Static Analysis of Composite Leaf Spring

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Abstract – Leaf springs finds its applications in various low motor and heavy motor vehicles. They are made of several leaf plates which bears an elliptical shape. The performance of the leaf spring is described by its strength. The leaves are held together by means of two U-bolts and a center clip. In Current study, leaf springs design is carried according to the available SAE J788 standards, where we are having several dimensions. The effect of leaf geometry taking the thickness (13.20, 21.20, 30, 37.50) for the composite materials (E-glass/epoxy, Graphite/epoxy) at the orientations ([-45|45|-45|45] and [-30|30|-30|30]) are studied. Analytical calculations are obtained by laminate theory. The laminate theory obtained is inputted to Mat lab codes. Results obtained are compared with Finite Element Analysis (FEA) results.

Keywords: Leaf spring, composite, FEA, static, deflection, stress.

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INTRODUCTION

Usually the leaf springs are made of several leaf plates which bears an elliptical shape. By using the leaf spring system, it is possible to guide the spring ends through a path when it deflects to behave like a supporting structure also act as an energy absorbing device.

Due to the unavailability of the resources in modern days it is better to always design a product with reduced weight which also results in decrease in cost. There are several ways through which one can reduce the total weight some are by choosing proper materials, modifying the geometry and also through choosing modem manufacturing techniques. In the automobiles one can find the usefulness of the leaf spring system and also it weighs 20% of the weight of the vehicle. Now a days in this growing world the usage of composite materials became revolution in a manufacturing industries, resulting one can able to attain the weight reduction of the leaf spring system without effecting its performance. C. K. Clarke [1] made a study on the possible failure of leaf spring system under the various loading parameters. Shiva Shankar [2] conducted a fatigue experiment to determine the life cycle of a leaf spring system. Niklas philipson [3] modeled a leaf spring system by employing standard manufacturing way and also performed a kinematic and dynamic simulations. Zhi'an [4] studied the concepts like the way in which the leaf spring system subjected to cyclic creep and deformation. M. Venkatesan et al. [5] propsed a replacement of conventional leaf spring system with the composite material made for the low motor vehicle. M. M. Patunkar et al. [6] conducted the comparative analysis between the composite made leaf spring system with the available system is to study the behavior of the system on various types of loads. J.J.Fuentes et a.l et al [7&8]in there study, where actually propagation of crack takes place which finally leads to fracture and also conducting investigations on the fractured system are done.

In this thesis we make use the analytical method laminate plate theory and study the geometric factor like thickness. To study the variation of design constraints like deflection and stress for the different orientation of laminae made by composite and compare the results of analysis software with the analytical solutions.

2. FINITE ELEMENT ANALYSIS

Three dimensional object is created using the modeling software and imported to the ansys environment to conduct the static analysis. Due to the axis of symmetry only the half section of the structure is considered. The structure later send to ansys to carry out the analysis and to impart the conditions. The model is created for the leaf spring of thickness 13.2 mm, number of leaves are 4 and dimensions are remain unchanged.

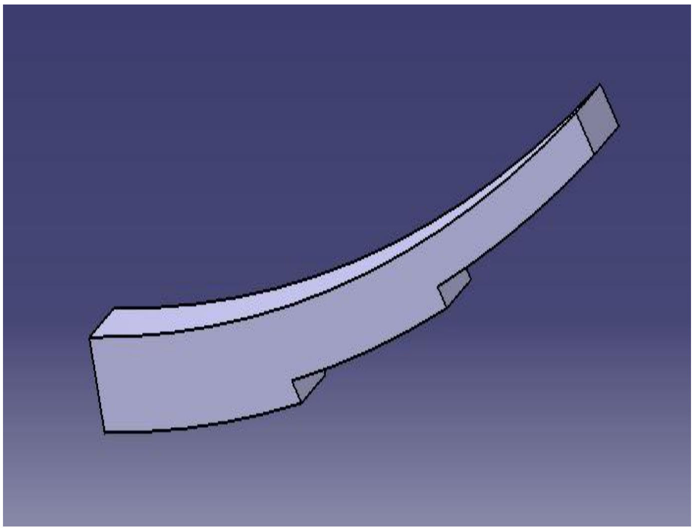

Fig. 1: 3-D model of the Leaf spring.

