ENHANCEMENT OF INTERFACE PROPERTIES OF ARAMID FIBER COMPOSITES WITH EFFECTIVELY ADHESIVE EPOXY MATRIX

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Keywords: Aramid fibers, Interface, effectively adhesive epoxy, interlaminar shear strength (ILSS)

ABSTRACT

An effectively adhesive epoxy (EAEP) has been synthesized by the reaction of isocyanate with epoxy resin, and . The strengthen of the EAEP adhesive property was ascribed to introducing polar group in epoxy molecular chain, molecular structural as shown in Fig.1. The Process performance, mechanical and micro fracture morphology of EAEP resin matrix were characterized. The interfacial properties of aramid fiber/epoxy composites were investigated by the methods such as interlaminar shear strength (ILSS). the result showed that interracial binding strength of the composites can be remarkbly improved which attributes to the fact that the polar groups are introduced into the molecular structure of resin.

1 INTRODUCTION

Aramid fiber-reinforced epoxy (AFRP) composites have been widely used for a variety of high-performance applications especially in aerospace and military due to their outstanding mechanical properties, innovative design possibilities, and advanced manufacturing methods[1, 2]. However, the poor interfacial bonding strength between aramid fibers and resin made AFRP prone to interface failure which has greatly limit its further applications[3, 4], owing to chemical inertness and surface smooth of aramid fiber.

Various methods have been attempted to modified resin matrix to improve the interfacial properties of aramid fiber composites include improving matrix adhesive performance and toughening epoxy resin. Application of high polarity resin is one of the effective means to improve matrix adhesive performance, further, affecting the interfacial and mechanical properties of composites[5, 6]. Toughening can overcome the inherent brittleness of epoxy polymer to match the fiber toughness. According to Morgan's reports [7, 8], the toughness of resin matrix should be matched with that of the fiber To reduce the interface stress. In addition, the viscosity of resin matrix would be related to the wet-out ability of the fiber, which will reduce the bubbles and defects among interface[9, 10].

There for, the purpose of this study is synthesizing of a effectively adhesive epoxy, which had been modified by isocyanate, for preparing high performance aramid fiber composites. To obtain the purpose, (i) Effectively adhesive epoxy was synthesized, and the process performance, mechanical and micro fracture morphology of EAEP resin matrix were characterized. (ii) The aramid fiber/EAEP composite was prepared, the adhesion between the modified aramid fibers and the resin matrix was evaluated through interlaminar shear strength.

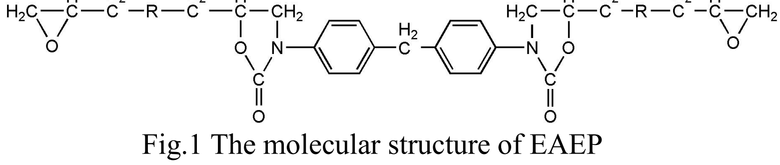


Fig.1 The molecular structure of EAEP

2. EXPERIMENTAL

2.1 Material

Diglycidyl ether of bisphenol-A (E-51, E-20) was supplied from Nanya Epoxy Resin Co., Ltd. Diphenyl-methane-diisocyanate (MDI) was provided by Wanhua Chemical Group Co.,Ltd. Dicyandiamide (DICY) and 2-Ethyl-4-methylimidazole was purchased from Beijing Reagent Co., Ltd. Aramid fiber fabric(23tex) was kindly provided by Jiangsu Tianniao high and new technique Co. Ltd.

2.2. Preparation of epoxy matrix

Two kinds of epoxy matrix were prepared consisting of general epoxy resin, EAEP resin. E-51 and E-20 (weigh ratio of 3:7) were mixed to form the general epoxy resin at 120℃. To fabricate EAEP, diphenyl-methane-diisocyanate (30 wt% of EP) was added to Diglycidyl ether of bisphenol-A (E-51), with 2-Ethyl-4-methylimidazole (0.05 wt% of EP) as catalyst by a mechanical mixer at 180 ℃ for 150 min. Then E-51 as diluent was added (40 wt% of EP) to form EAEP resin. Hardener DICY (30 wt% of EP) was then added to the general epoxy resin, EAEP resin, respectively.

