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Weight Optimization of Composite Cantilever Structure

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Abstract—*Reducing weight while increasing or maintaining strength of products is getting to be highly important research issue in this modern world. Composite materials are one of the material families which are attracting researchers and being solutions of such issue. The Automobile Industry has great interest for replacement of metal components with that of composite materials, since composite materials have interesting properties such as high strength to weight ratio, ease of fabrication, good electrical and thermal properties compared to metals. A laminated composite material consists of several layers of a composite mixture consisting of matrix and fibers. Each layer may have similar or dissimilar material properties with different fiber orientations under varying stacking sequence. There are many open issues relating to design of these laminated composites. Optimization of composites is of great importance. According to the condition of loading and material working condition, we can change its stacking sequence, number of plies and many other properties to withstand in that condition. Hence optimization can helps in modifying the material properties where needed and optimized the other areas of a component. In this paper work our main focus is on calculating the number of layers of composite laminates required to take the applied load and deflection of composite cantilever beam which can be used in many industrial work. For that composite beam made up of AS4 3501-6 Graphite-Epoxy is chosen for this analysis work. The research carried out in this paper work will enable to determine the beam strength due to Transverse loads. Also In this paper work, deflection is calculated with analytical solver developed in the Matlab software and its results are validated with Finite Element Analysis software.*

Keywords*: Composite material, Cantilever beam, Graphite-epoxy, stress, deflections etc.*

1. INTRODUCTION

One of the simplest definitions for optimization is "Doing the most with the least". Lockhart and Johnson (1996) define optimization as "The process of finding the most effective or favourable value or condition". The purpose of optimization is to achieve the "best" design relative to a set of prioritized criteria or constraints. Mechanical design includes an optimization process in which designers always consider certain objectives such as strength, deflection, weight, wear, corrosion, etc. depending on the requirements. However, design optimization for a complete mechanical assembly leads to a complicated objective function with a large number of design variables. So it is a good practice to apply optimization techniques for individual components or intermediate assemblies than a complete assembly. For example, in an automobile power transmission system, optimization of gearbox is computationally and mathematically simpler than the optimization of complete system. In an optimal design problem, the aim is to minimize or maximize a design objective and to satisfy a set of constraints. Design (or decision) variables, in an engineering design problem, are usually zero-one, discrete or continuous type. Use of fibre reinforced composites in mechanical, aerospace, automobile, shipbuilding and other branches of Engineering are growing. This is because of their high Strength-to-weight and Stiffness-to-weight ratio, and better mechanical properties than other materials. The anisotropic nature of reinforced composites provides the unique opportunity of tailoring such properties as stacking sequence, fiber orientation and thickness of laminate according to the design requirement. Consequently, design may be optimized over various objective function and design variable.

Fiber-reinforced composite materials are demanded by the industry because of their high specific stiffness/strength especially for applications where weight reduction is critical. By using composites, weight of a structure can be reduced significantly. Further reduction is also possible by optimizing the material system itself such as fiber orientations, ply thickness, stacking sequence, etc. Many researchers attempted to make a better use of material either by minimizing the laminate thickness thus reducing the weight, or by maximizing static strength of composite laminates for a given thickness. Designing a laminated composite material consists in selecting the best arrangement of the constituent materials within the laminate. Several optimization methods have been introduced to solve this challenging problem, which is often non-linear, non-convex, multimodal, and multidimensional, and might be expressed by both discrete and continuous variables Traditionally, selection of best arrangements or combination for lamina is performed by finding a combination of several straight-fiber layers with constant thicknesses such that the combination provides the best mechanical properties for a given application. However, allowing the fibres to follow curvilinear paths within the plane of laminate constitutes an advanced tailoring option that can lead to modification of load paths within the laminate and result in a more favorable stress distribution and an improved structural performance. These optimization techniques can be studied in two parts: constant stiffness design and variable stiffness designs

1. Constant stiffness, in which the composite part is considered as a single element with the same stacking sequence all over the domain. The design goal is to find an optimal stacking sequence that is uniform for the entire structure
2. Variable stiffness, in which the structure consists of multiple elements, each of them with a different stacking sequence. Here, material distribution and fiber orientation might change over the structural domain.

