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Effect of new epoxy matrix for T800 carbon fiber/epoxy filament wound composites

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Abstract

A new epoxy resin matrix with good adherence to T800 carbon fibers (T800 CFs) in filament winding was developed by addition of hardener and resin diluter. Interfacial behavior of the T800 CF/epoxy composites was analyzed according to the Naval Ordnance laboratory (NOL) ring test, short-beam-shear test and fracture surface observation. Meanwhile, scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FT-IR), X-ray photoelectron spectroscopy (XPS) and atomic force microscopy (AFM) were used in analysis of the interfacial behavior. The interfacial properties of the T800 CF/epoxy filament wound composites were improved by optimizing the matrices through increasing the toughness and reducing the viscosity, which is an important factor in influencing the wettability of T800 CFs. The Interlaminar shear strength (ILSS) of the unidirectional T800 CF/epoxy composites and the tensile strength of NOL-ring in this work reached to 123 and 2570 MPa, respectively. Also, the interfacial adhesion was much improved by the chemical reactions between the new matrix and the sizing on the T800 CFs.

Keywords: A. T800 carbon fiber; E. Filament winding; A. Composites; B. Interfacial properties; A. Resin matrix

1. Introduction

Mechanical performance of carbon fiber reinforced polymer (CFRP) composites depends not only on the properties of reinforcing fiber and matrix, but also on the fiber/sizing and sizing/matrix interfacial properties [1]. Therefore, many scientific efforts have been devoted to modify carbon fibers by a variety of methods such as gas-phase, liquid-phase and continuous anodic oxidation [2–6], and then to apply a very thin (usually on nanometer scale) coating of a prepolymer or resin to the modified carbon fiber surface [7–10] for the purpose of improving the interfacial properties between the carbon fibers and matrix [11,12], and meanwhile to prevent the fibers from damage through the process of manufacture. Many investigations on the nature of the fiber/sizing and sizing/matrix interphases have proved that the nanometer scale sizing plays a dominant role in the interfacial adhesion of the carbon fiber to resin matrix [13,14]. The functional groups of the sizing can react and/or interact with the matrix, which give rise to strong adhesion between the fiber and the matrix.

The filament winding process is an efficient and viable technique, and commonly using in the mass production of advanced fiber reinforced composites such as pressure vessels, pipes and shafts. Many of these kinds of filament wound composites are also using in such applications as aviation and spaceflight for their high strength, light weight and high stiffness. However, owing to the extreme inertness of surface caused by the alignment of graphitic crystallites [15,16], high performance carbon fibers such as T800/T1000 or M50J/M60J always failed to reach the expected

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properties in their reinforced composites. Therefore, modification of the interfacial behaviors between carbon fiber and matrix, and between matrix and sizing is a feasible way to improve the mechanical properties of the high performance CFRP.

In this research, development of new epoxy resins is tried to obtain high performance T800 CF/epoxy composites. For this purpose, a combination of hardeners was carried out and a diluter was added to the combined matrix, and then the effect of the new epoxy matrix was investigated according to the NOL-ring test and other mechanical property test methods. SEM, FT-IR, XPS and AFM were used to analyze the interfacial behaviors. Also, sizing effect was studied in consideration of chemical reactions between sizing and matrix, which could improve the performance of composites.

2. Experimental

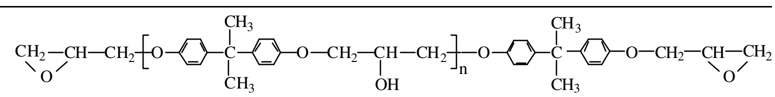
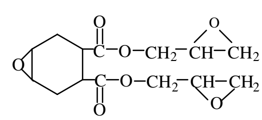
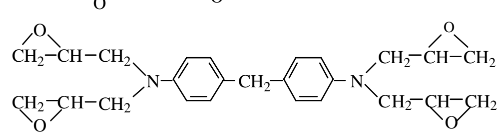
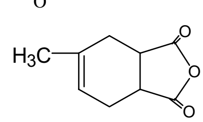
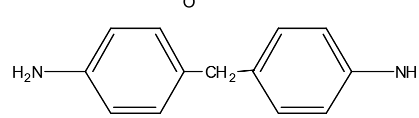
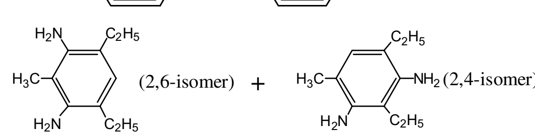
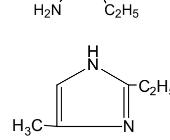
2.1. Materials

Three types of epoxy resins were used in this work. The diglycidyl ether of bisphenol A (DGEBA) type epoxy resin was supplied by Yueyang resin factory China (epoxy value, 0.51), the diglycidyl ester of aliphatic cyclo (DGEAC) type epoxy resin was provided by Tianjin Jindong chemical factory (epoxy value, 0.85), and the tetraglycidyl diaminodiphenyl methane (TGDDM) type epoxy resin was supplied by Shanghai Institute of Synthetic Resins (epoxy value, 0.80).

MeTHPA, DDM and 2,4-EMI, bought from Tianjin Synthetic Material Research Institute, China, were used as hardeners, 1 phr of 2,4-EMI was added into matrix when the hardener was MeTHPA. The unit phr is an abbreviation of part per one hundred base resins. A mixture hardener of two diethyltoluene diamine (DETDA) isomers (74–80% 2,4-isomer and 18–24% 2,6-isomer) was purchased from Lonza, Switzerland. The chemical structures of the resins and hardeners are shown in Table 1.

The liquid aromatic diamine (DETDA) was selected to be a less reactive hardener with an epoxy resin [17]. So in this work, it was mixed with the hardener DDM in a specific ratio to prolong the shelf life of the matrix. A diglycidyl ether type diluter with a low molecular weight was synthesized by authors to reduce the viscosity of resins. Both T300 and T800 CFs were obtained from Toray Co., Japan. T800 CFs possess a diameter of 5 μm, a tensile strength of 5.5 GPa, a modulus of 294 GPa and an elongation of 1.9%.

Table 1
Chemical structures of the materials

Materials	Chemical structures
DGEBA	
DGEAC	
TGDDM	
MeTHPA	
DDM	
DETDA	
2-methyl-4-eshyl-EMI	
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