

GLUED CONNECTION PROPERTIES AND EVALUATION ON ACOUSTICAL QUALITY OF MUSICAL INSTRUMENTS

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Abstract: This work deals with problems of gluing in production of stringed instruments. The focus of the work is in the evaluation of wood characteristics as a material for musical instruments production, falling in to the category of special artist wooden products. The influence of the glue on elasticity characteristics of wood is dealt as an essential component of musical instruments production. In the work is proposed the methodology for the analysis of the influence of different sorts of glue on elasticity characteristics of wood used in the industrial and master production of stringed musical instruments.

1 Introduction

The focus of the present contribution is the proposal evaluation properties of wood as a material for the manufacture of musical instruments, assigning the category of special artistic wood products. Discusses the impact of the glue as necessary components for the construction of musical instruments, the elasticity characteristics of wood.

The complete mastery of design and construction of wooden musical instruments include, among other assumptions, including perfect knowledge of the theory and practice, of course, gluing wood. In manufacturing and mass production of stringed instruments, as opposed to manual, master production in recent years begun to use and promote many types of synthetic adhesives, for reasons preparations simpler adhesive mixtures and related less time sensitivity of their applications. The setups are now used exclusively adhesives based on natural substances, which are hide glue.

The quality of the instrument is subject to the quality of the bond and its properties. Here is the place especially the mechanical properties of bond and the impact of using adhesive for elastic characteristics of wood [2].

2 Theoretical analysis

2.1 Adhesives used in the musical instruments making

Adhesives are a vital part of the construction of musical instruments. Using different types of adhesives is closely linked to production methods. In the event that it is a masterful hand manufacture, use old traditional techniques [4]. In the case of industrial, mass production technologies entering the synthetic adhesives, most polyvinylacetate (PVAC) adhesives and polyurethane adhesives (PUR).

Adhesives are non-metallic materials, plant and animal origin or synthetically prepared, have a high internal cohesion and adhesion to solid surfaces. Based on these properties are able to combine these solids [7].

2.1.1 Polyvinyl acetate adhesives

As the most solvent adhesives, either polyvinyl acetate homopolymer dispersions, based on actual polyvinyl acetate or copolymers, vinyl acetate copolymer-based, with most ester, are applied.

For assembly bonding wood polyvinyl acetate dispersion adhesives are suitable because they are non-flammable, resistant to microorganisms and create transparent colorless joints. Strength of glued joints and filling properties of these adhesives are similar to animal glues for joining, however, sufficient pressure is lower. Their negative sensitivity to exposure to water and weather effects, decrease the strength of the joint effects of increased temperature. As thermoplastics show a decrease in strength temperature (50 to 60)°C above the temperature of 130°C to decompose.

2.1.2 Polyurethane adhesives

A Polyurethane adhesives ranks polyadduct adhesives. They are produced in two versions: one-compound adhesives, two-component adhesives. The advantages polyurethane adhesives are: good adhesion to a wide range of materials, good mechanical strength of joints, flexibility, resistance to moisture and weathering, resistance to elevated temperatures, resistance to solvents, and simple processing technology with the possibility of curing a wide range of temperatures (0 to 160) ° C. Curing adhesives are non-toxic after the netting.

2.1.3 Hide glue

Most commonly used adhesives setups musical instruments are hide glues. These belong to the group glutin adhesives. Glutin adhesives are composed of substances arising from glutin and its hydrolytic decomposition. Glutin is insoluble in cold water only in it to swell. After swelling is soluble in hot water.

Warm solutions of hide glue are applied to the glued area with a brush. Open time service must be as short as possible. Glued components is necessary as soon as possible attached to him and pressed. Once the glued surfaces together a set loaded with pressure. The most commonly used pressure of 0.5 MPa. Time is pressing upon how quickly cures the adhesive joint. In practice, the elected time of pressing 2 to 6 hours.

2.2 Elasticity characteristics of wood

The results of long research work on Department of Physics, Electrotechnics and Applied Mechanics proved to be relevant for the evaluation of wood products specially designed for: density of wood, modulus of elasticity, sound velocity spread in the material, acoustic constant [3] [5]. The wood and materials based on its properties are dependent on moisture.

