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Three Dimensional Finite Element Analysis of Thin Hybrid FRP Skew Laminates for Thermo Elastic Behaviour of Different Materials

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Abstract

The present paper deals with the prediction of thermo elastic behavior of the thin four-layered Angle- ply Hybrid Fibre Reinforced Plastic (FRP) skew laminated composite plate with circular cut out by considering two composite materials Graphite-Epoxy and Boron-Epoxy materials which are subjected to uniform pressure load and thermal loading. The problem is modeled in ANSYS software based on the Classical Lamination Theory (CLT) which is suitable for the analysis of thin laminates with circular cut-out. The effect of size of the circular cut out and skew angle on the stresses are shown for Angle-ply laminates. The principle stresses and shear stresses are evaluated for different cross sections. The present analysis is useful for the safe and effective design of the skew laminates with circular cut out under uniform pressure load and thermal load conditions

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Keywords: Skew laminate, hybrid FRP, Finite element analysis, cross-ply angle-ply, classical theory, thermal stresses. Circular cut out

1. Introduction

Composite materials are replacing metals in many structural applications such as aerospace, transportation, novel and pressure vessels due to their high specific strength and specific modulus. Composite materials are useful for the safe and effective design when subjected to uniform pressure load and thermal loading.

Statical and dynamical behaviour of thin fibre reinforced composite laminates with different shapes Based on the classical laminated plate theory [1], Thermal buckling analysis of symmetric and antisymmetric cross-ply laminated hybrid composite plates with an inclined crack subjected to a uniform temperature rise [2] , buckling of functionally graded plates (FG plates) with an elliptical cut out under combined thermal and mechanical loads is investigated using Finite Element Method [3] ,The free vibration analysis of laminated composite skew plates with delamination

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around a centrally located quadrilateral cut out is carried out based on the high-order shear deformation theory (HSDT) [4] ,the prediction of interlaminar stresses in simply supported laminated FRP composite plate with a circular cut-out under transverse load using 3-D finite element analysis [5], the free vibration analysis of a thin Fibre Reinforced Plastic (FRP) skew laminated composite plate with a circular cut-out at the geometric centre [6], the interlaminar stresses are predicted for a bidirectional skew laminated unidirectional continuous fibre reinforced plastic (FRP) composite with a circular cut out at the geometric centre of the plate using three dimensional finite element method with geometric nonlinear option [7].

The present investigation intends to apply the finite element technique, based on classical lamination theory, for the analysis of symmetric and anti-symmetric thin laminates under uniform pressure load and thermal loading

Table.1.1, Nomenclature

Nomenclature	
l	length of the plate
h	Total thickness of laminate
S	(l/h), thickness ratio of the laminate
d/l	Diameter ratio.
α	Skew angle
Eij	Young’s modulus of lamina.
Gij	Shear modulus of lamina.
υij	Poisson’s Ratio of Lamina.
σ	Normal stress.
w	Deflection
τxy	Shear stresses

2. Problem modeling

2.1 Geometric modelling

A laminated composite general shell element (SHELL99) is used for meshing the geometry of the problem. This element is suited for modeling moderately thin laminates composite shells. As shown in the Fig.1, the element consists of number of layers of perfectly bonded orthotropic materials. The element gives results of high accuracy and discretization involves fewer elements. The lamination sequence is between the bottom and top faces of the element with the layer setup starting from the bottom face. This element is used to model the present problem with 0/90/90/0, layer sequence.

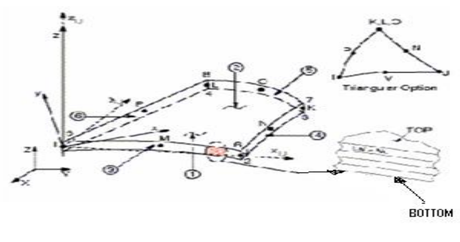

Fig.1, Geometric modelling

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2.2 Finite Element Modelling

The finite element model of the problem are shown in Fig.2, The side of the plate ‘l’ is taken as 20mm and five layers are considered with total thickness (h) of 1mm, so that the length to thickness ratio becomes ‘s’=20. The skew angle α is taken as a value varying from 0 to 50^0. A circular hole is placed at the geometric centre of the plate. The size of the cut out is varied as per the ratio d//l ranging from 0.1 to 0.6mm.

