DEFORMATION AND STRESS DEVELOPEDIN DRILLING OF HYBRID COMPOSITES

Vinay Kumar R[1]
PhD Scholar, MED, SJCIT
Chickballapur, INDIA

Suresh Gowda M V[2]
Associate Professor, MED, SJCIT
Chickballapur, INDIA

Aravind K U[3]
Professor& HOD, MED, EWCE
Yelahanka,Bangalore, INDIA

Abstract

The competitiveness in producing and using eco friendly materials is increasing with the increase in research in the particular field. Among the materials hybrid composites are becoming more familiar and famous as they can be tailored to required extensive properties and hence concentration is towards developing eco friendly composite material which is possible only through using the natural fibers along with the man made resin. Here in the study the natural fibers jute and glass are used along with the epoxy polymer to develop the eco friendly composite. As the fastening process gain much importance in all kinds of industries drillability of the concerned material is of major importance. Hence in this study drillability of the produced hybrid composite in terms of stress developed while drilling which is the major issue in drilling of composite is concentrated. The analysis is done using ANALYSIS in ANSYS v12.0.
Keywords: Optimization,Tsai-Wu failure criterion, Von-mises stress, Hybrid Composites

1 Introduction

Ansys FEM software is a popular dynamic analysis software, which is used specifically for polymer cutting or drilling. It can handle multiple-body deformable contact for interaction of tool and workpice. It includes a closure of crack and frictional sliding which are mainly considered for analysis. The complete procedure was followed by the method proposed by Marusich and Ortiz.

The FE constitutive model provides the solution for the damage in the FRP specimen by taking various drill-tool geometries as per experimental studies. The specimen dimensions are 20 x 20 cm2 and drill diameter is of 10 mm. The geometry of the specimen is shown in Fig. 1. The plate is of 20×20 x 2 mm3 dimensions and the hole to be drilled is of 8mm dimension. Tsai-Wu damage model was applied for determining the damage zone of the specimen. In this model, during drilling the outside hole zone is assumed to be with linear elastic behaviour. The FRP specimen was meshed using S4R quad-dominated element and 1600 nodes were considered for analysis. The tool drills were assumed to be rigid structures, which was meshed with R3D4 elements. Both FRP specimen and drill were assembled as shown in Fig. 1. The FRP composite specimen behaviour was assumed to be lamina type with failure strain data. The FE model was modelled based on elastic and Hashin’s damage model in ANSYS. For FE analysis, composite structure needs nine elastic constants (orthotropic properties) for Tsai-Wu damage model.

The uniform pressure load of 500 N is applied as the boundary condition, which is reference point of the drill. The specimens are constrained on all four sides and interaction between drill and specimen took place exactly at the centre of the specimen. The feed rate and drilling speed are assigned to the reference point of tool only in z-direction. The model was simulated for six different combinations as shown in Fig. 1

