A few Elastic Properties of Drilled Rectangular Bars of Poplar Wood

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Abstract

Some elastic properties of 13 rectangular clear bars of poplar wood in "free vibration of a free-free bar" method were examined with and without presence of drilled holes in different diameters of zero, three, five and eight millimeters on tangential surface exactly on the anti-node of the 1st mode of vibration, visible on two tangential surfaces. Specimens originated from planting region in Zanjan – Iran. Nominal dimensions of the bars were 20*20*360 mm. Considering three first modes of vibration, longitudinal modulus of elasticity and two shear moduli (G_{LR} and G_{LT}) were evaluated in Timoshenko beam theory and damping factor ($tand_{LT}$ and $tand_{LR}$) evaluated from logarithmic decrement calculations for both radial and tangential impacts of hammer. Step wise drilling showed no significant effect on E_L, G_{LR} and G_{LT} and $tand_{LT}$. But when the bars were impacted on tangential surface, the drilling holes, on their largest diameters could affect the $tand_{LR}$ while the effects of smaller holes on above mentioned factors were not obvious.

1 Introduction

In this research, Eastern poplar *(Populus Deltoides)* was used in free flexural vibration on free free bar. Each of the specimens vibrated based on their mechanical properties. Even small mechanical variations within the specimen due to anisotropy or defects can result in modal frequencies of vibration. The objective of this experiment was to detect these defects (especially hole) for longer and better performances of poplar wood.

The sound absorption and acoustical impedance in Poplar over different frequencies studied and compared with Beech and Alder. It was found that Poplar solid wood has the highest absorption, and observed the resonance in beech due to higher density and more proportion of rays.(Noorbakhsh 1997). ultrasonic longitudinal and shear wave velocities and densities for 12 Australian wood species was measured, comprising eleven hard woods and one soft wood by comparing the results with those obtained for European woods and similar ranges have found .(Bucur 1991).In order to compare the mode shapes

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of vibration before and after damage in timbers, modal-based testing was applied on wood bars in order to propose a new statistical algorithm for obtaining a defect indicator.(Hu et al., 2006).free vibration testing was used to generate the two initial mode shapes for damage detection in timbers and it was proved that the chosen Daubechies 3 wavelet was suitable and sufficiently sensitive to identify the location, extent and number of different damages(Hu et al., 2006). ultrasonic study has sought to 1) determine the ultrasonic parameters that are most sensitive to pallet part defects; and 2) specify which aspects of ultrasonic response signals best characterize defect size and location *(Daniel L. Schmoldt.,1994)*.by Assessment of Decay in Standing Timber Using Stress Wave Timing Nondestructive Evaluation Tools **,** the use of stress wave timing instruments to locate and define areas of decay in standing timber, the guide was prepared to assist field foresters. (Xiping Wang.,2004). Ultrasonic scanning experiments were conducted for detecting defects in wood pallet parts using rolling transducers. The paper reports the scanning results for stringers and deckboards. Sound and unsound knots,bark pockets, decay, splits, holes, and wane were characterized using several ultrasonic parameters. (M. Firoz Kabir., *2002)*. ULTRASONIC SIGNAL CHARACTERIZATION FOR DEFECTS IN THIN UNSURFACED HARDWOOD LUMBER describes initial work aiming to create an automated grading/sorting system for hardwood pallet parts using ultrasonic. Experiments were conducted on yellow-poplar *(Liriodendron tulipifera,* L.) and red oak *(Quercus rubra,* L.). Sound and unsound knots, cross grain, bark pockets, holes, splits, and decay were characterized using six ultrasound variables calculated from the received waveforms. (*Mohammed F. Kabir* ,.2001)

