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THERMO ELASTIC BEHAVIOUR OF A THIN HYBRID FOUR-LAYERED FRP SKEW CROSS-PLY LAMINATES WITH CIRCULAR CUTOUT

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ABSTRACT

The present paper deals with the prediction of thermo elastic behaviour of the thin four-layered Cross-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 by using 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 Cross and 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.

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

I. INTRODUCTION

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other. Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibres or fragments of the other material, which is called the reinforcement. The first modern composite material was fibreglass. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies. The matrix is a plastic and the reinforcement is glass that has been made into fine threads and often woven into a sort of cloth. On its own the glass is very strong but brittle and it will break if bent sharply. The plastic matrix holds the glass fibres together and also protects them from damage by sharing out the forces acting on them. Some advanced composites are now made using carbon fibres instead of glass. These materials are lighter and stronger than fibreglass but more expensive to produce.

They are used in aircraft structures and expensive sports equipment such as golf clubs.

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 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

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

II. 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 is quadratic and has six degrees of freedom per node namely, translations in x, y and z directions respectively, and rotations about x, y and z axes respectively.

The element gives results of high accuracy and discretization involves fewer elements. As shown in the Fig.3, 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.

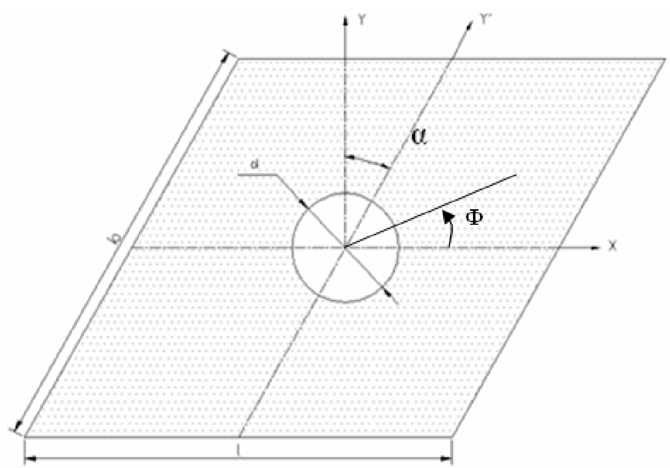

Fig.1, Geometric modelling

2.2. Finite Element Modeling

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 500. 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.

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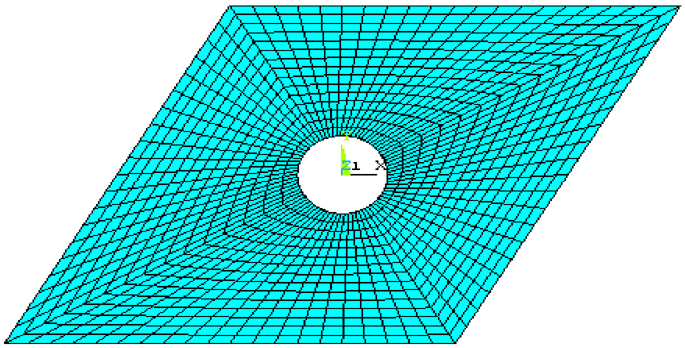

Fig.2, Finite element mesh on skew plate

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.

2.4 Material properties

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

	Boron-epoxy	Graphite-epoxy
Young's modulus in GPa		
E1	241873	141675
E2=E3	25511.5	12383.9
Poisson's Ratio		
ν12= ν13	0.25392	0.25772
ν23	0.26458	0.42057
Rigidity Modulus in Gpa		
G12=G13	6715.8	3880
G23	10084	4356
Temperature effects		
A1	5.30E-06	1.00E-07
A2	2.20E-05	2.80E-05
A3	2.40E-05	2.40E-05

III. RESULTS AND DISCUSSIONS

The Finite element model is generated in the ANSYS software and the stresses are obtained. The results are taken in Cross-ply laminates. The effect of skew angle and the effect of diameter of the cut out are taken into considered in the following cases. These results are taken the case of Four-layered Cross-ply laminates.

3.1 The 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

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3.2. Stresses Evaluation:

3.2.1 Analysis Of Cross-Ply Laminates: A laminate is called cross-ply laminate if all the plies used to fabricate the laminate are only $0^0$and 90^0.The proposed work deals with the static analysis of the Hybrid FRP thin skew laminates with cutout. The main aim is to evaluate the stresses in the clamped skew laminates, which are subjected to combined transverse pressure load and temperature load. Arrange the four layers in $0^0/90^0/90^0/0^0$.