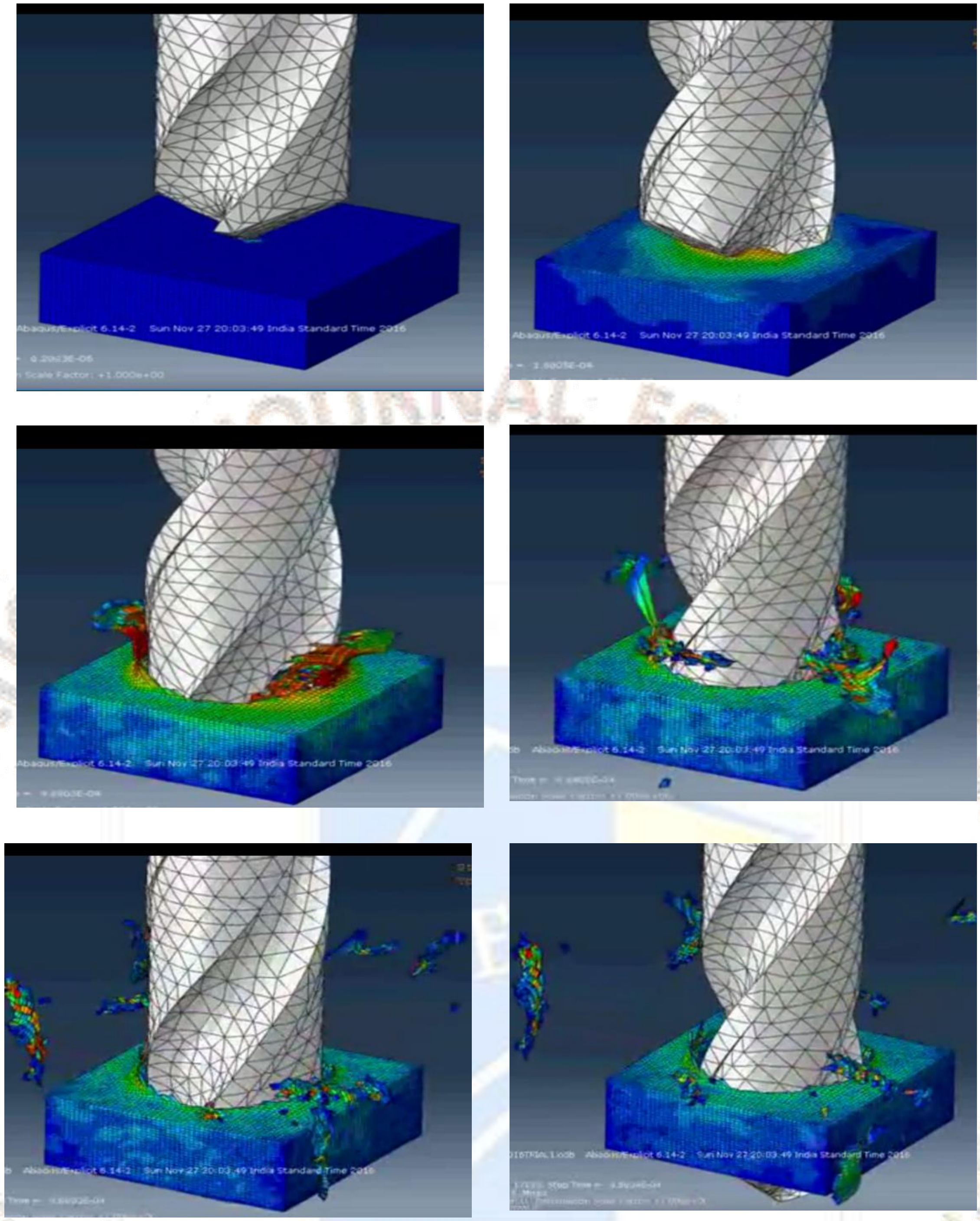

Fig. 1: Different drilling process of FRP structures

Basic steps of FEM

The elements are created by selecting the shell element and type is shell (181). Rectangular area is created by selecting the modelling and in that by selecting the rectangular option by two corners, after that a solid circular hole in the centre of the work piece was created as shown in Fig. 2.

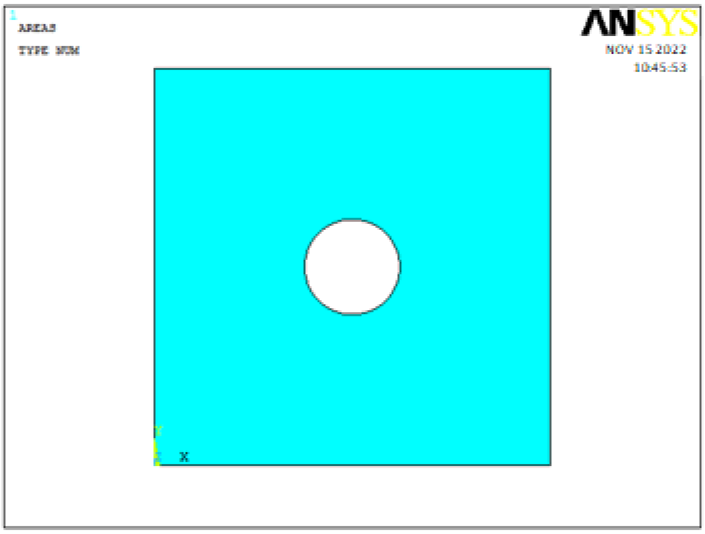

Fig. 2: 2D model of composite

Meshing

For finite element analysis the whole area is converted into finite number of small elements by meshing. After mesh a refinement of level two is done. Mesh density is uniform throughout the composite as shown in Fig. 3.

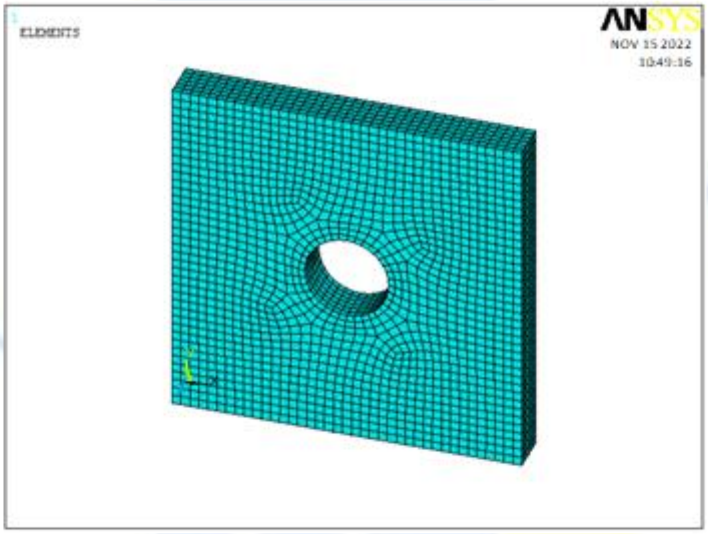

Fig3: Meshed composite

Loading and boundary condition

The boundary condition was applied by fixing the bottom and sides of the work piece. The drilling had the loading condition in the 'y' direction so bottom motion was fixed. The load was applied by selecting the circumferential pressure on drilled hole as shown in Fig. 4 and 5.

