ASPECTS OF DYNAMICAL ANALYSIS OF BIO-MATERIAL COMPOSITES

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Abstract: *The use of natural fibres as a replacement for traditional glass fibres and carbon fiber in composites has gained increasing importance in recent years as environmental concerns have led to a quest for sustainable alternatives.*
This paper presents the results of studies undertaken to evaluate dynamical mechanical properties of hybrid carbon - hemp composites and fiber glass - hemp composites to assess the suitability traditional carbon and glass fibers used in composites composition.
Hemp fibres, in the form of non-woven mat, randomly oriented in two dimensions, glass fibres in strand mat form and carbon fiber were used. The matrix was a polyester resin with rapid hardening characteristics - DERAKANE resin . The combination of a hand lay-up method, followed by compression moulding, was used in the fabrication of laminates
Keywords: *Natural fibers, Composite, Structure, dynamical mechanical properties*

1. INTRODUCTION

Composite materials for thermal insulation [1],[2],[3] are used in a wide range of applications; however, they are used with prudence in applications where transverse loadings appear, for instance, loadings given by transverse impact with low velocity. Since this type of materials is used also for applications involving new technologies like aeronautic industry, space missions or nuclear reactors, the mechanical properties must be more carefully investigated. In general, failures and imperfections are inevitable in composite structures. In this context, design concepts of composite structures are used to take into account these failures, such as damage tolerance and damage resistance. Damage resistance is connected on the material's capability to minimize the failures' effects given by impact, while damage tolerance is given by the material's capability to maintain its properties even after failures' appearance in material. Usually, these properties are called residual properties. One of the difficulties regarding the properties and evaluation of composites is, ironically, an advantage, namely, the capability to allow users to tailor their properties to suit the design needs [4],[5]. There are a huge number of fibers ranges and combination ways, resins for matrix, additives, stacking and orientation ways of laminate in a laminate, manufacturing possibilities (thermal treatments) and therefore is very difficult to extrapolate the composite behavior depending on these parameters for a certain combination of them [6],[7], [8], [9]. In applications, the use of composites based on natural fibers is yet limited at the so-called non-structural components such as inner components of cars. One of the main reasons for this limitation consists in the sensitivity of these composites at impact and the difficulty in critical evaluation regarding damages caused at impact. [10], [11].

2. MATERIALS AND METHODS

The research has been carried out on ten composite panels presenting a rectangular shape and being underpinned on all edges. All panels have the same material's structure:

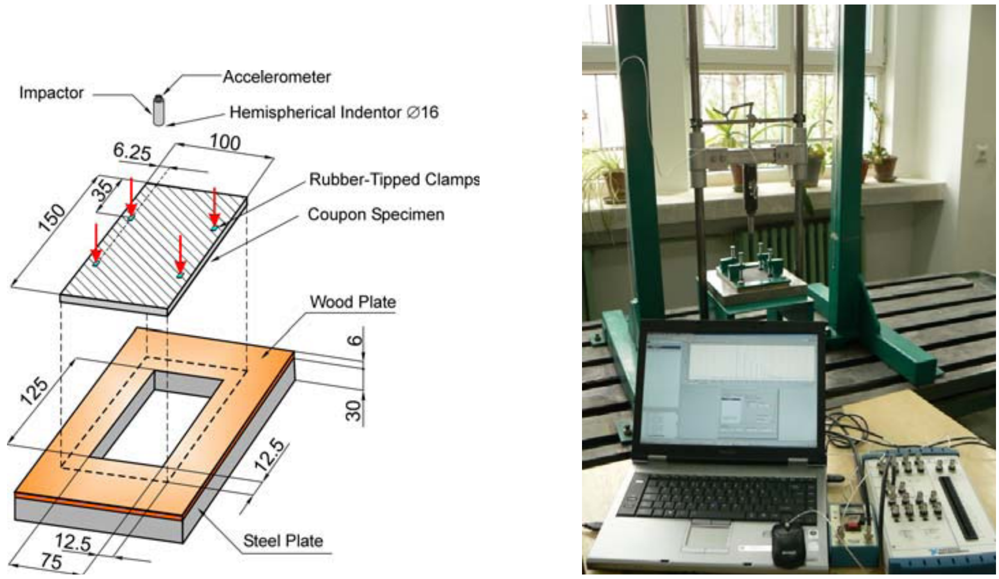
- a layer of thermosetting resin reinforced with carbon fabric;
- a layer of thermosetting resin reinforced with hemp fabric;
- a layer of thermosetting resin reinforced with carbon fabric;
- a layer of thermosetting resin reinforced with hemp fabric.