3.2.2: Case1- Taking all boron -epoxy layers

i) Effect of d/l at $\alpha = 0^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 0^0, τxy values are small compared to σx and σy.

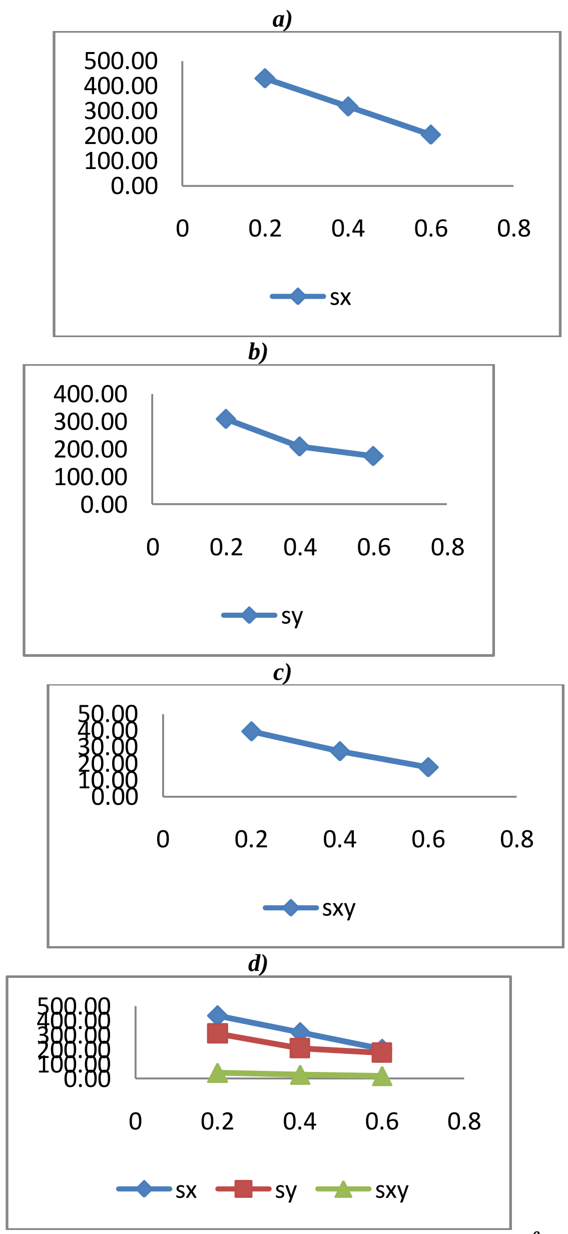

Fig. 3.1, Variation of s_x, s_y and $s_{xy}$with respect to d/l ($\alpha = 0^0$)

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ii) Effect of d/l at $\alpha = 30^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 30^0, σx and σy are same at d/l=0.6, τxy values are small compared to σx and σy.

