Properties of quartz fabrics reinforced cyanate ester resin composites produced by RTM processing

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Abstract: To produce the radar radome more efficiently, dimensional accurately, uniformly, environmental cleanlily, and apparent smoothly, an epoxy modified cyanate ester resin for the radar radome produced by Resin Transfer Molding (RTM) processing was developed. The properties of quartz fabrics reinforced cyanate ester resin composites were presented in this paper.

The property and processing parameters of the epoxy modified cyanate ester resin were introduced. Then the properties of the quartz fabrics reinforced cyanate ester resin composites were studied. Finally, a quartz fabrics reinforced cyanate ester composites radar radome was produced by RTM processing. The results indicated, the tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus, compression strength, compression modulus, density and Tg of the epoxy modified cyanate ester resin are 58.1MPa, 3.31GPa, 1.75%, 85.9MPa, 3.40GPa, 170MPa, 3.24GPa, 1.198g/cm^3 and 226℃, respectively. And ε and tanδ of the cyanate ester resin at the frequency of 16GHz are 2.91 and 0.010. The viscosity of the cyanate ester resin at different temperature was measured, and the variation of viscosity in 5 hours at 80℃ was measured too. The viscosity of the cyanate ester resin in 5 hours at 80℃ was not above 300mPa·s. As a result, the processing parameters of the epoxy modified cyanate ester resin were obtained. The tensile strength, tensile modulus, flexural strength, flexural modulus, and shear strength of the quartz fabrics reinforced cyanate ester resin composites are 362MPa, 14.6GPa, 552MPa, 14.2GPa, and 60.1MPa, respectively. ε of the composites at the frequency of 7 GHz, 10GHz, 13GHz, 16GHz and 35GHz are 3.17, 3.18, 3.16, 3.13 and 3.10, respectively, and tanδ of those are 0.0067, 0.007, 0.0078, 0.0093 and 0.0082. The radar radome was designed according to the mechanical and dielectric properties of the quartz fabrics reinforced cyanate ester resin composites. Eventually, the quartz fabrics reinforced cyanate ester resin composites radar radome was produced by RTM processing and tested.

Key word: quartz, cyanate ester resin, radar radome, RTM, property

1. Introduction

Radar radome is the important component to protect the antenna from hostile environment. High mechanical properties and thermal stability, excellent dielectric property is the basic requirements for materials to manufacturing radar radome[1-4]. Quartz fiber reinforced cyanate ester resin composites is an excellent material to produce high

performance radar radome due to its advantages such as high thermal stability, excellent dielectric property and good processing ability. The Cyanate ester resin composites radar radome was generally manufactured by compression molding or autoclave processing for the reason that many cyanate ester resins are solid at Room Temperature (RT)[5-7]. To produce the radar radome more efficiently, dimensional accurately, uniformly, environmental cleanlily, and apparent smoothly, an epoxy modified cyanate ester resin for the radar radome produced by Resin Transfer Molding (RTM) processing was developed. The processing parameters and properties of quartz fabrics reinforced cyanate ester resin composites were presented in this paper.

2. Experimental

2.1 Materials

Epoxy modified cyanate ester resin was provided by Changchun Institute of Applied Chemistry, Chinese Academy of Science. Quartz fabrics were provided by Hubei Feilihua Quartz Glass Co., LTD.

2.2 Preparation of samples

2.2.1 Preparation of the casting for the epoxy modified cyanate ester resin

At first, the epoxy modified cyanate ester resin is heated. When the temperature of the resin is between 70℃ and 100℃, the resin is melt. The viscosity of the resin at this temperature is about 75mPa • s. Second, put the melt resin in a vacuum oven with a temperature between 70℃ and 100℃ and vacuumed it under a pressure of -0.088MPa for half hour. Third, pour the vacuumed resin in the preheated steel mould which temperature is 120℃. Forth, the resin is cured in an oven. Finally, the cured casting is removed from the mould when the temperature of the mould decreases to room temperature and send the cured casting to machine.

