Electromagnetic Wave Absorption by Rice Hull Carbon

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We have carried out the project for the useful utilization of the remaining rice hull as an industrial carbon material. The rice hull carbon (RHC) powder is manufactured by carbonizing in a nitrogen gas atmosphere at high temperature, then crushing and sieving. The rice hull has a natural porous structure. The diameter of the unit cell is about 10 μ m. The porous structure retained even after the carbonizing and crushing. The composite material comprised of the RHC and Ethylene Propylene Diene Methylene linkage rubbers is manufactured by molding and vulcanizing. In this study, the characteristic of electromagnetic wave absorption (reflectivity) was measured in frequency band between 50MHz and 8GHz for the composite material. The composite material possessed a high characteristic of electromagnetic wave absorption for 2GHz-8GHz. The characteristics were further affected by the test piece thickness and the RHC powder content.

Key words: Rice-Hull, Porous carbon material, Rubber composite material, Electromagnetic wave absorption, Reflectivity.

1. INTRODUCTION

Rice is a staple food, and its amount is about 10 million tons per year in Japan. The rice hull is the by-product of the rice and the amount is about 2.6 million tons per year [1]. About 1.7million tons of the rice hull is reused as a fertilizer, a carbonizing chaff and a soil conditioner, etc. The rice hull contains about 80 mass% of the organic constituent and 20 mass% of the inorganic constituent. The main inorganic constituent is silica, whose amount is more than 95mass% [2]. The authors have carried out the project for the useful utilization of the remaining rice hull as an industrial carbon material [3,4].

The rice hull carbon (RHC) powder is manufactured by carbonizing the rice hull in a nitrogen gas atmosphere at high temperature, then crushing and sieving the carbonized particles. The RHC powder contains about 56 mass% of the carbon, about 32 mass% of the oxygen and about 9 mass% of the silicon. The RHC powder is expected to use as a functional filler for the plastics and rubbers, since it provides new functions for the composite material [5].

In this study, the characteristic of electromagnetic wave absorption (reflectivity) was measured in frequency band between 50MHz and 8GHz for the composite material comprised of RHC/Ethylene Propylene Diene Methylene linkage (EPDM). More over, the influence of RHC

powder contents and test piece thickness on the electromagnetic wave absorption was evaluated.

2. EXPERIMENTAL PROCEDURE

2.1 Manufacturing process

Fig.1 shows the manufacturing process of the RHC powder and the RHC/EPDM composite. At first, the rice hull was carbonized in nitrogen gas atmosphere at 900°C for 3 hours. The carbonized rice hull was then pulverized by a mill to obtain the RHC powder. The RHC powder was sieved by 106 μ m meshed filter to obtain the powder of 20 μ m median diameter. The composite material of the RHC powder and EPDM is manufactured by molding and vulcanizing.

Fig.2 shows the natural porous structure of the rice hull. The diameter of the unit cell is about 10 μ m. Fig.3 shows the macrostructure of the RHC powder. The porous structure retains even after the carbonizing and crushing.

2.2 Test pieces

The electromagnetic wave absorption characteristic was evaluated dividing the measuring bands into 50MHz-3GHz and 2GHz-8GHz.

Fig.4 (a) shows the test piece of S parameter method for 50MHz-3GHz. The shape of the test piece is toroidal. Fig.4 (b) shows the test pieces of arch method for 2GHz-8GHz. The geometry of the test piece is 300(w) $\times$ 300(h) $\times$ t(thickness).

Fig.1 Manufacturing process of RHC powder and rubber composite material.

Fig.2 Macrostructures of rice hull.

Fig.3 Macrostructures of RHC powder that was carbonized at 900°C.

Table 1 lists the RHC powder contents of the test pieces. The test piece thickness was 2.5mm for the test pieces to evaluate the effect of the RHC powder content. The powder content was 300 per hundred rubber (phr) when the effect of the test piece thickness was evaluated.

(a) Test piece for 50MHz-3GHz.

(b) Test piece for 2GHz-8GHz.

