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ANALYSIS 0F COMPLEX COMPOSITE BEAM BY USING SIMPLE BEAM THEORY AND FINITE ELEMENT METHOD

Ansys Benchworks 14.0

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ABSTRACT

Complex composite beam is one of the most common structural members that have been considered in design. This paper is intended to provide tools that ensure better designing options for composite beam of simply supported beam. In this Paper an analytical method &FEM approach calculating axial stiffness, Axial stress, Axial strain of complex composite beam.

The results show the strength of composite simply supported beam

KEYWORDS: Composite Beam , Finite Element Analysis, Ansys workbench 14.0.

I. INTRODUCTION

Composite materials are extensively used in aerospace, defense, marine, automobile, and many other industries. They are generally lighter and stiffer than other structural materials. A composite material consists of several layers of a composite mixture consisting of matrix and more than one material . Each layer may have similar or dissimilar material properties with different mechanical properties. Because, composite materials are produced in many combinations and forms, the design engineer must consider many design alternatives. It is essential to know the dynamic and buckling characteristics of such structures subjected to dynamic loads in complex environmental conditions. For example, when the frequency of the loads matches with one of the resonance frequencies of the structure, large translation/torsion deflections and internal stresses occur, which may lead to failure of structure components. The structural components made of composite materials such as aircraft wings, helicopter blades, vehicle axles and turbine blades can be approximated as laminated composite beams.

A composite material or a compound is a mixture of two or more distinct constituents which remain independent at the macroscopic level when they become part of a structure. The main advantages for the use composite materials are high strength , high stiffness to weight ratio, long fatigue life, resistance to electrochemical corrosion, and other superior material properties of composites. Those advantages are why composite materials are used in many fields of industry. Composites are widely used in the automobile, aerospace, and athletics industry. Examples of composites include bumpers, wings, bicycle frames, and downhill skis. Combined with the low weight and high strength characteristics of composite materials, the ability to optimize a composite structure for a specific property is useful to a design engineer.

Objective of Research

- To obtain the stress , strain and total deformation of the complex composite beam by simple beam theory
- To comparative study of analytical and ansys workbench.
- To find the natural frequency of complex composite beam.

II. LITERATURE REVIEW

W. S. Chan et al. (2009) focused a simple method based on classical lamination theory & determine the locations of the centroid and the shear center for composite beams with box cross-section.They analyzed aluminum beams with five web angles in both symmetric and unsymmetrical layups. For a symmetrical

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laminate layup of box beams, the both centroid and shear center locations move toward the bottom flange laminates as web angle is increased. For box beam with 90 web angle (a squared box beam), locations of centroid and shear center are coincided at its geometric center of cross-section. For an unsymmetrical laminate layup of box beam, the centroid location is closer to the bottom flange laminate comparing to the symmetric case. However, the shear center location is further from the bottom flange laminate.

Y.X. Zhang et al.(2010) studied on the recent development of the finite element analysis for laminated composite plates. The recent advances of Finite element analysis of composite laminated plate based on various lamination theories, with the focus on the theories for the buckling and post-buckling analysis, geometric non-linearity , large deformation analysis, failure and damage analysis of composite laminated plates. They concluded that, the composite material nonlinearity had significant effects on the geometrically nonlinearity, structural buckling load, post buckling structural stiffness, and structural failure mode shape of composite laminate plates and shells.

Jun Deng et al.(2011) presented on stress analysis of steel beams reinforced with a bonded CFRP (Carbon Fiber Reinforced Polymers) Plate. The analysis included the analytical solution to calculate the stresses in the reinforced beam under mechanical as well as thermal loads. The solution has been extended by a numerical procedure to CFRP plates with tapered ends, which can significantly reduce the stress concentration. Finite element analysis was employed to validate the analytical results, and a parametric study was carried out to show how the maximum stresses have been influenced by the dimensions and the material properties of the adhesive and the adherents.

Uttam Kumar Chakravartyet al.(2014) have investigated on the modeling of composite beam cross-sections. Theoretical models are available for simple composite beam cross-sections. But computational technique, such as finite element analysis (FEA), is considered for complex composite beam cross-sections. It is found that variational asymptotic beam sectional analysis (VABS) and boundary element method (BEM) are very popular and computationally efficient models for composite beam cross-sectional analysis.

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III. METHOD AND METHODOLOGY

the finite element method is used to simulate the response of a complex composite simply supported beam. To validate the model, ANSYS 14 is used to solve examples. A three layer symmetric simply supported complex beam with a different loading condition. The problem first solve the analytically and then with finite element method.

