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Investigation of Drilling of Glass Fiber Reinforced Composite

Dr. K. Senthil Kumar
Professor, Nehru College of Engineering and Research Centre, Kerala, India
Abilash K. J.
Student, Nehru College of Engineering and Research Centre, Kerala, India

Abstract:
Delamination is one of the most critical failure modes that occur during drilling of composites. The work was to analysis the influence of delamination during drilling by varying different factors affecting the hole quality and to find out the optimum drilling factor. The co relational analysis has been carried out using ANSYS software. The optimum values have been determined by taking account of the relationship between von misses stress, equivalent stress. The finite element analysis has been done by using Ansys 16.0 software which helped to find out the optimum values of drilling.

Keywords: *GFRP composite, Drilling, Delamination, Finite Element Analysis*

1. Introduction

Composite materials now a days have wide range of applications which are replacing metals with its wide range of properties. In the section of science and technology, it has been increased in application as they are being used to replace conventional materials which included in aerospace, aircraft, automobile, etc. As the application has been increased drilling of composite was become an immersive task which causes the delamination and internal breakage of laminates. As the defects occur during drilling are high, an optimum value has been needed to minimize the failure.

As the process carries forward the analysis for the delamination is an important factor in the case of optimization of parameters. With the multiple values, a multilevel optimization is an essential criterion. In taking this in accounts the finite element analysis technique is adopted with taking the cutting speed, feed rate and diameter, which are the main influence parameter in the quality of drilled hole. In FE the relationship between the von misses stress and the stress distribution on the composite plate during drilling has been taken in account.

2. Objectives

In this paper, importance's of glass fiber drilling is analyzed. Machining, mainly drilling cannot be avoided for the assembly with these materials. SO the main aim of the work was to reduce the delamination rate that is developed during drilling by finding out the optimum rate.

The objectives of the work are:

- Optimizing the various performance characteristic values that are developed such as thrust force, tangential force, torque
- Analysis the von misses stress, equivalent stress and to develop a co relation between these values to conduct an FEM analysis for the visualization of the material stress distribution.

3. Material Specification

The material used in this analysis was composite laminate which are made from cross ply glass fiber. The reinforcement was in the form of E-glass fiber tape and the matrix was epoxy resin L-12, with hardener k-15. The specimen plates were cut into piece of dimension 10 cm x 5 cm which are having a thickness of 4 mm. The fiber volume fraction is 0.56-0.60 and specimen having density valued 157-160 Kg/m^3.

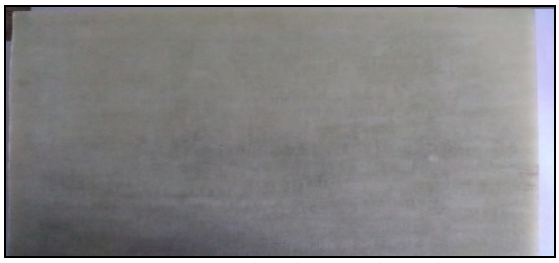

Figure 1: Final Fabricated Product

4. Experimental Setup

The key factor in the development of this work was the fabrication of the material as per the specification. Later wards the drilling is carried out with the specified feed rate and spindle speed. The dependently controllable factors that develop are the thrust forces and torque was identified using a dynamometer. The experiment has been conducted by Drilling of glass fiber reinforced by using a CNC drilling machine with HSS twist drill of 5mm and 8 mm diameter. Dynamometer which is linked with a multi channel charge amplifier and a data acquisition system was used for the validating the values that are obtained during drilling. A Profile projector has been used for observing the damage area around the hole and for checking the diameter of delaminated area.

Figure 2: CNC Vertical Drilling Machine

Figure 3: Dynamometer attached with work piece on the CNC drilling machine

In this research work, different parameters such as diameter, feed rate and spindle speed on the output responses has been studied. The following levels of input parameters were selected:

a) Three levels of feed rate b) Three levels of speed
c) Two different diameters of drill bit.

