Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 167 (2016) 223 – 230

Procedia Engineering

www.elsevier.com/locate/procedia

Comitato Organizzatore del Convegno Internazionale DRaF 2016, c/o Dipartimento di Ing. Chimica, dei Materiali e della Prod.ne Ind.le

Modeling of Falling Weight Impact Behavior of Hybrid Basalt/Flax Vinylester Composites

Simonetta Boria[a*], Ana Pavlovic[b], Cristiano Fragassa[b], Carlo Santulli[c]

[a]Mathematics division, School of Science and Technology, University of Camerino, Via Madonna delle Carceri 9, 62032 Camerino (MC), Italy
[b]InterDept. Research Centre on Advanced Mechanics and Materials, University of Bologna, Via Terracini 24, 40131 Bologna, Italy
[c]School of Architecture and Design, University of Camerino, Viale della Rimembranza, 63100 Ascoli Piceno, Italy

Abstract

The present experimental investigation is aimed at modeling the falling weight impact properties of thermosetting composites produced using a partially bio-based vinylester resin with flax and basalt fibers and using them both in a hybrid configuration, therefore obtaining three different types of laminates, fabricated by hand lay-up and resin infusion. Cure processes were accelerated and controlled by applying heat and pressure in autoclave.
After acquiring tensile and flexural data, falling weight impact tests were carried out at several energies of up to 40 J, so to induce penetration, but also to have information on the evolution and the different characteristics of damage produced. Modeling analysis was mainly based on the study of impact hysteresis cycles, which correlate the mode of energy absorption, whether quasi-elastic or producing irreversible damage and the rebound characteristics, in case the energy is not sufficient to produce penetration, from the patterns of force vs. displacement curves obtained during impact loading.

Peer-review under responsibility of the Organizing Committee of DRaF2016

Keywords: Falling weight impact; modeling; flax fibers; basalt fibers

1. Introduction

Producing hybrids containing vegetable fibers together with ceramic ones, such as glass or basalt, is a quite well known procedure in the literature on sustainable composites [1]. The idea is to combine a better environmental profile with inherent strength obtained from glass or basalt composites, with no much detrimental effect on the dynamical properties, in particular on impact. Most hybrids including plant fibers were fabricated using glass fiber composites [2], is some cases involving the use of bio-based polymers [3], less so with basalt fiber ones, which on the other side are of interest due to reduced need for sizing and the relatively higher ease of production [4-5]. In the

Peer-review under responsibility of the Organizing Committee of DRaF2016
doi:10.1016/j.proeng.2016.11.691

particular case of basalt, the advantages provided by the addition of plant fibers to basalt ones concern in particular reducing the brittleness of basalt offering some evidence of plastic behavior after yielding, capable of compensating the proneness to delamination of flax with a more flexible behavior, which appeared effective under impact loading, but also in terms of tensile stiffness. On basalt/flax hybrid composites including plant fibers, recent results demonstrated that intercalation of layers proved beneficial for flexural and interlaminar strength, but despite the higher complexity, did not result substantially beneficial for impact properties [6]. This suggests that simpler stacking sequences, such as sandwiching the softer layers (flax) between the stiffer ones (basalt), may be still of interest.

In recent years, an increasing number of studies have analyzed impact hysteresis curves on composite structures [7-8], obtained during fall weight impact by measuring the absorbed force over the displacement of the laminate, in other words determining the way in which rebound (if any) takes place and its correlation with damage produced: these analysis have also been performed on basalt fiber composites [9]. In these terms, modeling could provide further insight into these issues, especially by allowing predicting the modification of hysteresis curves, hence trying to define more precisely the mode of absorption for different levels of energy applied on the laminate, especially when approaching penetration [10]. However, this aspect has received limited attention in the literature so far.

2. Experimental tests and numerical modeling

2.1. Composite manufacturing

Composite laminates were produced by a hand layup procedure, stacking dry fabric layers by hand onto a planar support to form a laminate stack. Resin was applied to the dry plies after layup and then the amount of resin needed for full impregnation was added by means of resin infusion. Cure was realized by applying controlled heat and pressure in autoclave; laminates underwent an initial 24 hours curing at environmental conditions, then a post-cure, which consisted of a 3 hours treatment in autoclave at 100°C under a pressure of 6 bars.

Laminates were obtained using 8 sheets of fabric reinforcement. It was considered more suitable to use the softer fiber in the core layers and the harder one in the skin ones. Therefore laminates were manufactured using flax as the reinforcement of the four internal plies, while on both sides the two external layers were reinforced by basalt fibers. The thickness of each laminate is of 5.1 ± 0.2 mm.

2.2. Mechanical and impact characterization

Static tests were carried out in displacement control mode using an Instron universal tester equipped with a 200 kN load cell. In particular, tensile loading to failure was performed on laminates with dimensions 250x25 mm according to ASTM D3039-14, in displacement control mode, at a crosshead velocity of 2 mm/min. The strain was acquired using strain gauges, two per side of the sample. Three-point flexural tests on laminates with dimensions 120x15 mm according to ASTM D790-10 standard, in displacement control mode, at a crosshead velocity of 2.5 mm/min.

Falling weight impact (IFW) tests were carried out according to ASTM D7136/D7136M-15 standard, using laminates with dimensions 100x100 mm supported on a circular anvil with 60 mm opening. Impact was produced using a 1.25 kg mass with a hemispherical striker tip of 6.35 mm diameter. The height of falling weight was progressively changed to obtain different energies, using impact from 2.5, 3 and 3.26 meters to obtain energies of 30.62, 36.75 and 40 Joules, respectively. A scanning electron microscope (SEM), model Jeol JSM 35CF, was used for the characterization of fracture surfaces.

2.3. Numerical modeling

Numerical modeling was performed using LS-DYNA [11]. Both the impactor and the composite plate meshed with 8 node brick elements. A finer mesh (0.2 mm) was used in the impact region to obtain more accurate results.