Research on the microwave absorbing properties of ferrite/acetylene carbon black composites with different structures

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Abstract: This experimental study was aimed to investigate the microwave absorbing properties of composites with different structures prepared by filling nitrile rubber (NBR) with ferrite and acetylene carbon black (CB). The results show that the input impedance of the ferrite-filled composite was smaller than that of the CB-filled composites. The ferrite filled composite also matched the free space better than the CB filled composite. The two-layer and four-layer composites performed significantly better than the single-layer structure composites in absorbing microwaves. The maximum absorption attenuation of the four-layer NBR/CB composites reached 11.38dB.

1. Introduction
Microwave absorbing materials, referred to as absorbing materials, are functional composite materials that can effectively absorb incident radar waves, scatter them, and greatly attenuate them. The principle of wave absorption is that when electromagnetic waves propagate in the air and meet the medium, the electromagnetic wave is reflected at the interface due to the impedance of the medium and the free space impedance mismatch. In addition to reflection, the transmitted wave enters the inside of the medium. During the propagation, energy loss occurs due to the interaction between electromagnetic waves and the medium. When the electromagnetic waves encounter the back interface, impedance mismatch occurs again. Part of the electromagnetic wave is emitted into the air, and the other part is reflected back by the back interface. The waves continue to repeat the above process in the medium [1]. Therefore, in order to obtain materials with good absorbing properties, two aspects generally should be considered in the design of materials: impedance matching design and attenuation design. Impedance matching design refers to the creation of special boundary conditions to minimize the reflection coefficient R of the incident electromagnetic wave on the surface of the material medium (ideally R=0), so as to maximize the electromagnetic wave into the material[2]. In this paper, from the impedance matching design, acetylene carbon black (CB) and unsintered ferrite filled nitrile butadiene rubber (NBR) were used to prepare single-layer and two-layer composites. And CB filled NBR was used to prepare four-layer composites. The wave absorption performance of the composites was investigated.

2. Experiments
2.1 Experimental formulation
The experimental formula was designed as follows (the matrix was NBR, 100 parts).
1#: Single-layer structure material (unit: parts)

| The first group | The second group | The third group |
|-----------------|-----------------|----------------|
| Barium ferrite  | CB              | Heterogeneous ferrite |
| 20              | 50              | 20             |
|                 | 50              | 50             |
|                 | 25              |                 |

2#: Two-layer structure material (unit: parts)

| The first group | The second group |
|-----------------|-----------------|
| CB              | Barium ferrite  |
| 0               | 20              |
|                 | 0               |
|                 | 50              |
|                 | 0               |

3#: Four-layer structure material (unit: parts)

| The first layer | The second layer | The third layer | The fourth layer |
|-----------------|------------------|-----------------|-----------------|
| CB:2.5          | CB:5             | CB:7.5          | CB:10           |

2.2 Preparation of composites
The NBR rubber was initially smelted and plasticized in a two-roll mill, and then vulcanizing agent, activator, and antioxidant were added for mixing. After that, the corresponding acetylene carbon black and unsintered ferrite were added to compound according to the formulation. The composites were obtained by press molding (temperature 160℃, pressure 10MPa) in a plate vulcanizing machine.

2.3 Performance test
The free-space method was used to test the absorbing performance of the composites (the measurement frequency range was 8~18GHz).

3. Results and discussion
Figures 1 and 2 were the absorption curves of NBR/CB/barium ferrite composites and NBR/CB/heterogeneous ferrite composites with different structures.
Figure 2. The absorption curves of NBR/CB/ Heterogeneous ferrite composites with different structures.

It can be seen from Figure 1 and Figure 2 that the wave absorption performance of the composites with two-layer structure was obviously better than that of the composites with single-layer structure. The reason was that the first layer of the two layers of structure material was composed of ferrite which belonged to ferrite loss type. Its resistance was small, and it matched well with the impedance of free space so that the wave was easier to penetrate and reflected less [3]. Part of the electromagnetic wave was lost due to the polarization effect and natural resonance of the ferrite. The electromagnetic wave continued to propagate in the layer composed of CB. CB had a great loss ability of electromagnetic wave, which can be lost by converting it into heat energy. The single-layer structure material was composed of ferrite and carbon black. Its impedance was relatively large, and the degree of matching with free space was not so good. When electromagnetic waves entered, there was a large reflection of electromagnetic waves on the interface, and the electromagnetic waves entering the composite material were relatively reduced. Therefore, the absorption attenuation value of the composites was also smaller.

In order to prove that the impedance matching between ferrite and free space was better than that between CB and free space, the absorbing performance of the material was tested by injection from different surfaces of the composites. Figure 3 shows the absorption curve of the two-layer structure of the NBR/CB/barium ferrite composite material from different surfaces.

Figure 3. The absorption curves of NBR/CB/ Heterogeneous ferrite composites with different structures.

It can be seen from Figure 3 that the attenuation of electromagnetic waves measured from the
upper layer was significantly greater than that measured from the lower layer at the same measurement frequency. In the entire measurement frequency, the reflection attenuation of the former was not less than 4dB. The maximum attenuation value of the former can reach 12.5dB, which conforms that the impedance matching between ferrite and free space was better than that between CB and free space.

Formulation 3 was based on the principle of gradual transition of impedance, which constructed the composite material with input impedance gradually increasing from small to large. Figure 4 showed the absorption curves of single-layer and four-layer NBR/CB composites.

![Figure 4. The absorption curves of single-layer and four-layer NBR/CB composites.](image)

It can be seen from Figure 4 that the wave absorption performance of the four-layer structure material was obviously better than that of the single-layer structure material with the same 25 parts of carbon black filled NBR. The maximum absorption attenuation value of the single-layer structure was only 5.89dB, while the maximum absorption attenuation value of the four-layer structure reached 11.38dB.

4. Conclusion
1) The input impedance of the ferrite filled composite was smaller than that of the CB filled composite. The impedance matching between ferrite and free space was better than that between CB and free space.
2) Under the same conditions, the absorption performance of the two-layer and four-layer composites was obviously better than that of the single-layer composites. Especially, the absorption attenuation of the four-layer composites was greater than that of the single-layer composite in the whole measurement frequency range. The maximum absorption attenuation of the four-layer composites reached 11.38dB.

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