https://doi.org/10.22320/s0718221x/2025.17
ARTÍCULO

Surface quality of planed tangential and radial sections of thermally modified Silver fir wood

Dritan Ajdinaj[1]https://orcid.org/0000-0002-0845-378X♠
Holta Cota[1] https://orcid.org/0009-0008-9128-2029
Entela Lato[1] https://orcid.org/0009-0007-4338-2052
Doklea Quku[1] https://orcid.org/0009-0004-2814-2841

[1]Agricultural University of Tirana. Faculty of Forestry Sciences. Wood Industry Department. Kodër-Kamëz. Tirana, Albania.

♠Corresponding author: dajdinaj@ubt.edu.al

Abstract:
The quality of glued or coated wood largely depends on the strength of the bond between the adhesive or coating and the wood surface. The roughness of the surface plays a crucial role, as it significantly impacts both the wettability and the effectiveness of the bond. This study was carried out to provide information on the surface roughness of *Abies alba* (silver fir) planed after thermal modification, focusing on the anisotropic behavior of the material, particularly along the radial and tangential sections. Four groups of eight samples without defects were prepared. Half of the samples of each group presented clear tangential section while the other half presented clear radial ones. One group was used as control and the others were heated, applying three different temperatures 160 °C, 190 °C and 220 °C, at atmospheric pressure for 3 hours. The control and the three other heat-treated groups of samples were processed along the grain by a planer machine. 10 m/min feed speed was applied. Surface roughness measurements were performed with a stylus profilometer. A positive correlation was observed between the modification temperature and the roughness of the surface. It was noted that the radial section of natural wood presented greater roughness than the tangential one. For temperatures lower than 200 °C the roughness of both sections resulted almost equal, while above this temperature the roughness of the radial section increased over 20 % compared to the roughness of the tangential one. The information provided by this study is very important for the gluing and finishing processes that can be applied to thermally modified wood.

Keywords: Anisotropy, Silver fir, surface roughness, thermal modification, wood surface.

Received: 26.12.2023
Accepted: 30.01.2025

Introduction

The surface quality of machined wood is influenced by various factors, incluiding wood species and processing parameters (Kamperidou and Barboutis 2017, Kamperidou *et al*. 2020, Pakzad *et al*. 2023). In the case of thermally modified wood, the treatment regime parameters are also added to these factors (Pelit *et al*. 2021). It is already known that severe treatments have greater impact on the quality of the machined surface. The nature of the impact is unclear, because studies related to this issue give contradictory results.

The surface of Scots pine (*Pinus sylvestris* L.) wood, thermally modified at temperatures 190 °C and 220 °C according to the ThermoWood procedure, showed a significant reduction in the surface roughness after planning, compared to the milled surface of untreated wood. The measured roughness parameters R_a (the arithmetic mean surface roughness), R_Z (the surface roughness depth) and Rt (the total height profile) decreased as the temperature increased (Pinkowski *et al*. 2016). Thermally modified samples of Deodar cedar (*Cedrus deodara* Roxb.), Black pine (*Pinus nigra* Arnold.), Black poplar (*Populus nigra* L.) and Italian alder (*Alnus cordata* Loisel.), treated using Thermo-Vacuum technique at maximum temperature of 200 °C and milled with a CNC router, showed a smoother surface compared to control samples (Sandak *et al*. 2017).

Similarly, Beech (*Fagus sylvatica* L.), thermally modified according to the industrial Vacu process, showed smoother surfaces after peripheral planing and sanding (abrasive paper P100) compared to untreated wood (Lütkemeier *et al*. 2018). Other studies supported these finding, highlighting the positive impact of thermal modification on roughness of afterwards machined surfaces. This effect was more pronounced for higher temperatures and low heating rate, except of sanding process (Unsal and Ayrilmis 2005, Tu *et al*. 2014). The aforementioned studies attributed the improvement of the machined surface to the fact that thermally modified wood became “brittle” due to the degradation of hemicelluloses, making so the cutting process easier.

Thermal modification has been also reported to increase surface roughness. was reported The surface roughness of Scots pine (*Pinus sylvestris* L.), Eastern beech (*Fagus grandifolia* Ehrh.), Uludag fir (*Abies bornmulleriana* Matff.) and Sessile oak (*Quercus petraea* L.) wood, heated for 3 h, 5 h or 7 h at 140 °C and 160 °C under atmospheric pressure, increased after sawing or planing. The authors attributed the increase in surface roughness to the higher hardness of wood caused by the thermal treatment (Budakçi *et al*. 2011, Budakçi *et al*. 2013).

