Bending strength of CFRP laminated adhesive joints fabricated by vacuum-assisted resin transfer molding

Mahmoud R. Abusrea, Seung-Wook Han, Kazuo Arakawa, Nak-Sam Choi

PII: S1359-8368(18)30941-7

DOI: 10.1016/j.compositesb.2018.08.041

Reference: JCOMB 5871

To appear in: *Composites Part B*

Received Date: 23 March 2018

Accepted Date: 10 August 2018

Please cite this article as: Abusrea MR, Han S-W, Arakawa K, Choi N-S, Bending strength of CFRP laminated adhesive joints fabricated by vacuum-assisted resin transfer molding, *Composites Part B* (2018), doi: 10.1016/j.compositesb.2018.08.041.

Bending strength of CFRP laminated adhesive joints fabricated by vacuum-assisted resin transfer molding

Mahmoud R. Abusrea[a,b], Seung-Wook Han[c], Kazuo Arakawa[d], Nak-Sam Choi[c*]

[a] Faculty of Engineering, Cairo University, Giza 12613, Egypt
[b] Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Fukuoka 816-8580, Japan
[c] Department of Mechanical Engineering, Hanyang University, Ansan 426-791, South Korea
[d] Research Institute for Applied Mechanics, Kyushu University, Fukuoka 816-8580, Japan
* Correspondence to: Nak-Sam Choi. email: nschoi@hanyang.ac.kr

Abstract

The laminated joints used in this work were adhesive joints constructed using two dry carbon fiber halves. Some improvements were introduced to the joints to enhance their bending strength performance: stitching of the two halves together by fiber bundles and inserting extra carbon fiber covers in the joint connection. We studied three adhesive joints: a conventional basic and two improved laminated joints. All joint specimens were fabricated using a vacuum-assisted resin transfer molding (VARTM) process. The joints were evaluated with a bending test, and were compared to the bending strength of a jointless carbon fiber reinforced plastic (CFRP) laminate. Two acoustic emission (AE) sensors were placed on the specimen to monitor the fracture progresses during the test. The improved laminated joints, stitched and multiple-cover overlapped joints, showed enhanced bending strength and joint efficiency. The improvement depended significantly on the number of carbon fiber layers. The maximum increase was 24% for the stitched laminated joint of 5 layers and 58% for the multiple-overlapped joint of 6 layers, respectively. Such high joint efficiency was due to the effect of the carbon fiber reinforcement on the joints, by which many carbon fibers supported the strength in advance of reaching the maximum load point, as confirmed by AE measurement analysis.

Keywords— CFRP joints, vacuum-assisted resin transfer molding, bending strength, joint efficiency, acoustic emission

1. Introduction

Carbon fiber reinforced plastic (CFRP) composites have a significant advantage for their application in engineering structures, which is derived from their high strength-to-weight ratio [1]. They have been applied to heavy-duty structures in the aviation, spatial [2, 4], automotive [3], shipbuilding [4], and wind turbine [5] industries. These applications often involve large-scale manufacturing, and some parts are joined together from smaller components. In this case, the mechanical performance of the CFRP structure is highly dependent on the properties of the joints.

Because composite joints work as crucial load-carrying elements, their design and analysis are key processes in large-scale applications in order to accomplish light weight and efficient composite structure integration [6]. There are conventional mechanical fasteners, such as bolts, pins, and rivets, to join CFRP structures [7]. These mechanical joints are often preferred because they can be disassembled for repair and/or recycling [8]. However, drilling the holes necessary for joining the parts may induce localized damage in the composite owing to stress concentration when the joint is loaded. In contrast, adhesively bonded joints may have mechanical advantages in comparison to bolted joints because the reinforcing fibers are not cut, and thus, the stresses are transmitted more uniformly [9]. Therefore, bonded joints can provide high strength-to-weight ratio and good structural integrity [10-12].

Nowadays, adhesive joints are widely applied in many composite structures for aerospace, turbine, and ship designs [13]. These engineering structures are subjected to combinations of static, fatigue, and impact loadings. Not only conventional single-lap [9], double-lap [14], and stepped [15] adhesive joints, but also improved adhesive joints have been studied to ameliorate the mechanical performance of adhesive composite joints. For instance, Löbel et al. [16] enhanced the tensile strength by introducing z-pinning into CFRP double-lap joints. Another approach for adhesive joint improvement was reported by Mouritz et al. [17], who placed spiked metal sheets in the bond-line to facilitate mechanical load dispersion. Furthermore, stitching was proposed as a technique for reinforcing laminated joints. Dransfield et al. [18] and Heß et al. [19] clarified that the stitching enhanced the fracture toughness of laminated composites under peel loading. Kim et al. [20] made some stepped-lap joints as a function of the number of steps,