2 Materials and methods

The specific longitudinal modulus of elasticity (MOEL/ρ) and the shear modulus can be evaluated based on Timoshenko bar equations and Bordonné Solution (Bordonné, 1989; Brancheriau et al., 2002). In this equation, after obtaining the kth frequency through Fourier Transform, considering ak and bk, the value of longitudinal specific modulus of elasticity was determined using a linear regression formula as following:

$$\mathrm{a}_k = \left(\frac{MOE}{\rho}\right) - \left(\frac{MOE}{K \times G_{ij}}\right)\mathrm{b}_k \tag{1}$$

$$\mathrm{b}_k = \frac{4\pi^2 l^2 f_k^2 F_{2k}}{X_k} \tag{2}$$

$$\mathrm{a}_k = \frac{[4\pi^2 l^2 f_k^2 (1+\alpha F_{1k})]}{\alpha X_k} \tag{3}$$

$$X_k = m_k^4 \tag{4}$$

$$\alpha = \frac{I}{Al^2} \tag{5}$$

where *I*; moment of inertia, *A*; cross section area, *l*; length of the specimen, *K*;shape coefficient (the value of 5/6 can be used for a rectangular cross section), *Gij*; shear modulus in plane of vibration (GLT or GLR), ρ; specific gravity, *fk*; frequency of the kth mode of vibration obtained from FFT spectrum *mk*; the kth results in following Equation:

$$m_k = \frac{(2k+1)\pi}{2} \tag{6}$$

In Equations 1 and 2, *F1k* and *F2k* can be calculated as following:

$$F_{1k} = \Theta^2(m_k) + 6\Theta(m_k) \tag{7}$$

$$F_{2k} = \Theta^2(m_k) - 2\Theta(m_k) \tag{8}$$

$$\Theta_{(m_k)} = \frac{[m_k \tan(m_k)\tanh(m_k)]}{[\tan(m_k) - \tanh(m_k)]} \tag{9}$$

Higher correlation coefficients of the estimated trend lines in Equation 1 benefit the specimens with more homogeneity, where the Timoshenko model has been fitted initially to isotropic materials, and next to the clearest specimens. The selection was made based on trends with correlation coefficients higher than 0.99. Sampling was made selectively, numbers of wooden-sample and wholesome in shape were selected from spruce, the reason of selecting was: 1-this specie was accessible 2-this species is homogametic and it s categorized as a fast growth species (4 times faster than eucalyptus and 7 times faster than softwoods) 3-it can growth on many and different weather conditions 4-we could place the knot like real one in it and finally this species is commonly used in Iran (cutting species and then drying them was made very slow and without tension in the air in low temperature).

In this study, Eastern poplar *(Populus Deltoides)* timbers were randomly collected from plantations in Zanjan province in the region between West Alborz and North Zagros Mountains. Following ISO 3129 international standard. Rectangular and visually clear wooden bars (specimens) were obtained. The specimens were cut to their final nominal dimensions of 2*2*36 cm, R*T*L, and kept in a conditioning chamber at 21°C and 65 percents relative humidity for two weeks until their moisture content was stabilized. In controlled pathways, the 3 stepwise holes (three, five and eight millimeters) were produced with a drill on tangential surface of the bars where it could be seen on both surface of the bar.

The frequencies in different modes of free vibration on free free bar with A proper non-destructive test system (ndt lab) was used to analyze the properties in Eastern poplar *(Populus Deltoides)* timbers .

3 Results and discussion

when the bars were impacted on tangential surface,(fig.1) the drilling holes, on their largest diameters could affect the $tand_{LR,}$as as it was expected in the theory, because while it is impacted on tangential surface the wave is at the conflict with the hole, while it is vice versa on the radial surface (fig.2). The research findings indicated that the radial surface is a neutral axle for the wave.

It can be concluded that finger prints of holes on $tand_{LR}$ in proper directions might be applicable for hole identification.

Also as it remained in theory that just a single hole can not effect other mechanical properties (G_{LR} and G_{LT} and $E_{L)}$ because the amount of detriment is not enough, so further experiment with more and bigger holes in the species is need.

Figure 1.hole in plane with tangential surface of a 2*2*36 cm R*T*L bar.

