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Numerical Modeling of the Flax / Glass / Epoxy Hybrid Composite Materials in Bending

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Abstract

The main purpose of this paper is the numerical analysis of the mechanical behaviour in bending of the both flax / epoxy composite material and E-glass / flax / epoxy hybrid composite material. Theoretical results are compared with the experimental results obtained in bending tests in case of the both kinds of composites. The finite element analysis (FEA) is used for simulation of the mechanical behaviour of the beams. Three kinds of beams made of laminated composite materials are modelled with finite element method: a beam made of eight flax /epoxy layers; a sandwich beam having two glass / epoxy layers as bottom shell layers, four flax / epoxy layers as core, and again two glass / epoxy layers as top shell layers (*Hybrid 1*); a beam made of four flax /epoxy layers and four glass / epoxy layers alternately arranged (*Hybrid 2*). The composite layers are modelled as orthotropic materials because the layers are reinforced either with glass or with flax bidirectional woven fabrics. The theoretical results obtained in finite element analysis were compared with the experimental results obtained in bending tests in terms of both the force-displacement curves *(F-w)* on the elastic domain and the equivalent modulus of elasticity E_x of the beam. Regarding the equivalent modulus of elasticity E_x it was found that the greater values of the errors were 6.11% and 5.58% and these correspond to the *E*-glass / flax / epoxy hybrid composite in weft direction and warp direction of the flax fabric, respectively.

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Keywords: Composite material; flax; glass; modeling; bending.

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1. Introduction

During the last years the works published in the field of the composite materials focus on the composites reinforced with vegetable fibers (jute, flax, hemp, wood fibers) and composites based on reinforcement or filler materials obtained by processing of the wastes (rubber, aluminum, PETs, plastics etc.) [1-4].

Herein, in order to increase the rigidity of the panels reinforced with flax fabric, the flax reinforced panels were additionally reinforced with glass fabric. Therefore, glass / flax hybrid composite panels are obtained.

Numerical modelling of the composite materials reinforced with flax fabric became a necessity taking into account the widely using of such kind of composite material in different applications in automotive industry and in civil engineering (panels for in-door or out-door design) [1, 2]. Carbon reinforcement was combined with flax reinforcement in order to improve the damping in case of the hybrid carbon–flax reinforced composites [5].

The modelling with finite elements of the laminated composite materials is used for numerical analysis and simulation of the mechanical behaviour of the beam made of flax / epoxy composite and glass / flax / epoxy hybrid composite material. The main target is to show the advantages of the additionally reinforcement with glass fabric in case of the hybrid composite comparatively with the composite material reinforced only with flax fabric from both flexural strength and flexural modulus E_x point of view.

The properties of the layers were defined in Abaqus (student edition, Dassault Systemes), by taking into account the experimental results obtained in bending in case of the following composite materials: flax / epoxy and glass / epoxy composites. The composite layers are modelled as orthotropic materials. In case of the flax / epoxy layer, the values of the moduli of elasticity corresponding to the warp and weft directions of the flax fabric are different because the flax yarn used in warp direction is not the same with the yarn used in weft direction. It was simulated the bending of three kinds of beams (one is made of flax / epoxy laminated composite, two kinds of glass / flax / epoxy hybrid composites) defined by using the method of the three points according with the experimental set-up used in the in bending test of the composite materials.

The theoretical results obtained in finite element analysis (FEA) were compared with the experimental results obtained in bending tests in terms of both the force-displacement $(F - w)$ curves on the elastic domain and the equivalent modulus of elasticity E_x of the beam.

The work also shows the methodology used in numerical modelling of the beams made of laminated composite materials.

Nomenclature

E_1, E_2	equivalent elasticity moduli corresponding to the composite material with respect with the *1* and *2* axes respectively, of the material coordinate system whose axes are aligned with the reinforcement directions with fibers as axis *1* and weft direction of the flax fabric coincide;
E_x	equivalent elasticity modulus of the fictitious orthotropic material that is equivalent with the laminated composite material, with respect to the *Ox* axis;
ν_{12}, ν_{21}	*Poisson*'s ratios, corresponding to the reinforcement plane *12* with fibers, with respect to the local (material) coordinate system;
σ_{max}	maximum value of the normal stress recorded in bending test;
$\sigma_x, \sigma_y, \sigma_z$	normal stresses that develop at the level of an arbitrary point of the composite beam mechanically loaded with respect to the axes of the global coordinate system *xOyz*;
w	displacement with respect to the direction of the axis *Oz* of the global coordinate system.

2. Materials and test method

2.1. Materials

In this investigation, two kinds of composite materials are analysed: one composite material is made of eight flax / epoxy layers; the other one is a sandwich having two glass / epoxy layers as bottom shell layers, four flax / epoxy