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Morphological changes on beech wood surface during simulated ageing

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Abstract: *Morphological changes on beech wood surface during simulated ageing*. The subject of this work is morphological analysis of wood surface by means of roughness parameters and experimental study of degradation effects of simulated ageing on these parameters. The experimental results have shown that the degradation effects of simulated ageing were evident in enhanced beech wood roughness. More distinct changes in roughness were observed across the grain. The longer was the ageing process, the more distinct was the surface roughness, namely due to degradation of lignin and extractive substances.

Keywords: simulated ageing, morphological changes, roughness, beech wood

INTRODUCTION

To describe wood surface as comprehensively as possible, we need to know a wide range of properties of this material (morphology, chemical and thermodynamic properties – wood species, surface treatment, moisture content, ageing effects, and others.

Wood is a natural, heterogeneous material. In addition, it is anisotropic, porous and hygrophilous. These facts are significantly reflected in the surface properties of this material. The wood heterogeneity performs at all its structural levels – macro-, micro and sub-microscopic. It is the factor underlying the considerable variability of wood performance, and as such, it is always needed to consider with wood. Wood anatomical elements are very diverse shaped and arranged, and they form a very complex heterogeneous porous system, corresponding to their development. The pore shape, size, binding and arrangement in wood is strongly species-specific. The porous character of wood results in a very big inner surface and in considerable roughness of external surface. Consequently, an ideally smooth surface is not possible to obtain in real wood (KÚDELA 2012).

Wood surface morphology and wood chemical structure substantially affect wood wetting with liquids. Surface morphology is evaluated from anatomical and physical aspects.

From the physical aspect, the surface geometry is evaluated based on roughness and waviness. The principle of surface geometry evaluation in solids is the classification and quantification of deviations of the actually measured values from the values defined for a basic surface by contract.

In real wood surfaces, it is also necessary to consider the impact of the working tool as well as a range of other factor on the surface geometry. One of them is wood ageing. Wood ageing has also impact on the wood hydrophility or hydrophobicity and it also causes colour changes to wood surface. To understand the mechanism driving natural colour changes in wood during ageing will be useful for developing procedures to improve colour stabilisation in wood.

The ageing of materials is in general characterised as their slow degradation over a specific time interval, due to the effects various types of radiation, moisture and heat acting in interactions. The wood ageing caused by these factors is associated with changes to the morphology and chemistry of wood surface (HON 1981, FEIST 1990, WILIAMS 2001, REINPRECHT 2008, TOLVAJ *et al.* 2011, HUANG, X. *et al.* 2012).

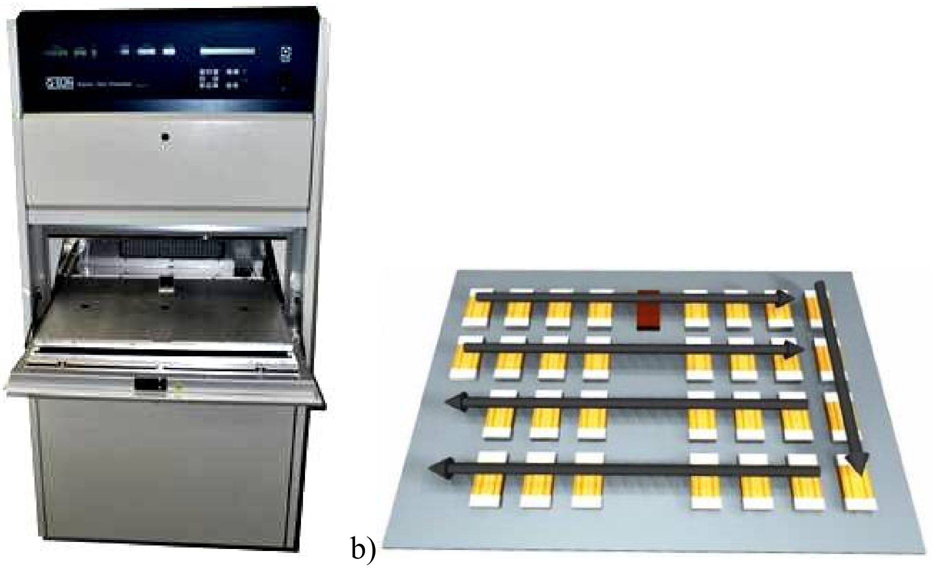
It has been revealed that the ageing process is needed to study in its whole complexity – to obtain results applicable for improving the quality of surface treatment and gluing of such surfaces.

