

PERFORMANCE OF MULTI-LAYERED WOOD FLOORING ELEMENTS PRODUCED WITH SLICED AND SAWN LAMELLAS

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Abstract:

The performance of multi-layered wood flooring produced with sliced and sawn top-layers was evaluated in this study. Slicing checks side orientation was evaluated by pressing the veneers with checks side oriented upwards and/or downwards the flooring surface. The performance of produced flooring boards were evaluated using a climate chamber test with regard to the dimensional stability (SS-EN:1910) and appearance. Delamination resistance was tested according to the ANSI delamination testing procedures. Results of the climate chamber test revealed immersing of a high amount of slicing checks to the surface of parquet boards after the first dry cycle. Checks tend to be larger around knots. Checking was qualitatively assessed as being more severe on the boards with checks side up. Dimensional stability was assessed to be slightly better for the sliced top-layers compared to the sawn ones. Parquet elements produced with veneers checks side facing downwards had poor delamination resistance. The best results regarding delamination resistance was achieved when using sliced lamellas with the checks side facing up.

Key words: *parquet; slicing; checks; wood flooring; dimensional stability.*

INTRODUCTION

Wood flooring manufacturing represents an important share in the wood products industry. In Europe, the wood flooring production was estimated at 86.6 Million. m² (FEP 2018), showing a stable development in the recent years. However, wood material was identified to hold only about 5% of the Europe's flooring market (FEP 2018). Wood flooring represent a rather low value-added product; therefore, the largest share of production costs is related to the raw material costs. Initial costs were identified to be the main factor affecting customer choice in new flooring investment (Jonsson 2005).

Multi-layered type dominates the wood flooring market with 81% share (FEP 2018) and this trend is expected to grow. Its structure represents a cost-effective utilization of the raw material and better technical capabilities e.g. dimension stability, weight. Parquet is a multi-layered flooring type that enables the "real wood" value of the product due to its specifications. According to (EN SS-EN:13756), parquet is a multi-layered flooring element with the top-layer thickness of min. 2.5mm. For the production of parquet top-layers, few species are utilized due to several reasons such as aesthetics, sustainable harvesting, species mechanical properties and/or availability. It is widely known that oak (*Quercus* spp.) is the most common top-layer species for parquet production cumulating 80.6% of all used species (FEP 2018). This aspect implies strong competition when sourcing the raw material due to limited availability. In consequence, flooring manufacturers challenge is to ensure an optimal utilization of the raw material.

Parquet top-layers processing starts with sawing of blocks (approximate thickness 80mm) into lamellas with thickness ranging from 3 to 5mm. The volume of sawdust is related to the width of the saw kerf. The amount of sawdust can represent a high proportion of the block when so many cuts are produced. Consequently, the high value of the valuable raw material is wasted. Many industries but also academics have sought alternatives for low/no kerf cutting and one of the most promising technique was found to be flat slicing (Peters and Patzer 1976, Johnston and Stlaurent 1978). Veneer flat slicing is a kerfless cutting technique that enables production of veneers with longitudinal section appearance. This is particularly important for the products aesthetics and mechanical properties. To produce flat sliced veneers, wood flitches are softened using hydro-thermal processes e.g. hot water soaking or steaming. Subsequently, flitches are cut into veneers using vertical and/or horizontal slicing equipment. The continuous cutting of a veneer slice is possible due to compression applied using a pressure bar on the outside part of the flitch (Lutz 1977, Kobayashi et al.1995).

Although, slicing can involve high material yield compared to traditional sawing, the quality of the produced veneers inherits specific defects. During slicing, the knife produce high compressive forces in front of the cutting edge. That together with the bending stresses applied by the knife face creates tension strain that leads to ruptures in a direction normal to the cutting direction (Marchal et al. 2009). These ruptures are generally called micro-checks. Depending on the veneer cutting type, peeling or slicing, micro-checks can be classified as lathe and/or slicing checks. The veneer face where checks are initiated is called the loose side or the open side while the opposite face is called the closed or the tight side (Lutz 1977).