EXP NO	Ø 5mm	Ø 8mm	Feed (mm/min)	Speed (rpm)
1	5	8	20	1000
2	5	8	40	1000
3	5	8	60	1000
4	5	8	20	1500
5	5	8	40	1500
6	5	8	60	1500
7	5	8	20	2000
8	5	8	40	2000
9	5	8	60	2000

Table 1: Selection of Orthogonal Array
Ø-Diameter, mm- millimeter, rpm-rotation per minute, min-minute

5. Results and Discussion

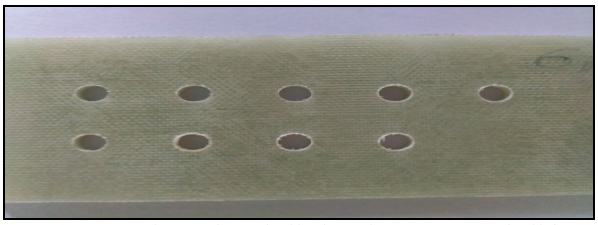

Figure 4: Glass fiber drilled with 5mm HSS drill bit

Exp No	Torque	Tangential Force	Thrust force
1	174.5	01.17	17.87
2	60.14	03.27	15.45
3	28.72	05.99	15.88
4	58.93	2.15	11.85
5	41.45	6.77	08.81
6	46.82	2.93	22.06
7	58.52	4.44	03.73
8	38.76	01.62	29.62
9	23.9	3.63	23.6

Table 2: Measured Output Responses When Drilling Using 5mm Diameter HSS Drill Bit

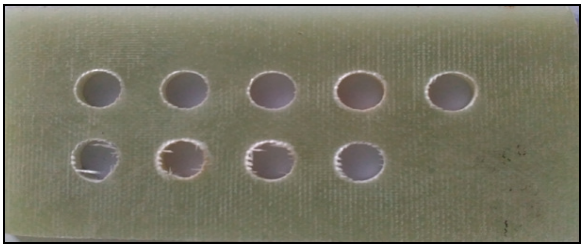

Figure 5: Glass fiber drilled with 8mm HSS drill bit

EXP No	Torque	Tangential Force	Thrust Force
1	168.1	2.33	54.81
2	31.82	4.35	43.15
3	24.02	3.05	44.1
4	44.01	5.24	64.26
5	19.56	22.93	35.37
6	33.39	6.531	40.35
7	31.82	7.27	27.01
8	31.82	6.82	43.32
9	23.7	6.51	40.77

Table 3: Measured Output Responses When Drilling Using 8mm Diameter HSS Drill Bit

The above shown figures (fig: 4 & fig 5) is the final output of the drilled material with 5mm diameter HSS drill bit. The table: 2 and table 3 is narrated with the output values which have been obtained during drilling, which is calculated with the aid of a dynamometer. From the table it has been observed that when the speed and feed rate values changes the output parameters are also changing.

6. Analysis

The FEA analysis is carried out with the aid of ANSYS software. FEA works by breaking down a real object into a large number (thousands to hundreds of thousands) of finite elements, such as little cubes. Mathematical equations help predict the behavior of each element. A computer then adds up all the individual behaviors to predict the behavior of the actual object. So for the FE analysis the modeling of composite plate work piece of dimension 10cm x 5cm with thickness of 4 mm was modeled in Ansys 16. With having density of 157-160 Kg/m3, Poisson's Ratio as 0.3 and modulus of elasticity as 75 GPa

