Study on the wettability of Pannónia poplar (P.x euramerica Pannónia) from two Hungarian plantations: Győr and Soltvadkert

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ABSTRACT

In Hungary large stocks of plantation poplar reached their cutting age. In frame of an OTKA project a comprehensive study of psychico-mechanical properties of both the poplar samples and poplar glulam has been conducted to evaluate the suitability of Pannónia poplar (P.x euramerica Pannónia) hybrid, from different plantations, for load bearing applications, especially for glulam production. The present paper is a parttime report of the project, on the wettability of Pannónia poplar samples originating from two Hungarian plantations: Győr and Solt (Soltvadkert), with the main question, that are the different sites with significant influence on the properties of the boards? Samples from the two plantation sites have been collected from different trunks and laboratory samples with tangential cut, have been prepared by planing. Wettability has been measured by sessile drop method, both with distilled water and diiodo-methan, using a PGX Goniometer. Surface tension has been calculated according to the Fowkes method.

1. INTRODUCTION

The spruce and other coniferous species generally involved in glulam production usually manifest densities between a 300-700 kg/m³. In Hungary in current years large stocks of plantation poplar reach the cutting age, and improving its utilization became a major goal, as poplar is first of all used by the paper industry. Pannónia poplar (P.x euramerica Pannónia) has been developed by F. Kopecky in 1961, in a forestry research center at Sárvár, Hungary. It is a fast growing species similar to the I-214 Italian poplar (P.x euramerica ,,I-214”), but its density is similar to the Robust poplar (P.x euramerica robust). The Pannónia poplar is the most frequent planted poplar hybrid nowadays (Molnár 2004). Its growth properties make it suitable for short, medium or long term (10-25 years) cultivation as well (Dr. Halupa-Dr.Tóth 1988).

The Hungarian poplar species can be classified in 3 density classes: very low density: ρ ≤ 360 kg/m³, semi low density: ρ= 361-400 kg/m³, not that low density ρ ≥ 401 kg/m³. The Pannónia poplar hybrid, regarding its density, belongs to this latest class. As Pannónia poplar (P.x euramerica Pannónia) has a density around 411 kg/m³, raises the question whether would it be suitable for glulam production.

In frame of OTKA K 116216 project a comprehensive study of psychico-mechanical properties (including the analysis of MOE, MOR, bending strength, compressive strength, etc.) of both the poplar samples and poplar glulam has been conducted to evaluate the suitability of Pannónia poplar (P.x euramerica Pannónia) hybrid, from different plantations, for load bearing applications, especially for glulam production.

The aim of the actual study is to find answer whether is the plantation with a relevant influence on the wettability of the boards and furthermore are there sites which could be favored due to the good wettability (and thus a supposed good adhesion) of their samples.

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2. MATERIAL AND METHOD

Pannónia poplar boards have been collected from different poplar trunks of two plantations: Győr and Solt and kiln dried to 8±1.2% MC. The boards have been planed and 20 defect free samples of 400 mm x 70 mm x 20 mm size, with tangential cut surface, have been prepared. All the samples have been conditioned for 30 days prior to measurements at 20±2°C temperature and 65% RH (Fig. 1).

After conditioning the samples have been freshly planed in order to enable the detection of the contact angle of the freshly machined surface, as in practice freshly machined surfaces are glued in course of glulam production. Although the samples have been prepared in the same way, their surface roughness also has been measured, to enable an eventual comparison of these results with other researcher’s data.

Surface roughness of the samples has been determined based upon 5 consecutive stylus tip measurements, performed on each sample, along a 17.5 mm trace, using a Mahr Perthen SP3 instrument, equipped with a stylus, with diamond head of 2 µm radius. Both Rₐ and Rₚ roughness parameters, considered widely used to describe the status of the surface (Magoss, 2000) have been calculated.

Fig. 1 Conditioning the Pannónia poplar samples

Fig. 2 Goniometer PGX equipped with dozier
Contact angle of the surfaces has been measured using a PGX Goniometer (FIBRO SYSTEMS AG, Sweden) (Fig. 2), dynamic method, and a 5 µl test liquid volume. The contact angle has been determined in the 1st second after release, as by this time the drop consolidated and 3 measurements have been performed on each sample. Contact angle has been determined both with distilled water (DW) and with diiodo-methane (DIM). The measurements have been performed with two different tube sets for distilled water and diiodo-methane.

