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The Role of Stacking Order on Mechanical Properties of Glass/Carbon Reinforced Epoxy Hybrid Composites Prepared by Resin Infusion Technique

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Abstract

The hybrid composites find various applications starting from the aircraft industry in various engineering fields such as marine industry and automobile industry because of their outstanding properties which cannot be achieved by the traditional materials. Fiber Reinforced Hybrid composites have significantly expanded their wide range of application in the aerospace industry in the present days because of their anticorrosive nature, less weight and less maintenance. The present work aims at developing of a special kind of hybrid composite made by reinforcing E-Glass and Carbon into Epoxy matrix. These new hybrid composite materials are fabricated by Resin Infusion Technique by keeping 0°/90° orientation of each layer of fibers and studied the effect of a different stacking sequence of each layer of glass and carbon on various mechanical properties. The ratio of fiber to the matrix is maintained at 60:40. The comparison of two different stacking is carried out. The results revealed that the laminate having carbon fiber on the extreme surfaces yields better flexural properties when compared to the laminate having carbon fiber on the extreme surfaces.

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Keywords: Mechanical properties, Resin Infusion Technique, Stacking sequence, Orientation.

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Nomenclature

kN	kilo Newton
MPa	Mega Pascal
GSM	Grams per Square Meter
ASTM	American Society for Testing and Materials
C	Carbon Fiber
C1	Single layer Carbon Fiber
G	Glass Fiber
G1	Single layer Glass Fiber
G2	Double layer Glass Fiber
UTM	Universal Testing Machine

1. Introduction

The hybrid polymer composites are emerging as an alternative to a traditional metal due to its stiffness, high strength and less weight for the application related to aerospace and automobile components. Thermosetting resins like epoxy are having high stiffness and strength, chemical resistance, significant dielectric behavior, corrosion resistance, low shrinkage during curing, improved mechanical and thermal properties. Hence the composite laminate used epoxy as a matrix can be found in the technical application like sporting goods, printed circuit board, and aerospace [1]. The hybrid composite materials prepared by reinforcing glass/carbon to epoxy give better flexural strength when compared composite of individual fibers [2]. When the orientations are considered as a paramount while fabricating hybrid composites by vacuum bag technique. It is found that 0°/90° orientation of the fibers yield the better tensile strength, tensile modulus, and peak load when compared with 45°/45° and 30°/60°orientations [3]. Nowadays, the drive shaft is made of glass/carbon composites with 0°/90° fiber orientation shows improved mechanical properties compared to traditional metal shafts [4]. The thickness of the hybrid composite laminates is having the major effect on flexural properties compared to tensile properties [5]. Recently, many methods have emerged as a replacement to the traditional Hand Lay-up method by Resin infusion Technique. The composites prepared by Resin infusion technique Rare having good mechanical properties compared to that of hand lay-up made [6]. The flexural strength is high for the stacking where the carbon fibers at the extreme ends, then the stacking where the glass layers at the extreme ends [7]. Hybrid composites made of glass and carbon reinforced epoxy-based composites have superior mechanical properties compared to glass fiber reinforced plastics. Therefore, hybrid composites can be used as a substitute for glass fiber reinforced plastics. A mixture of fiberglass and carbon fiber will increase the mechanical strength and overall stability of the material [8]. The mechanical properties of bidirectional woven hybrid composites depend on the correct orientation and stacking of each layer [9].The best way to improve the mechanical properties of composites by using modern techniques to improve manufacturing methods. One such method is Resin Infusion technique. The composites prepared by resin infusion technique will have fewer defects such as voids, air pockets. The air bubbles inside the layers of fibers will be readily entrapped away during resin flow, which uses the negative pressure to suck the resin into the mold cavity [10].Finally, hybrid composites have replaced other materials due to their excellent structural properties like tensile strength, flexural strength and impact strength with increased fiber reinforcement in the matrix. The strength and properties of the composite depend on the bond between the matrix and the fibers, the individual properties of the fibers, the presence of voids, and the use of ideal manufacturing processes such as resin transfer technology [11].

2. Materials and Method

2.1. Materials

The hybrid polymer composite laminates prepared by reinforcing E-glass fabric (631GSM) and carbon fabric (200GSM) into the epoxy resin matrix. The laminate was prepared by changing the stacking order of the carbon and glass fiber layers. The raw materials, E-glass and carbon woven fabric were supplied by SAERTEX India Private Limited, Pune, India. The epoxy resin (Araldite LY 5052-1) with a density range of 1.16-1.17 g/cm^3 and Hardener (Aradur 5052-1) with the density range of 1.16-1.17 g/cm3 were supplied by Huntsman Advanced Materials Americas Inc., Brewster, New York, USA. The resin and hardener are mixed in the ration of 100:38. Thereafter, alternating plies of glass/carbon are placed using resin infusion technique until the desired composition and thickness are achieved. The infused panels were subjected to step curing (60°C for 30min, 70°C for 60min, 85°C for 120min.) in an autoclave. After solidification composites were taken out from the autoclave and testing samples are prepared as per ASTM standards suiting to various studies.