2.2.1 Density of wood

Wood Density ρ [kg.m⁻³] gives the mass per unit volume of wood in some moisture. Calculate the proportion of mass m_w [kg] and volume of timber V_w [m⁻³], the weight and volume of timber is at the same moisture content.

$$\rho_w = \frac{m_w}{V_w} \quad (1)$$

2.2.2 Modulus of elasticity of wood

Modulus of elasticity expresses the internal resistance of the material against deformation. The modulus of elasticity is greater, the greater the voltage needed to induce deformation. Since there are anisotropii wood modulus of elasticity E (Young's modulus of elasticity) in normal tension (tension, compression, bending in all anatomical directions) and modulus of elasticity G , the tangential stress (torsion, shear).

To determine the modulus E [GPa] dynamic resonance method using the relationship [3]

$$E = 4l^2 \cdot f_r \cdot \rho \quad (2)$$

kde: f_r – resonant frequency of the material [Hz]

l – sample length [m]

ρ - material density [$\text{kg}\cdot\text{m}^{-3}$]

For calculations using the elastic characteristics of the methods we use Chladni patterns 2nd mode (0.2) and 4th mode (2.0). The resonance frequency of the 4th mode for rectangular thin plates it is possible to calculate the modulus of elasticity modulus E_l and E_r of the resonance frequency of the 2nd mode by the relationship::

$$E_l = D_1 \cdot 12 \eta \quad (3)$$

$$E_r = D_3 \cdot 12 \eta \quad (4)$$

where $\eta = 1 - \mu_{xy} \mu_{yx}$ a $\mu_{xy} \mu_{yx}$ are Poisson numbers characterizing the relative transverse deformation [6], while the constants D_1 and D_3 is:

$$D_1 \approx 0,0789 \frac{f_4^2 \cdot \rho \cdot a^4}{h^2} \quad (5)$$

$$D_3 \approx 0,0789 \frac{f_2^2 \cdot \rho \cdot b^4}{h^2} \quad (6)$$

where f_2 and f_4 are inherent resonant frequency of the 2nd and 4th mode [6], h is the thickness, a is length (in the direction along the fibers), b is the dimension in radial direction, ρ is the density of wood.

3 Experimental methods

In assessing the quality of wood for musical instruments and musical instruments themselves the most appropriate are non-destructive experimental methods. These are based on surveys of elastic characteristics of wood in static or dynamic loads. The number of known methods are suitable for our purposes, and in particular the available modal analysis using Chladni's patterns and dynamic resonance method.

3.1 Modal analysis using Chladni’s patterns

Chladni’s patterns method, based on the selected resonant frequency modes, allows to calculate the value of survey characteristics (El, Er, A). The measuring apparatus is on illustration 1.

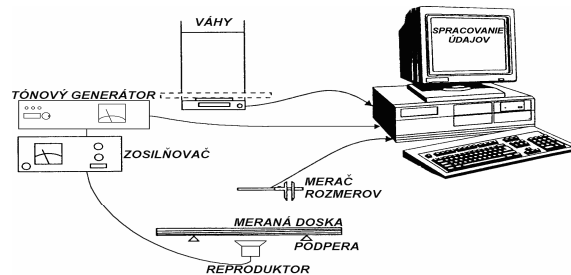


Figure 1. Apparatus used for modal analysis based on Chladni’s patterns.

3.2 Procedure of experiments

The proposed procedure of measurements, shape, size and number of measurements is stated in Table 1.

Table 1. Methods of measurement, the samples form, shape, size and number of samples

Method of measurement	Form of bodies (built wood/ glued wood)	Shape of experimental bodies	Dimensions of experimental bodies (mm)	Number of experimental bodies
Chladni’s patterns method	Built wood Wood JV	Rectangular plates	600 x 130 x 5	30
Chladni’s patterns method	Glued wood Wood JV	Rectangular plates	600 x 130 x 10	15

Procedure for investigation of elastic characteristics and the impact of these characteristics was carried out in several steps.

The first was the detection of elastic characteristics of the native maple wood used for the manufacture of stringed musical instruments. As the feedstock we used quarters sycamore naturally dried in housed stock 5 years. The quarters were made into timber radial with thickness 12 mm. Timber was re-stored for 2 more weeks because of the gradual release of moisture and tension in the wood. From such lumber we prepared through cutting on a band saw lumber with a thickness of 7 mm for test bodies shaped plate dimensions: length $l = 600$ mm, width $b = 130$ mm, thickness $h = 5 \text{ mm} \pm 0.1 \text{ mm}$. The dimensions were reached through format disc formatting, and equal thickness was reached through using of Wide leveling machines.

On these experimental bodies, using modal analysis based on Chladni’s patterns, resonant frequency of 4th mode was set and elastic characteristics were calculated.

