DESIGN AND FABRICATION OF A MULTI-LAYER RADAR ABSORBING COMPOSITE STRUCTURE

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ABSTRACT

A novel non-magnetic multi-layer radar absorbing structure (RAS) was designed and fabricated. The broadband absorbing performances and load-bearing capacities of RAS were evaluated through experimental tests. The testing results revealed that the designed lightweight RAS can satisfy the absorption of -10 dB from 8 GHz to 18 GHz with the thickness of 3.5 mm.

1 INTRODUCTION

Lightweight composite material has been broadly used in radar absorbing structure (RAS) due to their high specific modulus and high specific strength. Several types of RAS have been reported in the existing literatures, such as the honeycomb coated with dielectric and magnetic materials, absorbing foams, absorbing particle filled into the fiber reinforced laminate, and frequency selective surface (FSS). Recently, Lee et al.[1] and Choi et al.[2,3] fabricated a composite RAS consisting of a single-layer FSS film and composite laminate. Their testing results revealed that the fabricated RAS with a thin thickness (2.37 mm) could satisfy the 10 dB absorption in the X-band. However, the FSS film was directly pasted on the outer surface of the structure. In practical applications under various loading conditions, wear damage and local delamination that would lead to the abrupt degradation of absorption performance was a great concern.

In present paper, a novel non-magnetic multi-layer RAS was designed based on the frequency selective surface (FSS) with periodic square resistive pattern. The main aim was to achieve the broadband microwave absorbing and load bearing. Screen printing and vacuum assisted resin injection (VARI) process were adopted to fabricate the RAS. A serious of experimental tests was conducted to evaluate the electromagnetic wave absorption and mechanical performance, such as the free space technique system and low-velocity impact.

2 DESIGN AND FABRICATION OF RAS COMPOSITE LAMINATE

To meet the requirements of load bearing and broadband microwave absorbing, a wideband RAS was proposed as shown in Figure.1. The designed RAS was composed of double-layer FSS films and three layers glass fiber reinforced laminates. It was worth mentioning that there were several control parameters including the size of pattern, resistive, and the thickness of laminate spacers. The specific optimization method can be found in our previous studies [4,5].

Screen printing and vacuum assisted resin injection (VARI) process were adopted to fabricate the RAS, and the specific processes were shown in Figure.2. In present paper, the conductive ink was synthesized by mixing carbon nanoparticles and micro graphite flake with binders, solvents and various auxiliaries. The varying surface resistance values can be controlled by changing the mixing volume ratio. To achieve extremely low surface resistance of FSS film, metals or metallic oxides can be added into the ink, while for high surface resistance, dielectric nanoparticles should be filled into the ink. A nylon screen stencil with mesh number 120 per centimeter was used.

Unidirectional E-glass fiber cloth was utilized as the reinforced material, which has lower dielectric property and higher mechanical performance compared with carbon fibers and Kevlar fibers. The thickness of layer was 0.2 mm and the areal weight was 220 g/m^2. Vinyl ester resin that can be cured at ambient temperature in the presence of hardening agent and accelerating agent was used as the matrix material. The accelerating agent and hardening agent were Dimethylaniline and Methyl Ethyl Ketone Peroxide (MEKP). The resin was mixed with hardening agent and accelerating agent at the mass ratio of 100:1:1, and the curing time was about 30 min.

For the preparation of FSS films, the control of baking temperature and duration was crucial important to obtain a stable surface resistance. The thickness of fabricated RAS was 3.5 mm and a pure glass fiber reinforced laminate (GFLC) was prepared as the referential sample using the same process.