2.2.2 Preparation of the quartz fiber reinforced cyanate ester resin composites laminates by RTM

The quartz fiber reinforced cyanate ester resin composites laminates are manufactured by RTM processing. The quartz fiber perform is produced firstly. The quartz fiber fabric with a thickness of 0.2mm is cut into a little sheet with a dimension of 200mm × 240mm. 10 layers of the sheet with a dimension of 200mm × 240mm are put together to produce the quartz fiber perform. Then the quartz fiber perform is put into a mould which has been cleaned and coated with release agent. The mould with perform is connected with the RTM machine. The mould is heated to 90℃ and the epoxy modified cyanate ester resin is heated and vacuumed as described in section 2.2.1. Pour the heated resin into the resin container of the RTM machine which has been heated as the same temperature of the resin. Inject the resin under a pressure of 0.2MPa to 0.4MPa. The laminate is cured in an oven after resin injection. Finally, the cured laminate is removed from the mould when the temperature of the mould decreases to room temperature and send the laminate to machine.

2.2.3 Preparation of the quartz fiber reinforced cyanate ester resin composites radar radome by RTM

The quartz fiber reinforced cyanate ester resin composites radar radome is manufactured by the similar process as described in section 2.2.2. The quartz fiber perform of the radar

radome is produced on a wood mandrel. Then the radome perform is transfer to a steel mould which is connected with RTM machine. The cyanate ester resin is injected to the radome perform and the composite radome is cured in an oven. Finally, the cured composite radme is removed from the mould and tested.

2.3 Physical Properties

2.3.1 Viscosity of the epoxy modified cyanate ester resin

The viscosity of the epoxy modified cyanate ester resin is measured according to GB7193.1-87.

2.3.2 Mechanical properties for the casting of the epoxy modified cyanate ester resin

The tensile, flexural and compression properties of the resin casting are measured according to GB/T2567-2008.

2.3.3 Density and Tg for the casting of the epoxy modified cyanate ester resin

The density of the casting is measured according to GB/T1033.1-2008. Tg of the casting is measured by DMA(Dynamic Mechanical Analysis) method.

2.3.4 ε and tanδ for the casting of the cyanate ester resin

ε and tanδ for the casting of the cyanate ester resin is calculated by an analysis method of odd even model from the parameters measured on a WILTRON37269 test system.

2.3.5 Mechanical properties for the quartz fabrics reinforced cyanate ester resin composites

The tensile properties of the quartz fabrics reinforced cyanate ester resin composites are measured according to GB/T1447-2005.

The flexural properties of the quartz fabrics reinforced cyanate ester resin composites are measured according to GB/T1449-2005.

The shear strength of the quartz fabrics reinforced cyanate ester resin composites is measured according to GB3357-82.

2.3.6 ε and tanδ for the quartz fabrics reinforced cyanate ester resin composites

ε and tanδ for the quartz fabrics reinforced cyanate ester resin composites is calculated by an analysis method of odd even model from the parameters measured on a WILTRON37269 test system.

2.4 Radome Tests

The wave transmit test of the quartz fabrics reinforced cyanate ester resin composites radar radome made by RTM processing is carried out in a microwave anechoic chamber. The microwave transmissivity of the radome is tested at a typical operation wave length.

3. Results and Discussion

3.1 Viscosity of the epoxy modified cyanate ester resin

Figure 1 is the viscosity of the epoxy modified cyanate ester resin. The epoxy modified cyanate ester resin is solid at room temperature. It begins to melt at 70℃ and its viscosity decreases as its temperature is elevated. The viscosity of the epoxy modified cyanate ester resin is below 200mPa·s from 80℃ to 100℃ when the resin is initially melt. The viscosity of the resin increases with the keeping time of the resin at a certain temperature from 80℃ to 100℃. At 80℃, the viscosity of the resin is not above 300mPa·s in the initial 5 hours. And at 90℃ and 100℃, that is only in the

initial 4 hours and about 1 hour respectively. According to the viscosity of the epoxy modified cyanate ester resin measured at different temperature and the variation of the viscosity at different time, the injection temperature of the epoxy modified cyanate ester resin for the RTM processing is determined.

