University of West Hungary
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Theses of the doctoral (Ph.D.) dissertation

THE ADEQUACY FOR FURNITURE AND MARKET RESEARCH STUDY OF POPLAR SOLID WOOD PANELS

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I. THE OPPORTUNENESS, PRECEDENTS AND SCOPE OF THE RESEARCH WORK

Opportuneness

The solid wood panel, as a product discovered again and more and more frequently demanded, has been a well-known and used product for a long time.

The specifics of the project is the choise of the **poplar** wood as raw material for **solid wood panels**, which was motivated by the following two main factors.

The first factor is the solid wood panel, made by using natural base materials with little physical modification. Nowadays have been appeared customers, who demand, search and would like to use natural products in their lifes. This demand also results a return to the natural materials in the wood industry.

The second factor was the selection of the base material for the panels. It is also well-known that the solid wood materials with good quality are fewer and fewer and the significance of the wood in the national economy is groowing-up, in other words the demand of the customers for a higher aesthetical appearance and better quality of the final product becomes a big challenge for the technical experts of the wood industry.

The investigation of new application fields of the poplar wood can be a part of the new millennium projects concerning the utilisation of low valued felling materials. The poplar solid wood panel and the research concering the properties of the panel can be a part of this research work.

It is an important part of the economic policy to enlarge the using domains of the poplar wood which occupies 10,3% of the total forest area and 6,6% of the groving forests.

Precedents

In the studied hungarian and international literature the author couldn't find references to the measurement of the strength and elastic properties of the solid wood panels, in spite of the fact that this material is widely used nowadays as base material to the furniture industry.

The knowledge of the strength properties helps to utilise a panel having strength and deformation resistance properties suitable for different structure requirements.

The strength properties of the wood are affected besides by the discontinuity and the ortothrop construction on the different wood defects and other tension causing deficiencies. Increasing the volume, area or any dimension of the specimen results the increasing possibility of the wood defects number, which influence the strength properties. Most of the literatures take into consideration this size-effect to the solid wood on different solicitations (bending, shear, tension, compression load), less literature studied the size-effect of the wood based materials.

The size-effect has to be considered when using data of small specimens to determine the strength of larger structures and has to be established the dimension intervalls when the size-effect could be significant.

The scope of the research

The scope of the research was, recognising the above mentioned problems, to remove the prejudice and omission connected to the poplar wood by choosing as research the investigation of some mechanical properties of poplar solid wood panels made by the author. The results can give the possibility to outline the domains of application of the product, so in that way a better and more economical use of the wood exploitation can be realised.

The scope of the research is to solve the following problems:

- establishing a theoretical relationship between modulus of elasticity of the wood and modulus of elasticity of the solid wood panel, as well as the modulus of elasticity of the veenered solid wood panel
- measuring bending strength and the modulus of elasticity of the veneered solid wood panel and the uncovered panel, appointing the effect of the veneer cover
- the size-effect of the thickness and width to the variation of the bending strength and modulus of elasticity
- the effect of two different adhesive types to the values of the bending strength and modulus of elasticity
- an informative market research concerning the production and sale of the solid wood panel by questioning the panel manufacturers
    - data concerning the final product (species, dimensions, layers, adhesive types, etc.)
    - data concerning the activity of the questioned company (the proportion of solid wood panel production, number of employee, etc.)

- informations refeerring to the panel production technology (production parameters, yield ratio, problems and their solution, etc.)

II. MATERIALS AND METHODS

Base materials

Lumber
- grey poplar (*Populus x canescens*),
- I-214 poplar *(Populus x euramericana 'I-214'*),
- robusta poplar (*Populus x euramericana 'Robusta'*),
- marilandica poplar *(Populus x euramericana 'Marilandica'*).

Veneer
- marilandica poplar *(Populus x euramericana 'Marilandica'*)

Adhesives
- PVAC
- resorcinol based.

Specimens

Testing of wood with:
- specimens with standard dimensions.

Measuring of bending strength and modulus of elasticity using two adhesive types with:
- specimens sliced across the grain from the panel (450 x 25 x 20 mm).

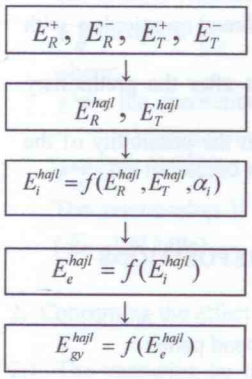
The effect of veenering studied with:
- specimens from panels veneered by the grain,
- specimens from panels veneered perpendicular to the grain,
- controll specimens.

