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ULTRASOUND AND VISUAL EXAMINATION OF WOOD BASED PRODUCTS

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ABSTRACT

In this paper we present two methods for non-destructive examination of wood based panels namely: visual examination based on algorithms and procedures specified for image processing to determinate surface discontinuities and ultrasound method that allows the determination of physical and mechanical parameters of the product, as well the debonding of multi-layered wood based panels. To unify the results, a data fusion method is presented, too.

Keywords: Ultrasound examination, Visual examination, Wood based products

1. Introduction

Wood is a natural composite whit complex structure and diverse properties function of essence, water content and testing direction. It can be used as timber, panels and batten boards. The timber utilized in the furniture industry can be upgraded by sticking veneer foils of noble essence on the basic materials. In this case, the basic material can be board or agglomerated wood chips stuck together in plates, a multi-layers structure being obtained. For other applications, the foils can be from composite materials, usually glass-epoxy.
In the latest time big efforts have made for the introduction of European quality standards, developing of new nondestructive evaluation techniques and adequate instruments for the wood and wood based products examination by ultrasound [1], [2], [3], visual [4], X rays [5]. These techniques shall emphasize and measure wood density, the presence and the surface occupied by knots, wood defects like decay, insect damage, splits, cracks, etc.
In the case of nondestructive examination of wood composites multi-layers, the mean issue is the determination of the regions in which isn't bonding between layers due to deficiency of glue. In the case in which the composite is ennobled by veneer layers applying, besides adherence, the problem of veneer quality evaluation is posed. The using of clasical ultrasound methods in which transducer-examined product coupling is assured through a layer of fluid isn't applicable due to hygroscopic property of wood and veneer damaging. Using the hertzian transducer-examined product contact [3] even if the impress is very small, reduce the control speed, therefore such equipment can't be mounted on production line.
In this paper is presented a system for nondestructive evaluation of quality of gluing between the layers of plywood in 3 layers, using ultrasound non-contact transducers.

In the same time, to examine the state of veneer layer a visual examination method is used, employing images acquired and processed through typically image processing.

2. Physical principle of nondestructive examination method for multi-layer plywood ungluing using ultrasound non-contact transducer

Being a composite multi-layer plate that presents a ungluing between the layers. An ultrasound beam generated by a non-contact transducer perpendicularly on superior surface of plywood, is propagated through material and is received by the second transducer, identically with the first, placed face to face with the reception transducer, on the other side of plywood, Fig. 1.

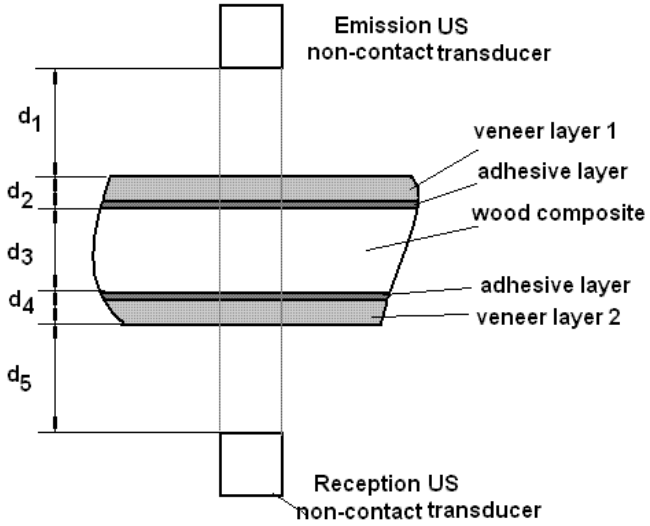

Fig. 1: Physical principle.

Usually, the thickness of the two veneer layers are identically, thus we can consider $d_2=d_4$. The thickness of adhesive layer is very small, and therefore, despite that the presence of adhesive influences the propagation, it wasn't considered in Fig. 1.
The time of flight, i.e. the time elapsed between the moment of emission and one of reception is given by the relation

$$t_t = \frac{d_1}{c_1} + \frac{d_2}{c_2} + \frac{d_3}{c_3} + \frac{d_2}{c_2} + \frac{d_5}{c_1} \tag{1}$$

where c_1 is the propagation speed of US in air at work temperature; c_2 is US propagation speed in veneer, c_3 is US propagation speed in wood material, d_1, ..., d_5 having the signification from Fig. 1.
The arrangement from Fig. 1 was preferred because if the distance between emission transducer and the reception one remains fixed, the vibration of the plywood didn't modify the distance traveled by ultrasound in air, then didn't influence the experimental results.
Considering the layered composite as a single material, for 100 KHz frequency of ultrasound beam, 4301±90m/s propagation speed was obtained. The wave length of ultrasound in composite will be approximate 4cm.
The presence of an ungluing in composite material is equivalent with the existence of a barrier in the way of US beam propagation, so that, on the barrier borders, the phenomenon of diffraction can appears [6], [7] (Fig. 2).

