

## THE INFLUENCE OF THE DEGREE OF THERMAL MODIFICATION OF OAK, SPRUCE AND MERANTI BLANKS ON SURFACE ROUGHNESS DURING THEIR SANDING

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### ABSTRACT

Products made of thermally treated wood have different requirements for the quality of the created surface, depending on the area of their application. While we can make do with a milled surface for tiling and flooring, we have more sophisticated products such as garden furniture, etc. require final surface sanding. The article focuses on the effect of thermal modification on the quality of the ground surface. It compares the surface quality of the ground surface of native woods oak, spruce and meranti with their thermally treated variants at temperatures of 160°C, 180°C, 200°C and 220°C. Quality is examined on a surface sanded with a belt sander with 80-grit sandpaper.

It points to the fact that the process of thermal modification slightly impairs the quality of the ground surface. However, when evaluating a surface on a larger scale, the quality of the created surface is influenced mainly by the "natural roughness of the wood" by the opening of anatomical elements of the wood, which are the primary source of increased roughness.

**Key words:** Thermally treated wood, sanded surface, surface roughness, natural wood roughness.

### INTRODUCTION

Thermowood is wood treated by heat, steam, and water, without harmful chemicals, with new physical and mechanical properties. This method of wood treatment has been known for several millennia. Thermal modification (heat treatment) is one of the environmentally friendly methods used to improve and develop the properties of wood materials (Očkajová *et al.* 2020, Kminiak *et al.* 2020a). This method, it is aimed to improve the properties of wood material without the use of chemicals. The method has shown that by exposing the wood material to temperatures between 170°C and 220°C in an oxygen-free environment, it is possible to modify wood components which are sensitive to moisture absorption and biodegradation (Dagbro *et al.* 2010, Demirel and Temiz

2015, Dagbro 2016, Korčok *et al.* 2019, Kminiak and Banski 2019).

Wood with these properties is like tropical wood, which in many cases can be replaced by temperate woods, which are less economically significant (Thermowood, 2016). Thermowood has two forms of treatment, the Thermo-S class is an increase in wood stability and the Thermo-D class is an increase in wood durability (ThermoWood Handbook 2003). The advantages of Thermowood particularly include the reduction of moisture absorption, dimensional stability, biological resistance, the attractive appearance of heat-treated wood, the application of material without surface treatment, the high durability of heat-treated wood, the displacement of resin from the material, as it causes a problem with cutting tools as well as with the

use of natural wood without surface treatment, the reduction of thermal conductivity, the increase of wood surface hardness (for weathered areas), the increase of resistance against cracks. Heat-treated wood has lower dynamic strength, mainly bendability and toughness, in terms of mechanical properties, which results in a more brittle wood, not excluding its versatile use in the exterior and interior of a very humid environment (Tepelně upravené dřevo Thermo Wood 2013, Kminiak et al. 2020b).

Thermowood is the subject of much research. The researches examine the changes in the physical-mechanical properties (Gunduz *et al.* 2009), the chemical properties (Reinprecht and Vidholdová 2008, Kačíková and Kačík 2011, ThermoWood Handbook 2003, Čabalová *et al.* 2016), the quality of the surface obtained (Budakci *et al.* 2013, Kvietková *et al.* 2015, Vančo *et al.* 2017, Kaplan *et al.* 2018) the colour of the wood, the woodworking (Sandak *et al.* 2017, Reinprecht and Vidholdová 2008, Král and Hrázský 2005), the workability in the context of energy consumption (Kubš *et al.* 2016), the stability against the impact of weather (Panayot and Jivko 2008, Yildiz *et al.* 2011), the granulometry of the chips (Barčík and Gašparík 2014), or sawdust (Dzurenda *et al.* 2010).

In terms of processing, heat-treated wood has no limitations compared to natural wood. A problem can be the formation of a fine fraction or dust when processing and sanding thermally treated wood, which is caused by an increase in fragility and a decrease in some mechanical properties (Reinprecht and Vidholdová 2008, Král and Hrázský 2005). Most of the mechanical properties of thermally modified wood are reduced because the weight and density of the thermally modified wood are reduced, as well as due to microcracks.

In the production of wood products, it is necessary to monitor their quality. For the product to meet certain quality requirements, production processes must be optimized, such as feed rate, machining direction, revolutions, etc.

