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# Stress Analysis of Laminated Boron / Epoxy Materials

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**Abstract:** ***In this paper the stress are exists in different plate or laminate plate. Multi-layered epoxy – boron composite laminated plate are mounted with slandered code [0$^o$ ,30$^o$,-45$^o$ ]. Properties of material are $E_1$=210Gpa, $E_2$-90Gpa, $V_{12}$=0.25, Gxy =4.8Gpa. in x and y direction. Found relation between stress and strain of epoxy-Boron materials. The computation of the stress and strain values for the angle play –three layered symmetric laminated plate with various lamination angles. Under unidirectional axial forces $N_x$ and $N_y$ and Bending moment $M_x$=$M_y$=$M_z$=0. Composite material is Epoxy and boron of engineering properties value of three layers plats. The several of numerous results of stress and strain distribution in the layers of the analyzed laminated plate subjected to axial forces $N_x$ and $N_y$ =1000N/m. it is analysis of stress and strain in various height of laminated plate.***

**Keyword**: Three layered laminated plate, stress and strain computation, and stress-strain distribution curves

## 1. Introduction

Studying the behavior of composite follows two different approach micromechanical handles the composite material combination of various materials and derives the average property considering the properties of single matrix of unite cell [1]. Considering the composite material as orthotropic materials uniform average properties [2]. The composite materials developed mechanical properties, the ability of composite materials to meet the permissible properties and improve in design of mechanical component. Boron /epoxy composite are the most used composite material in aircraft. They are usually used in a form of multilayer composite lamina [3, 4]. It is in the reinforcing of polymers that most developments have been made so far, and it is likely that there is still scope for improvement. There is a thriving, international reinforced plastics Industry [5, 6], for which both the science and technology are highly advanced. And although the level of awareness of the merits of reinforced plastics on the part of designers in general engineering seems to be low, the same is not true of the aerospace industry for which the potential benefits of very high strength and Stiffness, combined with low density, are easily recognized. [9, 10]

## 2. Stress and stress analysis on three layered laminated plate:-

The stress analysis of three layer composite material plate made up of orthotropic lamina with equal thickness the bounded together. In symmetric laminate all layers above mid-plane of laminate have the same angle as we play in the equivalents position bellowed the mid-plane. By using generalized hooks law in the principal material condition. Three play- boron-epoxy composite material using the unidirectional properties as shown fig.1

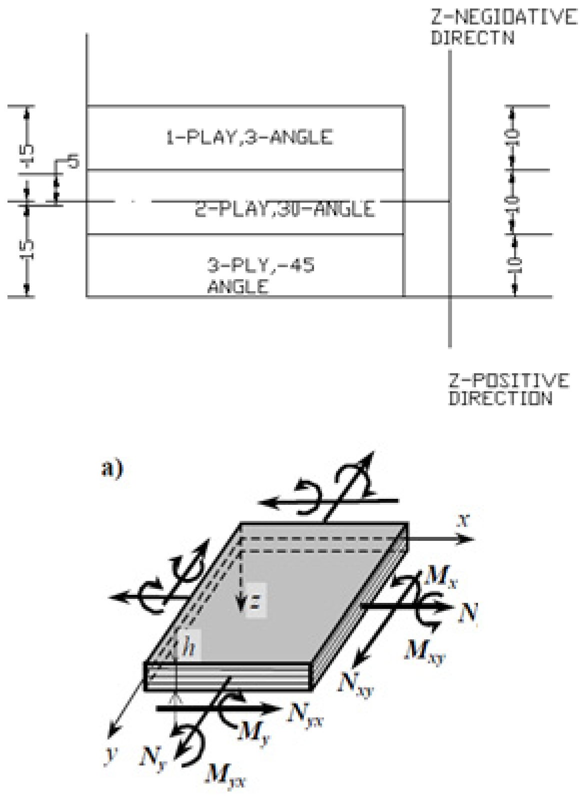



**Figure 1:** Three layer composite model.

Material properties

| $E_1$ | $E_2$ | $G_{12}$=$G_{23}$ | $V_{12}$ | $V_{23}$ | $V_{13}$ |
|---|---|---|---|---|---|
| 210 Gpa | 19Gpa | 4.8Gpa | 0.25 | 0.25 | 0.25 |