2.3 Boundary Conditions and Loading

All the sides of the skew plate are clamped. The skew laminate is subjected to the combined transverse pressure load of 1MPa and thermal load 200^0

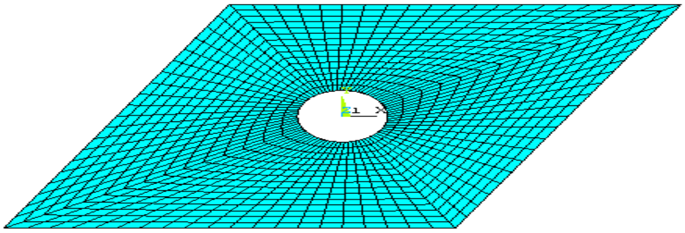

Fig.2, Finite element mesh on skew plate

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2.4 Material properties

The material properties used for the Graphite and Boron epoxy materials are given table below:

i) Young's modulus, For Boron-epoxy E1=241873 GPa, E2=E3=25511.5 GPa.
For Graphite-epoxy E1=141675 GPa, E2=E3=12383.9 GPa.

ii Poisson's Ratio, For Boron-epoxy ν12= ν13=0.25392, ν23= 0.26458.
For Graphite-epoxy ν12= ν13=0.25772, ν23= 0.42057.

iii)Rigidity Modulus, For Boron-epoxy G12=G13=6715.8 GPa, G23=10084 GPa.
For Graphite-epoxy G12=G13=3880 GPa, G23=4356 GPa.

iv)Temperature effects, For Boron-epoxy A1=5.30E-06, A2 =2.20E-05, A3 = 2.40E-05.
For Graphite-epoxy A1=1.00E-07, A2 =2.80E-05, A3 = 2.40E-05

3. Results and Discussions

The Finite element model is generated in the ANSYS software and the stresses are obtained. The results are taken in Angle-ply laminates. The effect of skew angle and the effect of diameter of the cut out are taken into considered in one case. These results are taken the case of Four-layered Angle-ply laminates of any two cases .The possible arrangements of material in individual layers are as follows.

Case1 - Taking all boron -epoxy layers
Case2 - Taking all graphite -epoxy layers
Case3 - Hybrid-1: Graphite-epoxy/Boron-epoxy/ Boron-epoxy/Graphite-epoxy
Case4 - Hybrid-2: Boron-epoxy/Graphite-epoxy/Graphite-epoxy/Boron-epoxy

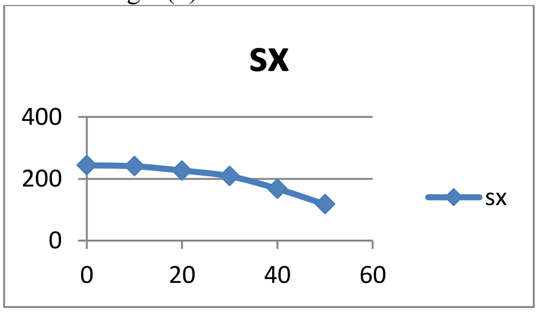
3.1. Stresses Evaluation:

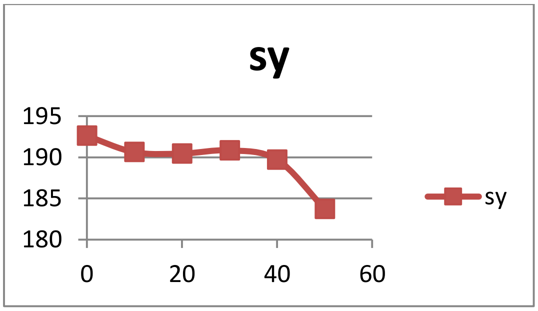
3.1.1 Analysis Of Angle-Ply Laminates:

In the Angle-ply, laminate all the four layers are arranged in the same (θ) value. The theta value is ranging from 0^0 to 90^0 degrees. For these values, the results are obtained for taking the same conditions effect of skew angle and the effect of diameter of the cut out.

3.1.2: Case1- Taking all boron -epoxy layer

a) Effect of skew angle (α) at θ= 0^0 and d/l=0.2





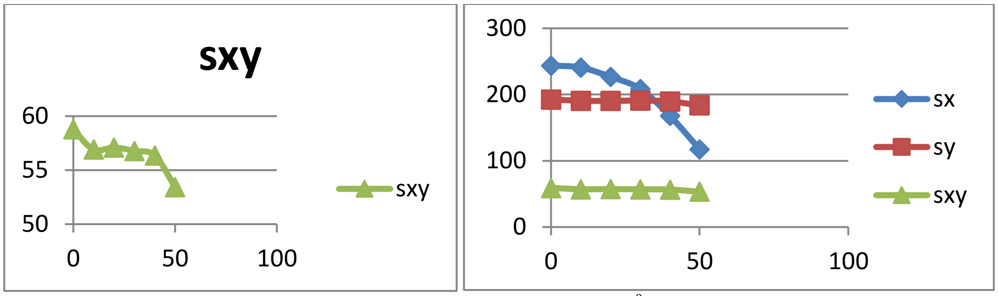


Fig. 3.1, Variation of s_x, s_y and $s_{xy}$with respect to α (θ=0^0 & d/l=0.2)