Other authors did not find any significant relationship between thermally modified wood and the roughness of its machined surface. Kvietková *et al*. (2015a) examined the surface roughness of thermally modified Silver birch (*Betula pendula* Roth.) wood after plane milling, using a stylus profilometer. A similar procedure to ThermoWood was applied at the temperatures from 160 °C to 240 °C. Results showed that thermal modification reduced the surface roughness of planed wood, but the decrease was not statistically significant. Similiar results were also observed for Beech (*Fagus sylvatica* L.) (Kvietková *et al*. 2015b).

On the other hand, there is a lack of data on the surface roughness of machined thermally modified wood, particularly concerning the tangential and radial sections. Due to their distinct structure, the two sections affect differently the quality of the machined surface. Studies on the planed surfaces of naturally grown Oriental beech (*Fagus orientalis* Lipsky), Anatolian chestnut (*Castenea sativa* Mill.), Black alder (*Alnus glutinosa* subsp. *Barbata* (*C.A.Mey.*) Yalt.), Scotch pine (*Pinus sylvestris* L.) and Oriental spruce (*Picea orientalis* (L.) Link.) reported smoother surfaces for tangential section compared to radial ones (Malkocoğlu 2007). The effect of different machining methods on the roughness of Beech (*Fagus sylvatica* L.) and Aspen wood showed higher roughness values on radial surfaces for all the machines studied (Kiliç *et al*. 2006).

In this context, the goal of this study is to provide information regarding the surface quality of thermally modified Silver fir (*Abies alba* Mill.) after planing, focusing on the tangential and radial sections. This information is valuable for the development of gluing and finishing processes for thermally modified fir wood, which is one of the most widespread species in Albanian forests and commonly used wood by Albanian wood industry.

Materials and methods

Air dried Silver fir (*Abies alba* Mill.) boards of 50 mm × 220 mm × 2000 mm were used to produce the samples. Boards were selected randomly at the lumberyard of SINANI sawmill, located near to Librazhdi town, Albania. They were produced from 5 logs harvested by the sawmill from forests older than 120 years and were transferred to the Faculty of Forestry Sciences in Tirana, where the boards were conditioned for more than 4 months. Before conditioning, each board was cut off into 4 parts of equal length. After conditioning, the mean equilibrium moisture content (EMC) of wood resulted 10,85 % (1,09 % standard deviation) and the density 470 kg/m^3 (30 kg/m^3 standard deviation), measured respectively according to the standards ISO 13061-1 (2014a) and ISO 13061-2 (2014b).

Four groups of eight defects free samples with dimensions of 25 mm × 45 mm × 400 mm were subsequently prepared. Half of the samples in each group presented clear tangential section, while the other half presented clear radial ones. One group was used as control and the others were heated, applying three different temperatures 160 °C, 190 °C and 220 °C. The heating process was conducted in a temperature controlled small chamber (France Etuves, France) under atmospheric pressure with the presence of the oxygen, for three hours. Before heating, samples were dried at 103 °C ± 2 °C until the moisture content (MC) 0 %. The density of oven dried samples resulted 440 kg/m^3 (20 kg/m^3 standard deviation). The increment of temperature from 103 °C up to the treatment temperature was set 1 min·°C^{-1}. The treated samples were cooled and later conditioned until they reached the constant weight. The mean EMC of the treated samples at 160 °C, 190 °C and 220 °C resulted 6,08 % (0,98 % standard deviation), calculated by weighing method.

Both the control and heat-treated samples were processed along the grain in the section of interest (45 mm section) using a planer machine available at the Faculty of Forest Sciences in Tirana (Samco Lab300, Mantovani Macchine, Italy). The machine had cutterhead diameter 72 mm, rotation speed 5100 rpm and three knives with dimensions 300 mm × 30 mm × 3 mm. 10 m·min^{-1} feed rate was applied by means of a Type4M feeding system (Olympia, Italy). The cutting depth was 1 mm.