2.2. Fabrication Methods

Two types of hybrid composite laminates were prepared as shown in Fig. 1 Preparing the first laminate, by keeping carbon layers kept at the exterior end and two glass layers kept after each carbon layer. The second laminate, by keeping alternate layers of carbon/glass. Both the laminates are prepared by keeping seven layers. These laminates were prepared by resin infusion technique, Where the negative pressure is used to suck the resin into the prepared mold cavity with a vacuum environment.

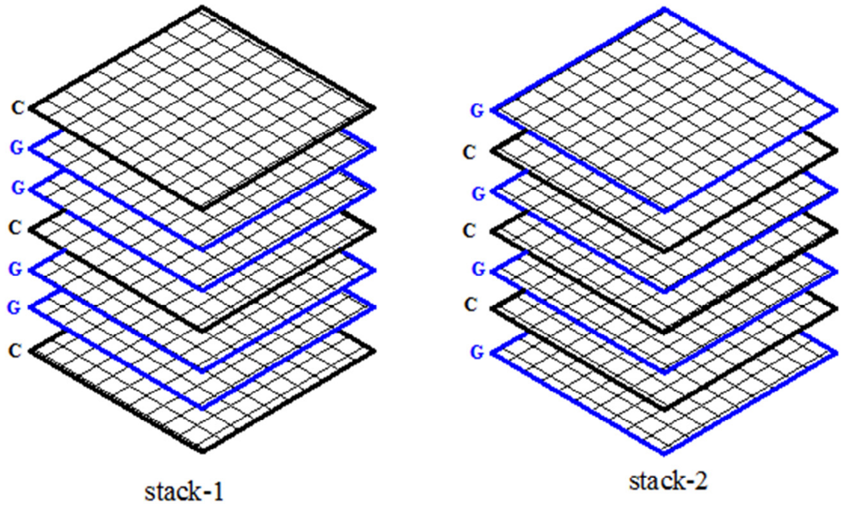

Fig. 1. Stacking order of fibers

These two different stacking sequences are used to determine the effect of the fabric arrangement on the mechanical properties of the hybrid composite. These stacked arrangements were made to compare the mechanical behavior of laminates prepared by varying fiber stacking order as shown in table1.

Table 1. Stacking sequence of Glass/Carbon in composites

Code	Stacking Scheme	Glass fiber content	Carbon fiber content
Stack-1	$C_1G_2C_1G_2C_1$	57%	43%
Stack-2	$G_1C_1G_1C_1G_1C_1G_1$	57%	43%

2.3. Mechanical Characterization

Tensile strength, flexural strength and compression strength were measured at a universal test machine (UTM) manufactured by BISS (Bangalore Integrated System Solutions), Bangalore with machine capacity of 250 kN. This test was conducted as per ASTM D3039, with a sample size of 250mm×250mm×3mm with 50mm gauge length at

2mm/min loading rate. The 3-point bending test was performed on a sample having a size of 100mm×100mm×3 mm in accordance with ASTM D790. The compression test was done on UTM for the specimen 155×25×3mm in accordance with ASTM D3410 with a gauge length of 25mm with a strain rate of 1mm/min.

3. Results and discussions

3.1. Tensile Strength

Table 2. Tensile strength Results

Stacking	Max Load(kN)	Tensile Strength(MPa)	Modulus(GPa)
Stack-1	24.837	389.551	15.074
Stack-2	26.745	358.690	26.745

The role of stacking order on the tensile strength of glass-carbon fiber reinforced hybrid composites is as shown in table 2.The highest tensile strength value for stacking order-1($G_1C_1G_1C_1G_1C_1G_1$) indicates that the tensile strength is higher when compared to stack-2, Where alternate layers of glass and carbon fibers are used in the laminate. The value of the tensile strength in the stack-1 sequence indicates maximum strength when alternating glass layers and carbon fiber fabric are used for preparation of composite material, which may be due to better bonding between layers of glass and carbon fabrics with epoxy resin. Figure 2 & 3 shows Fractured tensile of stack 1 & 2 specimen.

