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MECHANICAL BEHAVIOR OF WOVEN GLASS FIBER-EPOXY COMPOSITE LAMINATES WITH VARIABLE FIBER ORIENTATIONS

A.eldaim A. Ali.*[1] Seedahmed A.I.[2] & Ramadan Mohmmed[3]
[*1,2&3]Sudan University of Science and Technology, Polymer Engineering Department, Collage of Engineering and Industries Technology, Sudan

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ABSTRACT
Glass fiber reinforced polymer (CFRP) multidirectional composite laminates are vital for tensile and flexural strengths structures where mechanical properties can be optimized. This work focuses on the influence of the stacking sequence lay-up configuration on Tensile and Flexural strength of glass fiber reinforced epoxy composites. The following laminates were produced by Hand lay-up technique: [+45°/-45°]s, [0°/45°/90°]s, oriented [+45°/-45°/90°]s, which denoted (G4,G16 and G26) successively and were evaluated based on both Tensile and Flexural strength tests. All specimens were tested as per relevant ASTM standards using hydraulic servo material testing machine, mechanical properties were measured with an electronic extensometer. The experimental results showed significant improvement of mechanical properties in G26 laminate as its tensile strength and Flexural strength were higher than those of G16 and G4. As expected it is eventually due to the longitudinally oriented fibers in G16 and number of layers in G4. Further work and confirmation tests are recommended..

KEYWORDS: Woven Glass-Fiber, Tensile Strength, Flexural Strength.

1. INTRODUCTION
Contemporary technologies generally relevant to aerospace, aquatic and transportation applications require a unique set of material properties that cannot be achieved by most metallic materials and ceramics alone. Aeronautical applications require high specific strength and rigidity of structural materials, which cannot be obtained using conventional materials. Composite materials help us achieve desired properties by combining different materials in a relative manner. In general, it has high strength and a high specific modulus which makes it useful in various industrial applications involving such properties. Glass fiber polymer composites and carbon fiber polymer composites are used in modern industries as an alternative to metals and have the desired properties. Each type has its own field of application. Composite materials are broadly categorized as synthetic fiber reinforced materials and natural fiber reinforced materials. Synthetic fiber-reinforced compounds have applications in various fields due to their preferred properties when compared to natural materials; In addition, it can be custom-made according to consumer requirements [1-4].. Composite is a mixture of two or more constituents/materials (or phases) with different properties at the macroscopic or microscopic scale. Composites are classified by the geometry of the reinforcement: particulate, flake, and fibers or by the type of matrix: polymer, metal, ceramic, and carbon[4]. Fibers are the principal load-carrying constituents while the surrounding matrix helps to keep them in desired location and orientation and also act as a load transfer medium between them[5] The properties effectiveness of the fiber reinforced composites strongly depend upon the geometrical arrangement of the fibers within the matrix[6]. This arrangement is characterized by the volume fraction, the fiber aspect ratio[7]. the investigation is carried out on the effect of woven fibre orientations on tensile, flexural properties of woven E-Glass-fiber epoxy composite laminates. the Static and fatigue behaviour of glass-fibre-reinforced polypropylene composites was developed[8]. The fibre volume fraction of composite was 0.338. The effect of layer design on the static and fatigue performance was investigated[9]. carried out tests on laminates of ply orientations to determine the effect of ply orientation in fiber-reinforced laminated composite joints. The hand

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layup process has been put into practice, where the mechanics and actions of human hands were successfully used to inspire the design of gripping robots[10].

2. MATERIALS AND METHODS

Experimental Procedure

Selection of material

In this study, composite material was made up by glass fiber and epoxy resin with different fiber orientations and number of layers. The biggest advantage of modern composite material is that they are light as well as more in strength. The strength weight ratio of composite material is high. By choosing an orientation of fiber a new material can be made that exactly meets the requirements of a particular application. The new material produced is totally different from base material and its properties are different. The composite material has orthographic structure. Hence its properties are different in all directions.

Fabrication of composite

There are three types of FRP composite with different number of layer and different fiber orientations were fabricated using hand lay-up method[11]). Three samples of composites were produced from one different type of fabric(E-glass) using hand layup. Sample one four layers (-45/+45) s (G4), sample two six layers (0/+45/90) s (G16) and sample three six layers(45/-45/90)s (G26). Different specimens were formulated by hand layup method are shown in Table 1.