Thickness of each lamina is 10mm and mid plane are located at 15mm total dimension of laminate. To determain stiffness of matrix for 0$^o$ 1-play is,

$Q_{11}$= [$E_1$/1-($V_{21}$ * $V_{12}$)], $Q_{12}$= [$V_{12}$*E2/1-($V_{21}$ * $V_{12}$)]; $Q_{22}$= [$E_2$/1-($V_{21}$ * $V_{12}$)]; $Q_{66}$=$G_{12}$

The Transformer reduced stiffness matrix [$\bar{Q}_{ij}$] for each layers now,

$$[\overline{Q_{ij}}]^{[angle]} = \begin{bmatrix} \bar{Q}11 & \bar{Q}12 & \bar{Q}16 \\ \bar{Q}12 & \bar{Q}22 & \bar{Q}26 \\ \bar{Q}16 & \bar{Q}26 & \bar{Q}66 \end{bmatrix}$$

$$\left.\begin{aligned} \bar{Q}11 &= Q11*S4 + Q22*S4 + 2(Q12+2Q66)S2\,C2\,; \\ \bar{Q}12 &= (Q11+Q22-4Q66)*S2\,C2 + Q12(S4+C4) \\ \bar{Q}22 &= Q11*S4 + Q22*C4 + 2(Q12+2Q66)\,S2*C2 \\ \bar{Q}16 &= (Q11+Q22-2Q66)*C3S - (Q22-Q12-2Q66)*S3C \\ \bar{Q}26 &= (Q11+Q22-2Q66)*C*S3 - (Q22-Q12-2Q66)C3*S \\ \bar{Q}66 &= (Q11+Q22-2Q66)*S2*C2 + Q66(S4+C4) \\ C &= \cos\theta \quad S = \sin\theta \end{aligned}\right\} \text{---- (1)}$$

Now computing matrix $[\bar{Q}]^{[0o]}$ at $\theta = 0$ , 30,-45 using equation (1) we get,

$$[\bar{Q}]^{[0o]} = \begin{bmatrix} 224000 & 5056.65 & 0 \\ 5066.667 & 20266.667 & 0 \\ 0 & 0 & 4800 \end{bmatrix} \text{Mpa}$$

$$[\bar{Q}]^{[30o]} = \begin{bmatrix} 18225 & 45363.85 & 67370.81 \\ 45363.85 & 30898.34 & 20841.84 \\ 67370.81 & 20841.84 & 46997.12 \end{bmatrix} \text{Mpa}$$

$$[\bar{Q}]^{[-45o]} = \begin{bmatrix} 68397.37 & 60064.41 & -50931.37 \\ 60064.41 & 68397.375 & -50931 \\ -50931 & -50931 & 61063.647 \end{bmatrix} \text{Mpa;}$$

Compute the extensional stiffness matrix, $[A_{ij}]$ we get,

$$[A_{ij}] = \sum_{k=1}^{n} [\overline{Q_{ij}}]\,(h_k - h_{k-1}) \qquad \text{----- (2)}$$

$h = \sum_{k=1}^{n} tk$; $h_0=-15, h_1=-5, h_2=5, h_3=15$ so that

$$[A_{ij}] = \begin{bmatrix} 1.0902e+006 & 1.1049e+006 & 1.6439e+005 \\ 1.1049e+006 & 1.1956e+006 & -3.009e+005 \\ 1.6439e+005 & -3.009e+005 & 1.1206e+006 \end{bmatrix} \text{Mpa}$$

Determine coupling stiffness matrix, $[B_{ij}]$ as

$$[B_{ij}] = 1/2\left[\sum_{k=1}^{n} [\overline{Q_{ij}}]\,(h_k^2 - h_{k-1}^2)\right] \qquad \text{------- (3)}$$

Similarly bending stiffness matrix, $[D_{ij}]$ as

$$[D_{ij}] = 1/3\left[\sum_{k=1}^{n} [\overline{Q_{ij}}]\,(h_k^3 - h_{k-1}^3)\right] \qquad \text{------- (4)}$$

