CHARACTERIZATION BY NON-DESTRUCTIVE VIBRATION TEST OF A SEWN SANDWICH PLATE (100% COMPOSITES)

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Abstract – *In the ethics of any campaign for the promotion and popularization of an innovative material, it is necessary to pass it through all the standardized tests in order to classify it. To do this, we propose in this investigation the characterization of a sandwich structure whose two skins are made of composites and in the presence of a transverse structural element in the form of a seam. The vibrational method for characterizing innovative materials is expressed by analyzing the self-response spectrum of a standardized specimen excited by an impulsive walking effort. Its particularity of being a non-destructive characterization test makes it essential in the case of innovative materials because their first manufacture is always expensive. In the present study, the fabric of the structure is a sandwich plate sewn by rovings which consolidates the connection between the two skins and the core while ensuring transverse rigidity to the sandwich. The open end was censored by a vise while fixing the signal sensor to the other free end. The acquisition of the results was managed by the PULSE software and an analyzer based on the fast Fourier transformations (FFT). Compared to its analogues in the specialized literature, our experience gave very effective results, and the test piece remained solid and susceptible to further destructive tests for confirmation. However, our sandwich plate is distinguished by its complete composition in composite both the two skins and the seam rovings, for the filling of the core it is ensured by a constructive foam which in principle plays no structural role.*

***Keywords**: Characterization Non-destructive tests, Frequency,Modal analysis,Pulse*

I. Introduction

In the ethic of the innovative study of a new material, appeared the “Material Structures” where the material is presented directly in its structural form to undergo characterization tests. In the literature, two main types of characterization are distinguished by the destruction or not of the specimen during the test. In this axis of characterization of new materials, the researchers are divided into two categories. The former have opted for traditional destructive testing. In fact, the authors of the works [1], [3] and [10] practiced the three or four point bending test. Although the works using shock as a mode of characterization are very shady and diversified, we have tried to identify those closest to our investigation. On the one hand [2] and [11] used the low-speed cyclic impact for their characterization work, on the other hand the authors of [8] and [17] solicited their structures by a fast high-energy shock, in the same concept some have used laser shock [26]. While others have used damage to characterize or classify composite laminates [14], [15].

For the second category, the principle of non-destructive testing has two very interesting advantages, on the one hand the saving on the material which remains holy and allows several other tests of the same type and with the same specimen. On the other hand, the possibility of carrying out these tests on structures in service is an essential control asset which allows preventive repairs to the structure and thus avoids disaster. In recent decades this concept has caused much ink to flow. We can cite the works [4], [5], [6], [7], [10], [16] and [19] which solicited the specimen by hiking excitation and carried out a modal analysis of the auto spectrum thus characterizing the materials by their mechanical parameters without destroying the specimen. In order to enhance this type of test, the author of the thesis [21] has designed a non-destructive test bench. To check the state of the structures, the authors [22], [23], [24], [25] and [27] used fiber optics while others used ultrasound [28].

A sandwich panel is a material structure made up of three elements which are two skins (upper and lower) glued on each side to a core made of a material other than that of the two skins. Although the material of the core is clearly less resistant than the material of the skins, it seems that the structure built by such an assembly has better performance in terms of resistance than each material considered separately. This association of different materials then causes the assembled material obtained to acquire optimum mechanical properties. The bibliographic research undertaken has enabled us to discover that many works have been carried out in this context. The principle of the sandwich system has been largely monopolized by sandwiches with metal skins, but among recent works we note that composite skins have gradually begun to take their place. The innovation of a new manufacturing technology has greatly improved the performance of the new sandwiches. It consists of adding transverse reinforcements proven in the case of monolithic composites [1] and [2]. This manufacturing technology is applied to the case of sandwich structures where the transverse reinforcement plays the role of seams which not only ensure a strong bond between the two skins and the core but increase the resistance and thus give a more efficient structure than the sandwich structures. ordinary [3]. On the other hand, vibrational testing by modal analysis has the potential to provide the basis for the rapid and inexpensive characterization of elastic and viscoelastic properties of composites for design and fabrication [1], [3] and [10]. Knowledge of elastic properties is obviously necessary for design, but measuring elastic properties during manufacturing also improves quality control [4]. The non-destructive characterization test is a method that has been used by both [5] and [6]. It consists in obtaining the mechanical characteristics using vibratory modes. In this work, we propose to apply the methodology of characterization by non-destructive testing on our new stitched sandwich plate. This characterization of said structure is necessary for further popularization work on the structural material thus obtained..