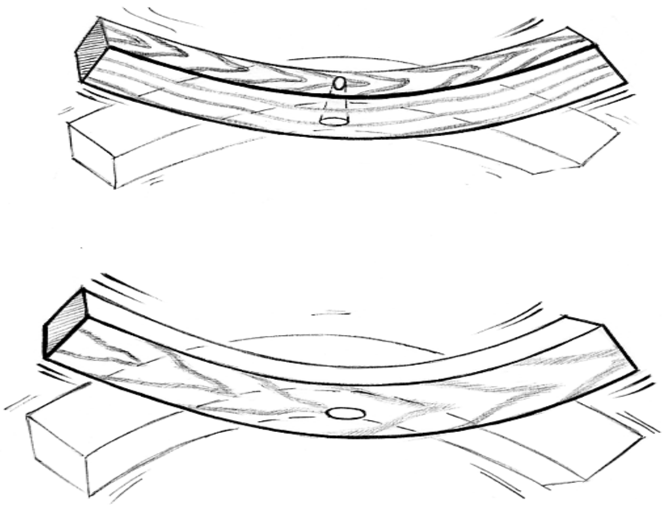

Figure 2 Schematic views of the most common setups for free flexural vibration on a free-free bar test. Sound recording from holed and hammer impact on end of a bar leaned on two soft thin supports, 0.22L from each end.

4 Conclusions

Elastic parameters of the bars were examined for their vibration properties based on Timoshenko bar equations, in order to find a procedure to make a confident choice of a clear specimen among the defected ones, considering three initial modes of vibration.(fig 3.) elasticity and two shear moduli (G_{LR} and G_{LT}) were evaluated in Timoshenko beam theory and damping factor ($tand_{LT}$ and $tand_{LR}$) evaluated from logarithmic decrement calculations for both radial and tangential impacts of hammer. Step wise drilling showed no significant effect on E_L, G_{LR} and G_{LT} and $tand_{LT}$. But when the bars were impacted on tangential surface, the drilling holes, on their largest diameters could affect the $tand_{LR}$ while the effects of smaller holes on above mentioned factors were not obvious. ANOVA, Analyses used for the analyses and Duncan used for grouping the analyzed parameters. (Table 1 and table 2).Finally, it was concluded by tracing $tand_{LR}$ while the bars are impacted on tangential surface ,holes in polar wood can be forecasted ,while it has largest diameters of the experiment.

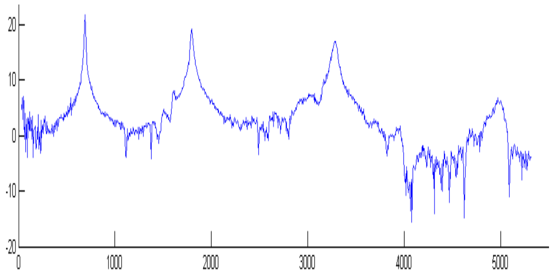

Figure 3 Three initial modes of vibration Magnitude of a Fourier Transform. Y axis corresponding to Amplitude in dB and X axis the frequency in Hz

Appendixes

Table 1- *ANOVA for the effects of the step-wise (0 to 8 mm) holes on mechanical properties.*

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
E' (GPa) R	Between Groups	25.832	3	8.611	1.101	0.358
	Within Groups	367.596	47	7.821		
	Total	393.427	50			
E' (GPa) T	Between Groups	17.529	3	5.843	.891	0.453
	Within Groups	308.049	47	6.554		
	Total	325.578	50			
DLE%	Between Groups	1770.324	3	590.108	2.537	0.068
	Within Groups	10930.963	47	232.574		
	Total	12701.287	50			
G (GPa) LT	Between Groups	.255	3	.085	1.716	0.177
	Within Groups	2.328	47	.050		
	Total	2.583	50			
G (GPa) LR	Between Groups	.390	3	.130	1.393	0.256
	Within Groups	4.390	47	.093		
	Total	4.781	50			
Ave.tand T	Between Groups	.002	3	.001	2.121	0.110
	Within Groups	.011	47	.000		
	Total	.013	50			
Ave.tand R	Between Groups	.000	3	.000	10.976	0.000
	Within Groups	.001	47	.000		
	Total	.001	50			

Table 2- *Duncan multiple comparison tests for the* affect the $tand_{LR}$

Duncan

HOLE	N	Subset for alpha = .05	
		1	2
1	13	.005710	
2	13	.005805	
3	12	.007106	
4	13		.012178
Sig.		.324	1.000

Means for groups in homogeneous subsets are displayed.

a Uses Harmonic Mean Sample Size = 12.735.

b The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Acknowledgements

we sincerely thank *Mr. Rahi Gaffarian* from Islamic Azad University, Karaj Branch for their caricatures and drawings.

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