Analytical analysis of composite beam

The following equations are used to calculate the elasticproperties of an angle ply lamina in which continuous fibers are aligned at an angle ɵ with the positive x direction.

$$\frac{1}{E_{11}} = \frac{\cos^4\theta}{E_X} + \frac{\sin^4\theta}{E_Y} + \frac{1}{4}\left(\frac{1}{G_{XY}} - \frac{2\vartheta_{xy}}{E_x}\right)\sin^2 2\theta$$

$$\frac{1}{E_{22}} = \frac{\sin^4\theta}{E_X} + \frac{\cos^4\theta}{E_Y} + \frac{1}{4}\left(\frac{1}{G_{XY}} - \frac{2\vartheta_{xy}}{E_x}\right)\sin^2 2\theta$$

$$\frac{1}{G_{12}} = \frac{1}{E_X} + \frac{2\vartheta_{xy}}{E_X} + \frac{1}{E_Y}\left(\frac{1}{E_X} + \frac{2\vartheta_{12}}{E_x} + \frac{1}{E_Y} - \frac{1}{G_{XY}}\right)\cos^2 2\theta$$

Elemental Stiffness Matrix

$$Q = \begin{bmatrix} Q_{11} & Q_{12} & Q_{16} \\ Q_{21} & Q_{22} & Q_{26} \\ Q_{61} & Q_{62} & Q_{66} \end{bmatrix}$$

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$$Q_{11} = \frac{E_{11}}{1-\vartheta_{12}\ \vartheta_{21}}$$

$$Q_{22} = \frac{E_{22}}{1-\vartheta_{12}\ \vartheta_{21}}$$

$$Q_{12} = \frac{v_{12}\ E_{22}}{1-\vartheta_{12}\ \vartheta_{21}}$$

$$Q_{66} = G_{12}$$

$$\overline{Q}$$

Matrix

Using trigonometric identities, Tsai and Pagano have shown that the Elements in the $\overline{Q}$ matrix can be written as,

$$\overline{Q} = \begin{bmatrix} \overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16} \\ \overline{Q}_{21} & \overline{Q}_{22} & \overline{Q}_{26} \\ \overline{Q}_{31} & \overline{Q}_{32} & \overline{Q}_{66} \end{bmatrix}$$

where

$$\overline{Q}_{11} = \overline{Q}_{11}\cos^4\theta + 2(Q_{12}+2Q_{66})\sin^2\theta\cos^2\theta + Q_{22}\sin^4\theta$$

$$\overline{Q}_{12} = (Q_{11}+Q_{22}-4Q_{66})\sin^4\theta\cos^2\theta + Q_{12}(\sin^4\theta+\cos^4\theta)$$

$$\overline{Q}_{22} = Q_{11}\sin^4\theta + 2(Q_{12}+2Q_{66})\sin^4\theta\cos^2\theta + Q_{22}\cos^4\theta$$

$$\overline{Q}_{16} = (Q_{12}-Q_{12}-2Q_{66})\sin\theta\ \cos^3\theta + (Q_{12}-Q_{22}+2Q_{66})\sin^3\theta\cos\theta$$

$$\overline{Q}_{26} = (Q_{11}-Q_{12}-2Q_{66})\sin^3\theta\ \cos\theta + (Q_{12}-Q_{22}+2Q_{66})\sin\theta\cos^3\theta$$

$$\overline{Q}_{66} = (Q_{11}+Q_{22}-2Q_{12}-2Q_{66})\sin^2\theta\ \cos^2\theta + Q_{66}(\sin^4\theta+\cos^4\theta)$$

Stress & strain of complex composite beam using Axial stiffness

Consider a load, P acting at the centroid, such that the equivalent axial stiffness is,

Therefore,

$$P = \overline{N}_x = \overline{EA}\varepsilon_X^C$$

Constitutive Equation of Composite Beam:-

The stress- strain relations for general complex composite beam can be written as,

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{bmatrix} = [\overline{Q}] \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

$$[\overline{Q}]$$

represents the stiffness matrix for the Complex composite beam.

The stresses in the K^{th} ply at a distance of Z_k from the reference plane in terms of strains and Complex composite beam can be expressed as,

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \sigma_{xy} \end{bmatrix} = \begin{bmatrix} \overline{Q_{11}} & \overline{Q_{12}} & \overline{Q_{16}} \\ \overline{Q_{21}} & \overline{Q_{22}} & \overline{Q_{26}} \\ \overline{Q_{31}} & \overline{Q_{32}} & \overline{Q_{66}} \end{bmatrix} \begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

Where,

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix} = \begin{bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{bmatrix} + z_k \begin{bmatrix} k_x \\ k_y \\ k_{xy} \end{bmatrix}$$

