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Thermo-mechanical Characteristics of Smart Skin Antenna Structures

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Abstract

Analysis on the thermo-mechanical behaviors of smart skin antenna structures under air flow is performed. The model is a conformal load-bearing structure, reducing radar cross section and increasing stealth functions are very important. The skin is modeled as a multi-layer sandwich structure composed of carbon/epoxy, glass/epoxy and a dielectric polymer. Furthermore, a dielectric layer is embedded on the middle surface of the sandwich structure to act as antenna or radars. The formulation of the structural model is based on the first-order shear deformation plate theory. Lastly, Newton-Raphson iterative method applied for solving the nonlinear equations of the thermal post-buckling analysis and numerical results are calculated by finite element method.

keywords: Multi-layer sandwich plate; Smart skin structure; Thermal post-buckling

1. Introduction

Throughout the history, researchers have endeavored to develop new and advanced technologies with the goal of achieving military advantage of the materials. Recently, many countries lead to develop so called stealth aircraft in order to avoid radar detection. For this reason, smart skin structures are investigated. The skin is a conformal load-bearing antenna structure reducing radar cross section and increasing stealth function. Finally, the structure is composed of laminated with special properties.

Smart skin structures have been widely investigated such as the design procedure including the structure design, material selection and design of antenna elements in order to obtain high electric and mechanical performances [1]. Kang et al. [2] performed analysis and optimal design of smart skin

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structures for buckling and free vibration using finite element method and genetic algorithm. Yoon et al. [3] designed and fabricated a simple conformal load-bearing smart skin antenna structures. Under the unidirectional compression load, the test and analysis results were compared. Yoo and Kim [4] presented the thermal buckling of the smart skin for the antenna performance and optimization to maximize the critical temperature and natural frequency.

Generally, laminated plate is replaced metal structures for the smart skin of aircraft wings and antenna to reduce the weight of structure. In this work, first-order shear deformation theory is employed and von-Karman strain-displacement relations are based to derive governing equations of the plate. Nonlinear analysis of the structural model in supersonic range is calculated by the first-order piston theory. The Newton-Raphson method is applied to solve the governing equations of the model. The thermal buckling characteristics of the smart skin are studied with design variables.

2. Modeling and formulation

2.1. Modeling

As shown Fig. 1, the smart skin model is introduced. The model is consist of 6 composite plates such as Glass/epoxy, Carbon/epoxy and Dielectric layer. The face sheets protect the dielectric layer due to external disturbances such as aerodynamic force and thermal loading. The carbon/epoxy layer was located on each side of the dielectric layer. Then, the honeycomb cores transmit shear between sheets, and provide the air gap to the antenna. Material Properties are presented in Table 1.

Table 1. Material properties of the smart skin

	G/E	C/E	Phenol	Honeycomb
E_1	24Gpa	67 Gpa	7.2 Gpa	0.09 Mpa
E_2	28 Gpa	57 Gpa		0.08 Mpa
ν_{12}	0.105	0.103	0.3	0.3
G_{12}	4.54 Gpa	5.9 Gpa		0.1 Mpa
G_{13}	1.0 Gpa	1.0 Gpa		19.7 Mpa
G_{23}	1.0 Gpa	1.0 Gpa		11.5 Mpa
α_1	9.7^{-6}/℃	2.1^{-6}/℃		1.5^{-6}/℃
α_2	17.7^{-6}/℃	2.1^{-6}/℃		1.5^{-6}/℃
ρ	2200kg/m^3	1450kg/m^3	9000kg/m^3	96.1kg/m^3

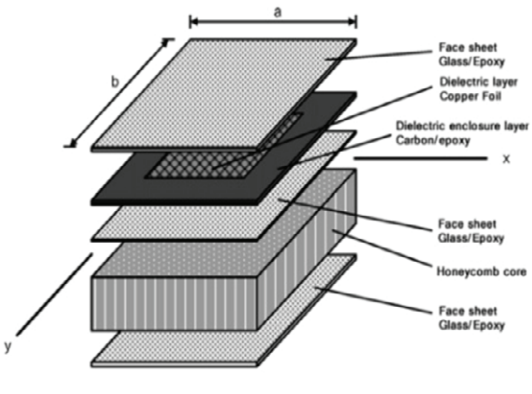

Fig. 1. The model of smart skin structure [3]

2.2. Formulation

The displacement fields for a composite plate based on the first-order shear deformation theory, and the von Karman strain-displacement relations for small strains with moderate rotations.

The stresses with thermal effect in laminate layers for the k^{th} layer are obtained by transformation of coordinates as