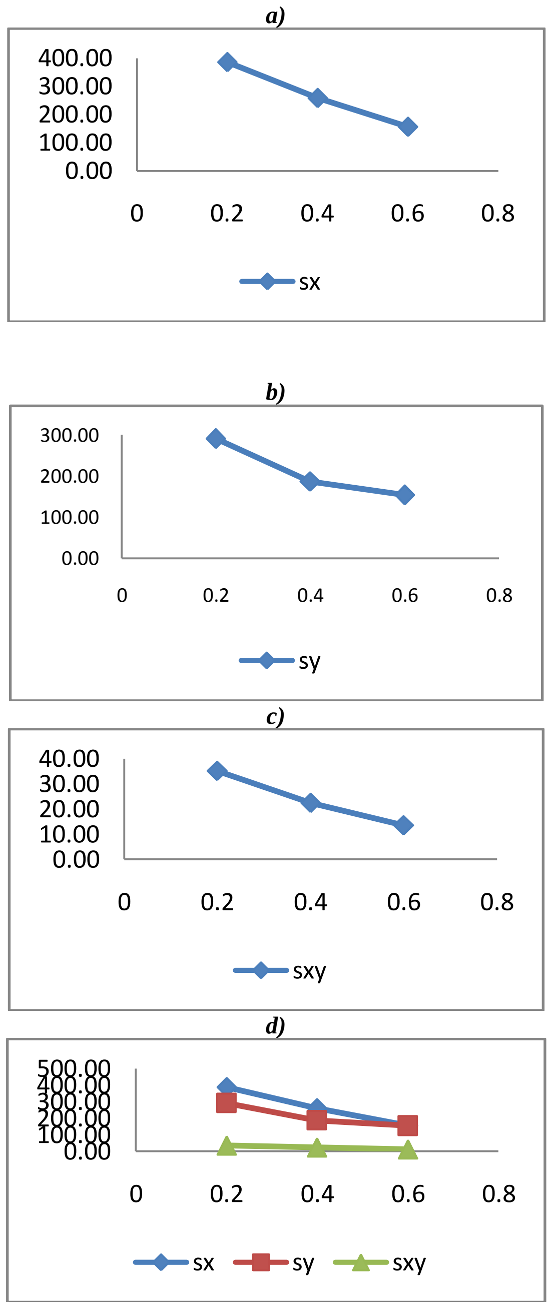

Fig. 3.2:Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 30^0$)

3.2.3: Case 2- Taking all graphite-epoxy layers

i) Effect of d/l at $\alpha = 0^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 0^0, stresses in case-2 are high compared to case-1

a)

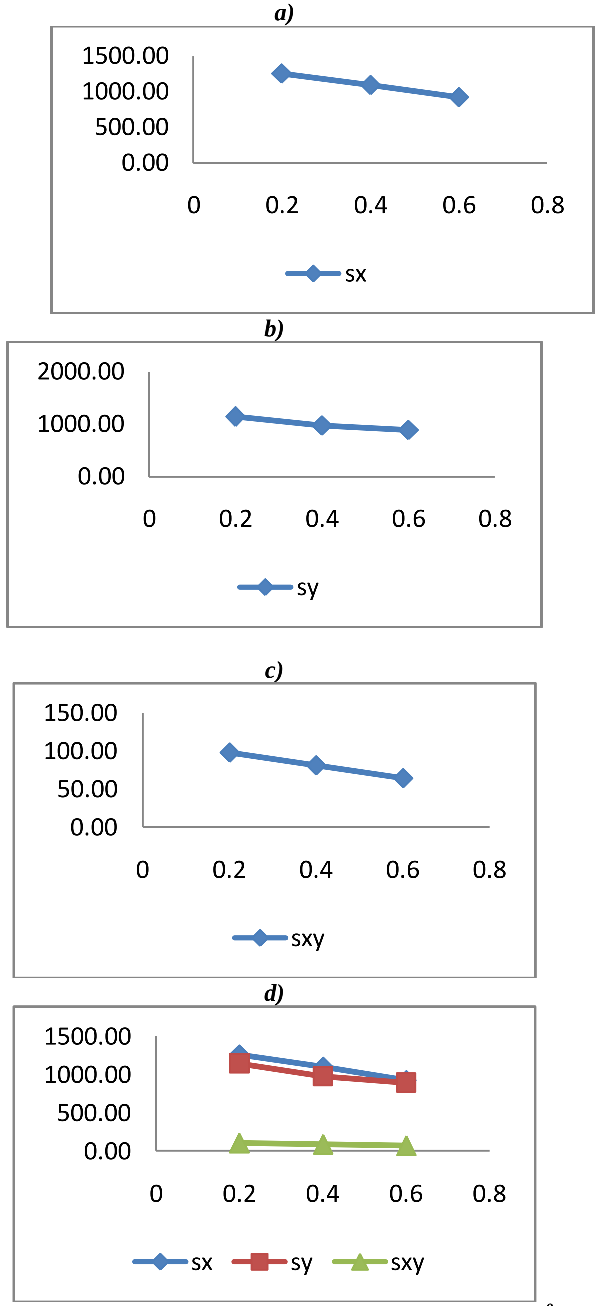

Fig. 3.3:Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 0^0$)

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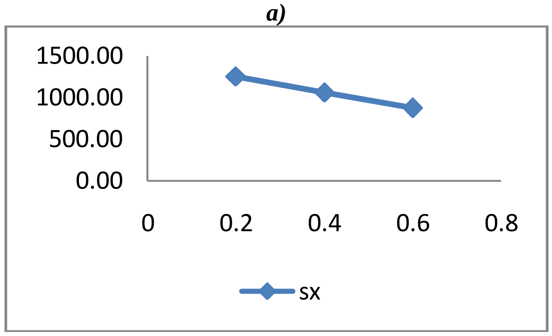
i) Effect of d/l at $\alpha = 30^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 30^0.

a)