b) Effect of skew angle (α) at θ= 0^0 and d/l=0.4

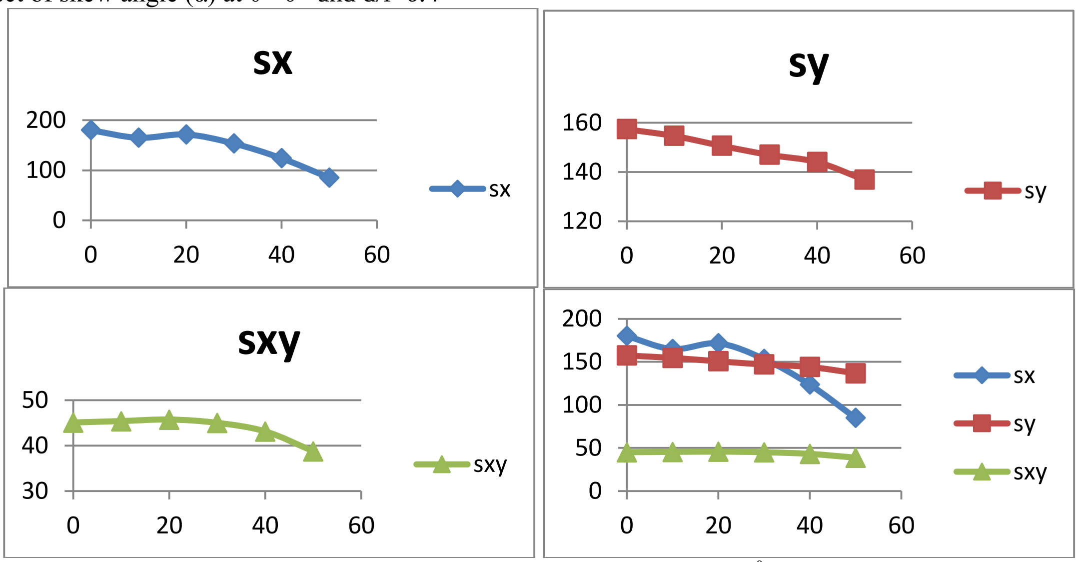


Fig. 3.2 ,Variation of s_x, s_y and $s_{xy}$with respect to α (θ=0^0 & d/l=0.4)

c) Effect of skew angle (α) at θ= 45^0 and d/l=0.2

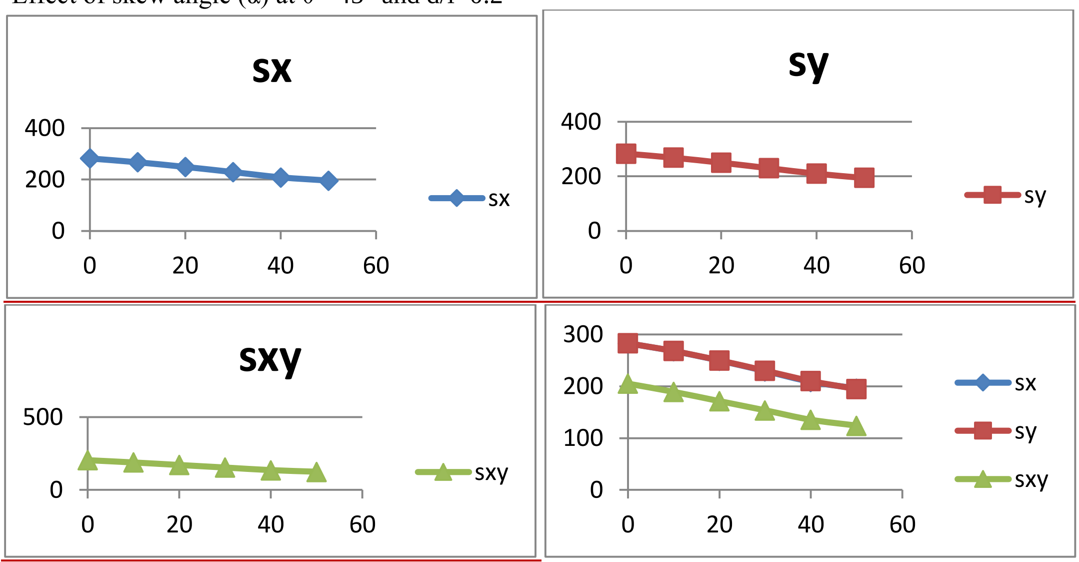


Fig. 3.3 ,Variation of s_x, s_y and $s_{xy}$with respect to α (θ=45^0 & d/l=0.2)