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II. *Material and Structure*

Generally the sandwich structure consists of a core with low rigidity to which are bonded two skins of a denser and more rigid material. For composite sandwich materials, the skins also consist of dies and reinforcements, thus offering performances equal to traditional materials but with a significant gain in mass.

The structure in sewn sandwich plate subject of our present study has in addition a seam connecting the skins (compost) between them in the form of edges forming a certain angle with the skins. These seams have the role of reinforcing the structure and increasing its mechanical properties in the transverse direction

Fig. 1 Photo without foam showing direction of stitching

II.1. Empirical formulation.

We learned from the specialized literature, [7] and [4] that the determination of the frequencies and eigen modes of a free vibration of straight beams also called Euler-Bernouli beams is calculated by the following expression (1) which will allow us thereafter to calculate Young's modules:

$$\omega_n = \frac{A_n}{L^2}\sqrt{\frac{EI}{\rho S}} \qquad (1)$$

In the previous expression (1) we can designate:

- L : Length of the beam without embedding (m)

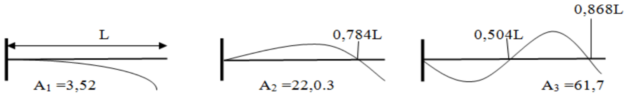
- E : Young's module (MPa).

- I : Moment of inertia of the test beam (m^4).

- ρ : Density of the test beam (kg/m3)

- S : Section of the test beam (m^2)

- A_n is a coefficient which depends on the boundary conditions of the excited beam. In the case of our study it is “Embedded — Free” and the values An according to the first three eigen modes of the beam are given on the following figure :



By expressing the pulsation as a function of the frequency for a "n" mode we obtain:

$$w_n = 2\pi f_n$$

(2)

From the combination of formulas (1) and (2) we can directly derive the expression of Young's module [5]:

$$E = \frac{\rho S}{I}\left(\frac{f_n 2\pi L^2}{A_n}\right)^2 = 48\pi^2\rho\left(\frac{L^2 f_n}{h.A_n}\right)^2$$

(3)

In this expression and after simplification appears the thickness h of the test beam which is expressed in mm.

On the other hand we have the expression of the shear modulus in the case of structures in vibration [5]:

$$G = \frac{32}{3}.\rho.\left(\frac{\pi . f_n}{A_n . h}\right)^2$$

(4)

- G : Shear module (MPa)

- fn : Natural frequency (Hz)

- An : The same constant related to the boundary conditions.

To calculate the Poisson's modulus we have:

Poisson's modulus we have:

$$G = \frac{E}{2(1+\nu)} \text{ and } \nu = \frac{E}{2G} - 1$$

(5)

II.2. Operating mode.

The operating mode used for the characterization of the material by non-destructive test consists of a PC with acquisition software in our case it is the PULSE Software. The computer is connected to it by a cable (internet) to a signal analyzer (FFT) which is in turn linked to the test piece by a signal sensor. The specimen, of total length "L" is embedded at its base by a vice and carries at its other end the type 4506 accelerometer (Piezometric with preamplifier and frequency range from 0.6 to 3500Hz according to y and z and 6000Hz for x :

The other face of the free end of the test piece receives an excitation with an impact hammer belonging to the entire operating mode. The acquisition of the results in the form of frequency self-spectra along the three axes then makes it possible to determine by suitable empirical formulas the different characteristics of the final composite material thus obtained.