The thickness size-effect studied with:
- specimens with dimensions: 450 x 25 x 20, 16, 12 mm (realised by planning)

The width size-effect studied with: 450 x 10, 20, 40, 60, 80 100 x 20 mm (realised by slicing).

Methods

- the steps of the research is presented on fig. 1.



$E_R^+,\ E_T^+$ -modulus of tension on radial and tangential direction

$E_R^-,\ E_T^-$ -modulus of compression on radial and tangential direction

$E_R^{hajl},\ E_T^{hajl}$ - modulus of bending on radial and tangential direction

E_i^{hajl} - the modulus of elasticity of the i -th element

α_i - the annual ring orientation of the i -th element

E_e^{hajl} - the theoretical value of the modulus of the panel using the deduced formula

E_{gy}^{hajl} - the measured mean value of the modulus of the panel

Fig. 4.1. The deduction steps of the modulus of elasticity

- the basis of the theoretical deduction:
  - the application of the beam elasticity conditions, the specimens are considered poles with straight axis, the loading type is pure bending
  - the slats are placed with different annual ring orientation, the model is a pole with joined stucture, the layers are joined immobilized
  - the deformation is determined by using the Mohr-analogy, in other word studying the connection between the integral form of the loading, the stress and deformation the deflection can be determined as the bending stress
- the basis of the experiments:
  - the tangential and radial tension and compression modulus of elasticity is calculated by the analysis of the deflection-stress graph, the tangential and radial bending modulus is calcualted with the tangential and radial tension and compression modulus
  - the annual ring orientation is calculated on the butt-end
  - the modulus of elasticity of the i -th element (E_i) is calculated by utilising Hankinson's formula and the tensorial theory

- the values of the bending strength and the modulus of elasticity are calcualted by the analysis of the deflection-stress graph and utilising the value of the force of rupture according to standard MSZ EN 310:1999

- the methods of the market research:
  - primary data collection, which means direct questioning with complete sampling
  - the companies received a written request after the preliminary acknowledgement
  - utilisation of standardized data sheet with the possibility of the establishment of importance order

III. THE SUMMARY OF THE RESULTS, PREPOSITIONS

1. Concerning the modulus of elasticity of the solid wood panel:

1.1. A theoretical relationship between the cross-directed modulus of elasticity of the solid wood panel and the modulus of elasticity of the raw material for the panel production has been established.

For even number of slats

$$E_e^{hajl} = \frac{n^3}{4 \cdot \left(\sum_{i=1}^{k} \frac{3 \cdot i^2 - 3 \cdot i + 1}{E_i} + \sum_{i=k+1}^{n} \frac{3 \cdot n^2 + 3 \cdot i^2 - 6 \cdot n \cdot i + 3 \cdot n - 3 \cdot i + 1}{E_i} \right)}$$

For odd number of slats

$$E_e^{hajl} = \frac{n^3}{2 \cdot \left(2 \cdot \sum_{i=1}^{k-1} \frac{3 \cdot i^2 - 3 \cdot i + 1}{E_i} + \frac{12 \cdot n \cdot k - 9 \cdot n - 6 \cdot k + 5}{4 \cdot E_k} + \sum_{i=k+1}^{n} \frac{6 \cdot n^2 - 12 \cdot i \cdot n + 6 \cdot n + 6 \cdot i^2 - 6 \cdot i + 2}{E_i} \right)}$$

where:

E_e^{hajl} - the theoretical value of the modulus of bending of the solid wood panel

E_i - the modulus of elasticity of the i-th element (slat of wood)

E_k - the modulus of elasticity of the middle (k-th) element

n - the number of the slats within the panel

1.2. A very strong correlation is existing between the theoretical values calculated by using formula presented on paragraph 1.1. and the measured values of the cross-directed modulus of elasticity of the solid wood panel, which is $r^2 = 0,82$ for multinomial function.

The form of the multinomial function is:

$$E_{gy}^{hajl} = 0,009 \cdot \left(E_e^{hajl}\right)^2 - 3,384 \cdot E_e^{hajl} + 573,216 \quad \text{(MPa)}$$

where:

E_e^{hajl} - the theoretical value of the modulus of the panel using the deduced formula

E_{gy}^{hajl} - the measured mean value of the modulus of the panel

The relationship is valid from the minimum value of the function (E_e~180 MPa).

