Focussed on: Fracture and Structural Integrity related Issues

Impact response of balsa core sandwiches

Nurdane Mortas
Department of Mechatronics Engineering, University of Gaziosman Paşa
nurmortas@gmail.com

Paulo N.B. Reis
Department of Electromechanical Engineering, University of Beira Interior
preis@ubi.pt

José A.M. Ferreira
CEMUC, Department of Mechanical Engineering, University of Coimbra
martins.ferreira@dem.uc.pt

ABSTRACT. The benefits of resins nano-enhanced on the impact response of sandwich composites made by fiber glass/epoxy skins and balsa wood core were studied. Afterwards, the influence of the core's discontinuity was analyzed in terms of impact strength. For better dispersion and interface adhesion matrix/clay nanoclays were previously subjected to a silane treatment appropriate to the epoxy resin. Resins enhanced by nanoclays promote higher maximum impact loads, lower displacements and the best performance in terms of elastic recuperation. The core's discontinuity decreases the impact strength, but the resin enhanced by nanoclays promotes significant benefits.

KEYWORDS. Sandwich composites; Nanoclays; Impact behaviour.

INTRODUCTION

Structural sandwich composites have been widely used in many engineering applications as consequence of their superior structural capacity in carrying transverse loads, superior bending stiffness, low weight, excellent thermal insulation and acoustic damping [1, 2]. These materials combine thin skins (to promote high in-plane mechanical properties) with low density cores (to fix the skins and to carry the transverse shear load or to provide other structural/functional duties). For this purpose a large variety of materials can be used. Usually, the skins are made of metal alloy sheet or fiber-reinforced polymer laminates and, in terms of core, metallic honeycomb, polymer foam, syntactic foam, Nomex and balsa wood can be used. For example, balsa is the lightest woods available and it offers salient mechanical and physical properties.

However, sandwich composites are very susceptible to the impact loads that occur during the operational or maintenance activities. To improve the impact performance of those materials many researchers propose the addition of low concentrations of nanoparticles into polymers without compromising density, toughness or the manufacturing process [2-7]. Montmorillonite (MMT) clay is the most popular nanoreinforcement for polymeric nanocomposites as consequence of its relatively high ion exchange capacity, high aspect ratio and economic advantages [8].

In this context, Hosur *et al.* [9, 10] showed that the sandwich composites with nano phased foam sustain higher loads and present lower damage areas as compared with neat sandwiches. Avila *et al.* [11] reported benefits in terms of energy absorption and failure modes with the nanoclays fillers on fiber glass/nano-modified epoxy face sheets and polystyrene foams. According to Reis *et al.* [2], the lowest displacements and the highest elastic recuperation occur for sandwiches with resin nano-enhanced. The best performance of the sandwiches with epoxy resin enhanced by nanoclays was also confirmed by the residual flexural strength, which increases with the introduction of the nanoclays [2]. On the other hand, Avila *et al.* [12] observed that the natural frequencies of the structural sandwich composites are altered by the addition of nano-reinforcements.
However, the balsa planks (boards) present finite dimensions. Consequently, there are discontinuities of the core that affect the mechanical properties. Therefore, the aim of this work is study the effect of these discontinuities (gap between cores) on the impact performance. For this purpose, a gap with 20 mm of length will be analyzed and the results will be compared with other ones obtained for sandwiches manufactured with continuous cores (control samples). The benefits of resins nano-enhanced on the impact response of sandwich composites made by fiber glass/epoxy skins and balsa wood core will be studied. The epoxy resin was enhanced by nanoclays with special treatment to improve their dispersion and interface adhesion. The results are discussed in terms of load-time, load-displacement and energy-time diagrams.

