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

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Abstract. The effects of oxygen plasma treatment power on Aramid Fiber III chemical structure and its reinforced bismaleimides (BMI) composite humidity resistance properties were investigated in this work. The aramid fiber III chemical structure under different plasma treatment power were measured by FTIR. The composite bending strength and interlinear shear strength with different plasma treatment power before and after absorption water were tested respectively. The composite rupture morphology was observed by SEM. The FTIR results showed that oxygen plasma treatment do not change the fiber bulk chemical structure. The composite humidity resistance of bending strength and interlinear shear strength are similar for untreated and plasma treated samples. The retention rate of composite bending strength and interlinear shear strength are about 75% and 94%, respectively. The composite rupture mode turns to be the fiber failure after water absorption.

1. Introduction

The aramid fiber III has been widely used in the fields of aviation, automobile due to its excellent properties such as low density, high strength and modulus [1, 2]. However, the aramid fiber III surface is very smooth and short of active functional groups that the adhesion strength is weak between the fiber and the matrix. 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 (Armos and Twaron) surface wettability and its reinforced composite interfacial properties [3, 4]. The composite humidity resistance is very important for evaluating the composite actual usability.

The purpose of this work is to investigate the effects of oxygen plasma treatment power on DAF III chemical structure and it’s reinforcing thermosetting bismaleimides (BMI) composite humidity resistance properties. The aramid fiber chemical structure was characterized by FTIR. The aramid fiber III reinforced BMI composite bending strength before and after water absorption was measured by three point bending test. The aramid fiber III reinforced BMI composite interfacial properties before and after water absorption was evaluated by short beam shear measurement. Furthermore, in order to analyze adhesion mechanism of composite before and after water absorption, the composite interlinear shear fracture morphology was observed by SEM.
2. Experimental

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

The fiber surface was modified by inductive coupling radio frequency (13.56 MHz) plasma reactor. The operation pressure was set at 30 Pa. The fibers were treated by oxygen plasma output power with 100, 200, 300, 400 and 500 W for 15 min, respectively. 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 bending strength and interlinear shear strength was tested before and after water absorption.

The composite bending strength was measured on three-point short-beam bending test method on a Shimadzu universal testing machine according to GB/T 1449-2005

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

The composite interlinear shear ruptures morphologies were observed by SEM (SU3500). The magnification was set at 500 ×.

3. Results and Discussion

3.1. FTIR
Figure 1 shows the FTIR results of aramid fiber III under different plasma treatment power. 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).The above peaks are the characteristic absorption peaks of the domestic aramid fiber III[5]. Compared with the untreated fiber sample, the chemical structure of aramid fiber III under different plasma treatment power do not change obviously. This phenomenon illustrates the oxygen plasma treatment do not break the fiber bulk structure.

![Figure 1. FTIR of aramid fiber with different oxygen plasma treatment power.](image-url)
3.2. Humidity resistance of composite bending strength
Figure 2 shows the humidity resistance of composite bending strength under different plasma treatment power. The composite bending strength of different plasma treatment power before water absorption is nearly 800-830 MPa. After water absorption, these samples decrease to 600-630 MPa. The composite bending strength humidity resistance before and after plasma treatment is similar. The retention rate of composite is about 75%.

![Figure 2. Effects of plasma treatment power on humidity resistance of composite bending strength](image)

3.3. Humidity resistance of composite interlinear shear strength
Figure 3 shows the humidity resistance of composite interlinear shear strength under different plasma treatment power. The ILSS value of untreated composite before water absorption is 49.35 MPa. After plasma treatment, the ILSS values increase to 59.06 MPa, 62.99 MPa, 59.83 MPa, 59.1 MPa and 57.6 MPa after 100 W, 200 W, 300 W, 400 W and 500 W plasma treatment, respectively. The result shows plasma treatment can improve composite interfacial adhesion. After water absorption, the ILSS value decrease to 46.2MPa for the untreated composite. And it decrease to 57.21 MPa, 60.84 MPa, 58.6 MPa, 58.2MPa and 54.9MPa after 100 W, 200 W, 300 W, 400 W and 500 W plasma treatment, respectively. The composite interlinear shear strength humidity resistance before and after water absorption is also similar. The retention rate of composite is about 94%.

![Figure 3. Effects of plasma treatment power on humidity resistance of composite interfacial strength](image)
3.4. Composite interfacial rupture morphology

Figure 4 shows the untreated and plasma treated composite interfacial rupture morphology before and after water absorption. It is found that the composite rupture mode before water absorption (Figure (a) and (c)) is almost the interface (Figure (a)) between the fiber and the matrix or the resin matrix (Figure (c)) for the untreated and plasma treated composite samples. However, after water absorption, it is found that the composite rupture mode turns to be the fiber break from the composite as seen from (Figure (b) and (d). This interesting phenomenon shows that the water molecule immerses into the composite inside during water-boiling. The rupture mode turns to be the fiber failure.

![Figure 4. Composite interfacial rupture morphology. Untreated, before (a) and after (b) water absorption Plasma treated, before(c) and after (d) water absorption](image)

4. Conclusion

The FTIR results showed that oxygen plasma treatment could not change the aramid fiber chemical structure. The composite humidity resistance of bending strength and interlinear shear strength are similar for untreated and plasma treated samples. The retention rate of composite bending strength and interlinear shear strength are about 75% and 94%, respectively. The composite rupture mode turns to be the fiber failure after water absorption.

Acknowledgments

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