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ASPECTS CONCERNING TO THE FREE VIBRATION OF THE RECTANGULAR PLATE MADE OF GLASS / RUBBER COMPOSITE MATERIAL

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ABSTRACT

In this work, it is shown the results concerning to the natural frequencies and damping coefficient obtained in case of a rectangular plate made of polymeric composite material reinforced both with glass woven fabric and recycled rubber. The first of all, the material structure is described (number of the reinforcement layers, the fiber volume fraction, the rubber content). Then, the Bruel & Kjaer equipment and the advanced method used for the determination of the natural frequencies are presented. The change of the damping coefficient with respect to the natural frequencies is graphically shown. This results was recorded during four tests.

Keywords: composite; moisture; absorption; tensile test.

1. INTRODUCTION

During the last years, the concerns of researchers from the field of the composite materials were focused on to develop new hybrid composite materials containing fillers in addition to clasical reinforcement materials (glass fibres, carbon fibres, nylon and so forth). The materials used as filler materials are often recyclable waste: wood flour, plastics, PET/HDPE [1], aluminum, paper, rubber from recycled worn tyres [3, 8] , CD/DVD disks [4] etc. Applications for these new hybrid materials require mechanical testing to determine the their mechanical characteristics.

For this purpose, the work presents experimental results concerning to the behaviour of a plate made of glass /rubber composite in case of the free vibration. The results are useful for panels made of such composite materials used for vibration damping. In fact, these results complement those concerning to the mechanical behaviour in bending, even after long time immersion in water[3].

In the following, the equipment used and the methodology of impact hammer testing will be presented. The main objectives of this research are: determination of natural frequencies and corresponding damping coefficients in case of a rectangular plate made of glass / rubber composite material.

2. MATERIALS. WORK METHOD

The first of all, a laminated composite plates having 3 mm in thickness, was manufactured by using the E-glass woven fabric to reinforce an epoxy resin mixed with recycled rubber. The hybrid composite material contains eight layers of E-glass woven fabric. The recycled rubber in form of particles whose dimensions are smaller than 500 μm, was obtained by recycling the wastes of automotive tyres. The weight ratio of the reinforcement materials (glass woven fabric and recycled rubber) was equal to 34%. To initiate and to accelerate the polymerisation process, a hardener agent was certainly mixed with the epoxy resin before of the admixture of the recycled rubber. According to the recommandations from the certificate of the epoxy resin used [5], the proportion between the two components was: 32 g hardener for 100 g resin.

A lower forming pressure was used to manufacture the plate by using hand lay-up technology.

The epoxy resin is widely used for manufacturing of the laminated composite materials by handing lay-up technology, injection with low pressure and filament wrapping. This kind of resin has a good behaviour for impregnation of timber.

Some physical and chemical characteristics of the epoxy resin in liquid state are: density - 1.15 g/cm^3 (25 ^oC); viscosity – 1550 $mPa\cdot s$ (25 ^{o}C); gel-time - 2.5 *hours* (at 23 ^{o}C, 100 g resin + 32 g hardener); manipulation time – 60 *minutes*; glass transition temperature T_g = 80 ^oC. The mechanical characteristics of the same resin without reinforcing are: tensile stress in tension $\sigma_t = 70\,MPa$; elongation in tensile test $\varepsilon = 5\%$; flexural stress $\sigma = 120\,MPa$; modulus of elasticity $E = 3100\,MPa$; impact strength $K = 40\,kJ/m^2$ - Charpy (unnotch specimen); toughness -83 Shore D15. Analysing its properties, one may remark that this resin has: lower viscosity, good mechanical properties. It has also a good behaviour in wet environment [5].

To experimentally analyse the free vibrations, the hybrid composite plate was cut so as its final dimensions were 440 x 240 mm^2. The mass of this plate was 0.488 kg. The testing method used consists in the hitting in the middle of the plate, with an impact hammer specially designed for soft structures. The replications to the vibrations of the rectangular plate was acquired by using of four accelerometers (Fig. 1) that record the signal on the transverse direction to the composite plate. These accelerometers were symmetrically located with respect to the middle of the plate where the impact hammer hits.

