ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 10, No. 4. 2004

Modeling and Study of Glued Wood Panel

Darius ALBREKTAS*, **Jonas VOBOLIS**

Faculty of Design and Technologies, Kaunas University of Technology, Studentų 56, LT-50131 Kaunas, Lithuania

Received 30 August 2004; accepted 22 October 2004

Widely used glued wooden panels have to meet quality requirements. Their mechanical properties are highly dependent on gluing quality. The paper presents the results of quality studies conducted according to an elaborated method, imitating gluing defects of panels. Glued oak wood panels were studied by the method of resonance vibrations in a special stand within 20 – 2000 Hz frequency range. Defects were imitated making incisions in the places of glue lines. Several defect variants were modeled – defect in the centre of panels, defect at the edge of panels and two defects – in the centre and at the edge. The change of panel amplitude-frequency characteristics was ascertained. It was found, that with increasing linear dimensions of defects, mean vibration amplitudes of panels decrease. It was obtained, that the modulus of elasticity along the grain comprise 12000 – 13000 MPa, while across the grain 933 – 1600 MPa, damping coefficients (tgδ) – 0.015 – 0.04. With increasing incision, the modulus of elasticity in the longitudinal direction practically did not change, meanwhile transversely they decreased down to 321 – 760 MPa, damping coefficients augmented up to 0.02 – 0.05. Critical incision lengths were ascertained under significant changes of transverse panel bend forms. When incision is at the edge, critical incision length comprises about 0.5 of the panel length, while when incision is in the centre or there are two incisions – about 0.3 of the panel length. It was found, that change peculiarities of the mentioned parameters characterize mechanical properties and the quality of panels.

Keywords: glued wooden panel, defects, resonance vibration, modulus of elasticity, coefficient of damping.

INTRODUCTION

At present glued wood is widely applied. Wood is glued for various reasons – seeking to use rationally small-size wood assortments, to eliminate defects worsening mechanical properties or the appearance of an article, striving to obtain assortments of larger dimensions or to ensure the stability of the form and dimensions of an article.

Mechanical wood properties (modulus of elasticity, coefficient of damping etc.) depend on various factors – hydrothermic processing method and quality, habitat, place within the log, occurring various defects, etc. Thus, the properties of an article glued from separate assortments will differ in different zones. Besides, glue lines are introduced, which may differ among themselves. Therefore, a panel glued from solid wood scantlings cannot be regarded as a monolithic slab. Wood assortments are glued in different ways. Two or more assortments can be glued by joining their faces, edges, ends, i.e. they are joined in respect of width, height and length. Two principal gluing methods are used – gluing at normal temperature, called "cold gluing" and gluing at high temperature, using heating. For gluing different adhesives, both natural and synthetic, are applied [1 – 4].

Violations of the necessary regime, application of improperly prepared adhesives or gluable surfaces lead to weak joints of bad quality. Glued assortments may partially or completely fail due to various reasons – greasy gluable surfaces, insufficient amount of glue or too thin glue, unequal distribution of the pressing force, insufficient pressing, glue in the packet is partially hardened before pressing, insufficient temperature, too high roughness of surfaces, etc. [3]. Thus, mechanical properties of such glued assortments may fail to meet raised requirements.

Therefore, it is urgent to ascertain and control their quality. The aim of the work is to study mechanical properties of a glued wood panel imitating gluing defects.

STUDY METHOD AND EQUIPMENT

Mechanical properties of wood and its products may be ascertained by different methods. They all may be divided into static and dynamic. One of the dynamic study methods is the method of resonance vibrations. Applying this method, resonance vibrations of the studied object are induced and, according to them, its mechanical properties are ascertained, i.e. modulus of elasticity, coefficient of damping, etc. The mentioned method was used to study panels glued from solid oak wood and their mechanical properties were modeled. A special stand was used for this purpose [5].

EXPERIMENTAL DATA

Panels of two types were studied. Their dimensions were $500 \times 500 \times 30$ mm (II panel) and $700 \times 700 \times 30$ mm (I and III panel). The moisture content of wood panels was 8 – 12 %. Within 20 – 2000 Hz range of frequencies, amplitude – frequency characteristics of these panels were determined (Fig. 1).