2.1 Material property

Two composite materials are chosen for the analysis are E-glass/Epoxy and Glass Reinforced plastic and their properties.

Parameters	Materials	
	E-glass/Epoxy	Glass Reinforced Plastics
Exx	34000Mpa	38000MPa
Eyy	6530Mpa	13000MPa
Ezz	6530Mpa	13000Mpa
NUxy	0.217	0.31
NUyz	0.366	0.05
NUzx	0.217	0.31
Gxy	2433Mpa	1000MPa
Gyz	1698Mpa	16MPa
Gzx	2433Mpa	60MPa
Mass density	2.6×10^3 kg/mm3	0.00000185 kg/mm3

Table 1: Material properties of E-glass/Epoxy and Glass Reinforced Plastic material

2.2 Finite element formulation

The model being imported from catia to ansys is meshed using necessary element. The element used is Brick 8noded solid185 element. SOLID185 is used.

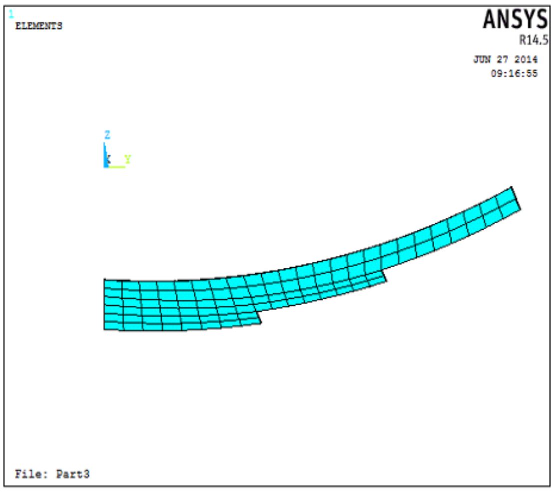

Fig. 2: Meshed view of the leaf spring.

2.3 Boundary Conditions

Always in the structural analysis the displacements are the main variables. If the type 1 boundary conditions are used, the displacement are mentioned along a segment of the boundary. When surface forces are mentioned along the boundary, the boundary conditions fall under Type II because the tractions are related to the derivatives of the displacements. A special case of the traction boundary conditions is the point load (also called the Force/Moment load). When the structure is subjected to tractions over a rather small area, it is better to recognize this condition as a point load. It is also possible When conducting an analysis with BEAM or SHELL element types, moment loads can also be applied.

In this analysis boundary conditions applied for the displacement along the axis of symmetry is constrained in x-direction, Ux = 0. Similarly for the displacement at the point of support ie., to the right top corner of the system is constrained in y-direction, Uy=0. Force of 7500N is applied at the bottom of the body.

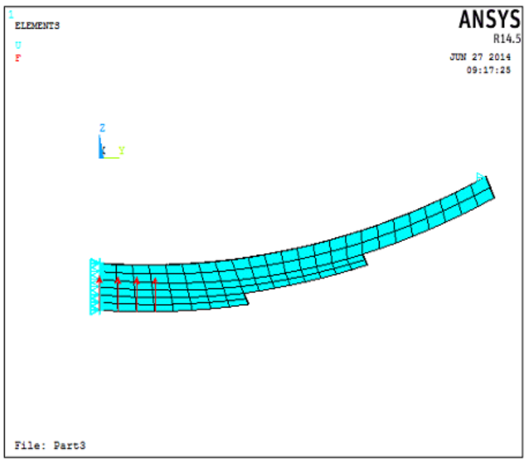

Fig. 3: Boundary conditions applied model.

2.4 Solution

The system is checked for the deflection in z-direction and the stress. Maximum deflection of the structure and maximum stress distribution of the leaf spring for the thickness 13.2 mm with the orientation [-45|45|-45|45], E-glass/Epoxy as the material as shown in Fig. 4 and Fig. 5.