Roughness is a measure of fine irregularities on the surface of the wood. The width, height, and shape of irregularities on the surface determine the quality of the product's surface. The roughness of the wood surface plays an important role, as any surface irregularities can manifest as thin layers that reduce the final quality of the wood (Hiziroglu and Kosonkorn 2006). Subtle irregularities on the surface of the wood will be reflected by the overlap and this affects the quality of the product and its final treatment. (Nemec *et al.* 2017, Hiziroglu 1996).

The aim of this paper is to define the effect of thermal modification on the quality of the created surface during sanding, depending on the type of wood (spruce, oak, meranti) and heat treatment conditions (temperatures 160°C, 180°C, 200°C and 220°C), by sanding at vertical belt sander.

## EXPERIMENTAL METHODS

### Experimental samples:

Sessile oak (*Quercus petraea*) and Norway spruce (*Picea abies*) was gathered in Vlčí jarok (Budča, Slovakia), at 440 m above sea level. Radial boards were sawed from the logs and processed in test samples measuring 20 mm × 100 mm with a length of approximately 700 mm. The samples were then dried to a residual moisture of 8%. The entire process was performed in the Research and Development Workshops of the Technical University in Zvolen (Zvolen, Slovakia).

Meranti (*Shorea spp.*) wood was obtained from Indonesia. The region of origin not specified by the importer (Wood Store, Prague, Czech Republic).

### Heat treatment and sample processing methods:

The processed samples, measuring 20 mm × 100 mm × 700 mm, were thermally modified in the Arboretum FLD (Czech University of Life Sciences, Prague, Czech Republic) in the town Kostelec nad Černými lesy. The S400/03 (LAC Ltd., Rajhrad, Czech Republic) chamber, shown in Fig. 1, was used for thermal modification, and was designed to heat the wood with ThermoWood technology at a maximal temperature of 300°C and a volume of 380 L. Five samples were prepared for each treatment. Thermal modification methodology of samples is published in the paper of Kučerka and Očkajová 2018, Očkajová et al. 2018.



Figure 1: Chamber S400/03

The heat treatment procedure for the individual temperatures was as follows: the application of temperature sensors and a humidity sensor for the sensors, the storage of samples in the chamber, the closure and locking of the chamber door, the setting of the heat treatment parameters with a computer program – target temperature, steepness [°C/hr.] for heating and cooling, heat treatment of samples, sample collection from the chamber.

The thermal modification was conducted at 160, 180, 200 and 220°C in six phases: 1st phase – increase of temperature to 40°C, 2nd phase – increase of temperature to 130°C, drying, 3rd phase – heat treatment – heating to working temperature, 4<sup>th</sup> phase – heat treatment – working temperature of 3 hours, 5<sup>th</sup> phase – cooling to 130°C and humidity treatment, 6<sup>th</sup> phase – cooling to 60°C with humidity treatment at the level of 4 – 7%. The process is complete when the temperature reaches 60°C.

