Research Article

Effect of Stacking Sequence on Mechanical Behavior of Woven Glass-Hemp Polyester Hybrid Composites

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Received: 27/02/2017
Revised: 07/06/2017
Accepted: 08/07/2017

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Abstract:

This investigation focused on tensile and flexural behavior of pure woven glass, pure woven hemp and glass-hemp polyester hybrid composites which are made using hand layup method with different stacking sequences. It is observed that hybridization of glass and hemp fibers gives tensile properties between pure hemp and pure glass polyester composites. Moreover, it was observed that by controlling the layering arrangement, flexural properties can be improved.

Keywords: Hybrid, hand lay-up, stacking sequence, mechanical properties

INTRODUCTION

Owing to the less mechanical properties of polymeric resins, the exploration for tougher materials led to the manufacturing of polymeric composites. Composite materials significantly developed for an age in several industrial applications for their stimulating mechanical properties.

Currently, natural fibers reinforced composites are developing in composite applications as they have advantages like low cost, low density and ease of availability. Also, composites prepared from natural fibers have high-specific stiffness and lightweight compared to prepared from glass fibers (Baets et al., 2014; Barkoula et al., 2010).

These benefits encouraged numerous researchers to investigate mechanical properties of natural fibers reinforced composites (Barkoula et al., 2010; Oksman, 2001; Muralidhar et al., 2012; Quynh Truong Hoang et al., 2010; Gehring et al., 2012; de Vasconcellos et al., 2014; Towo and Ansell, 2008; Assarar et al., 2011).

As far as this many natural fibers like sisal, cotton, ramie, kenaf, flax, hemp, coir, bamboo, pineapple, jute, banana, abaca, rice husk and ramie have been used for replacing synthetic fibers as a reinforcement of composite (Aggarwal, 1992; Al-Oraimi et al., 1995; Li et al., 2007; Hamid et al., 2012).

The main disadvantages of natural fiber reinforced composites are higher moisture absorption, fiber soaking, and its bonding with matrix (Tsang et al., 2000). Because of these they give less mechanical properties. Several chemical treatments have been used to enhance the bonding between fiber and resin. Also mechanical properties of these composites can be improved by manufacturing hybrid composites.

The hybrid influence can be explained by assuming that low elongation fibers that break first form cracks that are connected by the nearby high elongation fibers, therefore tolerating the stronger, low elongation fibers to reach their ultimate strength (Kretsis, 1987).

Several authors studied the effect of fiber weight fraction and layering arrangement on mechanical behavior of hybrid composites. Madhusudan et al. (2013) fabricated Banana-Pineapple hybrid composites. They observed that hybridization of natural fibers gave major change in flexural strength when compared with separate reinforcement.

Yahaya et al. (2014) fabricated woven kenaf-kevlar hybrid composites using hand lay-up method. They observed that the mechanical strength of hybrid composite is function of fiber weight fraction.

Kumar et al. (2014) studied mechanical and free vibration properties of sisal-coconut sheath hybrid composites. They fabricated hybrid composites with different layering arrangements using compression molding technique with and without using chemical treatments to the fibers. They found that chemically treated composites showed better properties than untreated composites. They also found that silane-treated composite showed improved static mechanical and free vibration properties for all layering arrangements. They also analyzed the failure mechanism for composites using scanning electron microscopy.

Yahaya et al. (2016) investigated mechanical properties for aramid-kenaf hybrid composites with different fiber orientation for spall-liner application. They saw that woven kenaf hybrid composites give 20.78% higher tensile strength than unidirectional composites and 43.55% higher than mat specimen. They also saw that impact strength of woven kenaf hybrid composites is higher than unidirectional and mat specimens.

Mohanta and Acharya (2015) fabricated luffa cylindrica-glass epoxy hybrid composites using hand lay-up method with different layering arrangement. They achieved best flexural and impact strength for composite having luffa cylindrical fibers at center upheld by glass fibers on each side.

The properties of the hybrid composites can be varied by changing type of matrix, type of fibers, length of fiber, weight fraction of each fiber and their arrangement in hybrid composites (Mishra et al., 2003).

The main goal of this study was to fabricate woven glass-hemp polyester hybrid composites with diverse layering arrangement of woven fibers and to study their effect on tensile and flexural properties.

