Materials and Design 68 (2015) 104–113

Contents lists available at ScienceDirect

Materials and Design

journal homepage: www.elsevier.com/locate/matdes

Fabrication, characterization and modelling of laminated composites based on woven jute fibres reinforced epoxy resin

Hind Abdellaoui [a,b], Hala Bensalah [a], Jamal Echaabi [a], Rachid Bouhfid [b], Abouelkacem Qaiss [b,*]

[a] Ecole Nationale Supérieure d'Electricité et de Mécanique, Hassan II University, Casablanca, Morocco

[b] Moroccan Foundation for Advanced Science, Innovation and Research (MAScIR), Institute of Nanomaterials and Nanotechnology (NANOTECH), Laboratory of Polymer Processing, Rabat, Morocco

ARTICLE INFO

Article history:
Received 24 September 2014
Accepted 30 November 2014
Available online 23 December 2014

Keywords:
Laminates
Fibres
Resins
Mechanical properties
Computational modelling

ABSTRACT

The aim of this work is the manufacturing and study of mechanical properties of laminated composite based on natural jute fibres and epoxy resin. The laminated have been prepared by using a compression system according to two jute fibre direction (0° and 45°), and two sample cutting directions (0° and 45°). The different used directions permit to reduce the anisotropic character of manufactured composites. The experimental results show that the mechanical properties increase with increasing of number of layers. The maximal Young's modulus of laminated with 1, 3, 5 and 7 layers were found respectively at 5264, 5902, 6400 and 5562 MPa in case of 0° fibre direction and 0° cutting direction. Moreover, the predicted modulus (Young's modulus, shear modulus and Poisson coefficient) in each fibre direction were found near to the experimental ones. The difference resides probably in the error in the considered assumptions about the perfect bonding between the fibres and matrix. It was also observed that the use of different staking orientation reduce the anisotropic character of obtained composites.

1. Introduction

Environmental concern is stimulating scientific research in the design of new materials for construction, furniture, packaging and automotive industries. Especially attractive are the new materials based on the natural components as natural fibres, which are a potential substitute for synthetic fibres as glass and carbon fibres.

The plastics composites began with the use of phenolic resins reinforced by cellulose fibres in 1908 [1]. Because of increasing environmental consciousness, the implementation of traditional composites structures, usually made of glass, aramid or carbon fibres with thermosetting matrix as unsaturated polyester, phenolic or epoxy has criticized [2,3]. The great matter of using the traditional and synthetic materials is how to conveniently dispose of them after the end of their useful life [4].

The introduction of natural fibres as sisal, flax, jute, grewia optiva, hibiscus sabdariffa and pine needle in composite materials, promises the realization of new eco-friendly materials [5–9]. The natural fibres are biodegradable and renewable, and have a low cost and density [10–16]. The natural fibre ar also considered as a biocomposite thank of their components as cellule, lignin, starch and polylactic acid [17–24].

Many studies have been carried out to investigate the suitability of natural fibres for using as reinforcing components. Many researchers [25–28] have already studied the natural fibres as substitute of glass fibres in order to improve the environmental performance of products.

Generally the mechanical properties of the polymeric matrix are improved with the use of natural fibres [29]. Garkhail et al. [24] have studied the poly(3-hydroxylbutyrate) (PHB) and flax fibres, where the mechanical properties of prepared composite (fraction volume fibres 10–40%) are greater with the use of a film stacking in comparison to injection moulding. In other work, Prunduş [29] has studied the laminated based on natural fibres reinforced the epoxy. That results show an increasing of mechanical properties with the use of natural fibres, especially the wood fibres. In other research, the composites based on epoxy matrix and jute fibres were studied, and an improvement of mechanical behaviour of composite was observed by using a jute fibres [30,31].

The variety of composite materials with different shapes are continuously replaced the conventional materials. This reality has caused an increasing interest in the modelling of composites. Several approaches are adopted to predict the behaviour of the composites using the modelling, which can used to determine the rigidity tensor of this type of materials in practical situations [32].

The composite laminates are obtained by superposition of the various layers of the materials with the same or different nature

* Corresponding author. Tel.: +212 0664301301; fax: +212 0530300671.
E-mail address: a.qaiss@mascir.com (A. Qaiss).

http://dx.doi.org/10.1016/j.matdes.2014.11.059
0261-3069/

[33]. Generally, the layers are identical from both the material and the thickness stand points. Each layer is formed by submerging the fibres in the matrix resin material. The layers generally are orthotropic (i.e. with principal properties in orthogonal direction to each layer) or transversely isotropic (with isotropic properties in the transverse plane), with the laminate then exhibiting anisotropy (with variable direction of principal properties), orthotropic, or quasi-isotropic properties [34].

