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USE OF TECHNIQUE OF ACOUSTIC LOADING RANDOM TO SIMULATE FAILURE/DAMAGE IN STRUCTURES BEAM TYPE

Júlio César Silva de Souza*[1], Fabíola Ottoboni Yamane[2], Ângelo de Souza[2], Antônio Carlos Ancelotti Jr.[2], José Juliano de Lima Jr.[2]

[1] Federal University of Itajubá
jcs_mecanica@yahoo.com.br

[2] Federal University of Itajubá
{ fabiolaottoboni@gmail.com, angelo@unifei.edu.br, antonio.ancelotti@gmail.com, limajr@unifei.edu.br }

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Abstract. *Fatigue can be defined as a failure occurring in materials and structures due to cyclic stresses which can cause the spread of cracks and flaws as delaminations in composite materials. When a component is subjected to stresses resulting from mechanical vibrations produced by acoustic waves, occurs a special case of fatigue, called acoustic or sonic fatigue. In this work is made an analysis of dynamic properties and failures arising in composite carbon fiber/epoxy subject to such fatigue. The technique used for determining the dynamic properties will be pulsed excitation, being a non-destructive test to determine the dynamic modulus of elasticity and damping materials. To simulate faults, will be used the technique of simulated random acoustic loading, which uses an apparatus which generates vibrations at resonant frequencies and constant amplitude. It will also performed a study fault in the structure when subjected to a passive vibration control. It is expected that the effects of fatigue in the material significantly reduce the values of the dynamic properties primarily due to the emergence and spread of damage, but it is expected that a minor effect on the structure fails when subjected to a passive vibration control.*

1 INTRODUCTION

The composite material definition is about the combination of two or more materials in a heterogeneous way, presenting different phases in order to acquire specific properties and characteristics [1]. Thus, the main objective of idealization and manufacture of composites is to obtain a material with excellent physical and mechanical properties for a particular project [2].

In the aircraft and aerospace industry, composites are distinguished by nobility of applications as well as new solutions and process development. For military aircraft, weight reduction may represent the ability to carry more weapons [3].

Most of the structural elements are under the action of oscillating stress during the time, the structures are subjected to cyclic stresses. Consequently, these structures break with tensions below the values of resistance limit supported, this type of occurrence is called fatigue [4]. However, when a material is forced to vibrate from a sound pressure gradient, present condition in structural parts very near to reactors and engines, it is considered to a special case of fatigue, known as acoustic or sonic fatigue.

Due to fatigue failure, all projects and structural elements subjected to the action of cyclic loading must be designed considering the useful life of the material, and using changes in the dynamic properties as a key parameter. One method for analysis of these properties during and after the event is the simulation by random acoustic loading [5,6].

Therefore, the main goal of this work is to characterize the effects caused by acoustic fatigue on the dynamic properties of composite beams with carbon fiber/epoxy used in aircraft structures. Finally, a comparative study using a layer of viscoelastic material in the beam is important to evaluate the influence on the process of damage propagation and damping in the structure when submitted to a passive control.

2 MATERIAL AND METHODS

Composite materials used in the present study were provided by Embraer - Aeronautic Brazilian Company - and the tests were carried out in the laboratory of vibrations at UNIFEI, which has all the infrastructure and equipment necessary for the work development.

The composite for the study was obtained by the consolidation of a carbon fiber/epoxy prepreg, fabric flat, 3000 filaments/cable, impregnated resin system 8552, widely used in the manufacture of structural components in the aerospace industry. This material is commercially supplied by Hexcel Composites, name 8552. The composites were consolidated in an autoclave at a pressure of 100 PSI and temperature of 180º C for two hours.

Firstly, for calculating the natural frequency of vibration and the storage modulus of the beam, a simple test was carried out with the clamped beams at one end and free at the other according to Figure 1-a. The tests were performed with a small hammer impact and the laser vibrometer OMETRON VQ-500-D. The vibrometer is used to measure the vibration velocity of a point on the surface of the beam, using an optical vibration sensor. The effective dimensions of the beams are shown in Table 1. A notch was created on each sample, with 7 mm from the point of attachment, with 0.5 mm of depth.