Immediately after plane milling, the measurements of surface roughness were performed with a stylus profilometer (Mitutoyo Surfest SJ-201P, Japan). The traversing speed during measurements, the tip radius and the top corner of the tip tool were 0,5 mm·s^{-1}, 2 µm, and 60 ° respectively. The roughness indexes values were determined with a resolution of ± 0,01 µm. The cut-off length was set 2,5 mm and the sampling length for each measurement was 12,5 mm. On each sample were performed 10 measurements, which provided a total of 320 measurements. Points of measurements were chosen randomly, distributed uniformly over the entire processed surface, without preferences between early or late wood. Measurements were carried out in parallel direction of the grain (Figure 1).

Figure 1: Measurement of radial section roughness in progress.

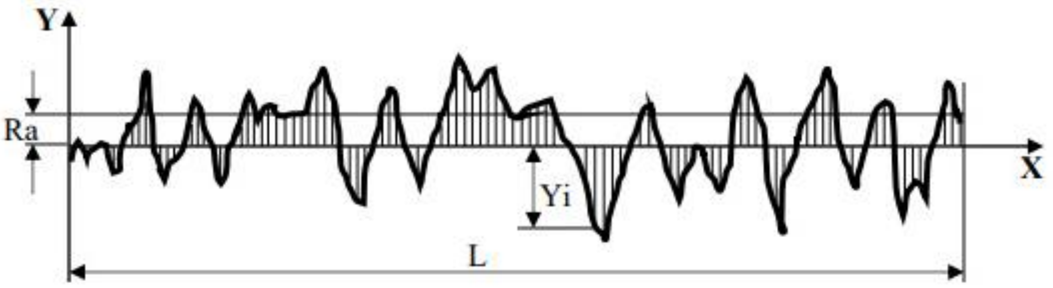
Ra (the mean arithmetic deviation of profile) and *Rz* (the mean of 5 peak-to-valley heights) parameters were measured according to ISO 4287 (1997) standard, applying Gaussian filter. The *Ra* parameter was calculated using the Equation 1:

$$Ra = \frac{1}{N}\sum_{i=1}^{N} Yi \qquad (1) \; .$$

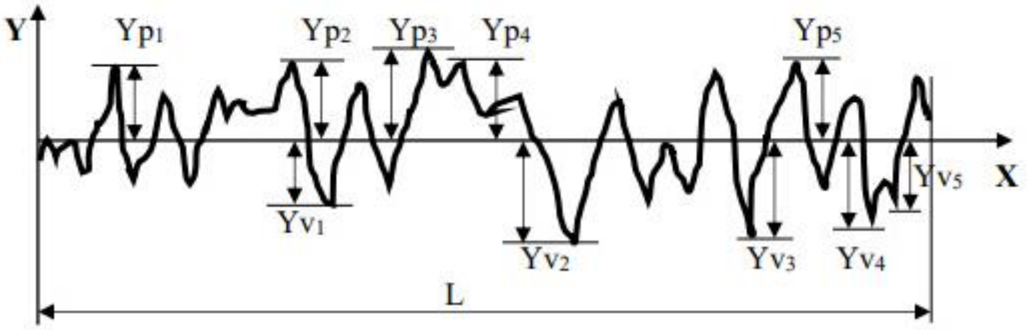
Meanwhile, the *Rz* parameter was determined by the Equation 2:

$$Rz = \frac{1}{5}\sum_{i=1}^{5} Ypi + \frac{1}{5}\sum_{i=1}^{5} Yvi \qquad (2)$$

After completing the measurements on each group of samples, the calibration of profilometer was re-checked in order to maintain its accuracy. A schematic illustration of both measured parameters (Figure 2).