Composite materials are gaining importance in a huge range of applications. Among others, reinforced plastics replace metal designs and are used in many industries including automotive and aerospace, targeting the request to build lightweight structures, a common driver for these industries. If Composite are arranged in specified stacking sequence required for specific application it can give high strength and stiffness values than metal and composites are light in weight than their opponents. Composite material have longer life than metals and other materials. Hence their use in many Aerospace and Automobile industries are increasing day by day.

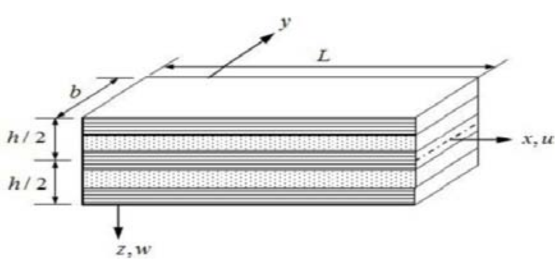

Fig. 1: Composite Beam laminates.

2. PROBLEM METHODOLOGY

2.1 Objective and Problem Formulation

As the Beam being a primary structural element or primary machine components it has several uses in industries and beam is a structural member mainly undergoes to bending. So main objective is to find the bending stress and deflection of a composite beam.

Objective Function: The Objective function of the optimization problem is minimization of weight. So the objective function is

$Weight\ (f) = \rho \times L \times b \times t$

Where

t = Total Thickness of Laminate which can be given by = N* tk,N = Total number of ply

tk = Thickness of each ply

Then the objective function becomes

$(x) = 0.0195 \times x1$

Subjected to following constraints

1. Deflection Constraints

$$\frac{PL^3}{3\ EI} \leq \delta$$

$$g_1(x) = \frac{35.59}{x_1^3} \leq 2.5\ mm$$

2. Tsai-Wucriteria

$$g_2(x) = F_1\sigma_1 + F_2\sigma_2 + F_3\sigma_3 + F_4\sigma_4 + F_5\sigma_5 + F_6\sigma_6 + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + F_{33}\sigma_3^2 + F_{44}\sigma_4^2 + F_{55}\sigma_5^2 + F_{66}\sigma_6^2 + 2F_{12}\sigma_1\sigma_2 + 2F_{13}\sigma_1\sigma_3 + 2F_{23}\sigma_2\sigma_3 \leq 1$$

2.2 Problem Statement

A Cantilever beam laminated composite beam as shown in figure 2 of length 0.5 m and width 0.07 m made up of AS4 3501-6 Graphite-Epoxy has following layup of [0/90/+45/-45]s. A uniform load of 200N is applied over the surface of beam. Assume that each ply is 0.35 mm thick and properties of unidirectional graphite/epoxy are given.

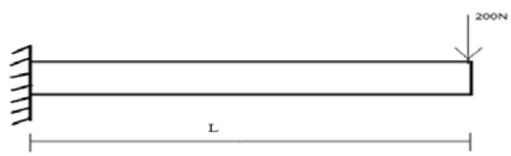

Fig. 2: Cantilever beam

Purpose: To determine the optimum weight of Laminated composite beam under deflection and failure criteria constraints and Find local stress at top and bottom of each ply.

Modal Specifications and Material Selection

□Layup [0/90/+45/-45]s, Beam length =L = 0.5 m

□Width = b =0.07 m, load = P = 200N

□Each ply thickness =tk =0.00035 m = 0.35 mm

-Fiber = Graphite.

-Matrix = Epoxy.

