Investigation the Flexural Characteristics of GFRP Composite Laminate with Artificial Delamination

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Abstract

Three-point bending load, the flexural performance of Glass/Epoxy laminate specimens has been successfully measured often with artificial flaws of various geometric patterns and three separate sizes placed at different places. The present work is aims to determine the optimum ply angle and to study the behavior of composite material under various loading condition likely to be flexural performance both experimental and analytical using Ansys. Film defects were created on the laminated at obituary location. Laminates are prepared using GFRP material and three point bending test was performed to study the results.

Keywords

Delamination, polytetrafluoroethylene (PTFE), Glass/Epoxy, Plies and hand Lay-up

1. Introduction

On the basis of recent investigations, an outline of composite materials is provided, together with information on their categorization, classification, and key advantages related to their mechanical and physical properties. The traditional methods of making composites and their applications were discussed there. The urgent necessity to develop new generations of composites that should include synthetic or natural materials by employing new effective manufacturing procedures was brought to light (Rajak, 2019). These orientations produce a number of more complex failure modes that are aimed at forming the GFRP composite laminate's most advantageous stacking sequence under axial loading conditions. In order to better understand and forecast the behavior of GFRP Composite laminates with varied unidirectional fiber orientations under plane stress circumstances, the investigations used MATLAB and simulation methods (ANSYS) to analyze stress, strain, and deformation values (Sadaq, 2022). Hybrid composite laminates damage behavior is investigation using flexural test. Specimens are created in the shape of a sandwich, with carbon/epoxy plies serving as the infill panels and aramid /epoxy layer acting as the core. The great energy absorption characteristics of aramid /epoxy composites are anticipated to be utilized by such a design. By applying low-velocity impact at various energies, we pre-damage homogeneous composites. The remaining flexural strength for the affected specimens is then assessed using three-point bending tests (Wagih, 2020). To assess their influence on the first critical buckling and re-buckling loads, researchers should look into the impact of multiple delaminations on the compressive, tensile, and flexural strength of E-glass/epoxy composites (Aslan , 2016). The bioactivity of the fibrous materials that are readily available around the world, their classification systems, and the fabrication methods used to conjure up the composite materials ought to be explored in order to determine the optimized distinguishing feature of the content for the intended application. Effectiveness of composite materials is primarily dependent on their individual materials and production technologies. To identify the most effective soluble fiber composite material for practical uses, an overview of a wide range of fibers, their properties, functionality, classification, and different fiber composite manufacturing procedures is offered. Fibers composite materials are a viable alternative to single metals or alloys due to their remarkable performance in the many domains of application (Rajak D.K, 2019). Numerous studies have been done on how the stacking order and hybridization affect the flexural characteristics and impact wear mechanism. In an effort to compare the findings on conventional composite laminates, the behaviors were also examined to ascertain the impact of the stacking sequence and the hybridization. Three-point arrangement bending tests were performed, and an observation was used to determine the failure mechanism. To analyze the contribute to impaired by analyzing the exterior and internal damages progression, impact trials were performed at various penetrating and rate of consumption (Papa, 2019). In order to execute optimum processes that minimize faults and produce appropriate consciousness, robust composite material that seems to be effective for the intended applicability, it is necessary to comprehend and research various types of composite fabrication methods. Since a few decades, several traditional manufacturing processes have been used to create composite materials. Newly developed computerized composite manufacturing processes include robot support for process, resulting results in fully automated and a significant increase in productivity (Dickson, 2018). Using a hand lay-up process and altering fiber percentages, an E-glass fiber reinforced polymer composite was created (15 percent, 30 percent, 45 percent, and 60 percent by weight percentage). Investigations were conducted into how the percentage of glass fiber affected the mechanical qualities such as tensile strength, bending strength, and impact strength. Using a Brinell hardness tester, the hardness of composite materials was assessed. The results revealed that adding more glass fibers significantly improved the mechanical properties of the composite that was created. As a function of fibre weight percent, tensile strength ranges from 28.25 MPa to 78.83 MPa, flexural strength ranges from 44.65 MPa to 119.23 MPa, and impact energy at ambient temperature ranges from 3.50 Joules to 6.50 Joules (El-Wazery, 2017). It was examined to see if the placement of specified local flaws, throughout this case, polytetrafluorethylene (PTFE), in the transverse tensile of FRPs, affected the losses in mechanical characteristics, impact and flexural, strengths. During infusing, PTFE was positioned in several levels of reinforcement fabric to accomplish this goal. The mechanical performance of the manufactured FRPs was then tested and assessed. According to the experiment, the maximum mechanical property loss occurred when PTFE was applied to FRPs in the centre of the thickness direction (Ashir, 2019). This review paper also intends to discuss new developments in hybrid nano-composites made of epoxy-based polymers and their uses. With high stability of outstanding mechanical toughness, heat resistance, barrier properties, chemical characteristic impedance, relatively low thermal correlations, and dissipation factor with negligible shrinking stress, hybridized epoxies excessive demands and excellent diversity as actually needed in the fields of electrical applications, automobiles, and space exploration industries (Saba, 2017). The purpose of this research is to characterize the damage done to fiber glass laminates subjected to low velocity, high mass impact and flexural. Finite element models are created with ANSYS. These models are able to predict approximate stress and strains induced in the laminates during the impact and also flexural test (Sadaq, 2015). The goal of the current effort is to explore pressure vessels (PV) composed of composite materials. The PV is constructed for the study using glass fiber with a 90° fiber angle, and hydrostatic testing is done. Later, the same PV is modeled in Ansys and examined with different fiber angles to ascertain the failure by taking into account the PV's deformation, stress, and strain using GFRP, CFRP, and hybrid composites. Finally, the results are validated (Sadaq, 2021).