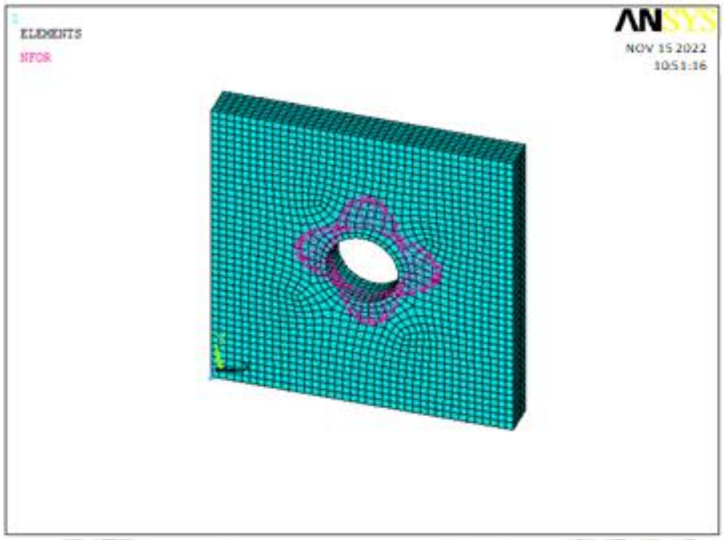

Fig4: Loading of the composite

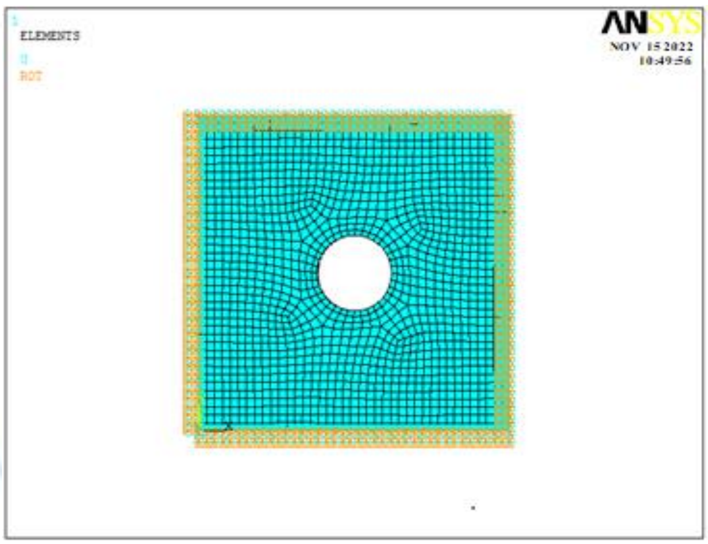

Fig 5: Boundary condition

Composite layers

Work piece had 6 layers of 0.5mm thickness each and orientation of $0^0/90^0/0^0/90^0/0^0/90^0$ respectively; this was done by selecting the shell element in section as shown in Fig. 6.

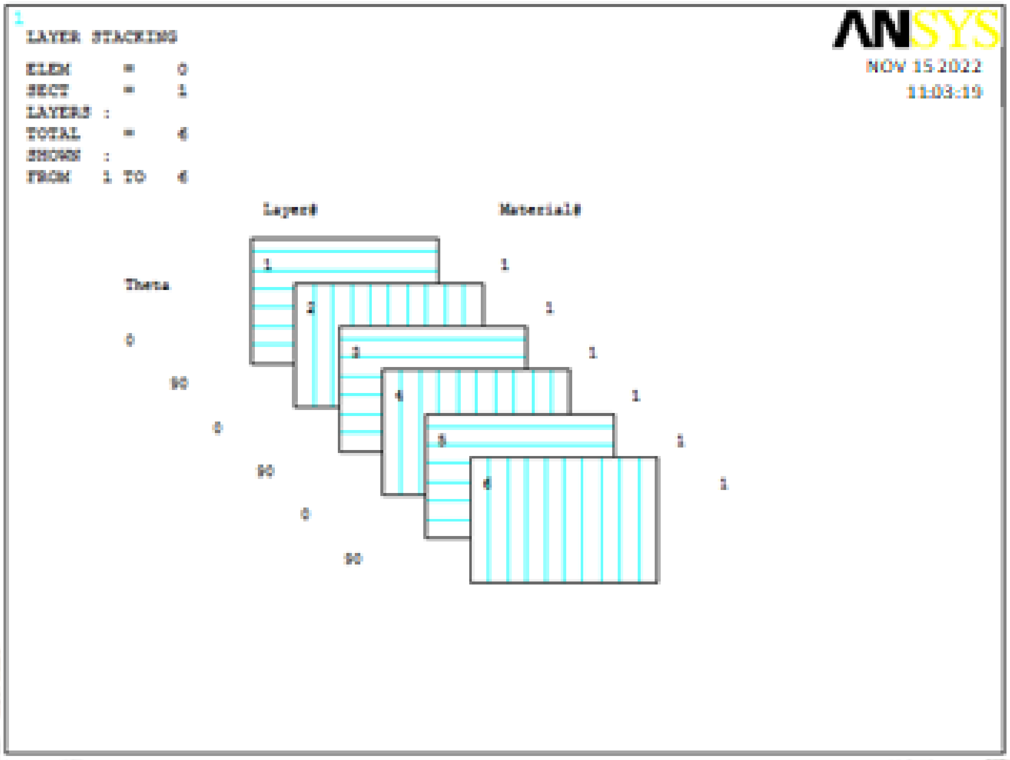

Fig6: Composite layers

Results and Discussion

Necessary data for the Tsai-Wu failure criteria was analysed by selecting the assumed temperature as 30°C (room temperature) and this was applicable for each layer. Finally, the maximum von-misses stresses are obtained as shown in Fig. 7 and 8.