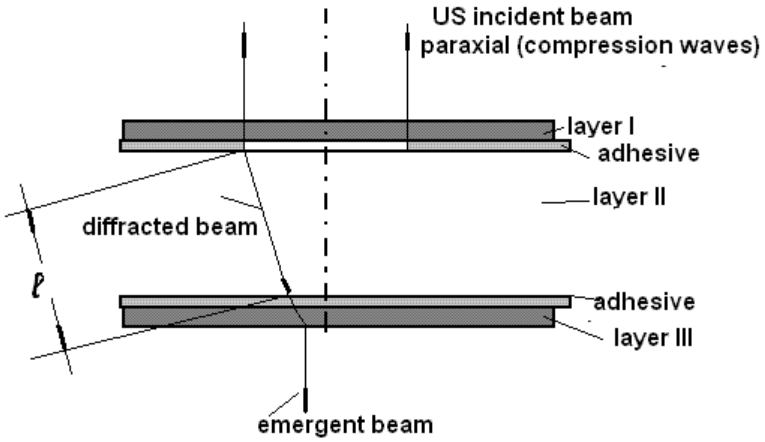

Fig. 2: US diffraction.

In the condition in which the adhesive layer is considered infinitely thin, the diffraction has take place on a barrier. For big angles of diffraction, function of elastic properties of the layers that the composite contain, a change into the propagation mode can take place; the compression waves could be transformed in shear waves (S wave). This phenomenon leads to an important attenuation of emergent ultrasound beam at the appearance of diffraction on a barrier.

Because the diffracted beam in layer II has lengthy bigger than d_3 ($\ell > d_3$) the total propagation time will increases.

Therefore, the measuring of the time of flight can serve as criteria for the determination of ungluing of multilayer wood composites.

To evaluate the states of veneer layers, the classical method of image processing is preferred. The composites are taken in picture with a video camera. The image is saved in *.BMP format, being presented as 3D matrix. This matrix can be decomposed in three 2D matrixes; each element of these matrixes contains information about the intensity of the three fundamental colors: red, green and blue (RGB). The red matrix contains the maximum of intensity about some possible defects that weren't emphasized at quality control operations of veneer and therefore, is the one with whom will work ahead.

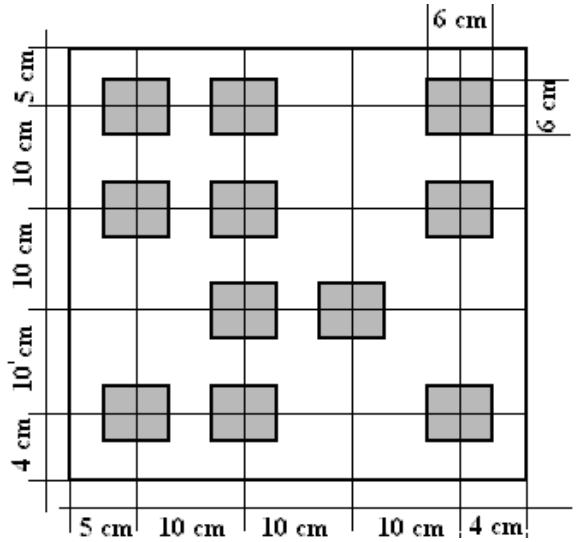

Fig. 3: Diagram of etalon.

3. The studied samples

The plywood consists in two layers 1mm thick beech veneer glued on two faces of a 2mm thick plate made of agglomerated poplar chips. Urelyte was used for gluing according to the usual procedure. The debonding was simulated by inserting rectangular frames made of 80μm thin Raylon foil, the frame thickness being 0.5mm and no adhesive being applied inside the frame.
The diagram of the etalon is presented in Fig. 3.
Also, plywood plates, which, after inspection with ultrasound using non-contact transducer, were destructive, controlled to confirm the justness of the method.

4. Experimental set-up

The principle scheme of measurement installation is presented in Fig. 4.