2. Methodology, Fabrication and Testing of Laminate

The basic pattern of 7 Mil E-glass cloth as shown in Figure 1. Due to its favorable strength-to-weight ratio, it was used in the current project. Table 1 displays the mechanical characteristics of E-glass fiber/epoxy resin. The fiber is affordable and available in a variety of forms. Since it is knitted in two ways that are approximately parallel, the fabric has a bilateral tensile and flexural modulus. This material might as well be worn for hand lay-up molding.

Table 1. Mechanical Properties of E-Glass fiber / Epoxy

Material	**Density (g/cc)**	**Tensile Strength (MPa)**	**Youngs Modulus (MPa)**
E-Glass fiber	2.550	1750e3	70e3
Epoxy Resin	1.300	125e3	4.0e3

Figure 1. Woven Glass fiber fabric

2.1 Laminate Preparation

A compressive fitted die mold hand layup procedure was used to produce the laminates. The steps for creating laminates made of glass and epoxy are as follows. Figure 2 illustrates the delineations and cutting of fiber cloth.

Figure 2. Cutting of woven fiber cloth

2.2 Stacking of Laminates

As indicated in Figure 3, the resin-hardener mixture was carefully poured on top of each layer of glass fiber after each layer had been carefully placed on the mould. A roller was used to remove any air bubbles and ensure that the fibers were properly soaked in resin, resulting in the best possible adhesion with surrounding layers. The laminate had a thickness of 2.1mm and was composed of 12 plies. As shown in Figure 4, the PTFE film was placed during hand layup into the specimen's centre on the contact plane of two locations to serve as an artificial defect that would cause delamination. In two places, the PTFE film was placed between the specimen's first and second layers (red in Figure 4), as well as its fifth and sixth layers (yellow in Figure 4). Polytetrafluoroethylene (PTFE) films are available in a range of shapes, including squares with sides of 6, 8, and 10 mm and circular films with diameters of 6, 8, and 10 mm. 80 microns thick is how thick the PTFE sheet is. Figure 5 displays the various specimen kinds following machining.

Figure 3. Stacking of layers

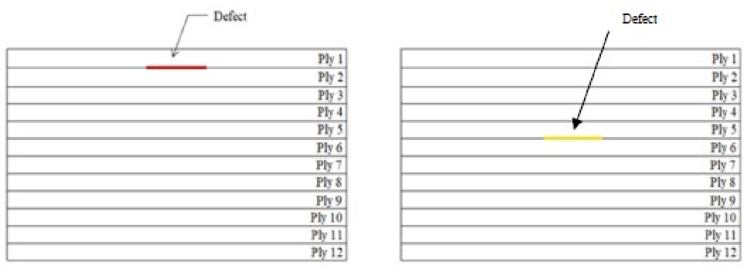

Figure 4. Position of artificial defects in laminates

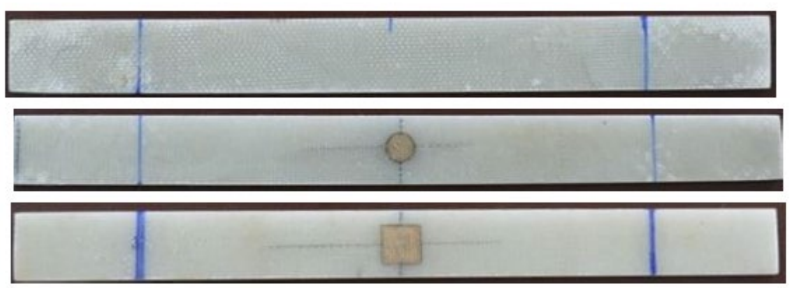

Figure 5. Specimens after machining with and without defects

2.3 Testing of specimen / procedure

The testing process is described below.