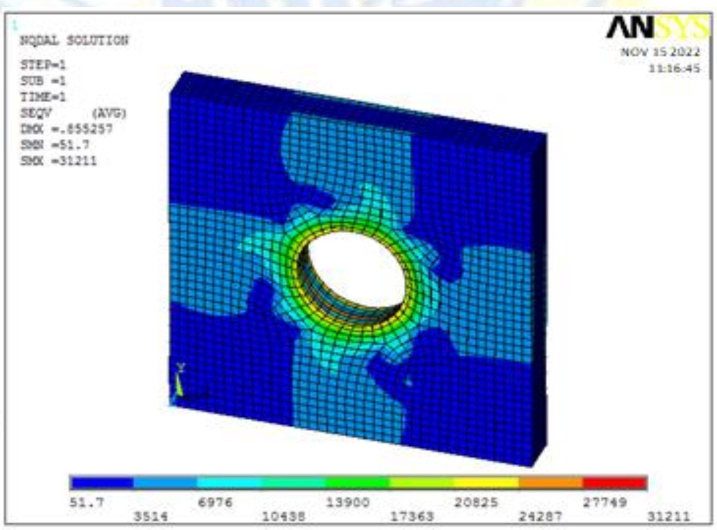

Fig7: Von-mises stresses

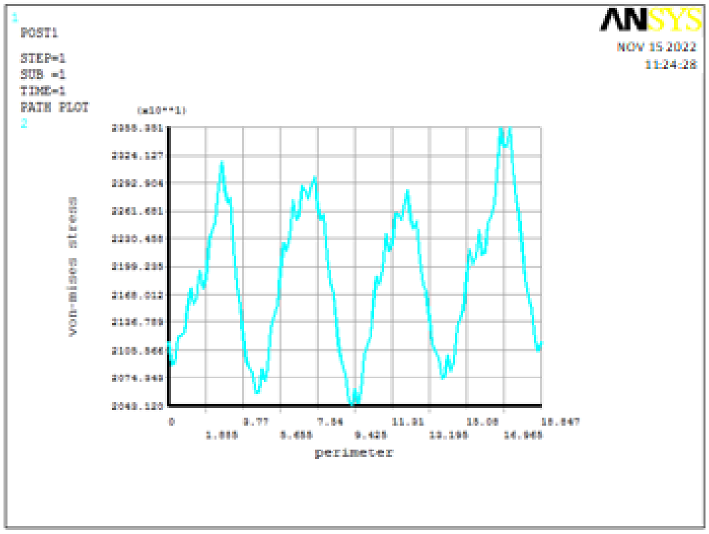

Fig8: Perimeter v/s Von-mises stress

Deformation

The deformation was obtained in all directions and the vector sum of the maximum displacement was analysed as shown in Fig. 9 and 10.

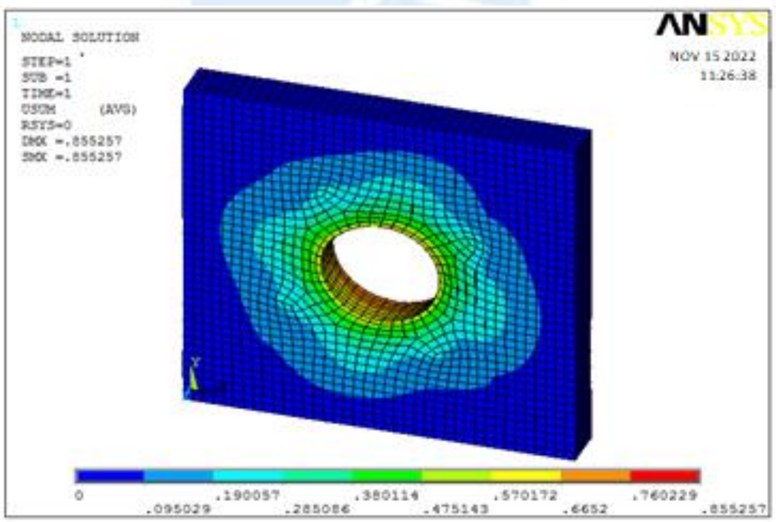

Fig9: Deformation of the composite

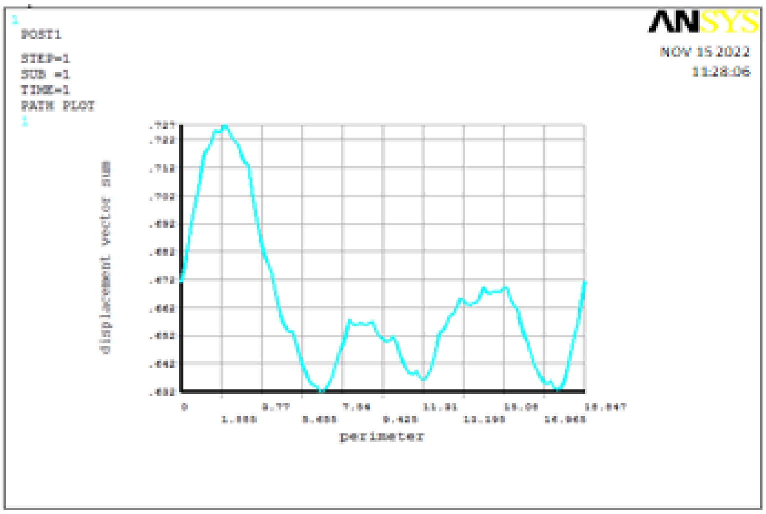

Fig 10: Perimeter v/s displacement vector sum

5.4 Tsai-Wu failure criterion

Tsai-Wu failure criterion is the best suited criteria for analysing failure in composites and is widely used for anisotropic materials. It shows that, if the failure index is more than one, the composite fails and is safe if the index is less than one. Generally, the material fails when it loses the load carrying capacity. Theoretical formula for Tsai-Wu failure strength index for isotropic composites is given by,

$F=F1xs_{xx}+F2xs_{yy}+F3xs_{zz}+F11xs_{xx}^2+F22xs_{yy}^2+F33xs_{zz}^2+F12xs_{xx}xs_{yy}+F13xs_{xx}xs_{zz}+F23xs_{yy}xs_{zz}+F44xs_{yz}^2+F55xs_{xz}^2+F66xs_{xy}^2$

Where,

$F1= (1/F_{Xt}) - (1/F_{XC})$,

$F2= (1/F_{Xt})-(1/F_{XC})$,

$F3= (1/F_{Zt}) - (1/F_{ZC})$,

$F11= (1/F_{XCt}) \times F_{Xt}$

$F22= (1/FY_{t+}) \times F_{YC}$,

$F33= (1/F_{Z+}) \times F_{ZC,}$

$F44= (1/FS_{YZ})^2$,

$F55= (1/FS_{XZ})^2$

$F66= (1/FS_{XY})^2$

Delamination

The layers after drilling the hybrid fibre composites are shown in Fig.11 and 12. Delamination is the major effect of the drilling process which has to be controlled as this will lead to the failure of the composite.