d) Effect of skew angle (α) at θ= 45^0 and d/l=0.4

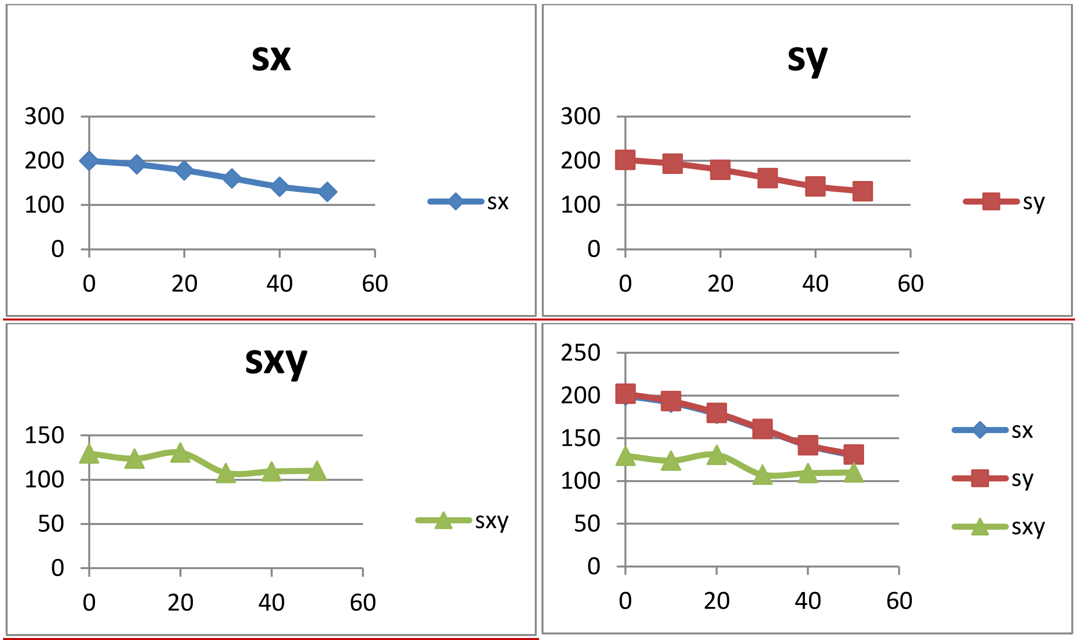


Fig. 3.4 ,Variation of s_x, s_y and s_{xy} with respect to α (θ=45^0 & d/l=0.4)

Conclusion: The values of σx, σY, τxy gradually decreases as increases the skew angle in all the above all cases

