Composites Science and Technology 71 (2011) 1632–1638

Contents lists available at ScienceDirect

Composites Science and Technology

journal homepage: www.elsevier.com/locate/compscitech

Aramid/epoxy composites sandwich structures for low-observable radomes

Ilbeom Choi [a], Jin Gyu Kim [a], Dai Gil Lee [a,*], Il Sung Seo [b]

[a] School of Mechanical Aerospace & Systems Engineering, Korea Advanced Institute of Science and Technology, ME3221, Guseong-dong, Yuseong-gu, Daejeon 305-701, Republic of Korea
[b] Agency for Defense Development, P.O. Box 35, Yuseong-gu, Daejeon, Republic of Korea

ARTICLE INFO

Article history:
Received 23 December 2010
Received in revised form 4 July 2011
Accepted 10 July 2011
Available online 23 July 2011

Keywords:
A. Sandwich
A. Structural composites
B. Mechanical properties
C. Finite element analysis (FEA)

ABSTRACT

Low-observable radomes are usually made of E-glass/epoxy composite due to its low dielectric constant which is necessary not to interfere electromagnetic (EM) wave transmission characteristics. Since aramid fibers have lower dielectric constant and higher strength than those of E-glass fiber, aramid fiber radome structures may have better the EM transmission and mechanical characteristics than those of E-glass/epoxy radomes. In this work, the low-observable radome was constructed with a sandwich construction composed of aramid/epoxy composites faces, foam core and Frequency Selective Surface (FSS) which had the abilities of transmitting EM waves selectively in the X-band range. The EM wave transmission characteristics of the low-observable radome were simulated by a 3-dimensional electromagnetic analysis software and also measured by the free space measurement method with respect to the pattern size of FSS and foam cores. The mechanical properties of the low-observable radome made of aramid/epoxy composite were measured by the 3-point bending test and compared to those of the conventional low-observable radome made of E-glass/epoxy composite.

1. Introduction

In a modern war, the detection of opposites before being exposed is important to have a position of advantage. For that reason, hiding weapon systems against opposites, which is also called stealth technology, has come to the fore.

The stealth technology makes weapon systems less visible to tracking systems of opposites such as radar, infrared and others. In order to maximize the performance of stealth techniques, Radar Cross Section (RCS) of weapon systems should be minimized because the distance detected by an opposite radar is proportional to the fourth root of RCS [1]. The RCS is the power reflected or scattered by a radar target which is expressed as the product of an effective area and an incident power density when the direction is back toward the radar [2]. Since the radar antenna is the main cause to increase RCS of the weapon systems, it is one of the most suitable structure to which the stealth technology could be applied to reduce the radar detection [3].

Aircrafts, warships and missiles have radar antennas for their performance. The radome (radar + dome) is a protective cover of radar antennas as shown in Fig. 1a. In order to shield radar antennas, the radome should be not only mechanically strong but transparent at the operational frequency range of the radar antenna [4]. The radomes are generally composed of materials that have high mechanical properties with low level of dielectric constants in order to shield the radar antennas from the external load and environmental conditions and to minimize the loss of EM wave which is transmitted to the radar antennas through the radome.

In this work, the low-observable radome was fabricated with aramid epoxy composite faces and foam core for the stealth performance. Polyvinyl chloride (PVC) and Polymethacrylimide (PMI) foams were used as the core materials embedded with Frequency Selective Surface (FSS). The function of FSS is transmitting or reflecting electromagnetic (EM) waves selectively.

The functional requirements (FRs) of the low-observable radome are as follows:

- FR_1: Have a resonance in the X-band frequency range (8.2–12.4 GHz).
- FR_2: Have more than 80% of the maximum transmission rate with less than 1 GHz bandwidth.
- FR_3: Have high specific strength for easy installation.

The EM transmission characteristics of the low-observable radomes were numerically simulated with the 3-dimensional commercial electromagnetic analysis software, CST Microwave Studio® (CST Gmbh, Germany). The EM transmission characteristics were also measured by the free space measurement system (HVS Technologies, Pennsylvania, USA). The high specific strength (FR_3) of weapon system has the benefits of mobility, fuel efficiency and easy handling of systems because of low weight. Especially, the mobility is a significant advantage for establishing superiority in action.

* Corresponding author. Tel.: +82 42 350 3221; fax: +82 42 350 5221.
E-mail address: dglee@kaist.ac.kr (D.G. Lee).

0266-3538/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.compscitech.2011.07.008

