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Evaluating the Effect of Finishing Materials on Viscous Elastic Properties of Particle Boards

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In the present research the investigation of finishing wood particle boards is presented. The testing process of wood particle boards involved an original stand. The following three types of finished boards underwent evaluation: finished with veneer on both sides, finished with veneer on the one side and with compensatory paper on the other side, and finished with melamine impregnated paper on both sides. It was established that the first vibrational modes of finished wood particle boards in two perpendicular directions share similarity with modes of the beam-shaped body in terms of their shape. It was obtained that the modulus of elasticity of wood particle boards with different finishing differs by approximately 30 % – 70 % in two perpendicular directions. It was established that when dealing with boards finished with veneer on both sides, with veneer on the one side and compensatory paper on the other side, and with melamine impregnated paper, the value of the modulus of elasticity in two perpendicular directions differs by 1.71, 1.54 and 1.34 times, respectively. It was found that in the case of boards finished with veneer on both sides and with veneer on the one side and compensatory paper on the other side, the coefficient of damping change in two perpendicular directions is less than the one of the board finished with melamine impregnated paper by 25 %.

Keywords: wood particle board, coefficient of damping, resonance vibration, modulus of elasticity, finishing materials.

INTRODUCTION

Wood boards appear to be the most widely used construction material. They can be used for furniture manufacturing, building interior, as well as in the construction of frame houses and in the production of musical instruments. Finished wood particle boards are often used for building interior and furniture production. Their surface can be covered with veneer, decorative paper, foil or other sheet materials.

Depending on their purpose, boards have to show certain mechanical, acoustic and other properties. In order to evaluate these properties and to detect various defects, different static and dynamic testing methods are widely used.

The dynamic method means forcing the studied object to vibrate and assessing its mechanical properties according to the vibration parameters [1 – 5]. The dynamic method gains advantage over the static one in the following ways: there is no destruction of the studied object, no need for the manufacturing of special specimens in most cases and better assessment of defects is possible. In this case it becomes possible to complexly evaluate viscoelastic properties of the specimen, as well as its coefficient of damping.

Dynamic tests of particle boards are very relevant, since the majority of products made of particle boards are exposed to dynamic loads. Therefore, the dynamic evaluation of board parameters enables to predict product behavior in the zone of dynamic loads.

Dynamic tests for small diameter logs and floor systems were performed [2 – 3]. In these cases transverse free vibrations of assortments were generated. By treating the assortment as a beam – shaped object and by applying the theoretical calculations of such object vibrations, it was possible to evaluate the modulus of elasticity.

Tests for particle boards were carried out in an analogous manner as observed in the case of beam-shaped objects [4 – 5]. During the testing process the board was fixed as a beam-shaped object so that its strength properties could be evaluated in different directions according to the parameters of transverse vibrations.

These methods are used only for beam-shaped products.

Mechanical properties of particle boards were assessed by means of the acoustic method [6 – 8]. In this case the speed of the acoustic wave was recorded. The interdependence between the speed of the acoustic wave and strength parameters enables to predict board properties.

Static and dynamic tests for plywood are performed in an analogous way [9]. In this case the dependence between the static and dynamic modulus of elasticity was evaluated. It was found that the dynamic modulus of elasticity is higher than the static one when there is a strong correlation between these parameters.

A multipurpose dynamic test stand is in use, which consists of an electronic system for recording and reproducing magnetic impulses of variable duration and shape and processing analog signals. Computer equipment is used for recording and reproducing magnetic impulses and processing useful signals [10].

Oriented strand boards underwent testing on the basis of the acoustic method. It was demonstrated that based on acoustic emission parameters, it becomes possible to detect cracks as well as other defects [11].

The dynamic method was used for evaluating the quality of wood particle boards [12]. This case involves

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exposing the board to resonant vibrations on the basis of which the modulus of elasticity and coefficient of damping are established. It was found that the modulus of elasticity is higher by approximately 30 % – 40 % in the longitudinal direction of mat forming, whereas, the coefficient of damping has similar magnitude in both directions of mat forming.

Covering thickness of wood particle boards is known to constitute 10 % – 15 % of board thickness in separate cases. There can be a significant change in viscous elastic properties of the product, depending on the direction the semi-finished board product is cut out of the board and the direction of fiber contained by the covering.

The objective of the study is to assess how finishing materials affect viscous elastic properties of wood particle boards.