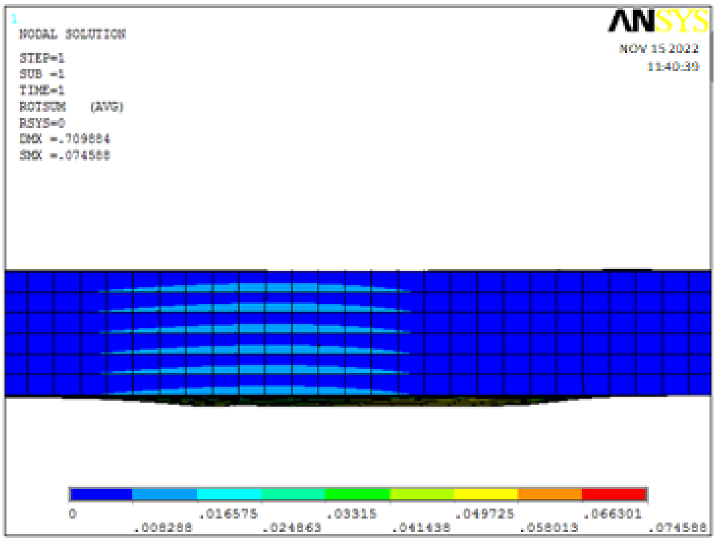

Fig 11: Layers of the composite after drilling

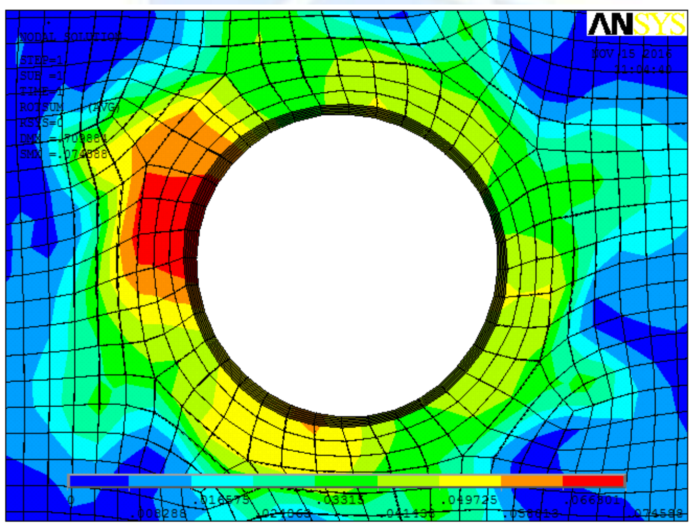

Fig12: Bottom surface of the composite after drilling

Strain in FRP composite

Fig.13 shows the graph between perimeter of the hole and strain. The maximum strain was found to be 0.709884 for drill bit with point angle 118^0. Fig. 14 shows the strain distribution of the FRP composite.

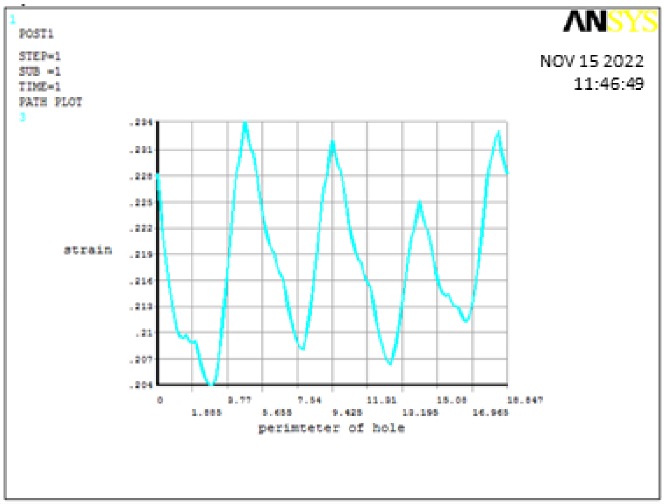

Fig 13: Perimeter of the hole v/s strain for 118^0 drill bit

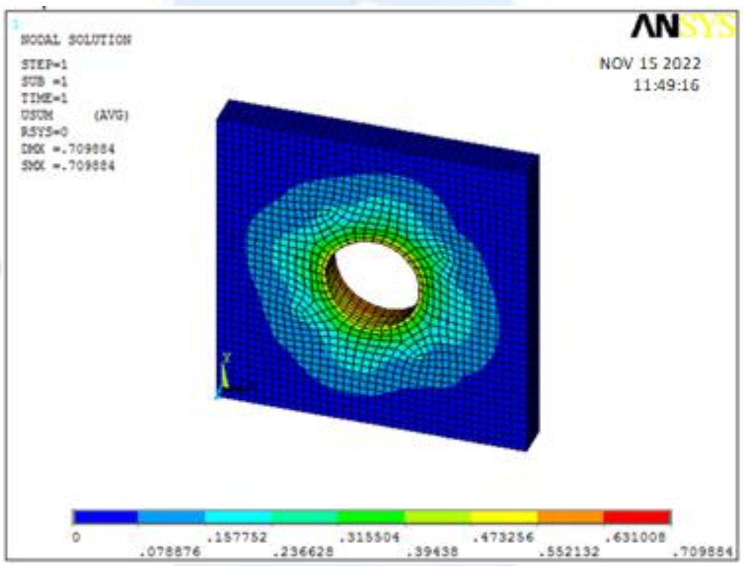

Fig 14: Strain distribution for 118^0 drill bit

Fig. 15 shows the graph between perimeter of the hole and strain. The maximum strain was found to be 0.855257 for drill bit with point angle 110^0. Fig. 16 shows the strain distribution of the composite.

