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Influence of the Stacking Sequence on the Tensile Properties of Hybrid Composite

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ABSTRACT

This study aims to investigation of the effect of stacking sequence on tensile properties of hybrid composite materials by using tensile test. Two groups of materials were used; first group is hybrid woven glass/ woven carbon epoxy laminates with stacking sequence (fiber glass-carbon-carbon) and (carbon-fiber glass-carbon). In the second group using hybrid woven glass/ woven carbon epoxy laminates with stacking sequence (fiber glass-fiber glass-carbon) and (fiber glass-carbon-fiber glass). From the experimental results, the stacking sequence (fiber glass-carbon-carbon) is preferable.

Keywords: Composite materials, bending behavior, Regression analysis, ANOVA.

1. INTRODUCTION

1.1 Hybrid Composite Materials:

Hybrid composite are more advanced composites as compared to conventional fiber reinforced composites. Composite containing a combination of different fiber types can be referred to as hybrid composites. The development of composite materials improving their performance by the reinforcement of two or more fibers (synthetic fibers with other synthetic fibers or synthetic fibers with natural fibers or synthetic fibers with metallic fibers) in a sign polymeric matrix. An example of hybrid composite material can be seen in figure (1).

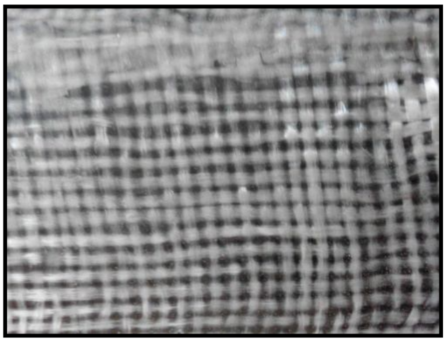

Figure (1): Hybrid composite material

1.2 Advantages of hybrid composites:

1. Better flexibility in the selection of fiber and matrix materials , which helps in better tailoring of the mechanical properties .for example the modulus, strength ,fatigue performance etc of glass reinforced composites can be enhanced by inclusion of carbon fibers .
2. Better wear resistance.
3. Low thermal expansion coefficient.
4. Combination of high tensile strength and high failure strain.
5. Better impact and flexural properties.
6. Reduced overall cost of the composite.
7. Low notch sensitivity.
8. Non catastrophic.

1.3 Types of hybrid composite:

There are several types of hybrid composites characterized as:

1. Interplay or tow-by-tow, in which tows of the two or more constituent types of fiber are mixed in a regular or random manner.
2. Sandwich hybrids, also known as cor-sheel, in which one material is sandwiched between two layers of another.
3. Interplay or laminated, where alternate layers of the to (or more) materials are stacked in a regular manner.
4. Intimately mixed hybrids, where the constituent fibers are made to mix as randomly as possible so that no over-concentration of any one type is present in the material.
5. Other kinds, such as those reinforced with ribs, pultruded wires, and thin veils of fiber or combinations of the above.

1.4 Applications:

1. Ailerons and floor panels of air crafts.
2. Helicopter rotor blades and drive shaft.
3. in automobile units, chassis members, suspensions, and structural body parts of cars and Lorries.

1.5 Aims of study:

This study aims to investigate the effect of stacking sequence on tensile properties of hybrid composite materials by using a tensile test.