The plies sequence has been carried out in the hand lay-up process using a roll for resin impregnation of carbon and hemp fibers. Finally, the structure's thickness has been 4 mm. The laminate panel has been maintained at room temperature for two weeks from which ten specimens of rectangular shape (150 x 100 mm) have been cut. The specimens have been subjected to impact by dropping a weight according to the standard ASTM-D5420-98a

(Fig. 1). The impact testing by dropping a weight is used to characterize the dynamic behavior of a material. The experimental setup consists in a two column frame and a weight which can be lifted and released in free fall with minimum friction by sliding along columns under own weight. The indentor presents a hemispherical head with a 16 mm diameter and its mass is equal to 1.9 kg. This indentor hits the middle of the rectangular specimen. The accelerometer is fixed on the upper part of the indentor and the signal (acceleration) is taken over in computer by help of an acquisition device type NI USB 6521 BNC.Using this kind of testing, some data regarding the mechanical properties of a material can be obtained, namely:

- The energy, *U*, absorbed during impact;
- The variation of impact force, *F*, at the impact moment;
- The variation of indentor's displacement, *d*, versus time, etc.

In case of impact testing by weight falling, the only measured feature versus time is the contact force, *F(t)*, exerted by the weight which falls on specimen while the specimen's deflection is determined as a function of time by numerical integration of the indentor's motion equation. The acquisition of experimental data (acceleration) as well as computing the response parameters described above have been carried out using a block diagram conceived by the LabView program.



a) b)

Figure 1. The specimen's geometry (a) and the impact device (b)

The height from which the weight is released has been computed with the well known relation:

$$H = \frac{v^2}{g}[m] \qquad (1)$$

where *g* represents the gravitational acceleration. The indentor's motion equation can be written by help of the following relation:

$$a(t) = g - \frac{F(t)}{m}\left(m/s^2\right) \qquad (2)$$

where *m* represents the impactor's mass.

The absorbed energy can be computed according to the relation:

$$U(t) = \int_0^t F(t)\cdot v(t)\cdot t \quad \text{(J)} \qquad (3)$$

The layered composite panel is made of: the first carbon layer (mat glass) having a thickness of 1.5 mm alternating with a second layer of hemp cloth with a thickness of 0.5 mm, and repeating the operation until a composite plate consisting of four layers is obtained. Finally, the laminated composite panel thickness is 4 mm. The panel obtained by using this method was kept at room temperature for two weeks after which 8 samples were made (the samples have a form suitable for tensile testing according to EN ISO 527-2).
The glass-hemp hybrid composite was made in a similar manner, should only be noted that the glass fibers have a volume fraction of 35%. (Fig.2)
The samples were coded C-Cnp (in the case of the hybrid composite carbon-hemp) and S-Cnp (in the case of the hybrid composite-glass hemp) and have been tested at impact.

a) b)

Figure 2. Sectional view of the composite hybrid C-Cnp (a) and the composite Hybrid S-Cnp (b)

3. RESULTS AND DISCUSSIONS

The damage resulting from dynamic mechanical stress is widely recognized as among the most severe forms of damage encountered in composite laminates . While, in the ballistic dynamics, this kind of damage is visible, the low speed dynamic mechanical stress is usually responsible for damages that are difficult to detect with the naked eye - the so-called damage BVID (Barely Visible Impact Damage) , but which can dramatically reduce the bearing capacity of the structure.
The polymer composites respond to dynamic mechanical stress by dissipating the kinetic energy of the projectile in a different manner compared with the metals, and they are capable of sustaining an extremely limited permanent deformation , the energy being frequently absorbed in common with creating large areas of delamination , which is leading to the reduction in strength and stiffness . Due to the inhomogeneity and anisotropy of the material, it is impossible to assess the severity of the damage by using the conventional fracture mechanics principles, but knowing the processes of initiation and the development of impact damage and identifying the parameters that influence this deterioration are necessary facts when planning to develop mathematical models used to assess damage.
Relying on the experimental data for the hybrid specimens S-Cnp and C-Cnp and their interpretation, their capitalization allowed the use of the results for both types of specimens, in the moment of impact, at the same impact speed, on a single graph.