In order to evaluate wettability, Young’s equation (Eq. 1) has been considered and the Fowkes model (Eq. 3) has been used for surface tension (also quoted surface free energy) calculation.

\[
\gamma_{SL} + \gamma_{SV} \cos \theta - \gamma_{SV} = 0
\]  
(Eq. 1)

\[
\gamma_{SL} + \gamma_{SV} = \gamma_{SV}
\]  
(Eq. 2)

\[
W_{sd} + W_{sl} = \gamma_{s} \times (1 + \cos \theta)
\]  
(Eq. 3)

\[
(y_{sl}^{f})^{\frac{1}{2}} \times (y_{sl}^{p})^{\frac{1}{2}} + (y_{sl}^{f})^{\frac{1}{2}} \times (y_{sl}^{p})^{\frac{1}{2}} = \frac{y_{s} \times (\cos \theta + 1)}{2}
\]  
(Eq. 4)

\[
y_{sl}^{d} = \frac{y_{s} \times (\cos \theta + 1)^{2}}{4}
\]  
(Eq. 5)

According to Fowkes the surface tension of the solid results as the sum of the polar and dispersive component

\[
y_{s} = y_{sl}^{p} + y_{sl}^{d}
\]  
(Eq. 6).

First the calculation of the dispersive component of the surface tension of the solid has been performed with a liquid which manifests dispersive forces, and in a second step the polar component has been calculated as well. Contact angle measurements thus have been performed both with distilled water (as polar component \(y_{sl}^{p} = 46.4 \text{ mN/m}\)) and diiodo-methane (dispersive component 50.8 mN/m).

3. RESULTS AND DISCUSSION

The results of the surface roughness measurements, the contact angle measurements (performed with distilled water and diiodo-methane) and the calculated values of the surface tension are represented in Table 1.

|       | Ra (µm) | Rz (µm) | Contact angle (DW)/SD | Contact angle (DIM)/SD | Surface tension (mN/m) |
|-------|---------|---------|------------------------|------------------------|------------------------|
| GYOR  | 7.15/1.14 | 53.52/11.36 | 72.32/4.51 | 31.08/7.27 | 47.17 |
| SOLT  | 8.2/2.37 | 56.38/15.47 | 68.58/4.88 | 28.17/5.11 | 49.97 |

Table 1. Results of the Pannónia poplar samples from two plantations: Győr and Solt

The results of the roughness measurements indicate that whilst the average roughness Ra is not significantly different, the Rz values show significant difference (t test, p=0.05). Since Rz is more sensitive to the real status of the surface than Ra (Csíha. 2003), and since the samples have been machined and treated in the same way, this difference in the roughness values suggests that there is an effect of the plantation on the quality of the timber. The samples have been investigated under microscope also, but no relevant difference in the anatomical structure could be identified. In the same time the samples originating from Solt, when exposed for short time soaking in water, manifested higher swelling than the ones from Győr, leading to the conclusion, that the differences in their anatomical structure need further investigation.

The contact angle values measured with distilled water are roughly two times higher than the one measured with diiodo-methane, and with both test liquids show significant difference (t test, p=0.05) between plantations. The higher
the contact angle the worse the wettability of the surface is. The samples from Győr show higher contact angle both with distilled water and diiodo-methane, than the samples from Solt, indicating that the samples from Solt have better wettability. The trend of the contact angle’s behavior has been the same with both test liquids: in case of Solt samples both the contact angle of distilled water and the contact angle of diiodo-methane have been lower than the same contact angles of Győr samples. The surface free energy calculated according to the Fowkes model has been also significantly different for the two plantation samples: the samples from Solt resulted significantly higher (t test, p=0,05) surface tension than the samples from Győr. According to the Young-Dupré equation, high surface tension of the solid indicates good wetting. The better adhesion with the same adhesive can be expected on samples originating from Solt plantation, but it is still a question how these results relate to the values of coniferous species frequently used in glulam production. In a parallel study F.Z. Brahmia et al. (2019) when investigating the wettability of some wood species with different fire retardants, published data on the contact angle of planed Scots pine surfaces, measured with distilled water, and they have found that the average contact angle is 63,7o. This value is significantly lower than the contact angle values measured on Pannónia poplar samples originating from Győr and Soltvadkert (72,32 and 68,58), leading to the conclusion, that Scots pine’s wettability (and consequently the expected adhesion) is better than the wettability of the Pannónia poplar samples originating from the two investigated sites.

As these preliminary results show uncertainty regarding the suitability of Pannónia poplar samples for glulam production, it is necessary to test the glulam performance itself, with known load bearing adhesive. On the other hand the surface tension of these boards also may need to be increased (by choosing a different machining type (for ex. sanding), or by chemical pretreatment, for example by nano-agents etc.).