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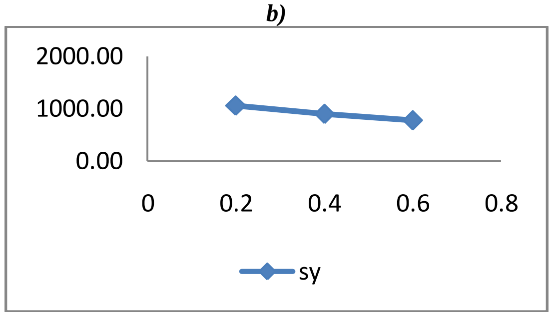
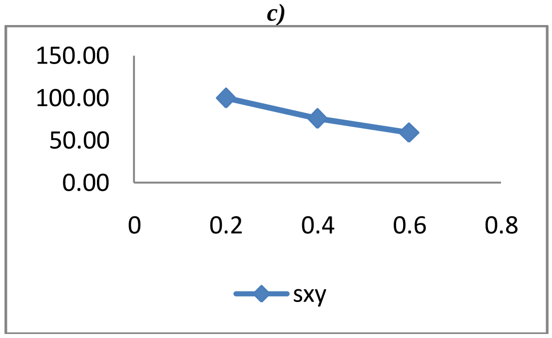


c)



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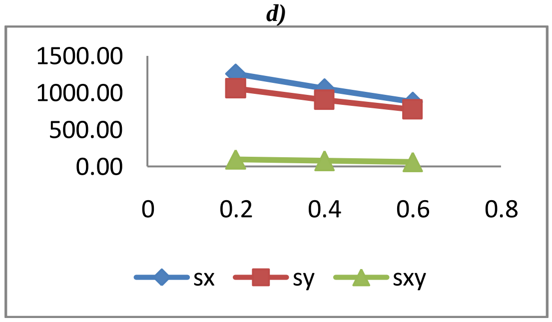

Fig. 3.4: Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 30^0$)

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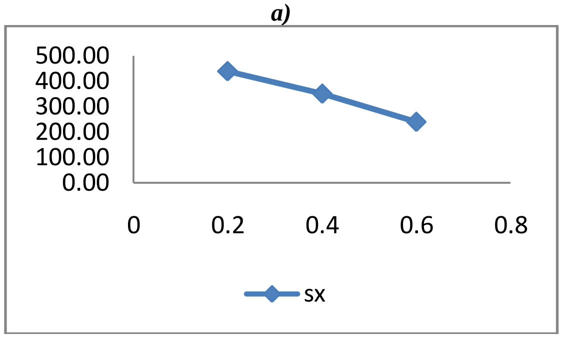
3.2.3:Case 3- Hybrid-1: Graphite-epoxy/Boron-epoxy/ Boron-epoxy/Graphite-epoxy

i) Effect of d/l at $\alpha = 0^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 0^0. Values of σy are more compared to case-1 and case-2.

a)



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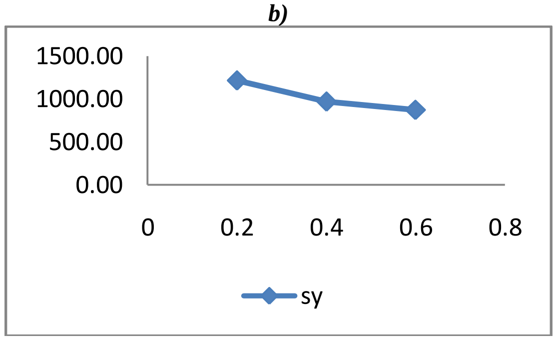

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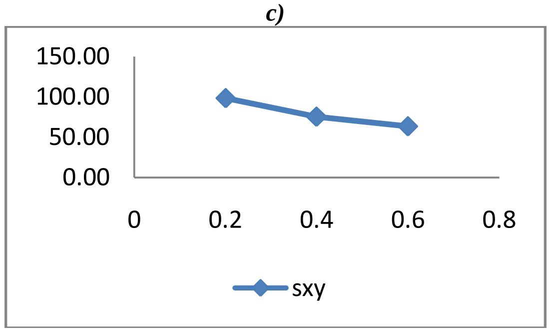

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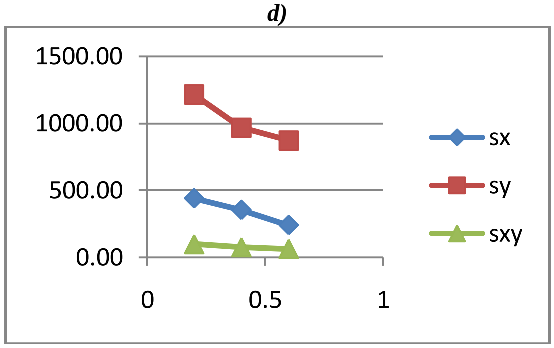