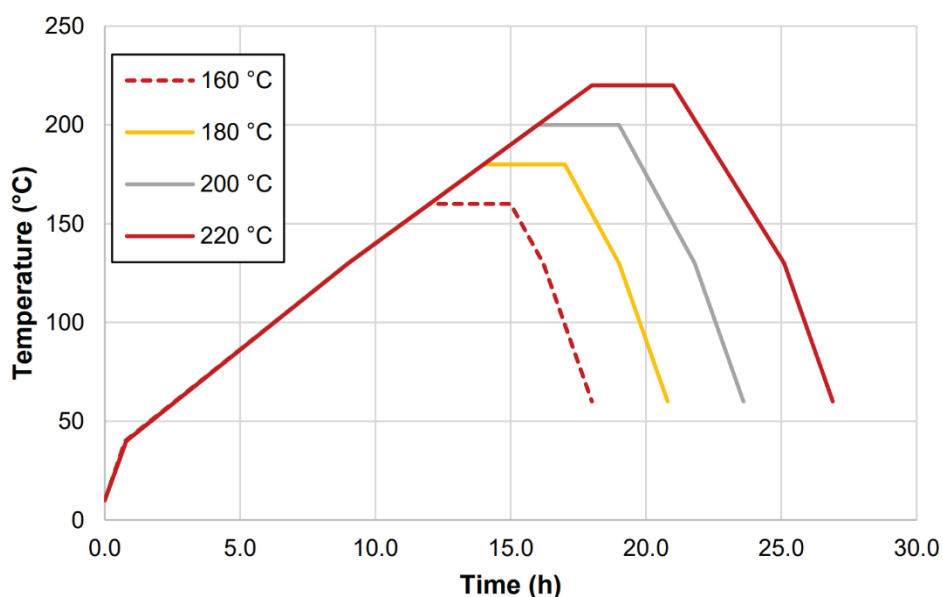


Figure 2: Durations and temperatures of heat-treatment of wood (Koleda et al. 2018)

**Machinery:**

A JET JSG-96 (JPW Tool AG, Fällanden, Switzerland), a narrow belt sander (NBS) with a cutting speed of  $10 \text{ m}\cdot\text{s}^{-1}$ , and a HIOLIT XO P 80 (KWH Group Ltd., Vaasa, Finland) grain sanding belt that kept individual pressure on the wood samples, were used in the laboratory experiments. A sharp sanding belt was used for each thermal treatment.



Figure 3: Narrow belt sander JET JSG-96 (JPW Tool AG, Fällanden, Switzerland)

**Measurement of surface roughness:**

The three-dimensional morphology of the samples was measured using the 3D – optical microscope Infinite Focus (Alicona Imaging GmbH, Graz, Austria) at five-fold magnification, with a vertical resolution of  $1 \mu\text{m}$  and a measurement area of  $10 \times 10 \text{ mm}^2$ . The surface morphology was then examined using the software IFM 2.0-1 from Alicona Imaging GmbH (Graz, Austria). As texture indicator, the amplitude parameters  $S_z$  (Maximum height of selected area).



Figure 4: 3D – optical microscope Infinite Focus Alicona

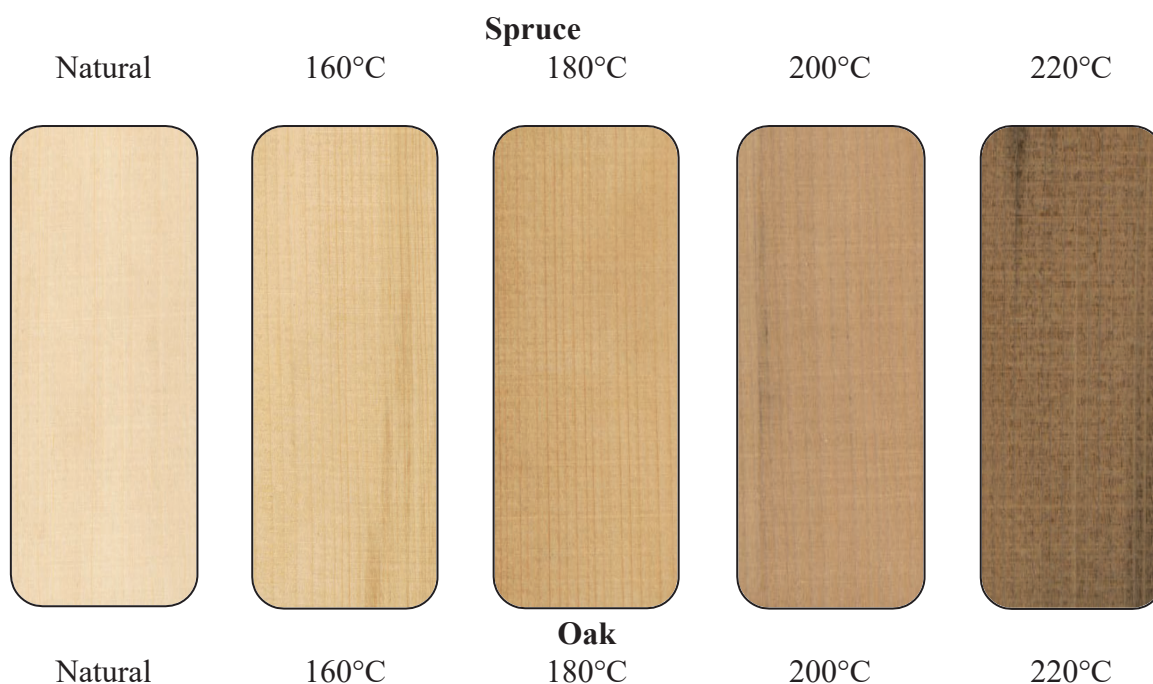




Figure 5: Colour range of thermally treated woods

Table 1: Effect of thermal modification on density (Koleda *et al.* 2020a)