- A micrometer was used to measure the test piece's length, width, and thickness.
- The test piece was placed on the rollers of the bending fixture, which is shown in Figure 6.
- The machine was activated, and the readings were recorded by the computer.
- The specimen after testing is shown in Figure 7, and it was deflected until the outer surface ruptured.

Figure 6. Three point bending fixture

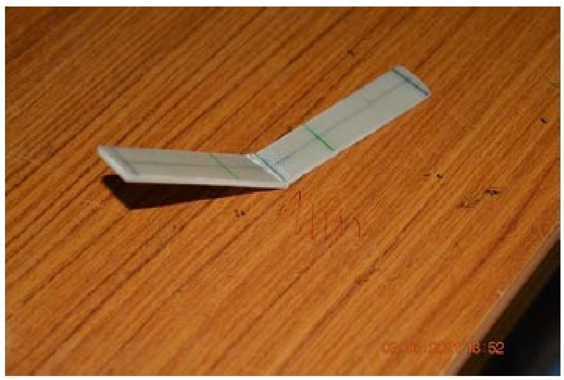

Figure 7. Specimen after testing

2.4 Finite Element Analysis of GFRP Laminate:

Select structure and the h-method from among the several model generation options available here. The preprocessor's element types SHELL and linearlayer99 will now be selected. A structural shell model can be applied in layers using SHELL99. A maximum of 250 layers are permitted by SHELL99. If more than 250 layers are required, a user-input constitutive matrix is available, and it provide actual constants for the preprocessor for the material number, layer count, fiber orientations, and layer thickness. Geometry and meshed model is shown in Figure 8. Its analysis performed is shown in Figure 9.