STUDY METHOD AND EQUIPMENT

The tests involved using an original dynamic stand and piece of equipment, including measurement methodology [13]. This equipment allows measuring the modulus of elasticity and coefficient of damping with accuracy of 5 MPa and 0.0001 r. u. respectively. The following three types of finished boards underwent evaluation: finished with veneer on both sides, finished with veneer on the one side and with compensatory paper on the other side, and finished with melamine impregnated paper on both sides. 3 pieces of each type of boards were selected with the following dimensions: (700×700×18) mm. Specimens were undergoing conditioning in the laboratory for several weeks by maintaining them at the temperature of (18 – 21) °C and with the relative humidity being 55 % – 65 %.

The specimens had points marked in 100 mm intervals in terms of length and width. As a result, each specimen had 64 characteristic points for fastening the sensor and measuring vibrations within the range of 20 Hz – 2000 Hz.

EXPERIMENTAL RESULTS AND DISCUSSION

Initially, amplitude-frequency characteristics were established at five characteristic points, namely at the angular points and the central point, which are shown in Figure 1.

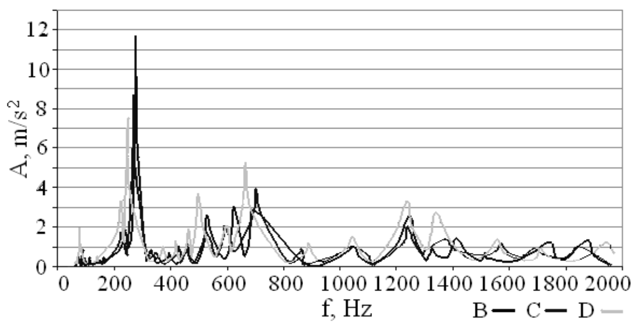


Fig. 1. Amplitude-frequency characteristics of boards: B – finished with veneer on both sides; C – finished with veneer on the one side and with compensatory paper on the other side; D – finished with melamine impregnated paper on both sides

It was determined that all types of boards have analogous amplitude-frequency characteristics. In all cases the number of recorded resonant frequencies reached 18.

Boards finished with melamine impregnated paper had the lowest first average resonant frequency (88.7 Hz), meanwhile, a higher frequency was obtained in the case of boards finished with veneer on both sides (89.7 Hz) and boards finished with veneer on the one side and with compensatory paper on the other side (90.9 Hz).

After establishing the first two resonant frequencies, it was possible to obtain vibrational modes of boards.

It was found that finished boards also vibrate in two perpendicular directions and in clearly expressed modes that are analogous to the ones of the beam-shaped body, therefore, when evaluating the modulus of elasticity, theoretical vibration calculations of the beam-shaped body can be applied to them [14]. Figure 2 shows vibrational modes of wood particle boards finished with veneer on both sides.

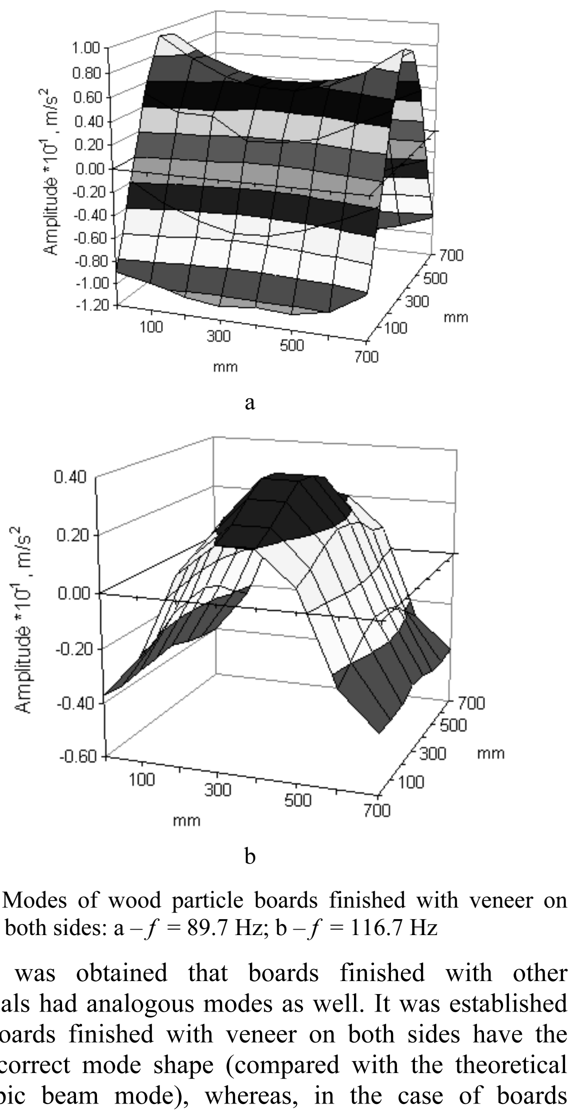
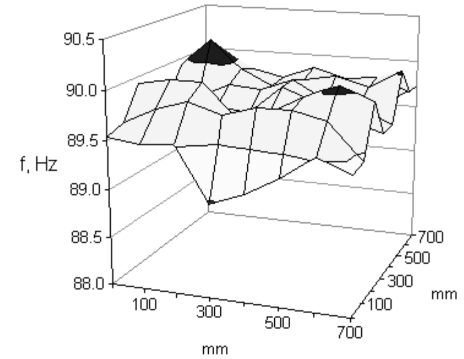