2. Concerning the effect of veneering the solid wood panel:

2.1. The veneering by the grain of the panel resulted a decreasing of the cross-directed bending strength with 10-30 %, and 10-40 % of the modulus of elasticity.

2.2. The veneering perpendicular to the grain of the panel resulted an increasing of the cross-directed bending strength by 5,0-6,5 times and the modulus of elasticity by 11-19 times.

3. Concerning the modulus of elasticity of the veneered solid wood panel:

3.1. A theoretical relationship between the cross-directed modulus of elasticity of the veneered solid wood panel and the modulus of elasticity of the raw materials for the panel production has been established.

For even number of slats

$$E_{fe}^{hajl} = \frac{n^3}{4 \cdot \left(\sum_{i=1}^{k} \frac{3 \cdot i^2 - 3 \cdot i + 1}{E_i} + \sum_{i=k+1}^{n} \frac{3 \cdot n^2 + 3 \cdot i^2 - 6 \cdot n \cdot i + 3 \cdot n - 3 \cdot i + 1}{E_i} \right)} \cdot v_m^3 + \frac{2 \cdot E_f \cdot v_f \cdot \left[3 \cdot \left(v_f + v_m\right)^2 + v_f^2\right]}{\left(2 \cdot v_f + v_m\right)^3}$$

For odd number of slats

$$E_{fe}^{hajl}=\frac{n^3}{\dfrac{2\cdot\left(2\cdot\sum_{i=1}^{k-1}\dfrac{3\cdot i^2-3\cdot i+1}{E_i}+\dfrac{12\cdot n\cdot k-9\cdot n-6\cdot k+5}{4\cdot E_k}+\sum_{i=k+1}^{n}\dfrac{2\cdot\left(3\cdot n^2+3\cdot i^2-6\cdot n\cdot i+3\cdot n-3\cdot i+1\right)}{E_i}\right)}{\left(2\cdot v_f+v_m\right)^3}\cdot v_m^3}+$$

$$+\frac{2\cdot E_f\cdot v_f\cdot\left[3\cdot\left(v_f+v_m\right)^2+v_f^2\right]}{\left(2\cdot v_f+v_m\right)^3}$$

where:

E_{fe}^{hajl} - the theoretical value of the modulus of the veneered panel using the deduced formula

E_f - the modulus of elasticity of the veneer

v_f - the thickness of the cover (veneer)

v_m - the thickness of the solid wood panel

3.2. The correlation between the theoretical value calculated by using the formula presented on paragraph 3.1. and measured values in both cases (the cross-grained modulus of elasticity of the panels veneered by the grain and perpendicular to the grain) is r^2=0,46-0,49.

4. Concerning the study of the size-effect:

4.1. The growth of the specimen's thickness with 70 % (1,6 times) resulted a decresing of the cross-grained bending strength with 16-32% and increasing of the cross-grained modulus of elasticity with 28-50%. The correlation between the thickness and the bending strength is r^2=0,58-0,83 between the thickness and the modulus of elasticity is r^2=0,67-0,89 i n the studied interval (12-20 mm).

4.2. The growth of the specimens's width by 10 times resulted an increasing of the cross-grained bending strength with 24-54%, and decreasing of the cross-grained modulus of elasticity with 28-50%. The correlation between the width and the bending strength is r^2=0,60-0,83 between the width and the modulus of elasticity is r^2=0,72-0,95 in the studied interval (10-100 mm).

5. The cross-grained bending strength of the solid wood panel weneered with PVAC adhesive is higher with 5,6-12,3%, the modulus of elasitcity is higher with 6,2-10,3% than the panels weneered with resorcinol. The cause has not been studied, but a possible explanation could be the different specifics of the cross-bond process of the two adhesive type.

6. The difference of the bending strength and modulus of rupture between the four poplar species is significant at 5% significancy level. The robusta poplar has the highest bending strength and modulus of elasticity values then the I-214 poplar, the grey poplar and the marilandica poplar.

IV. THE POSSIBILITY OF THE PRACTICAL UTILISATION

Utilising the deduced formula presented on paragraph 1.1. and 3.1., with the values of the modulus of elasticity of the base material a good estimation can be realised for value of the modulus of elasticity of the solid wood panel, so depending from the loading conditions can be defined the domain of utilisation for the final product.

