

Abstract of the PHD Thesis

**SURFACE STABILITY OF MASCHINED NATURAL WOOD
AT WETTING**

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Abstract

This study deals with the surface stability on the solid wood after different woodcutting method. Seven domestic wood species and five woodworking operations are analysed to defining the surface stability of solid wood. New surface roughness evaluation method is introduced to characterise and compare the movements of the different wood surfaces. The evaluation based on an optic 3D measuring method and the standardised 3D surface roughness parameters. In the frame of this method the correlation of the surface parameters and the best indicators of the surface stability are defined. Earlier research works only concern the stabilised phases of the wood surfaces. The new method can describe the surface movements during the watering process too. It is important to note that the characterisation of the surface movements affected by water is useful information for the experts of the wood industry. In the practice commonly the tactile measuring method is used and, therefore, discovering of the correlations between the 2D and 3D roughness parameters is part of my dissertation.

During the wetting process the water infiltrates into the inner structure of the wood material by the effect of the capillary forces resulting the sample swells. After the water infiltration and evaporation process the sample shrinks. The shrinking process is slower than the swelling process. The examined wood surfaces have never gotten back their original surface structure. The Robinia has the biggest surface stability among the examined wood species and the precision planning is resulted the most stable surfaces. The most instable surfaces are resulted by the sanding process.

Introduction

Well known that the surfaces of the processed wood show different pattern and the upper layer is instable. A word derived from the Latin meaning is constancy, balance. Therefore, surface stability is the resistance of the surfaces versus the environmental effects. Large number of influencing factors influences the surface stability. The main factors that cause the greatest changes in the surface of wood are the sunlight, the fluctuation of the air humidity and the temperature and the fungus damage. The different type of wood processing is also significant influencing factor. The main aim of this thesis work to define the surface stability of the wood depending on wetting. The fibrous wood is composed mostly of hollow, elongate, spindle-shaped cells always contain humidity. The moisture content (MC) of wood below the fibre saturation point is a function of both relative humidity and temperature of the surrounding air. The equilibrium moisture content is defined as that moisture content at which the wood is neither gaining or losing moisture; an equilibrium condition has been reached. Wood changes dimension as it gains or loses moisture below the fibre saturation point. It shrinks when losing moisture from the cell walls and swells when gaining moisture in the cell walls. The speed of the shrinking or the swelling process fundamentally influences the surface structure of the wood. The natural wood finishes, especially water-based finishes could cause quick moisture movement in the wood material. The effect of the exerted swelling depends on the type of the wood processing too. Some wood fibre could swell from the surface partly to adhere to the ambient fibres. Therefore, sanding process is used between the two surface treatments with water-based material. The added sanding process increases the manufacturing cost. The outer cell layers of a machined solid wood surface usually collapse and compact during processing due to the cutting forces. This layer is called deformation zone. The deformation zone is excessively instable, varies with temperature and MC variation of the environment. Consequently, the characterisation of the deformation zone is fundamentally important in order to achieve high quality wood surfaces in the wood industry.

The surface movements can be detected with optical surface roughness measurement during the watering process. Earlier research works published data only concerning the stabilised phases of the wood surfaces. Comprehensive study that describe the effect of every

influencing factor have not published yet. The development of the optical surface roughness measurement methods allow to describe the surface movements during the wetting process.

Objectives

In this research, the focus has been done on describing the behaviour of the deformation zone of processed solid wood surfaces during wetting with distilled water. An individual wetting procedure has been developed, whilst surfaces have been characterized by 3D roughness measurement. The evaluation has been performed after defining the convenient roughness parameter as indicator of surface topography changes of the deformation zone due to wetting. Based on indicators, sequence has been set among wood species and machining types regarding the results given by their deformation zone to wetting. The 3D surface roughness parameters are compared with the traditional 2D surface roughness parameters.

Material and methods

Investigations have been performed on seven wood species:

- Conifers: Norway spruce (*Picea abies* Karst.), larch (*Larix decidua* Mill.), scots pine (*Pinus sylvestris* L.);
- The ring porous species: beech (*Fagus sylvatica* L.), black locust (*Robinia pseudoacacia* L.);
- The diffuse porous species: sessile oak (*Quercus petraea* Liebl.), aspen (*Populus tremula* L.).

From each wood species, 25 samples have been taken; every wood processing method (planing, precision planing, sanding, thermos-smoothing, milling) was represented by 5 samples. The samples were prepared with dimensions of 100 mm x 100 mm x 25 mm (long. x rad. x tang.). For investigations all defect free, homogenous, radially cut boards have been selected. Before surface preparation the wood material has been kept for 2 months in climate chamber at 23 °C and 50% relative humidity. When adjusting the different machining parameters, the target was to achieve the smoothest surface possible, so the machining conditions have been set after several preliminary trials. After two months the samples moisture content is $\approx 8 - 12\%$, according the literature (Molnár 2004).