4. SUMMARY

Wettability of Pannónia poplar samples originating from two different Hungarian plantations Győr and Soltvadkert has been investigated in order to evaluate their suitability for glulam production. The samples from Győr show higher contact angle both with distilled water and diiodo-methane, than the samples from Solt, indicating that the samples from Solt have better wettability. The surface free energy calculated according to the Fowkes model has been also significantly different for the two plantation samples: the samples from Solt resulted significantly higher (t test, p=0,05) surface tension than the samples from Győr, indicating that the site of origin may have a significant effect on the quality of the boards. The better adhesion with the same adhesive can be expected on samples originating from Solt plantation. In the same time both sample batches manifested higher contact angle values measured with distilled water than the same way treated and machined Scots pine samples, meaning that their expected adhesion doesn’t reach the adhesion of Scots pine, a frequently used species in glulam production. As these preliminary results show uncertainty regarding the suitability of Pannónia poplar samples for glulam production, it is necessary to test the glulams performance itself, with known load bearing structural adhesive. On the other hand the surface tension of these boards also may need to be increased (by choosing a different machining type (for ex. sanding), or by chemical pretreatment, for example by nano-agents etc.).

ACKNOWLEDGEMENTS

We acknowledge the support gained from the NKFIH - National Research, Development and Innovation Office Hungary, within the frame of „ OTKA 116216: Complex analysis of the physico-mechanical and surface-physical properties of wood material with low density”.

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Lathe Checks Formation, Measurement and Effect on Plywood Quality - European Hardwoods

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ABSTRACT

Lathe check formation and measurement have received a lot of attention in the past. Reliable results about the lathe checks properties have been obtained mainly by using microscopy techniques, measuring the check depth and the frequency. However, microscopic measurements are time-consuming and laborious. Moreover, only a limited amount of specimens could be evaluated during the study, which often leads to high dispersion of obtained results.

In order to automatize the lathe check depth and frequency measurement several methods have been introduced, e.g. ultrasound, acoustic, however these methods do not give high quality information about the check properties. During the present study, the SMOF was used in order to measure high quantity of samples and evaluate the effect of processing parameters on check formation and properties. This method will enable to evaluate remarkable amount of checks immediately after the peeling process, from the wet veneer at microscopic level.

In this study the effect of peeling temperature and compression ratio on lathe checks properties were evaluated from European hardwoods. The results of the study show that at higher temperature, shallower and more frequent checks are formed compared to lower temperature. Moreover, higher compression ratio produced veneer with shallower and more frequent lathe checks. The results also reveal that the rays could affect the propagation direction of lathe check in veneer, hence the anatomical structure plays remarkable role in check formation.

1. INTRODUCTION

In veneer-based products, adhesive bond formation and performance highly depends on processing parameters, but also the quality of used veneer plays crucial role. It has been shown, that veneer and veneer-based products quality is affected by the lathe checks properties, which in turn are affected by processing parameters during soaking and peeling. Generally, at higher soaking temperature during peeling process the formation of deep lathe checks will be reduced (Meriluoto 1965; Dupleix et al.2013; Rohumaa et al. 2018). This will improve the integrity of the veneer (Rohumaa et al. 2016a), bonding quality (Rohumaa et al. 2013, 2014, 2016b) and veneer-based products shape stability (Blomqvist et al. 2014) and mechanical properties (Pot et al. 2015). Moreover, positive effect of higher soaking and peeling temperature is not the only way to reduce the lathe checking of veneer, but also it has been noted that the compression ratio affects the depth and frequency of lathe checks (Lutz 1974, Rohumaa et al. 2018). According to available literature, the lathe check phenomenon is almost constant and periodical for homogeneous wood species (Denaud et al. 2012; Palubicki et al. 2010). It is also shown, that lathe check depth and frequency correlate with each other, where the deeper checks tend to be less frequent than shallower checks (McMillin 1958; Denaud et al. 2007; Palubicki et al. 2010, Rohumaa et al. 2018). However, some studies show opposite results (Darmawan et al. 2015). These contradictions in published results highlight that there are still open questions about the lathe check formation and their role on product quality. The variation of results and contradiction in literature could be caused by many factors, e.g. different measuring techniques for lathe checks, processing parameters and anatomy of wood species.