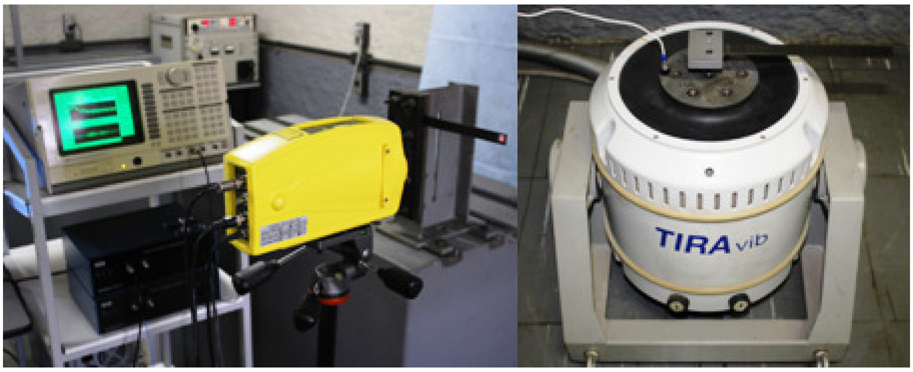

Figure 1: a- vibrometer; b - shaker

Sample	L [mm]	B [mm]	H [mm]	I [m^4]	Mass [g]
Carbon fiber/epóxi **BEAM 1**	202	19.80	1.92	$1.17x10^{-11}$	11.62
Carbon fiber/epóxi + viscoelastic material **BEAM 2**	202	19.80	2.92	$4.11x10^{-11}$	15.12

Table 1: Effective dimensions of beams

2.1 Logarithmic decrement method

The logarithmic decrement, which is the result of a simple impulse triggered in the system (free vibration) is obtained by the ratio of two successive amplitudes of the signal. The term logarithmic decrement refers to the logarithmic reduction rate related to the reduction of the movement after the pulse; the energy is transferred to other parts of the system or is absorbed by the element.

By analyzing the frequency spectrum, it is observed that there is maximum amplitude of vibration to the resonance frequency [7]. Then the logarithmic decrement for a resonance curve can be approximately given by Eq. (1):

$$\Delta = \frac{\pi(f_2 - f_1)}{f_n} \tag{1}$$

With: f_n - First natural frequency of the system (Hz); f_1 and f_2 - corresponding frequency bandwidth associated with the half power points (Hz).

Through the physical and geometrical values of the system, with the concepts of mechanical vibrations [8], the determination of the storage modulus E '(GPa), is given by Eq. (2). This parameter is associated with the stored elastic energy in each cycle.

$$E' = \left[\left(\frac{4\pi^2 f_n{}^2}{3I}\right)\left(\frac{33m}{140}\right)\left(1+\frac{\Delta^2}{4\pi^2}\right)\right]L^3 \tag{2}$$

With: I - Inertia moment of the cross-sectional area of the beam (m^4); m - beam mass (kg);

L - beam length (m).

The damping factor of the material is given by Eq. (3) [7]:

$$\zeta = \frac{f_2 - f_1}{2 f_n} \tag{3}$$

When $\Delta << 1$, $\zeta \cong \frac{\Delta}{2\pi}$ consequently there is the Eq. (4) [9]:

$$\eta \approx 2\zeta \tag{4}$$

With: η - loss fator.

The complex modulus is usually written by Eq. (5):

$$E'' = E'\eta \tag{5}$$

The internal damage (D) of the structure was determined by means of Eq. (6):

$$D = 1 - \frac{En}{Ei} \tag{6}$$

With: En - nth storage modulus; Ei - storage modulus initial

2.2 Vibration tests

The calculations were made according to the Eqs. (1-6). The modal parameters were obtained using the technique of the logarithmic decrement. The responses in time and frequency were obtained by a signal analyzer SRS - Stanford Research Systems Model SR 780. The time signals from the sensor, after being filtered and conditioned, they were acquired and interpreted using the MATLAB program. All tests were at a temperature of 23° C and relative humidity of 70%. Each resulting value is the average of three tests conducted with each sample.

After initial measurement of the dynamic properties, the beams were fixed in a shaker TIRAvib 5020 (Figure 1-b), subjected to forced vibration with the resonance frequency of the primary vibration mode. For this work were fixed intervals of 500.000 cycles for measuring properties, evaluating the spread of damage, in a total of 1 million and 500.000 cycles.