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \begin{bmatrix} \overline{Q_{11}} & \overline{Q_{12}} & \overline{Q_{16}} \\ \overline{Q_{21}} & \overline{Q_{22}} & \overline{Q_{26}} \\ \overline{Q_{31}} & \overline{Q_{32}} & \overline{Q_{66}} \end{bmatrix} \left\{ \begin{pmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \varepsilon_{xy}^0 \end{pmatrix} + z_k \begin{pmatrix} k_x \\ k_y \\ k_{xy} \end{pmatrix} \right\}$$

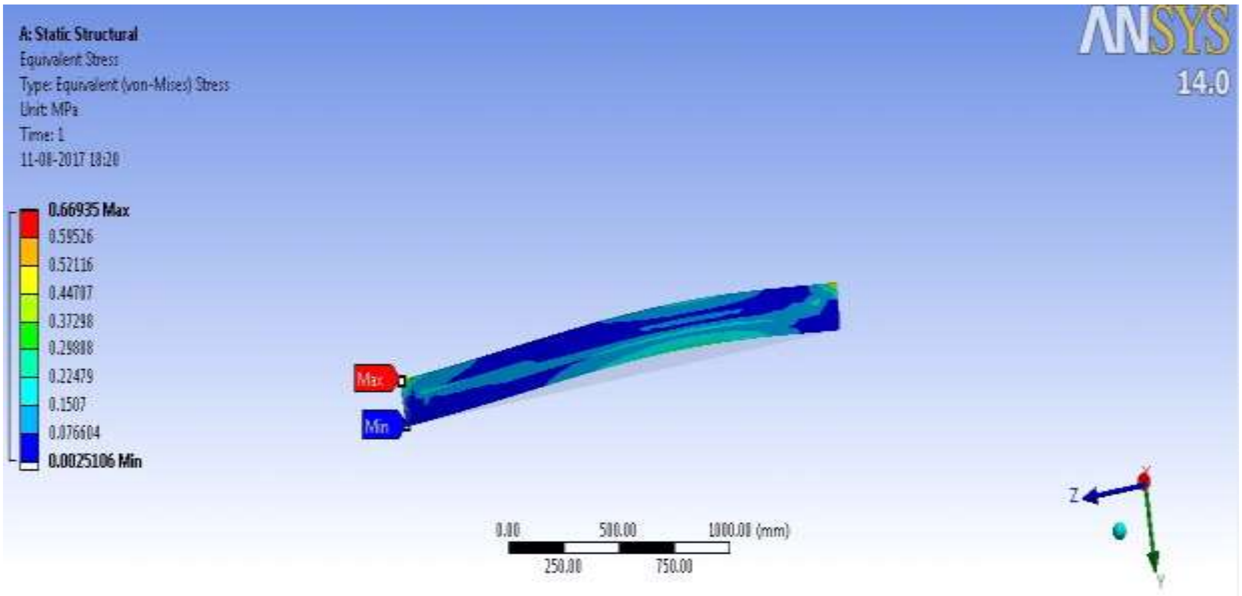
The strains in the complex composite beam vary linearly through the thickness whereas the stresses vary discontinuously. This is due to the different material properties of the layer resulting from different fiber orientation.

Computing Axial stiffness for composite Beam.

$$(EA)_{BEAM} = \frac{d_{11}}{a_{11}d_{11} - b_{11}^2}$$

IV. RESULTS

1-Stress analysis by vonmises criterion : find the maximum equvivalent stress maximum0.66935Mpa and minimum 0.0025106 Mpa