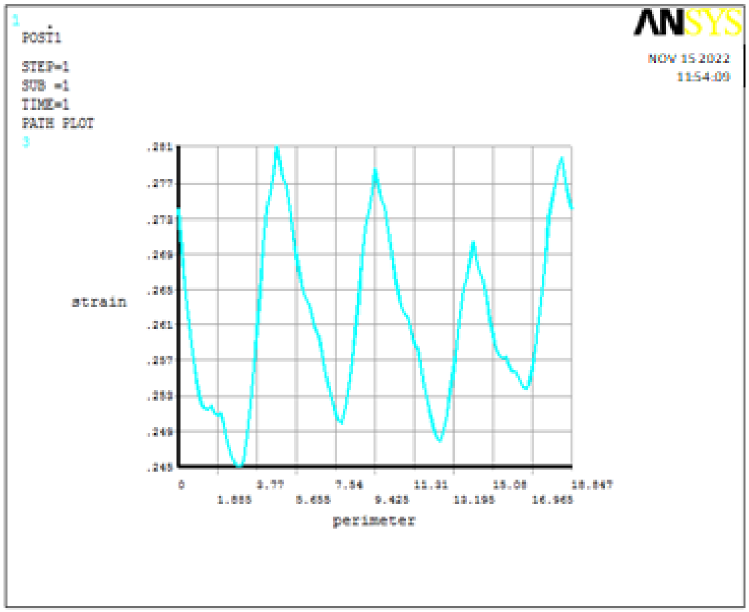

Fig15 Perimeter of the hole v/s strain for 110^0 drill bit

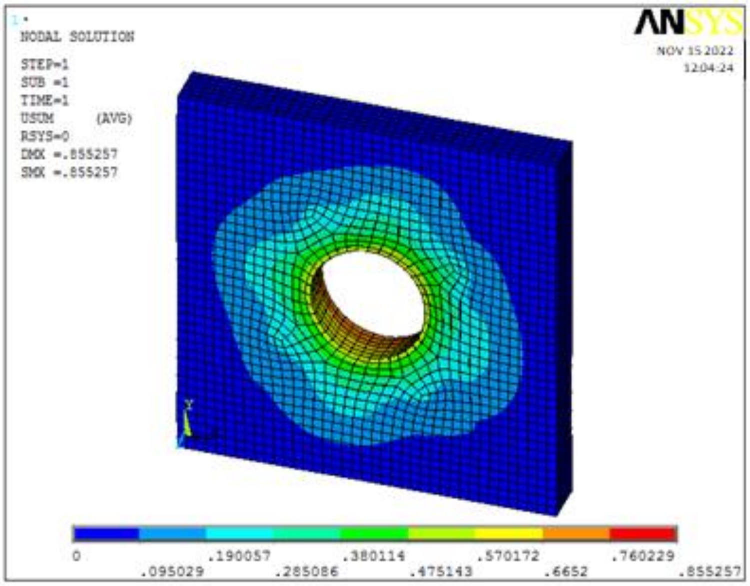

Fig 16: Strain distribution for 110^0 drill bit

Von-mises stress distribution

Fig. 17 shows the von-mises stress distribution of the composite for drill bit of 5mm with point angle 118^0. Fig. 18 shows the perimeter of the drilled hole v/s von-mises stress. The maximum stress was found to be 26009MPa.

