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STUDY AND ANALYSIS OF DRILLING IN GFRP COMPOSITES USING ANSYS 14.5.

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***Abstract*- Machining process are generally used to drill, or contour composite laminates for building products. In fact, drilling is one of the most commonly used manufacturing processes to install fasteners for assembly of laminate composites. The material anisotropy resulting from fiber reinforcement heavily influences the machinability during machining. Machining of fiber reinforced plastic (FRP) components is often needed in spite of the fact that most FRP structures can be made to near-net shape and drilling is the most frequently employed secondary machining process for fiber reinforced materials. Therefore, the precise machining needs to perform to ensure a better productivity of the composite. The drilling parameters and specimen parameters are considered were speed, feed rate, drill size and specimen thickness. A series of experiments were conducted on different orientation composite laminate specimens at specified cutting parameter and material parameter using ANSYS-14.5. The obtained value of delamination of the specimen were measured and analyzed. The analysis will predict the optimum orientation of GFRP.**

***Index Terms*- Drill, GFRP Composite, Speed, Feed rate, Drill size and Specimen thickness.**

I. INTRODUCTION

Now a days, the use of composite materials has increased in various areas of science and technology due to their special properties, namely for these application in aircraft, automotive, defence and aerospace industries as well others advanced industries. Drilling is a normally accomplished machining process in modern industry owing to the need for component assembly in composite structures. Mechanical drilling is used as generally for application mainly

- To create holes
- To enlarge holes

Drilling machines were first invented and developed by Arthur James Arnot and William Blanch Brain. Development and improvements of the drilling machine and components continued, which resulted in the manufacturing of heavier arbors and high speed steel and carbide drills. These components allowed the operator to remove metal faster, and with more accuracy, than previous machines. Variations of drilling machines were also developed to perform special drilling operations. During this era, computerized machines have been developed to alleviate errors and provide better quality in the finished product. The drilling machine has revolutionized industrial work of every kind and made so such a lot of complex tasks seem easy. Different tools and methods are used for drilling depending on the type of material, the size of the hole, the number of holes, and the time to complete the operation. Drilling is a cutting process in which a hole is originated or enlarged by means of a multipoint, fluted, end cutting tool. As the drill is rotated and advanced into the workpiece, material is removed in the form of chips that move along the fluted shank of the drill.

Composite materials are used more and more for primary structures in commercial, industrial, aerospace, marine, and recreational structures. Composites materials consist of a fibrous reinforcements bonded together with a matrix material, Occur naturally in your bones, in wood, horns etc. Allow the stiffness and strength of the material to change with direction of loading. Polymer Matrix Composites combine a resin system and reinforcing fibres, the properties of the resulting composite material will combine something of the properties of the resin on its own with that of the fibres on their own.

Overall, the properties of the composite are determined by:

- The properties of the fibre
- The properties of the resin
- The ratio of fibre to resin in the composite (Fibre Volume Fraction)

The geometry and orientation of the fibres in the composite

II. FIBER MATERIAL

S-Glass is generally used for polymer matrix composites that require improved mechanical properties compared to E-glass based composites. This is often the case when the material is operated under more extreme conditions.

III. COMPOSITION

S-Glass has a typical nominal composition of SiO_2 65wt%, Al_2O_3 25wt%, MgO 10wt%. Some other materials may also be present at impurity levels.

Table 4.1: Comparison of typical properties for some common fibres.

Materials	Density (g/cm^3)	Tensile Strength (MPa)	Young modulus (GPa)
E-Glass	2.55	2000	80
S-Glass	2.49	4750	89
Alumina	3.28	1950	297
Carbon	2.00	2900	525
Kevlar 29	1.44	2860	64
Kevlar 49	1.44	3750	136

Table 4.2: Component properties of S-glass fiber and epoxy matrix

	E (GPa)	V	G (GPa)
S-glass fiber	86	0.22	35
Epoxy matrix	4.5	0.4	1.6

IV. MATRIX MATERIAL

EPOXY RESIN

One of the most advantageous properties of epoxies is their low shrinkage during cure which minimizes fabric 'print-through' and internal stresses. The epoxy molecule also contains two ring groups at its centre which are able to absorb both mechanical and thermal stresses better than linear groups and therefore give the epoxy resin very good stiffness, toughness and heat resistant properties.

GLASS FIBER REINFORCED EPOXY RESIN

The ratio of the fibre to resin derives largely from the manufacturing process used to combine resin with fibre, as will be described in the section on manufacturing processes. In general, since the mechanical properties of fibres are much higher than those of resins, the higher the fibre volume fraction the higher will be the mechanical properties of the resultant composite. Typically, with a common hand lay-up process as widely used in the boat-building industry, Fibre Volume Fraction is approximately 50-60%. With the higher quality, more sophisticated and precise processes used in the aerospace industry, Fibre Volume Fractions approaching 70% can be successfully obtained. The material choosen for analysis the matrix composite dimension are 3 mm with 4 plies of even thickness.

