REMOISTENING OF THE WOOD BEFORE PLANING -A METHOD FOR IMPROVED SURFACE QUALITY?

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ABSTRACT
It is beneficial if the machining of wooden products is done at a moisture content equal to the climate the product is meant to be used in. For indoor products in central heated houses such moisture content is about 5-10%. For planing this is often a too low moisture content showing an increased risk of poor surface quality due to severe torn grain. Contrary to this too high moisture content will result in a fuzzy grain surface and problems with swelling and shrinkage of the product.

The roughness of a machined wooden surface is affected by a number of different parameters like cutting tool geometry, machine settings and wood structure. The latter is the hardest to control since the surface quality is a result of the local combination of density, grain direction and moisture content. The larger the variation in wood features the more difficult it is to find a combination of tools and machine settings that will give a high surface quality.

This study showed that by wetting the surface before machining, in this case planing, the average surface quality could be increased. No time dependences could be shown, wetting short before planing did show as good improvements as wetting treatment for 30 minutes or more.

The study was based on a total of 120 test surfaces of Scots pine (Pinus silvestris L.). In order to maximize the variation in grain angle and density variations the test surfaces contained both clear wood as well as green knots.

Keywords: Planing, wood, surface roughness, torn grain, fuzzy grain

INTRODUCTION
The surface quality of a planed wood product is a very important feature for many wood products, especially if the product will be visible like in furniture or interior decorations. The quality of a planed wood surface can be described as how rough it appears to be visually as well tactiley. But the mechanisms behind the planing result is a complex combination of a large number of parameters that can be divided into three major categories; wood features, tool geometry and machine settings. Where the two latter are chosen after the type of wood to be machined in order to avoid torn and splintered wood surface or improperly cut wood fibers resulting in a fuzzy, velvet like, surface.(1)

According to Aguilera and Martin, (2) the most important parameters are; specie, grain orientation, cutting depth, feed rate and cutting speed. But there are others like; tool geometry, sharpness of the cutting edge and moisture content of the wood that under specific conditions has large impact on the end result. Together they set the conditions for the chip formation mechanism.
In general it is simple to find a setting that generates a high quality of the wood surface when planing parallel to the grain, i.e. machining direction 90-0. Deviations from parallel grain direction in combination with high stiffness properties of the wood increase the risk of a torn surface. Conditions typical for this effect are in areas close to knots, see figure 1. (3-4)

Even closer to the knot the grain is oriented more in a 90-90 degree direction and the chip formation is changed to cutting perpendicular to the grain. According to McKenzie (5) the wood easily splits along the fibers causing a less smooth surface. If the moisture content is too high the stiffness of the wood decreases resulting in a fuzzy surface, if the moisture content is too low the material below the cutting plane can easily crack and cause rather severe torn.

Stiffness of wood is strongly affected by grain angle, density and moisture content. In general stiffness is very sensitive to changes in grain angle, e.g. at 45 degrees stiffness is reduced to 1/6 and at 90 degrees only 1/10 remains of the value at zero degrees. Regarding density an increase of 100 kg/m³ results in an increase of the longitudinal E-modulus by a factor of about 2,5 (6). The stiffness decreases linearly with about 1/5 from dry up to a moisture content of 30% in the longitudinal direction and up to 2/3 in the tangential direction (7).

In figure 1 the area close to a green knot is shown from a wetted and planed board. As could be noticed the roughness increases close to the knot, see distance \( D \) in the figure 1. It could easily be seen that when the annual ring reaches a certain diving angle downwards, see the left side of distance \( D \), a mix between torn and fuzzy grain occurs. The larger the diving angle become the structure became more fuzzy and less torn, to the right of \( D \). To the left of \( A \) in the figure it could be seen how the annual rings become more parallel to the surface and consequently the roughness decreases to a minimum. This specific sample originates from a test surface that was wetted for 120 minutes. The wood could be assumed to be very wet the whole way down to the cutting surface and therefore the fuzzy structure of the surface. A dryer sample would be more stiff and therefore showing more and larger torn.