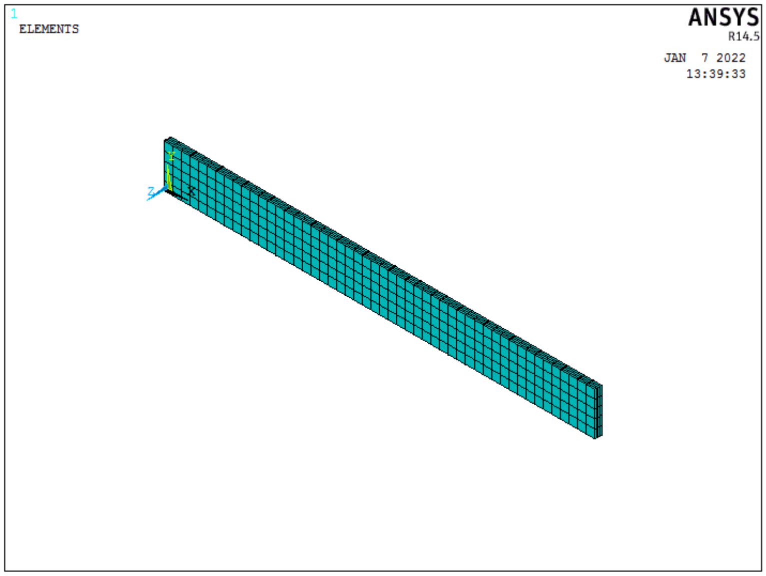

Figure 8. Isometric view of GFRP laminates under uniaxial tensile load

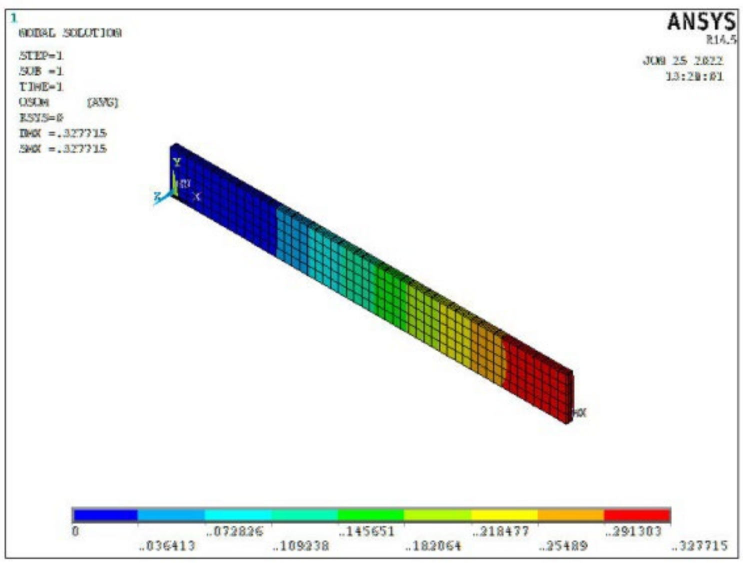

Figure 9. Analysis of composite laminate

3. Results And Discussion

The testing machine software produced graphs of load-deflection curves. From this test, the maximum flexural load and deflection were determined. The maximum stress and strain in each specimen's outermost layer are computed and noted using these values and dimensions. For each specimen, the slopes of the load-deflection curves were determined from the graphs' linear regions, as shown in Figures 10 to 13. Tha maximum load is reached up to 300N. in all cases Finally, for the various shapes, sizes, and places of delamination, the flexural strength were determined and are shown in Figures 14 and 15. Comparison results between experimentation and numerical (Ansys) results are shown in Figures 16 and 17.

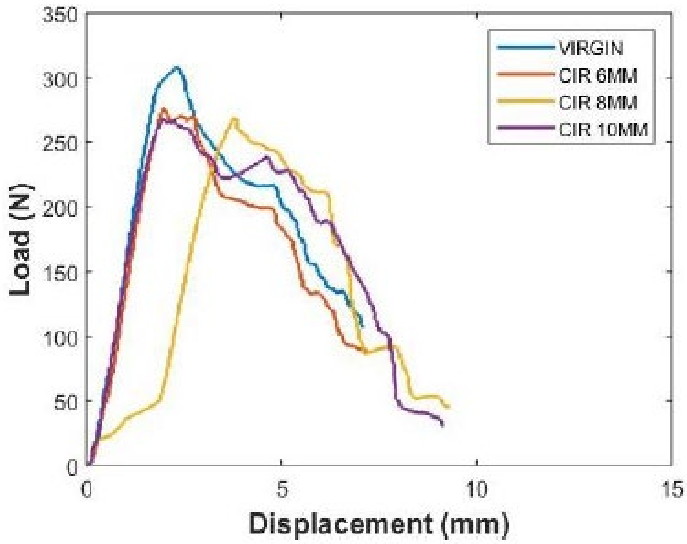

Figure 10. Load Displacement curve of circular defect at 1-2 layers

From the above Figure 10, maximum load reached is about 300N when there are no defects and the corresponding load decreases due to addition of artificial defects minimum load is attained at circular hole of 8mm diameter for the position 1-2.

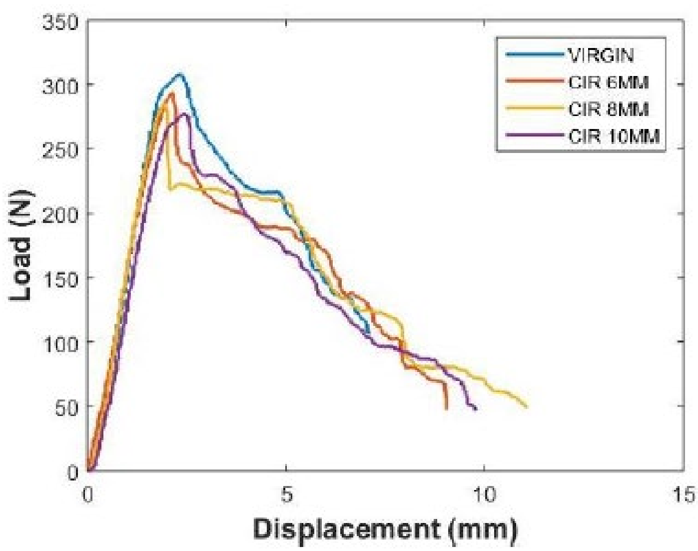

Figure 11. Load Displacement curve of circular defect 5-6 layer

From the Figure 11, maximum load reached is about 315N when there are no defects and the corresponding load decreases due to addition of artificial defects minimum load is attained at circular hole of 10mm diameter for the position 5-6. From the Figure 12, maximum load reached is about 321N when there are no defects and the corresponding load decreases due to addition of artificial defects minimum load is attained at square hole of 10mm*10mm for the position 1-2. From the Figure 13, maximum load reached is about 317N when there are no defects and the corresponding load decreases due to addition of artificial defects minimum load is attained at square hole of 10mm*10mm for the position 5-6. Minimum load was attained by the square hole of same dimensions at various locations.

