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Mechanical behavior and acoustic emission technique for detecting damage in sandwich structures

I. Ben Ammar [a,b,*], C. Karra [b], A. El Mahi [a], R. El Guerjouma [a], M. Haddar [b]

[a] LUNAM University, Maine University, <CNRS UMR 6613>, Acoustic Laboratory of Maine University (LAUM), Avenue Olivier Messiaen, 72085 Le Mans CEDEX 9, France[1]

[b] Mechanics, Modeling and Manufacturing Research Laboratory (LA2MP), National School of Engineers of Sfax (ENIS), BP 1173-3038 Sfax, Tunisia[2]

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ABSTRACT

The present study investigates the mechanical behavior under static and dynamic loadings and assesses damage by the acoustic emission method of two types of sandwich composite materials. The sandwich structures under study are both made of cross-ply laminates as skins and PVC closed-cell as foam with different densities: 60 kg m^{-3} and 100 kg m^{-3}. The mechanical behavior tests were conducted in static and cyclic fatigue loadings under 4-point bending. The sandwich structures considered in fatigue tests were damaged by a various number of shear damages in the foam. Static tests were performed to determine the failure parameters and characteristics used in fatigue tests. The damage density effect on the stiffness, hysteresis loops, dissipated energy and damping of sandwich structures, were studied for various numbers of cycles during cyclic fatigue tests. The acoustic emission method was used to identify and characterize the local damage in both types of sandwich materials under static 4-point bending tests.

1. Introduction

Sandwich composite materials have increasingly been used in a variety of industrial applications such as marine, automobile industry, aeronautics, and aerospace. Sandwich structures typically consist of two thin face sheets and a thicker lightweight core. The face sheets are generally composite laminates made from Kevlar, carbon or glass fibers, while the core may be made of honeycombs, cellular foam or balsa wood. This structure is more advantageous as compared to other traditional metallic materials. It is characterized by its anti corrosion power, lightness, simplicity of implementation, insulation, hardness, resistance to fatigue, flexibility, high rigidity, high flexural strength, low surface density, etc.

Assarar [1] and Idriss et al. [2,3] studied the effect of the distance between supports and the densities of the foam on the mechanical behavior of sandwich structures. They showed that the mechanical behavior of a lower density sandwich beam was linear at the beginning of the test, then it became non linear and when the distance between support decreased, the non-linear zone of the curve became shorter. Moreover, Idriss et al. [2,3] studied the effects of debonding lengths of the sandwich structures on the stiffness, hysteresis loops and damping for various numbers of cycles during fatigue tests. They showed that the stiffness of sandwiches decreased with the increase of lengths of debonding damage.

Farooq [4] was interested by the mechanical behavior of sandwich structures tested in static and fatigue. The studied sandwich panels were constituted by two skins of glass fibers/epoxy and core of different foam thicknesses and densities. The testing procedures of this study included static and fatigue testing of cores under compression, indentation, shear and three-point bending tests and skins in flexural tests. The experimental results were compared to the results obtained by the sandwich beam theory [5]. This comparison revealed a close agreement between both results. He showed that the foam play an important role in the performance of sandwich composites in different loading environments. The bending and shear stiffness increased both with the core density and thickness. However, the bending modulus decreased with the increase of core thickness.

Bezazi et al. [6,7], studied the stiffness degradation and the identification of damage mechanisms under static and fatigue tests of sandwich panels with PVC foam cores. The sandwich panels

* Corresponding author. Address: Mechanics, Modeling and Manufacturing Research Laboratory (LA2MP), National School of Engineers of Sfax (ENIS), BP 1173-3038 Sfax, Tunisia and Acoustic Laboratory of Maine University (LAUM), Avenue Olivier Messiaen, 72085 Le Mans CEDEX 9, France. Tel.: +216 52 370388.

E-mail addresses: Imen.ben_ammar.etu@univ-lemans.fr (I. Ben Ammar), chafik.karra@ipeis.rnu.tn (C. Karra), Abderrahim.elmahi@univ-lemans.fr (A. El Mahi), Rachid.el_Guerjouma@univ-lemans.fr (R. El Guerjouma), mohamed.haddar@enis.rnu.tn (M. Haddar).

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[2] http://www.u2mp.org/.

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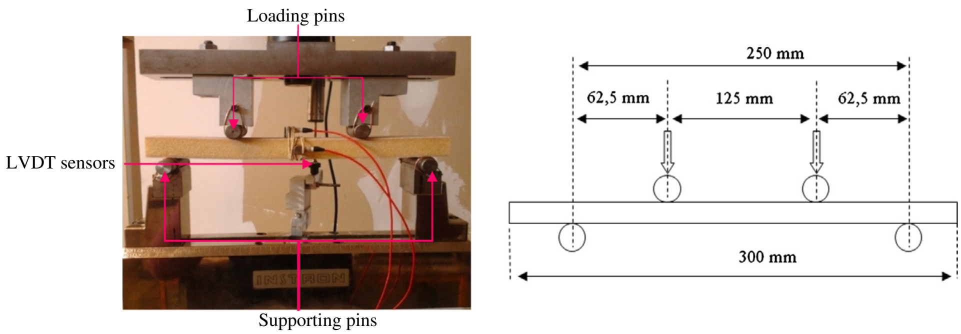

Fig. 1. Experimental four point bending set up and dimensions.