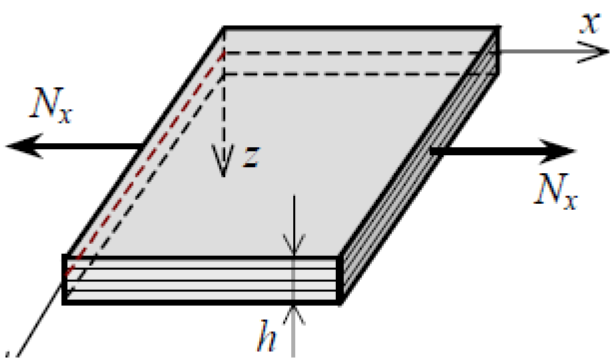
Calculate $[A_{ij}]$; $[B_{ij}]$, $[D_{ij}]$ matrix using equation 2, 3, 4 respectively, Now we have relation,

$$\begin{bmatrix} Nx \\ Ny \\ Nxy \\ Mx \\ My \\ Mxy \end{bmatrix} = \begin{bmatrix} A11 & A12 & A16 & B11 & B12 & B16 \\ A12 & A22 & A26 & B12 & B22 & B26 \\ A16 & A26 & A66 & B16 & B26 & B66 \\ B11 & B12 & B16 & D11 & D12 & D16 \\ B12 & B22 & B26 & D12 & D22 & D26 \\ B16 & B26 & B66 & D16 & D26 & D66 \end{bmatrix} * \begin{bmatrix} \epsilon_x^{\circ} \\ \epsilon_y^{\circ} \\ \gamma_{xy}^{\circ} \\ Kx \\ K_y \\ K_{xy} \end{bmatrix} \text{-- (5)}$$

$\begin{bmatrix} \epsilon_x^{\circ} \\ \epsilon_y^{\circ} \\ \gamma_{xy}^{\circ} \\ Kx \\ K_y \\ K_{xy} \end{bmatrix}$ = mid-plain strain and curvature, where $N_x$ and $N_y$ are normal force $N_{xy}$=shear force

$M_x$ and $M_y$ =bending movement; $M_{xy}$= twisting movement applying loading condiction

$N_x$ and $N_y$= 1000N/m




The mid-plane strain and curvature can be found by using equation (4) is simultaneous linear form, we have solved by MATLAB software, we get;

$$\begin{bmatrix} \epsilon_x^{\circ} \\ \epsilon_y^{\circ} \\ \gamma_{xy}^{\circ} \\ Kx \\ K_y \\ K_{xy} \end{bmatrix} = \begin{bmatrix} 5.2409*10E-5 \\ 0.0008711 \\ 0.00018038 \\ -1.02*10E-5 \\ 3.29*10E-7 \\ 1.32*10E-5 \end{bmatrix}$$

The strain and stress relation with each lamina, as

$$\begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix}_{\text{at any } angle^{\circ}} = \begin{bmatrix} \epsilon_x^{\circ} \\ \epsilon_y^{\circ} \\ \gamma_{xy}^{\circ} \end{bmatrix} + h * \begin{bmatrix} Kx \\ K_y \\ K_{xy} \end{bmatrix} \qquad \text{--- (6)}$$

The relation between stress and strain, we have

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} \text{At any angle} = [[\overline{Q_{ij}}]^{[angle]}] * \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{bmatrix}_{\text{at any } angle} \qquad \text{--- (7)}$$

The compute value of stresses and strains at each lamina in different location using equation (5) and (6) respectively.

## 3. Result and Dissuasions

In this present work the model of the angle –play symmetric layered composite plates with various fiber lamination angle $[0^o, 30^{0,} -45^0]$ . The models have been made up with three equal part with unidirectional composite lamina. The mechanical properties of boron-epoxy materials have thickness "h" shown table 2&3.the result of stress and strain values in each layers of analyzed symmetric angle of $[0^o, 30^{0,} -45^0]$ laminated plate subjected to axial force $N_x=N_y=1000$N/m and Bending movement $M_x$ , $M_y$ , $M_{xy}=0$ ,using equation 5&6 obtained value of stresses and strain respectively. The distributions of stress and strain curve of those the calculated through the layers as function of laminated angle. Stress is distributed over the thickness of composite materials. Computed results are shown in Table-2&3.