Material Properties-

Table 1 Fiber and Matrix Specification

Fiber material		AS4 Graphite
E_{f1}	GPa	225
E_{f2}	GPa	15
G_{f12}	GPa	15
υ_{12}		0.2
ρ_f	Kg/m^3	1800

Matrix material		3501-6 Epoxy
E_m	GPa	4.2
G_m	GPa	15
υ_{12}		0.34
ρ_m	Kg/m^3	1300

Table 2 Lamina Material Properties

Title	Value
Fiber volume fraction (Vf)	0.6
Thickness (mm)	0.35
Tensile modulus along X-direction (Ex), MPa	1.27E+05
Tensile modulus along Y-direction (Ey), MPa	1.12E+04
Tensile modulus along Z-direction (Ez), MPa	1.12E+04
Shear modulus along XY-direction (Gxy), MPa	6.56E+03
Shear modulus along YZ-direction (Gyz), MPa	6.56E+03
Shear modulus along ZX-direction (Gzx), MPa	3.64E+03
Poisson ratio along XY-direction (µxy)	2.79E-01
Poisson ratio along YZ-direction (µyz)	2.79E-01
Poisson ratio along ZX-direction (µzx)	5.31E-01
Tensile stress along X-direction $+S_x$ (MPa)	1.95E+03
Tensile stress along Y-direction $+S_y$ (MPa)	4.80E+01
Compressive stress along X-direction $-S_x$ (MPa)	-1.48E+03
Compressive stress along Y-direction $-S_y$ (MPa)	-2.00E+02
Shear stress along XY-direction S_{xy} (MPa)	7.90E+01
Tensile strain along X-direction $+e_x$ (mm/mm)	1.54E-02
Tensile strain along Y-direction $+e_y$ (mm/mm)	4.30E-03
Compressive strain along X-direction $-e_x$ (mm/mm)	-1.17E-02
Compressive strain along Y-direction $-e_y$ (mm/mm)	-1.79E-02
Shear strain along XY-direction e_{xy} (mm/mm)	1.20E-02
Density (kg/m^3)	1590

3. DESIGN ANALYSIS OF COMPOSITE BEAM

Following are Basic Assumptions are made in Beam Analysis.

-Plane section normal to the longitudinal axis of the beam bending remains plane and normal to it after bending.

-Plies of the beam are symmetrically arranged about neutral surface.

-Each ply is considered as linearly elastic. There is no shear coupling effect in the ply.

-Plies are perfectly bonded, so that no slip occurs at the interface.

-The stress Components are σ_x and σ_{xz}.

-The thermal and moisture effects are not considered.

-All Poisson's ratio effects are ignored.

A laminated cantilever composite beam with tip load is considered as shown below. the Beam is cantilever at x = 0. The Bending moment at section x is given by

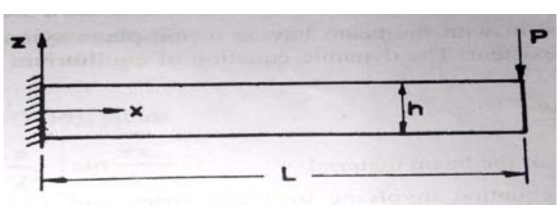

Fig. 3: A Cantilever Beam for design Analysis

$M = -P\,(L-x)\ for\ 0 \le x \le L$ ....(1)

From this we get

$$\frac{\partial^2 w}{\partial x^2} = -\frac{1}{E_x^b I}[-P\,(L-x)] \ldots\ldots\ldots\ldots\ldots..(2)$$

The solution of this equation is

$$w = \frac{1}{E_x^b I}\left[\frac{P(L-x)^3}{6} + C_1 x + C_2\right] \ldots\ldots\ldots(3)$$

The boundary conditions are

At x = 0, w = 0, dw/dx = 0...............(4)