The tests with the composite material were repeated using a layer of viscoelastic material, characterized by a tape-type double-sided acrylic mass model 287 (Figure 2).

Figure 2: Beam with viscoelastic tape

3 RESULTS AND DISCUSSION

The values obtained for the dynamic properties of the beam 1 are shown in Table 2, and for the beam 2 in Table 3. For beams, the average of damages after 500.000 cycles was 8.6%. However, in sequential tests, the damage evolution did not occur in a significant way. The value presented was 3.5% considering the same number of cycles

Nº Cycles	f (Hz)	Initial frequency reduction (%)	Δ	η	E´(Gpa)	E´´(Gpa)	Damage (%)
0	40.00	0	0.00192	0.00384	40.713	0.156	0
500.000	38.25	4.37	0.00179	0.00358	37.227	0.133	8.60
1000.000	38.00	5.00	0.00172	0.00344	36.741	0.126	9.70
1.500.000	37.75	5.62	0.00158	0.00316	36.258	0.114	10.90

Table 2: Dynamic properties of the beam without viscoelastic (beam 1)

Nº Cycles	f (Hz)	Initial frequency reduction (%)	Δ	η	E´(Gpa)	E´´(Gpa)	Damage (%)
0	33.50	0	0.0272	0.00868	10.00	0.086	0
500.000	32.00	4.47	0.0233	0.00741	9.65	0.071	3.50
1000.000	31.87	4.87	0.0196	0.00623	9.55	0.060	4.50
1.500.000	31.75	5.22	0.0187	0.00594	9.50	0.056	5.00

Table 3: dynamic properties of the beam with viscoelastic (beam 2)

The Figure 3 shows the variation of storage modulus as a function of cycle number for beam 1 and beam 2. It is observed that the storage modulus decreases with the increasing of number of cycles for both beams. This reduction is more pronounced for the beam 1.

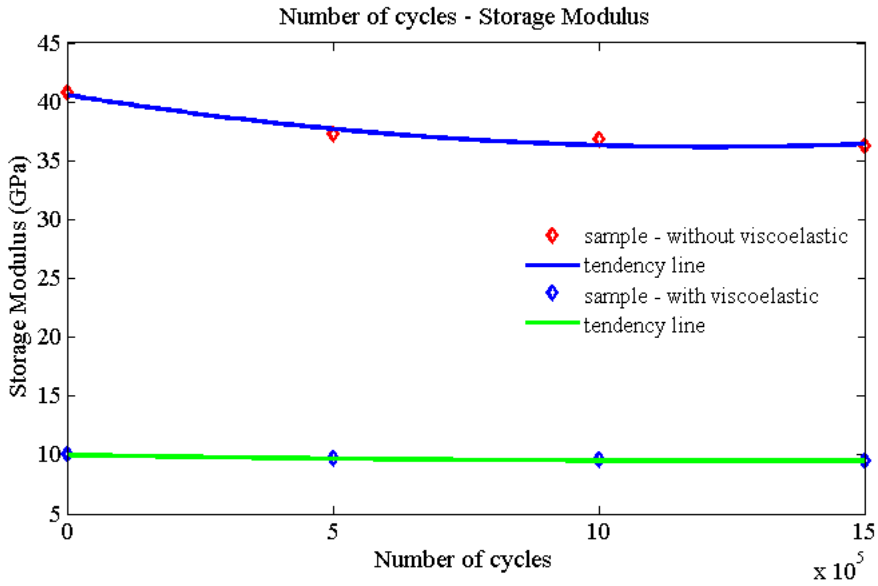

Figure 3: Storage modules versus number of cycles for beam 1 and beam 2.

The system loss factor (Figure 4) shows an increase of 50% in the average values in the presence of a viscoelastic layer. Promoting a significant increase in energy dissipation capacity of the system. When is desirable that some structure absorb energy and release part of this energy in the form of heat. Is recommended to use a material with high loss factor [10].