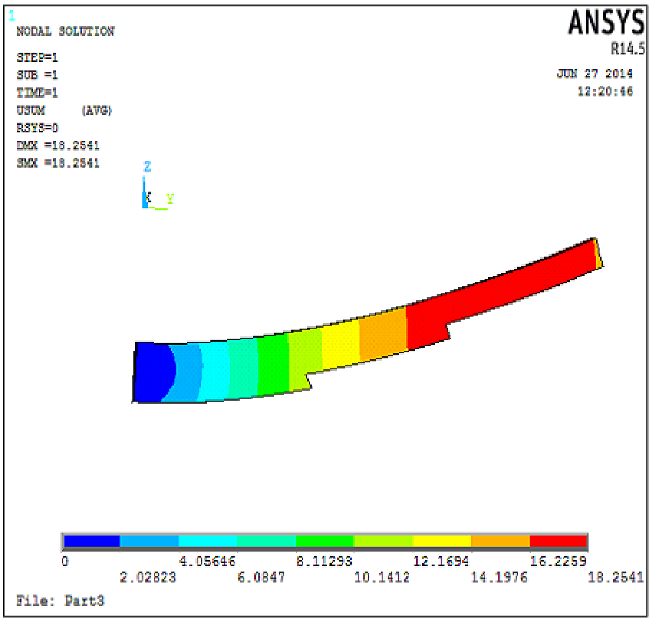

Fig. 4: The Maximum deflection of the model for the above considered problem

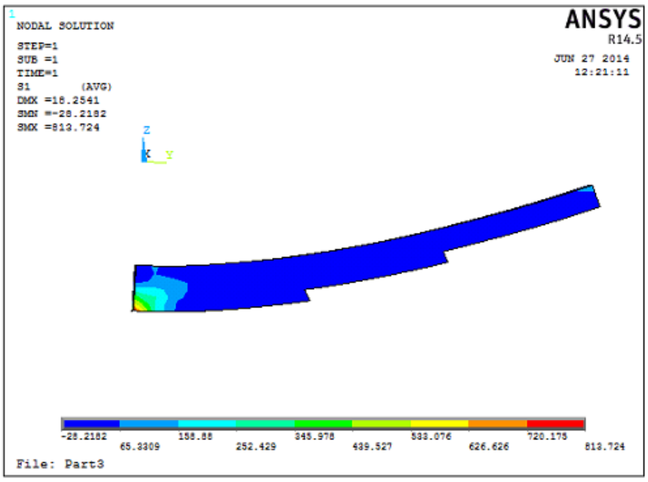

Fig. 5: The Maximum stress distribution in the model for the above considered problem.

Sl. No.	Orientation	Thickness t(mm)	Maximum deflection, δ(mm)	
			Analytical	FEA
1	[-45|45|-45|45]	13.2	16.7	18.2
2	[-45|45|-45|45]	21.2	11.09	11.43
3	[-45|45|-45|45]	30	8.38	7.14
4	[-45|45|-45|45]	37.5	6.93	6.69
5	[-30|30|-30|30]	13.2	20.72	23.12
6	[-30|30|-30|30]	21.2	13.57	13.69
7	[-30|30|-30|30]	30	10.35	9.48
8	[-30|30|-30|30]	37.5	8.47	8.03

Table 2: Analytical and FEA results of maximum deflection for E-glass/Epoxy material with various thickness

3. RESULTS AND DISCUSSIONS

The variation of stress and deflections with leaf parameters like thickness, material properties and orientation are tabulated in the following table.

Sl. No.	Orientation	Thickness t(mm)	Maximum Stress, σ(N/mm2)	
			Analytical	FEA
1	[-45|45|-45|45]	13.2	823	813.7
2	[-45|45|-45|45]	21.2	319.14	298.09
3	[-45|45|-45|45]	30	159.37	175
4	[-45|45|-45|45]	37.5	102	111.75
5	[-30|30|-30|30]	13.2	823	995.88
6	[-30|30|-30|30]	21.2	319.14	320.9
7	[-30|30|-30|30]	30	159.37	173.48
8	[-30|30|-30|30]	37.5	102	121.02

Table 3: Analytical and FEA results of maximum stress for E-glass/Epoxy material with various thickness

