ANALYSIS OF TWISTED COMPOSITE PLATES USING FINITE ELEMENT METHOD

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Abstract: A numerical study is carries out using finite element method to examine the twisted composite plate by varying the angle of twisting and number of layers in the composite laminate. A cross ply laminate subjected to cantilever boundary conditions with axial load analyzed by varying the twisting angle of the plate from 5^0 to 45^0. The variation of axial, normal and shear stresses are evaluated. Further the natural frequency, buckling load factor of the twisted composite plate is estimated with finite element based software ANSYS. It is observed that the varying the twisting angle, number of layers have a substantial influence on structural, natural frequency and buckling load factor of the composite materials.

Keywords: Twisting angle, Axial stresses, buckling factor, natural frequency

Introduction:

Fiber-reinforced composite laminates are widely used in aircraft, helicopters, turbine blades and in other industries. The application of composite materials for both blades in wind turbines and fan blades in aero engines has established the potential of these materials for rotating components [1]. Experimental works on simple geometries and numerical investigations on pre-twisted composite blades have shown the effect of fibre angle on the eigen frequencies [2,3]. Additional works on the modal damping of composites demonstrated their direction-dependent properties [4–6]. Fiber reinforced composite material in blade applications has stimulated a considerable amount of study. The transverse deflections of a straight tapered symmetrical beam attached to a rotating hub as a model for the bending vibration of blades in turbo-machinery were studied [7]. The forced vibration response of subsystems attached to a foundation with finite stiffness or mass estimated [8]. Using the finite element model, the dynamic stability aspects of a cracked orthotropic beam was analyzed [9]. The dynamic material behavior in a glass filament reinforced epoxy composite was presented [10]. Fiber orientation of the laminate has significant effect on vibrational behavior of composite materials. [11]. Rotating laminated blades design issues are analyzed with the perspective of vibrations. [12]

From the previous studies it is observed that, most of the findings are concentration of vibrations, structural by varying the geometrical, fiber orientation. The present work is focused on the effect of twisting angle of the composite laminate plate on the structural, vibrational and buckling factor.

FINITE ELEMENT MODELLING:

In this study the analysis of a twisted composite plate is predicted using finite element based software ANSYS. The elements used in numerical analysis to model the plate are SOLID191.This element has 3 degrees of freedom at each node.

The geometrical arrangement of the twisted composite FRP plate is shown in Fig.1.a. and b. The Composite plate is made with unidirectional fiber reinforced composite laminas with layup of $[0/90/90/0]_{2S}$ were taken. The length and width of the plate was fixed to 100mm.

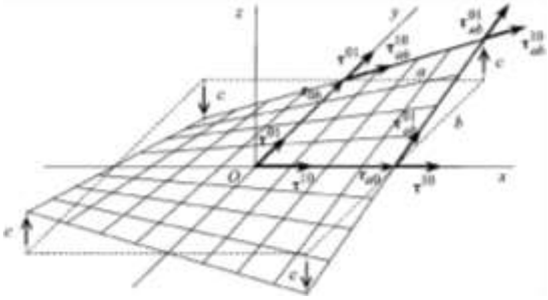


Fig. 1.a. Representation of Twisted Plate Fig.1.b. Geometrical model of Twisted Plate

The twisted composite plate is fixed at one end and subjected to a uniform pressure of 1MPa at the opposite side of the fixed end. The number of layers in the composite plate were varied from 4,8 and 16 to observe the plate behavior at different number of layers. In all the cases, the cross ply layers are arranged. The plate was made with Boron/Aluminum (B4/6061Al). The material properties required for the analysis were presented in Table.1.

Table.1.Material Properties of Boron/Aluminum lamina at 50% volume fraction of fiber [13]

Name of the Property	**Magnitude of the Property**
Longitudinal Modulus (E_1)	235GPa
Transverse Modulus (E_2)	137GPa
Transverse Modulus (E_3)	137GPA
Poisson's ratio (ν_{12})	0.3
Poisson's ratio (ν_{23})	0.17
Poisson's ratio (ν_{13})	0.3
In plane shear Modulus (G_{12}) and (G_{13})	47GPa
Out of Plane shear modulus (G_{23})	24GPa

Mesh convergence test was conducted with by increasing the number of element of the FE model. Converged FE model are used to extract the results of twisted composite plate.