**Table 2:** Obtainable Strain in laminated plates

| | height (h) | strain in-X | strain in-Y | share strain-xy |
|---|---|---|---|---|
| play-1 angle-0 | -15 | 0.00205409 | 0.000866165 | -0.00001762 |
| | -12 | 0.00174809 | 0.000867152 | 0.00002198 |
| | -10 | 0.00154409 | 0.00086781 | 0.00004838 |
| play-2 angle-30 | -5 | 0.00103409 | 0.000869455 | 0.00011438 |
| | 0 | 0.00052409 | 0.0008711 | 0.00018038 |
| | 5 | 0.00001409 | 0.000872745 | 0.00024638 |
| play-3 angle--45 | 10 | -0.00049591 | 0.00087439 | 0.00031238 |
| | 12 | -0.00069991 | 0.000875048 | 0.00033878 |
| | 15 | -0.00100591 | 0.000876035 | 0.00037838 |

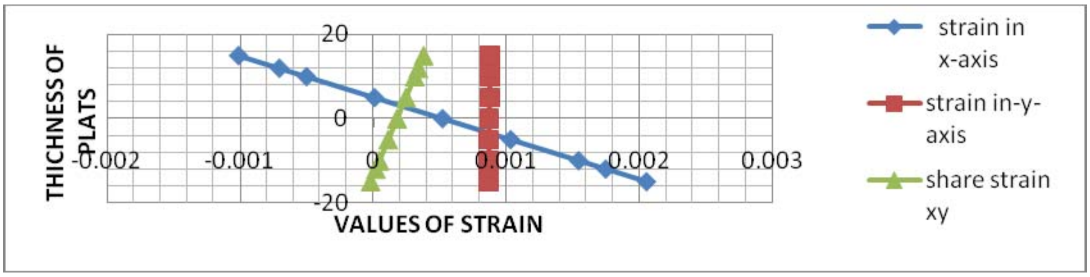



**Figure 2:** strain distribution curve

As shown in fig 2. curve plotted thickness viruses strains of X and Y and its share plane direction, clearly indicate that strain in x-axis increase the thickness from mid-plane of laminated plate as increase strain with constant forces $N_x$=$N_{y..}$ No strain at h= -5mm. It may be positive and negative direction for strains values. X-axis strain varies of total thickness from 0.00205409 to -0.00100591. Another strain in y-direction remains constant with increase the thickness of three laminated plate, there is no effect of thickness. At h=5mm , strain=0.001mm/mm Further that share strain increase as increase the thickness of plate, share strain in always positive direction. In terms of share strain is increase from bottom to top of total model. Share strain varies of total thickness from 0-0.00001762 to 0.00033878.

**Table 3:** Obtainable Stresses in laminated plates

| | Height(h) | STRESS -X | STRESS-Y | STRESS-XY |
|---|---|---|---|---|
| play-1 angle-$0^0$ | -15 | 50.4 | 27.962 | -0.084576 |
| | -12 | 43.551 | 26.431 | 0.1055 |
| | -10 | 38.985 | 25.411 | 0.23222 |
| play-2 angle-$30^0$ | -5 | 65.994 | 76.159 | 93.164 |
| | 0 | 61.22 | 54.45 | 61.941 |
| | 5 | 56.447 | 32.741 | 30.718 |
| play-3 angle—$45^0$ | 10 | 2.6908 | 14.109 | -0.20145 |
| | 12 | -12.567 | 0.55678 | 11.767 |
| | 15 | -35.454 | -19.772 | 29.72 |

