Analysis of Hybrid Composite Plate and Fiber Metal Laminated Plate

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Abstract—*the present project work is about the behavior of composite material plates under transverse loading. Finite Element Analysis of composite laminate, hybrid composite laminate and fiber metal laminate is done using ANSYS 12.0. Also different ply orientations are taken in consideration to get the best result. The results are compared with the steel plate. Results show that heavy steel material can be replaced by low weight composite material achieving same advantages that of steel material. Results are validated with analytical results. The classical lamination theory is used for the analytical solution. The best result is obtained with the unidirectional hybrid composite laminate.*

Keywords: Hybrid composite material, fiber metal laminate, Finite element analysis, Stiffness matrix, Deflection.

I. INTRODUCTION

Composite materials are the combination of two constituent materials having different properties, but when they are combined, they produce a material which has different properties from the individual components. For example, concrete is a composite, it is a mixture of Portland cement and aggregate. Fiberglass sheet is a composite since it is made of glass fibers imbedded in a polymer.

Composite materials have two or more chemically distinct phases on a microscopic scale, separated by distinct interface. The constituent that is continuous and is often but not always, present in the greater quantity in composite is termed as the *'matrix'*. The properties of matrix are improved to incorporate another constituent to produce composite. Generally composite have ceramic, metallic and polymeric matrix. The other constituent is known as '*reinforcement'* or *'reinforcing phase'*. The reinforcement is harder than matrix. The shape and dimensions of reinforcement decide the mechanical properties of composite. The reinforcement is either fibrous or particulate. Multilayered composites are known as laminates. Hybrid composites are multilayered composites with fibers. In fiber metal laminate a thin plate of metal is stacked over lamina of composite. [1], [2]

In this paper two composites materials are taken into consideration E-glass and S-glass. E-glass is commonly used fiber reinforcement. It has low water absorption property, good isolative property and it is relatively cheaper than other fiber materials. S-Glass has an extra high strength to weight ratio.The properties of composites are dependent on proportions and properties of the matrix and reinforcement. The proportions are expressed via *weight fraction* or *volume fraction*. In this paper volume fractions are considered while calculations. [11]

II. MECHANICAL PROPERTIES

The law mixtures is,

$$X_c = X_m v_m + X_f v_f$$

Where, X_c, X_m, X_f = appropriate property of composite, matrix and fiber respectively.

v_m, v_f = volume fractions of matrix and fiber respectively.[1]

In this paper, E-glass and S-glass are fibers while Epoxy resin is matrix.

Following are properties of E-glass/Epoxy and S-glass/Epoxy: [3], [8], and [10]

Table I. Properties of E-glass/Epoxy and S-glass Epoxy:

Properties	E-glass/ Epoxy	S-glass /Epoxy
Elastic modulus in longitudinal direction E_1, GPa	43.36	54.16
Elastic modulus in transverse direction E_2, GPa	7.923	8.034
Major Poisson's ratio μ_1	0.24	0.258
Minor Poisson's ratio μ_2	0.04385	0.03827
Shear modulus in 1-2 direction G_{12}, GPa	3.0693	3.096

III. LAMINA CONSTITUTES EQUATION:

The stiffness matrix for 0^0 symmetric lamina is:

$$Q = \begin{bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21} & Q_{22} & 0 \\ 0 & 0 & Q_{33} \end{bmatrix}$$

Where,

$$Q_{11} = E1/(1-\mu_1 \mu_2)$$

$$Q_{22} = \mu_2.E_1/(1-\mu_1 \mu_2)$$

$$Q_{21} = \mu_1.E_2/(1-\mu_1 \mu_2)$$

$$Q_{22} = E_2/(1-\mu_1 \mu_2)$$

$$Q_{33} = G_{12}$$

For θ^0 lamina:

The transformation matrix is given as,

$$T = \begin{bmatrix} m^2 & n^2 & 2mn \\ n^2 & m^2 & -2mn \\ -mn & mn & (m^2-n^2) \end{bmatrix}$$