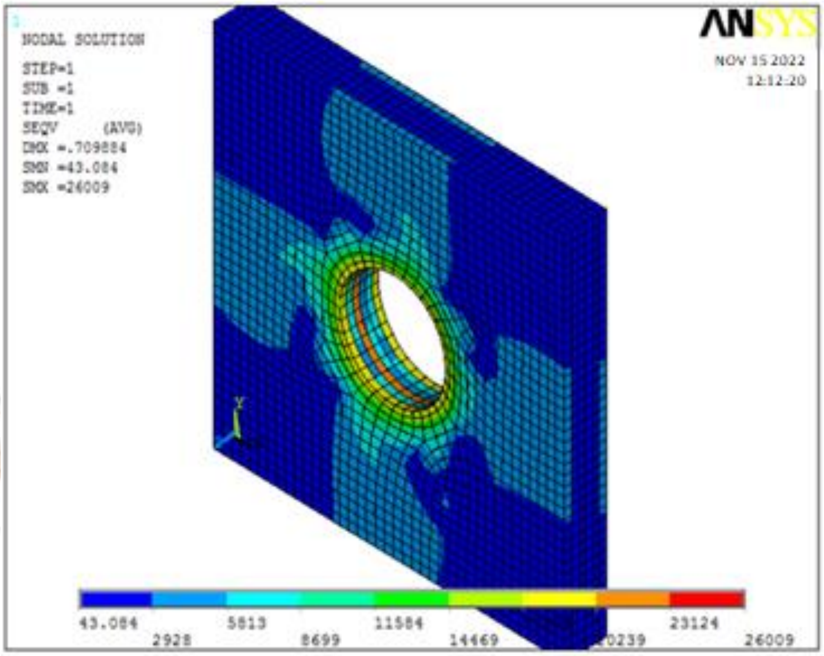

Fig5.17: Stress distribution for 118^0 drill bit

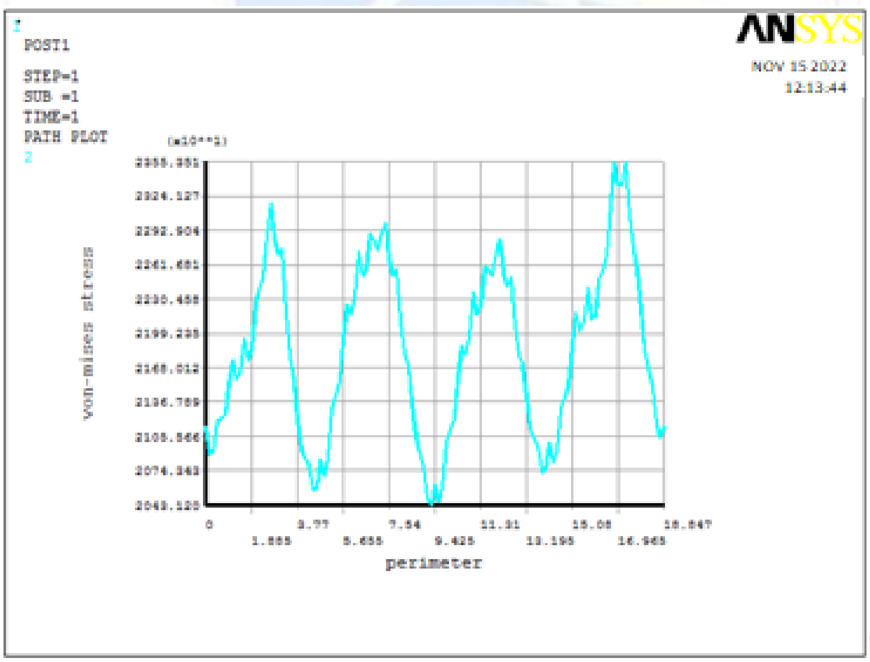

Fig 18: Perimeter of the hole v/s von-mises stress for 118^0 drill bit

Fig. 19 shows the von-mises stress distribution of the composite for drill bit of 5mm with point angle 110^0. Fig. 20 shows the perimeter of the drill hole v/s von-mises stress. The maximum stress was found to be 31211MPa.

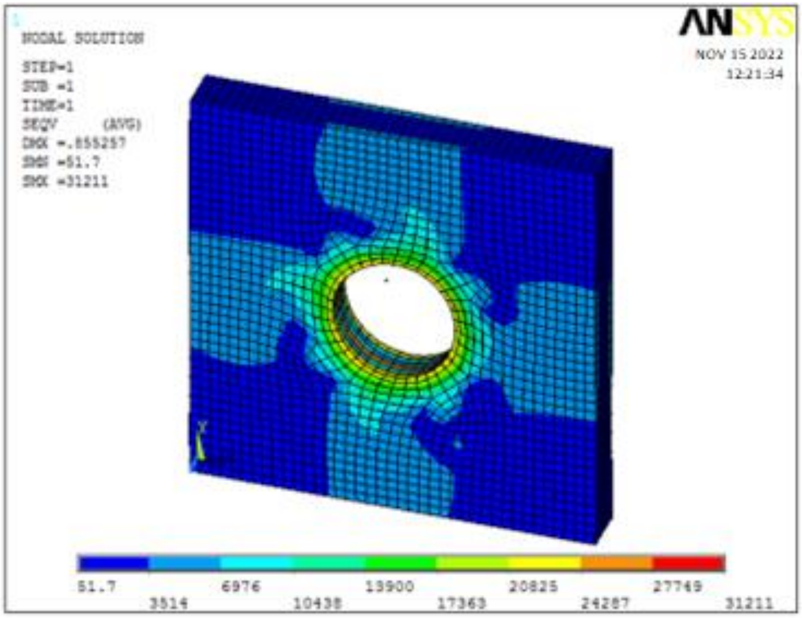

Fig 19: Stress distribution for 110^0 drill bit

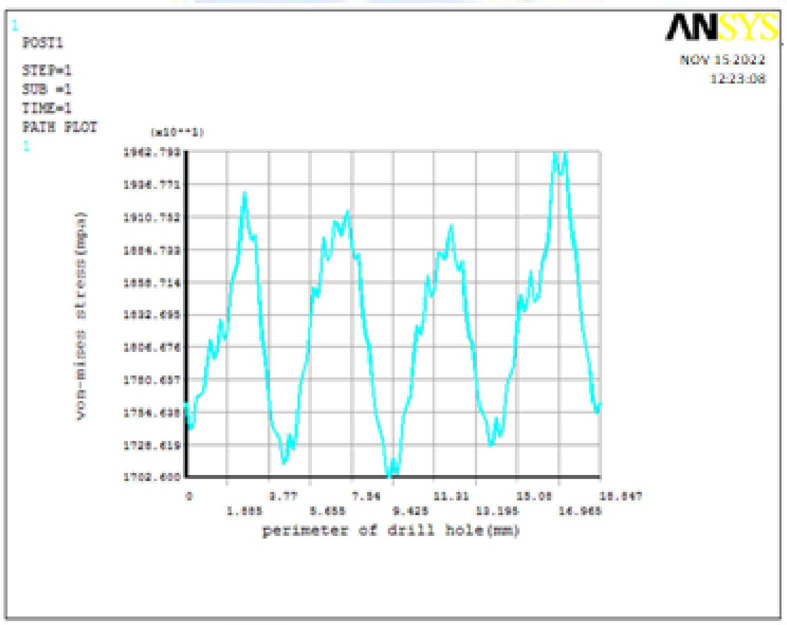

Fig 20 Perimeter of the hole v/s von-mises stress for 110^0 drill bit

Tsai-Wu failure strength index

Fig. 21 shows Tsai-Wu strength index and Table 1 shows the failure criterion values for drill bit of 5mm with point angle of 118^0. The maximum Failure strength index was found to be 0.713199.

