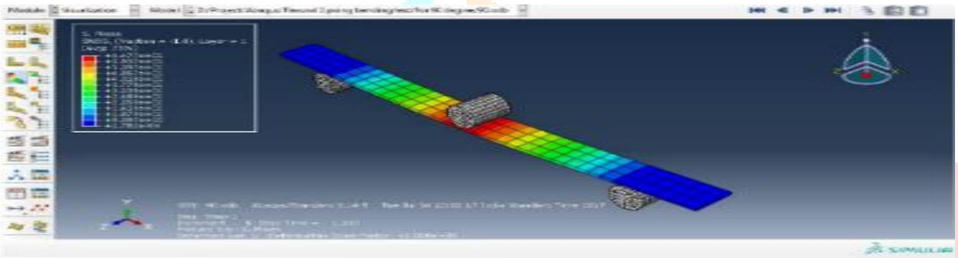


Fig 7: flexure strength 90^0

Fiber orientation vs mechanical properties using MAT lab

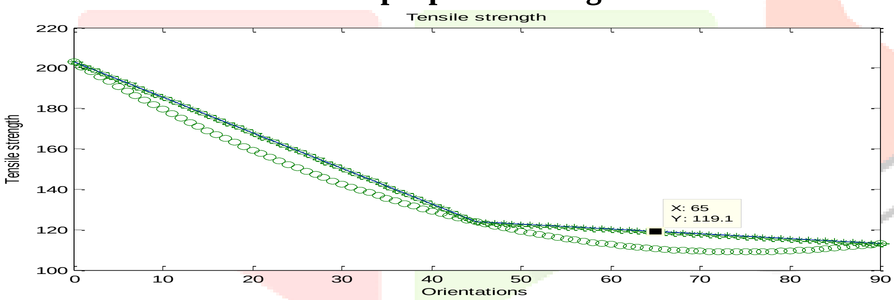


Fig 5: fiber orientation vs tensile strength

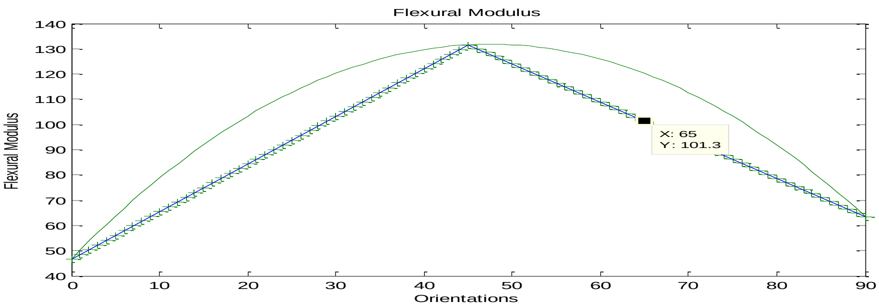


Fig 8: fiber orientation vs flexure strength

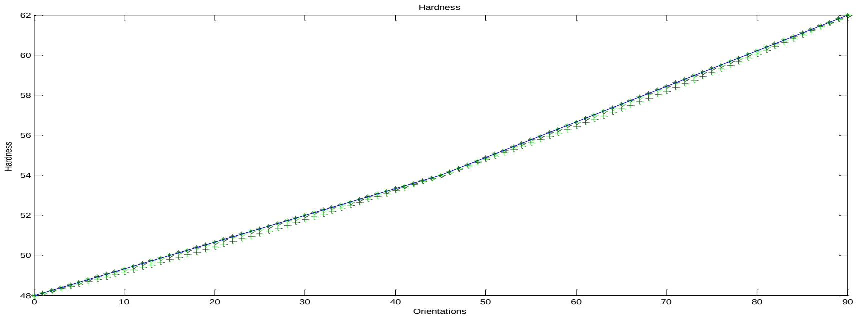


Fig 9: fiber orientation vs hardness strength

FE analysis of steel leaf spring:

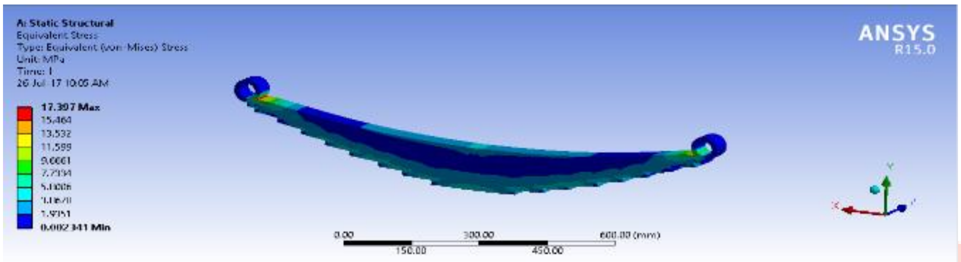


Fig 8: equivalent stress (steel)