Ra parameter



Rz parameter

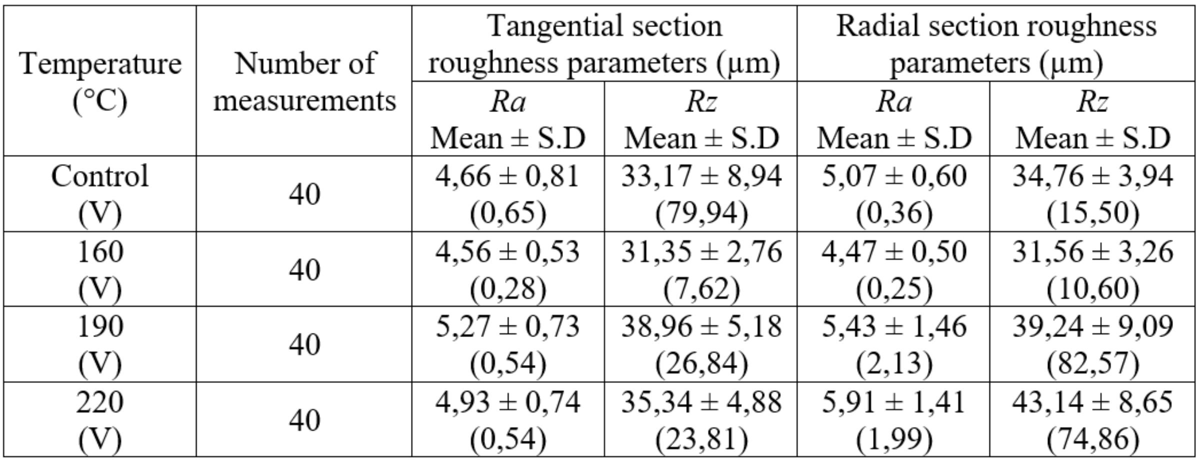
Figure 2: Schematic explanation of *Ra* and *Rz* roughness parameters. The associated equations are provided in the main text as Equation (1) and Equation (2).

The results were subjected to two-factor analysis of variance (ANOVA) to identify the significant effects of the analyzed factors (modification temperature as well as tangential and radial sections), using SPSS Statistics24 software (2016). Significance was accepted at the *P*-values < 0,05 level. Duncan test and t-Test were applied to analyze the differences in means.

Results and discussion

Table 1 presents the mean values of the roughness parameters *Ra* and *Rz* for the planed surfaces referred to four treatments states and both tangential and radial sections.

Table 1: Results of surface roughness for all combinations "treatment-section".



Temperature (°C)	Number of measurements	Tangential section roughness parameters (µm)		Radial section roughness parameters (µm)	
		Ra Mean ± S.D	*Rz* Mean ± S.D	*Ra* Mean ± S.D	*Rz* Mean ± S.D
Control (V)	40	4,66 ± 0,81 (0,65)	33,17 ± 8,94 (79,94)	5,07 ± 0,60 (0,36)	34,76 ± 3,94 (15,50)
160 (V)	40	4,56 ± 0,53 (0,28)	31,35 ± 2,76 (7,62)	4,47 ± 0,50 (0,25)	31,56 ± 3,26 (10,60)
190 (V)	40	5,27 ± 0,73 (0,54)	38,96 ± 5,18 (26,84)	5,43 ± 1,46 (2,13)	39,24 ± 9,09 (82,57)
220 (V)	40	4,93 ± 0,74 (0,54)	35,34 ± 4,88 (23,81)	5,91 ± 1,41 (1,99)	43,14 ± 8,65 (74,86)

S.D – Standard deviation; V – Variance.

It was noted that the radial section presented slightly more than 7 % greater roughness than the tangential one, for both parameters. It was observed that the radial section exhibited a roughness value approximately 7 % higher than that of the tangential section for both measured parameters.

Table 2 summarizes the differences between the roughness of radial and tangential sections for each group of samples, calculated by Equation 3.

$$D = \frac{Rrad. - Rtng.}{Rtng.} \times 100 \qquad (3)$$

Where *D* is the difference between the roughness of the sections (%), and *Rrad*. and *Rtng*. are respectively the roughness of radial and tangential sections (µm).

Table 2: Differences between the roughness of radial and tangential sections.

Temperature (°C)	Roughness differences between sections (%)	
	Ra	Rz
Control	8	5
160	-2	1
190	3	1
220	20	22

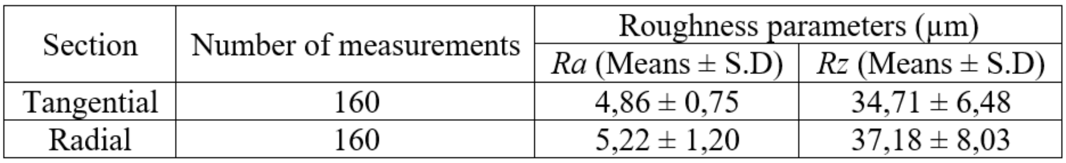
The two-factor analyze of variance (ANOVA) revealed a significant effect of both analyzed factors (section and modification temperature) on both roughness parameters (*Ra* and *Rz*). The interaction between the two factors was found to be significant resulted to be significant at the level 0,05 (Table 3).

Table 3: Results of the analysis of variance for the surface roughness.