Table 1. Stacking sequence and samples designation

Sr. No	Stacking sequence	Designations	Samples No.'s
1	Glass/Glass/Glass/Glass (-45/+45)s	G4	G11
			G12
			G13
2	Glass/Glass/Glass/Glass/Glass/Glass (0/+45/90)s	G16	G21
			G22
			G23
3	Glass/Glass/Glass/Glass/Glass/Glass (45/-45/90)s	G26	G31
			G32
			G33

Tensile test

Instron - Dynatup 9250HV machine was used to test the flexural and tensile strength of the corresponding standard samples. Tensile test was carried out using the ASTM D3039 standard[12]. For the tensile test, specimen was cut in the dimension of 250 mm x 25 mm x 1.6 mm (G16 & G26) and for G4 thickness is 1.2 mm as per ASTM D3039 standard by using the diamond cutter as shown in figures 1,2 and 3. In 250 mm length of specimen, 200 mm was considered for span length. Speed of testing for all samples was done at 2 mm/min. The test was performed four times for each sample, and abnormal results were excluded, tension machine shown in figure.4. The fractured tensile specimens is shown in figure 5.

fig 1. Tensile specimen G16 ($0^0/45^0/90^0$)

fig 2. Tensile specimen G4 ($+45^0/-45^0$) ($+45^0/-45^0/90^0$)

fig 3. tensile specimen G26

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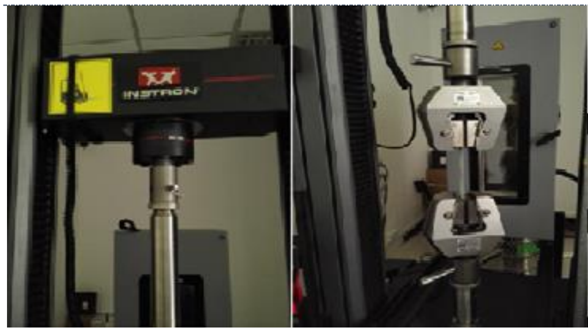

Fig 4.Tensile specimen before Loading

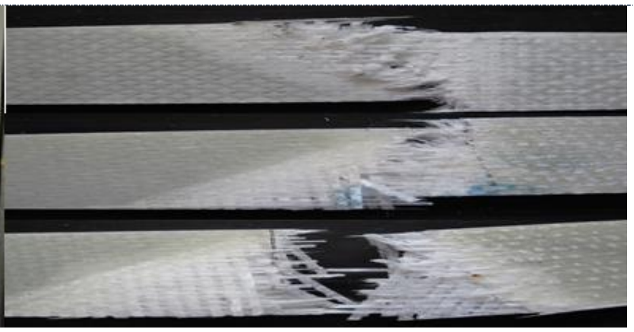

Fig 5. fractured tensile specimens

Flexural tests

Three-point flexural testing were conducted according to the ASTM D7264 [12]standards using the spring mass - testing machine. The specimens were machined for the dimensions of 130mm × 13 mm × 1.6 mm (G16 & G26) for G4 thickness is 1.2 mm fig 6, 7 and 8. The span of the specimens was considered 66mm. For this testing, the load cell of 100KN was utilized with the crosshead speed of 1mm/min [13].The test was performed four times for each sample, and abnormal results were excluded, Loading of bending specimen was done as shown in fig 9. The fractured Bending Specimens shown in fig10.

For a specimen in the three-point bending test, the flexural strength (σ_F), Flexural modulus (E_F) and strain to failure (ε_F) are calculated given by equations below:[14]

$$\sigma_F = \left(\frac{3WL}{2bt^2}\right)\left[1 + 6\frac{d^2}{L^2} - 4\frac{dt}{L^2}\right] \quad , \quad E_F = \frac{mL^3}{4bt^3} \quad , \varepsilon_F = 6dt/L^2$$

where σ_F is the flexural strength, W is the applied load, L is the support span, b the width and t the thickness of the sample, d is the displacement, m is the slope of the tangent to the initial straight-line portion of the load-deflection curve, d is the maximum deflection before failure, and ε_F is the strain at the centre of the specime

fig 6. flexural specimen G16 ($0^0/45^0/90^0$)

fig7. Tensile specimen G4 ($+45^0/-45^0$)

fig 8. tensile specimen G26 ($+45^0/-45^0/90^0$)