The aim of our work was experimental study of simulated ageing of beech wood with focus on changes in its roughness induced by changes in its morphology.

MATERIAL AND METHODS

We simulated ageing of beech wood on test specimens 15 × 60 × 100 mm in size. The radial and tangential surfaces of these specimens were milled. Before exposed to the ageing, the specimens were conditioned to an equilibrium moisture content of 12 %.

Before putting the specimens into the xenotest, their ends were covered with an aluminium sheet – for visual observations of their colour changes. The simulated ageing of wood was carried out in a xenotest Q-SUN Xe-3 (Fig. 1a).



a) b)

Fig. 1 Appliance Q-SUN Xe-3 and samples rotation during simulated ageing

Across the xenotest chamber, the test specimens were arranged in a regular spacing. To ensure the same illumination intensity and the same temperature for all the specimens, these were re-arranged regularly and systematically according to the recommendations (Fig. 1b).

The xenotest is possible to set various levels of natural ageing conditions. In our case we followed the standard ASTM G 155. This standard is fundamental for determining the natural conditions of simulated ageing for non-metal materials performed with a xenon discharge tube. The conditions for non-metal materials we used in our test are in Table 1.

Table 1 Ageing conditions specified by the Standard ASTM G 155

Ste p	**Function**	**Illumination intensity (Wm^{-2})**	**Temperature on a black panel (°C)**	**Air temperatur e (°C)**	**Relative air humidity (%)**	**Time (min.)**
1	Illumination	0.35	63	48	30	102
2	Illumination + spraying	0.35	63	48	–	18
3	End, turn to step 1					

As required by the standard, the temperature was set to 0.35 $W \cdot m^{-2}$ at a wave length of 340 nm. These values correspond to the average annual illumination intensity in the temperate climatic range. The temperature measured on the black panel represents the maximum temperature on the surface. The air temperature is adjusted to accelerate the changes to wood surface. During the first cycle, the relative air humidity is relatively low. In the second cycle, on the other hand, it is high, due to water sprayed onto the surface. In this way we studied the performance of wood surface during the transition from a low relative air humidity to high relative air humidity and *vice versa*. The first step took 102 minutes, the second 18, and then the cycle was repeated. The change to wood surface properties was investigates after 0, 86, 200, 350 and 500 hours.

The wood surface geometry of the test specimens was evaluated through their roughness parameters – *Ra*, *Rz*. WE used a contact profilometer SURFCOM 130A. The measurements were carried out on radial and tangential surfaces of all test specimens. The first measurement was done before putting the specimens into the xenotest, the subsequent ones were done at intervals specified in the preceding paragraph. The roughness was investigated parallel to grain and across the grain. The measured length was 30 mm, the basic length was 0.8 mm.

RESULTS AND DISCUSSION

The results of three-way variance analysis confirmed that the roughness was significantly influenced by the anatomical direction and the ageing time. The differences between the radial and tangential surfaces were not found significant. There was also confirmed significant influence of interaction between the anatomical direction and the ageing interval.

The experimental results imply that the roughness values were in all cases over 500 nm. This suggests that considerable roughness is a typical feature of beech wood surface. The high variability is due to the just mentioned very variable cell elements showing diverse structure and also due to the way of wood surface treatment and due to the cutting tool quality. The roughness values measured perpendicular to grain were considerably higher than parallel to grain, primarily due to the orientation of the cell elements. The lack of measurement precision and accuracy is, in our opinion, only of secondary importance..

Comparing our results with KÚDELA and LIPTÁKOVÁ (2005) we can see that the roughness of milled beech wood surface in our case was higher. Our mean arithmetical deviation R_a in the fibre direction was nearly five times higher and perpendicular to fibres nearly 3.5 times higher than reported by KÚDELA and LIPTÁKOVÁ (2005). The higher roughness in our case was due to much longer basic length – 0.8 mm, while the last cited authors used 0.075 mm. From REŠETKA (2013) it follows that roughness significantly increases with increasing basic length. Our results are in a good accordance with the results of REŠETKA when the fundamental length is the same.