Sl. No.	Orientation	Thickness t(mm)	Maximum Stress, σ(N/mm2)	
			Analytical	FEA
1	[-45|45|-45|45]	13.2	823	395.55
2	[-45|45|-45|45]	21.2	319.14	327.35
3	[-45|45|-45|45]	30	159.37	104.24
4	[-45|45|-45|45]	37.5	102	121.21
5	[-30|30|-30|30]	13.2	823	998.4
6	[-30|30|-30|30]	21.2	319.14	323.37
7	[-30|30|-30|30]	30	159.37	191.07
8	[-30|30|-30|30]	37.5	102	171.4

Table 4: Analytical and FEA results of maximum deflection for GRP material with various thickness

Sl. No.	Orientation	Thickness t(mm)	Maximum deflection, δ(mm)	
			Analytical	FEA
1	[-45|45|-45|45]	13.2	14.39	14.95
2	[-45|45|-45|45]	21.2	9.47	9.21
3	[-45|45|-45|45]	30	7.08	6.86
4	[-45|45|-45|45]	37.5	5.88	5.37
5	[-30|30|-30|30]	13.2	18.6	18.95
6	[-30|30|-30|30]	21.2	12.25	13.09
7	[-30|30|-30|30]	30	9.18	8.47
8	[-30|30|-30|30]	37.5	7.7	7.3

Table 5: Analytical and FEA results of maximum stress for GRP material with various thickness.

From the above results, by observing that the deflection decreases with increasing thickness will be more in case of the [-45|45|-45|45] combination compared to [-30|30|-30|30] combination of the lamina in leaf and also stress decreases with increasing thickness will be more for the [-45|45|-45|45] orientation compared to [-30|30|-30|30] combination of the lamina in leaf.

Also the deflection is very less for the glass reinforced plastic compared to E-Glass/Epoxy for the same thickness and orientations.

3. VARIOUS GRAPHS FOR DIFFERENT PARAMETERS

3.1 Variation of maximum deflection and maximum stress versus thickness.

The following fig. 6 to fig 9 shows the variation of deflection with thickness for orientations [-45|45|-45|45] and [-30|30|-30|30] with E-glass/Epoxy material. It is found that with the increase in the thickness of leaf results with the gradual decrease in the deflection and also the stress.

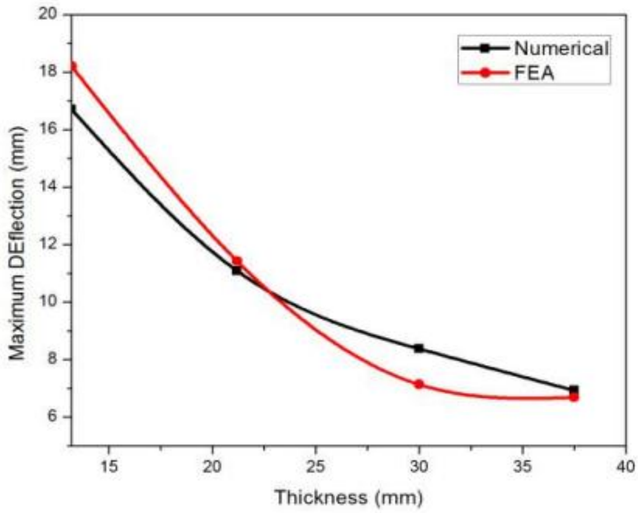

Fig. 6: Variation of Maximum deflection with the thickness for [-45|45|-45|45] orientation

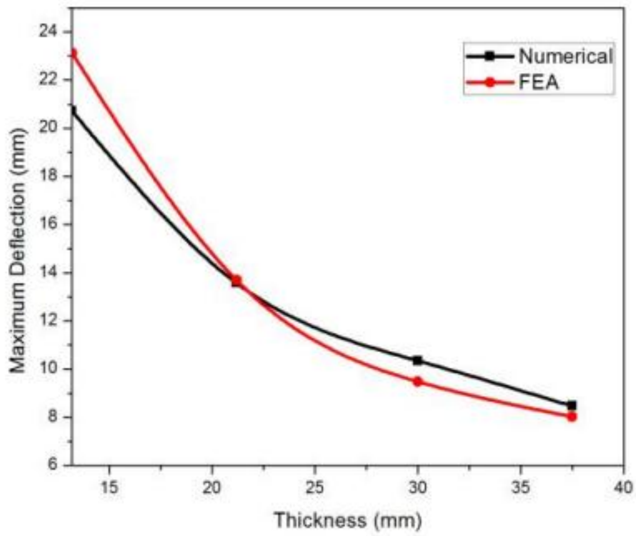

Fig. 7: Variation of Maximum deflection with the thickness for [-30|30|-30|30] orientation