EXPERIMENTAL PROCEDURE

The sandwich composite specimens were fabricated using skins of glass fibre/epoxy resin and core of balsa wood with 6 mm of thickness. The skins are composited by six ply laminates, all in the same direction, of woven bi-directional glass-fibre 1195-1000 (195 g/m^2). SR 1500 epoxy resin and a SD 2503 hardener, supplied by Sicomin, were used. The system was placed inside a vacuum bag and a load of 2.5 kN was applied during 24 hours in order to maintain a constant fibre volume fraction and uniform laminate thickness. During the first 10 hours the bag remained attached to a vacuum pump to eliminate any air bubbles existing in the composite. The post-cure was followed according to the manufacturer`s datasheet (epoxy resin) in an oven at 40 ºC for 24 hours. In order to improve the dispersion and interface adhesion matrix/clay, nanoclays were previously subjected to a special treatment appropriate to the epoxy resin. More details about the treatment and the dispersion/exfoliation on the epoxy matrix can be found in [3, 4]. The nanoclays content used in present study is 3 wt.% because, according with studies developed by the authors [4], is the best amount for this epoxy system.
Fig. 1 shows the square specimens, with 100 mm side and 8 mm thickness (100x100x8 mm^3), used in the present study. Low-velocity impact tests were performed using a drop weight-testing machine IMATEK-IM10. More details of the impact machine can be found in [13]. Impactor diameter of 10 mm with masses of 2.903 kg was used. The tests were performed on square section samples of 75x75 mm and the impactor stroke at the centre of the samples obtained by centrally clamping the 100x100 mm specimens. The impact energies used in the tests were 5 J. This energy was previously selected in order to enable the measuring of the damage area, but without promote full perforation of the specimens. For each condition, five specimens were tested at room temperature.

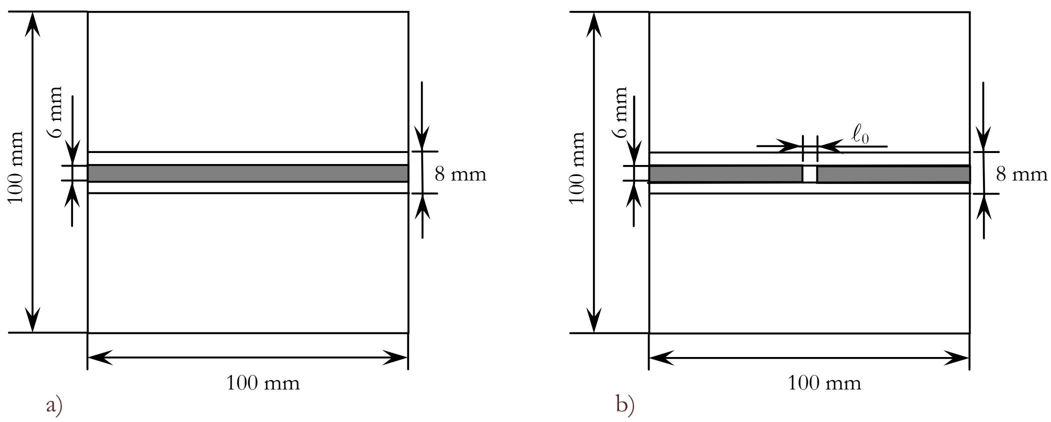

Figure 1: a) Control samples; b) Samples with different gap lengths (ℓ_0 = 20 mm).

RESULTS AND DISCUSSION

Impact tests were carried and Fig. 2 shows the load-time, load-displacement and energy-time curves for sandwiches with pure epoxy resin and epoxy enhanced by nanoclays. These diagrams are representative of all specimens tested and they agree with the literature [2-4, 14-15].

