

ASSESSMENT OF SURFACE ROUGHNESS AND DIMENSIONAL STABILITY IN SOME SPECIES OF THERMALLY TREATED WOODS

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Abstract:

*The objective of this study is to determine the surface roughness of some wooden species that grow in our county in Albania, like white Sessile oak (*Quercus petraea* (Matt.) LiebL.), Common beech (*Fagus sylvatica* L), Black Pine (*Pinus nigra* Arn.) and Silver fir (*Abies alba* Mill.) after the heat treatment process. The second objective of this study is to verify the impact of heat treatment on the weight loss of wood samples. Before the treatment, the samples were weighed and surface roughness is measured. Surface roughness is measured with a Contact Stylus Profilometer type Mitutoyo SJ-201. The next step in the experiment procedure was drying the samples at 0% humidity and then those were treated in cycles of high temperature. More specifically, the samples were treated with 2 and 8-hour cycles during which they were initially exposed respectively to temperatures of 120, 150, 180°C. After the heat treatment was finished the samples were planned in the planning machine with a horizontal cutter equipped with 3 blades, with constant feeding speed. The results of the study indicate that heat treatment decreases the surface roughness values of the wooden material.*

Key Words: *heat treatment; roughness; moisture; feeding speed.*

INTRODUCTION

Wood is a natural, sustainable bio-material with good features and superior formability which qualifies it to be used as an engineering and construction material in both exterior and interior decoration work (Okon et al. 2021).

The wood material is not found in large quantities and without difficulty. Activities for obtaining timber from forest areas have a great impact on the environment. These difficulties in obtaining the material have always led to searching for the efficient ways of using it. Not always, the wood material is capable to meet all quality requirements if its proper use. So considering that the wood material, is a deficient material, and highly exposed to the effects of moisture content, and the impact of fungi and insects, then we will have a material that requires special care in its use. These limit the outdoor applications of wood (Kocaeffe et al. 2008). For this reason, Improvement of the quality of wooden material is a big goal in itself. Technical and technological qualities are in the focus of continuous improvement. In this case we can mention different treatments such as wood drying, chemical treatments, heat treatment, protective treatments to prevent the decay of wooden materials from biological pests and atmospheric agents. We all know the great impact and the damage to the wood used for the production of furniture or as a raw material in other processes caused by the exchange of moisture with the surrounding environment. This damage is addressed to the cell wall polymers that contain hydroxyl and other oxygen-containing groups. Groups of polymers attract moisture through hydrogen bonding (Stamm 1964, Rowell and Banks 1985). Changes in moisture content have their consequences on dimensional stability as well as on the workability characteristics of the material. High-temperature heat treatment is considered a suitable method to improve wood characteristics. It reduces toxic chemical applications, required to increase wood durability (Kandem et al. 2002, Welzbacher and Rapper

2007, Mohareb *et al.* 2010) and enhance dimensional stability, reducing the hygroscopic behavior of the material (Kortelainen *et al.* 2006). High-temperature treatment can be viewed as a type of wood modification, due to the possibility of controlling color changes (Bekhta and Niemz 2003, Johanson and Moren 2006, Esteves *et al.* 2007) and mechanical performance (Bekhta and Niemz 2003, Welzbacher *et al.* 2007, Bal 2014). Wood treatment at high temperature is a very promising alternative to the chemical treatment (Poncsák *et al.* 2006). Heat treatment reduces the water absorbing capabilities of wooden material. This is achieved by modifying its chemical structure. Heat treatment causes a reduction of hemicellulose content, which impacts directly the dimensional stability of wood (Popper *et al.* 2005, Wang and Cooper 2005). Our focus in this article will be on the thermal treatment of wood in order to improve its technological qualities such as surface roughness.