Fig. 2. Modes of wood particle boards finished with veneer on both sides: a – f = 89.7 Hz; b – f = 116.7 Hz

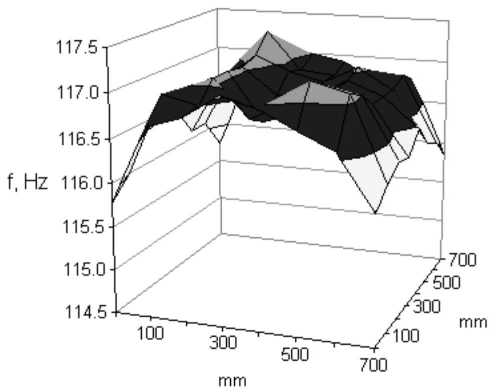
It was obtained that boards finished with other materials had analogous modes as well. It was established that boards finished with veneer on both sides have the most correct mode shape (compared with the theoretical isotropic beam mode), whereas, in the case of boards finished with melamine impregnated paper, it tends to be less correct.

The distribution of viscous elastic properties of boards was assessed. Figure 3 shows the resonant frequency distribution law for the board finished with veneer on both sides.

It was found that resonant frequency distribution in the plane did not exceed 2.5 %. The minimum distribution (1.2 %) was observed in the case of boards with veneer finishing on both sides, meanwhile, boards finished with veneer on the one side and compensatory paper on the other side had the maximum distribution (2.3 %). When dealing with laminated boards, there was approximate 1.7 % difference.



a



b

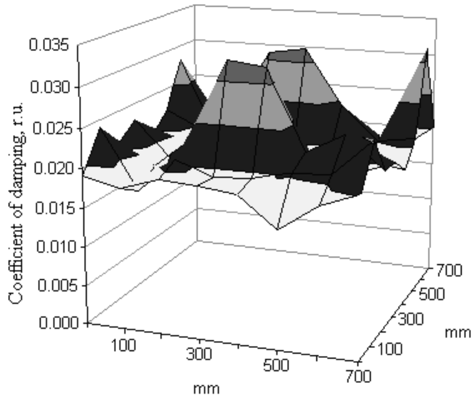
Fig. 3. Resonant frequency distribution low in the plane of the board with veneer finishing on both sides: a – when dealing with the first resonant frequency, b – when dealing with the second one

In addition, the distribution of the value of the coefficient of damping was determined in the presence of the first and second resonant frequencies [14]. Figure 4 shows the change in the coefficient of damping that occurs in the plane of the board finished with veneer on both sides.

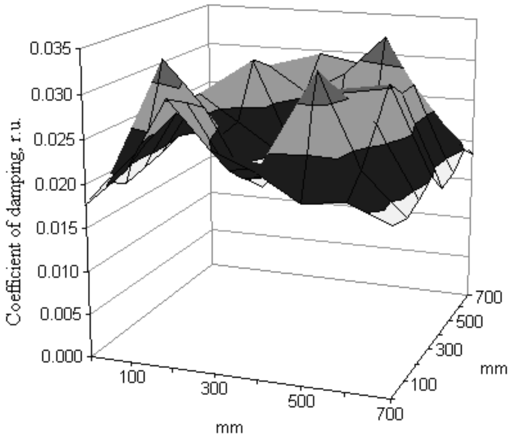
It was established that at the first resonant frequency the minimum and maximum values of the coefficient of damping are 0.015 and 0.0324, respectively, whereas, at the second resonant frequency they are 0.0173 and 0.0334, respectively (with the respective difference reaching 2.16 and 1.93 times).