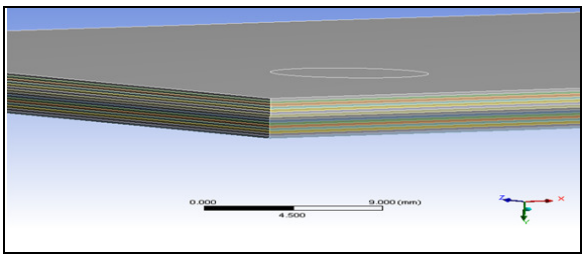

Figure 6: Model of work piece with the dimension

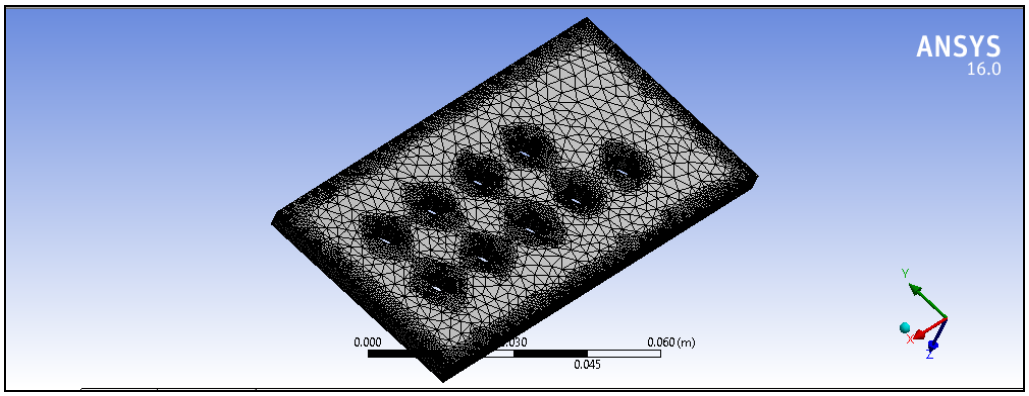

Figure 7: Model of work piece after drilling with 5mm diameter HSS drill bit with meshing

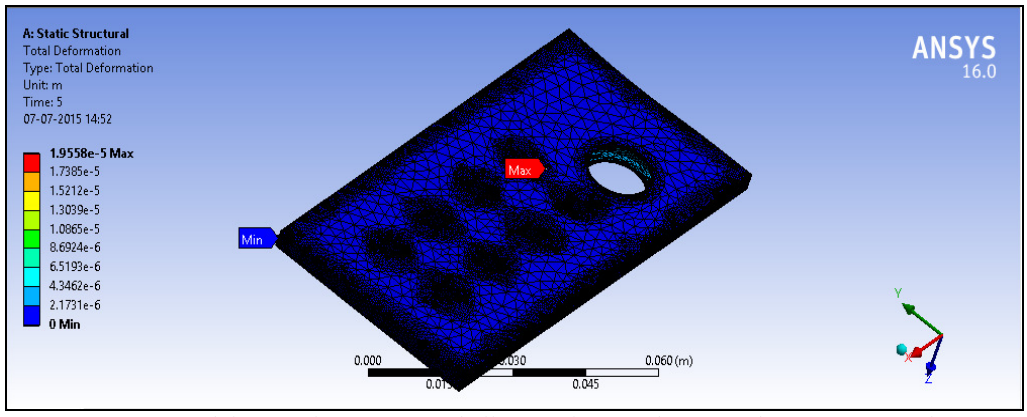

Figure 8: Model of work piece after drilling with 5mm diameter deformation analysis

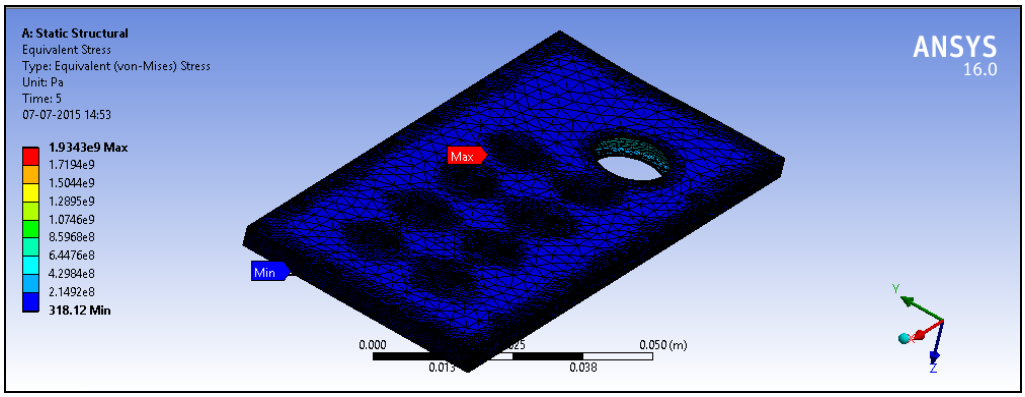

Figure 9: Model of work piece after drilling with 5mm diameter with equivalent stress