Machine parameters are chosen which produced the smoothest surface. Therefore, low depth of cut, minimal feed speed and maximal peripheral speed of the tool are used. In order to define the optimal working parameters concerning the thermos-smoothing and the precision planing pre-testing is applied.

After surface shaping 10 samples of 100 mm x 100 mm dimension have been prepared from each wood species and from every machining type. The depth of the deformation zone depends on the wood species and the wood processing methods. Generally the depth of the deformation zone are between 50 and 100 μm (Fisher, Schuster 1993). Wetting was performed with 1 ml distilled water, spread on a 100 mm x 100 mm surface, penetrating 50-100 μm deep. This quantity amounts the water content of a commercially available water based lacquer 80-120 ml/m² (Remmers) relative to the surface area of the sample. The distilled water has been instilled drop by drop onto the surface and spread with a wet brush.

The surface has been monitored by a GF Messtechnik MicroCAD type 3D optical surface roughness measuring instrument of IHD. The measuring has been based on phase measuring fringe projection (GF Messtechnik 2008) the measured surface was 12.5 mm x 9.5 mm, providing 23 different 3D parameters (S_a , S_q , S_k etc.). On one sample 1 place has been selected to monitor the behavior during wetting. The exact positioning of samples has been crucial, so a raster table, -adjustable in 2 directions has been used to enable measuring exactly the same area during monitoring. Surface roughness measurements have been initiated 5 minutes after wetting the surface with distilled water and repeated according to the result of the pre-testing.

The same area has been monitored by measuring its surface topography every 5 minutes up to 50 minutes. After one hour there were no relevant changes in the surface topography within 5 minutes, so the last 4 measurements have been performed 80, - 100, - 120 and finally 180 minutes after wetting. Data evaluation based on surface topography measurements has been done using ODSCAD 6.0 software. The mass of the samples has been also measured in the same time with roughness measurements, with an MC1 Laboratory LC 620 S type balance of 0.001 g precision. 1 ml distilled water resulted around 1g sample mass increase (Fig. 1). 30 minutes after wetting there was a 0.5 g mass loss due to an intense evaporation of the test water. After the first half hour the evaporation process slowed down, 2-3 days are necessary for samples to reach their original mass.

Fig. 1 shows the frequency of measuring surface topography and the number of measurements.

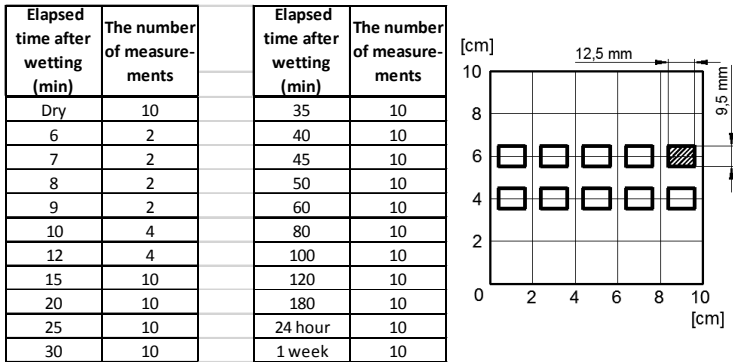


Fig. 1 Frequency of measuring surface topography and number of measurements

Conclusions

Water based paint systems gain advance, thus grows the relevance of describing the behavior of the deformation zone manifested during wetting. This research targeted the description of the behavior of planing, precision planing, sanding, thermosmoothing, milling surfaces after wetted with water, since the roughness developed during wetting might be associated with the adhesion of the surface treating material (paint/adhesive).

Investigations conducted on Norway spruce (*Picea abies* Karst.), larch (*Larix decidua* Mill.), scots pine (*Pinus sylvestris* L.), sessile oak (*Quercus petraea* Liebl.), black locust (*Robinia pseudoacacia* L.), aspen (*Populus tremula* L.) and beech (*Fagus sylvatica* L.) pointed out that the deformation zone of sanding surfaces has been the most instable. The deformation zone of thermos smoothing and precision planing surfaces has been the most stable. There are differences between wood species also regarding the stability of their deformation zone to wetting after the processing. The surface stability sequence are the followings regarding the anatomical structure: ring porous wood species, the diffuse porous wood species, and firs.

Considering the 23 roughness data provided by the measuring instrument, the following 3D surface roughness parameters have been

found suitable to characterize the nature of the wetting process: S_a – average roughness, S_k – core roughness depth, S_{pk} – reduced peak height, S_{vk} – reduced valley depth, S_{dr} – developed interfacial area ratio (except black locust). S_{sk} is suggested only for the characterization of the anatomical structure. Suggestion has been made the deformation zone to be characterized with at least the parameters above, since they one by one express different details of the status of the surface. It has been emphasized that characterizing the surface with one single roughness parameter could be misleading. Regarding the character of alteration of surfaces: they are the same in each case, differences appear only in their measure.