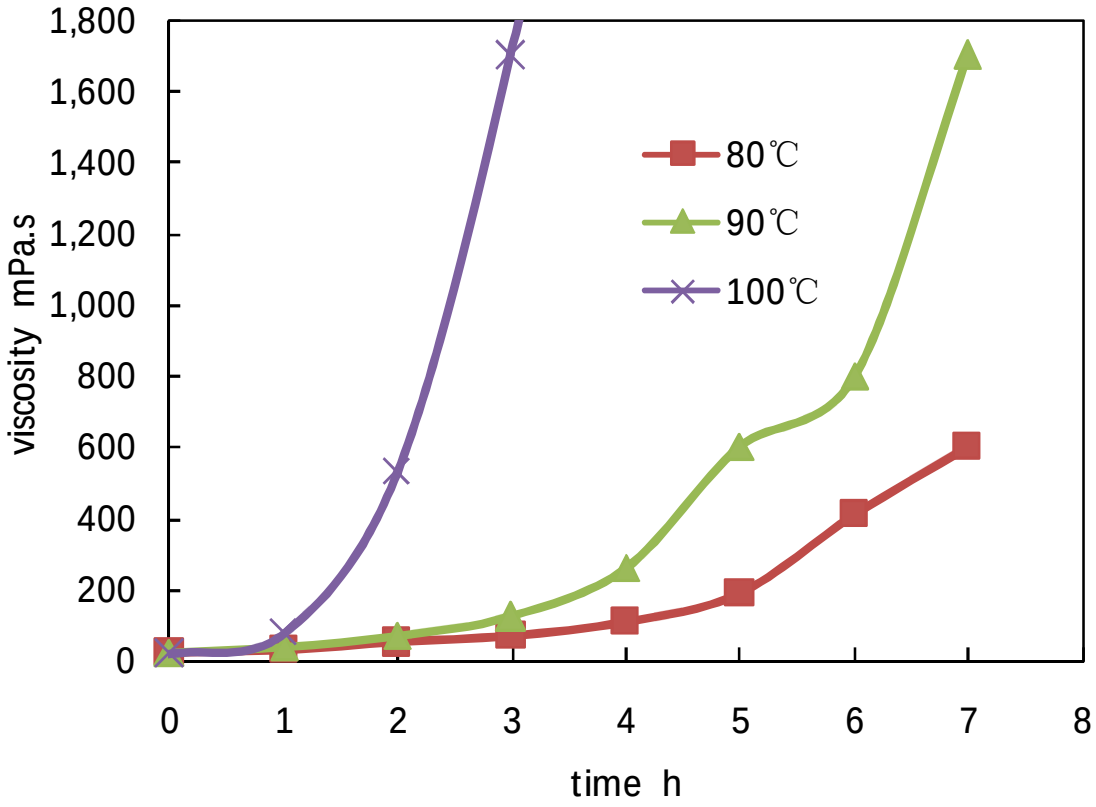

Figure 1 Viscosity of the epoxy modified cyanate ester resin

3.2Propeties of the epoxy modified cyanate ester resin

3.2.1Mechanical properties of the epoxy modified cyanate ester resin

Table 1 is the mechanical properties for the casting of the epoxy modified cyanate ester resin. The tensile strength, flexural strength and compression strength for the casting of the epoxy modified cyanate ester resin are 58.1MPa, 86.1MPa, 170MPa respectively. It indicates that the cured epoxy modified cyanate ester resin is strong enough to be used as the matrix resin of the radome composites.