In this work, the evaluation of the use of jute fibres as natural reinforcement in thermosetting matrix is established. A series of mechanical tests are performed for the manufactured laminates at 1, 3, 5, and 7 layers, according to fibre direction (0° and 45°) and to cutting direction (0° and 45°). The effect of fibre direction on mechanical properties is studied in case of different manufactured composites. The second time, the modelling step is considered by using a homogenization technique. The prediction of the mechanical modulus is performed in case of 0° and 45° fibre directions. Then, the comparison between experimental and predicted modulus is investigated.

2. Materials and methods

2.1. Materials

The used jute fibres issued by the SONAJUTE Company from Casablanca Morocco. The used jute fibre is made of 72% of cellulose, 13% of hemicellulose and 13% of lignin. The used resin is an epoxy SO 184 delivered by SORETP company from Casablanca Morocco.

2.2. Experimental section

2.2.1. The jute fibres preparation

The used jute fibres are canvas architecture, with a grammage of 0.022 g/cm^2. The dried samples at different layers (1, 3, 5 and 7 layers) were cut in two fibre directions (0° and 45°) as shown in Table 1.

2.2.2. The mould preparation

A stainless steel mould is used to realize parts of dimensions (120×120) mm^2. The mould consists of two rigid plates (top and bottom), with a screw–nut system to hold the compressed sample during the compression step. The design of the mould allows the release of resin excess after the compression of impregnated fibres (Fig. 1). The mould is first covered by a fat layer acting as a demoulding agent. A transparent film is also used to ensure smooth samples surfaces.

Table 1
Experimental conditions.

Case	Fibres orientation	Cutting direction (°)
1 layer	[0]	0
		45
	[45]	0
		45
3 layers	[0/0/0]	0
		45
	[0/45/0]	0
		45
5 layers	[0/0/0/0/0]	0
		45
	[0/45/0/45/0]	0
		45
7 layers	[0/0/0/0/0/0/0]	0
		45
	[0/45/0/45/0/45/0]	0
		45

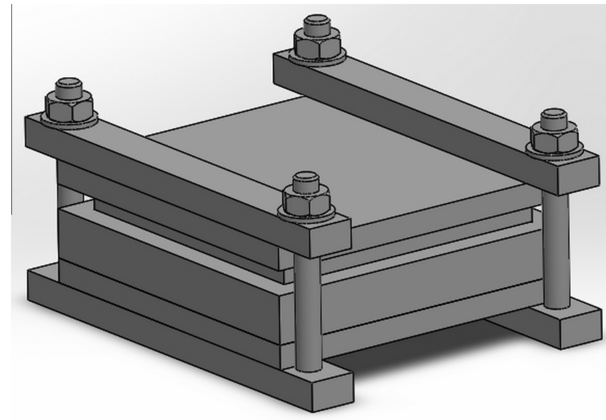

Fig. 1. The mould components.

2.2.3. The jute samples preparation

Firstly, the prepared jute fabrics are impregnated, spread over the bottom plate of the mould, where is followed by the closing mould step. The mould compression is provided by a hydraulic press at a compression pressure 0.36 MPa until a desired thickness, which defined by a half of initial thickness as shown in Fig. 2. After the compression step, the compressed mould is maintained by a screw – nut system until a period of 24 h for the curing step. Finally a demoulding step of sample is realized.

2.2.4. Cutting samples

The manufactured jute samples are cut in two different directions (0° and 45°), with a vice – saw system as shown in Fig. 3.

2.2.5. The samples crosslinking

First, the crosslinking temperature and time of the used epoxy resin were optimized by a temperature sweep. It is obtained for the epoxy:

$$T_{\text{Crosslinking}} = 150\ ^\circ\text{C} \quad \text{and} \quad t_{\text{Crosslinking}} = 15\ \text{min}$$

Then, the specimens are placed in an oven MTI (KSL 1400X) at a temperature of 150 °C for a period of 15 min as shown in Fig. 4.

2.3. Characterization techniques

2.3.1. Morphological characteristics

The morphology of laminated based on 1 layer is illustrated by using an optical microscopy at 10 magnifications as presented in Fig. 5. The optical microscopy (Leica microscope) is supported by Leica QWin V3 analysis software.

Fig. 5 shows that the yarn is composed by microfibrillar structures with dimensions of 145 μm. The microfibrillar structures are twisted by the compression effect within the manufacturing step.

2.3.2. Tensile testing

The tensile tests were performed on a universal testing machine INSTRON 8821S (Instron, USA) at 5 kN load cell. The samples are compressed at a crosshead speed of 3 mm/min. The dimensions specimen $(120 * 15)$ mm^2 were according to ISO 527-5 [35].

2.3.3. Torsional testing

Torsion tests were performed on an ARES-LS Rheometer, using the rectangular torsion mode. The specimen dimensions are: 6 mm width, 75 mm length, the thickness sample is defined for each number of layers. The torsion modulus is obtained in oscillatory tests performed in a sweep frequency mode (0.1–40 Hz).