Which on solution into (3) gives,

$$C_1 = -\frac{PL^2}{2} \quad and \quad C_2 = \frac{PL^6}{6} \ldots\ldots.(5)$$

Therefore, after replacing C_1 and C_2 from (3) into (1), we get

$$w = -\frac{PL^3}{6E_x^b I}\left[-3\left(\frac{x}{L}\right)^2 + \left(\frac{x}{L}\right)^3\right] \ldots\ldots(6)$$

The modulus when expressed in term of tip deflection is given by

$$E_x^b = \frac{PL^3}{3\,w_e I} = 4\,\frac{PL^3}{bh^3 w_e} \ldots\ldots\ldots(7)$$

The normal stress for the kth layer at the fixed end is

$$\sigma_x^k(0) = z\, f_1^k\,\frac{12\,PL}{bh^3} \ldots\ldots\ldots\ldots..(8)$$

4. OPTIMIZATION PROCESS

4.1 Design of Matlab Solver

Each lamina or ply of the laminate is quasi-homogeneous and Orthotropic, but the orientations of fibers may change from lamina to lamina.

1. All displacements are continuous throughout the laminate.
2. All deformations in the laminate are considered to be small.
3. The Laminate is thin and loaded in its plane only.
4. The laminates and its layers are assumed to be in the plane stress condition expect the edges (σz = τxz = τyz = 0)
5. Transverse shear strains γxz and γyz are negligible. This implies that a line originally straight and perpendicular to the laminate mid-plane remains straight and perpendicular to deformed state.
6. The bond between the plies in a laminate are perfect, that is, plies will not slip over each other and displacement and strains are continuous across interfaces of plies
7. Strain -displacement and Stress- strain relations are liner.

4.2 Program Description

The program makes use of the user input elastic properties (E1, E2, G12, µ12) of a single ply material in its given principal directions (1, 2, and 3) as well as the ply geometry and also tacking sequence to constructs the [A], [B] and [D] matrices of a laminated fiber-reinforced composite. Using these [A], [B] and [D] matrices, it finds the overall laminate elastic properties (Ex, Ey, Gxy, µxy, etc). This is for one Combination. The combinations are made by number of plies in a laminate. For example for 2 ply laminate having stacking sequence like [0°/±45°/90°], total combinations are 16 & For 3 ply laminate having stacking sequence like [0°/±45°/90°], total combinations are 64. Then deflection are calculated for each ply combinations, if the deflection is less than the allowable deflection value then this stacking sequence are selected as results. These results are given to the Tsai-Wu failure criteria and stacking sequence satisfying the failure criteria are selected as Optimum Stacking sequence for laminated composite Beam. A fundamental understanding of composite laminates and its basic theories are expected in understanding the concepts and results presented.

5. RESULTS AND DISCUSSION

5.1 MATLAB Solver Results

The values of [A], [B] & [D] matrix for whole laminates are as follows.

Extension Stiffness Matrix [A_{ij}]

$$[A_{ij}] = \begin{bmatrix} 6.72884E+05 & 1.00903E+05 & 1.27329E-11 \\ 1.00903E+05 & 3.46278E+05 & 2.18279E-11 \\ 1.27329E-11 & 2.18279E-11 & 1.29709E+05 \end{bmatrix}$$

Extension-Bending coupling Stiffness Matrix [B_{ij}]

$$[B_{ij}] = \begin{bmatrix} -3.78350E-10 & 1.81899E-11 & 7.27596E-12 \\ 1.81899E-11 & 2.96495E-10 & 7.27596E-12 \\ 7.27596E-12 & 7.27596E-12 & 1.27329E-11 \end{bmatrix}$$

Bending Stiffness Matrix [D_{ij}]

$$[D_{ij}] = \begin{bmatrix} 5.17557E+06 & 4.91221E+05 & -1.45033E+05 \\ 4.91221E+05 & 1.02128E+06 & -1.45033E+05 \\ -1.45033E+05 & -1.45033E+05 & 6.60601E+05 \end{bmatrix}$$