Table 1 Mechanical properties of the epoxy modified cyanate ester resin

Properties		Average value
Tensile strength	(MPa)	58.1
Tensile modulus	(GPa)	3.83
Elongation at break	(%)	1.75
Flexural strength	(MPa)	86.2
Flexural modulus	(GPa)	3.81
Compression strength	(MPa)	170
Compression modulus	(GPa)	3.24

3.2.2Thermal physical property of the epoxy modified cyanate ester resin

Tg of the epoxy modified cyanate ester resin is 226℃ according to DMA test. It means that the thermal stability of the epoxy modified cyanate ester resin is very good. The service temperature of the resin is above 100℃. The density of the cured resin is 1.198g/cm^3.

3.2.3 Dielectric property of the epoxy modified cyanate ester resin

Table 2 is dielectric properties of the epoxy modified cyanate ester resin. The dielectric properties of an epoxy resin which is specially designed to be used as the matrix of the wave transmitting composite materials are also given in table 2 as a reference. ε of the cyanate ester resin at the frequency of 16GHz is 2.91 which is similar to ε of the epoxy resin. tanδ of the cyanate ester resin at the frequency of 16GHz is 0.010 which is much low than tanδ of the epoxy resin. It shows that the epoxy modified cyanate ester resin is suitable to be used as the matrix resin of the radome composites.

Table 2 Dielectric properties of an epoxy resin and the epoxy modified cyanate ester resin

Properties	Epoxy resin	Epoxy modified cyanate ester resin
ε (16GHz)	2.87	2.91
tanδ(16GHz)	0.023	0.010

3.3Properties of the quartz fiber reinforced cyanate ester resin composites

Figure 2 is the laminate of the quartz fiber reinforced cyanate ester resin composites made by RTM processing, which is used to measure the mechanical properties and dielectric property of the composites.

Figure 2 Laminate of the quartz fiber reinforced cyanate ester resin composites by RTM processing

3.3.1Mechanical properties of the quartz fiber reinforced cyanate ester resin composites

Table 3 is the mechanical properties of the quartz fiber reinforced cyanate ester resin composites. The tensile strength of the composites is 362MPa. The tensile strength of the same quartz fiber reinforced epoxy resin composites is 344.6MPa.The epoxy resin has been discussed in section 3.2.3. It is obviously that the tensile strength of the quartz fiber reinforced cyanate ester resin composites is higher than that of the quartz fiber reinforced epoxy resin composites. The shear strength of the quartz fiber reinforced cyanate ester resin composites is 60.1MPa. It indicates that the interfacial strength between the quartz fiber and the cyanate ester resin is excellent.

Table 3 Mechanical properties of the quartz fiber reinforced cyanate ester resin composites

Properties		Average value
Tensile strength	(MPa)	362
Tensile modulus	(GPa)	14.6
Flexural strength	(MPa)	552
Flexural modulus	(GPa)	14.2
Shear strength	(MPa)	60.1

3.3.2 Dielectric property of the quartz fiber reinforced cyanate ester resin composites

Table 4 is dielectric properties of the quartz fiber reinforced cyanate ester resin composites at different wave frequency. ε of the composites at the frequency of 7GHz, 10GHz, 13GHz, 16GHz and 35GHz are 3.17, 3.18, 3.16, 3.13 and 3.10 respectively. It is almost constant at the wave frequency range from 7GHz to 35GHz. tanδ of the composites at the frequency of 7GHz, 10GHz, 13GHz, 16GHz and 35GHz are 0.0067, 0.007, 0.0078, 0.0093 and 0.0082 respectively. It is also almost constant at the wave frequency range from 7GHz to 35GHz. ε and tanδ of the quartz fiber reinforced epoxy resin composites at the frequency of 7GHz, 10GHz, 13GHz, 16GHz and 35GHz are also given in table 4 as a reference. The epoxy resin has been discussed in section 3.2.3 and section 3.3.1. The ε value of the quartz fiber reinforced epoxy resin composites at the wave frequency range from 7GHz to 35GHz is a little smaller than that of the quartz fiber reinforced cyanate ester resin composites. But the tanδ value of the quartz fiber reinforced epoxy resin composites at the wave frequency range from 7 GHz to 35GHz is much higher than that of the quartz fiber reinforced cyanate ester resin composites. It indicates that the quartz fiber reinforced epoxy resin composites is an excellent material at the wave frequency range from 7GHz to 35GHz for radar radome.