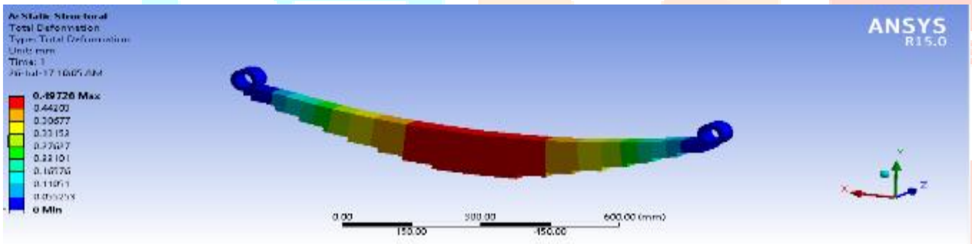


Fig 9: deformation (steel)

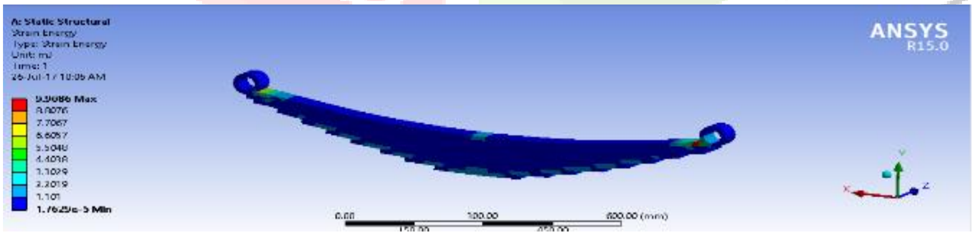


Fig 10: strain energy(steel)

FE analysis of composite FE composite leaf spring

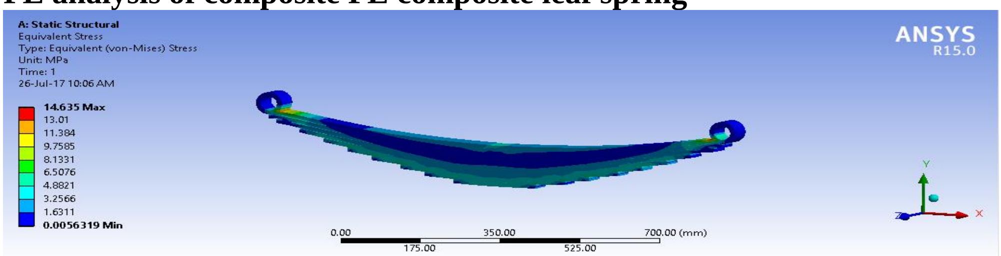


Fig11: equivalent stress(composite material)

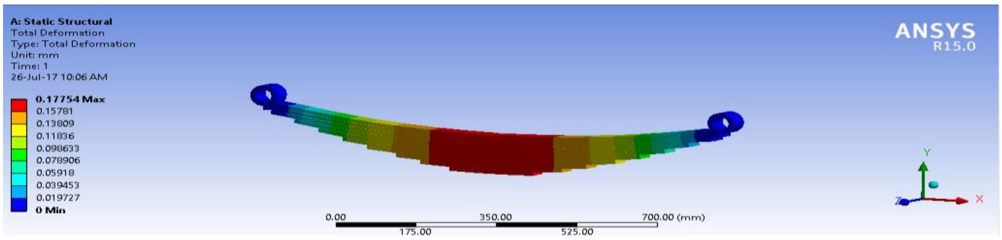


Fig 12: deformation (composite material)