The effect of lathe checks on the performance of wood products has been shown increasing interest over the last years e.g. mechanical properties of laminated veneer lumber (LVL) (Pot et al. 2015, Purba et al.2019), plywood bonding strength (Rohumaa et al. 2013), furniture veneered panels checking (Cassens et al. 2003). The latest described the issue of the veneered furniture checking and provided recommendations regarding technological aspects of processing veneered furniture panels.

To our knowledge, few studies grasp the influence of flat sliced veneers quality on the wood products realisation. Therefore, our aim with this study was to explore the effects of flat-sliced veneers as top-layer material for the performance of multi-layered parquet flooring elements. This is important in order to understand the feasibility of sliced lamellas for flooring production.

OBJECTIVE

The objective of this study was to evaluate the performance of multi-layered parquet elements produced using sliced and sawn top-layer lamellas. The main evaluation criteria were concerning the appearance, dimensional stability and delamination resistance of parquet elements. Another objective with this study was to evaluate if there is any effect of the veneer checks side orientation on the parquet quality. This is an important step in understanding the possibilities and limitations of enabling the slicing technique for parquet top-layer production.

MATERIAL, METHOD, EQUIPMENT

The material for parquet samples top-layer was oak. Eight sliced and eight sawn lamellas (control group) pre-formatted with the nominal dimensions of 2400x200x4.5mm were produced, dried and stored in a conditioning chamber to obtain a $6\pm0.3\%$ MC. Lamellas were then crosscut and glued onto a core-layer. The core-layer was composed from a Norway spruce (*Picea abies* L.) veneer, with nominal thickness of 2mm that was laminated onto a middle-layer composed of Scots Pine (*Pinus Silvestris* L.) strips of 10mm thickness running across the length of the element (Fig.1). For the checks side effect evaluation, half of the sliced top-layer lamellas were pressed with the open side on the surface of the parquet element and are further referred as "open-side", and the other half with the open side facing on the core and are further referred as "closed side".



Fig. 1.
Structure and dimensions of multi-layered parquet elements produced in this study.



Fig. 2.
Technological operations for manufacturing of parquet elements used in this study.

The sequence of technological operations for parquet samples manufacturing used in this study is presented in the Fig.2. For a homogeneous pressing, lamellas thickness was measured and were assigned into three batches. Gluing was done using two-component urea-formaldehyde (UF) adhesive applied using manufacturer instructions. Pressing was done using a heat press with temperature 106°C and applying a pressure of 236 kPa/m² for 120 sec. Afterwards, parquet boards were left to cool down for 24 hours. Following a rough sanding, a wood putty was applied in order to fill the large cracks and holes. After curing, parquet elements were sanded using progressive displaced band sanding belts with the final grit size of P120. Parquet elements were finished with a transparent water-based lacquer using ultraviolet curing. Last processing step was profiling on the sides of parquet elements with the special patented tongue-and-groove joint that enables the adhesive-free connection of flooring elements.

Testing of the flooring performance involved visual inspection before and after a climate-chamber test, dimensional stability and delamination test. Visual inspection involved both visual and tactile inspection of parquet boards for visible defects.

For the climate chamber test, parquet elements were center-cut into 1.2m long specimens and assembled into three samples as in Fig.3 (SS-EN:1910 2016) following the category of testing material i.e. open side, closed side and sawn. The climate chamber test represented a five-cycle program simulating two years of product exposure in an indoor environment. Details of the climate test are presented in Table 1. The climate conditions are set according to the Northern Europe indoor conditions requirements.

