DETERMINATION OF ABSORPTION COEFFICIENT OF FIBRE GLASS/EPOXI RESIN COMPOSITE MATERIALS THROUGH ULTRASONIC TECHNIQUES

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Abstract. Nowadays, the composite have numerous applications in different sectors. For these reasons, it's important to know the physical, mechanical/dynamical and acoustical properties of composites materials and in accordance with needs to improve some of properties. The paper presents the experimental results regarding sound absorption coefficient of fibre glass /epoxi resin composites, using ultrasound method based on elastic wave absorption in solid medium. The rectangular plane plates classified in 4 types in accordance with composites structures were tested. The tests revealed the anisotropic properties of composites and the capacity of plates to attenuate the high frequencies. The acoustic attenuation coefficient is influenced by thickness of plates and the pressure used to obtain the composite.

Keywords: woven composite, ultrasound, sound absorption coefficient, anisotropy

1. INTRODUCTION

One of the highlights of these technological advances is the ultrasound evaluation technique, an important tool with the potential to improve this material's quality and competitiveness [1].

The use of ultrasonic wave propagation as a nondestructive evaluation technique has proved to be a viable method to characterize wood. Research on ultrasound techniques has evidenced the efficacy of the method to determine the mechanical properties of wood (Bucur, 1984). Ultrasonic methods (NDT) in examining composite materials allows the highlighting of materials discontinuities and the determination of important properties such as elastically modulus, Poisson coefficient, hardness, acoustic attenuation coefficient and to obtain qualitative information about internal structure and porosity of the tested samples. The literature review presents numerous studies on determination of mechanical, thermal and acoustic properties through different methods [1,2,8]. This paper focuses on determination of sound

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absorption coefficient of composite made from fiberglass and epoxy resin using the method of absorbing elastic waves (ultrasound) in solid medium [3, 6, 7].

2. MATERIALS AND METHOD OF INVESTIGATION

The investigation method is based on determine absorption of elastic waves in solid medium [4,9]. Wave absorption represents the direct conversion of ultrasound wave energy in heat. The absorbed energy increases with increasing of ultrasonic wave frequencies. Due to attenuation, ultrasound pressure decreases with increasing the distance from sound source. If the change of pressure is noted with *dP* covering a distance *dx*, then:

$$dP = -\alpha P dx \tag{1}$$

the minus indicate the decreasing of sound pressure, α – attenuation constant.

Integrating relation (1) is obtained:

$$\int_{P_0}^{P} \frac{dP}{P} = -\alpha \int_{x_0}^{x} dx \quad \text{or} \quad \ln \frac{P}{P_0} = -\alpha(x - x_0)\,. \tag{2}$$

Noting with $d=x-x_0$, the distance of wave propagation, is obtained:

$$P = P_0 e^{-\alpha d} \tag{3}$$

The measurements of ultrasound pressure in two points separated by distance *d* allows the determination of values P1 and P2. Attenuation coefficient is measured in dB/m and is determinates with the relation:

$$\alpha = \frac{20 \log \dfrac{P_1}{P_2}}{d} [dB/m] \tag{4}$$

Depending on the values of attenuation coefficient, the materials are classified into:

a) materials with α low attenuation coefficient <10 [dB / m].
b) materials with attenuation coefficient range between 10 [dB/m] and 100 [dB/m]. For materials such as
c) materials with high values of attenuation coefficient over 100 [dB / m].

The experimental equipment consisted of a control ultrasound, oscilloscope, buffer rod for longitudinal and transversal waves, samples made from various materials, means of measurement of distance. The experimental set-up is shown in Figure 1.

