Materials and Design 32 (2011) 4803–4809

Contents lists available at ScienceDirect

Materials and Design

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

Qualitative separation of the effect of voids on the bending fatigue performance of hygrothermal conditioned carbon/epoxy composites

Aying Zhang [a,b], Dihong Li [a], Haibao Lu [a], Dongxing Zhang [a,*]

[a] Harbin Institute of Technology, Harbin 150001, PR China
[b] Harbin University, Harbin 150086, PR China

ARTICLE INFO

Article history:
Received 19 April 2011
Accepted 15 June 2011
Available online 23 June 2011

Keywords:
B. Laminates
F. Defects
E. Fatigue

ABSTRACT

This study investigates the effect of voids on the static bending and bending fatigue properties of T300/914 composite laminates that are exposed to room temperature, hygrothermal and drying environment, respectively. Displacement-controlled three-point bending fatigue tests were conducted on specimens, while damage in the composite was continuously recorded with a metallurgical microscope. After 40,000 cycles the fatigue test was stopped and residual properties were measured on the tested specimens. Reduction in material strength was found to depend on the level of the specimen's void content. The changes in weight and size gradually increased with an increase in porosity from 0.33% to 1.50% in the hygrothermal environment. It is found that the maximum rate of dimensional change occurred in the thickness direction. Both bending strength and fatigue performance were reduced with increasing porosity. The damage evaluation of aged specimens was more severe than non-aged and drying specimens.

1. Introduction

Carbon fiber reinforced polymer matrix composites have been used extensively in various fields including the aerospace, automobile, marine, and defense industries; largely due to their high strength/weight ratios [1,2]. These applications usually require a comprehensive understanding of their mechanical behavior in order to protect the composite laminates from negative environmental effects. For instance, bending strength, bending fatigue performance, residual bending strength at various temperatures, moisture, and mechanical loading all need to be considered [3]. Most of the previous mechanical studies have dealt with bending fatigue performance of the structural composite laminates where the matrix, whether it is a thermoset or thermoplastic, was well below its glass transition temperature, T_g. In these cases, the effect of voids on the mechanical properties of thick composite laminates is awfully neglected [4]. However, most of mechanical properties, such as the longitudinal compressive modulus, strength, bending, and shear properties, are severely influenced by voids [5]. More recently some researchers have noted that the impact toughness of composite laminates is also void sensitive [6].

Voids are among the most common manufacturing induced defects in composites [7,8]. There are several causes of void formation. The first involves the entrapment of gases (most often wet air) during impregnation of the fiber reinforcement with resin or during the lay-up. A second case entails volatiles arising from the resin system itself. Void growth may occur via diffusion of air or by coalescence with other surrounding voids. Beyond these two phenomena, void growth can also occur as the temperature increases [9]. Researchers have shown that voids have detrimental effects on the strength of composite laminates [10–13].

Structural components are subjected to static or cyclic (fatigue) loading of different types during the service condition. Fiber-reinforced plastic (FRP) (also fiber-reinforced polymer) is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually fiberglass, carbon, or aramid, while the polymer is usually an epoxy, vinylester or polyester thermosetting plastic. Generally, FRC with a polymeric matrix under cyclic loading show a degradation of performance as a result of damage [10]. Costa et al. [3] indicated that voids decrease the static strength and fatigue life of composite laminates, and cause a greater susceptibility to water penetration and environmental conditions. Chambers et al. [12] reported that increasing void content reduces both flexural strength and fatigue performance by acting on both the initiation and propagation stages of failure. The research supports the concept of a 'critical defect' which takes into account the defect's size, shape, and distribution, as well as the composite's fracture toughness. Almeida and Nogueira Neto [13] suggested that voids have a strong detrimental effect on the fatigue life of composite structures if the void content is above a critical value. Almeida reported that voids may cause a remarkable decrease in fatigue life while exerting only a minor effect on the static flexural strength.

* Corresponding author. Tel./fax: +86 451 86281403.
E-mail address: zhangdongxing@hit.edu.cn (D. Zhang).

0261-3069/$ - see front matter
doi:10.1016/j.matdes.2011.06.028