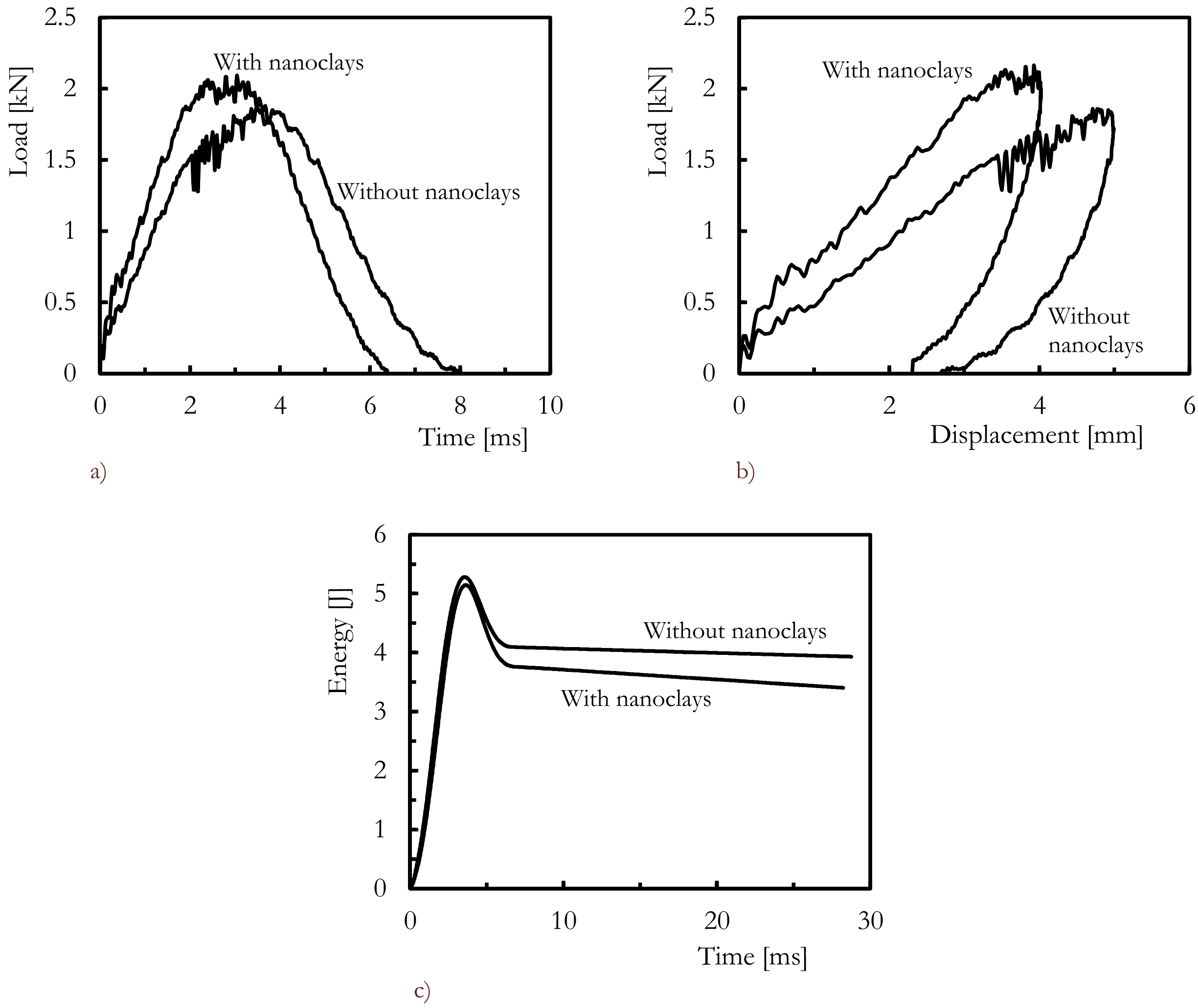

Figure 2: a) Typical load-time curves; b) Typical load-displacement curves; c) Typical energy-time curves.

In detail, it is possible to observe that the force increases up to a maximum value (P_{max}) followed by a drop after the peak load. The impact energy was not high enough to infiltrate full penetration, because the impactor sticks into specimens and rebound always. The beginning of the plateau coincides with the loss of contact between the striker and the specimen, so, this energy coincides with that absorbed by the specimen [3, 4, 16].

