Effects of oxygen plasma treatment on domestic aramid fiber III reinforced bismaleimide composite interfacial properties

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Abstract. Domestic Aramid Fiber III (DAF III) was modified by oxygen plasma treatment. The fiber surface characteristics was observed by Scanning Electron Microscopy. The results showed that oxygen plasma treatment changed surface morphologies. The effects of oxygen plasma treatment on DAF III reinforced bismaleimides (BMI) composite bending and interfacial properties were investigated, respectively. The ILSS value increased from 49.3 MPa to 56.0 MPa (by 13.5%) after oxygen plasma treatment. The bending strength changed a little. Furthermore, the composite rupture mode changed from interfacial rupture to fiber or resin bulk rupture.

1. Introduction
The aramid fibers have been widely used as reinforcement material in the fields of aviation, automobile, shipbuilding due to their low density, high strength, good toughness, excellent thermal-resistance, chemical corrosion-resistance and good impact resistance and so on [1, 2].

In this paper, Chinese produced aramid fiber-III (DAF III) and thermosetting bismaleimides (BMI, QY8911-II) were chosen as reinforcement and matrix due to their excellent performance. BMI resin possess high heat deflection temperature of above 250 °C, which far surpasses the value of traditional epoxy resins. DAF III is a recently developed type of para-aramid fibers manufactured in China, which is spun from poly-(polyamide benzimidazole-co-p-phenylene terephthalamide). However, because of their smooth and chemical inert fiber surfaces, which lead to poor fiber-matrix compatibility and weak adhesion between the fibers and the matrix [3-6]. Thus, it is necessary to modify the aramid fibers surface for expanding their application range. Plasma treatment was used to modify the fiber surface for improving composite interfacial properties.

The purpose of this work is to investigate the effects of oxygen plasma treatment on DAF III surface and it’s reinforcing thermosetting bismaleimides (BMI) composite properties. The DAF III/BMI composite bending and interfacial properties was evaluated by short beam shear measurement. The DAF III/BMI composite bending strength was measured by three point bending test. Furthermore,
in order to analyze composite adhesion mechanism, the fiber surface morphology and the composite interlaminar fracture morphologies were observed by SEM, respectively.

2. Experimental

2.1. Materials and plasma treatment
Aramid fibers III (polyheteroarylene-co-p-phenylene terephthalamide) were supplied by China Bluestar Chenguang Chemical Co. Ltd. The fibers were cleaned successively with acetone and distilled water and then dried in a vacuum oven for 3 h at 110 °C before further analysis. BMI resin (QY8911-II) was received from AVIC Beijing Aeronautical Manufacturing Technology Research Institute. Plasma was excited by an inductive coupling radio frequency generator (13.56 MHz). Oxygen was kept at a flow rate of about 20-30 SCCM. The operation pressure was set at 30 Pa. The fiber samples were treated for 25 min with plasma treatment power of 200 W. DAF III reinforced BMI composites were prepared through solution impregnating technique according to reference [7].

2.2. Characterization
Interlinear shear strength (ILSS) for DAF III/BMI composite was measured on three-point short-beam bending test method on a Shimadzu universal testing machine according to ASTM D-2344. Each ILSS value reported was the average of five successful measurements.

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

The fiber surface and composite interlinear shear ruptures morphologies were observed by SEM (SU3500). The magnification was set at 3000 × and 500 ×, respectively.

3. Results and Discussion

3.1. Composite interlinear shear strength
Figure 1 shows the ILSS value of DAF III reinforced BMI composite before and after oxygen plasma treatment. The ILSS value of untreated composite is 49.35 MPa, while it increases to 56.03 MPa with the increment of about 13.5% after oxygen plasma treatment. The results confirm that oxygen plasma treatment can improve the interfacial adhesion between DAF III and BMI matrix.

![Figure 1. ILSS of aramid fiber reinforced BMI composite](image-url)
3.2. Composite bending strength
Figure 2 shows the bending strength value of DAFIII reinforced BMI composites before and after plasma treatment. The bending strength value of untreated composite is 808 MPa. After plasma treatment, the value is 812 MPa. It seems that plasma treatment has tiny effects on composite macro-mechanical properties.

![Bending Strength Graph](image)

**Figure 2.** Bending strength of aramid fiber reinforced BMI composite

3.3. Aramid fiber surface morphology
The single DAF III fiber surface morphology was observed by SEM, and the typical micrographs before and after plasma treatment are shown in Figure 3. Obvious changes of the fiber surface morphology are observed before and after oxygen plasma treatment. As seen from Figure 3(a), the fiber surface is rather smooth, which means that the interfacial adhesion between the fiber and the resin may be poor. However, the fiber surface after oxygen plasma treatment (Figure 3(b)) turns to be rougher than the untreated samples, and some mild grooves and gibbous particles exist on the fiber surfaces. The results proved that oxygen plasma treatment can change the fiber surface physical morphology and this will enhance the adhesion properties between the matrix and the fiber. Therefore, the ILSS value increased after oxygen plasma treatment.
3.4. Composite fracture morphology

Figure 4 shows the morphology of interlaminar shear ruptures of composite. It is found that the rupture occurs mainly near the interface between the fiber and the matrix for untreated specimen in Figure 4 (a). However, the primary failure mode varies from interface failure to matrix or fiber failure for the oxygen plasma-treated specimen in Figure 4 (b). It also suggests that oxygen plasma treatment can enhance composite interfacial bond strength.

4. Conclusion

The ILSS results showed that oxygen plasma treatment can improve composite interfacial properties. The bending strength changed a little. SEM observation showed that fiber surface morphologies were changed a lot and the composite rupture mode changed from interfacial rupture to fiber or resin matrix rupture.

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