For the opposite direction of fiber inverse transformation matrix is:

$$T^{-1} = \begin{bmatrix} m^2 & n^2 & mn \\ n^2 & m^2 & mn \\ -2mn & 2mn & (m^2-n^2) \end{bmatrix}$$

Where, m = cosθ, n = sinθ [1], [2], [5], [9]

IV. STRESS-STRAIN RELATION:

Stress-Strain relation for θ^0 lamina is;

$$\begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix} = \begin{bmatrix} \overline{Q_{11}} & \overline{Q_{12}} & \overline{Q_{13}} \\ \overline{Q_{21}} & \overline{Q_{22}} & \overline{Q_{23}} \\ Q_{31} & Q_{32} & Q_{33} \end{bmatrix} \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \end{bmatrix}$$

In above equation $\bar{Q}$ matrix is the transformed stiffness matrix. The elements are,

$$\bar{Q}_{11} = Q_{11}m^4+2(Q_{12}+2Q_{33})n^2m^2+Q_{22}n^4,$$

$$\bar{Q}_{22} = Q_{11}n^4+2(Q_{12}+2Q_{33})n^2m^2+Q_{22}m^4,$$

$$\bar{Q}_{12} = \bar{Q}_{21} = (Q_{11}+Q_{22}-4Q_{33})n^2m^2+Q_{12}(m^4+n^4),$$

$$\bar{Q}_{33} = (Q_{11}+Q_{22}-2Q_{12}-2Q_{33})n^2m^2+Q_{33}(m^4+n^4),$$

$$\bar{Q}_{13} = \bar{Q}_{31} = (Q_{11}-Q_{12}-2Q_{33})nm^3+(Q_{12}-Q_{22}+2Q_{33})n^3m,$$

$$\bar{Q}_{23} = \bar{Q}_{32} = (Q_{11}-Q_{12}-2Q_{33})n^3m+(Q_{12}-Q_{22}+2Q_{33})nm^3,$$ [1],[2],[5],[9]

V. Deflection:

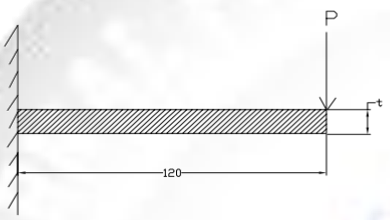

Fig.1: Schematic of load applied to rectangular plate

For a rectangular plate as shown in above fig., when force P is applied at the end and other end is fixed then deflection is given by,

$\delta = Pl^3 / (3EI)$

$E = 1 / (a_{11}t)$; a_{11} = the element of A^{-1} matrix [2]

VI. Results And Discussion:

The rectangular plate is of 120 mm in length and 70 mm in width. The Classical Lamination theory is used to calculate stiffness matrix and further calculations. In Ansys 12.0 Shell181 element is chosen which helps to provide layer wise information of the laminate. Mesh element size is 5. P = 1000 N [6], [7], [11]

E = E-glass/Epoxy; S = S-glass/Epoxy; Al = Aluminum.

Table II: Result Table

Sr. No.	Laminate	Thickness, mm	Deflection, mm		Stress, N/mm^2
			Analytical	FEA	
1	Steel plate	6	2.1769	2.09538	278.80
2	$[E_{90}/E_{0,2}]_s$	6	24.843	24.6816	116.217
3	$[E_{90,2}/E_{0,2}]_s$	8	15.910	15.726	278.47
4	$[S_{90}/S_0/E_{0,2}]_s$	8	7.564	7.426	47.618
5	$[S_{0,2}/E_{0,2}]_s$	8	3.995	3.724	163.624
6	$[Al/E_{0,2}]_s$	6	-	7.189	314.609
7	$[Al_2/E_{0,2}]_s$	8	-	2.85	159.899

Some FEA results:

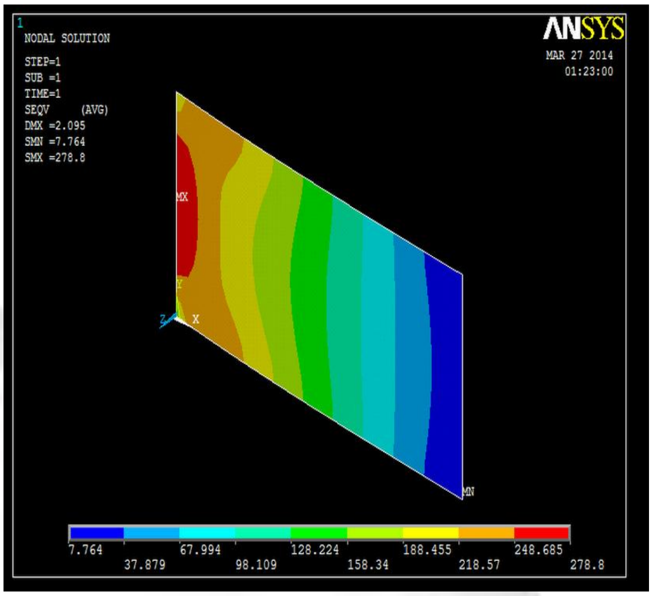

Fig.2: FEA of steel plate (6 mm)

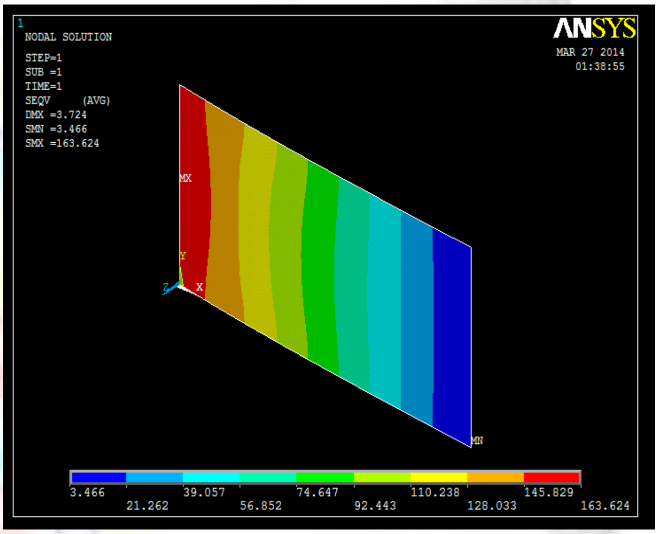

Fig.3: FEA of $[S_{0,2}/E_{0,2}]_s$ hybrid compositeplate (8 mm)

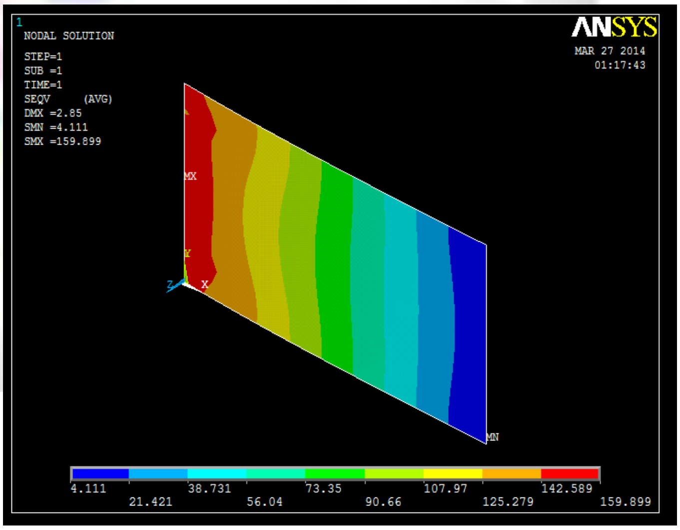

Fig.4: FEA of $[Al_2/E_{0,2}]_s$ Fiber metal laminate plate

VII. Conclusion

From result table it can be pointed that replacing the steel plate by hybrid composite plate or fiber metal laminate plate gives slightly more deflection than steel plate, but the stresses in plate are marginally minimum. The underlined values in result table shows that steel plate can be replaced by $[S_{0,2}/E_{0,2}]_s$ hybrid compositeplate and $[Al_2/E_{0,2}]_s$ Fiber metal laminate plate. These plates have less weight than steel plate.

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