Furthermore, it was determined that boards finished with veneer and melamine impregnated paper on both sides have similar distribution of their coefficients of damping. There was a considerably larger distribution in boards finished with veneer on the one side and with compensatory paper on the other side (with the respective difference being 6.87 and 4.57 times).

The modulus of elasticity of boards was calculated after the evaluation of resonant frequencies, geometric measurements, density and other parameters [14, 15].



a



b

Fig. 4. Coefficient of damping distribution in the plane of the board with veneer finishing on both sides in the presence of: a – the first resonant frequency, b – the second resonant frequency

Table 1 includes values of the modulus of elasticity and coefficient of damping.

It can be observed (Table 1) that at the first resonant frequency boards with veneer finishing on both sides have the lowest (0.0206 r. u.) coefficient of damping, whereas, boards finished with veneer on the one side and with compensatory paper on the other side have the highest (0.0240 r. u.) coefficient of damping. When the board vibrates in the perpendicular direction (at the second resonant frequency), the lowest (0.0233 r. u.) coefficient of damping is also obtained in the case of the board with veneer finishing on both sides and the highest (0.0287 r. u.) coefficient of damping is observed in the case of the board finished with melamine impregnated paper.

The board with veneer finishing on both sides had the lowest (3230 MPa) modulus of elasticity in analogous directions of board bending, meanwhile, the board finished with veneer on the one side and with compensatory paper on the other side had the highest (3565 MPa) modulus of elasticity. When the board begins to bend in the perpendicular direction, the lowest (4755 MPa) modulus of elasticity is obtained in the case of the board finished with melamine impregnated paper and the highest (5510 MPa) modulus of elasticity is noticed in the case of the board with veneer finishing on both sides.

Table 1. Values of the modulus of elasticity and coefficient of damping of boards

<table>
<tr><th>Sort of plate</th><th>Plate No.</th><th>f, Hz</th><th>E, MPa</th><th>E_{av}, MPa</th><th>tgδ</th><th>tgδ_{av}</th></tr>
<tr><td rowspan="6">B</td><td>1</td><td>88.4</td><td>3100</td><td rowspan="3">3230</td><td>0.0205</td><td rowspan="3">0.0206</td></tr>
<tr><td>2</td><td>90.3</td><td>3255</td><td>0.0192</td></tr>
<tr><td>3</td><td>90.4</td><td>3330</td><td>0.0220</td></tr>
<tr><td>1</td><td>117.8</td><td>5560</td><td rowspan="3">5510</td><td>0.0228</td><td rowspan="3">0.0233</td></tr>
<tr><td>2</td><td>116.6</td><td>5490</td><td>0.0204</td></tr>
<tr><td>3</td><td>115.7</td><td>5490</td><td>0,0268</td></tr>
<tr><td rowspan="6">C</td><td>1</td><td>90.6</td><td>3500</td><td rowspan="3">3565</td><td>0.0212</td><td rowspan="3">0.0240</td></tr>
<tr><td>2</td><td>90.2</td><td>3525</td><td>0.0278</td></tr>
<tr><td>3</td><td>91.9</td><td>3670</td><td>0.0230</td></tr>
<tr><td>1</td><td>111.4</td><td>5265</td><td rowspan="3">5505</td><td>0.0289</td><td rowspan="3">0.0266</td></tr>
<tr><td>2</td><td>113.2</td><td>5550</td><td>0.0268</td></tr>
<tr><td>3</td><td>114.3</td><td>5695</td><td>0.0242</td></tr>
<tr><td rowspan="6">D</td><td>1</td><td>88.3</td><td>3575</td><td rowspan="3">3540</td><td>0.0211</td><td rowspan="3">0.0210</td></tr>
<tr><td>2</td><td>89.1</td><td>3590</td><td>0.0214</td></tr>
<tr><td>3</td><td>88.8</td><td>3450</td><td>0.0205</td></tr>
<tr><td>1</td><td>103.1</td><td>4830</td><td rowspan="3">4755</td><td>0.0246</td><td rowspan="3">0.0287</td></tr>
<tr><td>2</td><td>103.7</td><td>4835</td><td>0.0306</td></tr>
<tr><td>3</td><td>102.5</td><td>4600</td><td>0.0309</td></tr>
</table>

