Damage detection in foam core sandwich structures using guided waves

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Abstract Sandwich structures, consisting of two face sheets and an intermediate foam core, have a high potential in aerospace applications. However, they are rarely used because it is difficult to inspect them by the conventional non-destructive techniques. Indeed, non visible damage of the sandwich face sheets can in fact be accompanied by a large skin/foam core delamination. This paper describes a new approach to detect sub-interface damage in such structures by using ultrasonic guided waves. These waves are excited with a PZT disc permanently bonded on the structure and their interaction with foam core damages is detected by scanning the structure with an air-coupled transducer. To carry out this monitoring technique, the first step was to analyse the propagation of waves guided in such sandwiches with both numerical and experimental tools. This allowed selecting the specific waves and their frequency which will be the most sensitive to skin/foam core delaminations and to make easier the interpretation of the measured waveforms. Finally, an adapted signal processing was implemented in order to localize and to characterize delaminations in sandwich panels.

1 Introduction

For high performance composite structure airframe design, sandwich structures own many advantages compared to monolithic stiffened structures. Indeed, they offer higher bending stiffness and strength at lower weight and thus contribute to reduce fuel consumption. They also make easier the structural integration and take part in

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the acoustic and thermal insulation. However, low velocity/energy impacts leave only non- (or barely) visible damage in the face sheet but can be accompanied by large sub-interface damage: skin/foam core delaminations or foam core crushing (Fig. 1). This kind of impact damage may arise due to accidental tool drops during maintenance or due to runway debris, hail and bird strikes in-service [1] and reduces drastically the load-bearing capacity of the structure.

Many nondestructive techniques have already been investigated for detecting delaminations in monolithic composite structures as for example ultrasonic pulse-echo C-scans, radiography, thermography [2] or the use of Lamb waves [3]. These methods can be also used to detect delaminations or cracks in the skins of such sandwich structures but are still not well adapted to detect foam core damages [1, 4]. So this paper describes a new inspection method to detect skin/foam core delaminations or foam core crushing in sandwich structures by using ultrasonic guided waves. These waves are generated in the structure with a PZT disc while their interaction with a sub-interface damage is detected by scanning the structure with an air-coupled transducer. The emitter is permanently integrated on the sandwich panel while the air-coupled transducer is used only during the maintenance stage. To set up this monitoring method, the first step is to analyze the propagation of waves guided by the sandwich structure. This allows the selection of two different monitoring configurations: the first one for detecting the foam core damage and the second one to localize it and to evaluate its size. The last method has already been exploited to detect such damage in sandwich structures using the $A_0$ Lamb mode at low frequency [5] and for testing damage in metallic structures below a composite repair [6]. In both configurations, the measured waveforms are interpreted with experimental and numerical tools.

2 Guided Waves In Sandwich Structures

In this section, the waves guided by the sandwich structure are analyzed in order to select the most sensitive ones to foam core damages. The sandwich structure (Fig. 1) is composed of three layers: a thin glass-fiber epoxy skin, a foam core and a thick glass-fiber epoxy skin. To characterize the propagation of Lamb waves in this struc-