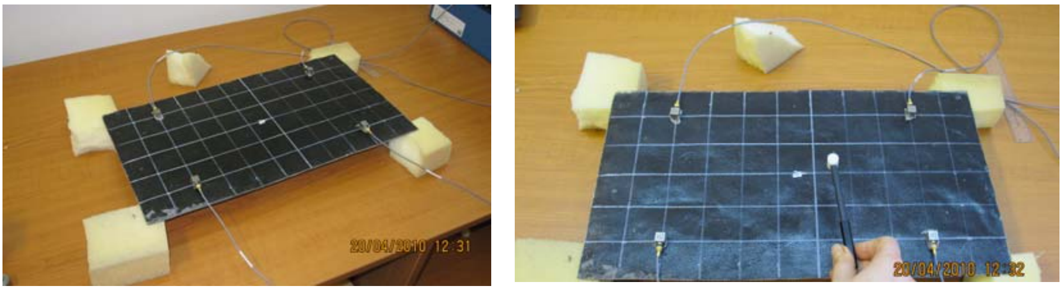

Figure 1. Analysis of the dynamical behaviour of the plate

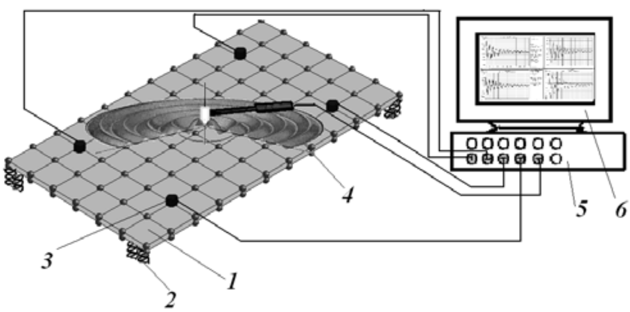

Figure 2. Scheme of the testing stand:
1– composite material plate analysed; 2 – elastic support; 3 - accelerometer,
4 - impact hammer; 5 - Pulse hardware; 6- Pulse software)

The experimental stand was built as it can be seen in Fig. 2. Each plate (1) was simply supported on a foam device (2) and hit with impact hammer type B & K 8204 (4) in central point of plate. The vibrations of plate were captured with four accelerometers type B&K 8320 (3) and transmitted to Pulse hardware and displayed with Pulse soft. It is assumed that the weight of the light accelerometers did not affect the values of natural frequencies extracted from experimental tests.

Herein, it is analysed the free vibration of the rectangular composite plate that was described above. In the literature [6, 7], different kind of supports were considered to simulate the free boundary conditions in case of the analysis of the vibration modes: sponge supports located at the corners of the plate or located along the edges; suspended plate; elastically support for entire surface of the plate etc. In this case, the first option was chosen, that was supporting on four pieces of sponge (Fig. 1).

A work program in Pulse soft was developed to capture and processing the experimental data. The captured signal was displayed with Pulse soft and the primary data were processed with ME'Scope VES 4.0 software. The connections of the testing stand has been configured, the types of measurements and implicit functions (Time, Fast Fourier Transform, Fourier Spectrum, Complex Time) were established. The results of measurement were displayed in a different task of soft and saved as files for proccesing with ME' Scope VES 4.0 soft.

The signals acquired by accelerometers were displayed on the monitor and then, applying the frequency response function, the values of the first natural frequencies and corresponding damping factor were obtained.

3. RESULTS AND DISCUSSIONS

Using Pulse system, the first results obtained refer to signals recorded by accelerometers as function of time like it is shown in the Fig. 3. It is already known that the dynamical behaviour of plates is governed by the damped harmonic motion [6, 7].

Applying FRF (Frequency Response Function) from Pulse program, it was obtained the values of first natural frequency in terms of Auto spectrum analysis as it can be seen in Fig. 4. In this chart of Amplitude versus frequency, the first picks represent the values of natural frequencies.