1.6 Literature review:

Levent Onal et.al. [1] studied the effect of stacking sequence on mechanical properties of stitched composites for low velocity impact damages tests were performed for the same volume fraction (Vf) with different hybrid sequence and ply angle.
The result showed that the incorporation of glass fibers in carbon reinforced structures improved impact properties and increased the strain to failure. Also the addition of carbon fibers to the surface of glass- reinforced composites increases the flexural modulus for undamaged samples.
Soma Dalbehera et.al [2] Investigated a new hybrid composite with epoxy as a resin and reinforcing both bio waste (jute) and traditional filler (glass) as a continues layered mat composites were used by keeping the position of glass and jute fabric as (0□ - 90□) and (45□ - 45□) for all stacking sequences the study of the effect of stacking sequence on tensile, flexural and interlinear shear properties of untreated woven jute and glass fabric reinforced epoxy hybrid composite has been investigate experimentally .
The results indicated that the properties of jute E- glass epoxy and its composites can be considerably improved by incorporation of glass fiber as extreme glass piles.
The results showed that the maximum piles flexural strength is observed in GJJG hybrid epoxy composites and maximum tensile strength is observed in GJJG hybrid epoxy composite.
Suhad Dawood Salman [3] tested five group samples of the hybrid materials that have specific volume fraction of glass fibers and Kevlar fiber in malty layers and then a tensile mechanical testing than the research was to investigate the influence of processing parameters on the mechanical properties (tensile) of the composites and determine an optimum processing route. A considerable positive hybrid effect was noticed for tensile, strength and tensile modulus, particularly for the samples consisting of more than one layer and reinforced with two kinds of fibers.
Gaurav AGARWAL et.al. [4] studied the effect of best stacking sequence (position and orientation) on the mechanical properties friction and wear response of hybrid composites. The main purpose of the study was to determine the best available stacking sequence for which the physical , mechanical and three body abrasive wear rate is optimum- test for mechanical properties (tensile, strength, flexural strength, inter laminar shear strength , impact strength and hardness) was done on glass – carbon hybrid composite. The composites were then subjected to test for three body abrasive wear on a designed experimental setup. Five different factors: (sliding velocity, fabric weight percentage, normal load, sliding distance and abrasive particle size) varied in steps to evaluate the friction and three bodies abrasive wear response of the composite Taguchi’s orthogonal array and analysis of variance (ANOVA) was applied to find out minimum specific wear rate. The results revealed the significance in arrangement of two different layers of fabric (glass and carbon) and the difference properties obtained by them.
Oliveira. et.al. [5] studied the influence of the stacking sequence (sandwich or laminated) on the mechanical properties of a hybrid composite (jute- glass) reinforcement in a polymeric matrix.

The objective is to evaluate possible use of this composite as substitute for glass fiber composites in some applications. The mechanical properties were determined in tensile and three point bend fracture characteristics.
Jae II lim [6] studied the effect of stacking sequence on the flexural and fracture properties of carbon / basalt/ epoxy hybrid composites. Two types of carbon / basalt/ epoxy hybrid composites with a sandwich from were fabricated: basalt skin - carbon core (BSCC) composites and carbon skin- basalt core (CSBC) composites.
Fracture tests were conducted and fracture surfaces of the carbon / basalt/ epoxy hybrid composites were then examined using scanning electron microscopy (SEM). The results shows that the flexural strength and flexural modulus of the (CSBC) specimen respectively were ~32% and ~ 245% greater than those of the BSCC specimen, however the inter laminar fracture toughness of the CSBC specimen was ~ 10% smaller than that of the BSCC specimen, SEM results on the fracture surface showed that matrix cracking is a dominant fracture mechanism for the CSBC specimen which interfacial debonding between fibers and epoxy resin is dominant fracture process for the BSCC specimen.
S.C Amlco . et.al. [7] studied the mechanical properties of pure sisal, pure glass and hybrid sisal/ glass compression – molded composites, in which various stacking sequences of fiber mat layers were used. It is shown that hybridization originated a material with general intermediate properties between pure glass and pure sisal. However the importance of controlling the stacking sequence to enhance properties was evident. For instance to optimize flexural behavior there must be glass fibers mainly on the top and bottom surfaces.
Furthermore, depending on the type of loading and stacking sequence, some hybrid composites show properties very close to those of pure glass.