Inverse of Extension Stiffness Matrix [A_{ij}]

$$[A_{inv}] = \begin{bmatrix} 1.55405E-06 & -4.52837E-07 & -7.63485E-23 \\ -4.52837E-07 & 3.01981E-06 & -4.63730E-22 \\ -7.63485E-23 & -4.63730E-22 & 7.70957E-06 \end{bmatrix}$$

Inverse of Extension-Bending coupling Stiffness Matrix [B_{ij}]

$$[B_{inv}] = \begin{bmatrix} 1.10752E-22 & 3.72010E-23 & -8.43667E-24 \\ 5.39296E-23 & -9.18007E-22 & -9.18007E-22 \\ 2.40265E-23 & -2.21652E-22 & -1.66822E-22 \end{bmatrix}$$

Inverse of Bending Stiffness Matrix [D_{ij}]

$$[D_{inv}] = \begin{bmatrix} 2.02821E-07 & -9.41665E-08 & 2.38549E-08 \\ -9.41665E-08 & 1.05439E-06 & 2.10816E-07 \\ 2.38549E-08 & 2.10816E-07 & 1.56530E-06 \end{bmatrix}$$

Now for Cantilever Beam case

Consider the calculations is for 24^{th} ply

The value Effective Modulus is calculated as

$$E_x^b = \frac{PL^3}{3\, w_e I} = 4\, \frac{PL^3}{bh^3 w_e}$$

Putting all the values, we get

$$E_x^b = 2.657\ GPa$$

And stress at the top and bottom of the 24^{th} ply

$$\sigma_x^k(0) = z\, f_1^k\, \frac{12\, PL}{bh^3}$$

$$(\sigma_x^{24})_{Top} = 7.3347 \times 10^{08}\ MPa$$

$$(\sigma_x^{24})_{Bottom} = 8.0015 \times 10^{08}\ MPa$$

The following is list of Optimum allowable stacking sequence obtained from MATLAB solver for Cantilever beam

Table 3: Allowable Stacking Sequence for cantilever beam

Sr. No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	0	0	-45	0	0	45	0	0	-45	90	45	90	90	45	90	-45	0	0	45	0	0	-45	0	0
2	0	0	-45	0	0	45	0	0	-45	90	90	45	45	90	90	-45	0	0	45	0	0	-45	0	0
3	0	0	-45	0	0	45	0	0	45	90	-45	90	90	-45	90	45	0	0	45	0	0	-45	0	0
4	0	0	-45	0	0	45	0	0	45	90	90	-45	-45	90	90	45	0	0	45	0	0	-45	0	0
5	0	0	45	0	0	-45	0	0	-45	90	45	90	90	45	90	-45	0	0	-45	0	0	45	0	0
6	0	0	45	0	0	-45	0	0	-45	90	90	45	45	90	90	-45	0	0	-45	0	0	45	0	0
7	0	0	45	0	0	-45	0	0	45	90	-45	90	90	-45	90	45	0	0	-45	0	0	45	0	0
8	0	0	45	0	0	-45	0	0	45	90	90	-45	-45	90	90	45	0	0	-45	0	0	45	0	0

Table 4: Interlaminar Stresses at top of the plies for Cantilever Beam in MATLAB (in MPa)