MATERIALS AND METHODS

To fabricate hybrid composites, woven hemp fiber yarn and woven glass fibers as reinforcement and polyester resin as matrix were used. Woven hemp and woven glass fibers were cut on required dimensions (300mm x 300 mm) which are shown in figure 1 and figure 2 respectively. The properties of fibers were tested using ASTM D3822 standard. The geometric and tensile properties of hemp yarn are shown in table 1. The tensile strength of E-glass is around 2400 MPa (Kistaiah et al., 2014).

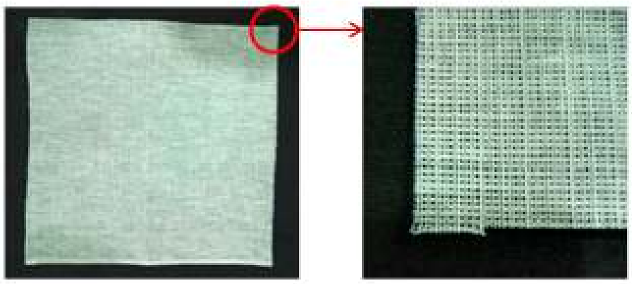

Fig. 1. Woven hemp fiber yarn

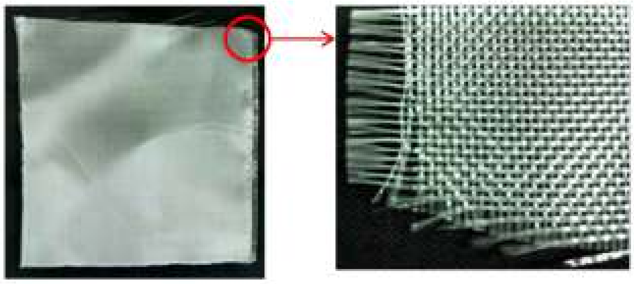

Fig. 2. Woven glass fiber

Table 1. Geometric and tensile properties of hemp yarn

Fiber	Diameter(mm)	Tensile strength (MPa)
Hemp yarn	0.2	426

Using hand lay-up method pure hemp ployester, pure glass polyester and glass-hemp polyester hybrid composites with six different layering arrangements were fabricated. The details of layering arrangements are shown in table 2.

The thickness of composite specimens was in between 3 mm to 3.5 mm and the overall weight

Table 2. Details of fiber layering arrangements

Sr. No.	Composite Plate Number	Stacking
1	H1	GGHHHHGG
2	H2	HHGGGGHH
3	H3	GGGGHHHH
4	H4	GHGHHGHG
5	H5	HGHGGHGH
6	H6	GHGHGHGH
7	H7	HHHHHHHH
8	H8	GGGGGGGG

Table 3. Tensile properties

Sr. No.	Composite Plate Number	Tensile strength (Mpa)	Tensile Modulus (Mpa)
1	H1	87.1	1300
2	H2	95.2	1530
3	H3	80.6	1450
4	H4	88.2	1390
5	H5	92.5	1360
6	H6	91.2	1380
7	H7	76.5	1280
8	H8	138	2490

fraction of fibers in hybrid composites was around 29 % (14% glass and 15 % hemp).

MECHANICAL CHARACTERIZATION

Mechanical Characterization (Tensile and Flexural) was carried out on Universal Testing machine (Tinius Olsen/LSeries H50KL). The test speed for tensile test and flexural test for specimens was 5 mm/min.

Tensile tests were carried out according to ASTM D638 standard. The specimens for the tensile testing were cut on the CNC vertical machining center. For each composite, five samples were tested.

Flexural tests were carried out according to ASTM D790 standard. The specimens for flexural test were cut in size of 127 mm x 12.7 mm. The span to depth ratio used was 16:1. For each composite, five samples were tested.

RESULTS AND DISCUSSIONS

Table 3 shows the results of tensile properties for different composite specimens.

Figure 3 shows difference in tensile strength with diverse layering arrangements. It can be seen that pure hemp polyester composite has lower tensile strength than pure glass. The tensile strength for the glass-hemp polyester hybrid composites with various layering arrangements varies between 80.6 MPa to 95.2 MPa which is greater than pure hemp polyester composite.

All the hybrid composites fabricated using same numbers (four) of glass and hemp layers and subjected to equal deformation through testing which show that the glass layers are mainly liable for total strength of hybrid composites. Glass fiber layers at center i.e. HHGGGGHH layering arrangement gives higher tensile strength (95.2 MPa) than other hybrid composites because glass fibers have higher modulus than hemp fibers.