Comparing the measured value of the bending strength and the modulus of elasticity of solid wood panels and veneered solid wood panels to other wood panels for furniture industry can be seen that in cases when the primary point of view are the value of the bending strength and the modulus of elasticity and a demand appears for natural products, the poplar panels veneered perpendicular to the grain can substitute the chipboards, the veneered chipboards, the flakeboards, the veneered flakeboards, the MDF boards and in some cases can be used instead of the OSB boards.

The case study of the national market research presents a view concerning the final product, the companies, the market and the production technology. The results of the market research can be utilised by the producers, distributors and users, as follows.

The producers can utilize the informations concerning the proportion of the base material and final product, the quantity yield (from dried sawn timber by species: beech 23-29 %, oak 28-38 %, locust 38 %, pine 50 %). According to the assessment, at present the manufacturing in self-supporting factory-units is not economical, because more than 50 % of the purchased raw material is dried sawn timber, or round timber with poor

quality. First of all, the solid wood panel can be an economically additional product for sawmills having drying chambers.

The testing of the technical parameters of the solid wood panels is not realised during the production, not even for the final product. Almost half of the producers are not considering necessary the testing of the product, because the buyers doesn't require any certificate. The information of the customers is related only to the wood specie and the panel dimensions. The producers are considering less of importance to indicate the utilized adhesive type, the resistance to loading and climate conditons, shape stability, durability, strength properties. A detailed certificate which contains all the technical parameters of the product and domain of utilization could rise the confidence and interest refeerring to the product utilization. The absence of the information concerning the strength requirements has the consequence of superfluous use of base material which could be changed by a correct information attached to the product.

Half of the requested companies are thinking that the market of the solid wood panels is growing in some measures, but they are spending slight or nothing to promotion, marketing, don't feel necessary the testing of their products. A consistent, long-term marketing politics can result in a growing interest to the furnitures from solid wood panel.

V. PROCEEDINGS, PRESENTATIONS AND POSTERS

Articles, proceedings

Gergely L. (1999) Nyár-faanyag bútoripari felhasználásának perspektívái Intarzia Faipari szakfolyóirat, Székelyudvarhely, 1999/7 pp.15-18.

Gergely L. (1999) Nyár faanyag bútoripari felhasználásának perspektívái "Tavaszi Szél" '99, Budapest, DOSZ Utókiadvány

Gergely L. (1999) Csavarállóság mérése. in: Roncsolásmentes faanyagvizsgálat. Mérési útmutató. 1999. pp. 25-31.

Gergely L. (2000) Négy nyár fafaj természetes szárítás során megfigyelt nedvességváltozása. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2000/7., pp. 15.

Gergely L. (2000) Négy nyár fafaj természetes szárítás során megfigyelt zsugorodása és fahibái. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2000/8.

Gergely L. (2000) Tömörfa lapok szélesítő toldásai. "Tavaszi Szél" 2000, Budapest, DOSZ Utókiadvány. pp. 37.

Dívós F., Gergely L. (2000) O posibilă nouă metodă de verificare a calităţii – detectarea defectelor de incleiere la panouri din lemn masiv cu ajutorul ultrasunetelor. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2000/9, pp. 13-14.

Gergely L. (2000) Nyár tömörfa lapok szilárdsági jellemzőinek vizsgálata. I. RODOSZ Tudományos Konferencia Kolozsvár (Románia), 2000. március 11-12. Matematika-Informatika-Csillagászat, Műszaki tudományok, Konferenciakiadvány, Kriterion Könyvkiadó, Kolozsvár (Románia), 2001., pp. 101-116.

Dívós F., Gergely L. (2000) Possibility of glue-defect detection in solid wood panels with ultrasound. in: 12th International Symposium on Nondestructive Testing of Wood University of Western Hungary, Sopron, Konferenciakiadvány, 2000., pp. 453.

Gergely L. (2000) Egyrétegű nyár tömörfa lapok vizsgálata „A VEAB régió doktoranduszainak tudományos fóruma", Konferenciakiadvány, Nyugat-Magyarországi Egyetem, Sopron, 2000. november 10., pp. 58-61.

Szopos S., Gergely L. (2001) Fahibák vizsgálata korszerű fizikai módszerekkel. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2001/9. pp. 31.

Gergely L., Szopos S. (2001) Ultrahangos defektoszkópia gyakorlati alkalmazása a faiparban. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2001/10. pp. 25-26.

Gergely L., Szopos S. (2001) Fahibák vizsgálata röntgensugaras rétegvizsgálat segítségével. Intarzia Faipari szakfolyóirat, Székelyudvarhely, 2001/11-12. pp. 48-50.