The next step was gluing. The two, above described shapes of wood, were glued to reach a plate with dimensions length $l = 600$ mm, breadth $b = 130$ mm, thickness $h = 10 \text{ mm} \pm 0,2 \text{ mm}$. Tree types of adhesives were used: polyvinyl acetate adhesive (PVAC), polyurethane adhesive (PUR) and hide glue modified with powderized formaldehyde (GF).

On the glued plates the modal analysis was made and the elastic characteristics of the glued wood were measured.

Consequently, the methods of mathematical statistics were used to evaluate the experimental results of individual tests. Based on the comparison of sets of values elastic characteristics of the samples measured before and after bonding, the impact on the adhesive characteristics was assessed.

4 Results and discussion

Measurements of elastic characteristics were used to survey the impact of adhesive and adhesive bond to these characteristics. The most observed properties were density and elasticity modulus. Measured figures were subsequently subjected to statistical analysis using STATISTICA 7. Through this program Multi-factorial analysis of variance and Duncan test for statistical significance were performed and found to affect various adhesives density ρ and modulus of elasticity E_x .

4.1 Density of wood

Table Table 2 is given the average figures of density before and after bonding, standard deviations, numbers of samples and coefficient of variation.

Table 2. Table of basic statistical characteristics of the feature density ρ :

ρ	Adhesive	Sample	arithm. mean	Number of samples	Standard deviation	Coeff. of variation.
1	PUR	r	634,4	30	31,70	5,00
2	PUR	l	635,7	15	29,71	4,67
3	PVAC	r	575,4	30	31,77	5,52
4	PVAC	l	619,3	15	40,76	6,58
5	GF	r	616,8	30	34,59	5,61
6	GF	l	640,1	15	29,05	4,54

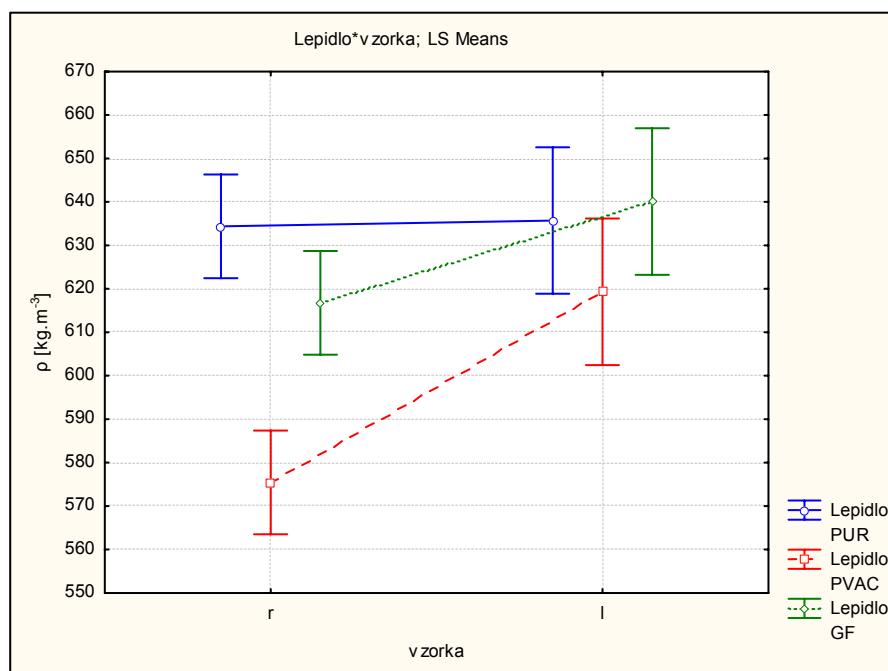


Figure 2. Impact of the adhesive on the density of wood

The tables Table 2 and Figure chart 2 point out that the slightest impact on the density has the PUR glue, then glue with formaldehyde addition and the greatest change in density caused the PVAC glue.

Table 3. Table of significance by Duncan test:

ρ	Adhesive	Sample	{1}	{2}	{3}	{4}	{5}	{6}
			634,38	635,71	575,44	619,33	616,78	640,09
1	PUR	R		0,8985	0,0000	0,1494	0,1115	0,6102
2	PUR	L	0,8985		0,0000	0,1392	0,0983	0,6750
3	PVAC	R	0,0000	0,0000		0,0000	0,0001	0,0000
4	PVAC	L	0,1494	0,1392	0,0000		0,8069	0,0687
5	GF	R	0,1115	0,0983	0,0001	0,8069		0,0448
6	GF	L	0,6102	0,6750	0,0000	0,0687	0,0448	

Table 3 shows the statistic significance of different density. On the grounds of Duncan test it can be stated that PUR adhesive does not have any statistically significant impact on density; adhesives PVAC and GF have statistically significant impact on density, although the figure is near the limits for statistic significance.

