

# Study of Composite Glass Laminate Reinforced with Carbon Fiber at Cutout Locations

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**Abstract** The present work deals with the finite element analysis of effect of cutout of different shapes in laminates and influence of fiber orientation on the strength of the woven Glass/Epoxy - Carbon/Epoxy hybrid composite laminate. Investigations have been carried out on laminated composites with and without cut-outs of different shapes and also for different fiber orientation. Simulation of tensile tests was carried out in system using Abaqus software. From analysis, it was noticed that straight-ply oriented composite laminates possess the maximum strength as compared to other types of fiber orientations. Also it is noticed that the maximum load carrying capacity increases with introduction of carbon fiber insert and it decreases with the introduction of cut-out.

**Keywords** Abaqus, Hybrid composites, Tensile properties

## 1. Introduction

A composite can be defined as a macroscopic combination of two or more structural materials which are insoluble with each other and having different physical and chemical properties. The composite material is manufactured and preferred for many reasons, some being for their strength, light weight, inexpensiveness, etc when compared to traditional materials. Hybrid composites are the fiber reinforced composites made by combining more than two different types of fiber.

Numerous studies have been made experimentally and analytically on hybrid composites. Gergely Czél, Meisam Jalalvand and Michael R. Wisnom [1] proposed elimination of stress concentrations in tensile and compressive testing of unidirectional carbon and epoxy composites. R. Murugan, R. Ramesh and K. Padmanabhan [2] investigated static and dynamic mechanical properties of carbon/epoxy-glass/epoxy hybrid laminates. K Anand Babu and Dr MD Abid Ali [3] focused his study on the finite element analysis of Glass/Epoxy composite laminate. Aditya Kumar Akshay Agrawal, Ranjan Ghadai and Kanak Kalita [4] conducted his research work in Ansys APDL for the analysis of stress concentration in isotropic and orthotropic laminates. K.Krishnamoorthy and T.Sasikumar [5] carried out his research in predicting the deformation of glass epoxy

composite laminates in Ansys and compared it with the experimental values obtained from UTM.

From the literature review, it can be noted that study has been focused on pure laminates and interlayer hybrid laminates. But study on reinforcement at the cut-out locations has not considered. So, the present research deals with the local reinforcements of carbon fibre at the cut out locations and on the orientation of fibre directions on the strength of the material.

## 2. FEA Analysis

The modelling of the composite tensile test specimens was done in Abaqus CAE software. The models considered for analysis were pure Glass-Epoxy and hybrid Glass-Carbon laminates with orientations of zero degree, ninety degree and forty five degree to the loading directions.

The following are the steps to be followed to model the specimen in Abaqus.

- Create the part with required dimensions
- Create the material and feed in the mechanical properties of the material
- Create composite lay-up
- Mesh the part
- Apply boundary conditions and analyse the part

### 2.1. Tensile Specimen Dimensions

The tensile specimens were modelled according to the ASTM D 3039/ D 3039M standards. The dimensions are given in the table 1 below.

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**Table 1. Specimen Dimensions**

Fibre Orientation	Width (mm)	Overall Length (mm)	Tab Length (mm)
0° UD	15	250	56
90° UD	25	175	25
45° UD	15	250	56

**2.2. Material Properties**

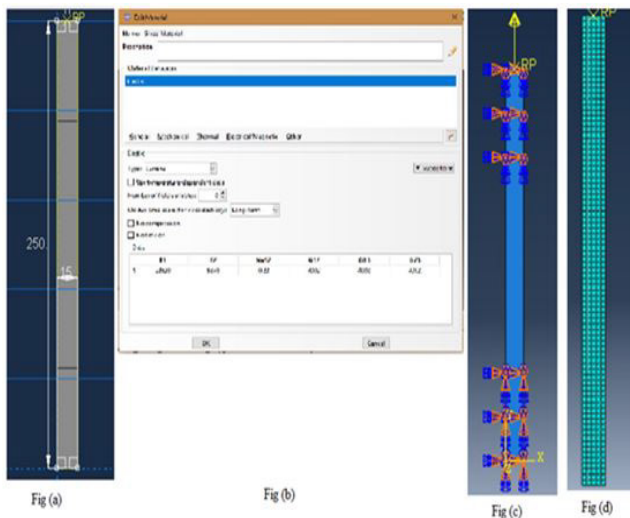
The material properties of pure glass laminate and glass carbon hybrid laminate are given in the below table 2.