The addition of nanoclays promotes major maximum impact loads with values, relatively to the control samples, around 11.9% higher. These results agree with the studies developed by Reis *et al.* [3] where, for example, the addition of clays promoted maximum loads around 16.1% highest than occurred in Kevlar with pure epoxy resin. For Gustin *et al.* [17] the differences observed in maximum forces results in the different failure modes, because each sample type has different tensile and shear properties. In terms of displacement, sandwiches manufactured with pure resin presented values about 17.0% higher. This phenomenon is interesting, because the displacement should be controlled, sometimes, in terms of design [3]. Finally, the elastic energy is calculated as the difference between the absorbed energy and the energy at peak

load [3, 4]. When the fillers are added better results can be found. The sandwiches manufactured with epoxy resin enhanced by nanoclays presents best performance in terms of elastic recuperation with values about 25.7% higher.
However, in real applications, the planks (boards) of balsa wood have finite lengths. In this case there are discontinuities between the cores of the sandwiches, because the boards do not touch. This absence of material, in terms of core, affects the mechanical properties of the sandwich, especially the impact strength.
In order to detect the effect of the gap's dimension, Fig.3 shows the typical load-time, load-displacement and energy-time curves. In this case, the control samples are compared against the specimens containing a gap of 20 mm for sandwiches manufactured with pure resin (Fig. 3).