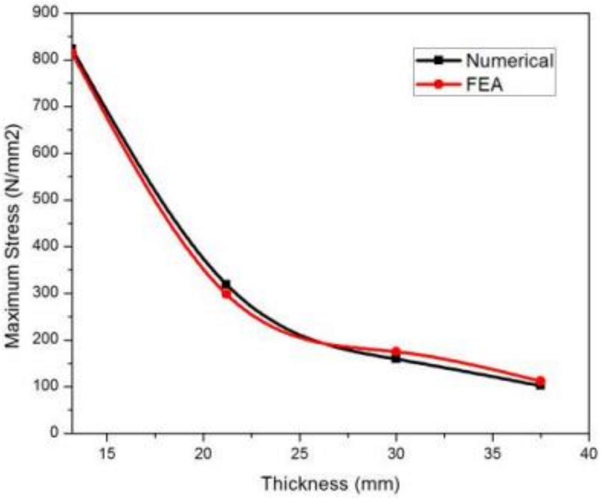

Fig. 8: Variation of Maximum stress with the thickness for [-45|45|-45|45] orientation

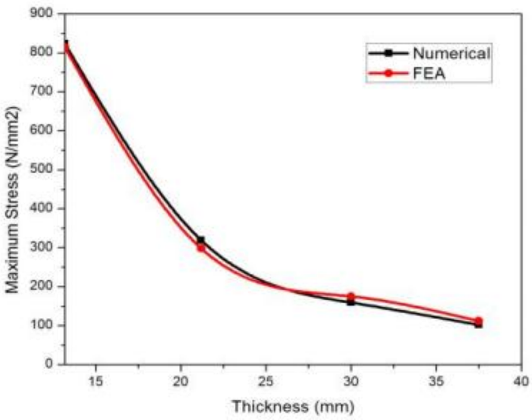

Fig. 9: Variation of Maximum stress with the thickness for [-30|30|-30|30] orientation.

The following fig. 10 to fig. 13 shows the variation of deflection against the thickness for orientations [-45|45|-45|45] and [30|30|-30|30] with Glass Reinforced Plastic material.

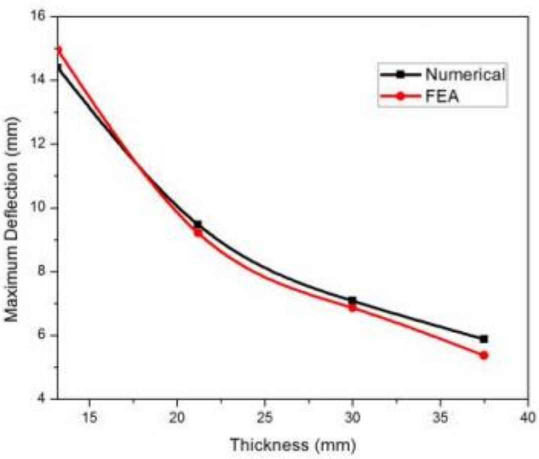

Fig. 10: Variation of Maximum deflection with the thickness for [-45|45|-45|45] orientation