We can summarize the operating mode on the photo of figure (2):

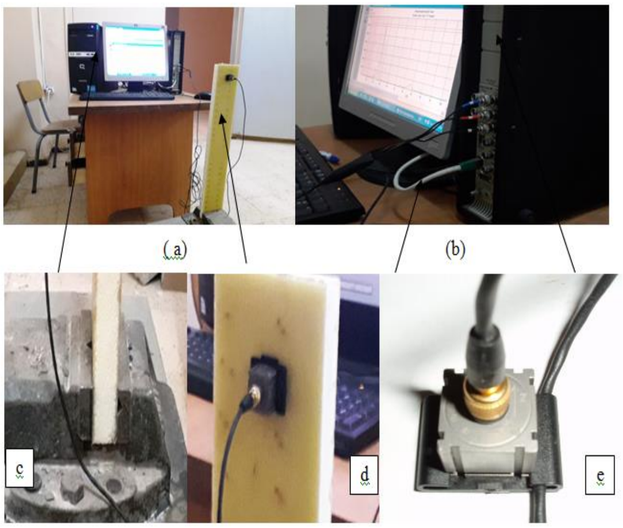


Fig. 2 Operating Mode : (a) Microcomputer and signal sensor (b) Mounting the sensors (c) Installation of the test piece (d) sticking the sensor to the free end (e) Type 4506 tri-axial sensor.

The sensor glued to the test tube in photo (c) of figure (2) is connected at its end by three contact plugs to the analyzer (FFT). This accelerometer has three essential characteristics: the first is the piez

Geometric property to transform the forces applied to it into electrical charges, the second is that it has an integrated preamplifier and the third is that it picks up the vibrations that come from three directions . In this way the acquisition is done along the three axes (Ox), (Oy) and (Oz). Depending on the display mode, we can have either the response spectra of the “material” structure in the three axes or the history of the displacement of the point of the sensor. Which gives it great sensitivity and a wide frequency range? In our case it is the auto spectrum which is given where the non dependence of the intensity of the excitation.

II.3. Tests carried out.

After placing the standard test piece in the vice which ensures its embedding, it is connected by the sensor to the signal analyzer. The software is started and a calibration is carried out. By operating simultaneously, the specimen is excited with the impact hammer, belonging to the operating mode of the said test, and the acquisition of the FFT (Fast Fourier Transform) analyzer based on the fast Fourier transformations is started. The operation is repeated several times to ensure the fidelity of the device and the assumption that the auto spectrum is independent of the intensity of the impact force. Each time we checked the self spectra along X, Y and Z which remained unchanged, on the other hand, the curves of the displacement histories which depend on the values of the applied forces changed with each recovery.

III. Results and discussions

Each acceleration spike corresponds to a specific mode of vibration. We note that for each mode we obtain the same frequency value (on the abscissa) and this in the three response spectra according to X, Y and Z .. For each of the modes we will give the graphs with the cursor in red which represents the spades values.

For figure (3) it is the first mode and one notes in the three graphs that it corresponds to the value of Frequency = 25 Hz

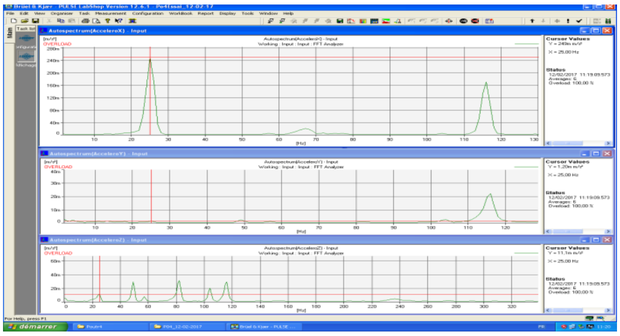


Fig.3. Graphs of the Self response spectra (1) along X, (2) along Y and (3) along Z

For figure (4) it is the second mode and we note in the three graphs that it corresponds to the value of Frequency = 57 Hz.