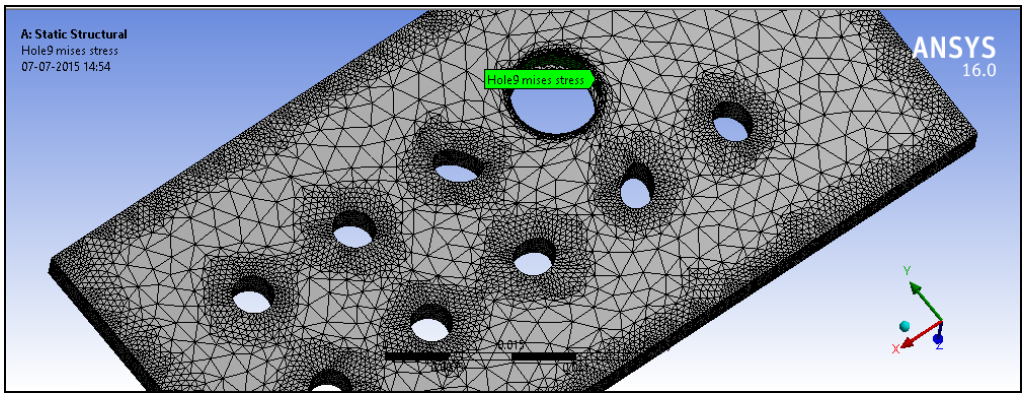

Figure 10: Model of work piece after drilling with 5mm diameter with static structural

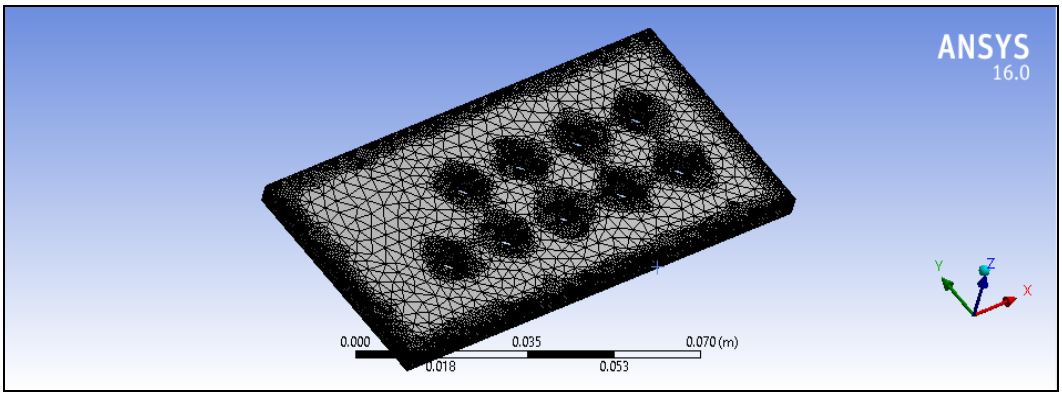

Figure 11: Model of work piece after drilling with 8mm diameter HSS drill bit with meshing