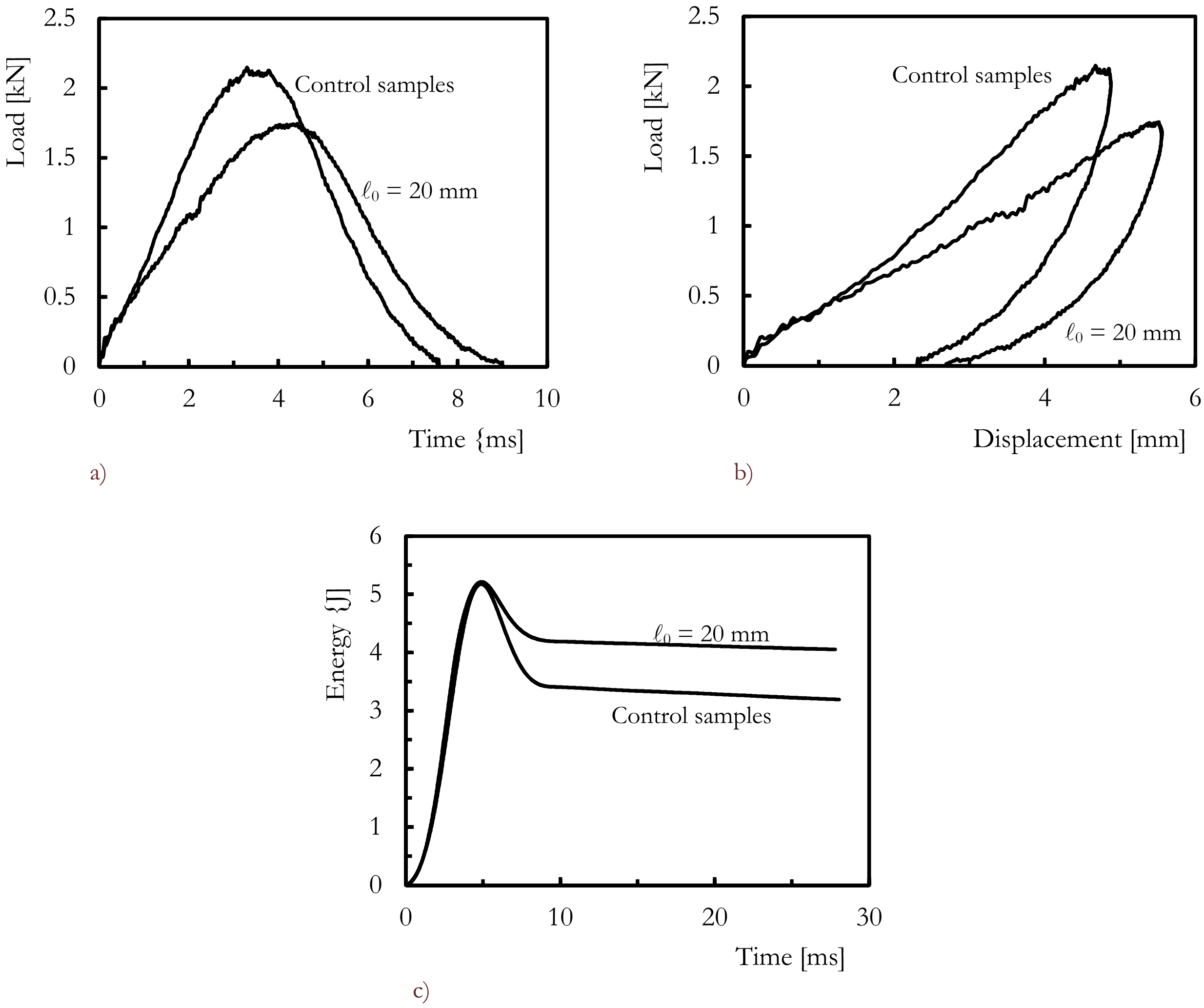

Figure 3: Comparison of the gap's effect in terms of a) load-time curves; b) load-displacement curves; c) energy-time curves.

These curves and the curves shown on Fig. 2 are very similar but with different values. The gap promotes a decrease of the maximum impact loads and elastic recuperation (energy dissipated) but the opposite tendency occurs for displacement and contact time. As consequence of a lower energy dissipated, the damage increases.
Tab. 1 shows the average values observed and the benefits promoted by the resin nano-enhanced. If, in terms of control samples, the benefits obtained with resin nano-enhanced were previously analyzed, the effect of the gap follows the same tendency. In both cases, the gap promotes a decreasing of the maximum impact load with values around 29.4%, for the sandwiches manufactured with pure resin, and about 24.3% for the other ones with nanoclays. On the other hand, in terms of displacement, the opposite tendency was observed. In this case, the displacement increases for both conditions, but with higher values for the sandwiches with pure resin. Values around 22.9% were found, while an increasing about 22% was observed for the sandwiches with resin nano-enhanced. This small difference in terms of displacement, however, was sufficient to promote the lowest damage areas when the resin was enhanced by the nanoclays. In fact, the gap with 20

mm length promoted a decreasing about 48.2% and 41.5% of the energy dissipated, respectively, for sandwiches with pure resin and resin nano-enhanced. These results were expected, because the matrix enhanced by clays present higher stiffness and, consequently, its ductile behavior decreases [3, 4, 18]. Therefore, the failure occurs along the matrix cracking promoted by the impact load [2].

Sandwiches	P_{mx} [kN]	SD [kN]	Displacement [mm]	SD [mm]	Energy Dissipated [%]	SD [mm]
CS without nanoclays	2.35	0.06	4.75	0.24	34.99	2.68
CS with nanoclays	2.63	0.05	4.06	0.11	43.98	1.51
ℓ_0 = 20 mm without nanoclays	1.66	0.19	5.84	0.44	18.13	8.63
ℓ_0 = 20 mm with nanoclays	1.99	0.15	4.96	0.31	25.72	0.52

Table 1: Effect of the gap on the different impact parameters.

CONCLUSIONS

The present work studied the benefits of resins nano-enhanced, and the discontinuities of the cores (gap between cores), on the impact response of sandwich composites made by fibre glass/epoxy skins and balsa wood core. Nanoclay Cloisite 30B, specially modified for better dispersion and interface adhesion matrix/clay, were dispersed in 3% of resin weight.

The maximum impact loads were obtained with resin enhanced by nanoclays. The opposite tendency was observed for the displacement at peak load, where the lower values were found for nanoclays filled sandwiches. Finally, sandwich composites manufactured with epoxy resin enhanced by 3 wt.% of nanoclays presents the best performance in terms of elastic recuperation.

In terms of core's discontinuity, the absence of material decreases the impact strength, but the resin enhanced by nanoclays promotes significant benefits in this context.

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