Vibrating by each of resonance frequencies, panel bends in a certain form. All panel bend forms may be distributed into two groups, i.e. close to theoretical slab bend forms and more complex ones. According to the values of resonance frequencies and bend forms, panel modulus of elasticity in transverse (across fibres) and longitudinal (along fibres) directions were determined, while according to the character of amplitude – frequency

*Corresponding author. Tel.: +370-37-300230; fax.: +370-37-353863.
E-mail address: *Darius.Albrektas*@stud.*ktu.lt* (D. Albrektas)

characteristics – coefficient of damping *(*tg*δ)* [5]. For a more accurate data processing, characteristic A, B, C panel zones were chosen. It was found, that modulus of elasticity and coefficient of damping of a glued solid wood panel similarly to a solid wood panel. In the longitudinal direction it is 11800 – 13000 MPa, in the transverse direction – 500 – 1600 MPa, while coefficient of damping (tg*δ*) – 0.015 – 0.040.

Resonance frequencies of panels are presented in Table 1.

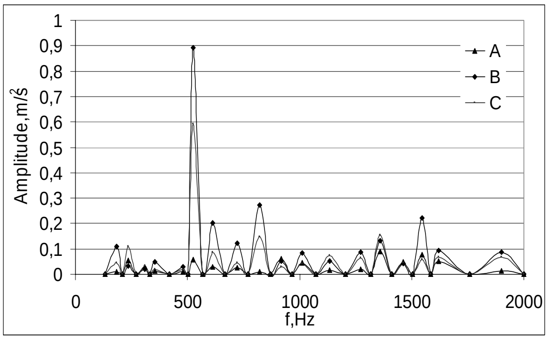
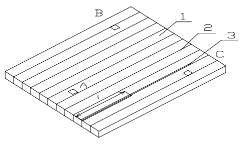


Fig. 1. Amplitude-frequency characteristics of panel II

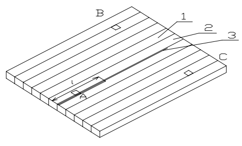
Table 1. Resonance frequencies of panels

Panel	Resonance frequency, Hz										
I	93	194	235	265	318	430	500	700	760	840	1180
	1270	1390	1480	1880							
II	184	236	308	355	480	524	612	720	822	919	1012
	1135	1273	1360	1462	1547	1620	1900				
III	77	92	170	229	277	316	408	496	592	726	763
	847	968	1019	1200	1246	1359	1464	1680	1753	1865	1940

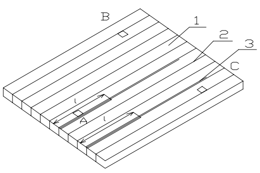
Later on failure defects were modeled an it was found, that with increasing defect panel bend forms, resonance frequencies, modulus of elasticity and coefficient of damping undergo changes. Defect is an incision in the place of glue line, the width of which is 1.5 mm, while the length was changing every 50 – 100 mm. In panel I, one incision was made at the edge (about 185 mm from the edge), in panel II – in the centre, in panel III – two incisions – at the edge and in the centre (Fig. 2).



a



b

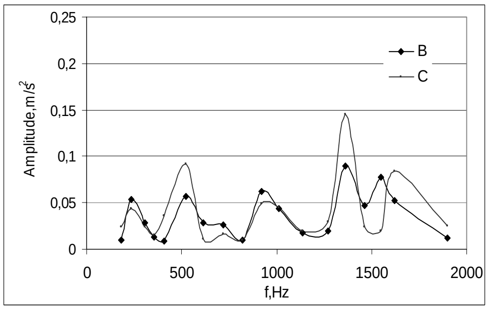


c

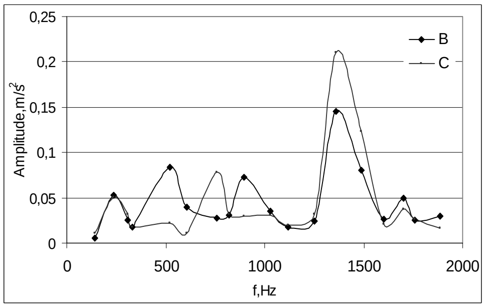
Fig. 2. Scheme of glued solid wood panels and modeled defects: a – defect modeled at the edge of the panel; b – in the centre of the panel; c – at the edge and in the centre of the panel; 1 – solid wood scantling, 2 – glue line, 3 – defect; l – incision length, A, B, C – characteristic panel zones

Changing the defect length, amplitude-frequency characteristics of panels were recorded. Changes in amplitude – frequency characteristics of one of the panels is shown in Fig. 3.