In addition to anatomical direction, the roughness was significantly affected by beech wood ageing and by the interaction between the two. Fig. 2 shows that the values of average arithmetical deviation measured perpendicular to grain increased with increasing simulated ageing interval, with *Ra* values nearly 2.5 times higher after 500 hours.

In the longitudinal direction, there was observed a significant increase until 86 of ageing process, later no significant changes occurred.

Qualitatively the same course was also observed in the maximum height of profile *R*z (Fig. 2), exhibiting, however, the values by one order of magnitude higher.

Light (UV radiation, infrared radiation), oxidation, moisture and heat induce a large number of changes to wood surface, such as enhanced surface roughness and cracks formation (FEIST 1990, TEMIZ *et al.* 2005). UV radiation causes depolymerisation, primarily of lignin and to some extent of polysaccharides, resulting in impairment of the middle lamella and releasing the cell elements in wood. Subsequently, the depolymerised components are, together with extractives, dissolved in water and leached from the wood. This results in the so called “plastic wood structure", due to more progressively degraded early wood (FEIST 1990, WILLIAMS and FEIST 1999, ROGER and ROWELL 2012). This is mainly typical for coniferous woods, but the phenomenon also observable in broadleaved species.

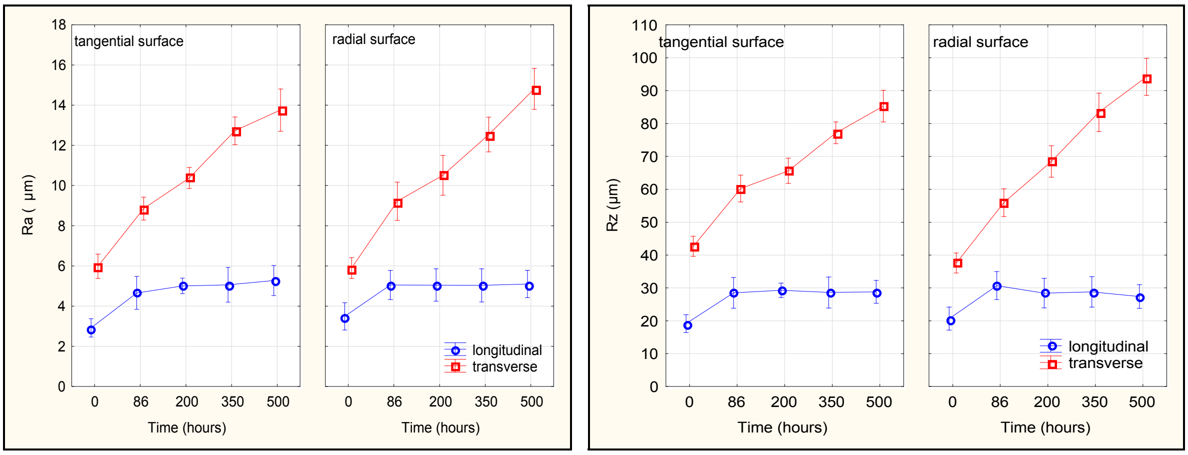


Fig. 2 Ageing effects on Ra and Rz in longitudinal and transverse direction

It is reasonable to expect that surface roughness will significantly affect wood wetting with liquids and increase expenditures on coating materials and glues.

CONCLUSIONS

The experimental results have shown that the degradation effects of simulated ageing were manifested through enhanced roughness of beech wood surface.

More distinct changes in roughness were observed across the grain. The longer was the ageing intervals, the more evident was beech wood surface roughness, in fact due to degradation of lignin and extractive substances.

It can be expected that these morphological changes caused by simulated ageing will also significantly affect the wood wetting with liquids.

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Streszczenie: *Zmiany morfologiczne na powierzchni drewna buka podczas sztucznego starzenia*. Tematem pracy jest analiza zmian wywołanych sztucznym starzeniem, takich jak parametry chropowatości. Badania starzenia drewna bukowego wykazały zwiększoną chropowatość powierzchni. W miarę postępowania starzenia największe zmiany zachodziły prostopadle do włókien. Było to spowodowane degradacją ligniny oraz substancji ekstrakcyjnych.

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