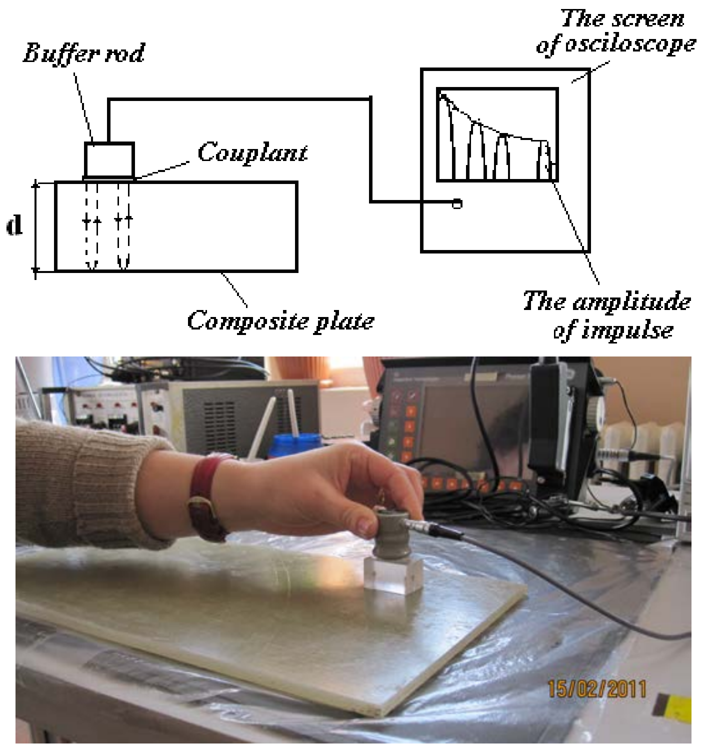

Fig.1. Experimental Set-up

The attenuation coefficient and ultrasound speeds were determined using pulse-echo method. The control equipment (Fig.1) which connects the buffer rod contains a cathode ray tube whose screen is observed, the applied voltage pulse encored and successive wave reflections on opposite sides of the parts tested. The experimental investigations were conducted in non-destructive testing laboratory of the National Institute for technical Physics of Iasi, coordinated by Prof. Dr. Raimond Grimberg.

The studied samples were rectangular plates made from fibre glass/epoxy resin composite with different structures (number of stratimat layers and fiberglass layers). For each structure, were carried out 15 samples and nondestructive test on acoustic attenuation properties wre performed on plates with good quality of surfaces. The buffer rod with longitudinal wave with frequency 4 MHz was coupled at the control device and was applied on the plate by means of ultrasonic coupling. Before tests, the weight and thickness of plates were determined (Table 2 and Figure 2).

Table 1. **The structure of composite plates**

Categories of plates	**Resin**	**Structure**	**Sizes Lxlxh**	**Type of pressure**
Composite 1 (15 samples)	unsaturated polyester resin based on dicycopentadiene and orthophthalic acid dissolved in styrene.	4 layers of stratimat (300 g/m^2) 3 layers of fibreglass	400x200x4	Normal pressure
Composite 2 (15 Samples)		5 layers of stratimat (300 g/m^2) 4 layers of fibreglass	400x200x6	Normal pressure
Composite 3 (15 Samples)		6 layers of stratimat (300 g/m^2) 4 layers of fibreglass	400x200x6	Low pressure
Composite 4 (15 Samples)		6 layers of stratimat (300 g/m^2) 4 layers of fibreglass	400x200x5	High pressure

