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In-plane Shear Properties of Glass Fiber Composite Laminates

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ABSTRACT:
Shear properties of glass fiber composite material is of great important in specifying the elastic constants of such orthotropic material. There are a lot of methods used to measure these important properties among of them ±45 tensile in-plane shear test. Cross ply glass fiber composite laminates of $[0/ 90]_{2s}$ are manufactured using hand-layup technique. ±45 tensile in-plane shear specimen is cut and manufactured from the produced [0/ 90]2s laminate. The test is simple and newly applicable. The main advantage of the test is its simplicity of manufacturing. The results give in-plane shear modulus for glass fiber composite laminates in range of 30.32GPa, while the shear strength is about 27 MPa. Modes of failure of the shear specimen is similar to doge bone shape.

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I. INTRODUCTION

Composites structure material have a lot of application which make them popular replacement for many monotonic material. The mechanical characteristic of such material mainly depend on stacking sequence and on the direction of load applied to fiber respect to principal material direction [1]. Failure in many composites material is due to shear stress.Thein-plane and interlaminar shear are two form of shear behavior. This fiber reinforced plastic composite (FRPC) structure have low shear modulus in comparisonto their longitudinal elastic modulus [2]. Many test procedure have been carried out to measure both in-plane shear strength and modulus through single shear plane. examples of such test methods; ±45 tension test, [3],10^o off-axis tensile test[4] Iosipescu sheartest [5–16], double notch shear test[17], Torsion test [18–21].

Khashaba [22]measured in-plane shear properties of glass fiber reinforced epoxy composites (GFRE) usingIosipescu (V-notch). The test results are compared with other test methods,such as the thin-walled tube torsion test and thesolid rod torsion test, the V-notch shear test uses a flatspecimen that is easier to fabricate while achieving apure and uniform shear stress–strain state over the testregion. It is concluded that Young's modulus measured from the stress–strain diagram drawn using strain gauge readings in thetension test is more than six orders of magnitude higher than those determined from the stress–strain diagram of the testing machine.

Mohamed et al [23] measured in plane shear properties if glass fiber composite laminates using ±45 of axis tension test, the results are acceptable for in-plane shear modulus whereas, miss estimated the shear strength.

The present study aims to measure in-plane shear modulus using simple test technique with great accuracy. Investigating the failure modes of such specimen under tension stress.

II. EXPERIMENTAL METHOD

Material and characterization

One type of GFRP composite laminate is manufactured using commonly hand layup technique. The details of the constituent materials of the composite laminate are illustrated in Table (1). The stacking sequences of GFRP laminate is a $[0/ 90]_{2s}$ composite laminate. The mechanical and physical properties of E-glass fiber and epoxy resin are shown in Table (2).

Table 1: The constituent materials of the composite laminates (CMB international Co.)

Material	Type
Matrix	Resin-Kemapoxy (150RGL)
Reinforcement fiber	E-glass (Alkialian)-roving-pl=2200 gm/km

Table 2: Mechanical and physical properties of E-glass fiber and epoxy resin [23, 24, 25]

Properties	E-glass	Kemapoxy(150RGL)
Density(kg/m2)	2540	1.07 ±0.02 kg/liters
Tensile strength (MPa)	2000	50-100

Tensile modulus (GPa)	76	1.2-4.5
Passion ratio	0.25	0.35
In plane shear modulus	30.8	1.24
Failure strain		1.7

±45 tensile in-plane shear test method

In this shear test method, a $[\pm45°]_{2s}$ laminate is loaded in axial tension to determine the in-plane shear properties. This test method is frequently used because the specimens are easy to be fabricated and no special test fixture is required, the specimen is shown in Fig.1. It is a simple test method for predicting in-plane shear modulus with an acceptable precision [26]. However, the laminate is not in a state of pure in-plane shear stress [27]. Thus, the calculated shear stress and strain values at failure should only be used with caution. There are several test standards/guides based on this test method, i.e., ASTM D3518 [28]. The ±45 ° tensile specimen has the following merits: good reproducibility, simple to make, is a conventional tensile test, economical in material requires, simple data reduction and is easy to test at high or low temperatures. The cross–ply [0/ 90]2s laminate was cut at 45^o to gives the ±45 tensile in-plane shear test of stacking sequence $[45/-45]_{2s}$