3.1.3: Case 4- Hybrid-2: Boron-epoxy/Graphite-epoxy/Graphite-epoxy/Boron-epoxy

a) Effect of skew angle (α) at θ= 0^0 and d/l=0.2

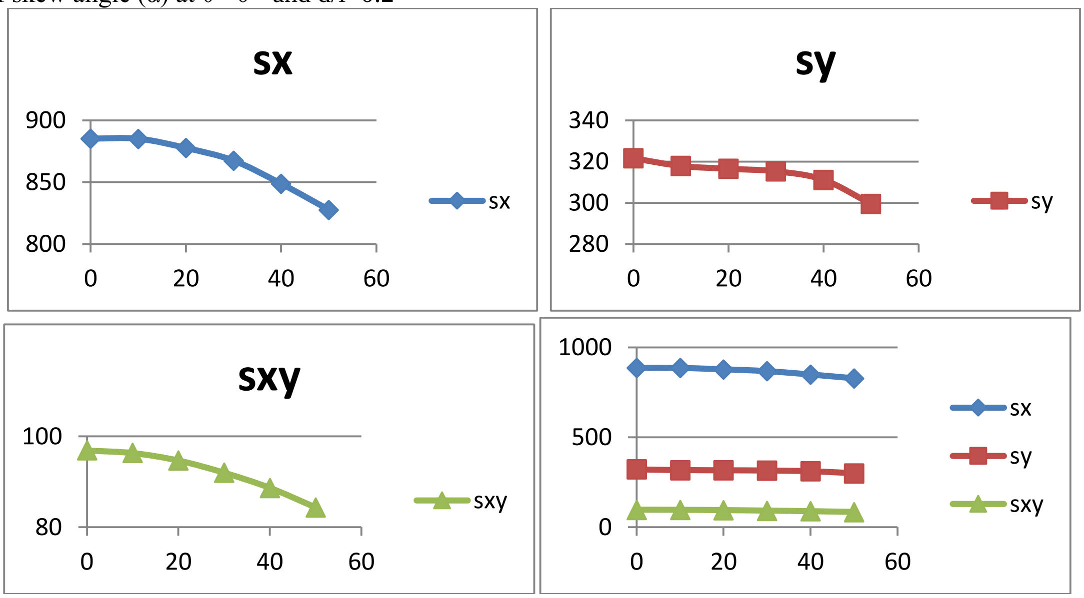


Fig.3.5 ,Variation of s_x, s_y and s_{xy} with respect to α (θ=0^0 & d/l=0.2)

b) Effect of skew angle (α) at θ= 0^0 and d/l=0.4:

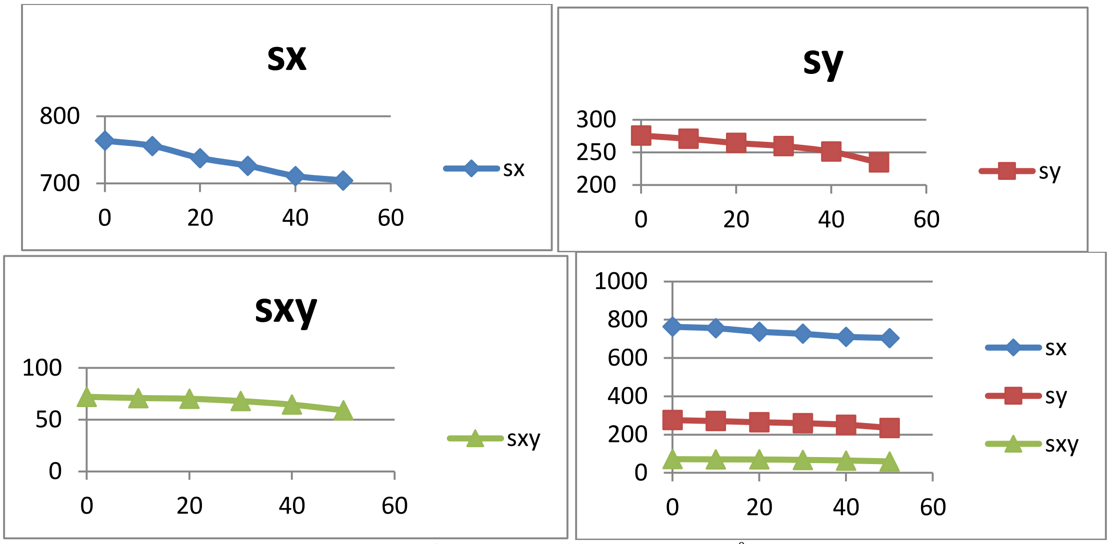


Fig.3.6,Variation of s_x, s_y and s_{xy} with respect to α (θ=0^0 & d/l=0.4)

c) Effect of skew angle (α) at θ= 45^0 and d/l=0.2 :