During cutting processes, various anatomical parts of wood are separated and the properties of the separated pieces are influenced by the grain pattern and, physical and mechanical properties of wood (Thoma *et al.* 2014). Grain structure make the micro-geometry of the created wood surfaces heterogeneous. (Goli 2003), (Goli *et al.* 2004, 2005) have systematically studied the effects of grain direction on the machined surface geometry, and especially the occurrence of certain surface defects, e.g., fuzzy grain. These authors have also discussed the mechanisms of defect formation, such as kinematics, cutting forces, shear induced splitting, transverse compression and tension, and presented experimental observations, which give directives for optimized cutting procedures in relations to surface roughness.

Wood treated at high temperature has less hygroscopicity than natural wood. Heating wood permanently changes several of its chemical and physical properties. The change in properties is mainly caused by thermic degrading of hemicelluloses. Heat treatment significantly reduces the tangential and radial swelling. (Gunduz *et al.* 2007).

MATERIALS AND METHODS

As testing material, we have selected four wood species that grow in our country. In total we have 160 specimens, 40 specimens for each wood type, with a length of 150mm, width of 50mm and a height of 25mm. Wood samples are obtained from the wood material sold in the local market. The wood samples are prepared in the Experimental Didactic Laboratory of the Wood Industry at the Faculty of Forest Sciences at the Agricultural University of Tirana. This is a laboratory equipped with proper tools and woodworking machineries to carry out different types of woodwork. It comes to the aid of the students and academic staff of this faculty in terms of preparing various materials and samples that will be used in various tests.

Wooden material for the samples first are sawn in a circular saw then are planned in a planning machine with a horizontal cutter equipped with 3 blades, with constant feeding speed. After this stage the roughness of the surface is measured. Then, after the heat treatment process we plan again the wooden samples and then the surface roughness is measured.

MITUTOYO SURFTEST SJ-201 instrument is used to measure the surface roughness. This instrument measures the surface roughness by the help of a special head. Through a built-in software we achieved a two-dimensional profile of surface irregularities. The surface roughness parameters are Ra, Ry, Rz, Rq. Respectively Ra is the average distance from the profile to the mean line over the length of assessment. Rq is the square root of the arithmetic mean of the squares of profile deviations from the mean line. Rz can be calculated from the peak-to-valley values of five equal lengths within the profile while maximum roughness (Ry) is the distance between peak and valley points of the profile which can be used as an indicator of the maximum defect height within the assessed profile (Mummery 1993). Therefore, such parameters which are characterized by ISO 4287 and DIN 4768 were recorded, wich is now a retired version of ISO. Now it is replaced with ISO 21920-2:2021.

According to (Goli 2003) in order to better evaluate the surface quality of wood it should be analyzed the primary profile. The primary profile is thus the sum of all the deviations of the measured profile from the nominal profile. The profiles are the sum of the form error profile, the waviness profile, and the roughness profile and is normally computed from the traced profile by excluding the nominal form by using the method of best fit least squares of the type and by excluding ultra-short wavelengths from the evaluation by using the "ls" profile filter, which considerably increases comparability (Thoma *et al.* 2014).

Table 1

The following table gives the data of weight, moisture content and surface roughness before the heat treatment

Type of wood		parameter		Mean
Black Pine (Pinus nigra Arn.)		W (gram)		138.92
		Sr (μm)	Ra	6.13
			Ry	53.5
			Rz	37.32
			Rq	7.86
		Mc (%)		10.09
Silver fir (Abies alba Mill.)		W (gram)		116.29
		Sr (μm)	Ra	5.8
			Ry	46.08
			Rz	34.62
			Rq	6.97
		Mc (%)		9.51
common beech (Fagus sylvatica L)		W (gram)		163.84
		Sr (μm)	Ra	5.55
			Ry	43.39
			Rz	32.53
			Rq	6.72
		Mc (%)		9.65
Sessile oak (Quercus petraea (Matt.) LiebL)		W (gram)		172.93
		Sr (μm)	Ra	6.8
			Ry	50.07
			Rz	43.94
			Rq	8.58
		Mc (%)		11.65

where:

- W – weight measured in grams
- Sr - Surface roughness
- Ra - Arithmetical mean roughness (Ra)
- Ry - Maximum peak (Ry)
- Rz - Ten-point mean roughness (Rz)
- Rq - Rq is referred to as the root-mean-square roughness
- Mc - Moisture content
- sd – Standard deviation

Number of samples used in each test is 40.

