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Oblique incidence performance of radar absorbing honeycombs

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ABSTRACT

Coated with carbon powder based absorbing material, the hexagonal honeycomb (HH) becomes a multifunctional structural material, possessing load-carrying and radar-absorbing abilities. The microwave absorbing behavior changes with the density and the thickness of the HH. Under oblique incidence, the radar absorbing hexagonal honeycomb (RAHH) still has excellent microwave absorbing ability. Under wide-angle oblique incidence where the oblique angle is 55°, the RAHHs lose their radar absorbing ability and become radar reflective structure. Through the research the RAHHs have the capabilities of load bearing and electromagnetic energy absorbing, but the oblique incident angle must be limited within 45°.

1. Introduction

Honeycomb is a two-dimensional periodic cellular material that is relatively strong and stiff normal to the microstructure but compliant in-plane. Honeycomb composites are commonly manufactured from planar sheets of aluminum, aramid paper, reinforced plastics or composite material. Honeycomb materials have a wide range of applications such as aerospace, automotive, rolling stock, marine, building, packaging and electronics, as cores in sandwich panels. In aerospace, some load-carrying structures are required to absorb microwave [1,2]. Various dielectric and magnetic materials are developed and coated on the surface of structures to absorb microwave energy [3–7]. An efficient way is to combine the mechanical and electromagnetic behavior into a structure [8–11]. Coated with radar absorbing materials on its wall [12–17] or foam-filled into the cell [18–22], honeycomb can be fabricated as a multifunctional structure, possessing load-carrying and microwave absorbing abilities. Adopting this method, dimension and weight of the aerospace structure can be greatly reduced. Vulnerability of radar-absorbing layers coated on the surface of the aerospace structure can be greatly reduced. Choi and Kim [23] developed broadband radar-absorbing honeycomb structure with novel design concept. To efficiently improve the absorbing performance, they used the transverse direction of a honeycomb structure made out of a lossy material. In that the honeycomb structure can be used in the transverse to the ribbon direction, the effective thickness in terms of the incident microwaves becomes very large, resulting in the enhancement of absorption bandwidth [23].

Under oblique incidence [24–27], the reflection of the microwave turns to complex. Kim and Kim [24] developed a two-layer laminate for wide-angle oblique incidence. The absorbing layer of rubber composite containing magnetic iron flake particles and the surface layer of low dielectric constant (carbon black composite and glass fiber composite) have been used. Both Transverse Electric (TE) and Transverse Magnetic (TM) polarization must be considered in in the absorber design. At the optimum thickness of the composite layers, a low value of reflection loss (less than −10 dB) has been predicted for wide incident angles up to 60° for both TE and TM polarization. On the while, the use of glass fiber composite as the impedance-matching layer reduces angle width greatly to about 40°, indicating that the dielectric property of impedance-matching layer plays a critical role in non-specular microwave absorbing properties [24]. Perini and Cohen [25] pointed that a tapered section of transmission line for impedance matching only works for nearly normal incidence. When the structure is illuminated with incident angles of more than 30°, the wave "sees" the RAM as a solid piece of lossy dielectric, and a substantial reflection occurs [25]. Zhang et al. [26] designed a magnetic absorber whose maximum angle range with −10 dB reflection coefficient can reach 57.8°.

Few literature concern the microwave absorbing abilities of radar absorbing honeycombs under oblique incidence. In previous research [18], the lattice grid even has a little wider microwave