Gergely L. (2001) Egyrétegű nyár tömörfa lapok minőségvizsgálata beltéri alkalmazásra. Szlovákiai Magyar Doktoranduszok és Fiatal Kutatók I.-II. találkozója. Konferenciakiadvány. Révkomárom, 2001 pp. 62-66.

Gerencsér K., Gergely L. (2002) Quality study of solid wood panels. Case study at the department of solid wood panel production of Sopron Tanulmányi Erdőgazdaság Co. sawmilling factory. Current Approaches to enterprise management. Zbornik z medzinárodnej vedeckej conferencie, Moderné prístupy k manažérstvu podnikov. Trnava, 2002. pp. 281-286.

Gergely L. (2002) Panouri din plop furniruite cu furnir de plop- o nouă materie primă în industria mobilei. Intarzia, 2002/12 pp. 33-35.

Hargitai L., Gergely L. (2202) A mágneses rezonancia tomográfia gyakorlati alkalmazási lehetőségei a fűrésziparban. I. rész: Bevezetés, alapelvek. Faipar, 2002/1. pp. 7-10.

Hargitai L., Gergely L. (2202) A mágneses rezonancia tomográfia gyakorlati alkalmazási lehetőségei a fűrésziparban. II. rész: nedvességtartalom és fahibák vizsgálata MR tomográfiával. Faipar, 2002/2. pp. 16-18.

Gerencsér K., Gergely L., Szabó G. (2002) Egyrétegű tömörfalapok ragasztási szilárdságának vizsgálata kisméretű próbatesteken. Faipar, 2002/3. pp. 24-28.

Presentations

Gergely L. (1998) Beszámoló a nyár faanyag táblásítási lehetőségeiről "A XX. Század műszaki és tudományos megvalósításai" Országos Szakmai Napok Kolozsvár, Faipari Szakosztály, 1998. október 16-18.

Hargitai L, Gergely L. (1999) Nyár faanyag bútoripari felhasználásának perspektívái "A faipar jelene és jövője" VII. Faipari Szaktalálkozó, Székelyudvarhely 1999. április 23.

Gergely L. (2000) Nyár tömörfa lapok szilárdsági jellemzőinek vizsgálata RODOSZ I. Tudományos Konferencia, Műszaki Tudományok Kolozsvár, 2000. március 11-12.

Hargitai L, Gergely L. (2000) Nyárfajták természetes szárítása " Faipar 2000" VII. Faipari Szaktalálkozó, Székelyudvarhely 2000. május 19.

Dívós F., Gergely L. (2000) Possibility of glue-defect detection in solid wood panels with ultrasound 12th International Symposium on Nondestructive Testing of Wood, University of Western Hungary, Sopron, 2000. szeptember 13-15.

Gergely L (2000) Egyrétegű nyár tömörfa lapok vizsgálata „A VEAB régió doktoranduszainak tudományos fóruma" Nyugat-Magyarországi Egyetem, Sopron, 2000. november 10.

Szopos S., Gergely L. (2001) Fahibák vizsgálata korszerű fizikai módszerekkel. Faipari Konferencia, Székelyudvarhely, 2001. május 18.

Gergely L. (2002) Egyrétegű nyár tömörfa lapok minőségvizsgálata beltéri alkalmazásra. Szlovákiai magyar doktoranduszok és fiatal kutatók második találkozója. Komárom, 2002. február 08-10.

Gerencsér K., Gergely L. (2002) Quality study of solid wood panels. Case study at the department of solid wood panel production of Sopron Tanulmányi Erdőgazdaság Co. sawmilling factory. KMaK 2002. Current Approaches to Enterprise Management. Section: IATM-Wood. Tranava, 4-6. April 2002.

Hargitai L, Gergely L. (2002) Nyár tömörfa lapok tulajdonságainak vizsgálata során kapott kutatási eredmények. „A Magyar Tudomány Napja" Nyugat-Magyarországi Egyetem, Sopron, 2002. november 28.

Posters

Gergely L. (1999) Nyár faanyag bútoripari felhasználásának perspektívái "Tavaszi Szél" Posztergalária, Budapest, 1999.

Gergely L. (2000) Tömörfa lapok szélesítő toldásai "Tavaszi Szél" Posztergalária, Gödöllő, 2000.

Divós F., Gergely L., (2000) Possibility of glue-defect detection in solid wood panels with ultrasound 12th International Symposium on Nondestructive Testing of Wood University of Western Hungary, Sopron, 2000. September 13-15.

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