Effects of Furfurylation on Acoustic Vibration Performance of *Paulownia* Wood

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This study investigated the effects of furfurylation on the acoustic vibration performance of *Paulownia* wood on the basis of improving dimensional stability. *Paulownia* wood was chemically modified with 25%, 50%, and 75% furfuryl alcohol and different curing times (8 h, 12 h, and 15 h). The dimensional stability of *Paulownia* wood was significantly improved after furfuryl alcohol modification. As indicators of acoustic vibration efficiency, the acoustic impedance (ω,), attenuation coefficient (δ), and periodic energy loss (tanδ/E) parameters were improved. The vibration sound evaluation indicator E/G was also evaluated. The best treatment conditions were 25% furfuryl alcohol and an 8 h curing time. Under these process conditions, the acoustic impedance ω, attenuation coefficient δ, and periodic energy loss parameter tanδ/E of the *Paulownia* wood increased by 21.1%, 156%, and 157%, respectively, the E/G indicator increased by 38.8%, and the specific dynamic elastic modulus E/ρ and acoustic quality constant R decreased by 36% and 45%, respectively. The sound quality was reduced under other process conditions.

Keywords: Paulownia; *Furfuryl alcohol; Furfurylation; Acoustic vibration performance*

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INTRODUCTION

Because *Paulownia* wood has light color, straight texture, uniform material quality, consistent ring width, and good acoustic vibration performance, it is used as resonance material for the production of musical instruments (Cheng 1983; Chang *et al.* 2014). The use of wood as a resonance element in musical instruments is different from its use in other applications. Acoustic applications necessitate that the wood have no defects such as cracking, knots, or insect damage, but there are also specific requirements with respect to wood density, ring width, number of rings, and microscopic characteristics. Currently, the wood outturn ratio for the production of musical resonance boards is generally 10% to 20%, which also shows the strict requirements for the wood used for instrument resonance components (Liu *et al.* 2010). Given the current shortage of timber resources worldwide, wood suitable for the production of resonant components for musical instruments is even rarer, which not only affects the quality of musical instruments but also affects the sustainable development of the musical instrument industry. For this reason, making functional improvements in the starting wood to improve the acoustic performance, utilization rate, and added value of musical instruments is imperative.

A good instrument soundboard requires stable pronunciation, high vibration efficiency, and good sound, which requires that the material composing the soundboard must have good dimensional stability and acoustic vibration performance. It follows that modifying it involves two aspects (Zheng 2003). There are many ways to improve the

dimensional stability of wood, including increasing the amount of hydrophobic agent used; painting; resin impregnation; acid and alcohol impregnation; polyethylene glycol (PEG) impregnation; extraction of polar substances; heat treatment; acetylation treatment; isocyanate treatment; formaldehyde treatment, and so on (Yu *et al.* 2002; Liu and Meng 2003; Guo *et al.* 2016). Of these, only heat and acetylation treatments have been used successfully in large-scale commercial production. The ideal wood modification technology should be environmentally friendly, cost-effective, easy to perform, and it should significantly improve the function of the wood over a long period without decreasing the favorable characteristics of the wood itself.

Furfurylation is an environmentally friendly and cost-effective technology, and it has broad commercialization prospects. Furfuryl alcohol is prepared by catalytic hydrogenation of furfural gas or liquid phase, and furfural can be prepared from raw materials such as corncobs, cottonseed hulls, and bagasse, all of which are renewable resources. The life cycle evaluation test shows that wood modified by furfuryl alcohol is environmentally friendly with almost no toxic effect on humans or animals during either use or disposal (Li *et al.* 2015; Dong *et al.* 2016; Mantanis 2017)

Furfuryl alcohol resin can improve wood's dimensional stability and durability, and reduce equilibrium moisture content (Pu *et al.* 2014; Gao *et al.* 2017; Yao *et al.* 2017a,b). This study explored furfuryl alcohol resin for improving the dimensional stability and the effects on acoustic vibrations of *Paulownia* wood.

EXPERIMENTAL

Materials

A total of 45 beams of *Paulownia* wood were selected with specifications of length (*L*) × width (*R*) × thickness (*T*) = 250 mm × 32 mm × 10 mm. The specimens had no decay, knots, cracks, insects, or other defects. The wood beams were processed and stored in a chamber at a constant temperature of 20 °C and relative humidity of 65%. After a month, the moisture content was 12%. The length, width, and thickness were accurately measured at room temperature (20 °C and moisture content of 65%), and the air-dry density was calculated according to the GB/T 1933 (2009) standard.

Method

Modification process

The furfuryl alcohol solutions (25%, 50%, and 75%) were prepared with 1.5% maleic anhydride, 2% borax, and distilled water. Whole-cell infusion was used to impregnate the *Paulownia* wood by vacuum impregnation. After removing the specimens, the wood was wrapped in foil and cured at 103 °C for 8, 12, or 15 h. After curing, the foil was removed, and the specimens were slow-dried in an oven at 60 °C until they were completely dry. The dried specimens were placed in the chamber kept at a constant temperature of 20 °C and relative humidity 65% for a month, which was the same way the untreated materials were stored. The test groups are shown in Table 1.

Table 1. Test Groups

Piece Number	Curing Temperature (°C)	Curing Time (h)	Solution Concentration (%)	pH
1	103	15	25	3.15
2	103	15	50	4.06
3	103	15	75	4.36
4	103	12	25	3.15
5	103	12	50	4.06
6	103	12	75	4.36
7	103	8	25	3.15
8	103	8	50	4.06
9	103	8	75	4.36

Determination of wood acoustic properties

Based on the beam vibration theory, the acoustic vibration performance of wood was measured by fast Fourier transform spectrum analyzer (FFT) with free-free conditions at both ends (Miao *et al.* 2015). As shown in Fig. 1, at the specimen wave node, a stretch tripod was used to support the specimen at the horizontal level. The length of the support point from the end of the specimen was 0.224 times of the total length of the specimen. And the samples were in a free-free condition. A small hammer was used to knock one end or the center of the specimen and receiving devices were placed under the other end of the specimen. The receiving device (it is a microphone) passed the received signal through preamplifier and filter. Pre-reading values of resonant frequency were obtained by FFT analysis. Data signals were collected using the A/D converter. The discrete signal data sequences of vibration waveforms were then entered into the computer to be processed by special software developed by ourselves, which allowed the other acoustic vibration performance parameters to be obtained (Huang 2013). The rate of change of each vibration parameter before and after furfurylation was then calculated using Eq. 1.