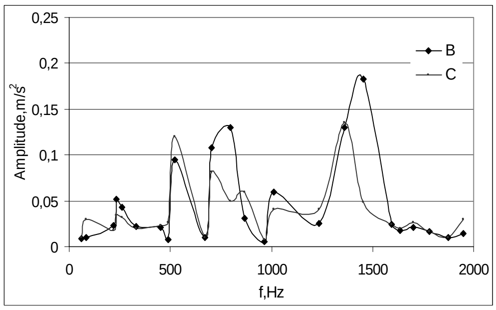
It was found, that with increasing linear dimension of defect, the amplitude of panel vibrations increases in the range of 1300 – 1500 Hz (about 1.5 times). Having increased defect length up to 450 mm, the amplitudes of lower (500 – 800 Hz) vibration forms increase.



a



b



c

Fig. 3. Changes of panel amplitude-frequency characteristics within B and C zones with increasing defect: a – no defect, b – defect length 250 mm, c – defect length 450 mm

Increasing incision (e.g. in panel I from 450 mm, in panel II – from 150 mm), the forms of panel transverse vibrations disappear – only the system of two or three joined among themselves vibrating masses remains. Thus, the ascertained critical incision length is the length when the first close to theoretical panel bend form disappears. Significant changes are observed also on others, more complex transverse panel bend forms. It can be seen, that depending on defect development place on panel, critical incision lengths differ. If with increasing incision at the edge, the first panel bend form transversely disappeared when incision length comprised approximately 0.5 of the

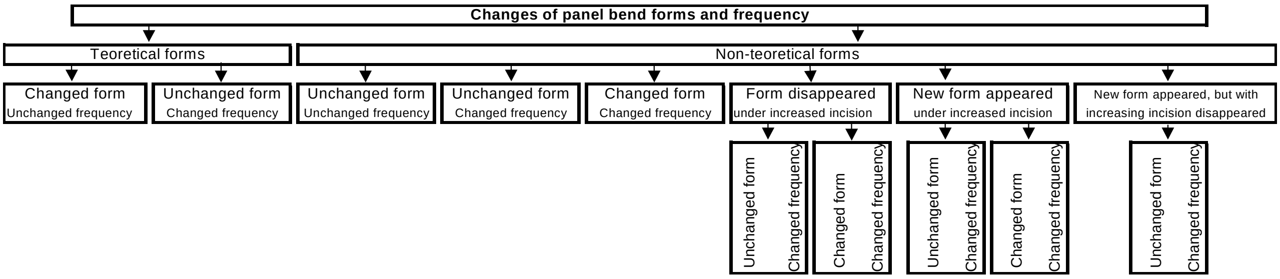


Fig. 4. Diagram of bend form and frequency changes of one of the panels

panel length, then with increasing incision in the centre and two incisions in the centre and at the edge, the forms disappeared when incisions comprised about 0.3 of the panel length.

General regularities have been ascertained independently of the place of defect development on the panel: resonance frequencies were increasing, especially within the range of lower frequencies (Fig. 3), in most cases, under the same panel bend form, resonance frequency was decreasing. Bend forms of defective panels according to their changes may be divided into groups (Fig. 4). As it was mentioned, due to differing individual scantlings and properties of glue lines, panels made of solid wood scantlings represent a complex system and in most cases its vibrations fail to comply with the regularities of a monolithic panel vibrations. Mechanical properties of panels, similarly to solid wood, differ greatly in different directions. Therefore, in most cases bend forms of such a panel are complex and dissimilar to theoretical bend forms. However, in some cases bend forms of these slabs are close to theoretical ones. (e. g. panel II, when the frequency of vibrations is 184 Hz, its bend form is close to the first theoretical slab bend in transverse direction, while when the frequency of vibrations is 524 Hz – in longitudinal direction).