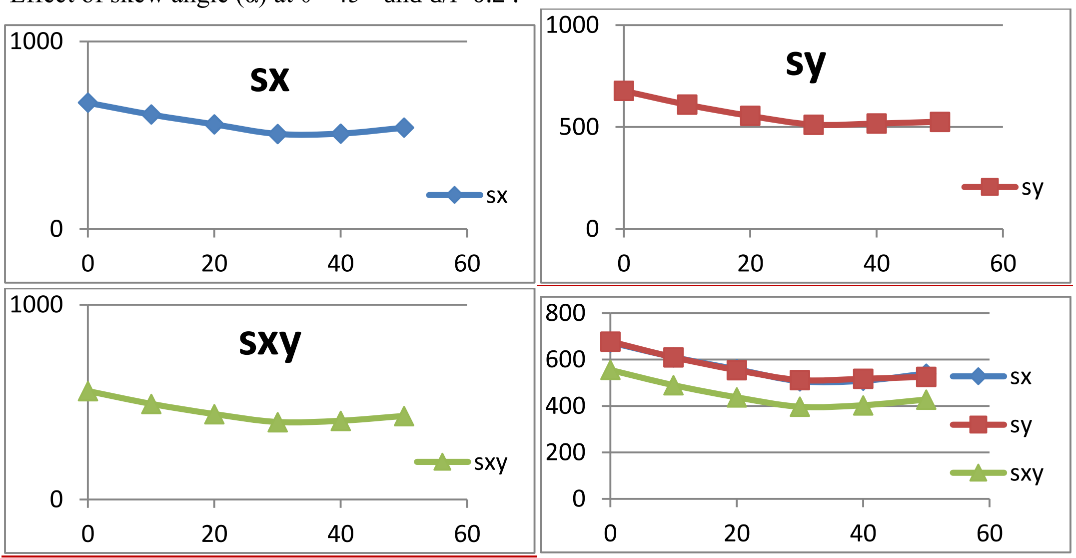
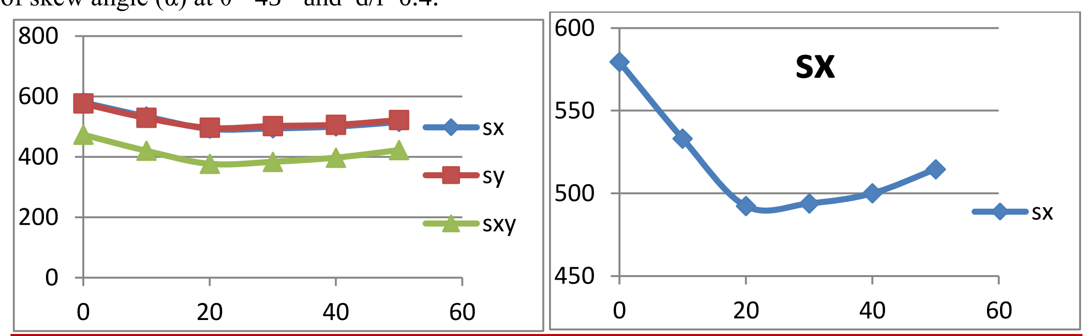
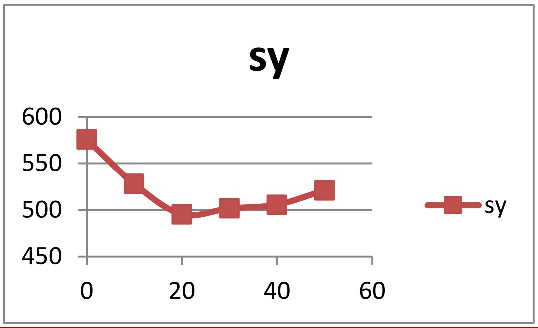


Fig. 3.7 ,Variation of s_x, s_y and s_{xy} with respect to α (θ=45^0 & d/l=0.2)

d) Effect of skew angle (α) at θ= 45^0 and d/l=0.4:





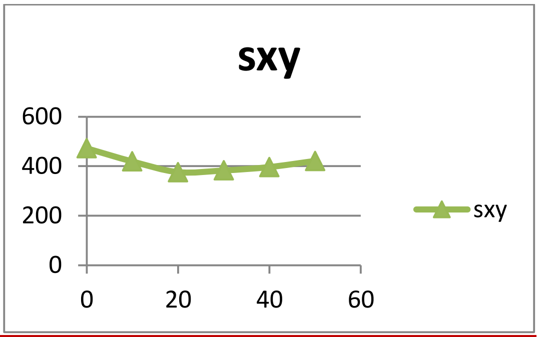


Fig. 3.8 ,Variation of s_x, s_y and s_{xy} with respect to α (θ=45^0 & d/l=0.4)

Conclusion: The variation of the σx with respect to the skew angle at the θ value 45^0 decreases gradually as the increase in the skew angle. In the fourth case the values of σx decrease from the skew angle of 0^0 to 30^0 and increases from the 30^0 to 50^0.

4. Conclusions And Discussions:

Importance of thermo elastic behaviour of the thin four- layered Angle-ply Hybrid Fibre Reinforced Plastic (FRP) skew laminated composite plate with circular cut out subjected to uniform pressure load and thermal loading using CLT two Cases has been discussed in this paper. The plate used is analysed using linear and geometric nonlinear analysis options available in finite element software ANSYS. Form the present analysis it is found that the non linear analysis is must for consider the plate for all fibre orientation consider for the study.

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