$$Change\ rate\ (\%) = \left|\frac{Modified - Premodified\ acoustic\ parameter\ values}{Premodified\ acoustic\ parameter\ values}\right| \times 100 \quad (1)$$

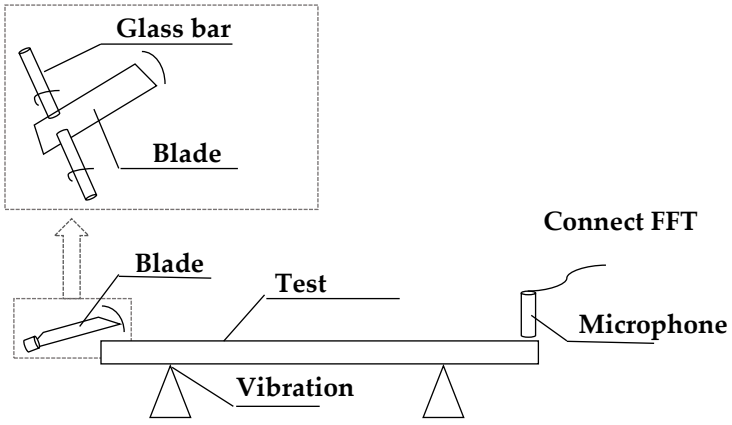


Fig. 1. The principle diagram of the materials used in the determination of resonant frequencies

Evaluating the performance of acoustic vibration

Generally, two factors are used to evaluate the performance of acoustic vibrations of an instrument's resonance board. First, the vibration efficiency measures the energy lost due to wood internal friction. Most of the energy is converted to acoustic energy, which is radiated into the air (Yano and Minato 1993). The physical parameters used to evaluate the quality of wood vibration efficiency include acoustic impedance ω, $tan\delta/E$, logarithmic decay rate δ, specific dynamic elastic modulus (E/ρ), and acoustic quality constant R. Different instruments have different requirements with respect to the loss coefficient. For the xylophone, the loss coefficient should be small. Violin soundboards require a loss coefficient in the middle and low range. For orchestral instruments, the loss coefficient should be high (Bremaue *et al.* 2010). The second factor is the acoustic vibration performance. The frequency response characteristics of soundboards should be distributed evenly and continuously in the music frequency range and have sensitive time response characteristics. The ratio of dynamic elastic modulus E to dynamic rigidity modulus G (E/G) is used to evaluate the vibration efficiency and integrated quality of the sound (Liu *et al.* 2006).

The acoustic impedance ω is mainly related to the time response characteristic of the vibration, and a small ω improves the response speed.

The attenuation coefficient δ and periodic energy loss parameter $tan\delta/E$ are important parameters for evaluating wood acoustic vibration efficiency.

Specific dynamic elastic modulus (E/ρ), representing the dynamic elastic modulus of cell wall other than cavity, was used to determine the magnitude of vibration acceleration.

A greater the acoustic radiation quality constant R resulted in a greater amount of sound energy radiated away and a higher conversion rate of energy.

The ratio of elastic modulus E to rigidity modulus G (E/G) can express the envelope characteristics of spectral characteristic curve, specifically, whether the tone frequency of the soundboard is distributed evenly and continuously and whether it has a sharp time response characteristic.

Dimensional stability measurement

The wood blocks of length (L) × width (R) × thickness (T) = 20 mm × 20 mm × 10 mm in the control and treatment groups were prepared according to the standard GB/T1934.2 (2009). There were five wood blocks in each treatment group, for a total of 50 wood blocks. The chordwise wet expansion rate a_R, radial wet expansion rate a_T, and volume wet expansion rate a_V, respectively, was measured according to Eq. 2,

$$a_R = \frac{l_R - l_{R0}}{l_{R0}} \times 100\% \quad (2)$$

where l_R is the chordwise length of the specimen after moisture absorption became stable after the sample had become completely dry, in mm; l_{R0} is the chordwise length of the specimen when completely dry, in mm. Radial wet expansion rate a_T was measured according to Eq. 3,

$$a_T = \frac{l_T - l_{T0}}{l_{T0}} \times 100\% \quad (3)$$

where l_T is the radial length of the specimen after moisture absorption became stable after the sample had become completely dry, in mm, and l_{T0} is the radial length of the specimen, in mm. Volume wet expansion rate a_V was measured according to Eq. 4,

$$a_V = \frac{l_v - l_{v0}}{l_{v0}} \times 100\% \quad (4)$$

where l_V is the volume of the specimen after moisture absorption became stable after the sample had become completely dry (mm^3), and l_{V0} is the volume of the specimen when completely dry (mm^3).

X-ray diffraction (XRD)

The XRD patterns of the samples before and after furfurylation were obtained using a D/MAX 2200 X-ray diffractometer (Rigaku Corporation, Sendagaya, Japan). Prior to the measurement, the sample was placed onto the supporter and compactly pressed. The XRD data were generated using a diffractometer with CuKα radiation (λ = 1.542 Å) at 40 kV and 30 mA over the angular range 2θ = 5° to 40°, and a step size of 5°·min^{-1}. The degree of crystallinity or crystallinity index (*CI*, %) for each sample was evaluated by Eq. 5,

$$C_I = \frac{I_{002} - I_{am}}{I_{am}} \times 100\% \quad (5)$$

where I_{002} is the maximum diffractive strength of the 002 crystalline plane and I_{am} is the diffractive strength of the non-crystalline plane.

Fourier transform infrared (FTIR) spectroscopy

FTIR measurements were performed using a Nicolet 6700 FTIR spectrometer (Thermo Fisher Scientific Co., Ltd., Waltham, MA, USA) in the range 3500 to 400 cm^{-1} with a scanning rate of 32 scans per min. The resolution for the spectra was 4 cm^{-1}.

Scanning electron microscopy (SEM)

The samples before and after furfurylation were analyzed with a QUANTA 200 electron microscope (FEI Company, Hillsboro, OR, USA) at the 500× and 1000× magnification. A radial-section with a thickness lower than 3 mm was selected for investigation. The samples were coated with platinum prior to the observation to improve the surface conductivity and observed at an acceleration voltage of 15 kV. The samples were mounted on the aluminum sample holder and placed in the specimen chamber in a vacuum condition of 0.06 mbar at room temperature.