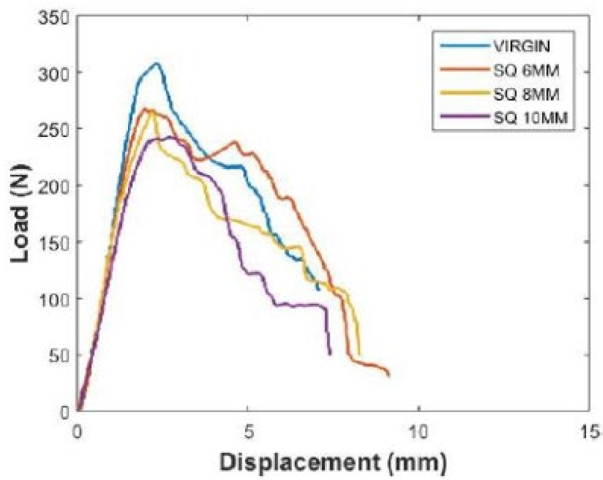

Figure 12. Load Displacement curve of square defects at 1-2 layer

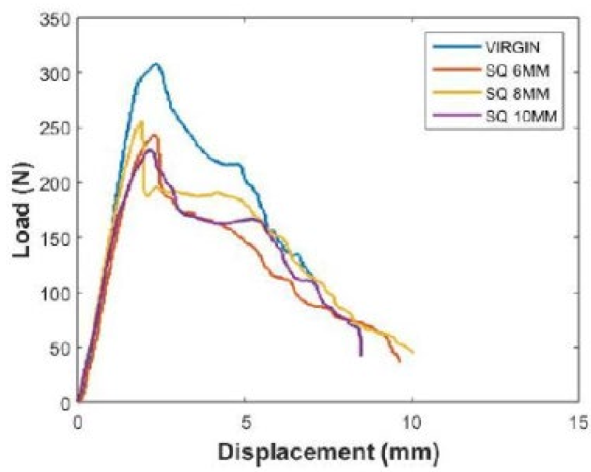

Figure 13. Load Displacement curve of square defects at 5-6 layers

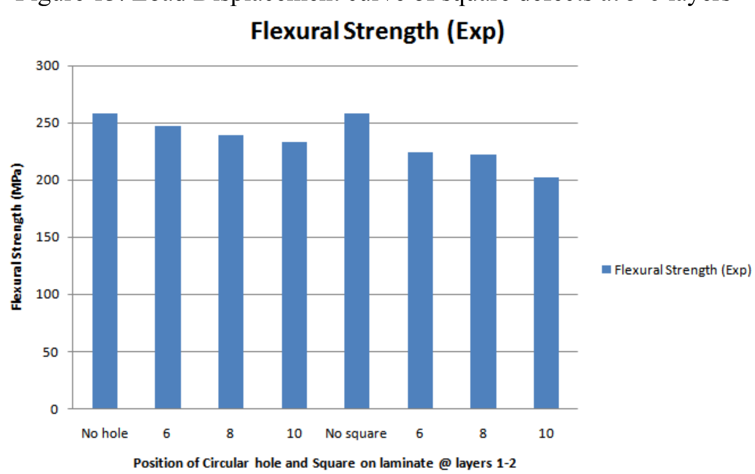

Figure 14. Flexural strength of the laminate before and after artificial defects @ layers 1-2