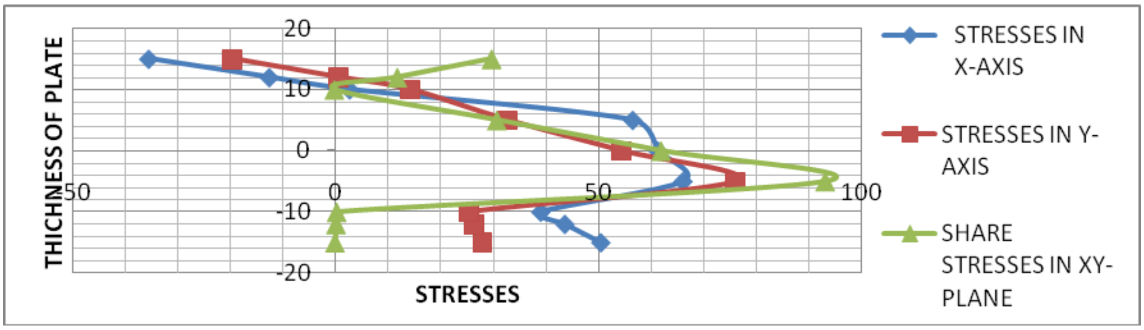



**Figure 3:** Stress distribution curve

The calculated stress is tabulated in table-3 stresses exists in x-direction-direction and shear plane with respective thickness plotted, as shown in fig.3. Maximum stress developed in x-direction at h=-5mm. stress decreased thickness from -5mm to 10mm and after 10mm will have compressive zone . Same conduction exists in case of stress in y-direction. Shear stress have constant at thickness 10mm to 15mm, maximum values at h= -5mm. after that shear values gradually decrease up to thickness h=10mm, the thickness 10mm to 15mm shear stress increase.

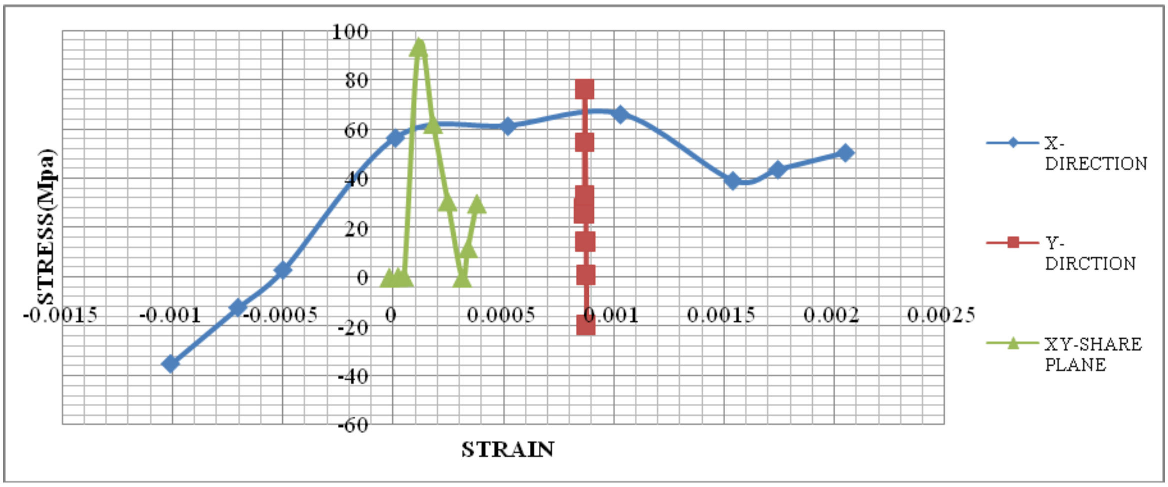



**Figure 4:** Stress-Strain curve

As shown fig.4, this is clear indicate stress –strain curve for y-direction strain remain constant value 0.001and stress still increase to infinity. Stress in x-direction the vales of stress 60Mpa have no strain, after that ultimate stress of 65Mpa but strain gradually increase in case of shear stress is fluctuating values of strain from 0 to 0.0005, this curve is totally positive zone.

## 4. Conclusion

In this study mainly focusing on thickness of composite laminated plate, stress-strain curve nature, and stress and strain distribution curve.

- The strain in y-direction remains constant with increase the thickness of three laminated plate, there is no effect of thickness. At h=5mm, strain=0.001mm/mm.
- Share strain varies of total thickness from 0-0.00001762 to 0.00033878. Stress in x-direction the vales of stress 60Mpa have no strain, after that ultimate stress of 65Mpa but strain gradually increase. In case of shear stress is fluctuating values of strain from 0 to 0.0005, this curve is totally positive zone.
- Maximum stress developed in x-direction at h=-5mm. stress decreased thickness from -5mm to 10mm and after 10mm will have compressive zone . Same conduction exists in case of stress in y-direction. Shear stress have constant at thickness 10mm to 15mm, maximum values at h= -5mm. after that shear values gradually decrease up to thickness h=10mm, the thickness 10mm to 15mm shear stress increase

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