ABSORBING PROPERTIES AND OPTIMIZATION OF Ni POWDER/M-GLASS FIBER REINFORCED EPOXY COMPOSITE PANELS

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In this paper, Ni powder/M-glass fiber reinforced epoxy composite panels with different Ni powders were prepared by mould pressing method, of which the ultrafine Ni powder is prepared by the liquid reduction method. The waveguide method can be used to measure the electromagnetic parameters of the samples in the frequency ranged from 8.2 GHz to 18 GHz. The results show that Ni powders distributed evenly during the M-glass fibers reinforced epoxy layers. The main absorbing mechanism of composite panels is magnetic loss. The absorbing properties of samples increase with the adding of Ni powder contents and the thickness of panels. Based on the theory of the transmission line, the optimization design of Ni powder/ M-glass fiber reinforced epoxy composite has been calculated. When the whole thickness of the composite panels is 4.6mm excepting the Al plate thickness with the absorbing layer of Ni powder/ M-glass fiber reinforced epoxy of 1mm, the whole absorbing properties improve gradually with the increase of frequency ranged from 8.2 GHz to 18GHz and the absolute value of the reflection coefficient R is above 10dB.

Keywords: Absorbing properties; optimization; Ni powder; epoxy; composite panel.

1. Introduction

In the national defense fields, stealth technology is always one of the key technologies of weapon equipment. In order to reduce the radar cross section (RCS) of weapon

equipment, such as aircraft, missile, tanks, more and more people focus their attentions on the improvement of radar absorbing materials (RAM) except for the object shape design. So the RAM with “thin, light, wide, strong” characteristics is becoming one of the important research aspects of modern stealth technology.¹⁻³ Electromagnetic parameters are the essential factors to the absorbing materials. Therefore, it is necessary to select proper absorbing materials with reasonable electromagnetic parameters and optimize the absorbing properties in order to improve the comprehensive performance of the absorbing materials.

2. Experimental

The superfine Ni powder is used as the absorbing material, which is prepared by the liquid reduction method with grain size of 5~15μm. Then the surface of the Ni powder is coating a layer of SiO₂ (1~10μm) by the sol-gel method as a kind of surface modification. The epoxy glue, which can be obtained by mixing E-51, thinner, coupling agent, triethylene tetramine (TETB) and different contents of the Ni powder, is spread evenly on the surface of the M-glass fiber by mould pressing method. The serial numbers of sample are shown as follows. Then the absorbing properties of samples were optimized by the software of multilayer radar wave reflection coefficient which designed by our team. The sample numbers are shown in Table 1.

Table 1. Serial numbers of sample with different contents of Ni powder

Sample number	the mass ratio of epoxy: Ni powder
E-51	Pure epoxy
B1	1: 0.3
B2	1: 0.5
B3	1: 0.7

The phase analysis of Ni powder is tested by X-ray diffraction with a model of Bruker D8 Focus. The metallographic analysis is tested by the MEF3 model metallographic microscope and the electromagnetic parameters of the composite panels are tested by the waveguide method with the testing frequency ranged from 8.2 GHz to 18 GHz.

3. Results and discussion

3.1. XRD analysis

Fig. 1 shows the XRD pattern of Ni powder prepared by the liquid reduction method. It is clearly to see that there are three sharp diffraction peaks at around 44°, 52° and 77° respectively, which are the characteristic peaks of Ni and the other impurity peaks such as NiO or Ni(OH)₂ are not appeared. It also proves that the state of Ni powder is FCC crystalline structure.

Fig. 1. XRD pattern of the Ni powder

3.2. Metallographic analysis

Fig. 2 shows the metallurgical figures of the composite panels, which is observed by metallographic microscope. As can be seen from Fig. 2 (a) and Fig. 2 (b) with different enlargement scales, Ni powder spread evenly between the layers of M-glass fibers. Such structure is comparatively coincides with our expectation. Furthermore, it also indicates that the selection of mould pressing method is suitable for preparing the composite panels.

