Composites: Part B 58 (2014) 251–258

Contents lists available at ScienceDirect

Composites: Part B

journal homepage: www.elsevier.com/locate/compositesb

Effect of stacking sequence on the flexural properties of hybrid composites reinforced with carbon and basalt fibers

I.D.G. Ary Subagia [a,b], Yonjig Kim [a,c,*], Leonard D. Tijing [d], Cheol Sang Kim [a], Ho Kyong Shon [d]

[a] Division of Mechanical Design Engineering, College of Engineering, Chonbuk National University, 567 Baekje-daero, Deokjin-gu, Jeonju, Jeonbuk 561-756, Republic of Korea
[b] Mechanical Engineering, Faculty of Udayana University, Denpasar, Bali, Indonesia
[c] Advanced Wind Power System Research Center, Chonbuk National University, Jeonju, Jeonbuk 561-756, Republic of Korea
[d] School of Civil and Environmental Engineering, University of Technology, Sydney (UTS), P.O. Box 123, Broadway, NSW 2007, Australia

A R T I C L E I N F O

Article history:
Received 6 September 2012
Received in revised form 2 October 2013
Accepted 25 October 2013
Available online 7 November 2013

Keywords:
A. Carbon fiber
Basalt fiber
A. Hybrid
E. Vacuum assisted resin transfer molding

A B S T R A C T

We investigated the effect of different stacking sequences of carbon and basalt fabrics on the flexural properties of hybrid composite laminates. The hybrid composites were fabricated using a vacuum-assisted resin transfer molding process. Three-point bending test was performed and the fracture surfaces were examined by scanning electron microscopy. The present results showed that the flexural strength and modulus of hybrid composite laminates were strongly dependent on the sequence of fiber reinforcement. All the stacking sequences showed a positive hybridization effect. The interply hybrid composite with carbon fiber at the compressive side exhibited higher flexural strength and modulus than when basalt fabric was placed at the compressive side. Here, the proper stacking sequence of basalt and carbon fiber layers was found to improve the balance of the mechanical properties of the hybrid composite laminate.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

In the last few decades, there has been increasing interest in using hybrid composite materials for structural applications due to their improved and better properties than their individual material constituent [1]. Hybrid composites are fabricated by combining two or more different reinforcement materials in a common matrix. By doing so, a new material is fabricated with new and additional properties [2]. Carbon fibers are widely known reinforcement materials due to their superior properties such as high mechanical strength and modulus of elasticity [3], low density, and good flame resistance. It makes carbon fiber irreplaceable in wide sectors of engineering technology such as for automobile, aircraft, ships, construction, and sport equipment [4–7]. However, carbon fiber composites are rather susceptible to stress concentration due to the brittleness of carbon fiber [4]. In addition, carbon fiber involves costly production. One way to improve the weakness of carbon fiber reinforced plastic (CFRP) composite is by replacing some layers of the carbon fiber by ductile fibers. This is called hybridization, which can lead to benefits in cost and enhancement of mechanical and physical properties, thus creating new types of materials. Park and Jang [8] incorporated polyethylene (PE) fibers with carbon fibers in an epoxy matrix to form a hybrid composite laminate. They used PE fibers because of its high elongation at break, and high specific strength and stiffness. They concluded that the mechanical properties of hybrid composite strongly depended on the reinforcing fiber position, such that, when carbon fiber was positioned at the outermost layer, the hybrid composite showed the highest flexural strength.

One of the recent promising materials for the fabrication of hybrid composites is basalt fiber. As an inorganic fiber, basalt fiber has good strength, modulus, better strain to failure than carbon fiber, high operating temperature range, good chemical resistance, can easily be processed, eco-friendly, and inexpensive [9–11]. Some researchers have indicated that basalt fiber has comparable or even better tensile and compressive properties than glass fibers [12,13]. Hence, basalt fibers gained increasing attention as a brand new reinforcing material for hybrid and composite laminates. Among the potential applications of the basalt-carbon fiber/epoxy composites would be on lightweight load bearing structures such as for vehicles. The weight of a vehicle directly impacts the energy consumption, i.e., less weight, less consumed energy. Carbon fiber composites are now being adopted in the automotive industry due to their excellent properties. The use of CFRP in cars could decrease the vehicle's weight by 40–60% [14]. However, the high cost of carbon fiber only limits its application to luxury cars and aerospace vehicles. Thus, there is a need to reduce the cost of CFRP without sacrificing a lot in its mechanical performance. The promising

* Corresponding author at: Division of Mechanical Design Engineering, College of Engineering, Chonbuk National University, 567 Baekje-daero, Deokjin-gu, Jeonju, Jeonbuk 561-756, Republic of Korea. Tel.: +82 63 270 4763; fax: +82 63 270 2460.
E-mail address: yonjig@jbnu.ac.kr (Y. Kim).

1359-8368/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.compositesb.2013.10.027

Table 1
Properties of the present carbon and basalt plain woven fabrics.

	Carbon fiber (C120-3 K)	Basalt fiber (EcoB4-F210)
Fabric weight (g/m^2)	200 ± 10	210 ± 10
Warp construction (Thread count/in)	12.5	22
Fill construction (Thread count/in)	13.5	26
Fabric thickness (mm)	0.25 ± 0.02	0.19–0.20

Table 2
Properties of the present epoxy resin (HTC-667C) material.