Modification	Spruce (Koleda <i>et al.</i> 2018)	Oak (Koleda <i>et al.</i> 2020b)	Meranti (Rajko <i>et al.</i> 2021)
natural	442.23	775.85	639
160	430.99	719.73	617
180	409.15	687.39	580
200	371.72	617.84	559
220	362.88	608.96	549

## RESULTS AND DISCUSSION

The obtained data were subjected to statistical analysis in the Statistica program. A two-factor variance analysis was used for the basic evaluation of the influence of the studied factors wood species and the degree of

thermal modification (Table 2). This showed that both investigated parameters are highly statistically significant ( $p > 0.005$ ). The analysis further showed that the wood factor is twice as important as the thermal modification factor.

Table 2: Two-factor analysis of the influence of the studied parameters

	SČ	Degrees of freedom	PČ	F	p
Absolute element	5074641	1	5074641	1531.264	0.000000
Wood species	181108	2	90554	27.325	0.000000
Degree of thermal modification	150858	4	37715	11.380	0.000001
Wood species*degree of thermal modification	18691	8	2336	0.705	0.685875
Error	198841	60	3314		

The mutual comparison shows that the quality of the created surface decreases, while the  $S_z$  parameter increases in the order of oak, spruce, meranti. While the average difference (independent of the degree of thermal modification) between  $S_z$  oak and  $S_z$

spruce is 15.7 % (reference oak), the average difference between  $S_z$  oak and  $S_z$  meranti up to 44.4 % (reference oak), the difference between  $S_z$  spruce and  $S_z$  meranti 27% (spruce reference).

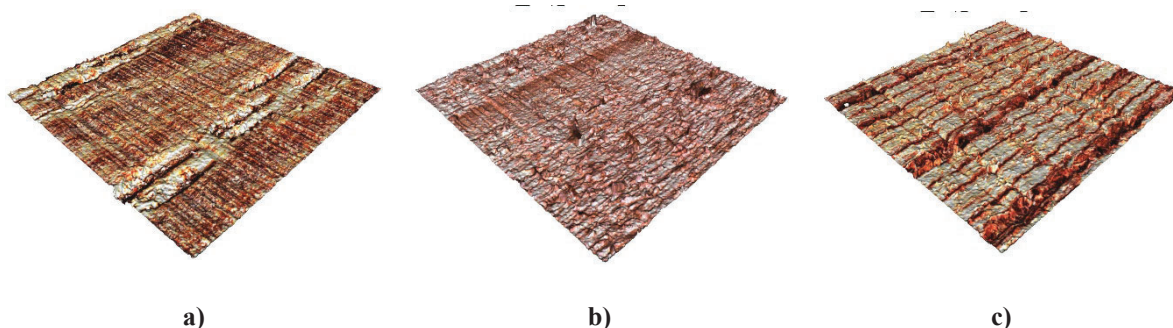


Figure 6: View of the 3D surface profile a) natural oak, b) natural spruce, c) natural meranti

As the view from the 3D representation of the surface profile suggests (Fig. 6), the significant characteristics of the surface are not caused by traces of the grinding tool, but by the anatomical structure of the examined material and its natural roughness. In the case of oak and meranti trees, it is the occurrence of stem rays. In the case of spruce wood, the cause can be considered significant differences between spring and summer wood and the very mechanism of surface formation, where different release of wood fibers occurs.

Like other technologies for processing thermally treated material, an increase in quality due to thermal modification can also be observed during grinding. This increase is manifested only up to a certain degree of thermal modification, beyond which the quality deteriorates again. In our case, the temperature of 220°C can be considered critical, where the quality of the created surface deteriorates, and this is the case for all investigated woods. However, this deterioration is approximately at the level of the surface quality of non-thermally treated wood.