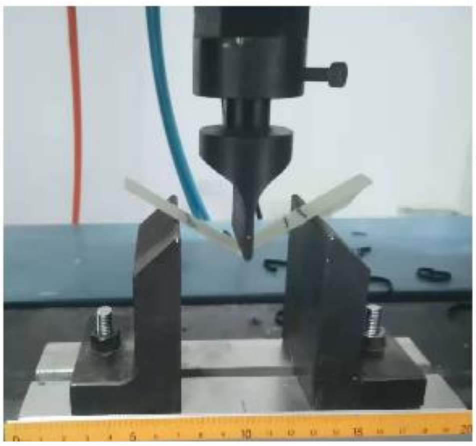

Fig 8. Loading of bending specimen

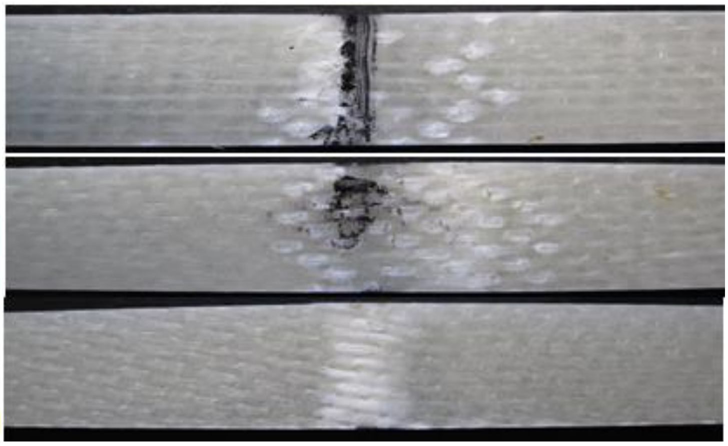

Fig 9. Fractured Bending Specimens

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3. RESULTS AND DISCUSSIONS

Tensile test results

The values of force obtained for all specimens fig11and for same specimens are shown in fig12, 13 and fig.14. The 6 layer glass G16 and G26 composites exhibited maximum tensile strength values of 248.19Mp and 191.21Mpa respectively, the sample G4 tensile strength is lower than G16 and G26 because (127.22Mpa) the tensile strength depend on the number of layers and the angles of the layers [15] so the G26 has higher tensile strength. The orientation increases the mechanical properties of glass mats [16-19]. The tensile modulus of G26 is 4819.22Mpa, G16 is 4239.69Mpa respectively and for G4 is 3457.06Mpa.

Flexural tests result

The values of force obtained for all specimens fig15and for same specimens are shown in fig16, 17 and fig.18.. Flexural or three-points bending tests were conducted following ASTM D7264 standard [24]. four samples of each composition were tested, and their mean flexural strength and force are analyzed. The flexural strength of G4, G16 and G26 composites were, 380.34Mpa, 347.52Mpa and 407.7MPa respectively. It is revealed that G26 stacking combination possess higher flexural strength and maximum force prior to failure. The flexural strength of G26 specimens rose up to 14.76 % compared to G16 and 6.71% compared to G4 composite materials due to the shape of the angles layers for G16 and the number of layers for G4. The fiber direction in the composites results in the materials being able to absorb more energy and offer higher molecular flexibility by opposing crack propagation.