Specific gravity (25 °C)	1.16 ± 0.02
Viscosity (cps, 25 °C)	1200 ± 500
Hardener	Modified aliphatic amine
Tensile strength (MPa)	63.7
Compressive strength (MPa)	88.2
Flexural strength (MPa)	81.3

properties and low cost of basalt fibers could be a potential candidate as reinforcement for CFRP to obtain a lightweight and low-cost material (since basalt fiber is much cheaper than carbon fiber) with comparable mechanical performance with CFRP. Several researchers have studied the incorporation of basalt fibers with other reinforcement materials in composite laminates. Lopresto et al. [9] reported better Young's modulus, compressive strength and flexural behavior for basalt fiber-reinforced plastic (BFRP) compared to glass fiber reinforced plastic, but the latter had better tensile strength. Manikandan et al. [15] concluded that basalt fiber composites showed generally superior properties than those of the glass fiber reinforced polymer. Extensive studies have been done on the improvement of properties of CFRP and BFRP by incorporating nanoparticles [16–18], filler fibers [2,19], and surface modifications [20] in the composite material. However, only very few studies have been carried out on the combination of carbon fiber and basalt fiber to affect the hybrid composite material properties. The hybridization of carbon fibers with basalt fibers would ultimately reduce the costs and expand the application fields of the hybrid composite material [21]. To the authors' best knowledge, no study has been carried out yet on the effect of different stacking sequences and number of basalt fiber and carbon fiber layers in a hybrid composite laminate.

In this work, interply hybrid composites were prepared with carbon fiber and basalt fiber as reinforcements and epoxy resin as the matrix. Some of the factors that can influence the mechanical performance of the composite from the reinforcement include fiber orientation, fiber shape, fiber material, and length of fiber [22]. The objective of this study was to investigate the effect of different stacking sequences of fabric layers on the overall mechanical properties of the hybrid composite. Three-point bending test was carried out to predict the flexural strength and modulus of hybrid composites, while scanning electron microscopy (SEM) was utilized to check the fractured surfaces of hybrid composite after flexural test.

2. Experimental

2.1. Materials

Carbon fiber (C120-3K, woven, 200 ± 10 g/m^2) was supplied by Hyun Dai Fiber Co. Basalt fiber (EcoB4-F210, woven, 210 ± 10 g/m^2) was supplied by Seco-Tech. A mixture of epoxy (HTC-667C) with modified aliphatic amine hardener was supplied by Jet Korea Co. and was used as the matrix. Tables 1 and 2 show the properties of the present woven fabrics and epoxy resin, respectively.

2.2. Fabrication of hybrid composite laminates

The hybrid composite laminates were fabricated using a vacuum-assisted resin transfer molding (VARTM) process. The VARTM is a liquid molding technique to manufacture complicated composite structures [23]. Generally, VARTM process consists of five steps, which include: (a) mold preparation and fabric lay-up; (b) sealing of the mold and creating a vacuum; (c) resin preparation and degassing; (d) resin impregnation, and; (e) curing of fabricated panels. Here, the hybrid composite laminates were fabricated following the flowchart shown in Fig. 1a and the curing process in Fig. 1b. The schematic layout of the present VARTM set-up is shown in Fig. 2. Carbon and basalt fabrics, cut to a size of 250 mm × 250 mm, were arranged with different stacking sequences on a bronze plate mold (300 mm × 300 mm). In the present study, for each configuration of carbon–basalt/epoxy composite laminate, a total of ten plies of plain carbon and basalt woven fabrics were stacked in every laminate. The weight fraction of both carbon and basalt fibers was about 62 wt% in every panel of hybrid composite laminate. The lamina was then wrapped with a vacuum bagging film using a sealant tape (AT200Y). The epoxy resin with hardener (epoxy/hardener ratio of 5:1) was then injected into the mold through a vacuum pump with a pressure of −80 kPa for more than 40 min. The wetted fiber reinforcements were cured in an autoclave for 2 h at a constant temperature and pressure of 65 °C and 80 kPa, respectively.

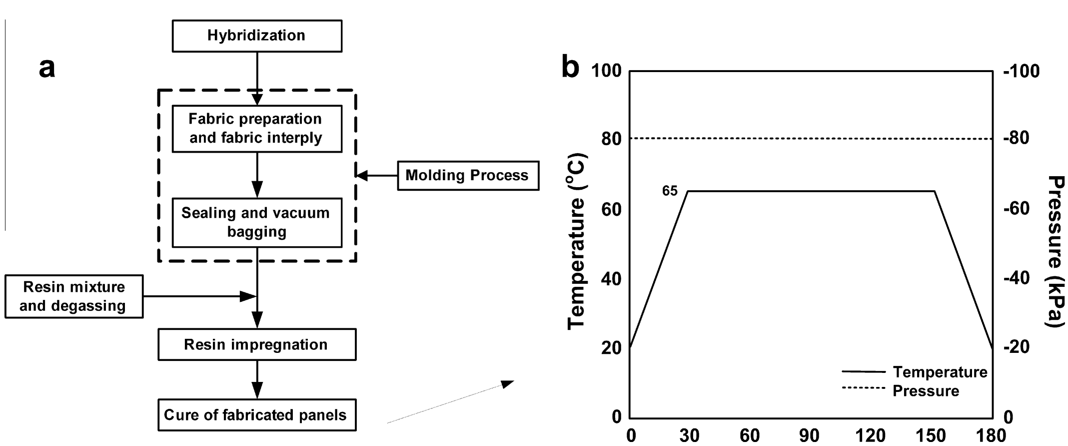

Fig. 1. (a) Process flow chart used in the fabrication of hybrid composites using VARTM, and (b) the curing process.

Download English Version:

https://daneshyari.com/en/article/817848

Download Persian Version:

https://daneshyari.com/article/817848

Daneshyari.com