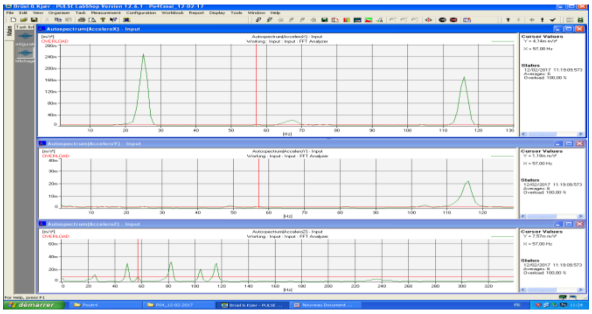


Fig.4. Graphs of the Self response spectra (1) along X, (2) along Y and (3) along Z

For figure (5) it is the third mode and we note in the three graphs that it corresponds to the value of Frequency = 116 Hz.

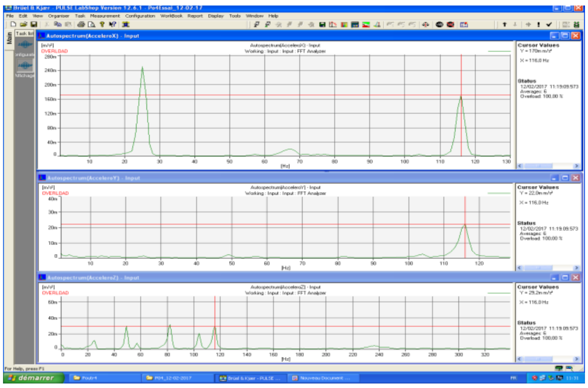


Fig.5 Graphs of the Self response spectra (1) along X, (2) along Y and (3) along Z

The calculation parameters taken from these graphs can be summarized in the table (1) we can at the same time notice that the spades are the same for each mode:

Table 1: Calculation parameters.

h (mm)	**23**	**23**	**23**
L0 (m)	**0,63**	**0,63**	**0,63**
L (m)	**0,6**	**0,6**	**0,6**
ρ (kg/m3)	**362,9**	**362,9**	**362,9**
Modes :	**Mode 1**	**Mode2**	**Mode3**
Fn (Hz)	**25**	**57**	**116**
An	**3,52**	**22,03**	**61,70**

The implication of these parameters in the calculations governed by the different formulas (2), (3) and (5), gives us the characteristics which we then summarize in table (2):

Table 2: Results of non-destructive characterization tests.

Directions	**OX**	**OY**	**OZ**
E (MPa)	2,12E+04	2,82E+03	1,49E+03
G (MPa)	3,64E+04	4,83E+03	2,55E+03
µ	-0,7084	-0,7084	-0,7084

It is necessary to point out that these characteristics relate to the structure taken as manufactured by a single material. Indeed the characteristics of the sandwich plate are much more important than the individual characteristics of the skins and core..

IV. Conclusions

As it has already been observed in the literature, once again, the characterization procedure by non-destructive testing has proved its worth. It gave us mechanical characteristics of the sandwich plate that were more efficient than the characteristics of the constituent elements considered separately. In fact, this characteristic generally distinguishes sandwich plates. This is expressed by an increase in the resistance of the sandwich assembly compared to the separate elements (skins and soul). In the literature in general, a low resistance of the skins to bending is reported, as can be seen in the work [8] which reports the low resistance of the skins to bending which would have given significant values. In our case, this drawback is non-existent because the design of the structural sandwiches clearly highlights the role of the seam rovings which ensure not only the connection (skin-core) but also the comfort and stability of the structure. The presence of these structural elements gives the sandwich panel better transverse resistance. This makes the structure very efficient by offering it maximum resistance with optimal mass (100% Composites).

V. *Futur Scope*

This work is part of a research axis of the "Analysis and Modeling" team of the laboratory to which it belongs. This axis consists in carrying out a broad popularization campaign of the so-called subject structure of the present study. The aim of this campaign is to innovate this structural material thus designed in the field of mechanical, civil and public works engineering. To do this, two application projects are in perspective. The first proposes the use of these panels as covering for aeronautical floors, while the second aims to use them as road guardrails.

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