Fig.3.5: Variation of s_x, s_y and $s_{xy}$with respect to d/l ($\alpha = 0^0$)

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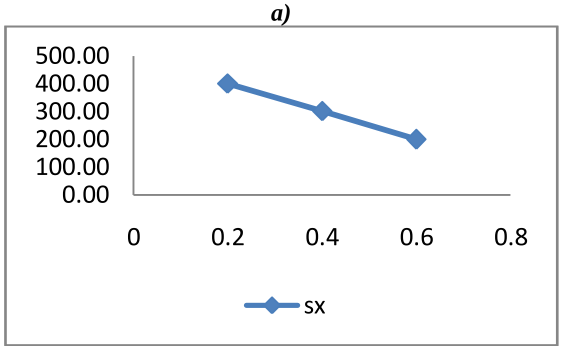
ii) Effect of d/l at $\alpha = 30^0$: The values of σx, σy, and τxy gradually decreases as increases d/l ratio at the skew angle 30^0.

a)



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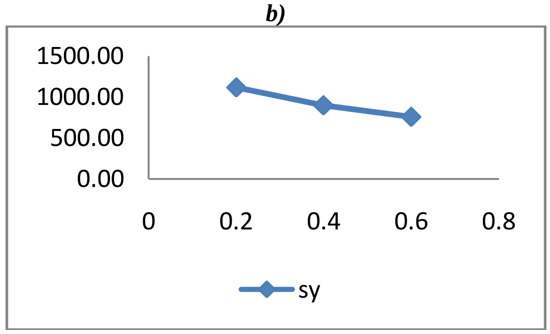

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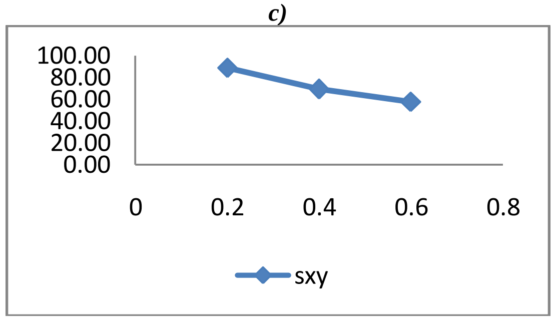

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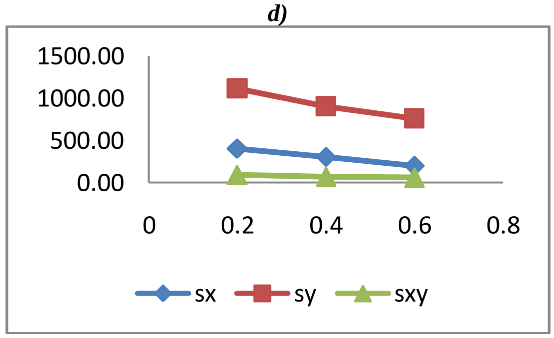
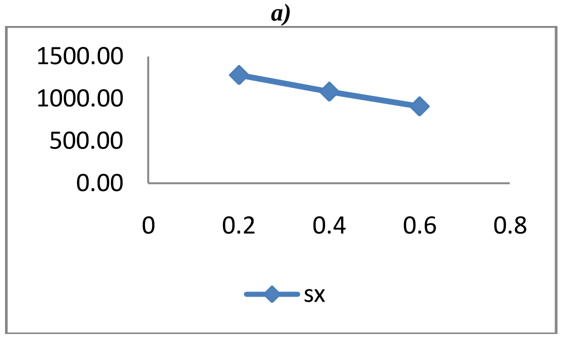


Fig.3.6: Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 30^0$)

3.2.3:Case4- Hybrid-1: Boron-epoxy/ Graphite-epoxy/ Graphite-epoxy/Boron-epoxy

i) Effect of d/l at $\alpha = 0^0$: The values of σx gradually decreases as increases d/l ratio at the skew angle 0^0. The values of σy, and τxy very less compared to σx.

a)