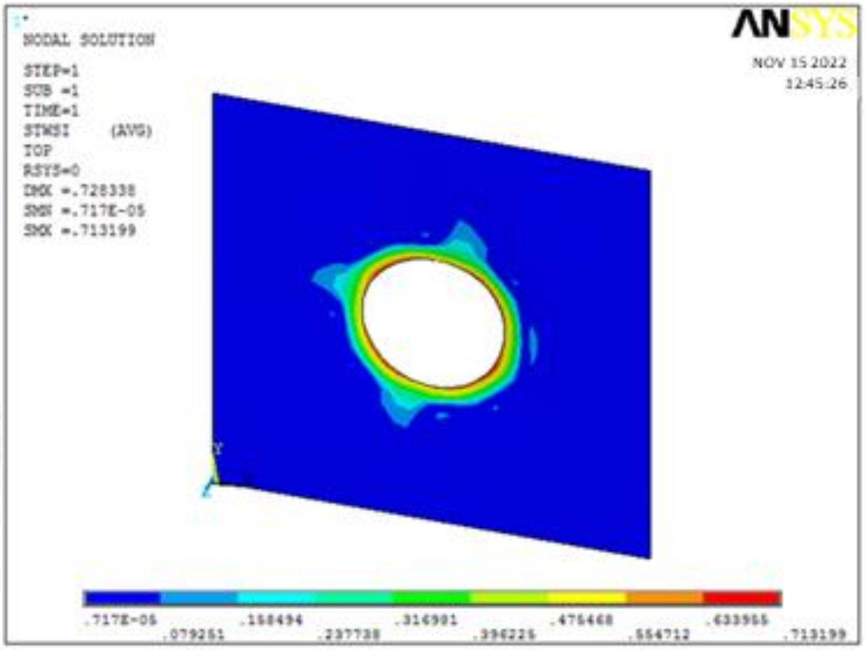

Fig. 21 Tsai-Wu strength index for drill bit of 118^0

Table 1: Failure criterion values for point angle of 118^0

	X	Y	Z
Stress in tension (MPa)	0.26e4	0.63e4	0.41e4
Stress in compression (MPa)	-0.26e4	-0.63e4	-0.41e4
Stress shear (MPa)	0.54e4	0.631e3	0.52e4
Strain(tension)	0.323	0.263	0.30
Strain (compression)	-0.323	-0.263	-0.30
Strain in shear	0.51	0.3	0.3
Stress Couplings	-1	-1	-1

Fig. 22 shows Tsai-Wu strength index and Table 2 shows the failure criterion values for drill bit of 5mm with point angle of 110^0.The maximum Failure strength index was found to be 55.179.

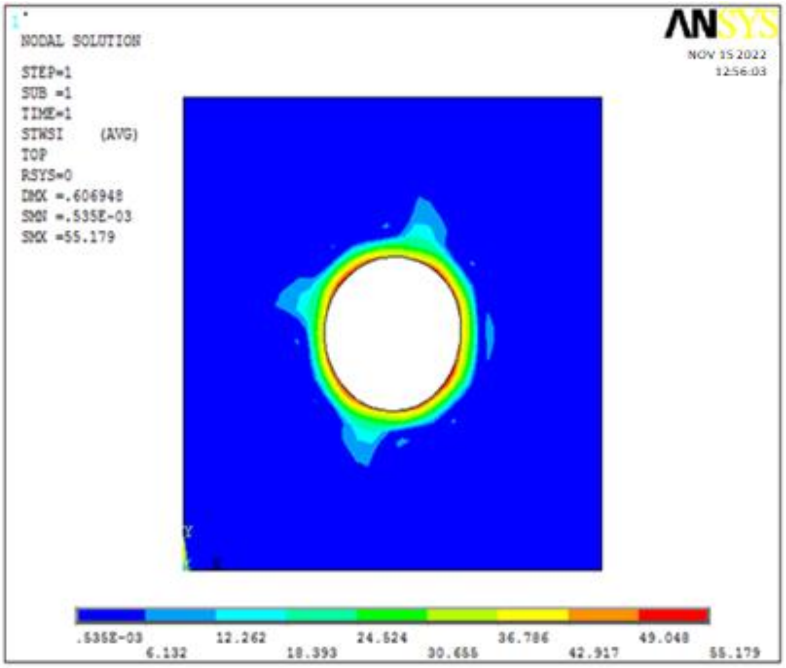

Fig. 22: Tsai-Wu strength index for drill bit of 110^0

Table 2: Failure criterion values for point angle of 110^0

	X	Y	Z
Stress in tension(MPa)	.284e5	.272e5	.320e5
Stress in compression(MPa)	-284e5	-.272e5	-.320e5
	XY	YZ	ZX
Stress shear(MPa)	0.143e5	0.631e5	0.52e4
	X	Y	Z
Strain (tension)	0.251	0.269	0.4
Strain (compression)	-0.2	-0.269	-0.4
	S_{XY}	S_{YZ}	S_{XZ}
Strain in Shear	0.51	0.00	0.30
Stress Couplings	-1	-1	-1

CONCLUSION

The overall results of Tsai-Wu strength index are given in the Table 3

Table 3: Summary of the results

Drill bit angle(^{0})	Load (N)	Pressure (GPa)	Von-mises Stress (MPa)	Strain	Tsai-Wu Failure index
118^0	706.75	25	26009	0.709	0.73199
110^0	848	30	31211	0.855	55.179

The results of FEM analysis are same as the elliptical damage of the material during drilling tests.The damage found in composite plate while drilling with drill is the lowest compared to other drills which gives a reasonable agreement with the experimental results.The digital image of the damaged areawas used to quantify the damage. As done for experimental pictures the damage area in numerical results is obtained through the image digitalization and processing using Image J 1.34, public domain software. By drawing an edge boundary of the damaged region represented by red color of elements gives A_{max}, after that drawing a circle touching the inner diametric periphery of the hole gives hole area.

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