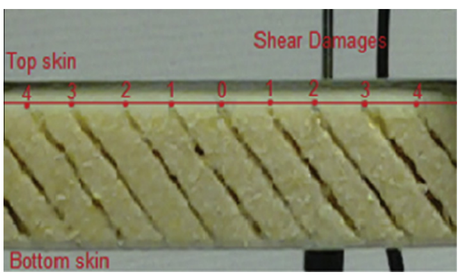

Fig. 2. Sandwich material with shear damages.

with cross-ply laminate skins made of glass fiber and epoxy resin were manufactured by vacuum moulding and subjected to three-point bending tests. Two PVC cores of similar type but with different densities were used. The effect of core density and thickness on the damage behavior was highlighted. They demonstrated that the sandwich with the higher core density withstood a higher load and possessed greater rigidity in static tests, combined with an enhanced fatigue resistance, when compared to the sandwich which had a lower core density.

The identification and analysis by acoustic emission of the damage mechanism in composites under an important load were studied by many researchers for the case of laminates but not thoroughly in the case of sandwiches.

Berbaoui et al. [8] studied the acoustic emission analysis of polymer concrete damage in creep. The concrete specimens were tested in 3-point bending and creep. The multivariate statistical analysis of collected signals was performed during the creep tests by a method of classification, composed of Fuzzy C-mean clustering [9] associated with a principal component analysis (PCA) [10]. They showed the appearance of three types of damage namely the cracking of the resin matrix, the interfacial decohesion and the break of aggregates which appeared at the end of the test. A correlation between the evolution of acoustic emission (AE) activity in the primary creep and the time to failure of the samples was established.

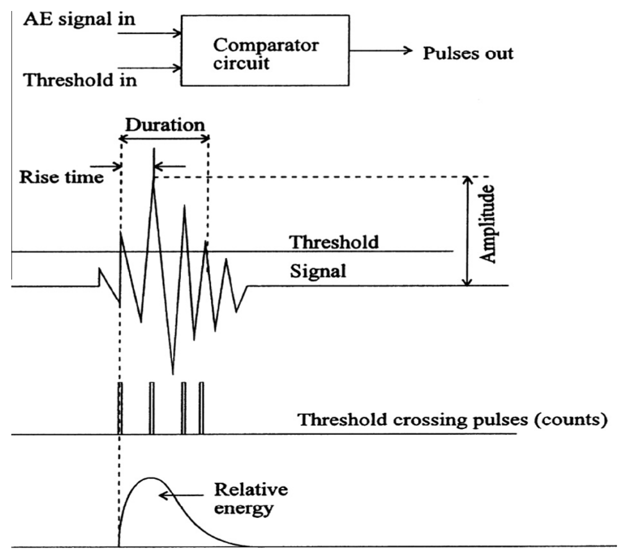

Fig. 4. Characteristic of a burst type of acoustic emission.

Marec et al. [11–13] used unsupervised pattern recognition analyses (fuzzy C-means clustering method) associated with a principal component analysis for the classification of the AE events monitored from unidirectional fiber–matrix composites. Each cluster resulting from the classification corresponded to a different damage mechanism identified in the materials. The composites used in this study were cross ply laminates composed of a glass

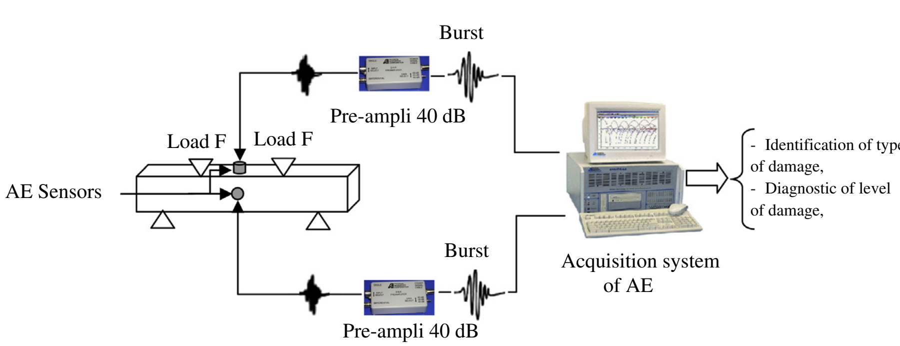

Fig. 3. Experimental set up of acoustic emission method.