**Table 2. Material properties**

Fibre Orientation	E <sub>1</sub> (GPa)	E <sub>2</sub> (GPa)	γ <sub>12</sub>	G <sub>12</sub> (GPa)	G <sub>13</sub> (GPa)	G <sub>23</sub> (GPa)
0° Glass	23.62	9.87	0.23	4.0	4.0	4.0
90° Glass	20.83	8.16	0.23	3.31	3.31	3.31
45° Glass	24.08	10.22	0.23	4.14	4.14	4.14
0° Glass Carbon	24.90	13.49	0.23	5.47	5.47	5.47
90° Glass Carbon	23.41	12.11	0.23	4.91	4.91	4.91
45° Glass Carbon	24.23	12.78	0.23	5.18	5.18	5.18

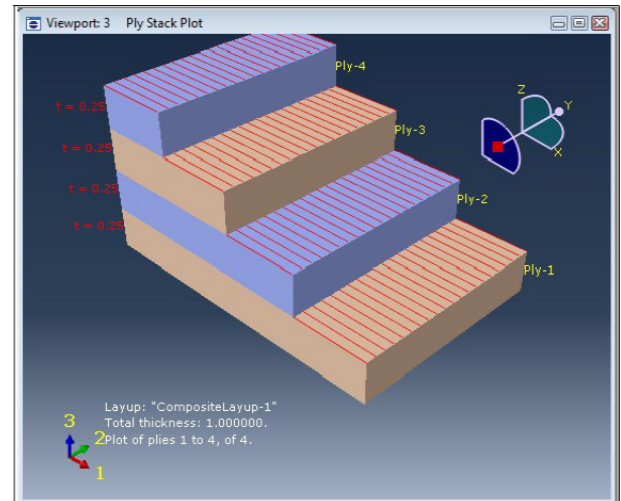
**2.3. Modelling in Abaqus CAE**

Figure 1(a) shows the part of zero degree tensile specimen. Figure 1(b) shows adding of the material properties of the zero degree tensile specimens. Figure 1(c) shows the tensile specimen after adding the boundary conditions. Figure 1(d) shows the tensile specimen after meshing.



**Figure 1.** (a) Creating the part (b) Creating the material (c) Applying boundary conditions (d) Meshing the part

Figure 2 shows the composite layup. It refers to the orientation of the fibres to the loading direction. In figure 2, the composite layup is shown for zero degree tensile specimens. Similarly, ninety degree and forty five degree specimens can be simulated.



**Figure 2.** Composite layup

Boundary condition that is applied to the specimens is fixed at one end and at the other end the part was loaded with the ultimate load the specimen can withstand. The peak loads for various specimens are given in the table 3.

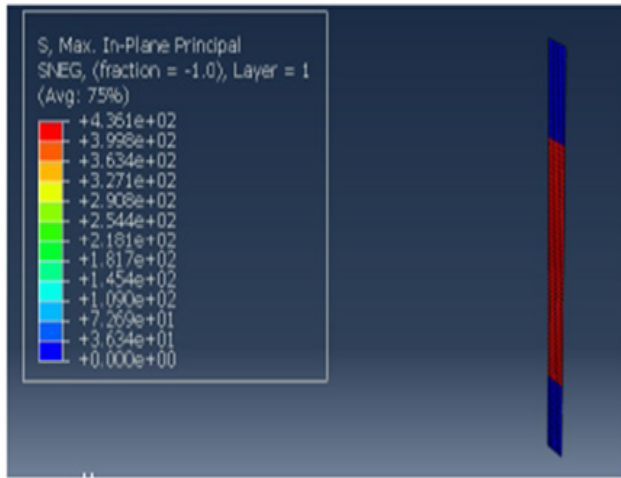
**Table 3.** Peak Load of various specimens