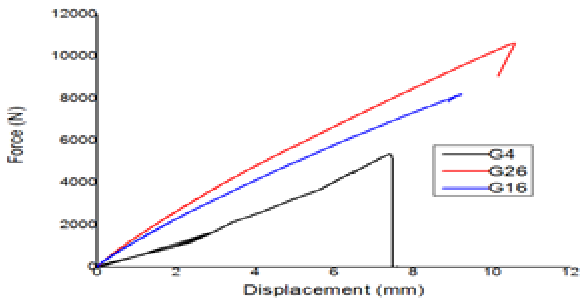

Fig11. Tensile test for sample G26 ,G16 and G4

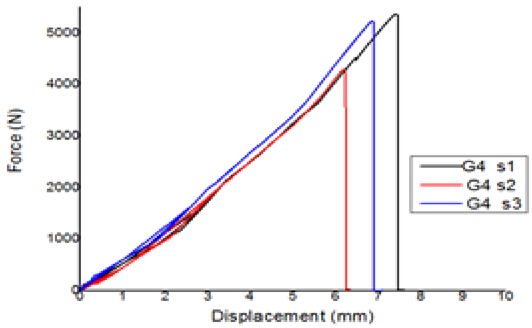

fig12 . Tensile test for sample G4 $(+45^0/-45^0)s$

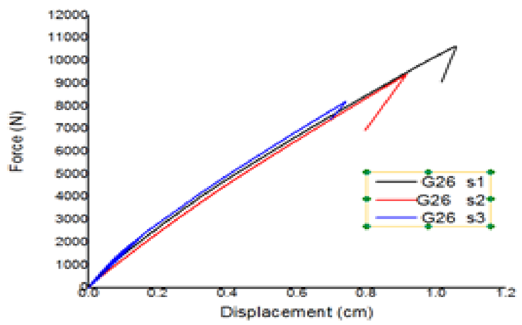

Fig13. Tensile test for sample G26 $(+45^0/-45^0/90^0)s$

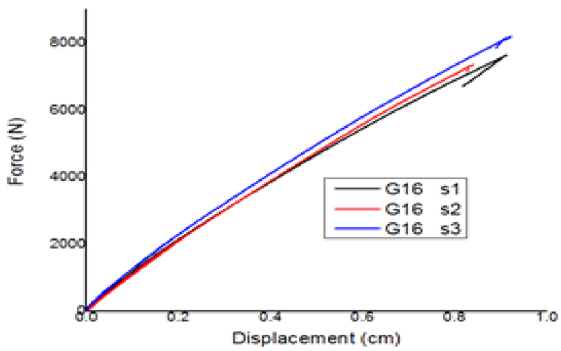

Fig14 . Tensile test for sample G16 $(0^0/45^0/90^0)s$

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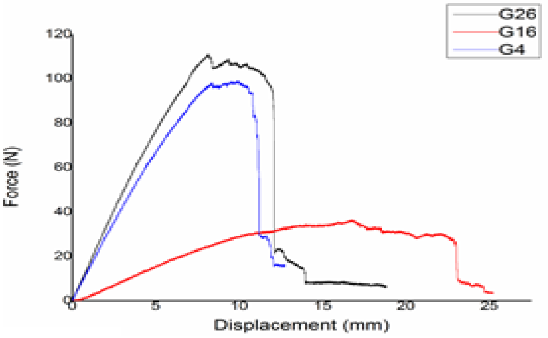

Fig15. Flexural force for sample G26 ,G16 and G4

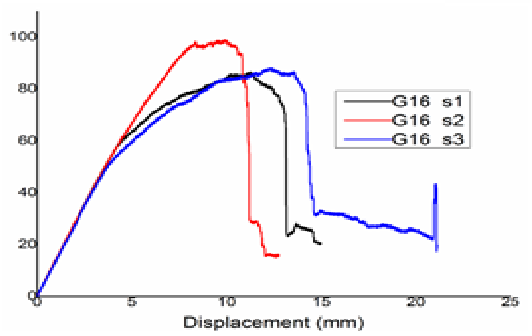

Fig16. Flexural force for sample G16 ($0^0/45^0/90^0$)s

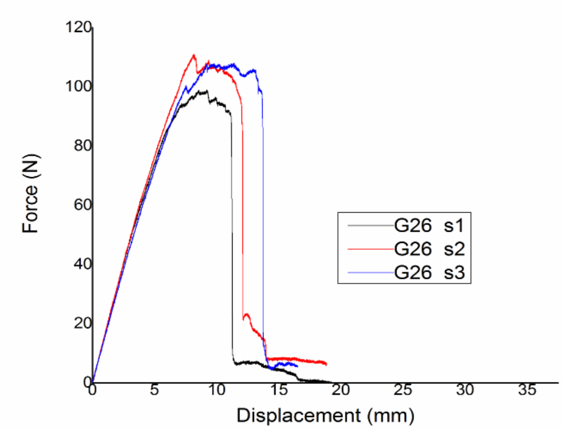

Fig17. Flexural force for sample G26 ($+45^0/-45^0/90^0$)s

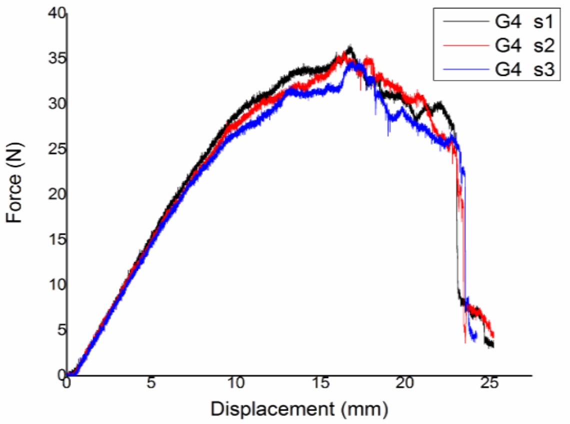

Fig18. Flexural force for sample G4 ($+45^0/-45^0$)s

4. CONCLUSION

The outcome of this work is the effect of woven glass fiber orientations on the mechanical properties of composites. The effect of glass/epoxy samples (+45°/-45°) s (G4), (0°/45°/90°) s (G16) and (+45°/-45°/90°) s (G26) was investigated along with the tensile and flexural. of the prepared composites. The following conclusions are made based on the experimental study:

- The tensile properties of with the various orientation of glass fiber epoxy composite are significantly improved the at same fiber number of layers and the tensile properties more affected by for different of layers. The maximum tensile strength has been obtained G26, G16 and G4 respectively.
- The maximum flexural strength of with the various orientation of woven glass fiber epoxy composite is achieved at same number of layers for G26.

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