It can be seen, that increasing incision, panel bend forms "acted" differently – some of them remained more stable, others exercised more significant changes. A deeper analysis will be made based on the changes of panel II forms. Close to theoretical panel bend forms may be divided into two groups: 1 – form and frequency, increasing incision, did not change; 2 – form changed insignificantly, frequency has also changed. Further from theoretical panel bend forms may be characterized as follows: 1 – increasing incision, form and frequency did not changed; 2 – form did not change, frequency has changed; 3 – form and frequency have changed; 4 – with increasing incision, the form disappeared (e.g. when there was no incision, vibration frequency of the panel comprised 612 Hz, and frequency was decreasing. When incision length reached 350 mm, this form disappeared. The panel bent in another form, when frequency was 1135 Hz, while when incision length reached 350 mm, this form disappeared as well); 5 – a new form appeared (e.g. when incision length reached 350 mm, vibration frequency of the panel was 92 Hz. Further increasing incision, the form did not change, while frequency decreased. In another case, when incision length was 150 mm, vibration frequency of the panel comprised 300 Hz. Later, increasing incision, changed the form and resonance frequency; 6 – a new form appeared, while further increasing incision, it disappeared (e.g. when incision length was 150 mm, panel vibration frequency was 262 Hz, while when incision length reached 450 mm, the panel failed to obtain this bend form).

During the mentioned study, in respect of sensitivity, the amplitude (m/s^2) of vibration acceleration was measured. Later the amplitude of vibration shift was also analysed. Increasing the lengths of incisions, changed also mean panel vibration acceleration and shift amplitudes (Fig. 5).

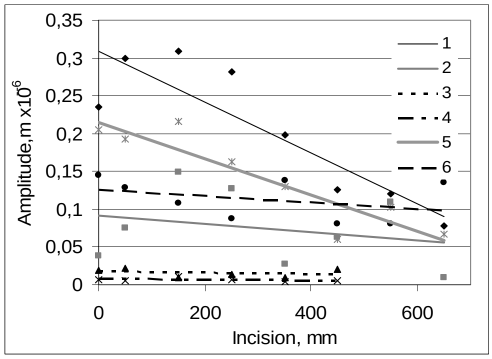
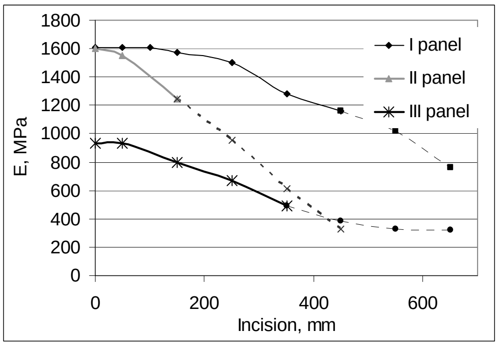


Fig. 5. Changes in panel vibration shift amplitudes: 1 – panel I, 64 – 93 Hz frequency range; 2 – panel I, 264-268 Hz; 3 – panel II, 83 – 184 Hz; 4 – panel II, 521 – 524 Hz; 5 – panel III, 45 – 77 Hz; 6 – panel III, 274 – 277 Hz

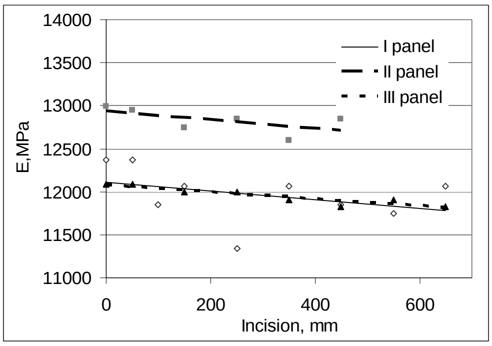
It can be seen, that with increasing incisions, in most cases mean panel vibration amplitudes decreased. Especially obvious amplitude decrease is observed in the range of lower frequencies (60 – 100 Hz), when panels vibrate of $700 \times 700 \times 30$ mm dimensions and the length of incisions varies from 150 to 450 mm. Further this decrease becomes less distinct. The number of incisions (panel I had one incision, panel III – two) had not much influence on this regularity. With increasing defect in the panel of smaller dimensions (II), amplitude change becomes insignificant.

Knowing panel bend form and frequency, in accordance with the methodic [5], panel modulus of elasticity were calculated. At the same time it was obtained, that with increasing defects, vibration frequencies and panel modulus of elasticity changed also (Fig. 6).