Measurements and visual inspections were performed after all climate test cycles except second moistening cycle. Moistening cycles are believed to not influence the outcome of the main regarded defect, slicing checks. Dimensional stability was tested according to the specifications in (SS-EN:1910 2016) in regard to dimensional changes (length and width), cup and bow of the parquet elements. Accordingly, dimensional change (ΔD) was calculated using equation (1):

$$\Delta D = \frac{D_f - D_i}{D_i} \times 1000 \text{ [mm/m]} \quad (1)$$

where: D_f is the dimension after the climate cycle;
 D_i is the dimension before climate cycle.

Delamination test was performed using an adapted method of the ANSI bonding test (ANSI/HPVA EF:2009). Five specimens per parquet board were extracted with nominal dimensions of 50.8x127 mm (width x length). The test was based on three cycles. One cycle consisted of four hours water soaking at temperature 24±3°C followed by nineteen hours oven drying at 51°C. According to the test, a delamination represents an opening with a continuous length of 50.8 mm, minimum depth of 6.4mm and width of 0.08mm. Therefore, specimens were checked after the first and third cycle using a 0.08mm feeler gauge. Delamination was considered between the top and middle layer only. In order to verify the experimental results, the delamination test was repeated on smaller specimens with nominal dimensions of 95x50.8mm (length x width).

Table 1

Cycles parameters for the climate-chamber

Cycle	RH[%]	T[°C]	Period
Conditioning	40	23	1 week
1	80	23	2 weeks
2	20	23	2 weeks
3	80	23	2 weeks
4	20	23	2 weeks

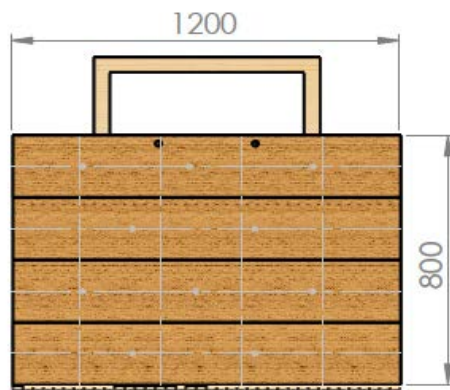


Fig. 3.
Climate-chamber test sample consisting of four parquet elements applied on a wooden frame; grey lines indicate the axes for the measurement of length and width; grey points represent cupping measurement points.

RESULTS AND DISCUSSION

Observations regarding the manufacturing process of parquet elements indicate that sliced top-layer strips could be used in a technological parquet manufacturing process. However, sliced top-layer lamellas containing knots close to the edge and sapwood presented visible defects such as fibres and/or putty tearing (Fig.4). Therefore, cannot be recommended for the utilization in the manufacturing of flooring elements without any special treatment. Having control over knots position within the slicing block is therefore crucial. Some parquet samples produced with sliced top-layers contained insect attack (Fig.4) and are not acceptable for product realisation (SS-EN:13489 2017).



Fig. 4.
Example of edge tear out due to edge-filled knots (left) and sapwood (right).

Beside general inspection and wood quality aspects, the main difference between the two groups of material, sliced and sawn, was the emerging of slicing checks on the surface of sliced top-layers (Fig.5). Checks appeared after first dry cycle (RH 20% T 23°C) and enhanced after the second one. Surface checking was more severe around knots (Fig.5). This was probably because of large induced checks due to sudden changes in fibres orientation. Differently, parquet elements build with sawn top-layer lamellas maintained a smooth and check-free surface after all climate-chamber cycles.



Fig. 5.
Slicing checks on the surface of clear wood (left) and around knots (right).