Consequently, it is hard to find a machine setting that handles all the variations in grain directions that normally can be found in wood. Especially the wood close to the knots will be high risk zones of both torn as well as fuzzy grain, foremost due to the transition from a parallel grain angle to an angle close to perpendicular to the cutting plane as well as an increase in density.

The hypothesis in this work is: the problem is that the wood is to stiff, especially in areas close to the green knots. A lower stiffness would reduce the risk of torn. Some reduction of stiffness can be achieved increasing the moisture content of the wood but if the moisture content is too high the risk of fuzzy grain will increase. The objective of this study is therefore to study if it is possible to reduce torn grain by adding water to the surface to be machined and at the same time avoid a too high moisture content causing fuzzy grain at the cutting depth of the surface.
**Figure 1**: Illustrating the edge of a board and the area close to a green knot with increased risk of severe torn or fuzzy grain. $D$ is showing the connection between, in this case fuzzy grain and diving annual rings. $A$ and $D$ is the face and $B$ the edge surface. $C$ is a green knot.

**MATERIALS AND METHODS**

**Material**

A total of 60 side board test pieces, made from Scots pine (Pinus silvestris L.) with dimension 500 x120x19 mm were included in the test. The test pieces were taken from a batch of boards classified as grade C by the European norm EN 1310:1997 (8). In table 1 the wood characteristics were summarized for each treatment period of time. The number of Annual Rings was measured in the radial direction of the rings and perpendicular to the face of the board, the number of fresh knots was the number of Fresh Knots present on the test board and the Sum of Fresh Knots was the total sum of knot diameters within the test surface, and is a measure correlating to the size of the area close to the knots that showed an increased risk of torn and fuzzy grain.

<table>
<thead>
<tr>
<th></th>
<th>No. Annual Rings</th>
<th></th>
<th>No. Fresh Knots</th>
<th></th>
<th>Sum of Fresh Knot Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Obs.</td>
<td>Mean</td>
<td>Std Dev</td>
<td>Mean</td>
<td>Std Dev</td>
</tr>
<tr>
<td>0 min</td>
<td>28</td>
<td>8.9</td>
<td>3.27</td>
<td>1.1</td>
<td>1.26</td>
</tr>
<tr>
<td>30 min</td>
<td>26</td>
<td>9.9</td>
<td>2.28</td>
<td>1.1</td>
<td>1.02</td>
</tr>
<tr>
<td>60 min</td>
<td>28</td>
<td>8.9</td>
<td>3.27</td>
<td>1.2</td>
<td>1.19</td>
</tr>
<tr>
<td>120 min</td>
<td>27</td>
<td>9.9</td>
<td>2.28</td>
<td>1.1</td>
<td>1.00</td>
</tr>
</tbody>
</table>

No sign diff

Table 1: Summary of 3 wood feature characteristics for the 4 different treatments.

The provenience of the boards was Västerbotten County, in the north of Sweden. Both faces of the 60 test pieces were planed, in total 120 planed surfaces were included in the study. The moisture content of the material was in average 7% at the start of the test. In order to study the impact of wetting time the material was divided into 4 groups, with 30 surfaces each. For the feature characteristics see table 1.
The research design was as follows:
Step 1, all faces were dimensioning planed in order to achieve a plane surface at start.
Step 2, the 120 faces were planed in a dry state with a cutting depth of 1,5 mm, and then quality graded.
Step 3, the material was divided into 4 groups, 30 test surfaces each, and wetted for 0, 30, 60 or 120 minutes.
Step 4, surfaces were planed a third time, cutting depth 1,5 mm, and graded once again.

Wetting

The test surfaces were put on top of a water saturated sponge for 0, 30, 60 or 120 minutes. The purpose was to wet the most outer part of the surfaces via the face side.

Machine settings

A Jonsereds PH-MB thickness planer set at a feeding speed of 15 m/min, and spindle speed 6000 RPM. The cutter head was mounted with 2 cutting knifes with 30 degrees rake angle. The cutting depth was set to 1,5mm. These settings were used to get the most aggressive conditions that the machine could perform, in order to provoke torn grain.