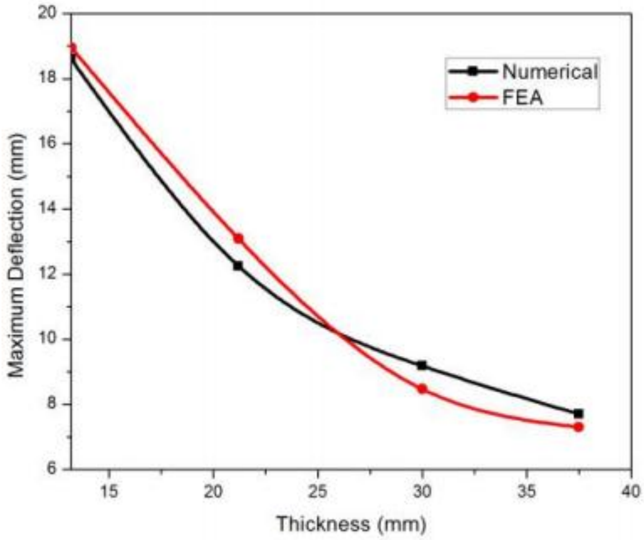

Fig. 11: Variation of Maximum deflection with the thickness for [-30|30|-30|30] orientation

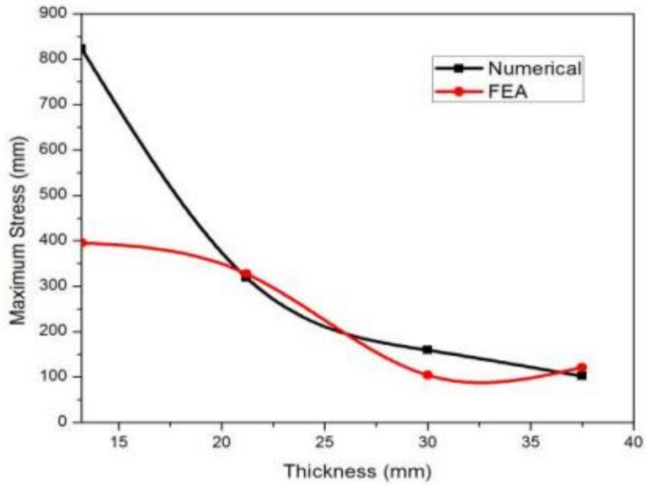

Fig. 12: Variation of Maximum stress with the thickness for [-45|45|-45|45] orientation

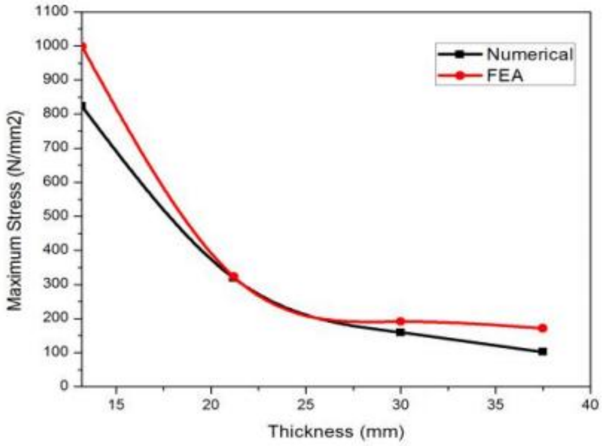

Fig. 13: Variation of Maximum stress with the thickness for [-30|30|-30|30] orientation.

From the above results, by observing that the deflection decreases with increasing thickness will be more in case of the [-45|45|-45|45] orientation compared to [-30|30|-30|30] orientation of the lamina in leaf and also stress decreases with increasing thickness will be more for the [-45|45|-45|45] orientation compared to [-30|30|-30|30] orientation of the lamina in leaf.

Also the deflection is very less for the glass reinforced plastic compared to E-Glass/Epoxy for the same thickness and orientations.

4. CONCLUSION

In the study on considering the thickness of leaf spring with the other factors like orientation and material property, the deflection and stresses are analyzed. From the results obtained various graphs has been plotted. The results obtained using analytically are compared with the FEA results. It is found that the Analytical results are very close to the FEA results. From the study we can conclude that the by increasing cross sectional area of leaves results in increasing the toughness that intern reduces the deflection and stress. The overall outcome of the study can be considered as follows,

- Stress and deflections are gradually reduced by increasing the thickness.
- The amount of stress and deflections are decreased by changing the orientation of the laminae.
- Stress and deflections are decreased by using proper composite materials.

Design constraints stress and deflection are the main concern in the present study, the parameters like thickness, material property and orientations are made as variables by which the study is made and finally concluded that these parameters having great effect on the strength of the leaf spring.

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