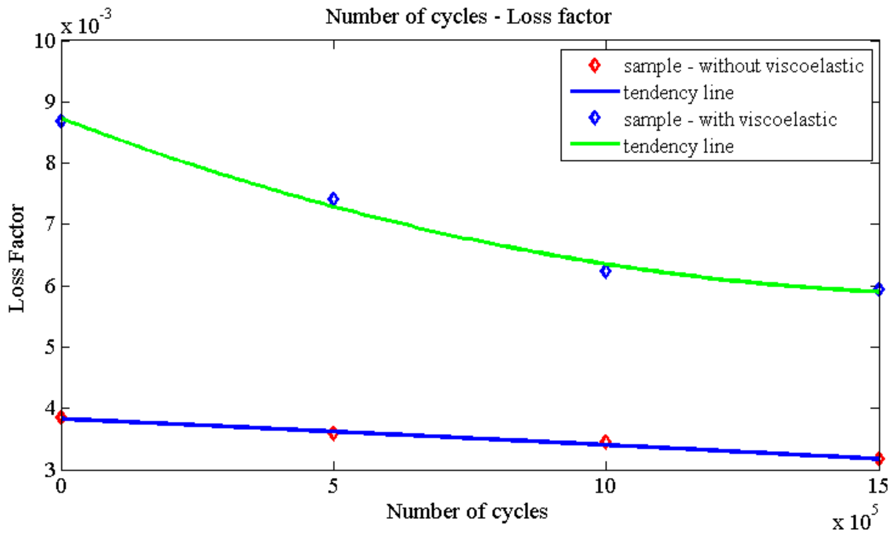

Figure 4: Loss factor versus number of cycles for beam 1 and beam 2.

The addition of the viscoelastic material reduced the spread of damage and increased the damping of the structure. as shown in Figure 5. This behavior is consistent with expectations. since a viscoelastic material has dissipation of energy capacity. In addition to the increase of mass in the system.

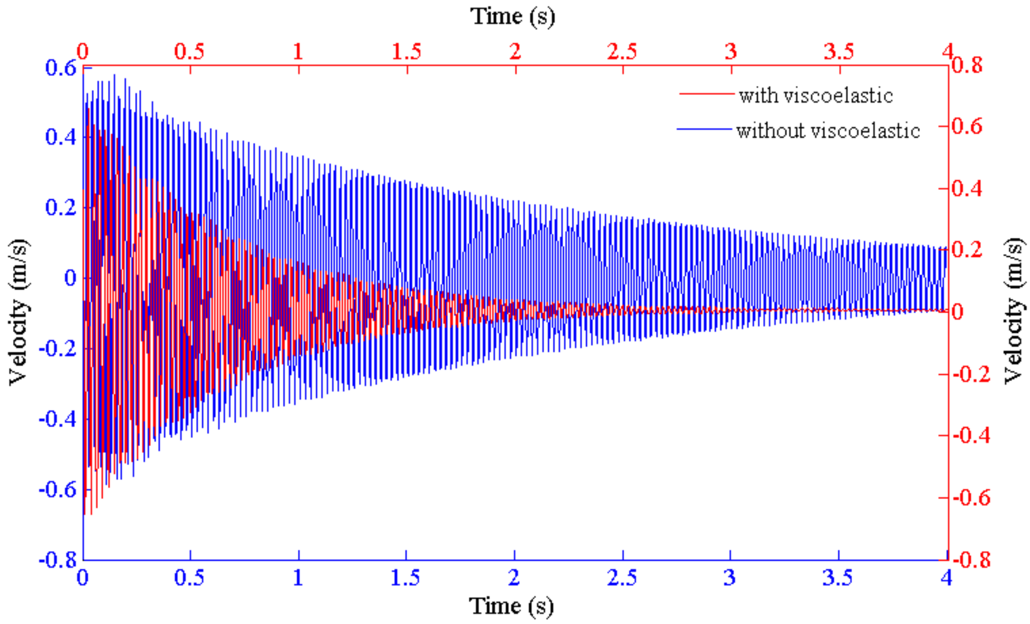

Figure 5: Impulsive response in time for beam 1 and beam 2

4 CONCLUSIONS

In the present work was studied how to get the answers about the damping and resonance modes of beams of carbon fiber/epoxy composite material with and without a viscoelastic tape.

It was concluded that using the viscoelastic material attached to the structure. There was a reduction in the damage propagation and an increase in the structural damping effectivity.

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