Journal of Fiber Bioengineering and Informatics 11:1 (2018) 29–39
doi:10.3993/jfbim00285

Effects of Hot Water Absorption and Desorption on Solid Particle Erosion of Poly(Ethylene Terephthalate)-Based Composites *

Bing Liu [a], Peng Zhu [a], Li-Min Bao [b,*]

[a] *Department of Bioscience and Textile Technology, Interdisciplinary Graduate School of Science and Technology, 3-15-1 Tokida, Ueda, Nagano 386-8567, Japan*

[b] *Faculty of Textile Science and Technology, Shinshu University, 3-15-1 Tokida, Ueda, Nagano 386-8567, Japan*

Abstract

Water aging is one of the causes of fiber-reinforced thermoplastic (FRTP) degradation during long-term service. It affects not only the mechanical properties of FRTPs, but also their erosion by solid particles. However, little research has been done on the effects of water aging on the erosion of FRTPs. The aim of this research was to study the effects of hot water absorption and desorption on the solid particle erosion of carbon-fiber-reinforced poly(ethylene terephthalate) (PET) composites. It was found that the PET-based composite erosion rate increased with increasing immersion time and decreased after redrying, whereas, the PET resin erosion rate decreased after hot water treatment. These effects depended on changes in the resin/fiber interfacial strength. Changes in the interfacial strength were investigated using short beam shear tests and dynamic mechanical analysis. It can be found that the interlaminar shear strength of the composite decreased sharply after hot water treatment based on the results of short beam shear tests and the storage modulus and glass-transition temperature decreased after hot water treatment according to the results of dynamic mechanical analysis.

Keywords: Solid particle erosion; Water absorption; Water desorption; Water Aging

1 Introduction

Fiber-reinforced plastic (FRP) composites have been used as alternatives to steel, metal, and wood in various applications over the last few decades. This is because of their high specific tensile strengths, modulus-to-weight ratios, and corrosion resistance. More recently, interest has shifted from thermosetting to thermoplastic matrices. This has extended the composite field in terms of thermoformability and improved recyclability because the thermoplastic matrix can be

*Project supported by Shinshu University Advanced Leading Graduate Program from the Ministry of Education, Culture, Sports, Science, Technology and financial support.

*Corresponding author.
Email address: baolimin@shinshu-u.ac.jp (Li-Min Bao).

1940–8676 / Copyright © 2018 Textile Bioengineering and Informatics Society
Mar. 2018

molten multiple times [1]. Because of its characteristic high tensile strength and modulus, light weight, solvent resistance, and relatively low cost, semi-crystalline poly(ethylene terephthalate) (PET) is a promising thermoplastic matrix for many applications [2]. However, the melt viscosities of thermoplastic matrices (500-5000 Pa s) are considerably higher than those of thermosetting resins (typically $<$100 Pa s) [3, 4], which makes it more difficult for the resin to impregnate a fabric. In our previous work, to solve this problem, we developed a solution impregnation method, which deceases the polymer viscosity, and used it to manufacture fiber-reinforced thermoplastics (FRTPs) with excellent mechanical properties [5].

In practical situations, materials degrade during long-term service. For example, the majority of wind turbines are installed near the seaside, where humidity is high. The effects on these materials of long-term exposure to a high-humidity environment are similar to those of water [6]. The tensile strength and elastic modulus of a composite decrease significantly with increasing water absorption [7] because the absorbed moisture or water can cause swelling and plasticization of the polymer matrix and debonding at the fiber/matrix interface.

Another concern in many energy applications is the wear and damage of composite surfaces caused by solid particles in the air [8], which can lead to lengthy maintenance periods, security risks, and other serious problems. PET, the common thermoplastic matrix used in the present work, is hygroscopic, i.e., it absorbs water from its surroundings (at equilibrium about 0.3% in 24 h), therefore the interface between the reinforcing material and PET is weakened by water absorption. It has been reported that the erosion resistance of composites depends on the fiber/matrix interface [9], therefore for composites operating in high-humidity environments for lengthy periods, it is important to investigate not only the erosion behavior of dry composites, but also the erosion behavior of the composites after water absorption. Most research has focused on the effects of various factors (e.g., impact angle, impact velocity, and amount of fibers) on solid particle erosion of FRTPs under dry conditions [10, 11]. However, less research has been performed on the effects of moisture/water aging on the erosion of FRTPs. It is therefore important to clarify the solid particle erosion behavior of FRTPs degraded by water aging.

The objective of this research was to clarify the effects of water absorption and water desorption on the solid particle erosion of carbon-fiber-reinforced PET thermoplastics. Higher temperature can accelerate the rate of water absorption, which can greatly shorten experimental time, therefore the kinetics of water absorption by carbon fiber/PET and PET resin at high temperatures were investigated. Short beam shear tests were used to determine the effects of water absorption and desorption on the interlaminar shear strengths (ILSSs) of carbon fiber/PET specimens. Scanning electron microscopy (SEM) was used to examine the eroded surfaces to study the effects of water absorption at the microstructural level. Changes in the viscoelastic behaviors of aged and unaged materials were examined using dynamic mechanical analysis (DMA).

2 Experimental Details

2.1 Materials

Carbon fibers are widely used as reinforcing materials because of their superior properties such as high mechanical strength and modulus of elasticity, low density, and good flame resistance [12].

The thermoplastic matrix used in this study was semi-crystalline PET supplied by the Toyobo