No	σ1 top	σ2 top	σ12 top
1	-1.0575e+09	5.5879e-09	0
2	-8.3059e+08	0	0
3	-1.5837e+08	-1.022e+08	-1.2518e+08
4	-1.1089e+09	1.0513e+07	-1.9549e+07
5	-1.0573e+09	8.0795e+06	-1.133e+07
6	-2.3468e+08	-9.881e+07	1.7093e+08
7	-1.6385e+09	2.237e+07	2.391e+07
8	-1.6804e+09	1.6695e+07	1.7248e+07
9	-3.9895e+08	-1.3553e+08	-2.6575e+08
10	6.2725e+08	-5.694e+08	1.3968e+08
11	-2.8453e+09	-4.534e+08	6.231e+08
12	2.5912e+09	-1.156e+09	-1.129e+08
13	0	0	0
14	2.3836e+09	1.790e+09	-1.7352e+09
15	-5.6471e+08	2.604e+09	4.7189e+08
16	1.6161e+09	1.156e+09	1.0284e+09
17	2.196e+09	-7.3314e+06	3.2732e+07
18	1.5559e+09	-3.767e+06	7.4726e+06
19	3.0342e+08	2.165e+08	-2.625e+08
20	1.2938e+09	-1.242e+07	-1.924e+07
21	9.9673e+08	-4.919e+06	-6.086e+06
22	1.9676e+08	1.302e+08	1.6746e+08
23	9.2384e+08	-9.314e+06	1.39e+07
24	7.3347e+08	-4.016e+06	4.8921e+06

Table 5: Interlaminar Stresses at bottom of the plies for Cantilever Beam in MATLAB (in MPa)

No	σ1 Bottom	σ2 Bottom	σ12 Bottom
1	-9.693e+08	5.1223e-09	0
2	-7.5508e+08	0	0
3	-1.4253e+08	-9.1977e+07	-1.1266e+08
4	-9.8566e+08	9.345e+06	-1.7376e+07
5	-9.2514e+08	7.0696e+06	-9.9138e+06
6	-2.0115e+08	-8.4695e+07	1.4651e+08
7	-1.3654e+09	1.8642e+07	1.9925e+07
8	-1.3443e+09	1.3356e+07	1.3799e+07
9	-2.9921e+08	-1.016e+08	-1.993e+08
10	4.1817e+08	-3.796e+08	9.3121e+07
11	-1.4227e+09	-2.267e+08	3.116e+08
12	0	0	0
13	-4.1381e+09	3.1333e+09	2.9187e+08
14	4.7672e+09	3.5804e+09	-3.4704e+09
15	-8.4706e+08	3.9065e+09	7.0783e+08
16	2.1548e+09	1.5416e+09	1.3711e+09
17	2.745e+09	-9.164e+06	4.0915e+07
18	1.867e+09	-4.5205e+06	8.9671e+06
19	3.5399e+08	2.5259e+08	-3.0624e+08
20	1.4787e+09	-1.42e+07	-2.1992e+07
21	1.1213e+09	-5.5349e+06	-6.8475e+06
22	2.1862e+08	1.4474e+08	1.8606e+08
23	1.0162e+09	-1.0246e+07	1.529e+07
24	8.0015e+08	-4.3815e+06	5.3369e+06

Following are the plot plotted between the minimum deflection of beam verses number of plies and interlaminar stress at top and bottom of the plies verses number of plies. From the first plot it is observed that deflection of beam goes on decreasing as the number of plies goes on increasing. Hence it is concluded that the deflection is inversely proportional to number of plies.

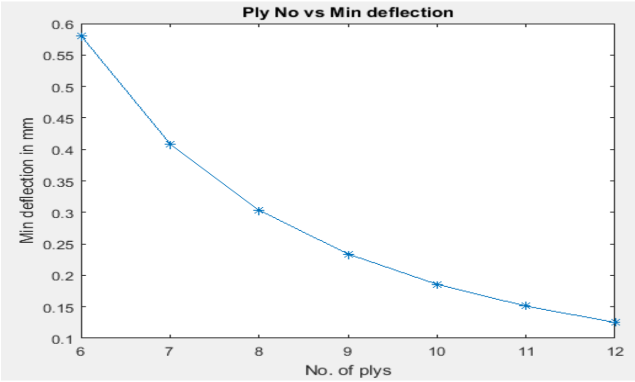

Fig. 4: Minimum Deflection Vs Number of plies for Cantilever Beam

In second plot Interlaminar stresses at top and bottom of each plies are calculated. The plot are as shown in figure 7. The blue line indicates the stress occurring at the top position of the beam and red line indicates the stresses occurring at bottom portion of the beam. From figure it is clear that stress at bottom are higher than the stress at top. The some layers are in compression whereas some are in tension. Maximum stress at bottom occurs at ply number 15 whereas maximum stress at top surface occurs at ply number 12