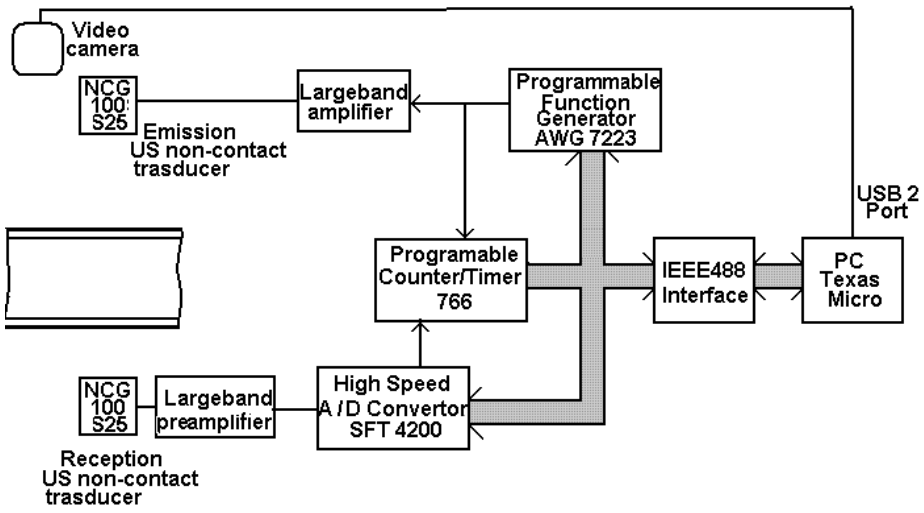

Fig. 4: Experimental set-up.

The emission and reception transducers are NCG100S25 type, produced by *ULTRAN GROUP* USA, having central frequency 100KHz, 25mm diameter of piezo-composite plate and 10mm air column. The emission signal, chirps with 100kHz central frequency, is delivered by programmable function generator AWG7223 and amplified until 200V amplitude, value recommended by the transducer's producer.
The US beam is received by the reception transducer, amplified in a large band preamplifier and digital converted in a high speed A/D Converter SFT 4200 type.
The time of flight represents the interval elapsed between first sinusoid from chirps of emission until the reception one. This interval is measured with Programmable Counter/Timer, the data being inserted into PC Texas Micro through IEEE488 interface. The image of veneer layer surface is taken with a digital video camera Surfcam CMOS 330K connected by USB 2 to the same computer the command of camera and the management of images are made with VideoCapturix software.
To global command of the equipment, a graphical user interface (GUI) developed in MATLAB 6.5 was used. In the same media, the functions for the acquisition of data, image processing and final classification has write.
The plywood has an advance longitudinal moving with 5cm/s and the US transducers scan the examined surface after a transversal direction with 2cm/s speed. The time of flight data were obtained from millimeter to millimeter.

5. Work method

To execute the measurements, a plywood plate that presents ungluing between layers and which was nondestructive examined with the procedure described in [3] is placed between the transducers. The average value of time of flight and dispersion of results are calculated into significant number of points.
According to 3σ rule (σ is the dispersion of time of flight data) [8], so long as the time of flight is in the interval

$$\bar{t} - 3\sigma \le t \le \bar{t} + 3\sigma \tag{2}$$

where $\bar{t} = \frac{\sum_{i=1}^{N} t_i}{N}$ represents the average time of flight for a sample without debonding and

$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (t_i - \bar{t})^2}{N(N-1)}}$ is the dispersion of data.

It can be considered that the multilayered wood composite plate has corresponding quality with 99.73% probability. If

$$t > \bar{t} + 3\sigma \tag{3}$$

Results that in the controlled zone exist a ungluing. If

$$t > \bar{t} - 3\sigma \tag{4}$$

results that in the basis layer of composite exists a fixed inclusion form a material of which propagation speed of compression waves is higher than this of wood, example being the metallic inclusion with an important surface.
For the veneer layers images processing we proceed hereby: the image is decomposed in the 3 matrixes on fundamental colors using ahead the red matrix. The region of interest (ROI) is delimited correlated with the displacing speed. It is searched that ROI shall be free of distortions, especially keg type. The ROI matrix is filtered by convolution with a Gaussian kernel and then the image is binarized with a adaptive threshold. To emphasize cracks of veneer layer the morphologic operators are used: dilatation and erosion.
Because the two morphologic operators are complementarily, the images of knots and/or cracks appear at 1:1 scale, therefore the dimensions result directly.
At the image of time off flight, the debonding zones appear larger that they are in reality with a scan step, therefore with 1mm.
In the basis of these observations, for the data fusions, the common referential has created.

6. Results

The time of flight measurements made on a region of composite having total thickness 4.5mm, without debonding (the adhesive layer after polymerizing having 0.25mm thickness) show that:

- the average time of flight $\bar{t} = 1.5\mu s$,
- the dispersion σ=0.12μs.

The time of flight measurements made on a region from the center of debonding zone show that:

- the average time of flight in the region with debonding $\overline{t} = 2.6\mu s$,
- the dispersion σ=0.16μs.

In Fig. 5 we present the image of the etalon presented in Fig. 3.