Quality grading

The Visio-Touch method for roughness grading of wooden surfaces was used. The method is based on a visual as well as a tactile manually assessment of the surface roughness into 5 grades (9-10): Excellent, Good, Fair, Poor and Very Poor. Excellent, stands for a defect free surface. Good is a surface in where it is possible to notice some minor defects by the naked eye like small rips around knots. Fair is described as small to medium sized torn grain spread over limited areas and/or up to a medium amount of fuzzy grain possible to eliminate by sanding. Poor is a surface with extended medium to large torn grain, an extra sanding operation is needed to be regarded as acceptable. Very Poor, is a very bad surface with large and deep torn that cannot be corrected by sanding only, a filler is needed to reach an acceptable surface.

Quantitative measuring of torn

As a complement to the qualitative assessments of the surface quality two quantitative measures were taken describing the size and spread of torn. The size of torn is expressed as the depth of the deepest torn observed and measured by the aid of a dial depth gage equipped with a 0,2 mm ball tip and an accuracy of 0,01 mm. The spread of the torn is defined by the size of the rectangle that encloses the observed torn, and expressed as a percentage of the total area of the test surface. See figure 1. The rectangle was measured by the aid of a caliper with an accuracy of 0,05 mm.
RESULTS AND DISCUSSION

In table 2 the effect of the wetting treatments are shown. The results were from a paired comparison test, in where the differences in surface quality before and after wetting were calculated for each test surface. A positive mean value indicate a positive effect by wetting the surface before planing.

It can be noticed that 3 out of 4 studied wetting treatments gave statistically significant improvements at a confidence level of 95%. At the same time no differences could be shown to exist between the 4 wetting treatments.

Table 2. Effect of wetting expressed as the difference between assessed grades before and after wetting treatment, positive value equals an improvement. Wetting time is the period of time the surface was in contact with water. The rest of measures are; number of observations, mean improvement, standard deviation and the 95% confidence interval for the true mean value.

<table>
<thead>
<tr>
<th>Wetting time</th>
<th>Number</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 min</td>
<td>30</td>
<td>0,90</td>
<td>1,094</td>
<td>0,4915</td>
<td>1,3085</td>
</tr>
<tr>
<td>30 min</td>
<td>30</td>
<td>0,67</td>
<td>1,242</td>
<td>0,2032</td>
<td>1,1301</td>
</tr>
<tr>
<td>60 min</td>
<td>30</td>
<td>1,00</td>
<td>0,983</td>
<td>0,6331</td>
<td>1,3669</td>
</tr>
<tr>
<td>120 min</td>
<td>30</td>
<td>0,36</td>
<td>1,130</td>
<td>-0,0549</td>
<td>0,7883</td>
</tr>
</tbody>
</table>

In table 3 the distributions of grades were shown both as well as after water treatment. Since no significant differences between the wetting times could be shown the results of all 120 test surfaces are shown in the same table. On the bottom line the distribution before wetting is shown, and in the column to the right the distribution after wetting.

The table shall be read as follows: A total of 26 test surfaces were graded as Good before wetting, corresponding number after wetting was 37. In the column Good before it can be seen that 17 out of 26 surfaces were unaffected by the wetting treatment and 8 were degraded. On the row Good after, it can be seen that 5 of the test surfaces were degraded from Excellent before wetting and a total of 15 were upgraded one or more degrees as a consequence of the water treatment.

Table 3: The table is showing the distributions of grading results before and after a wetting treatment of the surface before planing. On the bottom row the distribution of grades before wetting is shown and in the column to the right the distribution after wetting, expressed as number of observations.