Specimen	Type	Peak Load (N)
0° Only glass	Without Hole	6384.4
	Round Hole	2667.5
	Square Hole	2510.6
	Rhombus Shaped Hole	2039.9
90° Only Glass	Without Hole	7620
	Round Hole	3128.4
	Square Hole	2966.45
	Rhombus Shaped Hole	2334.1
45° Only Glass	Without Hole	411.9
	Round Hole	313.8
	Square Hole	304.02
	Rhombus Shaped Hole	294.2
0° Glass Carbon	Without Hole	485.45
	Round Hole	372.67
	Square Hole	362.86
	Rhombus Shaped Hole	353.05
90° Glass Carbon	Without Hole	343.2
	Round Hole	256.9
	Square Hole	244.81
	Rhombus Shaped Hole	232.4
45° Glass Carbon	Without Hole	407.34
	Round Hole	304
	Square Hole	294.21
	Rhombus Shaped Hole	286.8

**3. Results**

The maximum in-plane principal stresses were obtained

from Abaqus for different specimens. Figure 3 shows the maximum in-plane principal stress for zero degree only glass specimen.



**Figure 3.** Maximum in-plane principal stress for 0° only glass specimen

Similarly maximum in-plane principal stresses for ninety degree and forty five degree specimens were obtained. The summary of the tensile testing in Abaqus is shown in table 4.

**Table 4.** Summary of test results

Specimen	Type	Peak Load (N)	UTS (N/mm <sup>2</sup> )
0° only glass	Without hole	6384.4	436.1
	Round hole	2667.5	308
	Square hole	2510.6	278.9
	Rhombus hole	2039.9	284.5
0° Glass carbon	Without hole	7620	520
	Round hole	3128.4	360
	Square hole	2966.45	329.6
	Rhombus hole	2334.1	325.9
90° Glass	Without hole	411.9	17.59
	Round hole	313.8	18.89
	Square hole	304.02	17.81
	Rhombus hole	294.2	20.14
90° Glass carbon	Without hole	485.45	20.58
	Round hole	372.67	22.68
	Square hole	362.86	21.26
	Rhombus hole	353.05	24.18
45° Glass	Without hole	343.2	25.39
	Round hole	256.9	27.03
	Square hole	244.81	27.2
	Rhombus hole	232.4	31.43
45° Glass Carbon	Without hole	407.34	31
	Round hole	304	32.76
	Square hole	294.21	32.69
	Rhombus hole	286.8	38.77

## 4. Conclusions

The UTS obtained from the Abaqus is compared in the below table 5 for various tensile specimens.

**Table 5.** UTS for zero degree specimens

Specimens	UTS Without hole (N/mm <sup>2</sup> )	UTS Round hole (N/mm <sup>2</sup> )	UTS Square hole (N/mm <sup>2</sup> )	UTS Rhombus shaped hole N/mm <sup>2</sup>
0° Glass	436.1	308	278.9	284.5
0° Glass Carbon	520	360	329.6	325.9

- Only glass laminate has UTS of 436.1 N/mm<sup>2</sup> while carbon insert glass laminate has UTS of 520 N/mm<sup>2</sup> which is 19% higher.
- Only glass laminate with round hole of 6mm dia has UTS of 308 N/mm<sup>2</sup> while carbon inserted glass laminate has UTS of 360 N/mm<sup>2</sup> which is 17% higher.
- Only glass laminate with square hole of 6mm at the centre has UTS of 278.9 N/mm<sup>2</sup> while hybrid laminate has UTS of 329.6 N/mm<sup>2</sup> which is 18% higher.
- Only glass laminate with rhombus shaped hole has UTS of 284.5 N/m<sup>2</sup> while hybrid glass carbon laminate has UTS of 325.9 N/mm<sup>2</sup> which is again 18% higher.

Similar comparison can be made for ninety degree and forty five degree specimens which shows an average of 18% increase in UTS with the carbon fibre insert at the cut-out locations.

So, it can be concluded that local reinforcement of carbon fibre at the cut-out locations can be made which increases the strength of the laminate significantly while the weight of the laminate remains same.

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