Fig. 2. The metallurgical figures of sample

3.3. Electromagnetic parameters of the composite panels

Generally speaking, to the absorbing materials with excellent absorbing properties, it should be satisfied with two conditions: firstly, the electromagnetic matching between the materials and the air should be as good as possible to make sure most of electromagnetic waves can get access to inside of the material. Secondly, once the electromagnetic waves getting into the inside, the electromagnetic wave should be attenuated rapidly, namely, the electromagnetic loss of the materials should be as large as possible.⁴

Fig. 3. Electromagnetic parameters of composite panels with different Ni powder contents

Fig. 4. Electromagnetic loss tangent curves of composite panels with different Ni powder contents

The electromagnetic parameters curves and the electromagnetic loss tangent curves of composite panels with different Ni powder contents are shown in Fig. 3 from (a) to (d) and Fig. 4 respectively. From the curves, we can see that the magnetic and dielectric losses of the composite panels increase with the rising of the amount of the powders and the main absorbing mechanism of composite panels is magnetic loss. In addition, with the adding of Ni powder, the electromagnetic matching between the composite panels and air become worse and the absorbing properties of the composites improve with the increase of the absorbing powders contents. When the frequency is about 11 GHz, the magnetic loss tangent value reaches minimum of -0.4 and the dielectric loss tangent value reaches maximum at around 12 GHz with the value of 0.12. It indicates that the main absorbing mechanism of composite panels is magnetic loss.

3.4. The surface reflection coefficient of the composite panels

It is well known that the reflection and refraction will happen simultaneously when electromagnetic wave shoots on the surface of samples. The part of reflection is called surface reflection. Generally speaking, the smaller of the surface reflection coefficient demonstrate the better of the electromagnetic matching of the samples with the air. Fig. 5 shows the curves of the reflection coefficient at the surface of the composite panels, we can see from Fig. 5 that the absolute values of the reflection coefficient of the composite panels at the surface of the panels become smaller with the adding of the amount of Ni powders, which also means the electromagnetic matching performances between the sample and the air become worse.

Fig. 5. The curves of the surface reflection coefficient

3.5. Absorbing Property Optimization of Composites

M-glass fiber reinforced epoxy composite panels have great transparent properties to waves. According to measurement, its surface reflection coefficient is relatively lower than that adding absorbing powder with the value of -11.7dB. When we combine the M-glass fiber reinforced epoxy composite panels with the amorphous powders/ M-glass fiber reinforced epoxy composite panels with gradient layer structure served as the wave transparent layers, while the Al layers are considered as the layers of total reflection.

Based on the theory of the transmission line, the optimization design of Ni powder/ M-glass fiber reinforced epoxy composite has been calculated, and the suitable thickness ranges of B1, B2 and B3 are shown in Table 2.

Table 2. Thickness of absorbing layers at different composite panels

Absorbing layer number	B1	B2	B3
Thickness of absorbing layer/mm	1.2~2.7	1.0~2.4	0.7~2.8
The whole thickness of composites/mm	4.6	4.6	4.6

Fig. 6. The absorbing properties curves of composite panels

Fig. 6 shows the absorbing properties curves of composites. We can see from the curves that when the whole thickness of the composite panels is 4.6mm excepting the Al plate thickness with the absorbing layer of Ni powder/ M-glass fiber reinforced epoxy with 1mm thickness, the whole absorbing properties improve gradually with the increase of frequency ranged from 8.2 GHz to 18 GHz and the absolute value of the reflection coefficient R is above 10 dB in 8.2 GHz~18 GHz, which has a practical application value in the national defense fields.

4. Conclusions

The Ni powder/ M-glass fiber reinforced epoxy composite panels were prepared successfully by mould pressing method. Ni powders distribute evenly during the layers of the composite panels. The magnetic and dielectric losses of the composite panels increase with the rising of powders and the main absorbing mechanism is magnetic loss. With the addition of Ni powders, the electromagnetic matching between the composite panels and air become worse and the absorbing properties of the composites improve with the increase of Ni powders contents. Through calculation, the whole absorbing properties improve gradually at the frequency ranged from 8.2 GHz to 18 GHz and the absolute value of the reflection coefficient R is above 10dB at the whole frequency range.

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