Summarizing the watering experimental results, the effect of wetting on surface roughness may be quite different depending on conditions. Water penetrating into the upper surface layer always causes greater and smaller increase in the roughness parameters due to swelling and shrinkage, and permanent deformations. The deformation in the surface layer depends on the applied water thickness and the evaporation rate. The diffusion coefficient and the water infiltration rate play also an important role.

Correlation between the standardised surface roughness's parameters connecting metal surfaces have already published. The random position of the cutting plain of the wood surfaces are caused scattering of the surface roughness parameters. In spite of data scattering this correlation has been defined for the 3D surface roughness parameters connecting the processed wood surfaces.

The correlation between the 2D surface roughness parameters and the 3D surface roughness parameters are partly known. Therefore, systematic experiments are made to excavate the measuring requirements of the comparability. The experimental results have been shown that in the frame of the 3D optical surface roughness method special filtering method must use to justify the correlation between the 2D surface roughness and the 3D surface roughness parameters. It means the 3D optical surface roughness measuring method must calibrate based on the tactile roughness measuring method to measure processed wood surfaces.

Theses of the dissertation

I did scientific conclusion as follows on the basis of detailed theoretical and experimental studies.

1. thesis: Based on the 3D optical surface roughness measuring method surface roughness measuring and evaluation method is worked out in order to describe the surface movements exerted by wetting.
2. thesis: The surface roughness process is described and theoretically explained based on the experimental results for 7 wood species. The dynamic of the water infiltration and evaporation is taken into consideration. Pines: Norway spruce (*Picea abies* Karst.), larch (*Larix decidua* Mill.), scots pine (*Pinus sylvestris* L.); The ring porous species: beech (*Fagus sylvatica* L.), black locust (*Robinia pseudoacacia* L.); The diffuse porous species: sessile oak (*Quercus petraea* Liebl.), aspen (*Populus tremula* L.). The surface roughness ($S_a, S_{pk}, S_k, S_{vk}, S_{sk}, S_{dr}$) of the stabilised condition always is higher than the initial surface roughness parameters.
3. thesis: Surface stability definition is introduced. Surface stability is characterised by initial and the stabilised S_k or R_k ratio. The S_a, S_{pk}, S_{sk} parameters are also appropriate.
4. thesis: The sequence of the surface stability is defined concerning the experimented wood species depending on the wood processing methods. Based on the experimental results is pointed out that the deformation zone of sanding surfaces has been the most instable for every wood species. The deformation zone of precision planing surfaces has been the most stable. The surface stability sequence are the followings regarding the anatomical structure: ring porous wood species, the diffuse porous wood species, and firs.

5. thesis: The deformation in the surface layer depends on the applied water thickness and the evaporation rate based on diffusion coefficient and the water infiltration rate. The difference of the experimental results of the black locust and the scotch pine surfaces is verified the thesis (Fig. 51).
6. thesis: The S_q/S_a (R_q/R_a) ratio is introduced based on the experimental results. Correlation is derived between the ratio and the skewness (Fig. 79). The empirical equation of the correlation is the followings:

$$-S_{sk} = 4.69 \cdot (S_q/S_a - 1.3)$$

7. thesis: Based on excessive measuring data relative surface roughness parameters are defined, which could forecast the extent of the surface movements concerning the experimented wood species (Fig. 60. 70. 73)

Important notes for the practice

1. Wood changes dimension as it gains or loses moisture below the fibre saturation point. It shrinks when losing moisture from the cell walls and swells when gaining moisture in the cell walls. Wood is anisotropic material which contains hollows therefore, local deformations are existed and the stabilised surface roughness different from the initial surface roughness.

2. The effect of the simultaneous water infiltration and evaporation process, the water mass, diffusion coefficient of the wood the air conditions (MC, temperature, velocity etc.) define the surface roughness of stabilised wood surface

3. The upper 20 μm surface layer is modified by wood processing therefore infiltration and the wood processing process does not modify evaporation process considerably. Consequently, the wood machining process influence the surface roughness fundamentally.

4. The deformation of the sanded wood surfaces increases the diffusion coefficient in the upper 10 – 20 μm surface layer; therefore, the lacquer infiltration is increased. This effect was published earlier without detailed explanation.

5. The S_q and S_a (R_q és R_a) surface roughness parameters in contrast of the experience of the metal industry are independent parameters. Therefore, the S_q and S_a ratio an important surface roughness parameter in the wood industry and correlation exists between the ratio and the skewness.

6. The optical surface roughness method could deliver false data based on the working theory of these optical surface roughness measuring apparatus. If the reflexion of the surface is diffute, the surface roughness parameters could be correct. If the reflective surface is specular the signal could be lead to miscalculation. The sanded surface is the most diffute therefore, the optical method deliver correct data in this case. Concerning the hard wood species (e.g. *Dalbergia cochinchinensis*) the deviation could be 300 %.

Publications

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