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Implementation of eco-sustainable biocomposite materials reinforced by optimized agave fibers

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Abstract

Although several works have recently been published in literature about biocomposites, i.e. about composites with polymeric matrix reinforced by natural fibers, only a few articles have been devoted to the implementation of high performance biocomposites for structural and semi-structural applications. The present study aims to give a contribution by considering biocomposites obtained by using an eco-friendly partially bio-based epoxy (green epoxy) and sisal (agave sisalana fibers) obtained by a proper optimization process.
Through a systematic experimental analysis, three different types of biocomposites obtained with a suitable manufacturing process, such as random short fiber biocomposites, random discontinuous fibers biocomposite obtained through the preliminary manufacture of MAT fabrics, and unidirectional long fibers biocomposites obtained through the preliminary manufacture of unidirectional "stitched" fabrics, have been studied.

Keywords: biocomposites; natural fibers; agave fibers; eco-friendly matrices.

1. Introduction

Biocomposites reinforced with agave fibers are eco-compatible or renewable materials already used in the automotive field and in other field of the industrial production, limited to non-structural applications (filling

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material, soundproofing, etc.), in which the particular properties, such as lightness and low cost, both lower than those of any composite reinforced with synthetic fibers, along with good thermal and acoustic insulation capacity, are particularly appreciated.

Such biocomposites for non-structural applications are generally constituted by environmentally friendly polymer matrix composites reinforced with short or discontinuous agave fibers, randomly oriented; commonly, they are obtained by molding or extrusion processes, and are characterized by low mechanical strength, usually comparable with that of the matrix, along with higher stiffness properties.

Although agave fibers have good mechanical characteristics, combined with high toughness, good fiber-matrix adhesion and low damageability, characteristics that can also be further improved with a suitable optimization procedure (proper selection and suitable extraction process, see Zuccarello and Zingales (2017), Zuccarello and Scaffaro (2017)), at present high performance eco-sustainable or renewable bio-composites that could be used in structural and semi-structural applications (see Murherjee and Satyananrayana (1987), Belaadi et al. (2014), Chand and Hashimi (1993), Chan et al. (1989), Silva et al. (2008), Thomason et al. (2008), Belaadi et al. (2008), Kaewkuk et al. (2013), Bisanda and Ansell (1999), Joseph et al. (1996), Singh et al. (1996)), have not yet been fully developed. The need for high performance renewable biomaterials is particularly felt in the automotive field (Furqan et al. (2015), Yan et al. (2015), Omrani et al. (2015), Koronis et al. (2013)), characterized by the need to significantly limit the environmental impact associated with the production of materials commonly obtained from petroleum chemistry (plastics, synthetic rubbers, resins, synthetic fibers, paints, solvents, etc.) with irreversible release into the atmosphere of large quantities of carbon dioxide and other polluting substances.

This requirement is determined by both the objectives imposed by European standards in terms of recyclability of materials for automotive applications, and the objective of reducing the weight of the vehicle and therefore its consumption, always acting in the direction of reducing pollution. The vehicle’s weight reduction is also particularly important in the modern development of hybrid and electric vehicles, which are characterized by high overall weight, due to the heavy contribution of energy accumulation systems (batteries).

In order to contribute to the development of high performance bio-composites, i. e. biocomposites for structural and semi-structural applications, in this work the mechanical properties of different green epoxy composites, have been evaluated. Particular attention has been paid to the optimization process of agave fibers, which consists in the proper choice of the variety (sisal), the position of the fibers in the leaf (“medium third” of agave leaves) and the age of the leaf itself (about 4 years), otherwise the appropriate selection of the extraction process (see Zuccarello and Zingales (2017), Zuccarello and Scaffaro (2017)). In detail, such optimized agave fibers have been used in order to implement suitable MAT and unidirectional fabrics. These particular fabrics have been subsequently used for the manufacture of biocomposites by means of suitable processes that allow the production of a high quality biocomposites, even with high volume fiber concentration. Moreover, short fiber biocomposites with 3D random orientation, obtained by simple mixing of short fibers (length of about 3-4 mm) and green epoxy matrix, have been analyzed. In particular, both the common hand lay-up procedure (and vacuum bagging technique) and a high-pressure molding process have been used in the work, which has been implemented by means of removable aluminum molds.

2. Materials: matrix and fibers

Taking into account previous studies, carried out by the same authors (Zuccarello and Zingales (2017), Zuccarello and Scaffaro (2017)), the attention of this work has been paid on the development of green epoxy matrix biocomposites reinforced by optimized sisal fibers.

These preliminary studies have been carried out on short-fiber biocomposites with random orientation (2D) and long-fiber unidirectional biocomposites made by green epoxy matrix and PLA, reinforced by different types of sisalana and marginata agave fibers. Such preliminary studies have shown that these materials have high mechanical strength, making them suitable for structural use. The mechanical characteristics can be further enhanced by the realization of unidirectional and angle-ply laminates obtained with hand lay-up process followed by an appropriate cure process characterized by the application of suitable pressure. In the studies reported in literature, the mechanical characteristics of the biocomposites reinforced by agave fibers are generally relatively low, due to both the limited