2.3 Preparation of aramid fiber prepreg

First, the epoxy resin was applied to a release paper by shear rollers at 95 ℃ to prepare a uniform resin film, and the amount of the resin per unit area was controlled at (42.5 ± 2) g/m2. Then, the resin films were superimposed on each side of aramid fiber bundles heated up to 120 ℃ and pressurized so that the aramid fibers were impregnated with resin matrix to form a prepreg.

2.4 Sample preparation

The mixture was transferred to an open mold and evacuated to a vacuum oven until no visible bubble could be found, then cured at 120℃ for 2.5 h. Dumbbell shaped specimens with the dimension of 75 mm × 10 mm × 4 mm were prepared and specimens with the dimension of 80mm × 15mm × 4mm, according to Chinese standard GB/T 2567-2008 for tensile tests and bend test. Following the same curing stages, 17 plies of 100mm × 100mm prepregs were laminated for interlaminar shear strength (ILSS).

2.5 Characterizations

All the mechanical properties were tested on a universal testing machine (Instron 1211). The SBS tests were conducted to determine ILSS that was calculated from the maximum load and the known dimensions of the specimens. ILSS test specimens of 20 mm × 10 mm × 2 mm were prepared and measured at a crosshead speed of 2 mm/min according to JC/T 773-2010. The tensile fibre bundle test (TFBT) was measured at a crosshead speed of 1 mm/min and the elongation of specimen during tension was accurately measured by the extensometer with a gauge length of 25 mm.

The morphology of the fracture surfaces of bend test specimens and the aramid fiber/EAEP composite were elucidated by Scanning electron microscope (SEM).

3. RESULTS AND DISCUSSION

3.1 Properties of EAEP resin

Fig.2 and Fig.3 show the mechanical properties of EAEP resin and general epoxy resin. Tensile strength and bending strength of the EAEP resin has been improved obviously compare to the general epoxy resin. To elucidate the modified effect， the fracture surfaces of specimens were examined by SEM as shown in Fig.4. The general epoxy resin exhibited a typical brittle fracture, indicating the aramid composite easy to create the interface stress. While SEM images showed rough fracture surface and intense matrix plastic deformation in EAEP resin, suggesting much energy dissipating during fracture, explained the improvement of mechanical properties. This can also explain the increasing of strength.