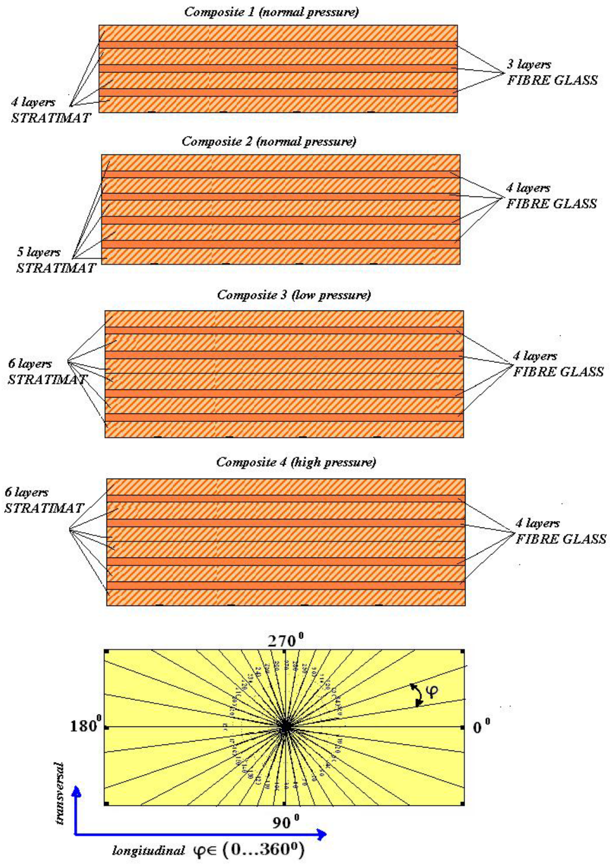

Fig.2. The structure of composite materials

Table 2. **The charactersitics of samples**

Code	Composite 1		Code	Composite 2		Code	Composite 3		Code	Composite 4	
	Weight w [kg]	Thikness d [mm]		Weight w [kg]	Thikness d [mm]		Weight w [kg]	Thikness d [mm]		Weight w [kg]	Thikness d [mm]
16	0.520	4	106	0.683	6	151	0.768	6.7	181	0.456	4.2
17	0.512	4	107	0.672	6	152	0.786	6.4	182	0.542	5
18	0.535	4.51	108	0.679	6	153	0.747	6	183	0.552	4.8
19	0.524	4	109	0.708	6	154	0.785	7	184	0.560	5
20	0.534	4	110	0.709	6.037	155	0.849	7	185	0.532	4.8
21	0.498	4.1	111	0.705	6	156	0.757	7	186	0.546	5
22	0.523	4	112	0.676	6	157	0.812	7.66	187	0.543	4.7
23	0.521	4	113	0.710	6	158	0.845	7	188	0.575	5
24	0.519	4	114	0.677	5.81	159	0.799	6.8	189	0.529	4.5
25	0.519	4	115	0.679	6	160	0.678	6	190	0.518	4.5
26	0.537	4	116	0.713	6	161	0.735	6.5	191	0.540	4.8
27	0.541	4.7	117	0.649	5.55	162	0.763	6.5	192	0.517	4.5
28	0.557	4.77	118	0.696	6	163	0.720	6	193	0.534	4.7
29	0.519	4	119	0.705	6	164	0.727	6.5	194	0.580	5
30	0.502	4	120	0.680	5.77	165	0.772	7	195	0.509	4

3. RESULTS AND DISCUSSION

For each studied plate were measured the amplitudes of two successive pulses and then applying equation (4), was determined the attenuation coefficient α. For each type of material were made five measurements, making then statistical processing. The results and final values obtained are presented in Table 3.

Table 3. **Experimental results**

Code of samples	Thickness d [mm]	Amplitudes				α1 [dB/mm]	α 2 [dB/mm]	α 3 [dB/mm]	α average [dB/mm]
		A0	A1	A2	A3				
110	6.037	682	594	552	512	0.198767	0.105507	0.10823	0.137501
114	5.81	488	362	180	100	0.44651	1.04453	0.878735	0.789925
120	5.77	678	398	300	120	0.801895	0.425518	1.379341	0.868918
117	5.55	470	380	206	142	0.332664	0.958257	0.582266	0.624396

Code of samples	Thickness d [mm]	Amplitudes				α1 [dB/mm]	α 2 [dB/mm]	α 3 [dB/mm]	α average [dB/mm]
		A0	A1	A2	A3				
157	6.71	1174	910	660	464	0.329737	0.41579	0.456113	0.400547
158	7.05	842	806	352	270	0.053836	1.020688	0.326749	0.467091
159	6.56	1266	666	446	342	0.850486	0.530913	0.351551	0.57765
164	6.01	934	858	638	368	0.122661	0.428175	0.795251	0.448696
28	4.77	702	342	290	282	1.30948	0.300327	0.050939	0.553582
27	4.7	544	438	350	242	0.400531	0.414494	0.681926	0.498984
21	4.1	626	402	372	296	0.938284	0.164308	0.484152	0.528915
18	4.51	1070	360	282	210	2.097921	0.470303	0.56776	1.045328
185	4.42	1010	812	410	342	0.428802	1.342861	0.35637	0.709344
187	4.6	1292	724	620	338	1.093582	0.292813	1.145543	0.843979
190	4.17	962	640	468	376	0.848897	0.651962	0.455914	0.652258
191	3.95	820	724	444	418	0.273799	1.075218	0.132692	0.493903

In Figure 3 are compared the attenuation coefficient for tested plates. Within the same types of material were obtained different results - with quite large variations of the attenuation coefficient, which indicates the anisotropic nature of the plates, even in the same conditions of manufacturing technology.