Figure 4 shows typical stress-strain tensile curves for different composites. It is observed that pure glass

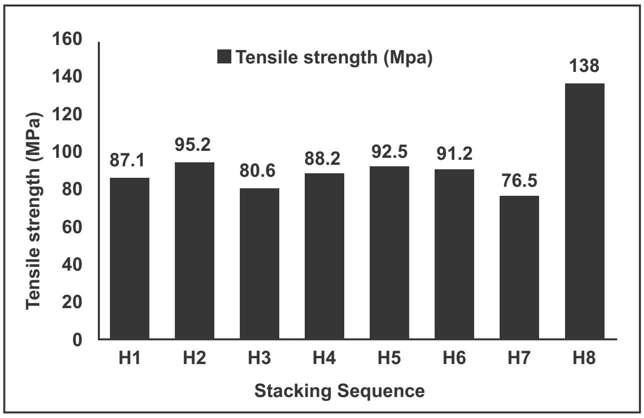

Fig. 3. Difference in tensile strength with diverse layering arrangements

polyester composites permitted higher strain before breakage because glass fibers are stronger and have high modulus than hemp fibers. The failure was driven mainly by fiber breaking as fibers were weaved. The hybrid composites showed intermediate behavior between pure glass and pure hemp polyester composites.

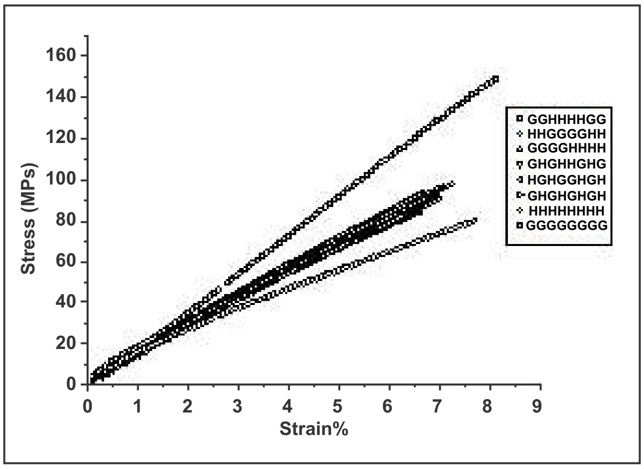

Fig. 4. Typical stress-strain tensile curves for various composites

The hybrid composite having GGHHHHGG layering arrangement showed flexural strength of 136 MPa which is nearer to that of pure glass polyester

Table 4. Flexural Properties

Sr. No.	Composite Plate Number	Flexural strength (Mpa)	Flexural Modulus (Mpa)
1	H1	136	5330
2	H2	131	4240
3	H3	61.6	1400
4	H4	119	4530
5	H5	106	2590
6	H6	92.6	3200
7	H7	106	4070
8	H8	142	4330

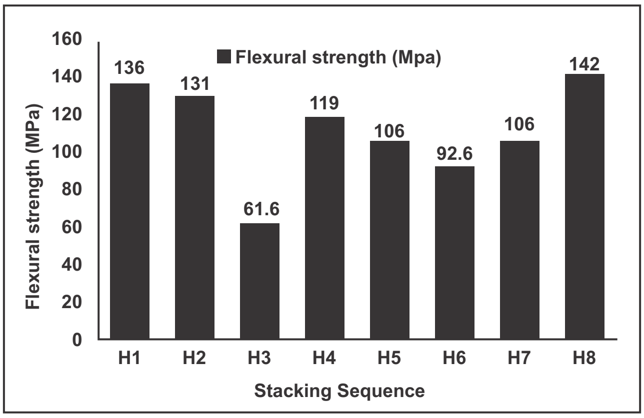

Fig. 5. Difference in flexural strength with diverse layering arrangements

composites. From this observation it can be said that the flexural strength of hybrid composites can be controlled by extreme layers of fiber.

CONCLUSIONS

The effect of layering arrangement on tensile and flexural properties for glass-hemp polyester hybrid composites were investigated in this study. Successful fabrication of glass-hemp polyester hybrid composites was done using hand lay-up method. The hybrid composites showed in-between properties between pure glass and pure hemp polyester composites.

For greater tensile strength for glass-hemp hybrid composites, there must be glass fiber layers at center as HHGGGGHH layering arrangement gives higher tensile strength (95.2 MPa) and for greater flexural strength for glass-hemp hybrid composites, there must be glass fiber layers at extreme places as GGHHHHGG layering arrangement gives maximum flexural strength.

ACKNOWLEDGEMENTS

This work is carried out as a part of research project sanctioned by Science and Engineering Research Board (SERB), New Delhi (SB/FTP/ETA-113/2012 dated 29-10-2015).

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