Checks variation in size and shape was assessed as rather large, therefore, it was decided that their counting as suggested by (Cassens et al. 2003) may give limited information. The qualitative evaluation of parquet samples pointed out that checks are usually easier to detect by touching than by visual inspection. As a result, it can be inferred that within parquet elements with sliced top-layers, closed side of the lamellas tend to have less sharp, convex shaped checks when compared to the open side. Lamellas open side checking may impose even safety issues of the product while checking on the closed side may produce slight unpleasant feelings due to some roughness. This is probably due to the fact that emerging surface checks in the case of closed side samples, are the checks bottom-ends that are rather narrow. Differently, when using veneers with open side, sanding of the top layer exposes the middle-top part of the checks that is considerably wider than their tips. This aspect is represented in Fig.6 by showing checks distribution for a section of sliced veneers viewed under microscope. From microscope inspection it can be seen that slicing checks run generally 70-90% of the lamellas thickness. For both sample groups, open and closed side orientation of the lamellas, with the given sanding thickness, the final surfaces before the finishing step contained surface checks. It is therefore interesting to further research the effect of checks depth on the checking behaviour of finished products when checks are bellow the surface of finishing layer.

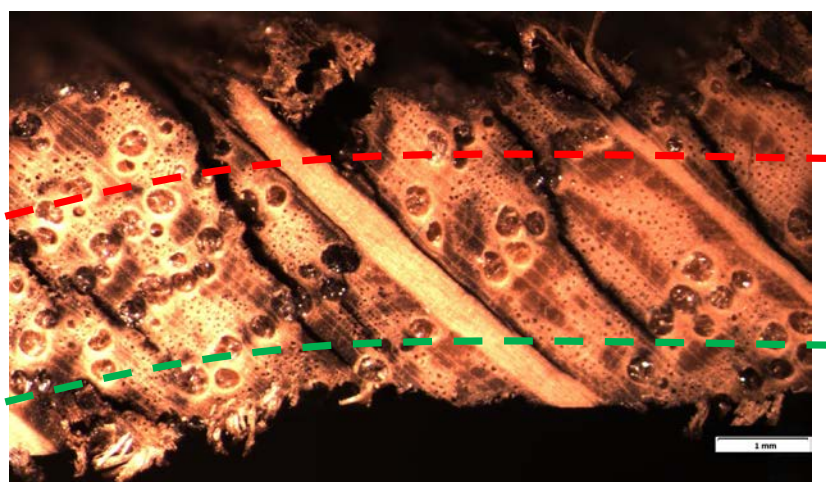


Fig. 6.
A section of sliced veneers used in this study; dashed lines represent approximate end surfaces of the parquet top-layers when using open side up (red) and closed side up (green).

This can be achieved with an optimization of the slicing process that involves low checks depth i.e. depth of checks to be max. 50% of the veneer thickness. The most important aspect is that checks once opened will interact with external agents such as liquids and will deteriorate faster the aspect of the surface finish of the parquet boards. As a result, neither group of the tested sliced lamellas could be accepted for flooring products realisation.

Results of the dimensional stability are presented in Fig.7. Lengthwise to the grain dimensional change presented in Fig.7a shows insignificant differences between the testing samples. A sensitive parameter for flooring performance is the dimensional change in the width of the element. A high expansion coefficient together with poor installation procedures can lead to large product failures. We can observe in Fig.7b, that flooring elements produced with sliced top-layer lamellas have slightly lower width variation when compared to sawn elements. One reason could be that the wood material from the two groups come from different growth areas and might have inherited different levels of anisotropy i.e. swelling/shrinking ratio. The results presented in the Fig.7c-d show the changes in cup and bow of the parquet elements. Sliced elements group, independently of orientation of the slicing checks, had a better dimensional stability when compared to sawn-based top-layers flooring elements regarding these parameters. Beside differences in swelling/shrinking ratio of material with different growing conditions, another reason could be that there are changes in mechanical behaviour of the top-layers due to the induced slicing checks. Checks might release part of the lamellas shrinking/swelling strain, therefore, sliced lamellas would deform to a lesser extent when compared to sawn elements.