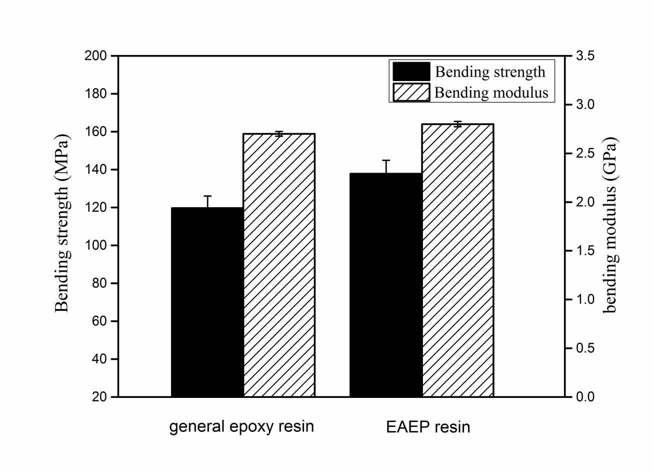


Fig.2 the bending strength of different systems

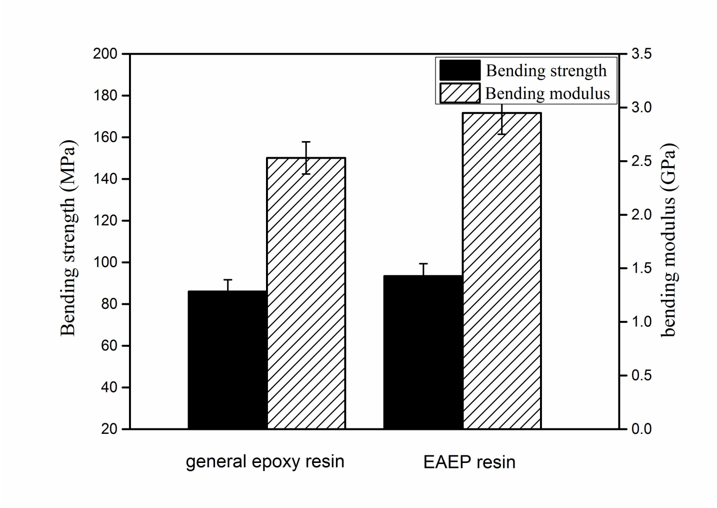


Fig 3 the tensile strength of different systems

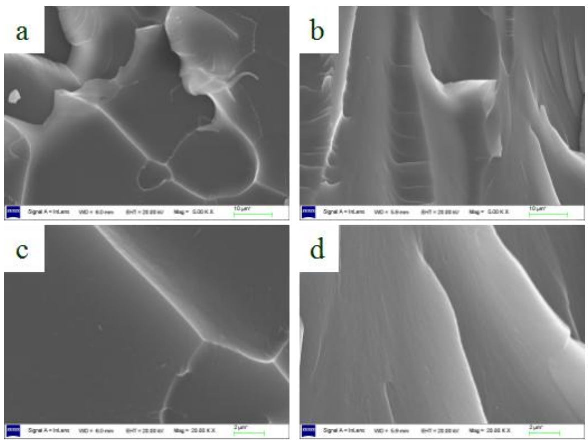


Fig.4 SEM images of different epoxy resin systems: (a、c) general epoxy resin;
（b、d） EAEP resin

3.2 Properties of aramid fiber/EAEP composite

Fig.5 shows the ILSS of AFRP composites. The ILSS value of composites with general epoxy matrix is only 38 MPa for its weak interfacial adhesion. while that of aramid/EAEP resin composite was increased by 22%. The EAEP resin had significant advantage on ILSS. The using of EAEP resin substantially enhanced toughness due to the introduction of polar groups. The fracture morphologies of AFRP composites are exhibited in Fig.6. The matrix in the interlaminar region of AFRP composite with general epoxy resin was thin and rare, as evidenced by the clean fiber surfaces, indicating weak interfacial adhesion between prepreg layers (Fig. 6(a、c)). Fig.6(b、d) showed a rough surface, even fibre has been split, indicating much energy consumption during interlaminar fracture.

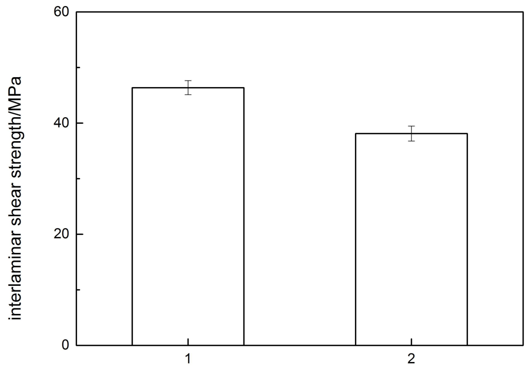
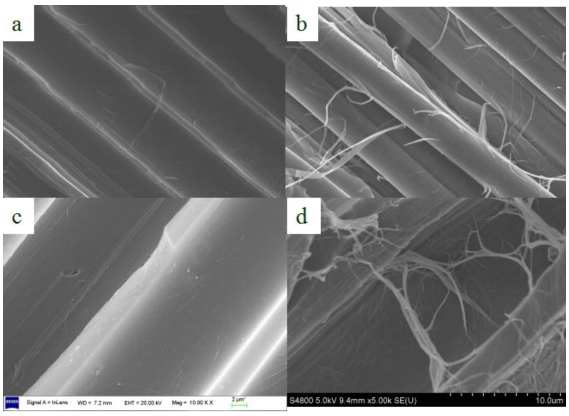


Fig. 5 the interlaminar shear strength test of aramid/EAEP resin composites (1) and aramid/general epoxy resin (2).



(a) (b)

Fig. 6 the SEM images of aramid/EAEP resin composites (a、c) and aramid/general epoxy resin (b、d).

4. CONCLUSION

The adhesive performance of epoxy can be improved by reacted with isocyanate, owing to the content of polar groups increased, besides, the strength of EAEP resin matrix has been enhanced. From the SEM images of specimens fracture surfaces, toughness of EAEP resin is improved, compared to general epoxy resin. The aramid fiber/EAEP resin exhibited excellent interface properties, which was attributed to the effectively adhesive propert and the enhanced toughness of EAEP resin matrix, the effectively adhesive propert provided a stronger interface and the suitabe thoughness of matrix can matching the ductile fiber thus the interface stress was relieved. It can be obtained from the interlaminar shear strength test and the morphology of the composite fracture surfaces.

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