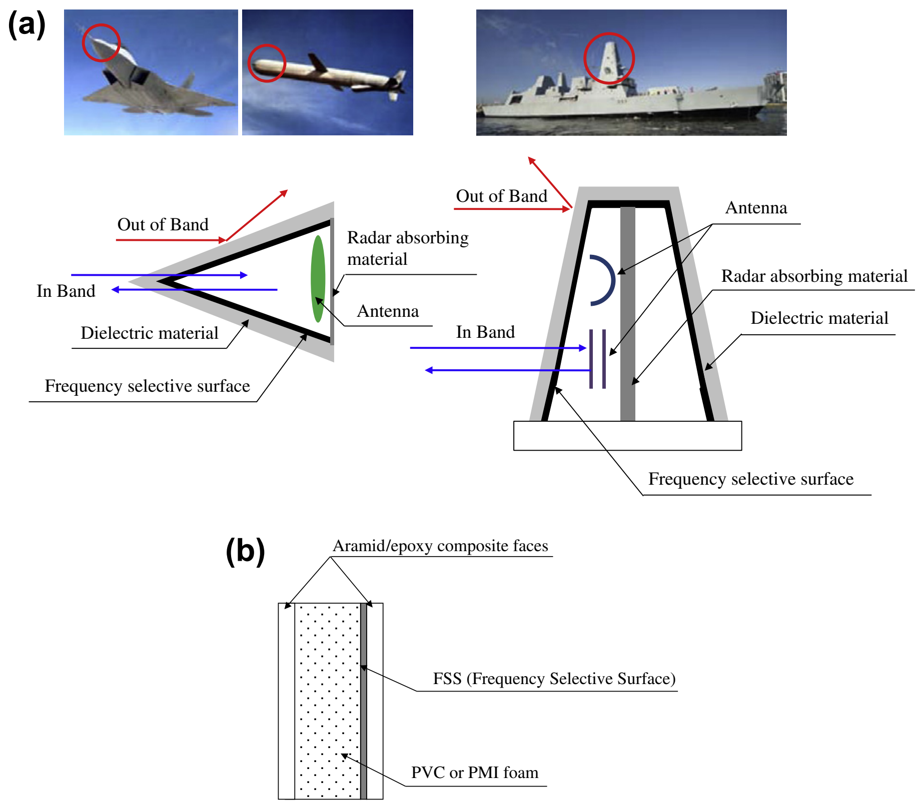

Fig. 1. Schematic diagrams: (a) radar and the low-observable radome systems and (b) sandwich structures of the low-observable radome.

2. Fabrication of the low-observable radomes

The low-observable radomes were fabricated as sandwich structures with the composite faces, foam core and FSS as shown in Fig. 1b. For the face materials, the plain weave aramid fabric (1000 denier Heracron, Kolon, Korea) was used as reinforcement because the aramid fiber has high mechanical properties and low EM transmission loss. The epoxy resin (RS1212, Hankuk fiber, Korea) was used as matrix to prepare prepreg. The prepreg composed of the plain weave fabric aramid/epoxy was cured with the autoclave vacuum bag degassing method under the cure cycle in Fig. 2. The thickness of each layer was 0.235 mm and the numbers of layers were 3,4,5,6 and 7 for the thicknesses of aramid/epoxy composites as 0.74 mm, 0.94 mm, 1.15 mm, 1.39 mm and 1.69 mm, respectively. After curing, the fiber volume fraction was 60%.

As the core materials, PVC foam (Divinycell HT110, DIAB Inc., Sweden) or PMI foam (WF110 and IGF110, Degussa, Germany) were selected since the PVC and PMI foams have similar dielectric properties to those of the free space. The FSS was composed of thin copper foil of 20 µm thickness and polyimide film of 4 µm thickness. The plain weave fabric aramid/epoxy composite, foam core and FSS were bonded with an epoxy adhesive (Araldite®, USA), and cured at 80 °C under 0.1 MPa pressure. After curing, the thickness of the adhesive layer was 0.1 mm.

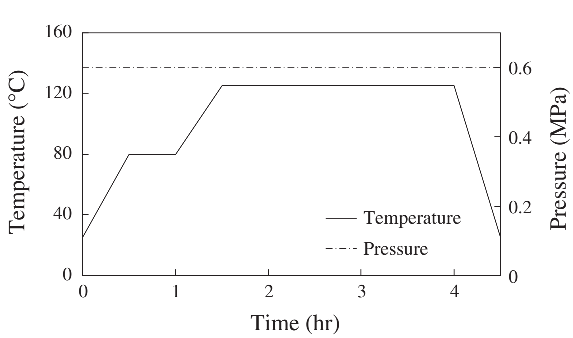

Fig. 2. Cure cycle of the plain weave fabric aramid/epoxy composite.

3. Electromagnetic transmission characteristics of the low-observable radome

3.1. Electromagnetic transmission characteristics of the face material and core material

The dielectric constants of the face materials were measured with the free space measurement system as shown in Fig. 3 [5]. The scattering parameter, S_{ij} can be determined as follows.

$$S_{ij} = \left.\frac{V_i^-}{V_j^+}\right|_{V_k^+=0 \quad for\ k\neq j} \tag{1}$$

In Eq. (1), S_{ij} is found by driving port j with an incident wave of voltage V_j^+, and measuring the reflected wave amplitude, V_i^-, coming out of port i [6]. The complex reflection scattering parameter S_{11} was measured placing the specimen at the position of focal point of the transmitting antenna. The value of S_{11} was related to the complex relative permittivity from the transmission line theory as follows [7].

$$S_{11} = \frac{jZ\,tan(\beta d) - 1}{jZ\,tan(\beta d) + 1} \tag{2}$$

where, Z is the normalized wave impedance, β is the phase constant and d is the thickness of a specimen. Z is expressed as

$$Z = \frac{1}{\sqrt{\varepsilon_r}} \tag{3}$$

where ε_r is the relative permittivity of material.