The quasi-static tensile tests were done in a displacement-controlled manner with a displacement speed of 2 mm/min, during which the force (F), the longitudinal and transverse strains, (ε_{xx}) and (ε_{yy}) were recorded. With these values, the shear stress τ_{12} and shear strain γ_{12} can be calculated as:

$$\tau_{12} = F / 2wt \qquad 1$$

$$\gamma_{12} = \varepsilon_{xx} - \varepsilon_{yy}$$

Where w is the width of the specimen and t is the thickness. The longitudinal and transverse strains are measured using two perpendicular-element strain gauges. Fig. 2 show the digital strain meter attached with the specimen, in the machine grippes.

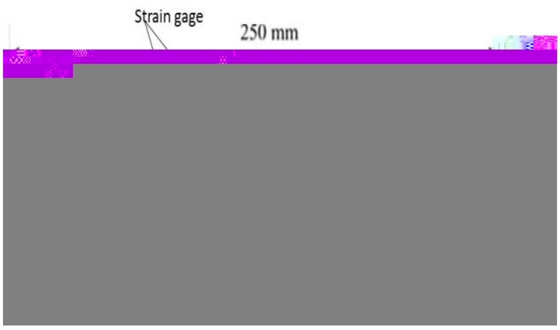

Fig. 1. ±45 tensile in-plane shear test standard specimen

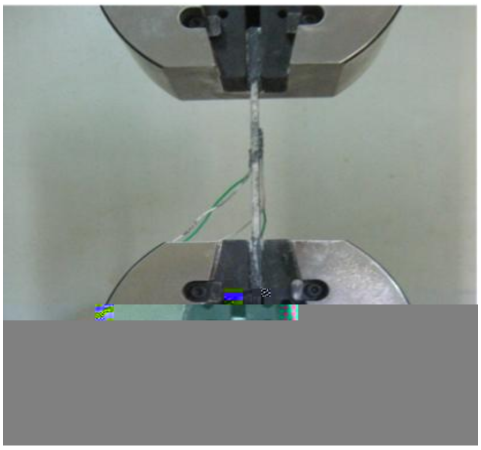

Fig. 2.Tension Specimen between the machines

III. RESULT AND DISCUSSION

Figure 3 shows stress-longitudinal strain curve for $[45/-45]_{2s}$ tension test specimen. This test is curried out to determine the shear strength and modulus of the material under consideration. Defining shear strength is still debatable as to which load value should be used [22]. The first load drop was considered to be the shear load responsible for material failure [22]. Mohammedet all [23] defined the shear strength as the strength at maximum portion of curves. Some investigators [22] defined the in-pane shear strength as the stress value corresponding to the ultimate load. The latter definition for shear strength is more suitable for nominal strength failure criteria [22]. Fig. 4 shows the relation between the shear stress and strains measured in both longitudinal and transverse direction. From this figure, the relationship between the shear stress τ_{xy} and shear strain (γ_{12}) is constructed as illustrated in Fig. 5. The values of the in-plane shear stress and strain are calculated as:

$$\tau_{12} = \frac{F}{2wt}, \gamma_{12} = \varepsilon_{xx} - \varepsilon_{yy} \qquad 2$$

Where (w) is the width of the specimen and (t) is the thickness. The longitudinal and transverse strains are measured using two perpendicular-element strain gauges. Hence, the in-plane shear modulus has determined from the slope of the shear stress-strain diagram at 0.5% as:

$$G_{12} = \frac{shear\ stress}{shear\ strian} = \frac{15.16}{0.5} X\ 100 = 30320\ MPa = 30.32\ GPa \qquad 3$$