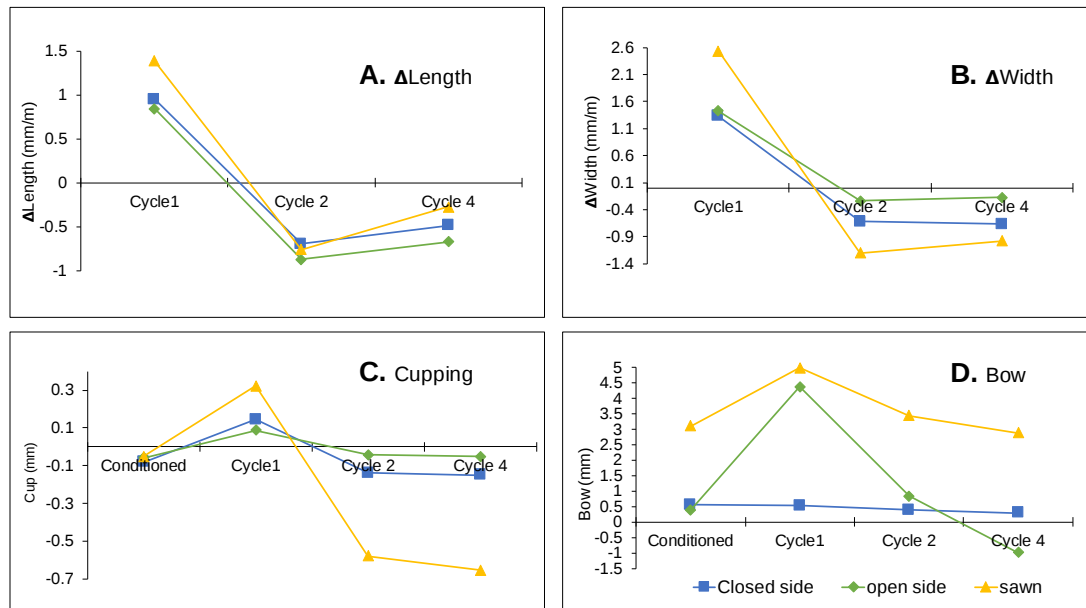


Fig. 7.

Dimensional stability results for the parquet elements produced with sliced and sawn top-layers; A – Length variation, B – Width variation, C - Cupping, D – Bow.

Delamination results are represented in the Fig.8. Parquet specimens produced with sliced top-layer lamellas have different delamination behaviour depending checks side orientation. Closed side produced specimens, that represent common recommendation of the veneer manufacturers, showed a rather poor delamination resistance. One possible reason for this could be the high roughness due to checking behind the knife edge. This can be also noticed in the Fig.6. Considering the standard specification that flooring elements must have minimum 85% of the specimens passing the test. Parquet specimens produced with sliced top-layer lamellas with the open side as the lamination face showed evident limitations in using such material for flooring manufacturing. Differently, lamellas produced with the open side facing the surface of the element had superior delamination resistance even compared to sawn-based samples. With the assumption that slicing checks can be significantly reduced, the use of sliced lamellas in such way can be worth considering. Due to the industrial environment of the sample manufacturing tests, this aspect should be further evaluated under more controlled conditions. This aspect can be of great importance for laminated structures with structural purposes as an accidental lamination of two veneers with open sides may have strong negative impact on the performance of the laminated products quality.

CONCLUSIONS

The current study evaluated the qualitative aspects of multi-layered flooring produced with sliced and sawn top-layer lamellas. Results show significant limitations when using sliced top-layers for the parquet manufacturing due to the emerging slicing checks on the products in service. Regarding checking behaviour, flooring elements are recommended to be produced with the top-layer lamellas closed side facing the surface. However, delamination results performed in this study showed that for the same structure delamination resistance is rather low. In this context, the feasibility of using slicing lamellas for flooring manufacturing can be assessed as limited but it is open subject for further veneer slicing quality optimization. Beside theoretical raw material yield gain, dimensional stability were found to be important advantages of using sliced top-layers for multi-layered wood flooring manufacturing.



Fig.8.
Rate of specimens passing the delamination test depending on the top-layer material; the table represents raw test results.

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