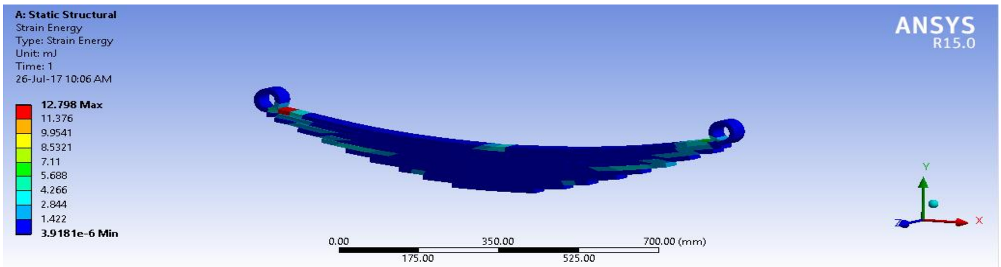
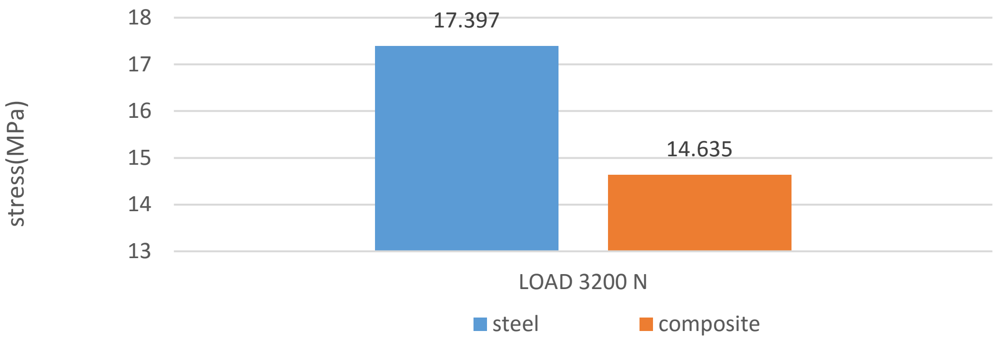
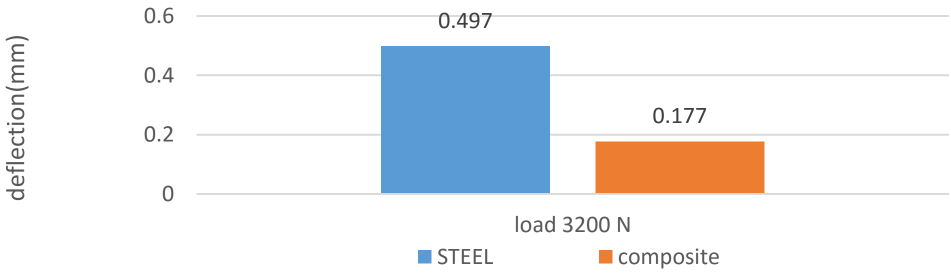


Fig 13: strain energy (composite material)

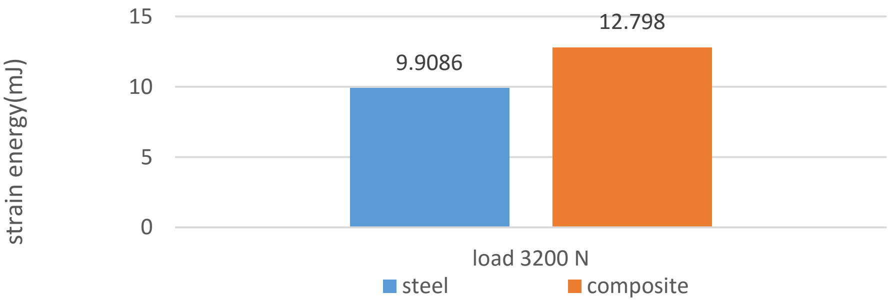
Comparison of equivalent stress, deflection & strain energy between FEA steel and FEA composite leaf spring:



Graph 1: equivalent stress vs load



Graph 2: deflection vs load



Graph 3: strain energy vs load

CONCLUSION

A comparative study has been made between composite and steel leaf spring with respect to stress and deflection. From the static analysis results, we see that the von-misses stress in the steel is 17.397 Mpa, deflection is 0.497 mm & strain energy is 9.9086 mJ. And the von- misses stress in E-glass/ Epoxy is 14.635Mpa, deflection is 0.177 mm & strain energy is 12.798 mJ. The composite (E-Glass/epoxy) leaf spring reduces stress and deflection respectively. From the results, it is observed that the composite leaf spring is more economical than the conventional steel spring.

Finally observed, glass/epoxy with 0^0orientation in tensile, 45^0orientation in flexural & 90^0orientation in hardness have higher strength stiffness and load carrying capacity than any other orientation. Hence, it is preferred for designing of structures like which is more beneficial for sectors like aerospace, automotives, marine, space etc.

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