RESULTS AND DISCUSSION

Effect of Furfurylation on the Dimensional Stability of Paulownia Wood

The chordwise, radial, and volume wet expansion rates of *Paulownia* wood decreased after furfurylation, which indicated that the dimensional stability of *Paulownia* wood had been improved (Table 2). This outcome was consistent with results from previous studies (Baysal *et al.* 2004; He *et al.* 2012a,b; Pu *et al.* 2014). The furfuryl alcohol resin modification technology reduced wood radial and chordwise wet expansion rates effectively, mainly because the furfuryl alcohol polymer filled in the cell cavity and cell walls of the wood, reducing the penetration of water vapor effectively. Nordstierna *et al.* (2008) studied nuclear magnetic resonance technology on the furfuryl alcohol oligomers and lignin models. They found that furfuryl alcohol resin developed a chemical bond with wood cell wall composition in the polymerization process and fixed the cell wall structures, thus enhancing the dimensional stability of the wood.

Table 2. The Dimension Value

Piece Number	α_R Average Value (%)	α_R Standard deviation	α_T Average Value (%)	α_T Standard deviation	α_V Average Value (%)	α_V Standard deviation
Control	4.4	0.02	0.05	0.01	6.7	0.03
1	3.6	0.013	0.02	0.007	6.1	0.026
2	2.5	0.012	0.01	0.006	4.2	0.023
3	2.1	0.011	0.014	0.006	3.7	0.014
4	3.7	0.014	0.01	0.006	5.9	0.025
5	2.7	0.012	0.015	0.006	4.1	0.023
6	2.3	0.011	0.009	0.005	3.6	0.013
7	3.2	0.013	0.03	0.008	5.8	0.025
8	2.9	0.012	0.02	0.007	3.9	0.017
9	2.5	0.012	0.012	0.006	3.5	0.013

Furfurylation and the Density of Paulownia Wood

As shown in Fig. 2(a), the density of *Paulownia* wood increased greatly after furfurylation. The increase in density was the largest, 157%, at a concentration of 75% and curing time 8 h. As shown in Figs. 2(b) and 2(c), the effect of curing time on the rate of change in density was not significant at a concentration of 50%. At a concentration of 25%, the rate of change in density decreased slightly as curing time increased. At the concentration of 75%, the rate of change in density first decreased, then increased as curing time increased. Furfuryl modification is a complex chemical process. The furfuryl alcohol liquid enters the interior of the wood through pressurized impregnation. Some of it enters cell cavity and act as a physical filling, and some of it reacts with wood components to increase rate of weight gain of the wood, which in turn leads to a change in density. If the concentration of furfuryl alcohol is different, the length of curing time after impregnation is also different, as is the quantity of volatiles, the amount of furfuryl alcohol remaining in the wood, and the degree of interaction with the wood. This explains the relationship between the rate of change in density and concentration, curing time, and other factors.

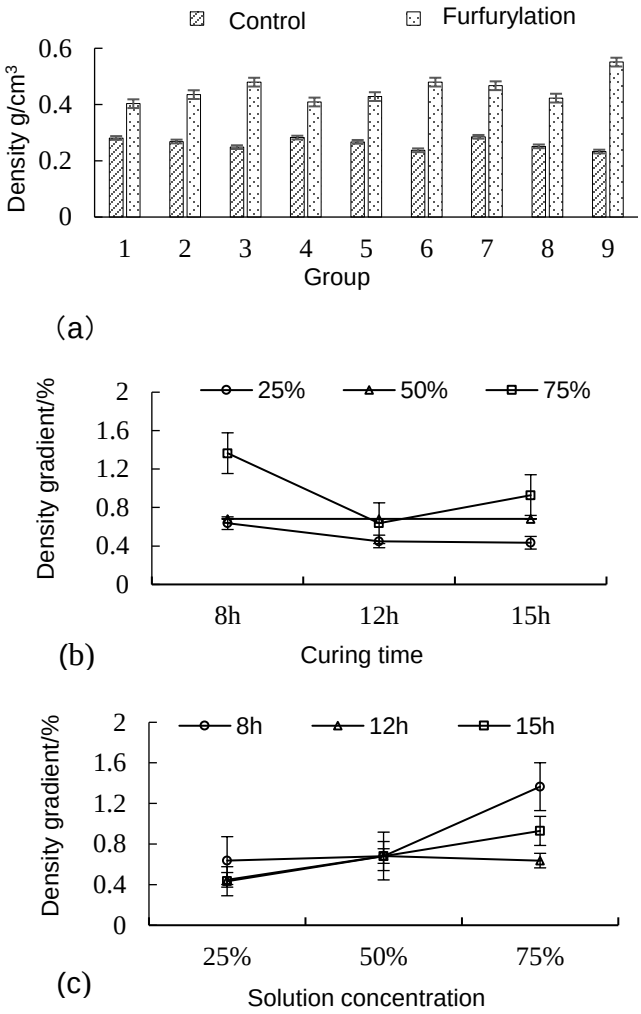


Fig. 2. Density variation

Effect of Furfurylation on the Acoustic Vibration Parameters of Paulownia Wood

The acoustic impedance ω is mainly related to the time response characteristic of the vibration, and a small ω improves the response speed. As shown in Fig. 3, *Paulownia* wood subjected to furfuryl modification had a reduced acoustic impedance ω and rates of change ranging from 19% to 36%. A higher concentration of the modifier resulted in a greater the rate of change. At a concentration of 75% and curing time of 8 h, the rate of change in acoustic impedance was the greatest at 36%. Therefore, furfurylation improved the response speed of *Paulownia* wood, and the higher the concentration of modifier, the more pronounced this increase was.

