Study on the Effect of Fabric Parameters on the properties of Wave-Transparent Composites

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Abstract: Novel fabric structures of wave-transparent composites having excellent dielectric property were successfully prepared using autoclave moulding. The influence of fabric parameters (such as weaving patterns, hollow ratio, mix structure) on the properties of quartz fiber-reinforced modified cyanate ester composite were systematically investigated. The results show that satin weave fabric-reinforced composites have better mechanical performance than plain weave fabric-reinforced composites. With hollow ratio of fabric increasing the dielectric properties of composites becomes better, except for the mechanical performance. The prepared hollow/solid quartz fabric-reinforced composites in this study display lower dielectric constant and better mechanical properties than quartz/Aramid III and quartz/Poly-p-phenylene benzobisoxazole(PBO).

1. Introduction

Radar antenna technology is developing toward higher frequency, wider bandwidth, lower power consumption and higher integration which bring higher requirements on high performance wave-transparent composites. To meet the demands of modern science and technology information industry, these wave-transparent materials has not only good processing characteristics and high mechanical property, but also lower dielectric constant, lower dielectric loss and outstanding heat resistance. Quartz fiber, as a representative of excellent performance reinforced phase, has outstanding thermal and mechanical properties with extremely low and stable dielectric loss over wide temperature and frequency ranges. However, Quartz fiber also has several performance disadvantages including higher dielectric constant, higher density etc., which can not fully meet the requirements of new generation radar system. Here, in order to overcome the drawbacks of quartz fiber, we present a novel fabric structure for fabricating a series of wave-transparent composites. The influence of fabric parameters, such as weaving patterns, hollow ratio, mix structure, on the properties of quartz fiber-reinforced modified cyanate ester composite were systematically investigated. It is supposed that
the weaving parameters play an important role in determining properties of wave-transparent composites.

2. Experimental

2.1 Materials

The modified cyanate ester resin was synthesized by our laboratory. A series of different quartz fibers were purchased from Hubei Feilihua (Jing Zhou) co. Aramid III fibers and PBO fibers were supplied by China Bluestar Chengrand (Cheng Du) co. Acetone was purchased from Beijing chemical works (Beijing).

2.2 Preparation

The modified cyanate ester resin (MCE) solution was prepared at a concentration of 50 wt% in acetone. A range of different fabric prepregs (weight of resin/fiber = 1:1) were obtained by impregnation process. Several layers of as-received fabric layer were piled into a metal plate which had been coated releasing agent. After that, the metal plate was placed into the autoclave and the samples were cured according to the following schedule: 100 °C for 2h, 120 °C for 3.5h, 130 °C for 4.5h at 850 kPa as the applied pressure.

2.3 Characterization

The tensile properties of the composites were determined using dumbbell specimens with size 180 mm in length, 10 mm in width and 2.2 mm in thickness at 1 mm/min crosshead speed on Instron 5569 instruments, USA. The compression performance of the composite were determined using rectangular specimens with size 110 mm in length, 10mm in width and 2mm in thickness in the shear loading mode. The flexural properties of the composites were determined using rectangular specimens with size 50mm in length, 15mm in width and 2.2mm in thickness in the three point bending mode. The interlaminar shear properties of the composites were determined using ladder-like specimens with size 35mm in length, 15mm in width and 15mm in thickness at 7 mm/min speed on hydraulic universal testing machine. An average value of 5 tests for the single code was reported as the result. The dielectric properties of the composites were measured using circular specimens having the diameter of 50.5mm and 3.3mm as a thickness according to the ASTM D150-11 standard.

3. Results and discussion

3.1 Effect of weaving patterns on mechanical properties of composite

The patterns of quartz fabrics mainly divided into plain weave and satin weave as to fiber reinforcement. Two kinds of fabric composites are prepared and their mechanical performances are shown in Figure.1. Generally, these results indicate that the mechanical property of satin weave composite sample was lower than that of plain weave composite. However, the interlaminar shear strength of composite may not vary much between satin weave and plain weave.
3.2 Influence of hollow ratio on mechanical and dielectric properties of composite

Hollow ratio is one of important factor in quartz fibers, which represents the ratio of inner diameter and outer diameter of hollow quartz fiber. Dielectric performance of 32% and 50% hollow ratio composite were analyzed and shown in Table1. It can be seen that both their dielectric constant and loss factor are less than 2.65 and 0.004, respectively.

Table 1. Influence of different fabric hollow ratio on the dielectric properties of composite

| Hollow ratio | Dielectric constant (10GHz) | Loss factor (10GHz) |
|--------------|-----------------------------|---------------------|
| 32%          | 2.61                        | 0.003               |
| 50%          | 2.50                        | 0.003               |

Mechanical properties of 32% hollow ratio of composite was measured and compared with that of 50% hollow ratio of composite as shown in Fig. 2. Compare to the 32% hollow ratio of composite, the tensile strength (268 MPa), compressive strength (239 MPa), flexural strength (351MPa) and interlaminar shear strength (41.3 MPa) approximately decreased by 16.3%, 4.4% , 4.8% and 18.5%, respectively, when the hollow ratio of quartz fabric reach the maximum (50%). All of tensile strength, compressive strength, flexural strength and interlaminar shear strength decreased, which could be caused by hollow structure.
Figure 2 The mechanical properties of different fabric hollow ratio of composite.

3.3 Effect of mix structure on mechanical and dielectric properties of composite

In order to improve the properties of the wave-transparent composites, the fiber reinforcements is employed with hollow/solid quartz fiber, quartz/aramid III fiber and quartz/PBO fiber, respectively. Dielectric properties of different mix structure of composites were performed and results are shown in Table 2. Quartz/aramid III fiber-reinforced composite and quartz/PBO fiber-reinforced composite have a dielectric constant of 3.37 and 3.42, respectively. However, it can be seen that the dielectric constant and loss factor of hollow/solid quartz fiber-reinforced composite is less than 2.8 and 0.004, respectively.

Table 2 Influence of different mix structure of fibers on the dielectric properties of composite

| Mix structure       | Dielectric constant (10GHz) | Loss factor (10GHz) |
|---------------------|-----------------------------|---------------------|
| Hollow/solid quartz | 2.73                        | 0.003               |
| Quartz/aramid III   | 3.37                        | 0.007               |
| Quartz/PBO fiber    | 3.42                        | 0.003               |

Fig. 3 shows the evolution of tensile strength, compressive strength, flexural strength and interlaminar shear strength collected during the mechanic test on the composite materials. It can be seen that the highest tensile strength of composite is quartz/aramid III fiber-reinforced composite (634 MPa). However, hollow/solid quartz fiber-reinforced composite possess fine mechanical performance, which included tensile strength (421MPa), compressive strength (393MPa), flexural strength (614MPa) and interlaminar shear strength (55MPa).

Figure 3 The mechanical properties of different mix structure of composite.

4. Conclusion

Novel fabric structures of wave-transparent composites having excellent dielectric property and mechanical performance were successfully prepared using autoclave moulding. The influence of weaving parameters on the dielectric constant, loss factor, tensile strength, compressive strength, flexural strength and interlaminar shear strength of mixed fabric/MCE composites was evaluated. In generally, hollow/solid fabric-reinforced MCE composites have a better dielectric performance and mechanical properties than others.
5. References

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