A COMPARATIVE STUDY ON DAMPNG PROPRERTIES OF CARBON FIBER COMPOSITES USING NANOCOMPOSITES MATRICES FOR NOISE REDICTION.

R. Volponi[1*], M.Aurilia[2]

[1] *CIRA Italian Aerospace Research Centre, Advanced Materials and Technologies Laboratory, Via Maiorise 81043 Capua (CE) Italy*
[2] *IMAST S.c.a.r.l., Technological District on Engineering of polymeric and composite Materials and Structrures, P.le Fermi,1 – 80055, Portici (NA), Italy*

Keywords: Nanocomposite, carbon nanotubes, damping, noise reduction

Abstract

The dissipation of vibro-acoustic energy in composites materials in order to improve the comfort inside planes has been deeply investigated in the recent decades, as their use in aeronautics has been constantly increased.

Different approaches have been considered which involve both design of the structures and intrinsic properties of materials.

One of the most promising approach recently proposed is based on Carbon Fiber Composites with Nanocomposite Matrix obtained by mixing nano-tubes into the basic epoxy resin.

In this work the effects of different kinds of carbon nanotube used as epoxy resin filler on damping proprieties have been considered.

1 Introduction

1.1 Theoretical basis

The intrinsic properties of a polymeric matrix to dissipate mechanical energy generating heat depends on internal motions of polymer chains and on friction with inclusions.

A viscoelastic model describing that proprieties is possible be thought as a mechanical structure made by a spring, for elastic behaviours and a cylinder-piston, for viscous part. Spring and piston-cylinder are posed in parallel as in fig.1

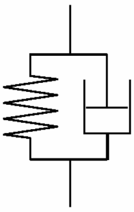

Fig. 1 Viscoelastic model known as Kelvin-Voigt

The equation for that model is :

$$\sigma = E\varepsilon + E^{*}\frac{d\varepsilon}{dt}$$

Eq.1

Where ***E*** is the is the Young module, so the term ***Eε*** is related to the elastic behaviour of material, while $E^{*}\frac{d\varepsilon}{dt}$ is responsible for damping

Not ever is possible to analyze the viscoelastic proprieties of a materials in acoustic range by systems that make a cyclic mechanical stimulus and record the simultaneous response.

So other systems are been developed.

One of these is the so called logarithmic decrement.

In the time domain the logarithmic decrement δ is the natural log of the ratio of the amplitudes of any two successive peaks:

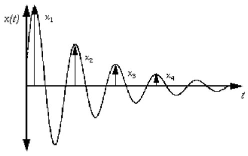

Fig 2 Damped oscillations

$$\delta = \frac{1}{r}\ln\left(\frac{X_i}{X_{i+r}}\right) = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$

Eq. 2 Logarithmic decrement

Usually are used samples stick shaped with a edge fixed and the other free.

The damping ratio is then found from the logarithmic decrement:

$$\zeta = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}}$$

Eq.3 Damping Ratio

An other way to valuate the damping proprieties of a material is to study his response in the frequencies domain.

So is possible to use the half-power bandwidth method. In this method, FRF amplitude of the system is obtained first. Corresponding to each natural frequency, there is a peak in FRF amplitude. 3 dB down from the peak there are two point corresponding to half power point.

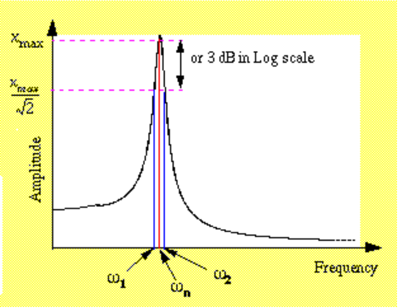

Fig 3 Half-power bandwidth method

The damping ratio can be valued by:

$$2\zeta = \frac{\omega_2 - \omega_1}{\omega_n}$$

Eq. 4

Finally is possible relate each natural frequency of the system with his intrinsic proprieties by:

$$v_{ij} = \frac{n(a/b, i, j.)}{2\pi a}\sqrt{\frac{Eh^3}{12\gamma(1-\upsilon^3)}}$$

Eq. 7

Where v_{ij} is the frequency of the modus (i,j), ***n(a,b,i,j)*** is a factor that depends by the ratio between the length ***a*** and the width ***b*** of the sample, the modus (i,j) and in the end by the configuration of sample (es. free, clamped) ***E*** is Young modules, ***h*** the thickness, γ the linear density and υ the Poisson modules.

1.2 Materials

In this work the effects of different kinds of carbon nanotube used as epoxy resin filler on damping proprieties have been considered.

In the experimental screening it has been verified that the dissipative behaviour of an epoxy-resin depends either on the *mass percentage* of dispersed nanotubes and on the *aspect ratio,* which is an intrinsic parameter of the selected nanofiller, being defined as the ratio between the length and the diameter of a nanotube.