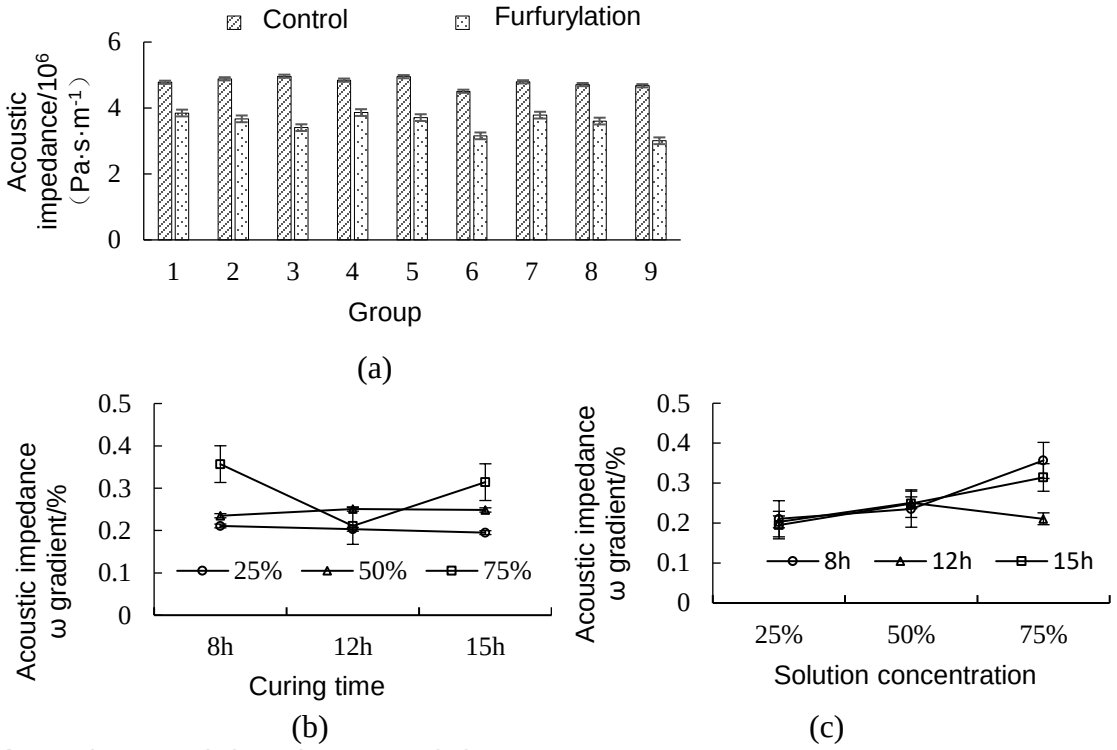


Fig. 3. The acoustic impedance *ω* variation

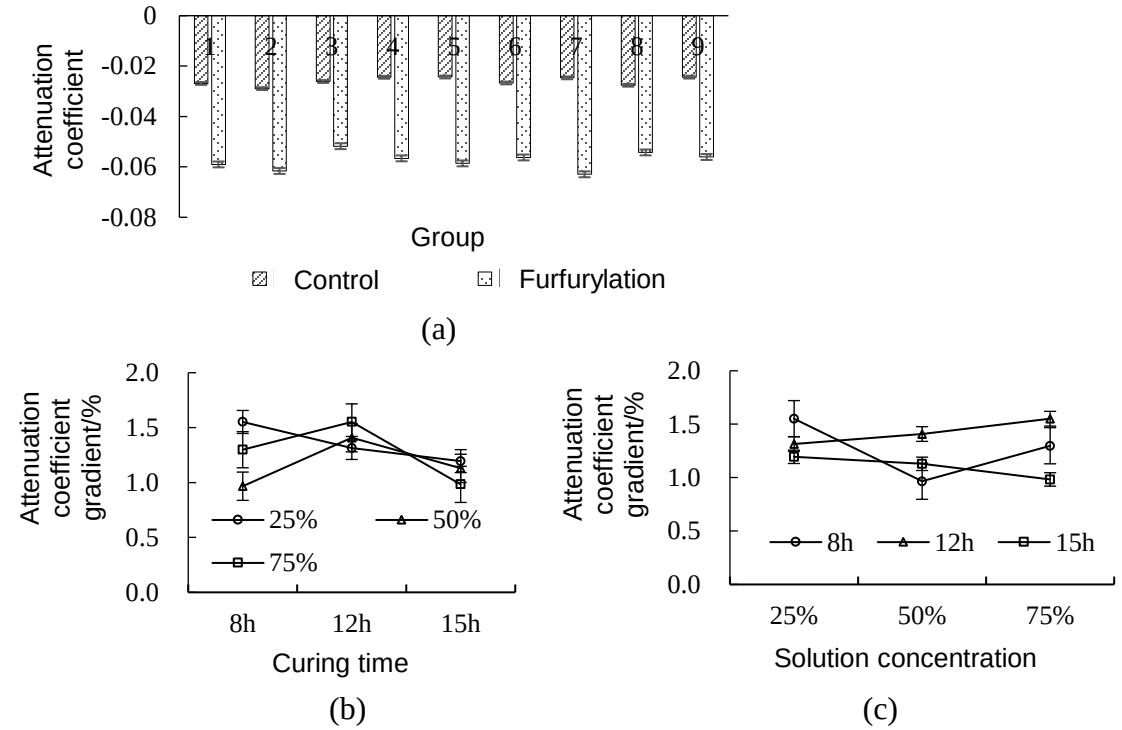


Fig. 4. The attenuation coefficient δ variation

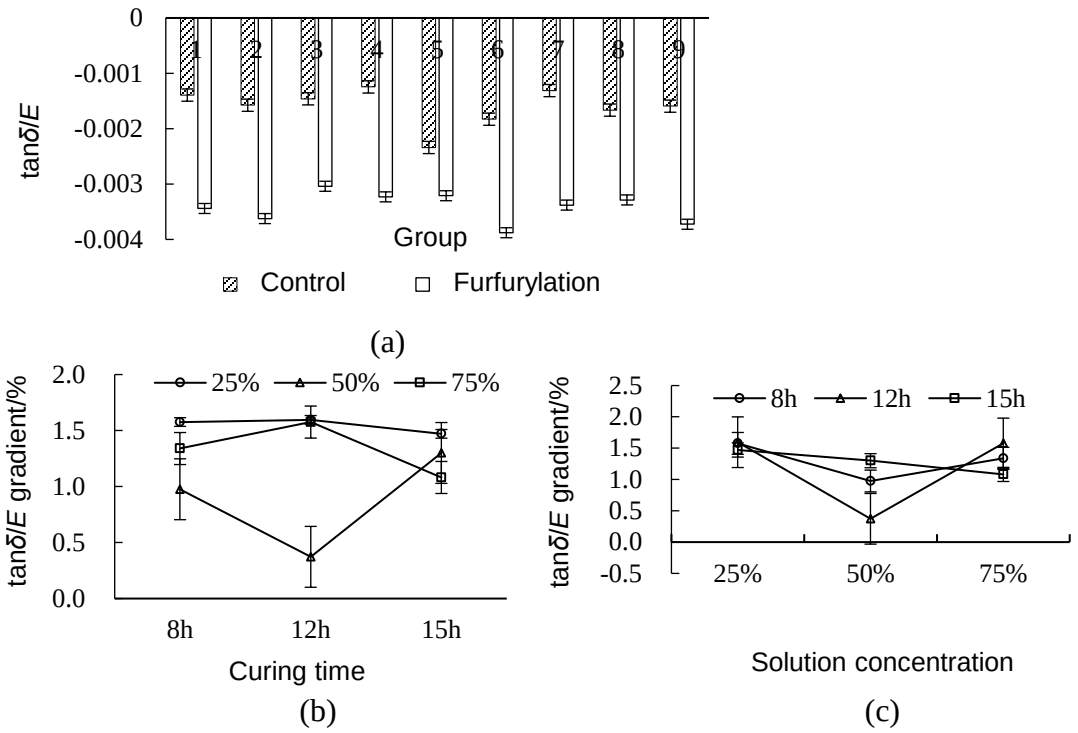
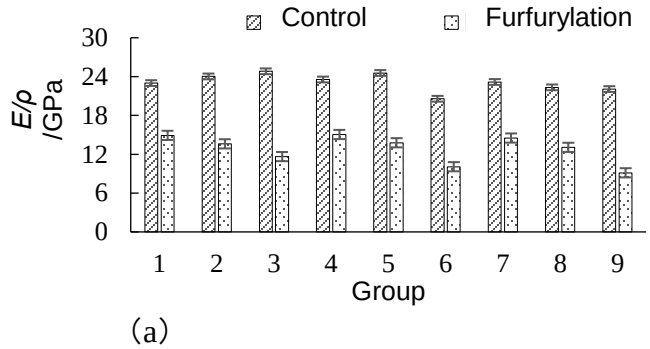