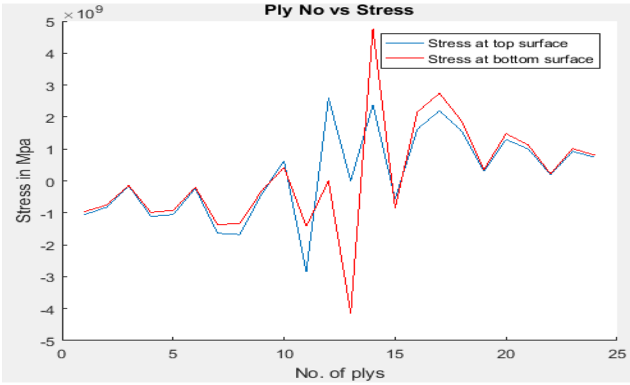

Fig. 5: Stress variation with ply number for Cantilever beam

5.2 Finite Element Results

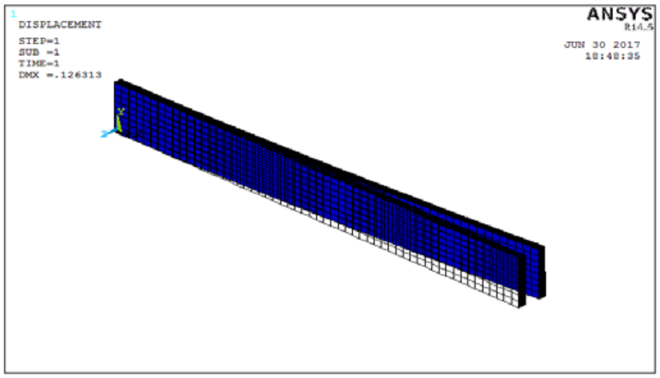

Fig. 6 Deflection of Cantilever Beam

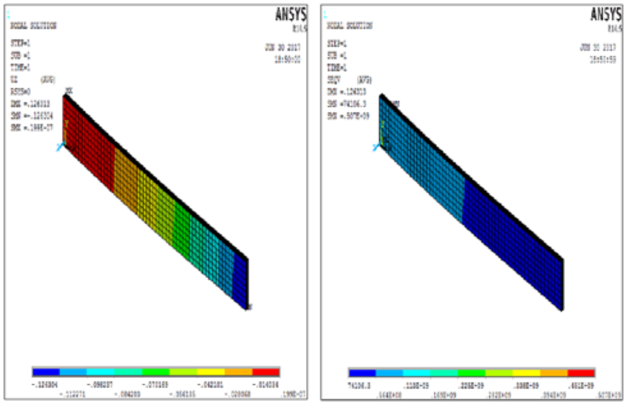

Fig. 7: Z- Component of displacement and Von-misses stress of beam

Following are finite element results of Interlaminar stress occurs at each ply at top and bottom

Table 6: Interlaminar Stresses at top of the plies for Cantilever beam by FEM (in MPa)