Fig. 6 shows, that panel modulus of elasticity in longitudinal direction, independently of defect development place, has changed insignificantly, meanwhile its change in transverse direction was distinct. The least decrease of modulus of elasticity in transverse direction was under increasing defect at the edge (decreased from 1606 MPa to 760 MPa, i.e. by 53 %), with increasing defect in the center of the panel, modulus of elasticity



a



b

Fig. 6. Change of panel modulus of elasticity in transverse (a) and longitudinal (b) directions with increasing defects; here a dotted line represents panel modulus of elasticity exceeding critical defect lengths

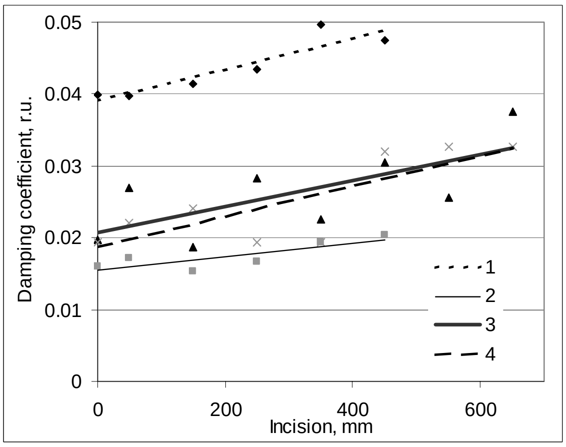


Fig. 7. Regularity of mean coefficient of damping change in panels: 1 – panel II, 83 – 184 Hz frequency range; 2 – panel II, 516 – 524 Hz; 3 – panel III, 45 – 77 Hz; 4 – panel III, 274 – 277 Hz

decreased by 80 % (from 1602 MPa to 326 MPa), while when two defects were developing, modulus of elasticity decreased by 66 % (from 933 MPa to 321 MPa). Modulus of elasticity was ascertained according to close to theoretical panel bend forms, while when incisions reached critical values and the form disappeared – modulus of elasticity was ascertained only observing resonance frequencies (marked in dotted lines in Fig. 6). The following ratios of initial panel modulus of elasticity and modulus of elasticity under critical incision length were ascertained: when defect was developing at the edge – 1.26, when in the center – 1.29, when two defects were developing – 1.40.

With increasing defects, the change of coefficient of damping was also recorded (Fig. 7).

It can be seen, that, independently of panel dimensions, modulus of elasticity, number and place of incisions, with increasing defects, coefficient of damping increases. This increment is the greatest in the range of low frequencies (e.g. for panel II – within 80 – 190 Hz, panel III – 40 – 90 Hz range).

Having conducted this study, it may be stated, that gluing quality may have a great influence on mechanical properties of glued solid wood panels. On the other hand, having ascertained in this way mechanical properties of panels (e.g. modulus of elasticity, coefficient of damping), their quality may be assessed.

At the same time, modeling gluing process (e.g. leaving unglued zones), it is possible to correct and obtain necessary mechanical properties of panels (e.g. obtain panels of high coefficient of damping).

CONCLUSIONS

1. It was found, that mechanical properties of panels made from glued solid wood scantlings are close to the mechanical properties of solid wood.
2. It was ascertained, that change regularities of mechanical properties are analogous independently of defect development place. With increasing defect in any place of a panel, modulus of elasticity decreases, while coefficient of damping increases.
3. It was found, that the properties of a glued panel are mostly influenced by defects in the panel center. Modulus of elasticity in transverse direction, with increasing defect at the edge, decreased by 53 %, while with increasing defect in the center or under two defects – at the edge and in the center – by 66 – 80 %.
4. It was ascertained, that coefficient of damping, with increasing defects, increases from 0.015 – 0.04 to 0.02 – 0.05.
5. Modeling gluing, it is possible to change mechanical properties of glued wood structure – e.g. obtain panels of high coefficient of damping.

REFERENCES

1. **Kovalcuk, L. M.** Technology of Pasting. Moscow, Lesnaja promyshlenost, 1973: 420 p. (in Russian).
2. **Lopez–Anido, R., Gardner, D. J., Hansley, J. L.** Adhesive Bonding of Eastern Hemlock Glulam Panels with E-Glass/Vinyl Ester Reinforcement *Forest Products Journal* 50 (11 – 12) 2000: pp. 43 – 47.
3. **Freidin, A. S.** Strength and Durability of Glued Joints. Moscow, Chemija, 1981: 287 p. (in Russian).
4. **Pihcelin, F., Kamoun, C., Pizzi, A.** Effects on Wood Glueing, Taining and Other Wood Adhesives *Holz Roh- und Werkst.* 57 (5) 1999: pp. 28 – 37.
5. **Albrektas, D., Vobolis, J.** Investigation of Mechanical Parameters and Defects of Solid Wood Glued Panels *Materials Science (Medžiagotyra)* 9 (4) 2003: pp. 368 – 373.