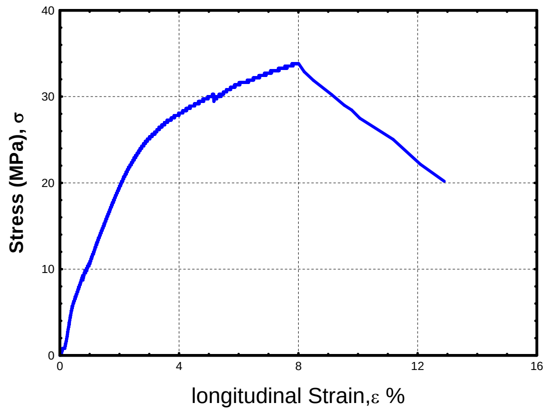

Fig. 3. Tensile stress longitudinal strain curve for [45/-45]2s specimen

Shear stress-strain flows linearly at the beginning of the test, the fracture mode of the specimen is "dog bon" like shape. Furthermore, it must be remarked that the narrowing of the specimen to the 'dog bone' like shape does not happen in a uniform manner over the entire specimen, but starts near the clamped ends and then gradually grows along the entire specimen length [23].

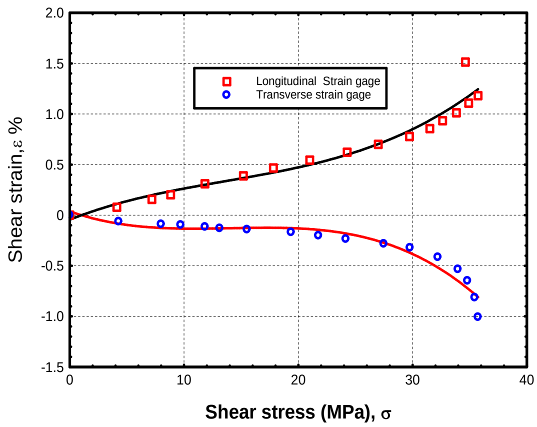

Fig. 4. Shear stress longitudinal and transvers strain curve for $[45/-45]_{2s}$ specimen

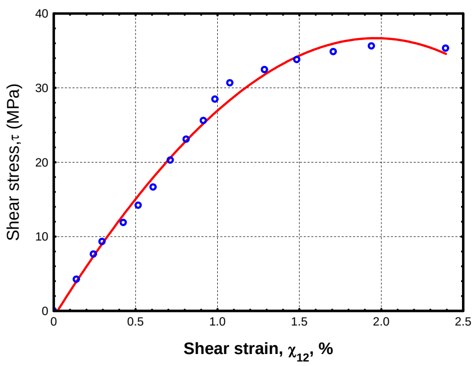

Fig. 5. Equivalent shear stress verses shear strain for $[45/-45]_{2s}$ specimen

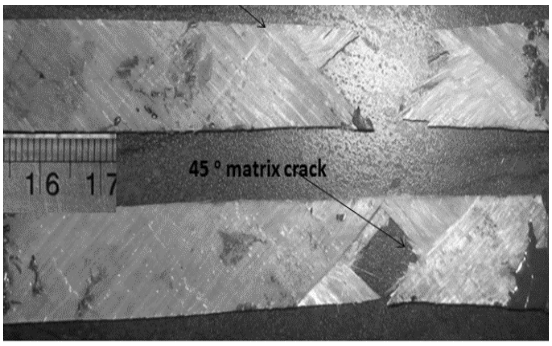

Fig. 6. Failure mode of $[45/-45]_{2s}$ Shear test

IV. CONCLUSION

It is proved that in-plane shear modulus can be measured using simple tensile test specimen. This technique is mainly based on the fiber direction in the composite laminates. A stacking sequence of $[45/45]_{2s}$ can give a good results. While this test is lower estimated the shear strength. The simplicity and flexibility of the test make it acceptable for research proposed. But it is carefully acceptable in industry field as there is error due to direction of fiber not perfectly achieved.

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