Table 3: The effect of thermal modification on the quality of the created surface during sanding

Wood species	Degree of thermal modification	Maximum height of selected area Average	Maximum height of selected area Standard deviation	Maximum height of selected area -95.00 %	Maximum height of selected area +95.00 %
Oak	0	267,1818	25,74498	215,6842	318,6794
Oak	160	171,3786	25,74498	119,8810	222,8762
Oak	180	179,3928	25,74498	127,8952	230,8904
Oak	200	179,2464	25,74498	127,7488	230,7440
Oak	220	235,8286	25,74498	184,3310	287,3262
Spruce	0	280,2620	25,74498	228,7644	331,7596
Spruce	160	214,2666	25,74498	162,7690	265,7642
Spruce	180	201,0294	25,74498	149,5318	252,5270
Spruce	200	234,4372	25,74498	182,9396	285,9348
Spruce	220	312,3932	25,74498	260,8956	363,8908
Meranti	0	392,4602	25,74498	340,9626	443,9578
Meranti	160	273,8602	25,74498	222,3626	325,3578
Meranti	180	297,7336	25,74498	246,2360	349,2312
Meranti	200	260,5982	25,74498	209,1006	312,0958
Meranti	220	401,7158	25,74498	350,2182	453,2134

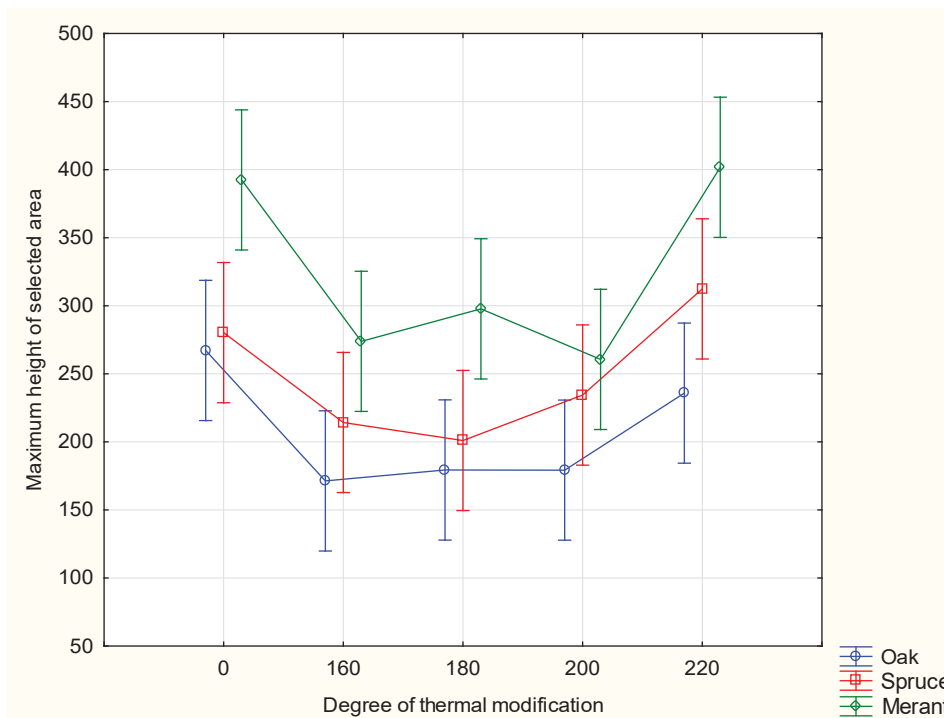


Figure 7: The effect of thermal modification on the quality of the created surface during sanding

**CONCLUSSIONS**

In the article, we focused on the comparison of the quality of the ground surface of native woods oak, spruce and meranti and we compared how it is affected by thermal modification at different temperatures of 160°C, 180°C, 200°C and 220°C. We found that with increasing treatment temperature, the

quality of the surface of all woods is better, but only up to a certain limit, which in this case is the treatment temperature of 220°C. We consider this temperature to be critical, as it deteriorates the surface quality of all types of wood. At this treatment temperature, the surface quality of all woods returned to the original level of native wood. It is assumed

that this can be caused by an increase in brittleness and a decrease in some mechanical properties, as chemical reactions of lignin occur.

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