Fig. 5. The *tanδ/E* variation

When less energy is consumed by factors such as internal friction, more remains for acoustic radiation, and there is higher energy conversion efficiency of acoustic vibration. The attenuation coefficient δ and periodic energy loss parameter *tanδ/E* are important parameters for evaluating wood acoustic vibration efficiency.

Compared with the rates of change of attenuation coefficient δ and periodic energy loss parameter *tanδ/E* after furfurylated modification in Figs. 4 and 5, the furfurylation can significantly improve the acoustic energy conversion rate of *Paulownia* wood. When the concentration was 25% and curing time was 8 h, the rate of improvement was the most significant, and the rate of change was 156% and 157%. This was likely because, at low concentrations, when furfuryl alcohol resin is crosslinked with the wood, the three-dimensional network structure reduces the displacement between wood molecules, and decreases intermolecular and interfacial frictions, thereby reducing the amount of heat consumed by internal friction (He 2012; Dong *et al.* 2016).



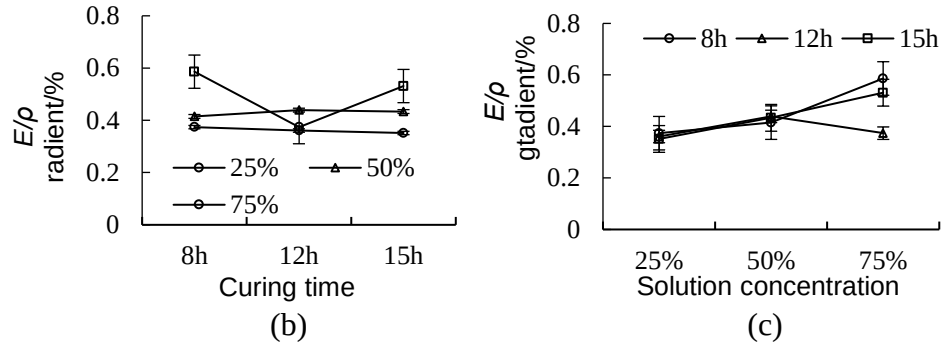


Fig. 6. Specific dynamic elastic modulus *E/ρ* variation

Specific dynamic elastic modulus (*E/ρ*), representing the dynamic elastic modulus of cell wall other than cavity, was used to determine the magnitude of vibration acceleration. A greater specific dynamic elastic modulus (*E/ρ*) value corresponds with a greater vibration acceleration, resulting in a higher vibration efficiency. As shown in Fig. 6, the specific dynamic elastic modulus of *Paulownia* wood was reduced greatly after furfurylation, and higher concentrations of furfuryl alcohol resulted in a greater reduction in the specific dynamic elastic modulus. At a concentration of 75% and curing time of 8 h, the rate of change was highest, at 58%. When the concentration was 25%, the specific dynamic elastic modulus decreased to a minimum of 36%. This result indicated a negative effect on the acoustic modification of *Paulownia* wood.

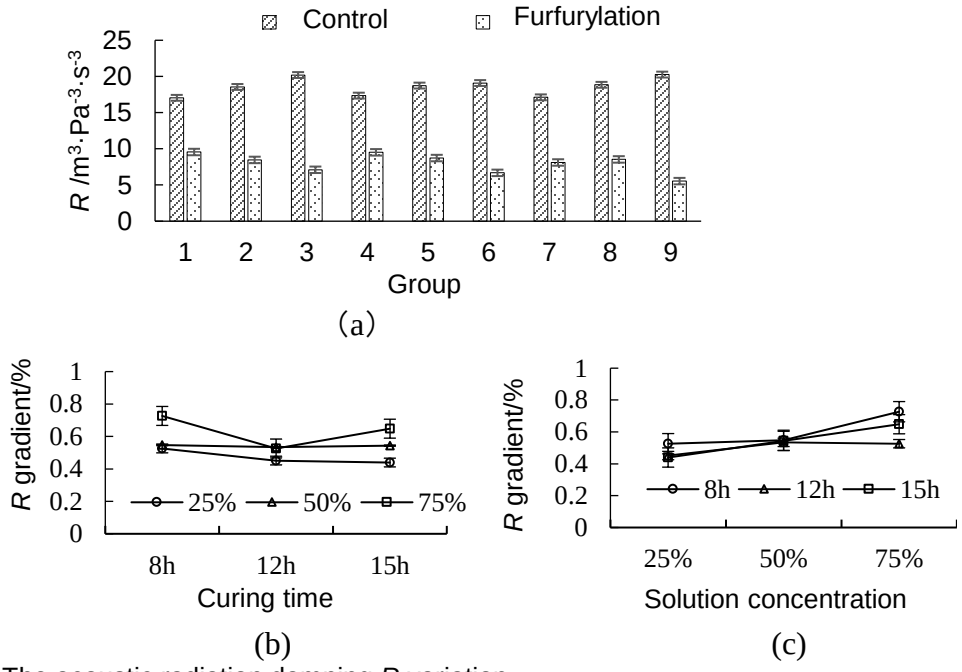


Fig. 7. The acoustic radiation damping *R* variation

A greater acoustic radiation quality constant *R* resulted in a greater amount of sound energy that radiated away and a higher conversion rate of energy. As shown in Fig. 7, the acoustic quality constant *R* of *Paulownia* wood drastically decreased after furfurylation. A higher concentration produced a greater rate of change. When the concentration was 75% and curing time was 8 h, the acoustic quality constant *R* was decreased by 73%. When the

concentration was 25% and curing time was 15 h, the reduction rate was 44%. Figures 6 and 7 show that changes in these two kinds of parameters had similar results, and the factors that caused changes in these two parameters were the same, mainly because as the concentration of furfuryl alcohol increased, *WPG* and wood density also increased, which led to decreases in density-related parameter values. The amount of incoming energy converted to acoustic energy and sound pressure are reduced. This may be due to the small molecular weight of furfuryl alcohol, which allowed it to enter into the cell cavities through cell walls or to react with lignin (He 2012), increasing the density of the wood. Furfuryl alcohol solutions are generally acidic, and high-temperature curing causes the cellulose and hemicellulose to become partially degraded within the wood so that specific dynamic elastic modulus of cell wall decreases, and the higher the concentration of furfuryl alcohol, the greater the reduction.