Table 4.3: Linear coefficients for the fiber volume fraction of glass/epoxy ($V_f = 0.7$).

Material	kE_1	kE_2	$k\gamma_{12}$	kG_{12}
Glass/epoxy	0.066	0.14	−0.034	0.14

Composite variables in such composites are assumed to have a constant ratio and the matrices are considered relatively weaker than the fibers. The strength of the fiber in any one of the three axes would, therefore be one-third the unidirectional fiber composite, assuming that the volume percentage is equal in all three axes.

DRILL BIT

It's important to match the material of the bit to the material being drilled to produce the best results.

V. TYPES OF DRILL BIT MATERIAL TO ANALYSIS

METAL

The most common type used

1. HSS drill
   - Low cost

HSS COMPOSITION :

1.20 -1.40% carbon; 0.50% Manganese; 1.00% maximum Silicon; 3.5 to 4.5% Chromium; 2.25-2.75% Vanadium; 5.60- 6.40% Tungsten; 5.60- 6.40% Molybdenum; 5.0 to 7.0% Cobalt.

INPUT:

Material	HSS
Point angle	118^0
Size	6mm
Helix angle	33^0
Chisel edge angle	129^0

WORKPIECE:

Modelling of composite sheet with layers upto 4 layers of lamina. Workpiece of dimension 14*12 cm with thickness of 5 mm was modelled in ansys 14.5 by using workbench in number and density of 300 gsm.

The input of drilling parameter is given to the material of GFRP for different orientations is given.

The HSS constant spindle speed, feed rate & drill diameter is given for analysis.

Spindle speed	300 rpm
Feed	0.01mm/rev
Drill dia	12mm

MESH:

Constructing the finite element workpiece model the solid elements were used to mesh the workpiece with uniform mesh density all over the work piece. They had a disadvantage of increasing the computational time.

BOUNDARY CONDITIONS:

According to drilling machine setup the boundary conditions was applied to material. The base in longitudinal direction was fixed in the experimental setup after the point load & twisting torque was applied in axial direction.

COMPOSITE LAMINATES:

Workpiece has 4 layers of GFRP. Appropriate model was constructed for modelling of different layer to make composite lamina. The work piece is manufactured for the orientation of $\{0^0/90^0/0^0/90^0\}$

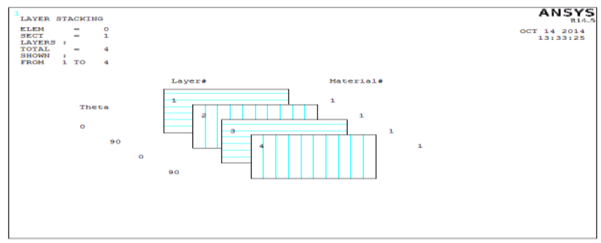

Fig 6.1: Laminates arrangement

MESHING:

Meshing is the process of discretization of material for applying and even distribution of loads.

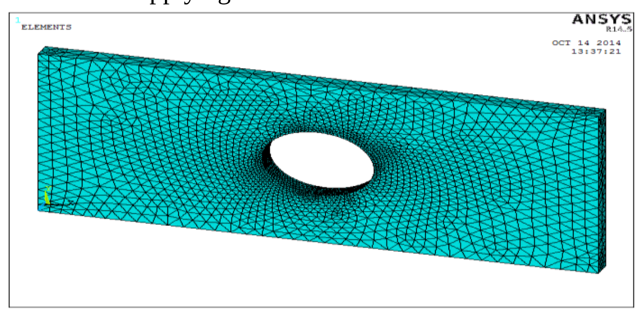

Fig 6.2: Meshing of composite model

SOLUTION:

We had given the point load and twisting torque to the material by defining structural load condition.

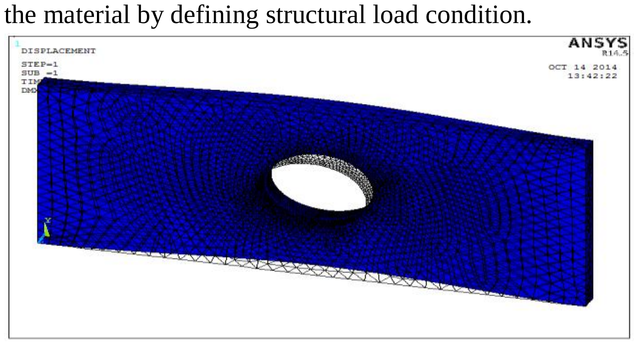

Fig 6.3: Point, twisting loads applied to the composite

LOADS CALCULATED IN X DIRECTION:

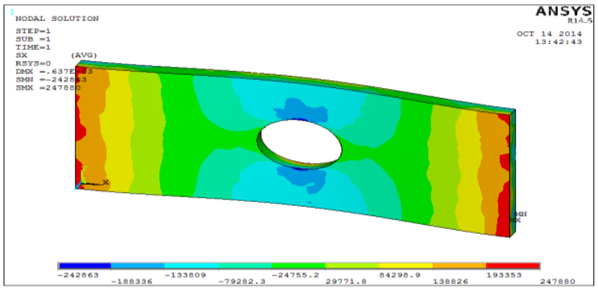

Fig 6.4: Tensile load in x direction

LOADS IN Y DIRECTION:

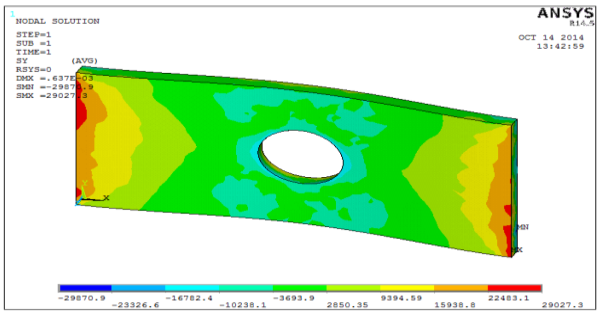

Fig 6.5: Compressive load in y direction

SHEAR STRESS

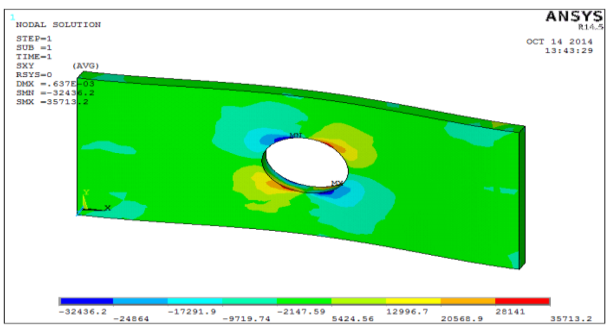

Fig 6.6: Shear loads acting during drilling.

The Tsai-Wu criterion is applied to composite shells. The Tsai-Wu failure criterion is a phenomenological failure theory which is widely used for anisotropic composite materials which have different strengths in tension and compression.

$F = F_1 \times S_{XX} + F_2 \times S_{YY} + F_3 \times S_{ZZ} + F_{11} \times S^2_{XX} + F_{22} \times S^2_{YY} + F_{33} \times S^2_{ZZ} + F_{12} \times S_{XX} \times S_{YY} + F13 \times S_{XX} \times S_{ZZ} + F_{23} \times S_{YY} \times S_{ZZ} + F_{44} \times S^2_{YZ} + F_{55} \times S^2_{XZ} + F_{66} \times S^2_{XY}$

The Failure values for the orientations calculated and the results are:

F(1) = 6.18
F(2) = 6.168
F(3) = 6.312
F(4) = 6.42

VI. DELAMINATION

Delamination is defined as "the separation of the layers of material in a laminate. Delamination can occur at any time in the life of a laminate for various reasons and has various effects. Various defects are caused by drilling, delamination is recognized as the most critical.

Delamination factor is defined by ratio of maximum diameter(of damaged zone around hole) to actual diameter.

Delamination Factor = D_{max}/D_{actual}

Where

D_{max} is damaged diameter around the hole
D_{actual} real diameter to be drilled

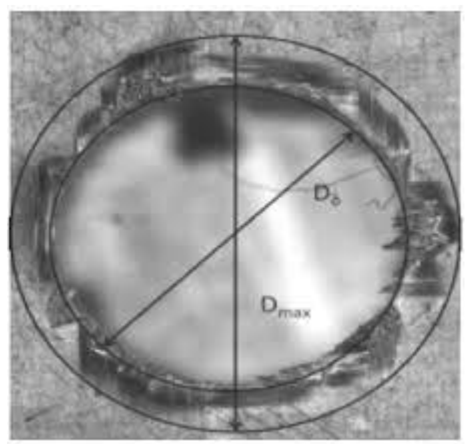

Fig 5.1: Delamination

DELAMINATION FOR ORIENTATION

ORIENTATION	**DELAMINATION (D_{MAX}/D)**
$(0^0/90^0/0^0/90^0)$	1.03
$(90^0/0^0/90^0/0^0)$	1.028
$(0^0/45^0/0^0/45^0)$	1.052
$(45^0/0^0/45^0/0^0)$	1.07

VII. CONCLUSION

The simulations were conducted for constant spindle speed (300 rpm), feed rate(0.01) & drill size (6mm) on the FRP for different orientations. The pressure force applied to the composite materials with combination of orientation. These experiments were conducted by using ANSYS 14.5, the delamination factor for have been calculated and got the optimized orientation.

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