2. EXPERIMENTAL WORK

Number of steps has been followed to begin the experimental work:

1- Calculation of the volume fraction of the fiber glass and carbon fiber their weight is determined before molding with epoxy resin. The volume fraction can be calculated by using the following equations:

$$\text{Vf) fiberglass} = \frac{wf/\rho f}{wr/\rho r + wf/\rho f}$$

$$\text{Vf) carbon fiber} = \frac{wc/\rho c}{wr/\rho r + wc/\rho c}$$

$$\text{Vf) hybrid} = \frac{wf/\rho f + wc/\rho c}{wr/\rho r + wf/\rho f + wc/\rho c}$$

The values of the volume fraction are listed in the following table:

Table (1): The values of the volume fraction

Type of composite	Volume fraction (%)
Hybrid glass/ carbon composite	29

2- Molding:

A gypsum mold with dimension (40 cm x 20cm) is used in this work. The mold is placed on the metallic pipe as shown in figure (2). The mold was inserting in a sack made from polyvinyl alcohol (PVA) as a catalyst to interact.

Figure (2): Gypsum mold

The mold was then covered by layer of rectangular sheet of woven fiber. Thereafter, place another sack of (PVA) with the provisions of the closer from the top and bottom to avoid exit the epoxy resin. Gradually, the epoxy resin was found in side. The (PVA) sack from the top as shown in figure (3).

Figure (3): The mold covered by a sack of (PVA)

2- In the same time, the vacuum device was switched on for the purpose of the exit of excess epoxy resin from outlet pipe which is connected with vacuum device. Figure (4) illustrates the vacuum device.

Figure (4): Vacuum device

3- After about (20) minute the solidification of specimen was finished and vacuum device was switched off.
4- The specimens are then cut by using electrical cutting machine. The grinding operations were applied for specimens to obtain the finish shape and dimensions of specimens. Final shape of specimen is shown in figure (5) according to the ASTM (D638) type I.

Figure (5): Final shape of specimens

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5- Static tests were performed by tensile test machine in Materials Engineering department, Al-Mustansiriyah University to find the relation between stress and strain.

3. EXPERIMENTAL RESULTS

In this chapter, the tensile stress vs. strain behavior is presented for two groups of materials, first group is hybrid woven glass/ woven carbon epoxy laminates with stacking sequence (fiber glass-carbon-carbon) and (carbon-fiber glass-carbon). In the second group using hybrid woven glass/ woven carbon epoxy laminates with stacking sequence (fiber glass-fiber glass-carbon) and (fiber glass-carbon-fiber glass).
Figures (6 and 7) show the effect of stacking sequence on the stress-strain relation for the (CCF) and (CFC) respectively.

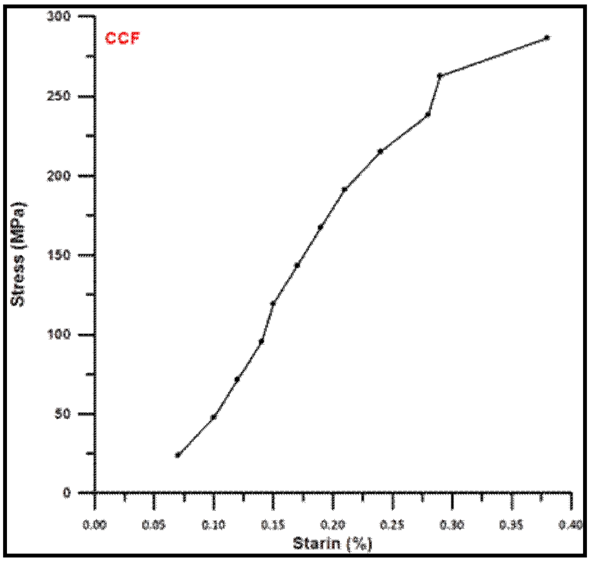

Figure (6): Stress-strain curve for stacking sequence (CCF)