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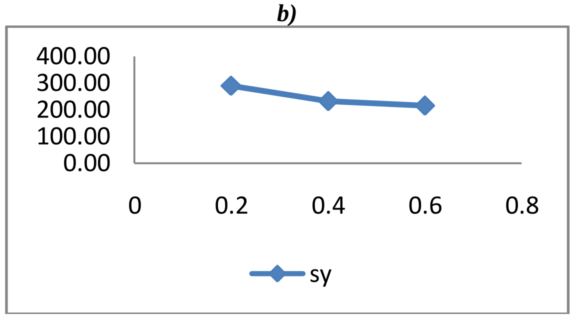

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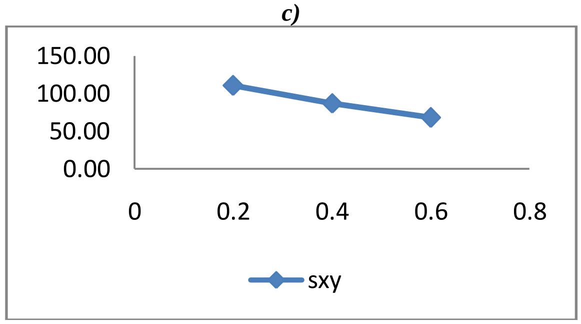

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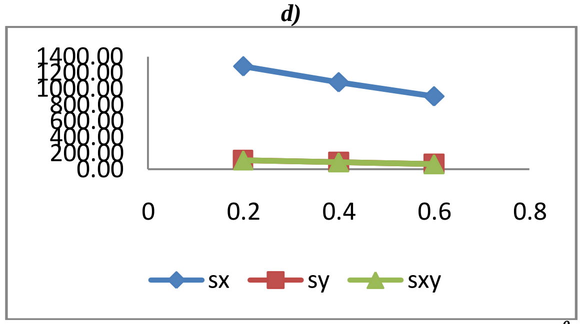

Fig.3.7: Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 0^0$)

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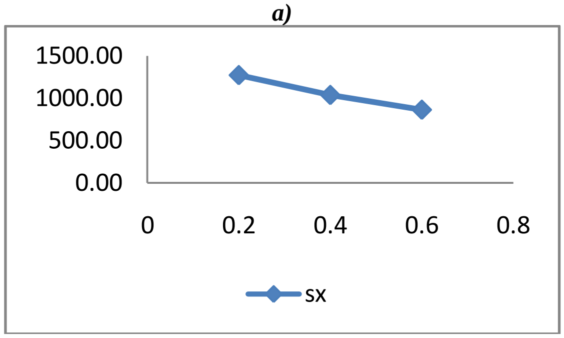
ii) Effect of d/l at $\alpha = 30^0$: The values of σx gradually decreases as increases d/l ratio at the skew angle 30^0.

a)



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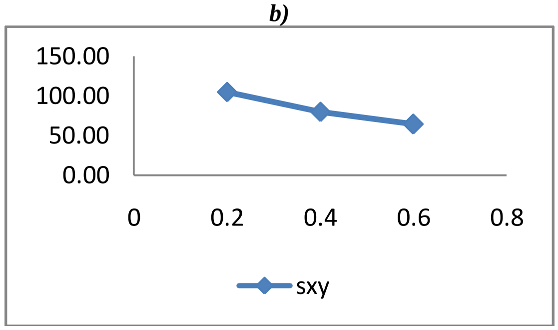

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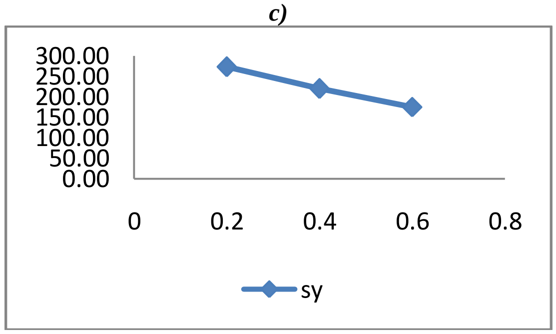

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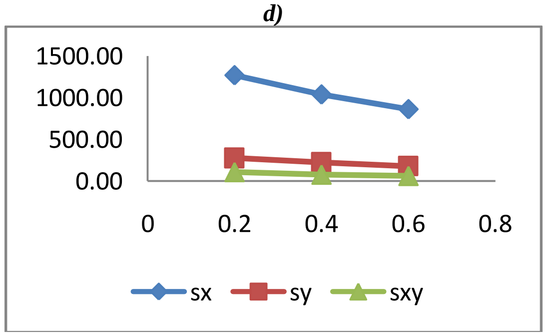

Fig.3.8: Variation of s_x, s_y and s_{xy} with respect to d/l ($\alpha = 30^0$)

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