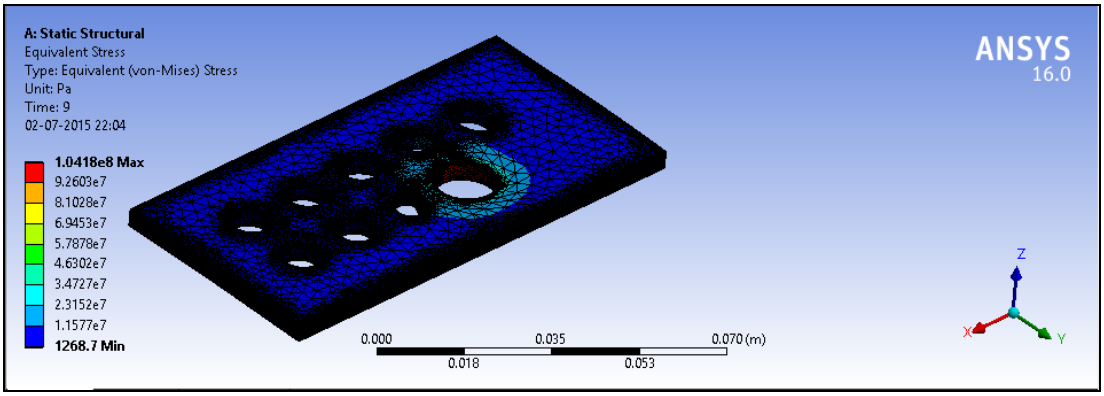

Figure 12: Model of work piece after drilling with 8mm diameter with equivalent stress

Step no	Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8	Hole 9
1	1.14E+09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	5.65E+07	6.77E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	4.79E+06	2.96E+07	3.22E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	2.29E+06	1.29E+07	6.04E+07	6.56E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	5.62E+05	2.63E+06	8.68E+06	3.99E+07	4.62E+08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	4.39E+07	2.27E+07	5.70E+06	2.39E+06	1.35E+06	5.20E+08	0.00E+00	0.00E+00	0.00E+00
7	2.32E+07	5.76E+07	2.64E+07	5.46E+06	2.21E+06	5.91E+07	6.53E+08	0.00E+00	0.00E+00
8	2.81E+06	1.79E+07	3.68E+07	1.68E+07	3.20E+06	8.62E+06	3.92E+07	4.32E+08	0.00E+00
9	8.20E+05	2.02E+06	1.07E+07	2.14E+07	1.03E+07	1.52E+06	5.26E+06	2.41E+07	2.68E+08

Table 4: Distribution of Von misses stress during drilling of 5mm diameter HSS drill bit

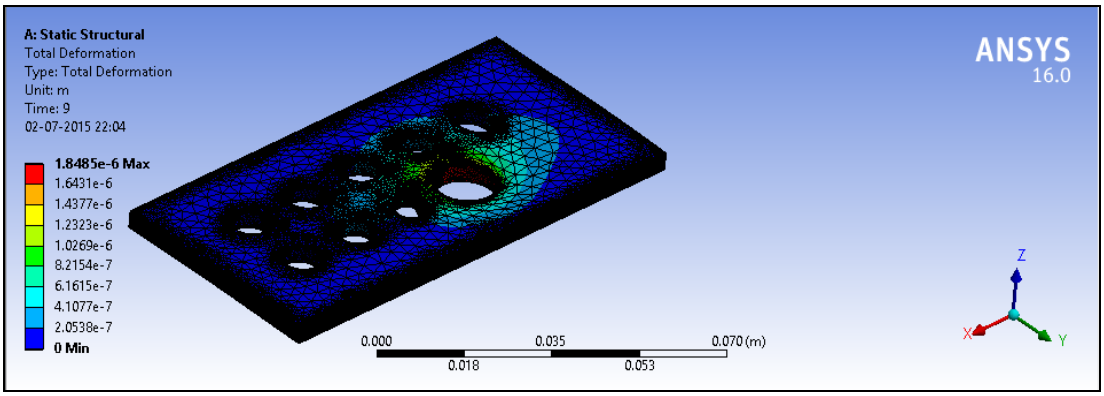

Figure 13: Model of work piece after drilling with 8mm diameter deformation analysis

