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Dimpling monitoring and assessment of satellite honeycomb sandwich structures by distributed fiber optic sensors

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Abstract

Dimpling in the face sheets of honeycomb sandwich structures due to mismatch in the thermal expansion coefficient of the constituent materials, with emphasis on its monitoring and assessment, was studied by utilizing embedded distributed fiber optic sensors. Strain distributions along optical fibers embedded in the face sheet of the sandwich structures were monitored during manufacturing. Based on finite element analysis results, the strain data was interpreted and dimpling monitoring capability was discussed. Simple analytical model to predict the dimple profile and thus assess the dimpling condition from the strain data was also presented and evaluated.

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*Keywords:*Honeycomb sandwich structures; dimpling; strain monitoring; fiber optic sensor

1. Introduction

Weight reduction of honeycomb core sandwich structures for satellite applications requires the use of thinface sheets and large cell size core. This, however, can lead to notable dimple formation in the face sheets during manufacturing or operation at low-temperature conditions due to mismatch in thermal expansion coefficients of the constituent materials, such as carbon fiber reinforced plastic (CFRP) and aluminum honeycomb core. While dimpling can reduce the mechanical properties of the structures [1], it can also promote failure in adhesion of components attached on the face sheets [2]. A way to detect and assess dimpling of the face sheets is therefore needed to verify the quality and health of the structures.

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In previous studies [2,3], fiber Bragg grating (FBG) sensors have been applied on the face sheets to detect dimpling. The measurements are however limited to only one point within a single cell, and thus cannot give detailed information about the dimpling condition and the state of the whole sandwich structure. Rayleigh backscattering based fiber optic distributed strain measurements[4] however seem promising as they can provide the accuracy and high spatial resolution needed to detect the small deformations induced by face sheet dimpling.

Face sheet dimpling of honeycomb sandwich structures, including a method to monitor and assess the dimpling, was studied by utilizing embedded distributed fiber optic sensors. Strain distributions along optical fibers embedded in the face sheet of the sandwich structures were monitored during manufacturing. Based on finite element analysis results, effect of adhesive configuration onthe dimpling monitoring capability was discussed. Simple analytical beam model was also presented to predict the dimple profile and thus assess the dimpling condition from the strain data. The model was evaluated against finite element analysis predictions and measurement results.

2. Experimental setup

Sandwich panel specimens as shown in Fig. 1 consisting of CFRP face sheets and aluminum honeycomb core were manufactured for the monitoring experiments. 100 mm × 100 mm face sheets consisting of three T700S/2592 pre-preg plies in [0/90/0] configuration were cured beforehand in an autoclave. Fiber optic sensors (cladding diameter 100 μm) were embedded in the 0-degree plies of the face sheet. The optical fibers are thus embedded in the top side (outer surface)and in the bottom side (adhesion surface) of the face sheet. The face sheet and the core were adhered in oven using REDUX 312UL adhesive film. Varyingdimple depths were obtained by using one to five layers of adhesive film resulting in different fillet sizes. 3/8” cell diameter aluminum honeycomb core was used. Before adhesion the core was aligned with the face sheet so that the embedded fibers would go through the center of the cells. The specimens were cured for 3 hours at 135ºC while 0.035 MPa vacuum was applied. Before cooling, the vacuum was released and the specimen were let to cool freely to room temperature.

At the end of the heating cycle the adhesive has cured thus adhering together the constituent parts. During cooling, dimples are formed in the face sheets due to the different thermal shrinkage of the core, adhesive and face sheet materials. Strains along the embedded optical fiber sensors were therefore measured during the cooling stage using a Rayleigh backscattering based distributed strain monitoring system (LUNA OBR 4600) capable of millimeter-order spatial resolution. After cooling, the face sheet profile at the locations of the embedded optical fibers was measured using a laser displacement sensor.

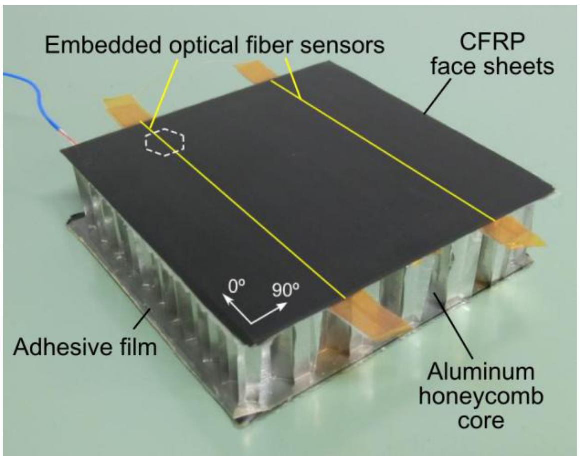

Fig. 1. Honeycomb sandwich panel specimen with embedded optical fiber sensors