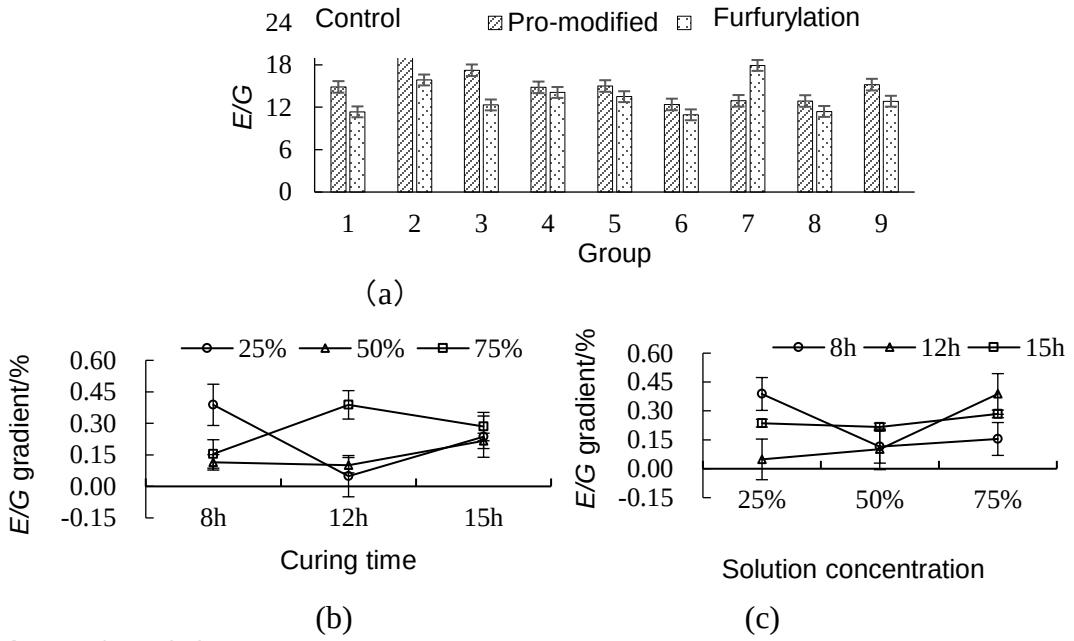
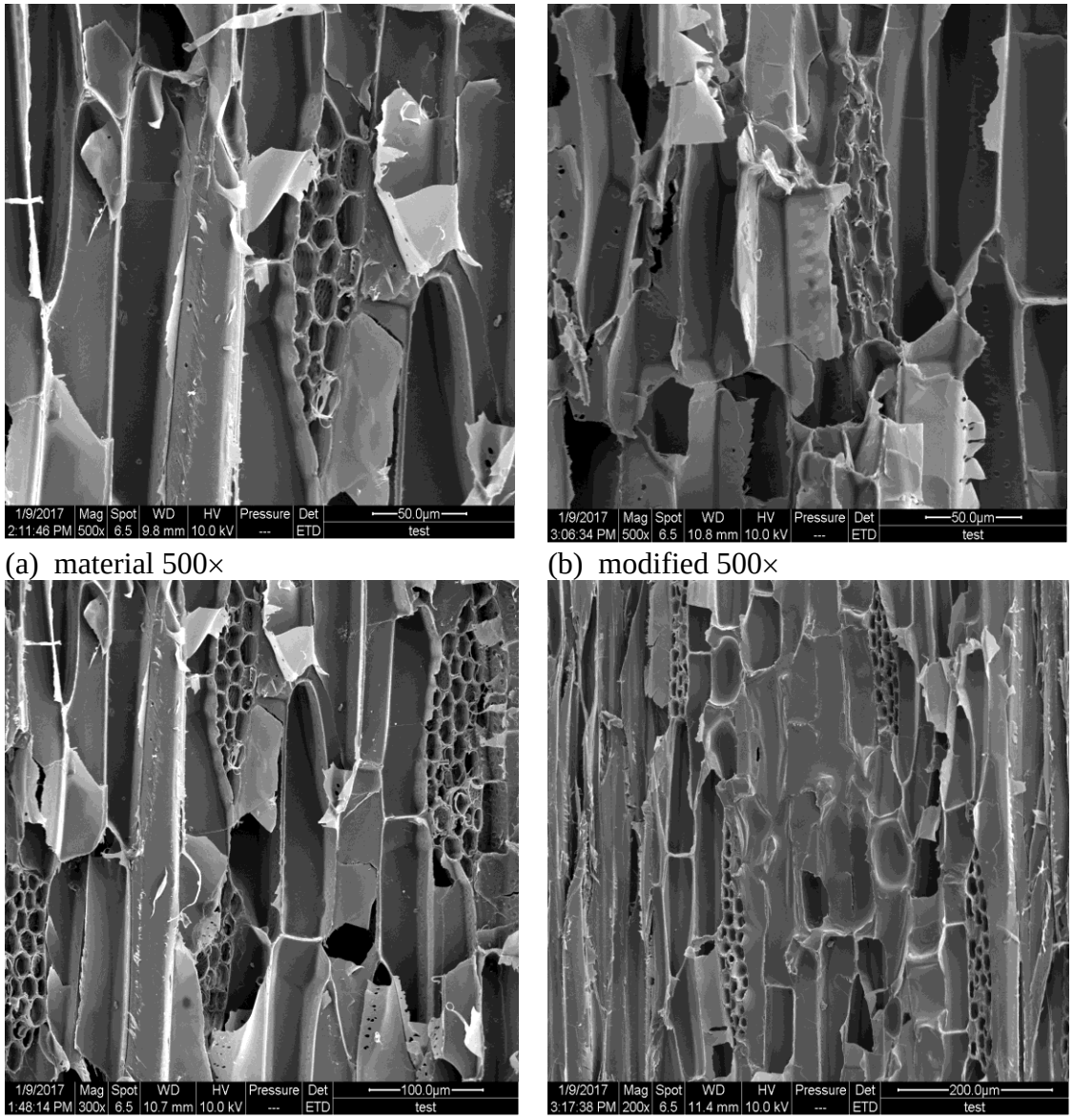