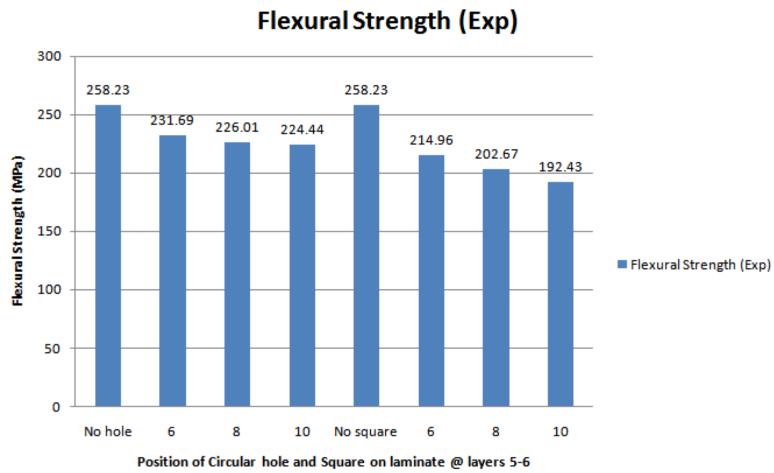

Figure 15. Flexural strength of the laminate before and after artificial defects @ layers 5-6

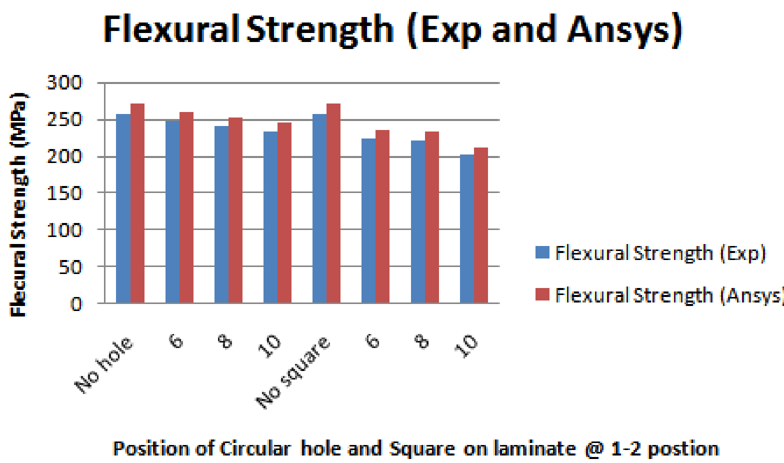

Figure 16. Flexural strength of the laminate before and after artificial defects @ layers 1-2 by exp. and Ansys

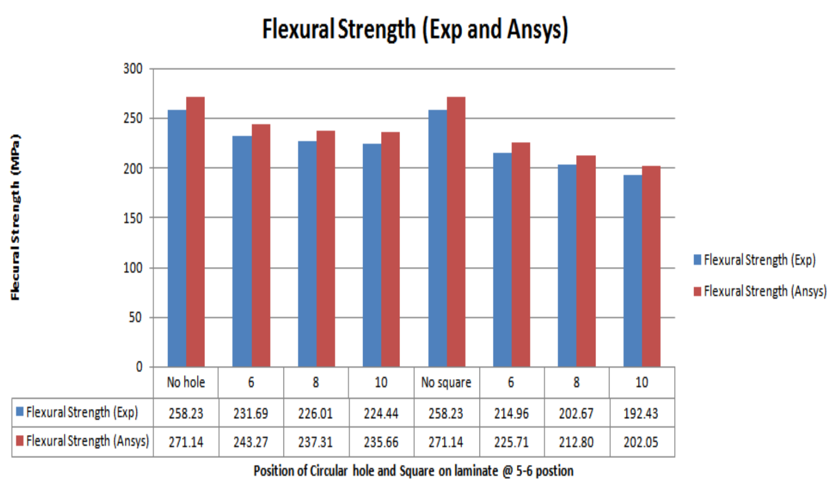

Figure 17. Flexural strength of the laminate before and after artificial defects @ layers 5-6 by exp. and Ansys

4. Conclusions

The following observations were reached after a thorough analysis of the flexural behavior under three-point bending for the Glass/Epoxy laminate samples with and without artificial defects of different geometric shapes (circle and square) and with three different sizes (6mm, 8mm, 10mm) placed at different locations:

- For both the samples with and without defects, a linear behavior up to a peak was seen in the load deflection graph, followed by a nonlinear trend.
- When compared to a no defects specimen, a specimen with a square defect of one side 10 mm at layer 5 or 6 showed a maximum drop in flexural modulus of 42.5 percent.
- When the flaw is moved from the layers 1-2 to the layers 5-6, a fall in modulus of 5-8 percent is seen.
- When a member is subjected to flexural loading, the shape and location of delamination are crucial, and their existence should be taken into account at the design stage.
- The average percentage variation between experimentation and numerical (Ansys) is found to be 5% in the conditions of defects arrangement over the laminate.

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