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Damage identification and mechanical assessment of impacted sandwich composites

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Abstract

Sandwich composites are often subjected to low velocity impact, a random and thus feared type of loading. Vulnerability of sandwich materials under such an event depends on the skins and core structure and skin-core interfaces. The paper presents ways to identify the damage severity occurred during low velocity impact tests, with further assessment of the residual mechanical performance of some kind of sandwich composites. In this study, non-destructive inspections (NDI) have been mixed with mechanical destructive testing in a comprehensive structural health monitoring (SHM) approach, meant to evaluate the damage tolerance of such materials, intended to be used on some structural components of a green energy power unit.

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Keywords: sandwich materials; low velocity impact; infrared thermography; bending after impact; residual mechanical performance.

1. Introduction

The sandwich type materials are introducing an unrivalled variety of materials, with associated mechanical parameters, that are recommending them for many and diversified applications. Like all layered composites, sandwiches are prone to many structural threats during their service life, due to the particular interface between layers and the characteristics of each one. Difficulties in ensuring full reproducibility in the manufacturing technology can add extra-problems in offering reliable mechanical reference. Low velocity impact, followed by shear bending loading is the kind of in service event which can take advantage of these vulnerabilities and

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compromise the safety of sandwich materials and associated structures. For this reason, extended tests have to be run in order to identify and characterize the damages inflicted during a variety of probable invasive events and evaluate the consequences on the structural performance, in a comprehensive SHM approach.

A rich literature on sandwich materials reported results obtained worldwide during experimental work and modeling/simulation of low velocity impact [1]. It accounted the main aspects of this phenomenon: recording the main parameters during the impact, characterization of the incurred damages and the consequences they have on the residual mechanical performance of the material, damage detection, and damage initiation or progress prediction. Recent works focused in particular on the second [2,3,4] and third aspect [5,6].

This paper presents results obtained during low velocity impact tests, intermediate NDI using infrared thermography (IRT) and final assessment of the residual mechanical performance with bending after impact (BAI) tests, all performed on a category of sandwiches intended to be used as platforms of a wind turbine supporting tower, on which water tanks will be mounted.

2. Tested materials

The materials used in this series of tests have been of two types:

- Sandwich composites with honeycomb core
- Sandwich composites with foam core

Both sandwich types had glass fiber reinforced plastic (GFRP) skins. There were two thicknesses considered for the skin, corresponding to the number of layers. The thin skins, averaging 2.3 mm in thickness, involved four layers: two reinforced with felt type fabric at the outside and two reinforced with roving type fabric in the middle. The thick skins, averaging 4 mm in thickness, involved seven layers, with three more layers in the middle, reinforced with roving type fabric. In both cases, the matrix was a unique polyester resin. A gel coat layer was applied on the faces finally placed on the outside of the sandwich panel, while the inside layers in contact with the core material, reinforced with felt type fabric, ensured a stronger skin-core interface. The honeycomb core was made of impregnated paper, shaped in 9 mm side hexahedral cells. The foam core was made of medium density polyurethane foam. Both core materials were 30 mm thick. The tested materials have been single core or double core sandwiches, in the second case a single felt fabric reinforced layer separating the two cores in the sandwich mid-plane.

The samples made from these materials had 100x450 mm in-plane dimensions. That dimensions complied with the rig used for mounting the standard low velocity impact samples [7] and with the requirements of the standard concerning the bending tests of sandwich composites [8].

3. Low velocity impact tests

The low velocity impact tests were performed with an instrumented impact hammer (Fig. 1), with the fixture used for standard laminated samples described in [7]. The DAQ NI USB 6009 collected data from a force transducer placed behind the hemispherical, 15 mm in diameter steel impact head, fitted with strain gauge sensors, with a 2,500 to 5,000 sampling rate. The impact tests have been performed at 10 J and 20 J energy levels.

The impact force history had, in most of the cases, quite different shapes as compared to those obtained during impact events on laminates and thin sandwiches [9]. In Fig. 2 and Fig. 3 are presented the curves obtained for the samples proving the weakest post-impact behavior during BAI tests. Deep craters, close to penetration, were observed only on the samples having honeycomb cores and thin faces, at 20 J impact energy levels. In the other cases, the effect of the impact event was a small indentation or barely visible damages (BVD). Some honeycomb core sandwiches with thick faces experienced local buckling of the honeycomb paper wall under the impact area.

The impact force history curves showed important distortions in the last situations or when a near penetration deep crater occurred, with consistent lowering of the peak force value. The variability of the impact force history curves obtained for sandwiches with honeycomb core depended also on the part of the cell opposed to the impact point: cell wall or empty mid-cell. The dips observed on many curves are supposed to denote the occurrence of the latter case or local skin-core de-bonding in the case of sandwiches with foam core.