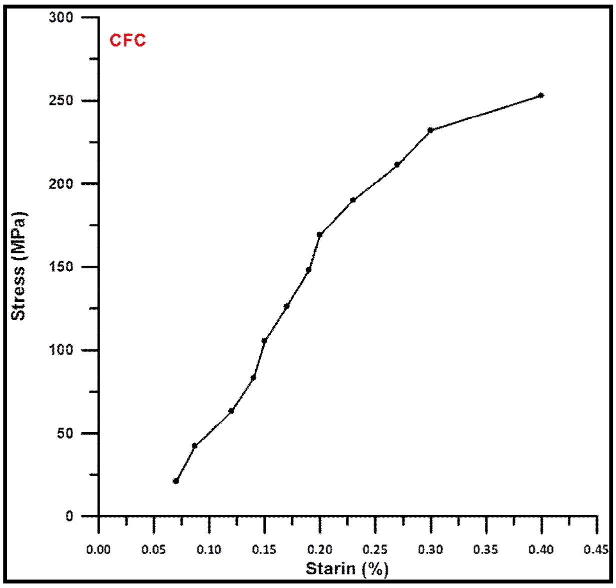

Figure (7): Stress-strain curve for stacking sequence (CFC)

Figures (8 and 9) illustrate the effect of stacking sequence on the stress-strain relation for the (CFF) and (FCF) respectively.

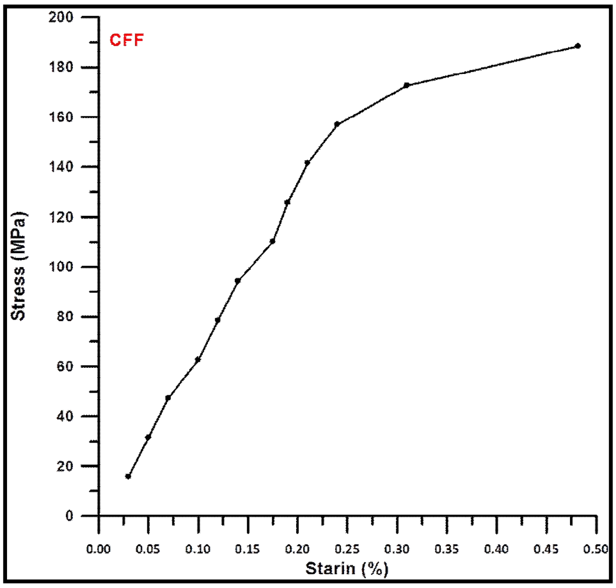

Figure (8): Stress-strain curve for stacking sequence (CFF)

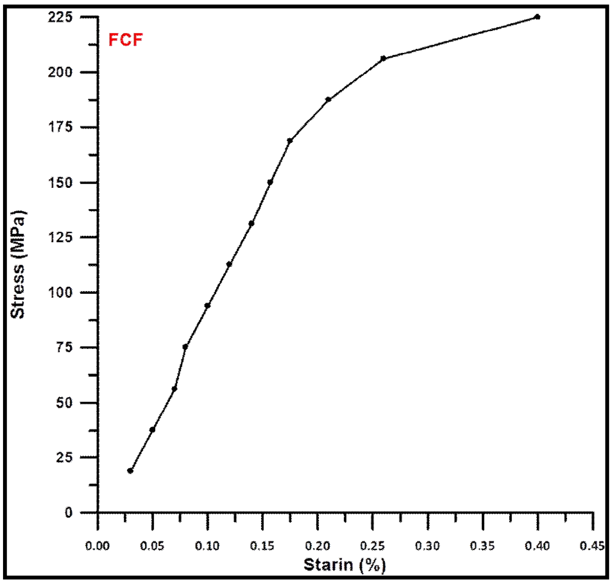

Figure (9): Stress-strain curve for stacking sequence (FCF)

Based on the experimental results it is observed that the stacking sequence for the first group (CCF) yielded higher properties than the (CFC). While, the stacking sequence (FCF) for the second group yielded higher properties than (CFF).

4. CONCLUSION AND FUTURE WORK

Based on the experimental results, the maximum tensile stress and strain are observed in stacking sequence (CCF), this indicates that there is a clear improvement in the tensile properties of glass-fiber when hybridized with carbon-fiber. This is due to carbon-fiber having higher mechanical properties when compared with glass-fiber.

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