Two different of epoxy resins systems are been investigated.

First Epon 862 with Epicure W as hardener and nanotube multiwalled and nanofiber.

An other system considered is a commercial system based on epoxy and a DDS (diammin difenil sulfone) with multiwalled nanotube with different aspect ratio.

Finally unidirectional carbon fiber coupons are been infused with epoxy-DDS resin system charged with low aspect ratio carbon nanotubes.

2 Experimental results

The first is an non toughened system based on a bisphenol F epoxy resin and ammine.

That system has a very low initial viscosity.

Filled with different percentage of nanotube and nanofibers a preliminary damping effect are been valuated.

As samples are quadrangular shaped the damping effects are been valuated clamping the sample by a side. Then by an accelerometer fixed on a side the logarithmic damping are measured.

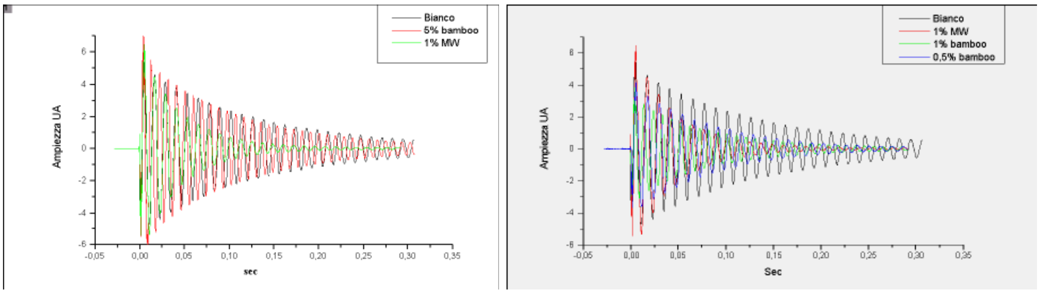

Fig.4 Damping measurement in time domain

Sample	Logarithmic decrement δ	Damping Ratio ζ
Pure Resin **Epon 862+ Epicure W**	0,091795	0,0023246
+ 0,5 % nanofiber	0.09260	0,0023451
+ 1% Multiwalled	0.24929	0.0063045
+ 5 % nanofiber	0.09322	0.0023607

Sample	Frequency 1° Mode	Damping Ratio ζ
Pure Resin **Epon 862+ Epicure W**	82,66	0,097266
+ 0,5 % nanofiber	81,25	0.089723
+ 1 % nanofiber	103.10	0.074975
+ 1% Multiwalled	84,29	0,145925
+ 5 % nanofiber	106.21	0,06431
+ 0,5 % nanofiber **tick 3mm**	180,37	

Tab.1-2 Results

The second matrix tested is a commercial epoxy resin system based that have DDS as hardner but without toughening agents. That kind of epoxy systems have a good resistance to high temperature and ah high elastic modules. Are wide used in aeronautic.

Unfortunately have also an high initial viscosity, so is necessary to heat to reduce it.

That matrix are been filled with nanotubes with to different aspect ratio; Nanocyl 7000 with aspect ratio about 150 and Iolitec with an aspect ratio of about 50.

Samples are length about 120 mm, width 30 mm and thick 3,5 mm.

The samples are clamped by an end and free in the other and stimulated by an hammer witch records the impulse with a load cell. The vibration are recorded by an accelerometer.

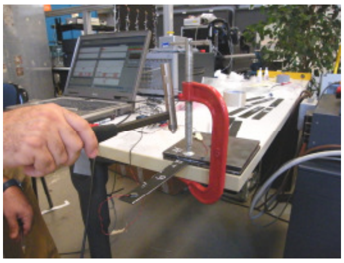

Fig 5 Hammer test

Coupons	Freq 1° Mode	Damping
Pure	51.0	1,28%
1%MW Nanocyl 7100	49,09	1,93%
3%MW Nanocyl 7100	104,4	1,8%
1%MW IoLiTec	54	2,19%

Tab.3 Results

Finally coupons of carbon fiber composites with nanocharged matrix are made rowing carbon fiber on a plate in one direction.

Then the plate is put inside an vacuum bag and infused with the resin charged with 0.5% low aspect ratio nanotubes.

After the cure cycle some coupons are cutted from the carbon fiber plate and test with hammer test.

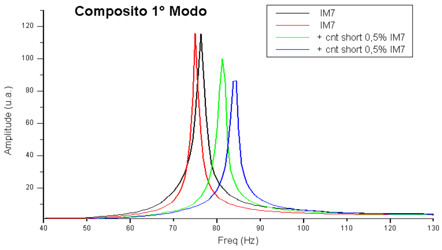

Fig. 6 Damping proprieties of composite samples

This research is carried out from the ARCA research program, founded by Italian Ministry of Education, University and Research (MIUR) (DM 24436)