Parameter	Factor	Sum of squares	Degrees of freedom	Mean squares	Fisher's F-test	Sig. (*P*-value)
Ra	Intercept	14847,054	1	14847,054	22309,904	0,000
	Section (A)	14,194	1	14,194	21,328	0,000
	Modification temperature (B)	44,912	3	14,971	21,280	0,000
	A × B	15,980	3	5,327	8,004	0,000
	Error	415,267	624	0,665		
Rz	Intercept	758098,983	1	758098,983	25112,46	0,000
	Section (A)	953,068	1	953,068	31,571	0,000
	Modification temperature (B)	3618,278	3	1206,093	39,953	0,000
	A × B	534,630	3	178,210	5,903	0,001
	Error	18716,660	620	30,188		

Table 4 presents the values of the surface roughness parameters for the milled sections. A t-Test was applied to assess the influence of the milled sections on the surface roughness, regardless whether the samples were modified or not. The t-Test revealed significant differences between the data grouped by sections ($p < 0,05$), indicating a clear influence of the section on the roughness values.

Table 4: Comparative results for the section (t-Test).



Section	Number of measurements	Roughness parameters (µm)	
		Ra (Means ± S.D)	*Rz* (Means ± S.D)
Tangential	160	4,86 ± 0,75	34,71 ± 6,48
Radial	160	5,22 ± 1,20	37,18 ± 8,03

S.D – Standard deviation.

The results obtained in this study for the control samples, align with findings from the literature. Several studies investigated the effects of planning process parameters on the surface roughness of different wood species, including Scotch pine (*Pinus sylvestris* L.) and found out that the radial direction produced rougher surfaces comparing to the tangential direction. This finding was based on the fact that in the radial direction fibers tended to break off from the springwood tissue (Sogutlu 2010, Sogutlu and Togay 2011). Regarding fir wood, the difference in surface roughness between the radial and tangential sections resulted from the slight heterogeneity of wood cells in radial section, where there is a high percentage of parenchyma cells per surface unit. On the other hand, the roughness of planed radial and tangential sections of thermally modified fir wood could not be compared due to the lack of data from previous studies.

It was observed that temperatures of 160 °C and 190 °C significantly reduced the roughness differences between the two sections. However, at 220 °C, the roughness of the radial section was more than 20 % higher than that of the tangential one, indicating an increasing difference in roughness between the two sections as the temperature exceeds 200 °C.

Duncan test analyze was applied to assess the influence of modification’s temperature on surface roughness, regardless the milled section. Comparative results of this test identified three homogenous groups referring respectively control samples, those modified at temperature 160 °C and those modified at temperatures 190 °C and 220 °C (Table 5). A non-linear relation was identified. At 160 °C, the surface after planing was smoother. The values of both roughness parameters were about resulted about 7 % lower than those of control samples. This trend was not observed at 190 °C and 220 °C. At 190 °C, the roughness parameters increased by 10 % for *Ra* and 15 % for *Rz* compared to the control samples, while at temperature 220 °C the increment was 11 % for *Ra* and 16 % for *Rz*.

Table 5: Comparative results for the modification temperature (Duncan test).

Temperature (°C)	Number of measurements	Roughness parameter (µm)		Homogenous group
		Ra	Rz	
Control	80	4,87	3,97	I
160	80	4,52	31,46	II
190	80	5,35	39,10	III
220	80	5,42	39,24	III

Other authors have also reported similar results regarding the surface roughness of thermally modified wood at atmospheric pressure. Gurau *et al*. (2017) studied the effect of different heat treatment durations at 200 °C on subsequent surface roughness of planed beech (*Fagus sylvatica* L.). The heat treatment was applied at atmospheric pressure. The results showed a gradual increase in the surface roughness of the planed wood which became more pronounced with longer treatment durations. The heat treatment caused weight loss of wood and increased its fibrousness due to material loss in the cell structure and the degradation of hemicelluloses, which plays an important role as a coupling agent between the cellulosic microfibril reinforcement and the lignin-rich matrix.

Because of hemicelluloses degradation during this process the wood's brittleness was increased or its resilience and toughness were reduced (Kotilainen 2000, Hughes *et al*. 2015, Cao *et al*. 2022). This caused greater propagation of cracks, leading to a rougher surface on the thermally modified wood after mechanical processing (Fengel and Wegener 1989, Korkut and Kocaefe

2009, Mamoňová *et al*. 2022). The slightly smoother surface obtained at 160 °C can be explained by the fact that the hemicelluloses had not degraded to significant extent.