Fig. 8. *E/G* variation

The ratio of elastic modulus *E* to rigidity modulus *G* (*E/G*) can express the envelope characteristics of spectral characteristic curve, specifically, whether the tone frequency of the soundboard is distributed evenly and continuously and whether it has a sharp time response characteristic. A large *E/G* value indicates that the spectrum is distributed very evenly across the entire frequency domain and can evenly enhance and radiate out the vibration energy, which means that the sound is better. Comparison of the *E/G* before and after the furfurylation showed that the *E/G* value had no obvious change (Fig. 8). Only when the concentration of furfuryl alcohol was 25% and curing time was 8 h did the *E/G* value increase, and the rate of change was 39%. Under the other process conditions, *E/G* values were all reduced. This showed that furfurylation at the concentration of 25% and curing time of 8 h can significantly improve the sound quality of *Paulownia* wood. This showed that the treatment has a positive effect on the change in *Paulownia* acoustics.



(a) material 500× (b) modified 500×

(c) material 500× (d) modified 500×

Fig. 9. Scanning electron microscopy of furfurylated wood cells

Effect of Furfurylation on the Surface Morphology of Paulownia Wood

Figure 9 shows surface SEM images of *Paulownia* wood before and after furfurylation. By comparison, the furfuryl alcohol poly mainly penetrated wood cell cavities and gaps, which indicated that the furfuryl alcohol poly was impregnated into the wood. The furfurylated *Paulownia* wood ray cells were mostly blocked by the furfuryl alcohol polymer filled inside the wood. This is because the wood modifiers are polymerized inside the wood. This filling reduced the wood's water absorption and swelling properties. Because the wood modifier becomes viscous after drying, filling in the wood's internal structure and undergoing cross-linking reactions with internal groups within the wood, dimensional stability of the wood is thereby enhanced.

Furfuryl alcohol has an inflation effect on the cell wall and a filling effect on cell cavities, both of which reduce the cushioning effect of wood porous material to impact

energy. Thus, the impact toughness of furfurylation materials should decline (Xu 2012; Bastani *et al.* 2015). In addition, the furfuryl alcohol molecules are cured in cell walls to form a resin, which may have a strengthening effect on the cell wall matrix. However, according to Buchelt *et al.* who analyzed the microstructure of modified materials, this strengthening effect may affect MOE, which may decrease the specific dynamic elastic modulus and acoustic quality constant (Buchelt *et al*. 2014).

Effect of Furfurylationon the Crystallinity of Paulownia Wood

Furfurylation had an obvious effect on the crystallinity of *Paulownia* wood, as shown in Figs. 10 and 11. The crystallinity of *Paulownia* wood material was 57.9%. *Paulownia* wood specimens No. 1, 4, and 7 were modified by 25% of furfuryl alcohol, after which their crystallinities increased by 59.9%, 58.5%, and 59%, respectively. *Paulownia* wood specimens No. 2, 3, 5, 6, 8, and 9 were modified by 50% and 75% furfuryl alcohol, and their crystallinities were reduced. The results showed that for the same curing time, a greater concentration of furfuryl alcohol produced a smaller change in the crystallinity of *Paulownia* wood. At the same concentration, the rate of change in crystallinity did not remain constant over curing time. When the furfuryl alcohol concentration was 25% and 75%, the rate of change in the crystallinity of *Paulownia* wood first decreased then increased as curing time continued.

Furfuryl alcohol resin modifying agent is an amorphous material. In the process of drying curing, low concentrations of furfuryl alcohol resin poly occurred itself crosslinking reaction and chemical reactions with wood in the amorphous region that results in expansion of the amorphous area. The expansion of the amorphous area led to a slight decreasing of the crystallinity, but the hemicellulose hydrolysis led to a significant increasing of crystallinity. As a whole the crystallinity increased to a certain degree. In term of higher concentrations of 50% and 75%, more expansion of the amorphous area lead to decreasing significantly of the crystallinity, but the hemicellulose hydrolysis was less due to higher pH, leading to a slight increasing of crystallinity. As a whole the crystallinity decreased to a certain degree.

Appropriate increases in the relative crystallinity of wood are conducive to enhancing the efficiency of its acoustic vibrations and improving its sound. These results show that the acoustic vibration characteristics of *Paulownia* wood improve at a furfuryl alcohol resin concentration of 25% and curing time of 8 h.