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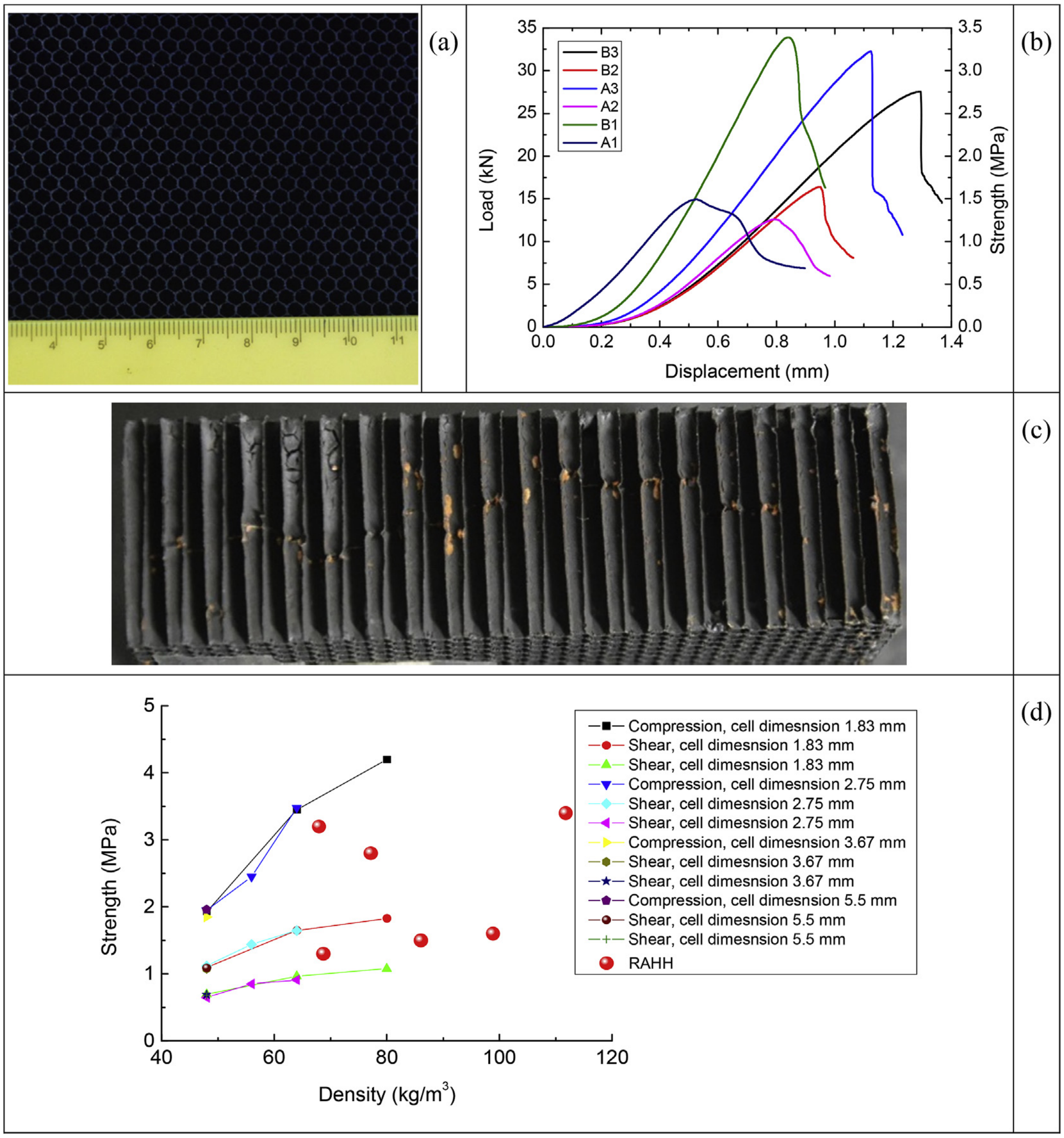

Fig. 1. RAHH (a) topology, (b) compression curves, (c) failure mode and (d) strengths compared with typical aramid HHs.

Table 1
Specifications of radar absorbing RAHHs.

Sample	Cell dimension (mm)	Thickness (mm)	HH density (kg/m^3)	RAHH density (kg/m^3)	Coating density (kg/m^2)
A1	1.83	10	32	86.0	0.54
A2	1.83	20	32	68.7	0.74
A3	1.83	30	32	67.9	1.08
B1	1.83	10	48	111.7	0.64
B2	1.83	20	48	98.8	1.02
B3	1.83	30	48	77.1	0.87

absorbing bandwidth, 13.5 GHz, under oblique incidence, while under normal incidence the bandwidth is 10 GHz.

Present study is focused on the radar absorbing behaviors of the aramid HH, especially under oblique incidence. The HH was coated with dielectric composites to satisfy the microwave absorbing function, which was studied by experiments.

2. Manufacturing method

Manufacturing aramid honeycomb begins as a coil of foil. Foil goes through the printer for adhesive lines to be printed. Then the foil is cut to size and stacked into piles using the stacking machine. Following this, the stacked sheets of foil are pressed using a heated press to allow the adhesive to cure and bond the sheets of foil together, forming a block. The block can be cut into slices. Finally the honeycomb is expanded to hexagonal topology to make the HH. The HH is then coated with radar absorbing material by dipping. For honeycomb coatings, the carbon powder is mixed in a thermoplastic resin using a high speed mixer. All materials in the experiments are commercially available. The honeycomb cores are