The most homogeneous plates in terms of attenuation coefficient values were recorded for composites type 3 and 4 (with 6 stratimat layers of 300 g/m2 and 4 layers of fiberglass, obtained by low pressure respectively high pressure).

Composites type 4 (obtained by high pressure) has a good behavior, being characterized by the higher attenuation coefficient. For the other types of composites 1 and 2, the values of attenuation coefficient indicate lower values as shown in Figure 3, but the differences between composites are not essential.

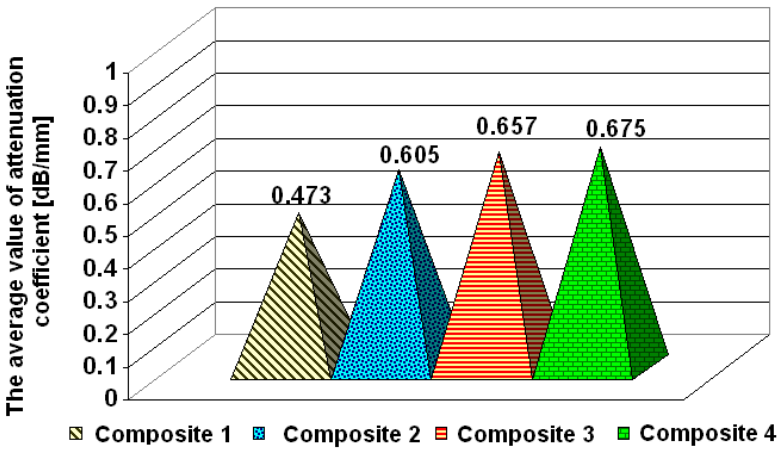

Fig.3. The variation of attenuation coefficient for each type of tested composite

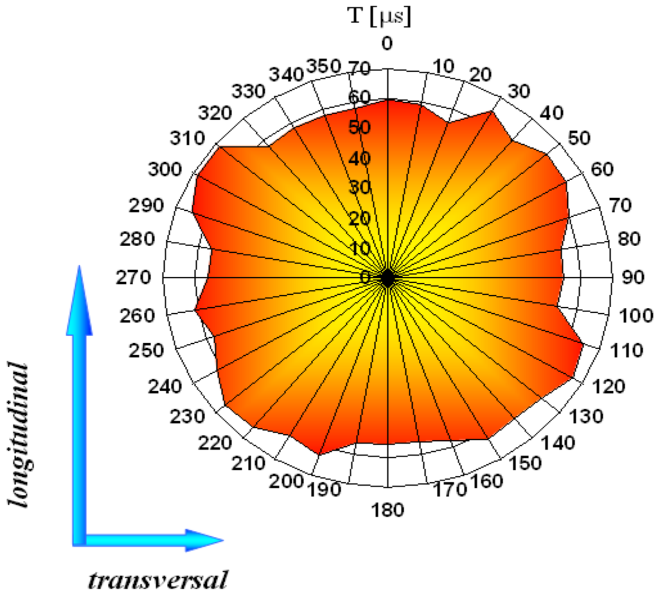

Fig.4. The variation of ultrasound time propagation

It is known that the anisotropic structure of the composite influence both the non-mechanical and mechanical properties. For this reason, an anisotropy test was done with ultrasound method too. It was measured the time of ultrasound propagation in different points fixed by polar coordinates (see Figure 2). Successive measurements were recorded in the five points on the plate, after which they were processed statistically and presented in the graph in Figure 4. Time wave propagation is expressed in microseconds.

5. CONCLUSIONS

The results of this study revealed that the composite structure, the thickness of plates and the manufacturing process directly influences the values of acoustic attenuation coefficient in terms of good properties of ultrasound attenuation. Also, the used method explores the anisotropy of plates without deterioration of structure.

6. ACKNOWLEDGEMENTS

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