* here B – boards finished with veneer on both sides; C – boards finished with veneer on the one side and with compensatory paper on the other side; D – boards finished with melamine impregnated paper on both sides

In other works [5, 7] it was found that modulus of elasticity of trimmed particle boards (thickness 16 mm – 22 mm) is 2700 MPa – 3500 MPa. Our obtained values of modulus of elasticity are higher for a finish. In the mentioned works it was found also that coefficient of damping of boards (when the oscillation frequency was 90 Hz) was about 14 1/s. Our obtained values of coefficient of damping converted into these units (using known method [16]) were 10.64 1/s – 17.36 1/s.

Figure 5 shows the comparison (ratio of value) between the modulus of elasticity and coefficient of damping in two directions of board bending

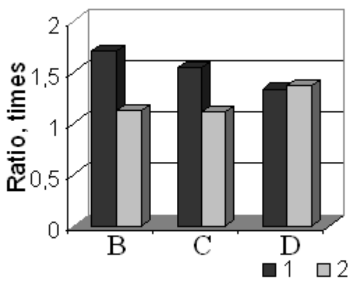


Fig. 5. The comparison of viscous-elastic properties of finished wood particle boards in two perpendicular bending directions: B – boards finished with veneer on both sides; C – boards finished with veneer on the one side and with compensatory paper on the other side; D – boards finished with melamine impregnated paper on both sides; here 1 – modulus of elasticity; 2 – coefficient of damping

It was established that the most significant difference (reaching 1.71 times) in the modulus of elasticity in two perpendicular directions is observed in the case of boards with veneer finishing on both sides. Boards finished with veneer on the one side and with compensatory paper on the other side have a small difference (reaching 1.54 times) in values. The most similar values of the modulus of elasticity (reaching 1.34 times) can be noticed in the case of boards finished with melamine impregnated paper.

The most significant change (by 1.37 times) in the coefficient of damping in two perpendicular directions occurs in the case of boards finished with melamine impregnated paper. When dealing with other types of finishing, the coefficient of damping had similar analogous values (1.11 and 1.13 times, respectively).

The modulus of elasticity is known to be higher in the longitudinal direction of mat forming of unfinished wood particle boards than in the perpendicular direction by 30 % – 50 % [12]. Therefore, when finishing boards with veneer, the oriented direction of veneer fiber becomes crucial in terms of the direction of mat forming. Since wood used for veneer manufacturing has different properties across and along the fiber (the modulus of elasticity differs by up to 20 times), this leads to different fiber properties in these directions as well. When boards are finished with veneer, their modulus of elasticity can increase or decrease, depending on the orientation between the above-mentioned directions.

When compared to unfinished boards, the coefficient of damping of finished boards tends to increase, as the board construction becomes more complex in the general case.

Since melamine impregnated paper has similar properties in all directions, boards with its finishing retain similar properties as in the case of unfinished boards.

Thus, when finishing wood particle boards, it is important to cut semi-finished board products out of unfinished boards in an oriented way and to select the respective fiber direction for finishing materials.

CONCLUSIONS

1. It was demonstrated that the first vibrational modes of finished wood particle boards in two perpendicular directions share similarity with modes of the beam-shaped body in terms of their shape.

2. It was obtained that the modulus of elasticity of wood particle boards with different finishing differs by approximately 30 % – 70 % in two perpendicular directions.

3. It was established that when dealing with boards finished with veneer on both sides, with veneer on the one side and compensatory paper on the other side, and with melamine impregnated paper, the value of the modulus of elasticity in two perpendicular directions differs by 1.71, 1.54 and 1.34 times, respectively.

4. It was found that in the case of boards finished with veneer on both sides and with veneer on the one side and compensatory paper on the other side, the coefficient of damping change in two perpendicular directions is less than the one of the board finished with melamine impregnated paper by 25 %.

5. It was shown that when finishing wood particle boards, it is necessary to know in which direction semi-finished board products are cut out of unfinished boards, including the direction of the fiber of finishing materials. In addition, when manufacturing separate parts (shelves and others), it is necessary to evaluate isotropy of finished boards by cutting out semi-finished board products in an oriented way.

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