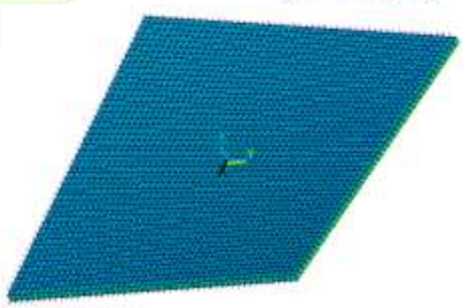


Fig.2. Finite element model of twisted plate at 5^0

RESULTS AND DISCUSSIONS:

This section presents the variation of axial, normal and shear stresses by varying the twisting angle of the composite plate with different number of layers. Fig.3 shows the variation of Axial stresses are increasing with increase in the twisting angle of the plate. From 5^0 to 15^0 the growth in the stresses is slow but after 15^0 fast growths in theses stresses was observed with twisting angle. Increasing the number of layer in the twisted composite laminate is decreasing the magnitude of axial stresses and so significant differences are noticed for 8 layers and 16 layers in the composite laminate.

Fig.4-5. show the variation of normal stresses with respect to various twisting angles of the plate. Compared to Axial stresses, the Normal stresses intensity (σ_Y and σ_Z) is less and the same trend has observed for these stresses also. No clear differences are noticed for different number of layers. At 25^0 twisting angle, minimum normal stresses in Z-direction was observed.

Fig.6-7. show the variation of shear stresses in XY plane and YZ plane. Compared to τ_{XY} stresses, τ_{YZ} stresses are high. Here, the 4 layer laminate showed less stresses at higher twisted angle plate.

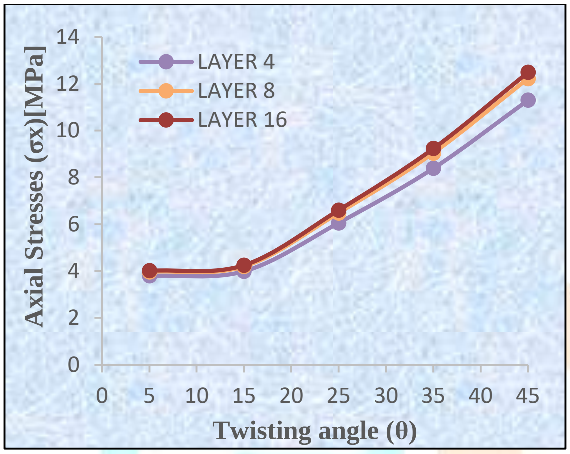


Fig.3 Variation of (σ_X) with respect to (θ)

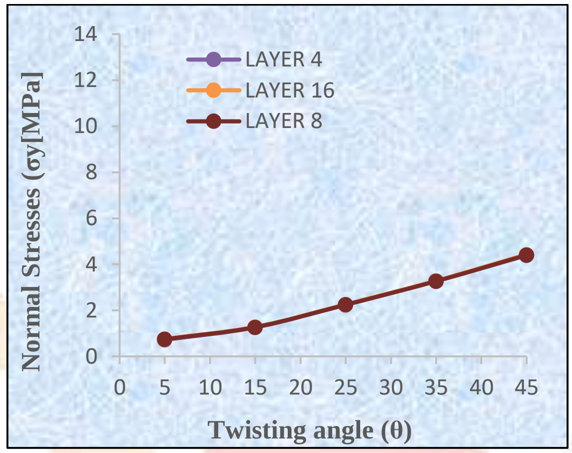


Fig.4 Variation of (σ_Y) with respect to (θ)

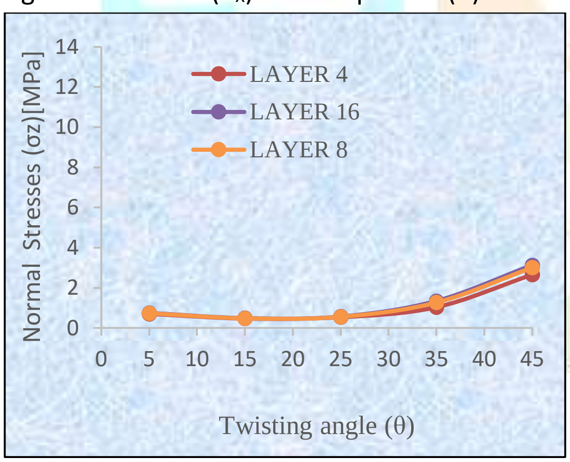


Fig.5 Variation of (σ_Z) with respect to (θ)