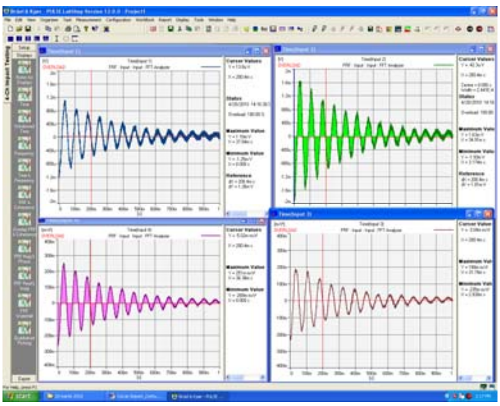

Figure 3. Acquisition of the output signals recorded by accelerometers

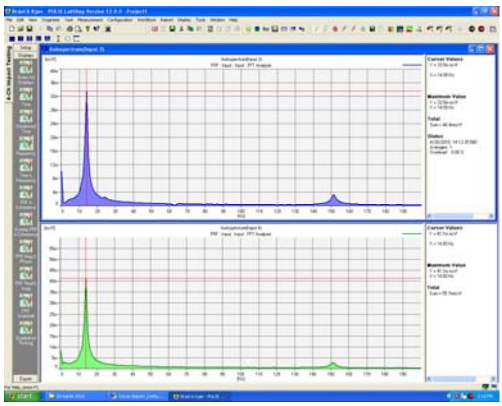

Figure 4. Auto spectrum analysis with Pulse program

Table 1 – Values recorded for frequencies and damping factors during tests

Test 1		Test 2		Test 3		Test 4	
Frequency [Hz]	Damping [%]	Frequency [Hz]	Damping [%]	Frequency [Hz]	Damping [%]	Frequency [Hz]	Damping [%]
15.3	3.47	15.4	3.45	15.6	3.23	15.3	3.49
28.6	2.52	57.8	1.41	32.5	1.22	61.9	0.555
66.2	0.589	66.7	0.424	42.4	0.312	149	0.801
266	0.463	84.5	0.271	68.2	0.306	266	0.548
-	-	266	0.442	266	0.462	752	0.000175
-	-	752	0.000666	-	-	-	-

The first value of the natural frequency recorded was equal to 15.544 Hz.

Then, appliyng the Fast Fourier Transform to the time signal exported from Pulse to ME' Scope soft, the values of natural frequencies and damping coefficient were obtained (Table 1).
Fig. 5 graphically shows the changing of the damping factor with respect to the natural frequencies in case of the rectangular plate made of hybrid composite material involved. It is noted that the results (Fig. 5) were from the processed signals recorded by the four accelerometers placed symmetrically with respect to the middle of the plate.

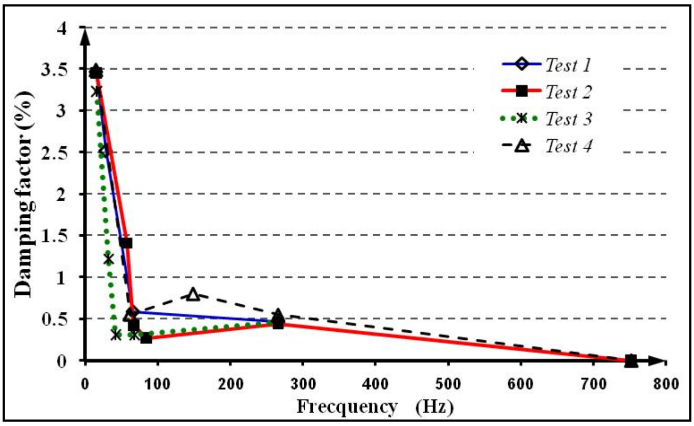

Figure 5. Damping factor versus frequency in case of the plate analysed

4. CONCLUSION

This experimental method represents a non-destructive way used to predict the dynamical behaviour of woven composite, in order to design panels or other similarly structure used in different applications such as automotive industry, soundproofing panels for highway, in concert halls architecture, sound insulation of buildings and so forth.
On the other hand, from ecological point of view, the using of the milled rubber obtained from shredded non-reusable tires represents a research subject of a great interest during the last years.

5. ACKNOWLEDGEMENT

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