4.2 Elasticity modulus

In table 4 are given the average values of modul of elasticity before and after bonding, standard deviations, numbers of samples and coefficient of variation.

Table 4. Table of basic statistical characteristics of the feature

E	Adhesive	Sample	arithm. mean	Number of samples	Standard deviation	Coeff. of variation
1	PUR	r	12,0	30,0	1,37	11,4
2	PUR	l	11,7	15,0	0,79	6,7
3	PVAC	r	9,4	30,0	1,58	16,8
4	PVAC	l	9,9	15,0	1,49	15,0
5	GF	r	11,3	30,0	1,44	12,8
6	GF	l	12,0	15,0	1,01	8,4

The table Table 4, as well as the graph Figure 3 point out that the PUR adhesive reduce the figure of elasticity modulus by 0,3GPa, glue with formaldehyde powder addition increased E value by 0,7GPa, PVAC glue increased modulus value by 0,5GPa.

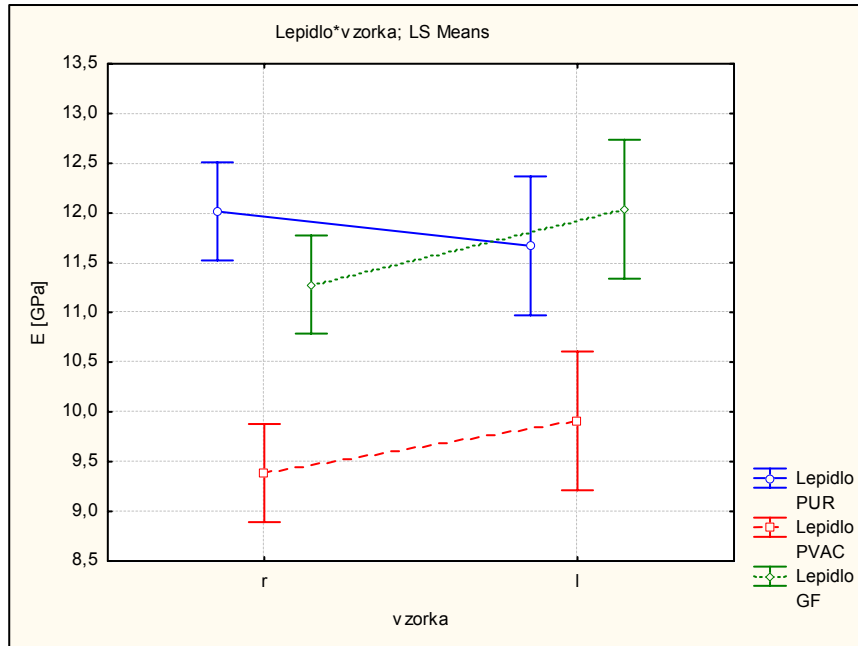


Figure 3. Impact of the adhesive on the elasticity modulus E

Table 5. Table of significance by Duncan test:

E	Adhesive	Sample	{1}	{2}	{3}	{4}	{5}	{6}
			12,016	11,67	9,3843	9,9097	11,281	12,038
1	PUR	R		0,423037	0,000004	0,000005	0,108512	0,959293
2	PUR	L	0,423037		0,000003	0,000078	0,368878	0,425936
3	PVAC	R	0,000004	0,000003		0,224123	0,000027	0,000004
4	PVAC	L	0,000005	0,000078	0,224123		0,001511	0,000006
5	GF	R	0,108512	0,368878	0,000027	0,001511		0,111009
6	GF	L	0,959293	0,425936	0,000004	0,000006	0,111009	

Although there were any changes in the figures of elasticity modulus, Duncan test (Table Table 5.) did not confirm statistically significant differences.

5 Conclusion

Based on changes in elastic characteristics can be concluded and recommend to use the individual adhesives for the construction of musical instruments. Since changes in the modulus values are not statistically significant, we have chosen the order of adhesives according to the changes in density figures. As most appropriate adhesive glue and, therefore, causing little change in the density is the PUR adhesive. Next in order is the GF glue and the biggest change and thus the least appropriate showed PVAC glue.

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