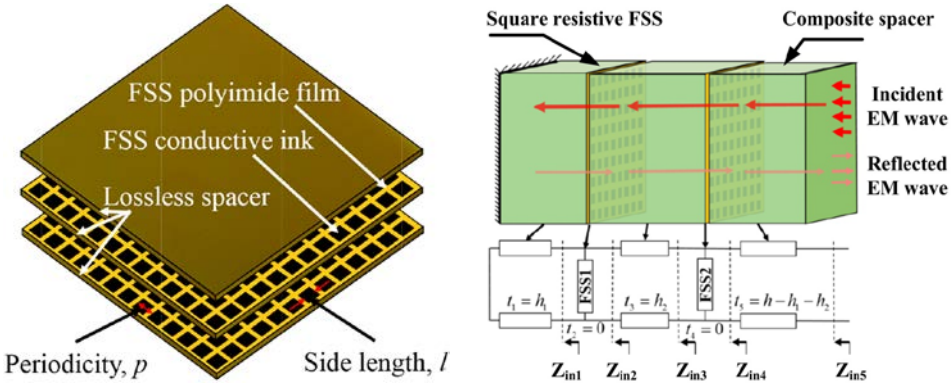

Figure 1: Schematic diagram of lightweight RAS

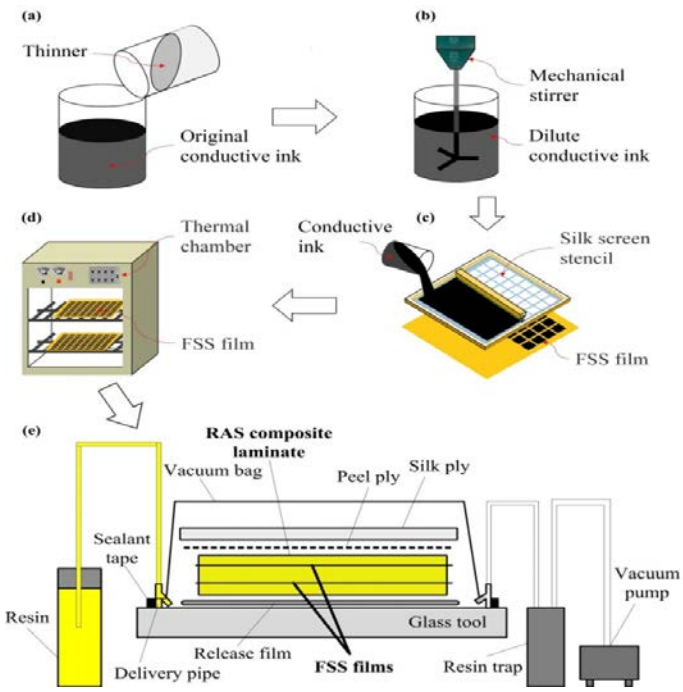

Figure 2: Schematic diagram of screen printing and VARI process

3 EXPERIMENTAL

A serious of experimental tests was conducted to evaluate the electromagnetic wave absorption and mechanical performance, such as the electromagnetic wave absorption test and low-velocity impact.

Free space technique system was utilized to measure the reflection loss of transverse electromagnetic (TEM) waves. The system consisted of a pair of spot-focusing horn lens antennas, a sample holder, an Agilent E8363C network analyzer and a computer for data acquisition.

The drop-weight impact test was performed at room temperature using Instron Dynatup 9250HV drop weight impact testing machine according to the ASTM D5628-07 standard. The impact energies were set as 20J and 150J.

The measured reflectivity of RAS proposed in this paper was shown in Figure.3. It can be seen that the lightweight RAS can satisfy the absorption of -10 dB from 8 GHz to 18 GHz with the thickness of 3.5 mm. The experimental results were agreement with the numerical simulation results. Figure.4 revealed that the impact response of RAS undergoing various impact energy. Through the comparison of test curves, it can be seen that, due to the embedment of FSS film, the overall damage resistance and tolerance of composite laminate was slightly degraded. It was owing to the interface delamination between FSS film and glass fiber laminate. For the pure GELC, the main damage modes were fiber breakage and crack growth. The interfacial delamination was the main failure factor for RAS.

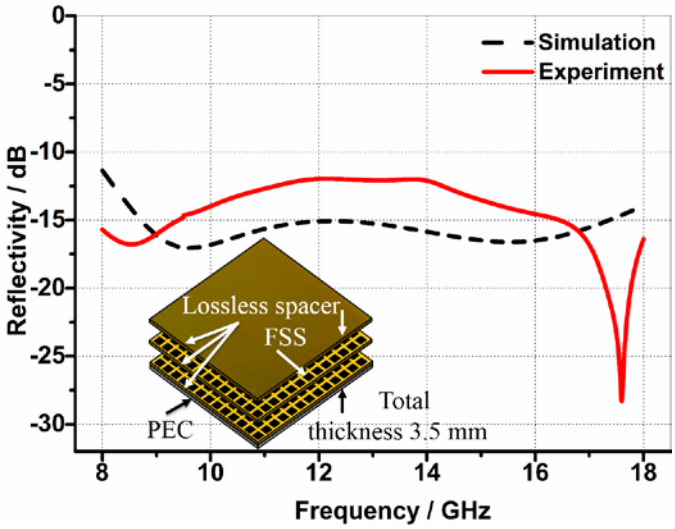

Figure 3: Comparison of reflectivity between simulation and experimental results

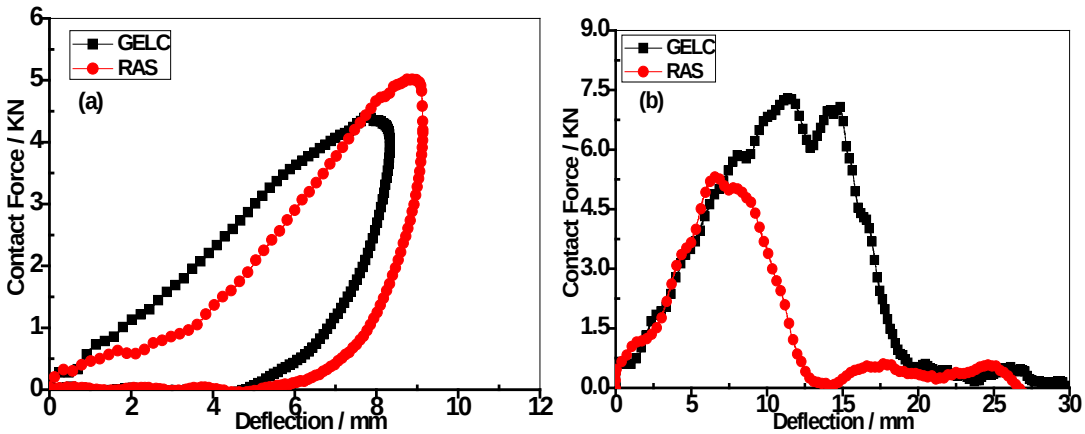

Figure 4: The impact response of pure GELC and RAS under various impact energy: (a) 20Jand (b) 110J.

4 CONCLUSIONS

In present paper, a non-magnetic broadband radar absorbing structure was designed based on the frequency selective surface. A lightweight RAS laminate (3.5 mm) composed of glass fiber laminate and FFS film was fabricated by screen printing and VARI process. The radar absorbing performance and mechanical performance were evaluated though experimental tests. The results revealed that the

designed and fabricated RAS exhibited a wider 10 dB bandwidth from 8 GHz to 18 GHz. In the case of high impact energy, the overall damage resistance and tolerance of composite laminate was slightly degraded due to the effect of weak interfacial between laminate spacer and FSS film.

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