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Manufacturing and testing composites based on natural materials

F.A.O. Fernandes[a,*], J.P. Tavares[a], R.J. Alves de Sousa[a], A.B. Pereira[a], J.L. Esteves[b]

[a]*TEMA – Centre for Mechanical Technology and Automation, Department of Mechanical Engineering, University of Aveiro, Portugal.*
[b]*Department of Mechanical Engineering (DEMEC), University of Porto, Portugal.*

Abstract

This work focused on the development of composite structures fully based on natural materials. The developed sandwich structures are based on natural fibers and cork acting as a core. The natural fibers used resulted from compounding flax fibers with bio-resin. The core material is agglomerated cork. The aim of this study is to compare these natural structures against similar synthetic sandwiches based on fiberglass and epoxy resin. Several laminates were produced and then subjected to static and dynamic mechanical testing, carried out via bending and impacts tests respectively. After carefully analyzing the results, it was possible to conclude that the proposed materials show compatible mechanical properties and can even compete against synthetic materials. On top of that, natural materials keep the obvious advantage of eco-friendliness.

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1. Introduction

Currently, society is aware of environmental problems. Sustainability and recyclability are commonly discussed themes in academia and industry. The feeling of self-responsibility and awareness about the environmental problems led society to change habits, reusing resources and using renewable products. There is a clear trend of substituting synthetic and non-renewable materials by natural and renewable materials with similar or even better properties.

* Corresponding author. Tel.: +351 234 378150; fax: +351 234 370953.
E-mail address: fabiofernandes@ua.pt

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In this work, sandwich structures made from natural materials are developed. The core consists on agglomerated cork and the skins on flax fibers and bio-resin. This new compound was developed by keeping a balance between sustainability and mechanical properties, proposing a green structure without compromising the mechanical performance. Standard sandwich structures are mainly used due to their strength and weight, being constituted by two outer thin layers responsible for the structure strength and by a softer core responsible for absorbing most of the energy and also for its low weight.

The skins are usually made from fibers such as carbon, glass or Kevlar® or even aluminum sheets. On the other hand, the core is usually made of low density materials such as polymeric or metal foams. These structures can be employed in very demanding applications, as in aerospace, civil construction, automotive, sports, etc [1]. Basically, the surface where the force is applied is under compression and the outer one under tension. On the other hand, the sandwich core supports the shear loads.

Metals have good advantages such as high rigidity, good impact resistance and low cost. However, these are relatively denser, relatively harder and can oxidize. Composite materials are usually made of a polymeric matrix and fibers of same nature. The matrix is responsible for the material adhesion, being responsible for a correct loading distribution. It also allows obtaining complex geometries. Currently, the more common are polyester resins, vinyl and epoxy. The fibers orientation is very important for the overall structure strength.

The core material of a sandwich structure is also very important, since it greatly influences the structure performance. Thus, the final application deeply influences the choice of the core material. The core structure can be a solid block or even a honeycomb. Nevertheless, researchers are looking for new natural and recyclable materials, which can be a better option if these structures can have a similar mechanical behavior to those typically used.

In the literature, there are recent works where cork was used as an energy absorbing material. Alcântara et al. [2] compressed agglomerated cork and concluded that it has a great capacity for energy absorption. Castro et al. [3] concluded the same by testing cork as a core material in lightweight sandwich structures with carbon fiber face sheets. According to Castro et al. [3], in the three point bending tests, parameters such as cork granules size, density and the bonding process greatly influenced the sandwich performance. Nevertheless, in the core, shear stresses were not affected by cork granules size. In addition, cork–epoxy agglomerates presented a significantly better core shear stress limit, which reduces the crack propagation region, placing cork–epoxy agglomerates in the leading edge of currently available materials used within sandwich structures [3]. In the same work, during the impact tests, all cork-based sandwich presented considerably higher load values than those obtained for other type of high performance core synthetic materials. In these impacts was also verified an intrinsic characteristic of cork, the excellent recovery capacity. This characteristic makes it an optimal material to use in multi-impact applications, continuously and effectively absorbing energy after impact, as concluded by Fernandes et al. [4,5], Jardin et al. [6], Ptak et al. [7] and Tchepel et al. [8]

Hachemane et al. [9] performed static and dynamic tests on cork core sandwiches with jute/epoxy face sheets. These structures could be considered natural if not made with epoxy resin. Nevertheless, the initial force, the maximum force and the extent of damage are influenced by cork's density and by the impact energy. In other study, Sousa-Martins et al. [10] used agglomerated cork as core material in sandwich structures with aluminum face sheets. These structures were subjected to shock waves from explosions with success from a protective perspective.

Recently, there is a growing interest by researchers in natural fibers, studying their properties and comparing their performance against synthetic or non-natural fibers. Zhu et al. [11] investigated the effect of fiber configuration on the mechanical properties flax/tannin composites and Petrucci et al. [12] performed three point bending tests on hemp and flax fiber laminates. Fernandes et al. [13] tested high density polyethylene filled with cork powder and coconut short fibers, concluding that the addition of coconut fibers increased the elastic modulus by 27% and the tensile strength by 47% when compared to the samples without coconut fibers.

Kabir et al. [14] used hemp fabrics as reinforcements with polyester resin to form composite skins and carried out alkalization, silane and acetylation treatments on the fibers surface. Kabir et al. [14] suggested that a suitable chemical treatment of the fiber surface can increase the mechanical strength by 30%.

Duigou et al. [15] tested bio-sandwiches and concluded these are very attractive in terms of environmental impact. However, Duigou et al. [15] suggested that further improvements in bio-sandwich mechanical strength are necessary in order to be a valid option for demanding applications, substituting the currently used and non-environmental friendly sandwiches.