Mechanical Characterization of Carbon Fabric Reinforced Polymer Composites

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Abstract
Fibre reinforced polymer matrix composites are widely used in many aerospace structural applications because of their superior specific properties when compared to conventional metallic materials. Because of these properties, they are replacing metals in many engineering applications. In the present study explores the mechanical properties of carbon fabric reinforced polymer composites. The composite laminates were fabricated using hand layup method. The laminated composite is tested by using non-destructive techniques (NDT) to identify the defects. The mechanical properties of composites like Inter Laminar Shear Strength (ILSS), Flexural Strength & Tensile strength.

Keywords: Carbon Fabric**,** defect, ILSS, Flexural strength, Tensile strength

Introduction

Composite material is a combination of two different materials which has strength to weight ratio and possess high strength and lighter in weight. Composite materials are used in industries like aerospace, automobile, marine applications etc. Mechanical properties are exhibiting more in composite materials. Cylindrical shell structures are used to store a large quantity of fluids and solids. Cylindrical thin shells are subjected to loading in three types of forces: axial compression, circumferential (lateral) compression and shear. In this paper we are discussing the different diameter of thin composite cylindrical shells with varying thickness and also additives are added. The failure behaviour of the GFRP specimen pipes of different diameters and thickness are subjected to lateral compression loading with and without additives is discussed.

Y. Pratap reddy et al [1] investigated the numerical buckling analysis of the composite cylindrical shell under compressive loading with and without holes on the lateral surface of the cylinder. They predicted the buckling factor, deformation and interlaminar shear stresses of the specimens. L. Gangadhar and T. Sunil Kumar [2] has done numerical analysis of buckling of GFRP composite cylindrical shell with and without cutouts under compression loading. They determined the compressive stress, buckling load and lateral strain of the specimens with and without cutouts using ANSYS. Tafreshi, A [3] has studied on delaminated GFRP composite cylindrical shells under combined axial compression and bending. They observed the instability analysis of the delaminated layer of the composite cylindrical specimen. R S Priyadarsini et al [4] investigated the numerical and experimental study of buckling of composite cylinders under axial compression. They evaluated the buckling behaviour of the thin cylindrical shell and compared with numerical analysis. Eyvazian Arameh et al [5] has studied experimentally the corrugated metal composite tubes under axial compression loading. They observed the crushing behaviour of the metal composite tube. Kiyoshi Kemmochi [6] has exact solutions for stress and deformation analysis of the composite cylindrical pipe subjected to lateral compression loading. M Xia et al [7] analysed the composite laminated cylindrical pipes under lateral compression loading. They evaluated the stresses and deformations in the multi layer composite cylindrical pipe experimentally and compared with theoretical results. PK Kopparthi et al [8] shows that the defect does not have an affect on the tensile strength of the composite and the presence of defect influences highly the flexural properties. The objective of this work was done on Carbon fabric reinforced polymer composites without and with defects present in the laminate. These are tested under NDT technique for identifying the defects present in the laminates. Then the laminated are cut into specimens for testing of mechanical properties like ILSS, Flexural strength and Tensile strength.

Experiments

2.1 Materials and Methods

The laminates consisted of phenolics resin as matrix and carbon fabric (3K) as the reinforcement. The laminates were fabricated by using hand layup method with vaccum bagging (Figure 1) to the size of 250 mm × 205 mm × 3.5 mm. Two different laminates with and without artificial defect were manufactured with 0.5 volume fraction. Release film and small pieces of studs were used as defects in the laminate and are placed at 6^{th} layer of the laminate. Thermography is non-destructive testing (NDT) technique is used to confirm the defects present in the laminate. The laminate with defects are tested using thermography are shown in figure 2.

Inter-laminar shear stresses are the source of failure, unique characteristic of composite structure. The presence of inter-laminar shear stress in the laminated composite leads to de- lamination. Inter-laminar shear stress arises due to various reasons. The inter-laminar shear strength (ILSS) is one of the most important parameters in determining the ability of a composite to resist delamination damage. Inter-laminar Shear Strength (ILSS) was performed using eq. (1) according to ASTM D2344. The specimens are used for ILSS testing with the dimensions of 60 mm × 15 mm × 3.5 mm. The flexural tests are conducted to determine the mechanical properties of resin and laminated fiber composite materials. Flexural test with three point bending was performed using eq. (2) according to ASTM D790. The specimens are used for flexural test with the dimensions of 110 mm × 15 mm × 3.5 mm. Tensile properties, such as tensile strength, tensile modulus, and Poisson’s ratio of flat composite laminates, are determined by static tension tests in accordance with ASTM D3039 by using eq. (3). The specimens are used for tensile test with the dimensions of 220 mm × 25 mm × 3.5 mm.