Fig.4 Geometry of test pieces for electromagnetic wave absorption. (a) is used for S parameter method, (b) is used for arch method.

2.3 Electromagnetic wave absorption tests

The electromagnetic wave absorption in the 50MHz-3GHz was measured by the S parameter method. Fig.5 shows the measuring system of the S parameter method. The test piece was put into a jig and the measurement, applied the incident wave perpendicularly to the test piece.

Table 1 Thickness and RHC powder contents of test piece.

No.	Thickness [mm]	Content [phr]
1	2.5	100
2		200
3		300
4		400
5	0.5	300
6	1	
7	1.5	
8	2	
9	2.5	
10	5

Fig.5 Measuring system by S parameter method for 50MHz-3GHz.

Fig.6 Measuring system by arch method for 2GHz-8GHz.

The electromagnetic wave absorption characteristic under 2GHz-8GHz was evaluated by using the arch testing method. Fig.6 shows the measuring system of the arch testing method. The incident wave was applied from the transmitter to the test piece. The amount of electromagnetic wave absorption (reflectivity) was evaluated using the power loss between the incident wave and the reflective wave in each frequency.

(a) 50MHz-3GHz.

(b) 2GHz-8GHz.

Fig.7 Effect of RHC powder content in RHC/EPDM on electromagnetic wave absorption (reflectivity).

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Effect of powder content on reflectivity

Fig.7 (a) shows the effect of the amount of RHC powder on the characteristic of electromagnetic wave absorption for 50MHz-3GHz. The electromagnetic wave absorption was low, and about -3dB or less.

Fig.7 (b) shows the effect of the RHC powder on the characteristic of electromagnetic reflectivity for 2GHz-8GHz. The test piece with 200 phr has considerably high electromagnetic wave absorption of about -35dB at about 7GHz. The test piece with 300 phr has about -15dB peak value at about 5.3GHz absorption frequency.

The distance between the RHC powders is considered to be narrow in the RHC/EPDM in which a lot of RHC powders were included. We have confirmed that the high powder composite of the RHC/EPDM had a

(a) 50MHz-3GHz.

(b) 2GHz-8GHz

Fig.8 Effect of Board thickness on electromagnetic wave absorption (reflectivity).

high electromagnetic wave shielding under low frequency band of 1-1000MHz, although the wave penetrated in the low powder content of RHC/EPDM. The results of Fig.7 (a) implies that the electromagnetic wave is almost reflected on the test piece surface under low frequency bands. Therefore, it is considered that there is a reasonable amount of RHC powder content for the wave absorption.

Moreover, the peak absorption values and the absorption frequency are changed with amount of the filler content as shown in Fig.7 (b).

3.2 Effect of test piece thickness

Fig.8 (a) shows the effect of test piece thickness on the reflectivity for 50MHz-3GHz. The test piece with thickness 5mm has the peak value of about -5dB at about 50MHz, and about -10dB at about 2.7GHz.

Fig.8 (b) shows the effect of test piece thickness on the

reflectivity for 2GHz-8GHz. The test piece thickness 1.5mm obtained the high electromagnetic wave absorption of about -25dB at about 8GHz. Moreover, the test piece with thickness 2.5mm obtained about -15dB at about 5.5GHz, and the test piece with thickness 5mm was obtained about -10dB at about 2.6GHz. The peak values and the absorption frequency are changed with the test piece thickness.

These results show that there is an optimum combination of the RHC powder content and the test piece thickness to obtain a high electromagnetic wave absorption for a given frequency band.

4. CONCLUSION

The characteristic of electromagnetic wave absorption was measured in frequency band of 50MHz-8GHz for the composite material of RHC/EPDM. The authors evaluated the influence of RHC powder contents and test piece thickness. The summary of the obtained results was described as follows.

- (1) The considerably high electromagnetic wave absorption of about -35dB at about 7GHz was obtained for test piece with 200 phr.
- (2) The peak values and the absorption frequency are changed with the powder contents and test piece thickness.
- (3) There is an optimum combination of the RHC powder contents and the test piece thickness to obtain a high electromagnetic wave absorption for a given frequency band.

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