No	σ1 top	σ2 top	σ12 top
1	-1.2685e+09	0	0
2	-8.555e+08	0	0
3	-1.258e+08	-1.842e+08	-1.521e+08
4	-1.178e+09	1.2685e +07	-1.994e+07
5	-0.0563e+09	8.704e+06	-1.122+07
6	-2.632e+08	-9.314e+07	1.709e+08
7	-1.112e+09	2.412e+07	2.839e+07
8	-1.6804e+09	1.546e+07	1.256e+07
9	-3.9895e+08	-1.689e+08	-2.482e+08
10	5.992e+08	-5.694e+08	1.44e+08
11	-2.456e+09	-4.534e+08	6.52e+08
12	2.863e+09	-1.224e+09	-1.91e+08
13	0	0	0
14	2.863e+09	1.665e+09	-1.25e+09
15	-5.2255e+08	2.159e+09	4.978e+08
16	1.6161e+09	1.178e+09	1.428e+09
17	2.6043e+09	-7.3485e+06	3.3722e+7
18	1.1562e+09	-3.484e+06	7.25e+06
19	3.767e+06	2.156e+08	-2.75e+08
20	1.2938e+09	-1.656e+07	-2.00e+07
21	9.314e+06	-4.797e+06	-5.98e+06
22	1.9676e+08	1.620e+08	1.112e+08
23	9.2384e+08	-9.123e+06	1.58e+07
24	7.0696e +08	-3.916e+06	5.23e+06

Table 7: Interlaminar Stresses at bottom of the plies for Cantilever beam by FEM (in MPa)

No	σ1 Bottom	σ2 Bottom	σ12 Bottom
1	-9.258e+08	0	0
2	-8.225e+08	0	0
3	-1.5286e+08	-9.562e +07	-1.258e+08
4	-9.5642e+08	9.025e+06	-1.178e+07
5	-9.0258e+08	7.2583e+06	-9.123e+06
6	-1.9215e+08	-8.704e+07	1.465e+08
7	-1.5236e+09	1.8642e+07	2.0924e+07
8	-1.5586e+09	1.3356e+07	1.379e+07
9	-3.012e+08	-0.766e+08	-2.092e+07
10	4.2017e+08	-3.796e+08	9.314e+07
11	-1.5897e+09	-2.526e+08	3.85e+09
12	0	0	0
13	-3.8561e+09	3.2228e+09	2.863e+08
14	4.8565 e+09	3.3722e+09	-3.470e+09
15	-8.2326e+08	4.0065e+09	6.978e+08
16	1.995e+09	1.5416e+09	1.4511e+09
17	2.782e+09	-9.564e+06	3.891e+07
18	1.867e+09	-4.5205e+06	9.71e+06
19	3.5399e+08	2.452e+08	-3.539e+08
20	1.5007e+09	-1.235e+07	-2.192e+07
21	1.1003e+09	-5.9867e+06	-6.475e+06
22	2.1956e+08	1.4474e+08	1.736e+08
23	0.7662e+09	-1.0246e+07	1.462e+07
24	7.9915e+08	-4.9752e+06	5.128e+06

6. CONCLUSION

In the present work, general classical lamination theory has been employed to predict the stiffness matrices connecting the forces and stress as well as moments and curvature. In this design analysis of laminated composite beam is carried out with two cases for weight and deflection minimization of beam. First is composite simply supported beam with uniformly distributed load and Second case is composite cantilever beam with point load at its free end. The number of different combination of optimum allowable stacking sequence obtained is 8. The number of optimum allowable plies obtained in this work is 24 i.e. the laminated is symmetric at 12th ply. The objective function is minimization of weight and minimum weight for 24 plies is 0.468 kg. The interlaminar stress acting on ply surface are calculated in which some are positive and some are negative values, it is because of in bending of beams of beams some layers are in tension and some are in compression. The Stress values obtained from both MALAB and Helius validates each other.

Table 8: Results summary for Cantilever Beam

Deflection by MATLAB (mm)	Deflection by ANSYS (mm)	Weight of Beam (kg)	% Error in Deflection
125	126.37	0.468	1.048

In this case, a deflection value for MATLAB is 125 mm while in Ansys is 126.31 mm. These values have percentage difference of 1.048 % between them. In this case maximum stress at top surface obtained at clamping zone area where the supports are given. The stress is Tensile in nature and maximum stress value obtained at ply no. 14 i.e. 2.3638E+09 MPa. The maximum stress at bottom surface is obtained at ply no. 14 and its value is 4.7672 E+08 MPa

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