Specimen S-Cnp, C-Cnp (v=3m/s; v=4 m/s)

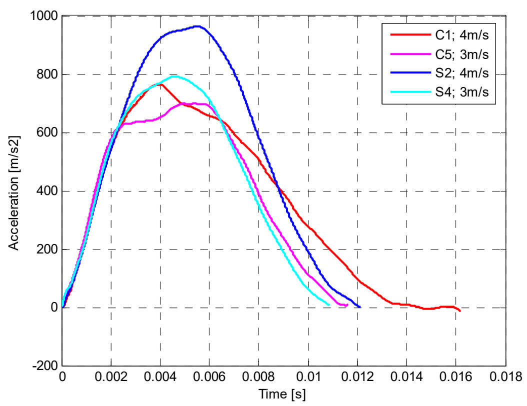


Figure 3. Changes in acceleration at the impact for different impact speeds of specimens S-Cnp, C-Cnp

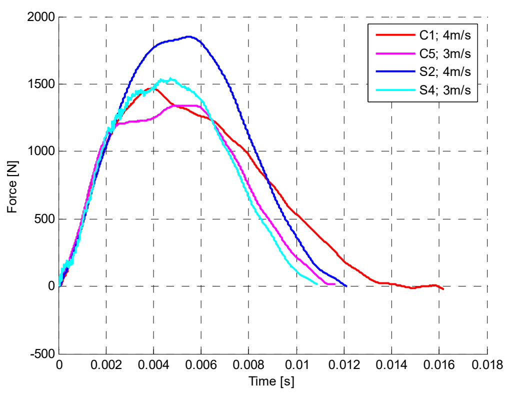
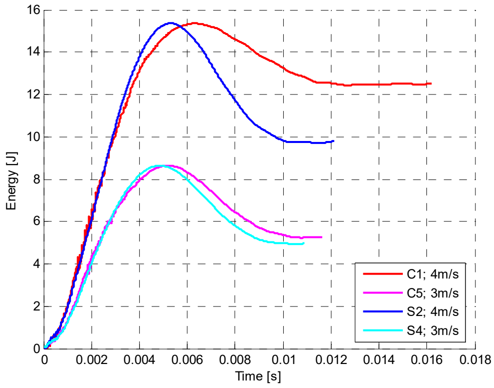


Figure 4. Changes force-displacement variation at the impact for different impact speeds of specimens S-Cnp, C-Cnp



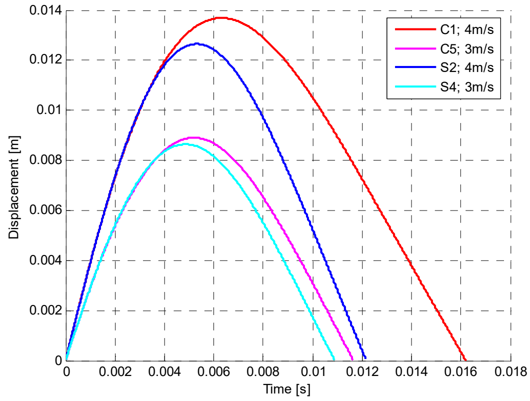


Figure 5. Changes in energy at the impact for different impact speeds of specimens S-Cnp, C-Cnp

Figure 6. Changes displacement of the projectile at the impact for different impact speeds of specimens S-Cnp, C-Cnp

4. CONCLUSION

During the analysis of the graphs of fig . 3-6 it can be seen that in the case of the specimen dynamically stressed with different values of the initial velocity , the absorbed energy accumulates in time and increases up to a plateau of consistency . After reaching a maximum value for the force, it decreases over time , being absorbed by the material . The decrease in the force occurs after the energy reaches this consistency plateau.

It is already known from literature (Cantwell 1988, Sierakowski et al 1997) that, if a composite laminate is subjected to low speed dynamic stress , the initiated damage propagates through the material , from the area where the hammer struck . For a rigid material, the shape of the cracks resembles, in section, the shape of a " pine tree ", with the tip being in the impact area, unlike the case of a flexible material, where the cracks are propagated from the surface which is opposite to that where the hammer hit. Therefore, the damage develops in a " reverse pine tree " shape, with the tip located on the surface which is located under the contact area of the hammer.

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