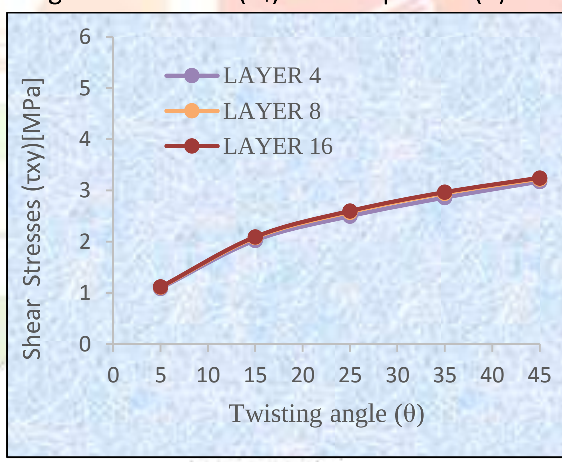
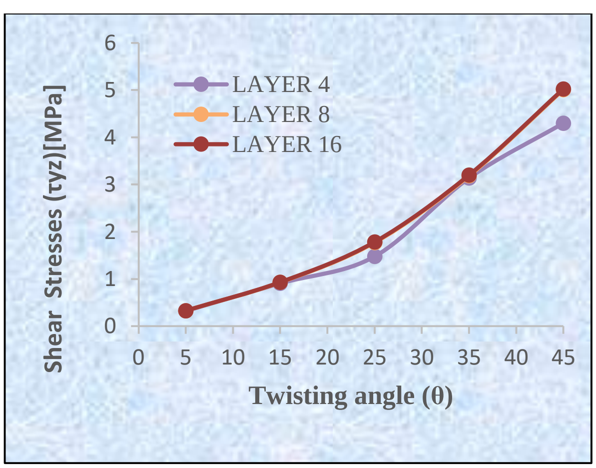


Fig.6 Variation of (τ_{XY}) with respect to (θ)



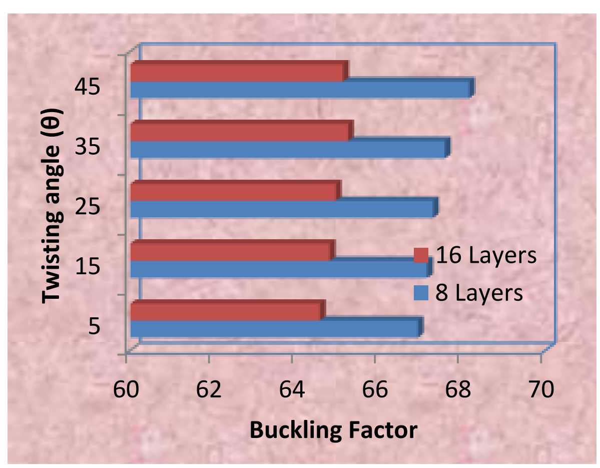


Fig.7. Variation of (τ_{YZ}) with respect to (θ)

Fig.8. Variation of Buckling Factor with respect to (θ)

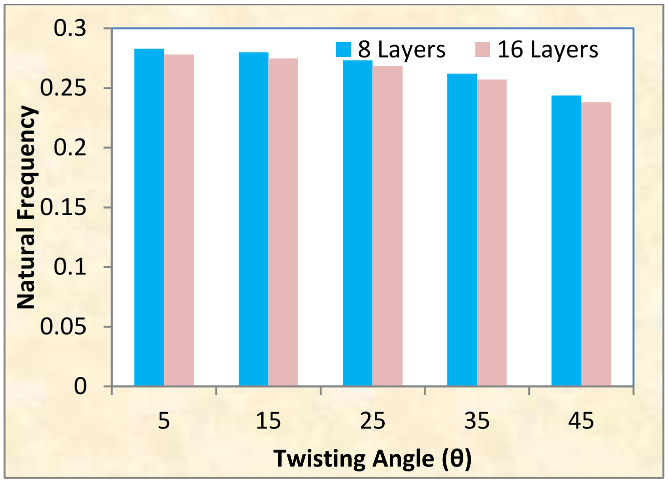


Fig.9 Variation of Natural Frequency with respect to (θ)

Fig.8. shows the variation of buckling factor with respect to the twisting angle of the Plate. At higher twisting angles, the buckling factor is high. High buckling factor is high for minimum number of layer i.e 8 layers. Fig.9. shows the variation of natural frequency with respect to twisting angle. The twisted plate showed good natural frequent at lower angle of twist.

CONCLUSIONS:

On the basis of the present study, this has dealt with the effect of twisting angle and number of layers under various conditions. The following conclusions are drawn:

(1) Under cantilevered boundary conditions, the axial stresses are high compared to normal stress and shear stresses due to the application of applied load in axial direction.
(2) The Number of layers in the laminate has significant effect on the axial stresses. Foe high number of layers the axial stresses are less
(3) At higher twisting angle, the stresses are high.
(4) The buckling factor is high at highest twisting angle of the plate
(5) The natural frequency high at lower twisting angle anf it is decresing with increasing the twisting angle.

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