Conclusions

Improving gluing and coating properties of thermally modified wood would significantly expand its range of applications. In this context, surface roughness is a key factor, as it has a major impact on both the wettability and the strength of the bond between the adhesive or coating and the wood surface. Due to the anisotropic structure of the wood, the radial and tangential sections influence the roughness of the machined surface in different ways. Heat modification of Silver fir (*Abies alba* Mill.) at atmospheric pressure demonstrated that both the processed section as well as the temperature of modification are statistically significant factors influencing surface roughness. In untreated wood, the radial section exhibited higher roughness than the tangential section due to the light heterogeneity of wood cells in the radial section, which contains a higher proportion of parenchyma cells per surface unit. Modification at temperatures below 200 °C nearly equalized the roughness between the sections. However, above this threshold, the roughness of the radial section increased significantly, exceeding the tangential section by over 20 %, showing a clear trend of divergence with rising temperatures. A positive non-linear correlation was observed between modification temperature and surface roughness. At lower modification temperatures, planed surface were slightly smoother than that of untreated wood, likely because the hemicelluloses had not degraded significant. However, as temperature exceeded 160 °C, surface roughness increased by more than 10 % compared to untreated wood.

The results of this study appear to be valuable for wood specialists. They provide guidance on selecting the appropriate section for achieving better gluing or coating quality of thermally modified wood, based on its specific use conditions,

Authorship contributions

D. A.: Conceptualization, funding acquisition, methodology, investigation, writing. H. C.: Methodology, investigation, literature review. E. L.: Investigation, literature review, writing - review and editing. D. Q.: Statistical analysis, writing - review and editing.

Acknowledgements

This research was funded by the Project "Evaluation of low-quality domestic timber using new gluing and modification techniques", in the framework of "Scientific and Technological Cooperation Programme 2020 - 2022" between governments of Albania and Kosovo.

References:

Budakçi, M.; İlçe, A.; Korkut, D.; Gürleyen, T. 2011. Evaluating the Surface Roughness of Heat-Treated Wood Cut with Different Circular Saws. *BioResources* 6(4): 4247-4258. https://doi.org/10.15376/biores.6.4.4247-4258

Budakçi, M.; İlçe, A.; Gürleyen, T.; Utar, M. 2013. Determination of the Surface Roughness of Heat-Treated Wood Materials Planed by the Cutters of a Horizontal Milling Machine. *BioResources* 8(3): 3189-3199. https://doi.org/10.15376/biores.8.3.3189-3199

Cao, S.; Cheng, S.; Cai, J. 2022. Research progress and prospects of wood high-temperature heat treatment technology. *BioResources* 17(2): 3702-3717. https://doi.org/10.15376/biores.17.2.Cao

Fengel, D; Wegener, G. 1989. *Wood: Chemistry, Ultrastructure, Reactions.* 2nd Edition. Walter de Gruyter, Berlin, Germany.

Gurau, L.; Irle, M.; Campean, M.; Ispas, M; Buchner, J. 2017. Surface quality of planed beech wood (*Fagus sylvatica* L.) thermally treated for different durations of time. *BioResources* 12(2): 4283-4301. https://doi.org/10.15376/biores.12.2.4283-4301

Hughes, M.; Hill, C.; Pfriem, A. 2015. The toughness of hygrothermally modified wood. *Holzforschung* 69(7): 851-862. https://doi.org/10.1515/hf-2014-0184

ISO. 1997. Geometrical product specifications surface texture profile method terms, definitions and surface texture parameters. ISO 4287. ISO: Genève, Switzerland.

ISO. 2014a. Physical and mechanical properties of wood – Test method for small clear wood specimens. Part 1: Determination of moisture content for physical and mechanical tests. ISO 13061-1. ISO: Genève, Switzerland.

ISO. 2014b. Physical and mechanical properties of wood – Test method for small clear wood specimens. Part 2: Determination of moisture content for physical and mechanical tests. ISO 13061-2. ISO: Genève, Switzerland.