Lathe check formation and measurement have received a lot of attention in the past as well as more recently (Denaud et al. 2007, 2012; Tomppo et al. 2009; Palubicki et al. 2010; Dupleix et al. 2013; Antikainen et al. 2015; Darmawan et al. 2015; Rohumaa et al. 2018). Mostly the lathe check depth and the frequency have been measured
under the microscope from dry veneer. However, microscopic measurements are time-consuming and laborious. In order to automatize the lathe check depth measurement process, the checks have to be measured from the green veneer since accurate measurement of checks from the dry veneer is complicated due to the waviness of the veneer (Tompson et al. 2009). During this study a semi-automated lathe checks measurement device (SMOF), described by Palubicki et al. (2010), was used. SMOF will enable to measure precisely all checks and their parameters through the whole mat of peeled veneer. Moreover, this method also provides information on veneer microscopical structure.

This paper shows how lathe checks are formed on birch and beech during veneer processing and how anatomical structure affects lathe check formation.

2. MATERIALS AND METHODS

2.1. WOOD MATERIAL

In this paper, European beech (Fagus sylvatica L.) and Silver birch (Betula pendula Roth) logs were used. The material was selected carefully and only material without visual defects was used. The logs were soaked and peeled at different temperatures from 20 to 80°C. This range of temperature corresponds to the common distribution also used in industry. Following soaking, the logs were immediately peeled at different compression ratio (0, 5, 10, or 15%). Immediately after peeling, veneer ribbons were cut and the checks were measured.

2.1. MEASUREMENT METHODS

In LaBoMaP a specific apparatus has been developed in order to measure the lathe check parameters, called SMOF (Système de Mesure d’Ouverture des Fissures) and this apparatus is described more in detail by Palubicki et al. (2010). The SMOF (Fig 1.) enables to measure automatically and precisely the position and the depth of a large number of checks by slightly bending the veneer on a wheel with previously approved diameter.

Figure 1: The SMOF (optical lathe check measuring system). LVDT is the linear variable differential transformer.
3. RESULTS AND DISCUSSION

The lathe check depth is highly influenced by compression ratio and by soaking temperature, which softens the logs prior peeling process. Higher compression ratio will form shallower checks, which could be sometimes hard to detect visually (Fig 2). The results show (Fig. 2), that at higher soaking temperature and higher compression ratio checks are visually almost undetectable. This could cause often non-periodical detection of checks. At lower soaking temperature and at higher compression ratio deeper and periodical checks are formed as demonstrated in Fig 2. These images also support previously described finding, where some of the checks could not be revealed for visual or automatic detection and therefore, increase variability in measured results.

Figure 2: The effect of soaking temperature and compression ratio on lathe check properties. Where the compression ratio varies from 0% to 15% of the veneer thickness for a) soaking at 50°C, b) soaking at 60°C, c) soaking at 70°C, d) soaking at 80°C (Rohumaa et al. 2018)
The comparison of obtained results with other studies conducted under similar conditions (Dupleix et al. 2013; Rohumaa et al. 2016a), shows that the rise of soaking temperature from 50°C to 80°C will have a decreasing effect on lathe check depths, which is approximately 15-20%. Interestingly, soaking temperature has a much more significant effect on birch than on beech veneer by decreasing the depth of lathe checks approximately by 30-35% in the same range of soaking temperature (Dupleix et al. 2013; Rohumaa et al. 2016a). The reason might be found in the different anatomical structures, where beech has much higher volume of rays (approx. 20%) compared to birch (approx. 10%). According to literature, rays could resist crack growth in tangential direction, but act as weak planes in radial direction (Boatright and Garrett 1983; Ashby et al. 1985). This is also supported by present study, where the lathe checks will more favorably propagate along the rays at lower temperature (Fig. 3a) and will pass through the rays at higher temperature (Fig. 3b). This weaker plane caused by rays in radial direction could also explain the deeper checks compared to the results on birch wood obtained by Dupleix et al. (2013) and Rohumaa et al. (2016a).

![Figure 1: The effect of temperature and anatomical structure on lathe check propagation. Arrows show check propagation a) along and b) through the ray (Rohumaa et al. 2018).](image)

4. CONCLUSIONS

The results of the study show, that the higher the soaking temperature the shallower and more frequent lathe checks are. However, the effect of compression ratio during peeling is much greater than the effect of soaking temperature on veneer checking. The results show, that the higher compression creates veneer with shallower and more frequent checks.

The results also show that the anatomical structure of wood material most probably will have effect on check formation. In beech veneer, lathe check propagation is affected by rays, which resist crack growth in tangential direction, but act as weak planes in radial direction. Moreover, in birch veneer lathe checks are uniform and not affected by rays to such an extent.
ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the Bourgogne Franche-Comté region and thank the Xylomat Technical Platform from the Xylomat Scientific Network funded by ANR-10-EQPX-16 XYLOFOREST.

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