<table>
<thead>
<tr>
<th>Surface Grade</th>
<th>Excellent after</th>
<th>Good after</th>
<th>Fair after</th>
<th>Poor after</th>
<th>Very Poor after</th>
<th>Sum after Wetting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Good</td>
<td>5</td>
<td>17</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>37</td>
</tr>
<tr>
<td>Fair</td>
<td>1</td>
<td>6</td>
<td>19</td>
<td>10</td>
<td>8</td>
<td>44</td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td>Very Poor</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>7</td>
</tr>
</tbody>
</table>

In table 4 two quantitative measures describing the occurrence of torn is shown, Torn area and Torn depth. The measures were expressed as the observed differences before and after wetting of the test surface, grouped by the test surfaces grade before wetting. The reason is for this grouping is to better understand how the degree of torn changed by the wetting treatment. As can be noticed for the 12 test surfaces of Excellent grade before wetting no torn could be observed after wetting. For the other grades the torn decreased after wetting. A statistically significant decrease
for all except for the group of Good and the largest observed depth where no change could be proven by a 95% confident interval. For all grades, except Excellent, more than 75% of the surfaces showed the same degree of torn or less after the wetting treatment was done.

Table 4: Summarized observed differences in measured Torn area and Torn depth, before and after wetting, a positive mean value represents a decrease of the defect by wetting. Grouped by the assessed grades before wetting treatment, dry-grade.

<table>
<thead>
<tr>
<th>Dry-Grade</th>
<th>No.</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Conf. Int (+/-)</th>
<th>Sig. Diff.</th>
<th>Mean</th>
<th>Std Dev</th>
<th>Conf. Int (+/-)</th>
<th>Sig. Diff.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>12</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>-</td>
<td>0,00</td>
<td>0,00</td>
<td>0,00</td>
<td>-</td>
</tr>
<tr>
<td>Good</td>
<td>26</td>
<td>0,46</td>
<td>1,064</td>
<td>0,430</td>
<td>Yes</td>
<td>-0,01</td>
<td>0,233</td>
<td>0,094</td>
<td>No</td>
</tr>
<tr>
<td>Fair</td>
<td>38</td>
<td>1,66</td>
<td>2,130</td>
<td>0,700</td>
<td>Yes</td>
<td>0,21</td>
<td>0,452</td>
<td>0,150</td>
<td>Yes</td>
</tr>
<tr>
<td>Poor</td>
<td>19</td>
<td>2,92</td>
<td>2,320</td>
<td>1,119</td>
<td>Yes</td>
<td>0,32</td>
<td>0,257</td>
<td>0,124</td>
<td>Yes</td>
</tr>
<tr>
<td>Very Poor</td>
<td>25</td>
<td>3,11</td>
<td>4,198</td>
<td>1,733</td>
<td>Yes</td>
<td>0,26</td>
<td>0,472</td>
<td>0,195</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In general, the cutting tools and machine settings used in this study will in most of the cases give a rather good result when the wood grain is parallel to the surface like the normal situation for clear wood. The problems with torn or fuzzy grain will occur in regions close to the green knots where the grain direction becomes more and more perpendicular to the surface. So was the case as well in this study, torn and fuzzy grain was foremost found near by the green knots and only in very small amounts in the areas of clear wood.

The wetting treatment did show a positive effect and improved the surface quality regardless of treating time. As could be shown the number of Very Poor surfaces were reduced to about ¼ of the dry planed frequency which must be regarded as very positive outcome of these tests. Less positive was that the number of Excellent surfaces decreased by 50%. By a closer look it could be concluded that the single reason behind this degradation was an increase of the amount of fuzzy grain since neither Torn depth nor Torn Area increased for these surfaces. In practice, fuzzy grain is considerably easier to correct than torn grain. The loss of high quality surfaces due to fuzzy grain is somehow less dramatic, since in practice fuzzy grain is considerably easier to correct than torn grain by a simple sanding operation.

An interesting outcome from the test was that the 0 minute treatment was as good as the longer time treatments, a very promising result in an industrial point of view.

Why wetting seems to have a positive impact is a complex questions that need further studies to fully explain. One plausible explanation is that the grain close to the knots adsorbs water capillary while clear wood absorbs water much slower through the cell wall.

CONCLUSIONS

The average surface quality for a whole batch can be increased by adding water to the surface short before planning. A positive impact can though not be guaranteed for single objects. No strong time dependency regarding the length of the water treatment can be proven to exist based on the findings in this study.
REFERENCES