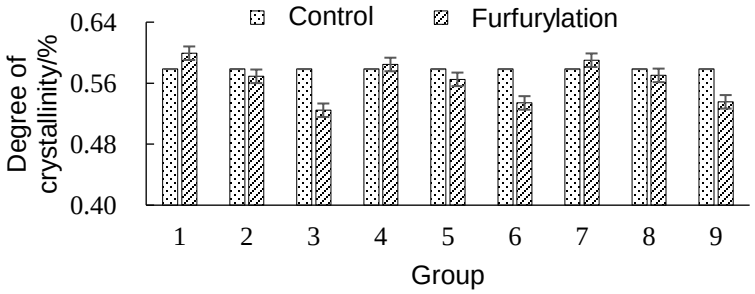


Fig. 10. The degree of crystallinity values

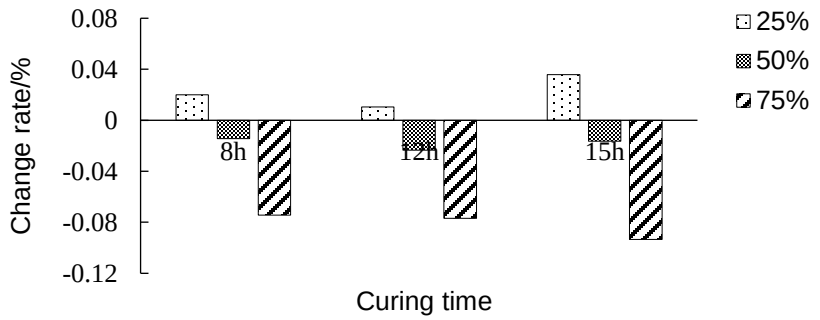


Fig. 11. The change rate of degree of crystallinity after furfurylation

Effect of Furfurylationon the Infrared Spectra of Paulownia Wood

As shown in Fig. 12, the infrared spectrum of *Paulownia* wood specimens treated with different impregnation processes had a shape slightly different from that of untreated material. Only near characteristic peaks of 3400, 1227, 1059, and 1030 cm^{-1} did some subtle changes in the absorption intensity occur. The absorption peak of 3400 cm^{-1} is related to stretching vibration of hydroxyl-OH. As the concentration of furfuryl alcohol resin increased, the intensity of this absorption peak decreased to some extent. This may be because furfuryl alcohol is a small molecule that can access wood cells easily. The furfuryl alcohol itself can be cross-linked to fill in the non-crystalline region of cellulose, reducing free hydroxyl groups to undergo chemical reactions. It can also react with free hydroxyl groups, decreasing the free hydroxyl content. The higher the concentration, the more intense the reaction, so the dimensional stability of the wood is enhanced and so helps improve pronunciation stability of the specimens. The absorption peak near 1736 cm^{-1} is related to stretching vibration of carbonyl (C = O) on the carboxyl group, which is the characteristic absorption peak of hemicellulose.

As the concentration and curing time of furfuryl alcohol resin increases, the absorption of this absorption peak decreases, indicating that the content of C = O decreased. This is likely because of the acetylation of polysaccharide chain in the hemicellulose undergoes hydrolysis and breakage to produce acetic acid, so that the amount of carbonyl (C = O) is reduced, water absorption of the wood also is reduced, increasing the dimensional stability. Wood furfuryl modification is a complex chemical reaction. Under the conditions of heating and in the presence of a catalyst, the furfuryl alcohol oligomer undergoes linear and bulk polymerization until a solid material is formed. This is accompanied by reactions between the furfuryl alcohol monomer or polymer and the wood cell wall polymer (cellulose, hemicellulose, and lignin), ultimately forming a grafted product of multi-branched as well as highly cross-linked furfuryl alcohol polymer and wood cell wall chemical components. In this way, the lignin benzene epoxy bond stretching vibration near 1269 cm^{-1} and the C-O stretching vibration of cellulose, hemicellulose, and lignin near 1030 cm^{-1} underwent subtle changes.

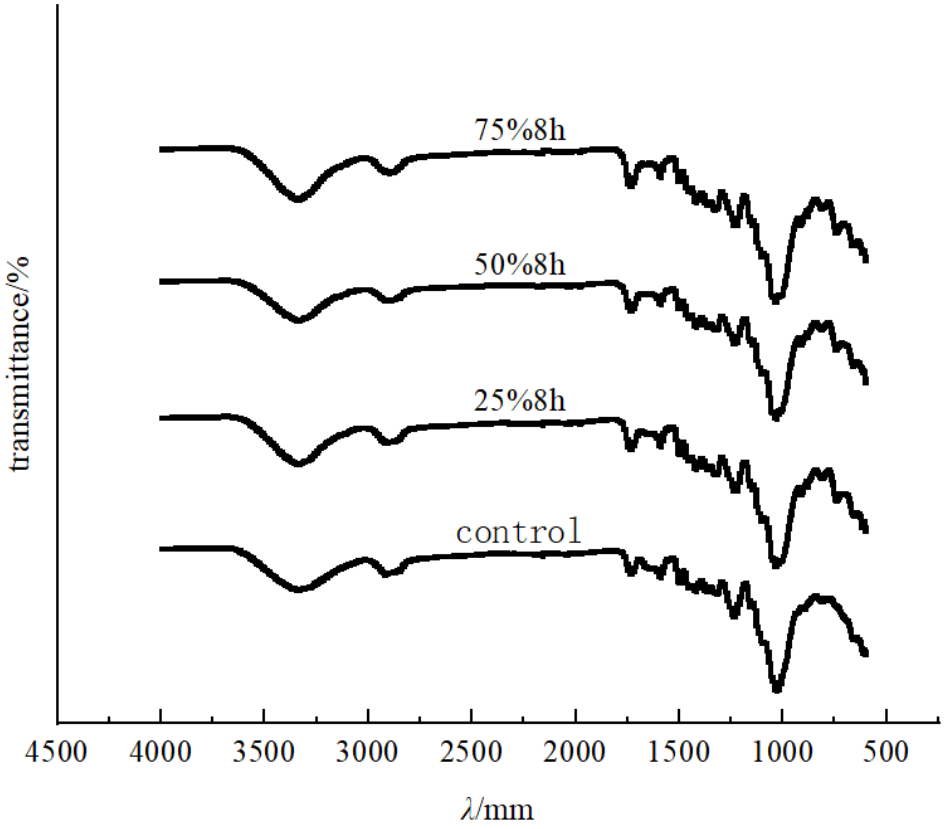


Fig. 12. The Infrared spectrum characteristic

CONCLUSIONS

1. The improvements in the acoustic vibration performance of *Paulownia* wood indicated that the dimensional stability of *Paulownia* wood had improved significantly, and the sound stability was improved after furfuryl modification. The three parameter values of acoustic impedance ω, attenuation coefficient δ, and periodic energy loss parameter $tan\delta/E$ were greatly reduced. This improved the vibration response speed, reduced attenuation, and improved the vibration efficiency of *Paulownia* wood, and was conducive to maintaining a certain residual sound, so that the sound of the instrument is full and lingering.
2. In contrast, the furfurylation reduced specific dynamic modulus (E/ρ) and acoustic radiation quality constant R. This result was not conducive to *Paulownia* wood vibration acceleration and energy conversion, and the higher the concentration of furfuryl alcohol polymer, the greater the negative impact of this effect. From the view of evaluation of the vibration sound indicator E/G, when the concentration of furfuryl alcohol polymeris 25% and curing time of 8 h, it can significantly improve the sound quality of *Paulownia* wood.
3. From the view of analysis of characteristics of *Paulownia* wood after impregnation with furfuryl alcohol, the furfuryl alcohol resin polymer mainly penetrated the cell gaps and cavities, which can help guarantee reaction between furfuryl alcohol resin modifier and the wood. In addition, the crystallinity of *Paulownia* wood impregnated with

furfuryl alcohol also changed, increasing at the concentration of 25% and curing time of 8, 12, and 15 h, but it decreased at concentrations of 59.9%, 58.5%, 59%, 50%, and 75%. However, the *Paulownia* wood infrared spectra shape did not change after furfuryl modification. Only the absorption intensity showed some slight changes near the characteristic peaks of 3400, 1736, 1269, and 1030 cm^{-1}.

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