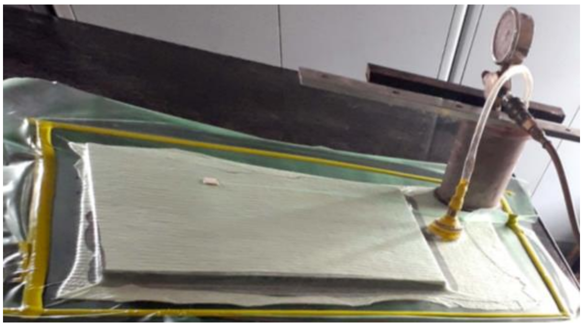
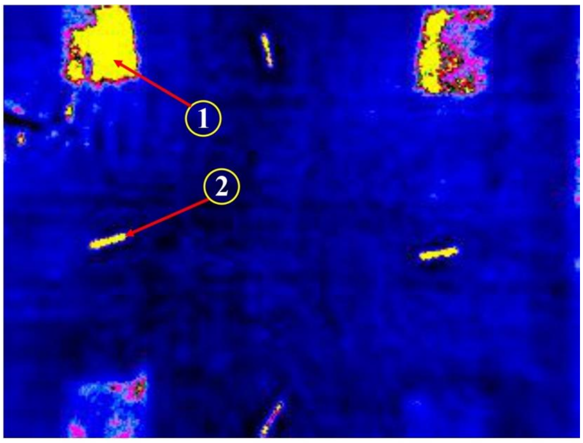


Figure 1: Laminate prepared with hand layup and vaccum bagging



1- Release Film 2- Stud

Figure 2: Laminate tested with thermography

$$ILSS = \frac{3P}{4A} \quad (1)$$

$$\sigma_f = \frac{3PL}{2bd^2} \quad (2)$$

$$\sigma_t = \frac{Tensile\ laod}{Area} \quad (3)$$

Results and Discussions:

3.1 Inter laminar shear strength (ILSS)

The inter laminar shear strength was tested and calculated as per ASTM D2344 and given in Table 1. From Table 1, it is clear that the inter laminar shear strength of 33.79 MPa of laminate without defects and 18.005 MPa of laminate with defects. Therefore the inter laminar shear strength decreases when there are defects in the composite laminate.

Table 1. ILSS test for laminates without and with defects

S.No	Laminates	Thickness (mm)	Width (mm)	Breaking Load (N)	ILSS (MPa)
1	Without defect	3.5	15	2523.58	33.79
2	With defect	3.5	15	1329.42	18.005

3.2 Flexural test

The flexural strength was tested and calculated as per ASTM D790 and given in Table 2. In case of flexural strength, the flexural strength of 495.96 MPa of laminate without defects and 338.52 MPa of laminate with defects. It is observed that the flexural strength [9] entirely depends on the quality of the laminate, any defects present in the laminate will decrease the flexural strength.

Table 2. Flexural test for laminates without and with defects

S.No	Laminates	Thickness (mm)	Width (mm)	Breaking Load (N)	ILSS (MPa)
1	Without defect	3.5	15	1003.94	463.96
2	With defect	3.5	15	731.70	338.52

3.3 Tensile test

The tensile strength was tested and calculated as per ASTM D3039 and given in Table 3. From Table 3, the tensile strength of laminate with and without defects varies from 136.63 MPa and 387.56 MPa respectively. Defects in the laminate can have a great impact on the strength of any laminate [10].

Table 3. Tensile test for laminates without and with defects

S.No	Laminates	Thickness (mm)	Width (mm)	Breaking Load (kN)	ILSS (MPa)
1	Without defect	3.5	25	36.078	387.56
2	With defect	3.5	25	12.46	136.63

Conclusion

The mechanical properties like ILSS, flexural and tensile properties of carbon fabric reinforced polymer composites without and with defects are performed. The defects inserted in 6th layer of the laminates. After the results are obtained, it is observed that a drastic change in properties between the two laminates. From the results, it is concluded that the defects in composites can cause a radical change in mechanical properties of CFRP composite.

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