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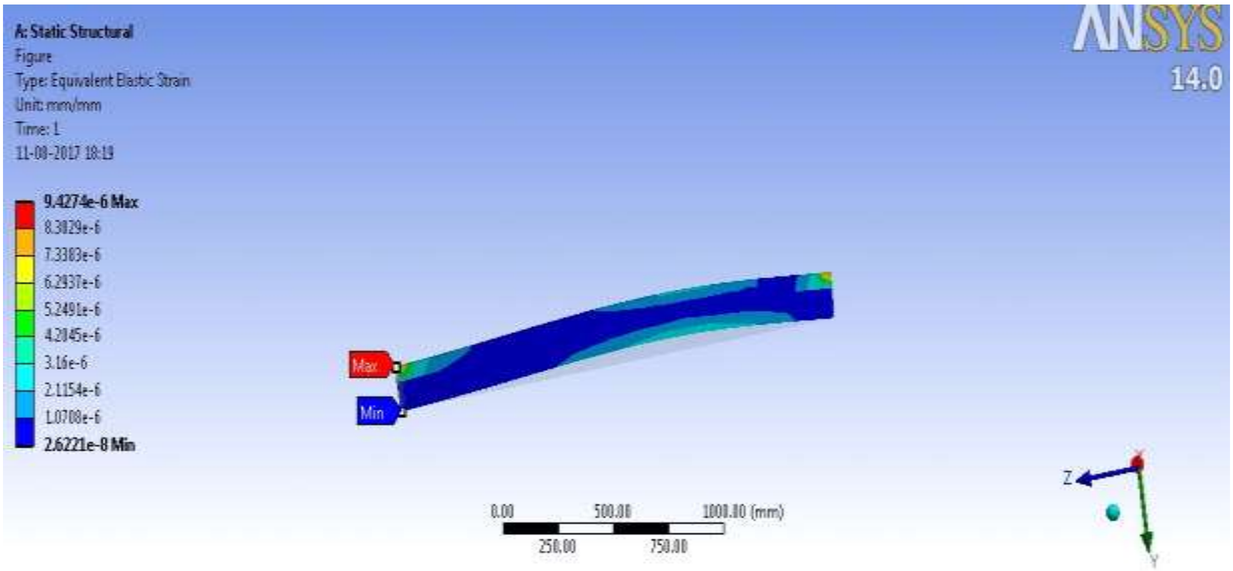
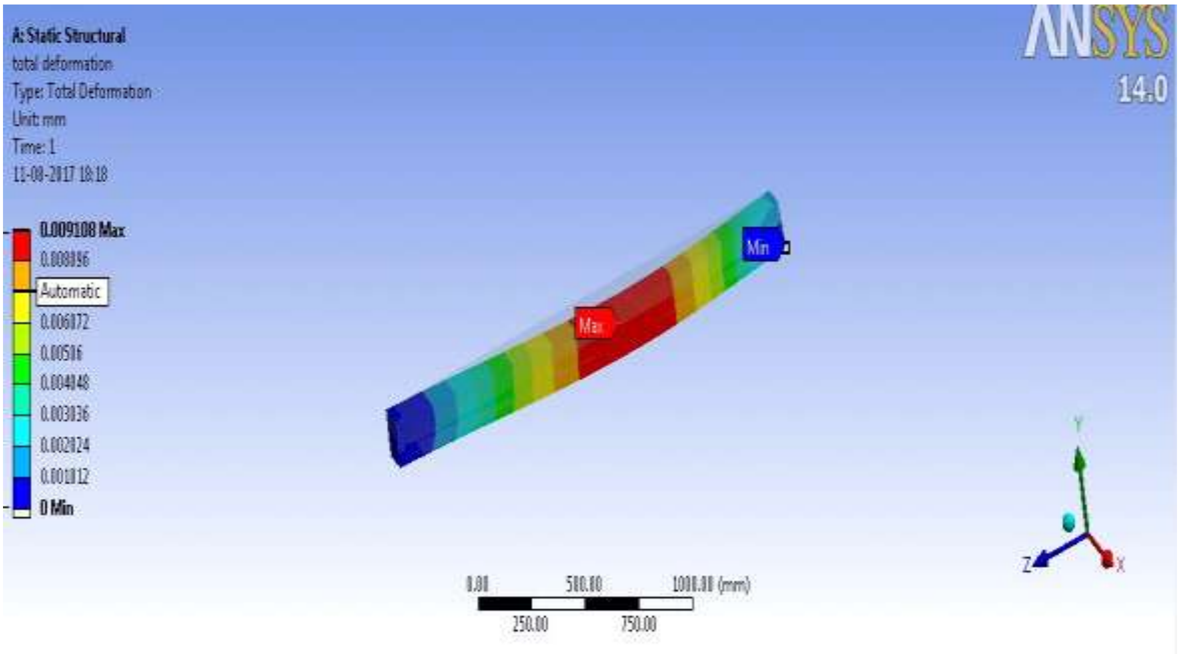
2-strain analysis : find the elastic maximum strain 9.4274e-6mm/mm and minimum 2.6221e-8mm/mm



3-Total deformation- find max 0.009108mm and minimum 0



V. CONCLUSION

Three dimensional FEM model was developed to study the effects in behaviour of composite beam subjected to various vertical loads. The concrete damage plasticity model and Gattesco nonlinear steel beam model were used to predict the highly nonlinear behaviours of structure. Explicit solver was used due to the complex contact interactions and material nonlinearities. The following conclusions could have been made in this study.

- The FEM model was analyzed with various levels of low-velocity impacts in combined axes. The results of the FEM model with various speeds were analysed in basis of element distortion and static state prediction. Best agreement was observed with optimum values of velocities 0.5 mm/s and 1.0mm/s in the applications of vertical and axial tensile loadings respectively.
- The comparison of the failure modes and ultimate limit state values between FEM model and experiment was brought that the FEM model is reliable. Therefore, this FEM model is applicable for

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the analysis in underlying mechanisms governing the behaviours of various levels of axial tensile loads on the negative moment region of steel-concrete composite beam. Finally, this FEM model is suggested for the design analysis in postponing the failure of structure subjected to biaxial forces through locally strengthening with stiffness wherever necessary

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