Effects of plasma treatment pressure on Aramid fiber III/BMI composite humidity resistance properties

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Abstract. The effects of oxygen plasma treatment pressure on Aramid Fiber III chemical structure and its reinforced bismaleimides (BMI) composite humidity resistance properties were investigated. The aramid fiber III chemical structure under different plasma treatment pressure were measured by FTIR. The composite interlaninar shear strength with different plasma treatment pressure before and after absorption water were tested by short-beam bending test method, respectively. The FTIR results showed that oxygen plasma treatment didn’t change the fiber bulk chemical structure. The composite humidity resistance of interlanimar shear strength was enhanced after plasma treatment. The retention rate of composite interlaninar shear strength was above 95%.

1. Introduction

The aramid fiber III are widely used in the fields of aviation, automobile due to its excellent properties such as low density, high strength and modulus[1, 2]. However, because of its smooth and chemical inert fiber surfaces, which limit its application in composite system [3, 4]. Thus, the fiber surface need to modify to improve its surface properties. In our previous work, plasma is proved an effective method to enhance the aramid fiber surface wettability and its reinforced composite interfacial properties [5].

The purpose of this work is to investigate the effects of oxygen plasma treatment pressure on aramid fiber III chemical structure and its reinforcing thermosetting bismaleimides (BMI) composite humidity resistance properties. The aramid fiber chemical structure was characterized by FTIR. The aramid fiber III reinforced BMI composite interfacial properties before and after water absorption was evaluated by short beam shear measurement.

2. Experimental

2.1. Materials

Aramid fibers III (polyheteroarylene-co-p-phenyleneterephthalamide) were supplied by China Bluestar Chengrand Chemical Co. Ltd. The fibers were cleaned successively with acetone and then dried in a vacuum oven for 3 h at 110 ° C.

The fiber surface was modified by inductive coupling radio frequency (13.56 MHz) plasma reactor. Oxygen was kept at a flow rate of about 20-30 SCCM. The operation pressure was set at 10 Pa, 20 Pa,
30 Pa, 40 Pa and 50 Pa. The fiber samples were treated for 15 min with plasma treatment power of 200 W. BMI resin (QY8911-II) was received from Beijing Aeronautical Manufacturing Technology Research Institute.

2.2. Characterization
The chemical structure of aramid fiber III were analyzed by infrared spectrometer (Nicolet-20, DXB) at 4 cm⁻¹ resolution and signal-averaged over 32 scans.

Composite water absorption tests were carried as follows: dry, pre-weighed composite specimens (40 mm × 50 mm × 2 mm) were immersed into distilled water (98 ± 2 °C) for 24 h. Then, the composite interlaminar shear strength was tested before and after water absorption.

The composite interlaminar shear strength (ILSS) was measured on short-beam bending test method on a Shimadzu universal testing machine according to ASTM D-2344.

3. Results and Discussion

3.1. FTIR
Figure 1 shows the FTIR results of aramid fiber III with different plasma treatment pressure. It is found that the absorption peak at 3275 cm⁻¹ belongs to N - H stretching vibration on the amide bond. The absorption peak at 1634 cm⁻¹ is contributed to C = O stretching vibration peaks (amide I band). The absorption peak at 1512 cm⁻¹ is N - H group in-plane bending vibration peak (amide I band), 1307 cm⁻¹ is C - N groups stretching vibration absorption peak (the amide II band), which are the characteristic absorption peaks of the domestic aramid fiber III[6]. Compared with the untreated fiber sample, the chemical structure of aramid fiber III under different plasma treatment pressure do not change obviously.

![Figure 1. FTIR of aramid fiber with different oxygen plasma treatment pressure.](image)

3.2. Water absorption
Figure 2 shows the water absorption of composites via plasma treatment pressure. It is found that the water absorption of untreated fibers reinforced BMI composite is the largest, while all the other five plasma-treated samples are relatively lower within the beginning two hours. For the untreated sample, the water absorption is 0.22%. For the plasma-treated fiber samples, the water absorption are 0.14%, 0.11%, 0.09%, 0.21% and 0.17%, respectively. The phenomenon maybe due to the composite interface adhesion. If the composite interface adhesion is good, the water molecule can not diffuse into composite inner easily. After being immersed into water for 24 h, the water absorption achieves 0.51% for untreated
sample and 0.42%, 0.39% and 0.24% after plasma treated for 10 Pa, 20 Pa, 30 Pa, respectively. However, with the plasma treated pressure increasing to 40 Pa and 50 Pa, the water absorption is larger than the untreated one, which means that the interfacial adhesion of the fiber and the matrix is poor and then the water molecule diffusing into composites along the fiber–matrix interface.

**Figure 2.** Effects of plasma treatment power on humidity resistance of composite bending strength

### 3.3. Humidity resistance

Figure 3 shows the humidity resistance of composite interlaminar shear strength under different plasma treatment pressure. The ILSS value of untreated composite before water absorption is 49.35 MPa. After plasma treatment, the ILSS values increase to 58.68 MPa, 59.94 MPa, 62.99 MPa, 61.2 MPa and 62.1 MPa after plasma treated pressure set at 10 Pa, 20 Pa, 30 Pa, 40 Pa and 50 Pa, respectively. The result shows plasma treatment can improve composite interfacial adhesion. After water absorption, the ILSS value decrease to 46.2 MPa for the untreated composite. And it decrease to 58.32 MPa, 58.7 MPa, 62.7 MPa, 59.7MPa and 61.1MPa after plasma treated pressure set at 10 Pa, 20 Pa, 30 Pa, 40 Pa and 50 Pa, respectively. The retention rate of composite interlaminar shear strength is about 94% for untreated sample. After plasma treatment, the retention rate of composite interlaminar shear strength exceed 95%.

**Figure 3.** Effects of plasma treatment pressure on humidity resistance of composite interlaminar shear strength
4. Conclusion
The FTIR results showed that oxygen plasma treatment didn’t change the fiber bulk chemical structure. The composite humidity resistance of interlanimar shear strength was enhanced after plasma treatment. The retention rate of composite interlanimar shear strength was above 95%.

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