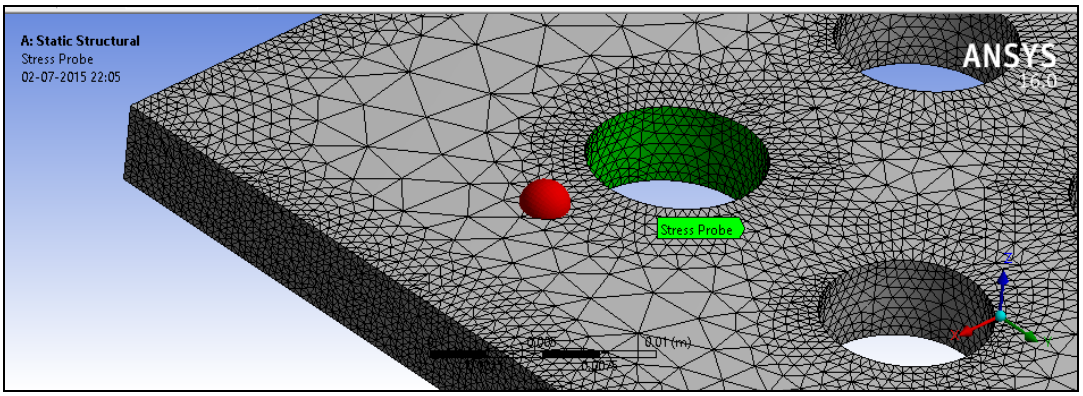

Figure 14: Model of work piece after drilling with 8 mm diameter with stress probe

Step no	Hole 1	Hole 2	Hole 3	Hole 4	Hole 5	Hole 6	Hole 7	Hole 8	Hole 9
1	**4.72E+08**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
2	**7.29E+07**	**2.61E+08**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
3	**8.54E+06**	**3.86E+07**	**1.25E+08**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4	**5.26E+06**	**1.99E+07**	**8.05E+07**	**2.56E+08**	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
5	**1.19E+06**	**3.45E+06**	**1.19E+07**	**5.08E+07**	**1.80E+08**	0.00E+00	0.00E+00	0.00E+00	0.00E+00
6	**5.53E+07**	**3.38E+07**	**7.10E+06**	**3.76E+06**	**2.01E+06**	**2.05E+08**	0.00E+00	0.00E+00	0.00E+00
7	**3.48E+07**	**7.33E+07**	**4.17E+07**	**8.02E+06**	**4.31E+06**	**8.28E+07**	**2.54E+08**	0.00E+00	0.00E+00
8	**4.07E+06**	**2.74E+07**	**4.88E+07**	**2.65E+07**	**5.19E+06**	**1.36E+07**	**5.41E+07**	**1.68E+08**	0.00E+00
9	**1.62E+06**	**2.58E+06**	**1.62E+07**	**2.82E+07**	**1.42E+07**	**2.24E+06**	**7.81E+06**	**3.30E+07**	**1.04E+08**

Table: 5 Distribution of Von misses stress during drilling of 8mm diameter HSS drill bit.

The above shown figures imply the analysis of glass fiber when continuous drilling process is carried out. So in this case there will be stress transfer and the impact of the nearby hole drilling will transfer stress and this will cause the damages. The von misses stress analysis is carried out with relation of each drilled holes. During continues drilling there will be stress transfer and this stress transfer will cause the internal breakage of the layer which will end up with the failure. When higher the feed rate is used the intensity of stress

is higher which cause much more stress and the layer breakage will occur. The case with higher the speed and feed rate will implies more thrust force and torque which cause the transformation high. So from this relation with higher the speed and lower the feed case the transfer is more over same and less delamination and the chance for internal breakage of layer is less. The stress transfer impact has been tabulated and it has been shown in table for the 5mm and 8 mm drill bit. In the table during doing first step only first hole will have stress and during second step of drilling second hole there will be an impact of stress of the second hole to the first and likewise while drilling each hole the stress transfer is tabulated with the help of fem software.

7. Conclusion

The objective of this work was to analysis the rate delamination generated when drilling an glass fiber reinforced composite material using a CNC drilling machine. The experiment was successful carried out and co relation has been obtained. The finite element simulations were carried out on a glass fiber sheet after making holes to study the effect of cutting forces and torque values.

The experiment has been performed by twist drills of various diameters of HSS on glass fiber composite under varying parameters according to the design of experiments. The critical analysis of results shows that with variations of different parameters, thrust force, tangential force and torque values changes. It has been calculated that when speed is varied the thrust forces and torque values is not much effected. From the results it was concluded that thrust force, torque and tangential force varies throughout the

work piece during machining and when cutting forces and torque values are high then delamination factor is also more. The correlation analysis gave the dependence in the output and input parameter.

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