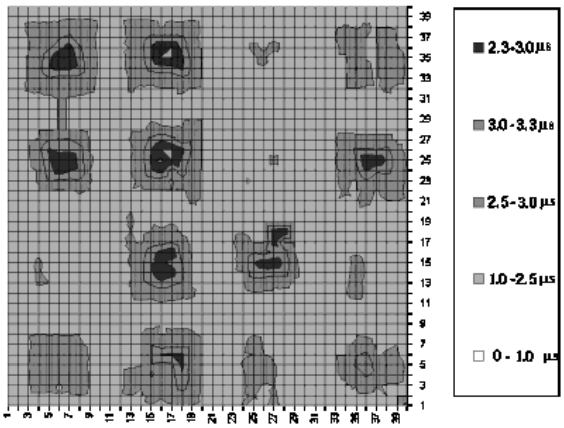

Fig. 5: The original image of time of flight.

To amplify the quality of the image, the filtering with Gaussian filter was applied, the results being presented in Fig. 6.

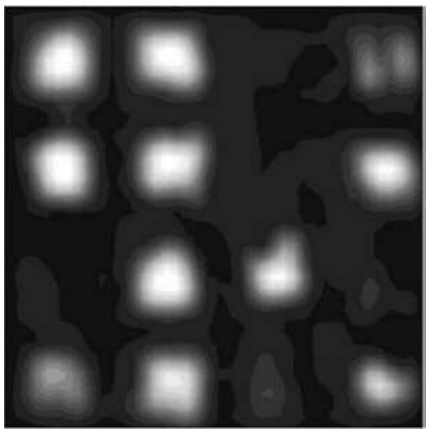

Fig. 6: Filtered image of the etalon.

To not complicate the images, another region of multilayered wood composite that present defects of veneer layer was selected. The image of a region that presents defects is presented in Fig. 7.

Fig. 7: The image of the plywood with defects.

After the application of the image processing algorithm described above, the region of interest is presented in Fig. 8.

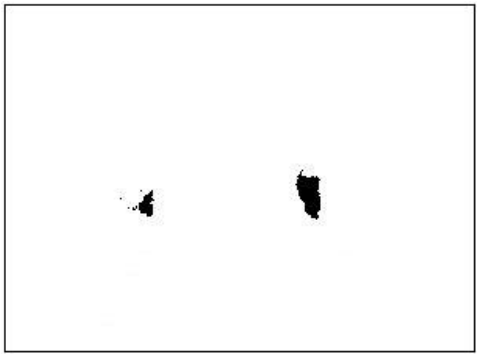

Fig. 8: The binarized image of the defects.

7. Conclusions

The multilayered wood based composite materials can be nondestructive evaluated using the method of ultrasound generated and received by non-contact transducers, this method characterizing exactly the regions with debonding between the plywood layers.
To evaluate the quality of veneer layer, the numerical algorithm of image processing was used, that allow the emphasizing of knots, cracks or incorrect joint of veneer.

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8. References

[1] Bucur V, Ansell MP, Barlow CY, Pritchard J, Garros S, Deglise X. 'Physical methods for characterising wood composite panel products.' Holzforschung, 52 no 5 (1998) 553-561.
[2] Sandoz J.L. Benoit Y., Demay L., Wood Testing using Acousto-Ultrasonic Technique, Proc. of the 12th Int.Symp. on Nondestructive Testing of Wood, Sopron, Hungary, 2000.
[3] Grimberg R., Savin A., Lupu A., Iancu L., Rotundu C., A Method to Determine the Debonding Zones in Multilayer Wood Materials, Proceedings of the 15th World Conference of Non-Destructive Testing, Roma, Italy, (2000), IDN 522.
[4] Grimberg R, Savin A., Andreescu A., Iancu L., Steigmann R, Nondestructive evaluation of timber, panels and batten board, The 1st INTERNATIONAL CONFERENCE ADVANCED CONCEPTS IN MECHANICAL ENGINEERING, Bul.Inst.Polit.Iasi, t. L(LIV), Fasc.6B, 2004, pg.147-152.
[5] Lindgren O., Medical CAT Scanning X ray absorption coefficient, Proc. of 8th Int.Symp. on Nondestructive Testing of Wood, Vancouver, 1997.
[6] Morse P.M., Feshbach H., Methods of Theoretical Physics, McGraw-Hill Ed., NY, 1953
[7] Schmerr Jr., Fundamentals of Ultrasonic Nondestructive Evaluation, ch.8, Plenum Press, NY, 1988.
[8] Bendat J.S., Piersol A.G., Random Data: Analysis & Measurement Procedures, John Willey &Sons Inc., NY, 1986.