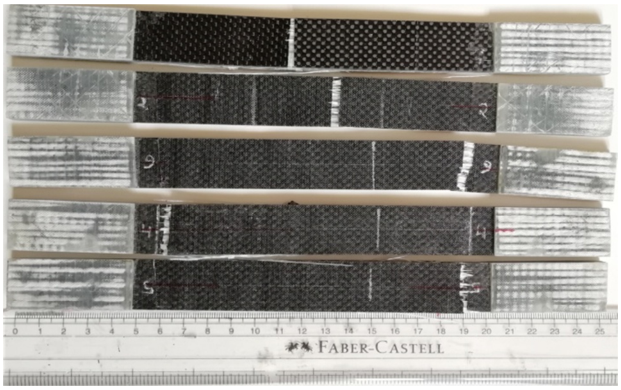

Fig. 2. Fractured tensile specimens for stack-1

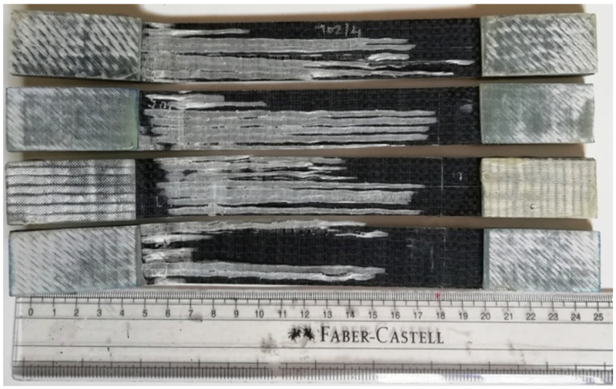

Fig. 3. Fractured tensile specimens for stack-2

3.2. Flexural Strength

Table 3. Flexural strength Results

Stacking Scheme	Max Load(kN)	Flexural strength(MPa)
Stack-1	0.496	449.650
Stack-2	0.762	672.821

The comparison of the flexural strength of glass and carbon fibers reinforced epoxy hybrid composites with different stacking schemes is as shown in table 3. The flexural strength is high for the stacking where the carbon fibers at the extreme ends, then the stacking where the glass layers at the extreme ends i.e., the stacking-2 will yield the better flexural property than the stacking-1. The reason why the bending strength is lowered when the glass fabric is at an extreme is that the extreme outer layer is subjected to stretching and compression in the case of a bending load, and the breakage easily spreads in the case of the glass fabric due to the brittleness of the glass fabric compared to carbon fabrics.

3.3. Compressive Strength

Table 4 depicts the role of stacking order on the compressive strength of glass and carbon fiber reinforced epoxy hybrid composites.

Table 4. Compression strength Results

Stacking Scheme	Max Load(kN)	Compression strength(MPa)
Stack-1	23.616	304.591
Stack-2	18.479	282.658

Comparison of the compressive strength of glass and carbon fiber reinforced epoxy hybrid composites with different fiber stacking schemes. The compression strength is high for the stacking where the glass fibers at the extreme ends, then the stacking where the carbon layers at the extreme ends. i.e., the stacking-1 yields the better flexural property than the stacking-2.

4. Conclusions

Based on the above analysis of glassy carbon composites, the effects of fibers reinforced position and each layers orientation on the mechanical behavior of materials were studied. Comparison result of mechanical properties for stack 1 & 2 is as shown in figure 4.

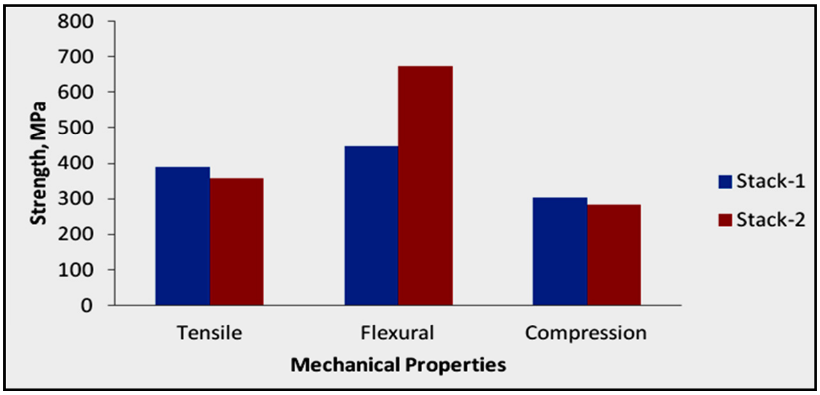

Fig. 4. Comparison of mechanical Properties for stack-and stack-2

These are the findings from the experimental work carried out,

1. The best stacking sequence (position and orientation) is for stacking scheme-1 for the tensile strength, i.e., when carbon fabric at the extreme end, two glass layers below each layer of carbon fabric.
2. The flexural strength is high for the stacking where the carbon fibers at the extreme ends, then the stacking where the glass layers at the extreme ends. i.e., the stacking -2 yields the better flexural property than the stacking-1.
3. The compression strength is high for stacking-1. When carbon fabric at the extreme end, two glass layers below each layer of carbon fabric.

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