Table 4 Dielectric property of the composites with different matrix at different frequency

Matrix of composites	Frequency(GHz)	7	10	13	16	35
Epoxy resin	ε	3.11	3.11	3.09	3.08	2.92
	tanδ	0.014	0.016	0.015	0.012	0.015
Cyanate ester resin	ε	3.17	3.18	3.16	3.13	3.1
	tanδ	0.0067	0.007	0.0078	0.0093	0.0082

3.3.3Wave transmit test of the quartz fabrics reinforced cyanate ester resin composites radar radome

The radar radome was designed according to the mechanical and dielectric properties of the quartz fabrics reinforced cyanate ester resin composites. Figure 3 is the quartz fabrics reinforced cyanate ester resin composites radar radome manufactured by RTM processing. Figure 3a is the radome prior to coating. Figure 3b is the radome which is painted with rainwater proof coat.

a. Prior to coating **b. after coating**

Figure 3 the quartz fabrics reinforced cyanate ester resin composites radar radome manufactured by RTM processing

Table 5 is the microwave transmissivity tested of the quartz fabrics reinforced cyanate ester resin composites radar radome. The antenna of the radar is put in the ramdome. The test direction of 0° is on the symmetry axis of the radome. The antenna is rotated to both side of the randome around an axis which is on the

symmetry axis of the radome when the microwave transmissivity is tested. The microwave transmissivity of the radome prior to coating is slight higher than that of the radome after coating[8]. The effect of the rainwater proof coat on the microwave transmissivity of the radome is acceptable. The microwave transmissivity of the coated radome is above 0.82. The microwave transmissivity increases with the test direction angle increasing. The reason for this phenomenon is that the radius of curvature for the radome is increased. In summary, the microwave transmissivity of the quartz fabrics reinforced cyanate ester resin composites radar radome manufactured by RTM processing is good.

Table 5 Microwave transmissivity of the quartz fabrics reinforced cyanate ester resin composites radar radome

Direction(°)	Prior to coating	After coating
0	0.86	0.82
5	0.82	0.86
10	0.86	0.82
15	0.88	0.87
25	0.93	0.92
50	0.96	0.94

4. Conclusions

The properties of quartz fabrics reinforced cyanate ester resin composites are studied in this paper. An epoxy modified cyanate ester resin is selected as the matrix of the composites. The viscosity of the epoxy modified cyanate ester resin at 80℃ is not above 300mPa·s in 5 hours. The tensile strength, tensile modulus, elongation at break, flexural strength, flexural modulus, compression strength, compression modulus, density and Tg of the epoxy modified cyanate ester resin are 58.1MPa, 3.31GPa, 1.75%, 85.9MPa, 3.40GPa, 170MPa, 3.24GPa, 1.198g/cm^3 and 226℃, respectively. And ε and tanδ of the cyanate ester resin at the frequency of 16GHz are 2.91 and 0.010. The quartz fabrics reinforced cyanate ester resin composites is manufactured by RTM processing. The tensile strength, tensile modulus, flexural strength, flexural modulus, and shear strength of the quartz fabrics reinforced cyanate ester resin composites are 362MPa, 14.6GPa, 552MPa, 14.2GPa, and 60.1MPa, respectively. ε of the composites at the frequency of 7 GHz, 10GHz, 13GHz, 16GHz and 35GHz are 3.17, 3.18, 3.16, 3.13 and 3.10, respectively, and tanδ of those are 0.0067, 0.007, 0.0078, 0.0093 and 0.0082. Eventually, the quartz fabrics reinforced cyanate ester resin composites radar radome is produced by RTM processing. The microwave transmissivity of the quartz fabrics reinforced cyanate ester resin composites radar radome is good.

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