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Dynamic Response of Green Sandwich Structures

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Abstract

Synthetic fibre-synthetic foam core sandwich composites are widely used for many structural applications due to their superior mechanical performance and low weight but the limited end of life disposal options and environmentally friendly character are currently envisaged as barriers to their continued development. The objective of this article is to analyse the suitability of using agglomerated cork as core material in sandwich structures to be used in applications where energy absorption due to low velocity impacts can be of importance. Green sandwich specimens with flax/epoxy face sheets and agglomerated cork as core have been manufactured and their response to low velocity impacts has been compared to the results obtained with similar specimens using traditional synthetic core. This study shows that the peculiar deformation mechanisms of cork can allow to tailor the damage extension through-the-thickness thus providing in principle a better damage tolerance after impact.

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Keywords: Polymer matrix composites; Sandwich structures; Natural fibres; Low velocity impact; Cork

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1. Introduction

The need for sustainable materials with the aim to alleviate the environmental impact of engineering materials and increase their end of life disposal options has definitely stimulated, over the last two decades, a resurgent interest in natural fibres as reinforcement in polymer matrix composites [1,2]. Also sandwich structures cannot be considered exempt from these environmental concerns, especially if one considers their increasing use in aerospace, marine,

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automotive and transportation fields, dictated by the enhanced flexural stiffness and lightweight coupled with additional benefits related to the specific application, such as thermal and acoustic insulation, ease of forming, fire retardation. Typically, sandwich structures for these applications use thin laminated face sheets bonded to synthetic honeycomb or foam cores. Cork is a natural cellular material obtained from the bark of the oak (*Quercus suber L.*) and is periodically harvested from the tree, usually every 9–12 years and is therefore a renewable resource [3]. Cork exhibits several interesting properties, namely low density, reduced permeability to liquids and gases and thermal insulation properties in addition to a peculiar mechanical behaviour characterized by nonlinear elasticity, exceptional compressibility without fracture, and unusual dimensional recovery capability, which gives rise to outstanding energy absorbing performance [4,5]. These properties can be ascribed to the three-dimensional structure of cork that may be described as an array of closed prismatic, on average hexagonal cells stacked base-to-base making rows oriented in the radial direction of the tree and assembled side by side, forming a honeycomb-type structure [5].

A major concern that still hinders a much more widespread usage of sandwich composites is their susceptibility to damage due to impact loading and therefore cork and its products, such as agglomerated cork, are envisaged as ideal core materials for sandwich structures. The successful application of sandwich structures depends on an in-depth characterization and understanding of the sandwich constituent materials (face sheets, core, and adhesive), and also of the whole structure under quasi-static and dynamic loading scenarios. In this regard, studies on cork and related sandwich structures are available in literature, but they are mainly focused on quasi-static properties, such as in compression, tensile and shear [6-8]. On the contrary, the response of cork and resulting sandwich structures to impact loading has received considerably less attention, including some studies on low velocity impact [9-12], ballistic response [13], dynamic crushing behaviour [14] or blast wave response [15].

It is to be noted that in most studies sandwich structures based on agglomerated cork were characterized by skins made of carbon fibre reinforced polymers or aluminium, thus not allowing a full exploitation of the environmentally friendly character of cork. The aim of the present work is to analyse the response to low velocity impact of green sandwich panels consisting of flax/epoxy face sheets and two different types of core materials, namely agglomerated cork and Rohacell 110WF rigid foam, for comparison purposes. This sandwich construction, based on flax/epoxy skins and agglomerated cork as core material, has been already investigated by Mancuso et al. [16] who reported results of an extensive and detailed characterization of the flexural behaviour of such structures intended as structural components of small sailing boats, without addressing the response to impulsive loadings.

2. Materials and methods

The unidirectional prepreg material system (FLAXPREG UD 180) based on epoxy matrix with a fibre areal weight of 180 g/m^2 was supplied by Lineo. The face sheets were manufactured with a quasi-isotropic configuration [+60/0/-60]s and the panels were vacuum-bagged and fully cured under pressure in an autoclave to the manufacturer's specifications. The agglomerated cork (ECOPAN) was supplied by Etruria Cork Srl with a nominal density of 145 kg/m^3 and a thickness of 30 mm. This is a product used in the building industry as thermal and acoustic insulating material, therefore not specifically optimized for applications in composites. For comparison purposes, a closed-cell rigid foam based on polymethacrylimide (PMI) highly suited for autoclave prepreg processing and all typical resin infusion processes was used, namely Rohacell® 110WF supplied by Evonik Industries AG. This foam core has been provided with a density of 110 kg/m^3 and a thickness of 30 mm. The flax fibre laminates with a thickness of 1.4 mm and the two different cores were cut to required dimensions (10 × 10 cm) and Redux 609 by Hexcel, an epoxy film adhesive containing a cotton scrim, was used to bond the face sheets to the core. To ensure the bond between the face sheets and core was uniform and that the epoxy was fully cured, sandwich structures were vacuum-bagged and fully cured without additional pressure in an autoclave to the manufacturer's specifications.

In order to characterize the static compressive behaviour of agglomerated cork and Rohacell, at least five specimens (30 × 30 × 30 mm) for each core material were tested in a Zwick/Roell Z010 testing machine equipped with a 10 kN load cell with a test velocity of 5 mm/min. Both core materials and the whole sandwich structures were subjected to low velocity impact tests using an instrumented drop-weight impact testing machine (CEAST/Instron 9340). The hemispherical impactor had a diameter of 20 mm and the dropped carriage had a total mass of 8 kg. The