Kamperidou, V.; Barboutis, I. 2017. Mechanical strength and surface roughness of thermally modified poplar wood. *PRO LIGNO* 13(4): 107-114. https://www.proligno.ro/en/articles/2017/4/KAMPERIDOU.pdf

Kamperidou, V.; Aidinidis, E.; Barboutis, I. 2020. Impact of structural defects on the surface quality of hardwood species sliced veneers. *Applied Sciences* 10(18). e6265. https://doi.org/10.3390/app10186265

Kiliç, M.; Hiziroglu, S.; Burdurlu, E. 2006. Effect of machining on surface roughness of wood. *Building and Environment* 41(8): 1074-1078. https://doi.org/10.1016/j.buildenv.2005.05.008

Korkut, S.; Kocaefe, D. 2009. Effect of heat treatment on wood properties. *Düzce University Faculty of Forestry Journal of Forestry* 5(2):11-34. https://dergipark.org.tr/en/download/article-file/274958

Kotilainen, R. 2000. Chemical changes in wood during heating at 150-260 °C. PhD thesis. Department of Chemistry of Jyväskylä University. Jyväskylä, Finland. https://converis.jyu.fi/converis/portal/detail/Publication/18746316

Kvietková, M.; Gašparík, M.; Gaff, M. 2015a. Effect of thermal treatment on surface quality of beech wood after plane milling. *BioResources* 10(3): 4226-4238. https://doi.org/10.15376/biores.10.3.4226-4238

Kvietková, M.; Gaff, M.; Gašparík, M.; Kaplan, L.; Barcík, Š. 2015b. Surface quality of milled birch wood after thermal treatment at various temperatures. *BioResources* 10(4): 6512-6521. https://doi.org/10.15376/biores.10.4.6512-6521

Lütkemeier, B.; Konnerth, J.; Militz, H. 2018. Distinctive impact of processing techniques on bonding surfaces of acetylated and heat-treated beech wood and its relation to bonding strength. *Forest Products Journal* 68(4): 372-382. https://doi.org/10.13073/fpj-d-17-00077

Malkocoğlu, A. 2007. Machining properties and surface roughness of various wood species planed in different conditions. *Building and Environment* 42(7): 2562-2567. https://doi.org/10.1016/j.buildenv.2006.08.028

Mamoňová, M.; Ciglian, D.E.; Reinprecht, L. 2022. SEM analysis of glued joints of thermally modified wood bonded with PUR and PVAc glues. *Materials* 15(18). e6440. https://doi.org/10.3390/ma15186440

Pakzad, S.; Pedrammehr, S.; Hejazian, M. 2023. A Study on the Beech wood machining parameters optimization using response surface methodology. *Axioms* 12(1). e39. https://doi.org/10.3390/axioms12010039

Pelit, H.; Korkmaz, M.; Budakçı, M. 2021. Surface roughness of thermally treated wood cut with different parameters in CNC router machine. *BioResources* 16(3): 5133-5147. https://doi.org/10.15376/biores.16.3.5133-5147

Pinkowski, G.; Krauss, A.; Piernik, M.; Szymański, W. 2016. Effect of thermal treatment on the surface roughness of Scots pine (*Pinus sylvestris* L.) wood after plane milling. *BioResources* 11(2): 5181-5189. https://doi.org/10.15376/biores.11.2.5181-5189

Sandak, J.; Goli, G.; Cetera, P.; Sandak, A.; Cavalli, A.; Todaro, L. 2017. Machinability of minor wooden species before and after modification with thermo-vacuum technology. *Materials* 10(2): 121-133. https://doi.org/10.3390/ma10020121

Sogutlu, C. 2010. The effect of the feeding direction and feeding speed of planning on the surface roughness of oriental beech and Scotch pine woods. *Wood Research* 55(4): 67-78. http://www.woodresearch.sk/wr/201004/07.pdf

Sogutlu, C.; Togay, A. 2011. The effect of the process parameters in the planing processes on the surface roughness of cherry and pear woods. *African Journal of Biotechnology* 10(21): 4392-4399. https://www.ajol.info/index.php/ajb/article/view/93660

SPSS. 2016. Statistical software for data management. SPSS Statistics 24. IBM: New York, USA.

Tu, D.; Liao, L.; Yun, H.; Zhou, Q.; Cao, X.; Huang, J. 2014. Effects of heat treatment on the machining properties of Eucalyptus urophylla × E. camaldulensis. *BioResources* 9(2): 2847-2855. https://doi.org/10.15376/biores.9.2.2847-2855

Unsal, O.; Ayrilmis, N. 2005. Variations in compression strength and surface roughness of heat-treated Turkish river red gum (*Eucalyptus camaldulensis*) wood. *Journal of Wood Science* 51: 405-409. https://doi.org/10.1007/s10086-004-0655-x