RESULT AND DISCUSSION

All these samples are subjected to drying to 0% humidity and then are weighed again to see weight loss. The change is showed in the Table 2.

Table 2

Weight change depending on humidity

Type of wood	Specimen	Moisture content (%)	Weight (gr)	Dry weight (gr)	Difference (gr)
Black Pine (Pinus nigra Arn.)	40	10.09	138.92	131.01	7.91
Silver fir (Abies alba Mill.)	40	9.51	116.29	107.09	9.2
common beech (Fagus sylvatica L)	40	9.65	163.84	152.53	11.31
Sessile oak (Quercus petraea (Matt.) LiebL)	40	11.65	172.93	160.83	12.1

Bringing the samples in 0% moisture content and to check the weight loss was the first stage of the experiment. A dry wood increases dimensional stability, which is highly required for several uses.

The samples are treated with 2 and 8-hour cycles during which they are initially exposed respectively to temperatures of 120, 150, 180°C. After the heat treatment is finished the samples are planned in the planning machine with a horizontal cutter equipped with 3 blades, with constant feeding speed. *The results of the study indicate that heat treatment decreases the surface roughness values of the wood material, as we can see in the table below. Earlier in this article are explained the operations performed to prepare the specimens.*

Table 3

Improvement in % of surface roughness after heat treatment cycles of 2 and 8 hours in temperatures of 120°C, 150°C and 180°C

Material	Temperature	Hours	Ra	Ry	Rz	Rq
Black Pine (Pinus nigra Arn.)	120	2	6.02	49.69	35.29	7.55
		8	5.9	49.57	35.17	7.43
	150	2	5.81	45.78	33.16	7.14
		8	5.54	45.51	32.89	6.87
	180	2	5.46	41.73	30.89	6.59
		8	4.94	41.21	30.37	6.07
Silver fir (Abies alba Mill.)	120	2	5.71	42.29	32.61	6.68
		8	5.59	42.17	32.49	6.56
	150	2	5.52	38.4	30.5	6.29
		8	5.25	38.13	30.23	6.02
	180	2	5.19	34.37	28.25	5.76
		8	4.67	33.85	27.73	5.24
common beech (Fagus sylvatica L)	120	2	5.47	39.61	30.53	6.44
		8	5.35	39.49	30.41	6.32
	150	2	5.29	35.73	28.43	6.06
		8	5.02	35.46	28.16	5.79
	180	2	4.97	31.71	26.19	5.54
		8	4.45	31.19	25.67	5.02
Sessile oak (Quercus petraea (Matt.) LiebL)	120	2	6.7	46.27	41.92	8.28
		8	6.58	46.15	41.8	8.16
	150	2	6.5	42.37	39.8	7.88
		8	6.23	42.1	39.53	7.61
	180	2	6.16	38.33	37.54	7.34
		8	5.64	37.81	37.02	6.82

CONCLUSIONS

In conclusion, it was found that the density, swelling and surface roughness of the red-bud maple decreased for all treatment conditions (temperatures and times).

We can witness a plastification effect on the surface of the solid wood caused by the heat applied. The lignin located in near the surface of the sample is subject of the thermoplastic effect, caused by temperatures above 160°C and this causes a denser surface. Also, the wooden materials with rough surface requires much more sanding process compared to one with smooth surface, which leads to decrease in thickness of material and, therefore, increase the losses due to the sanding process. Heat treatment resulted in varying amounts of weight loss, depending on the treatment temperature and time.

Heat treatment of wood resulted in a significant reduction of water adsorption. The availability and/or accessibility of the free hydroxyl groups of the wood carbohydrates play an important role in the process of water adsorption and desorption. It is by no doubt that heat treatment results in a reduction of the accessible, free hydroxyl groups and several causes are reported, e.g. depolymerization of the carbohydrates and especially hemicelluloses causing a reduction of the total amount of hydroxyl groups, including the free

hydroxyl groups; an increase of the relative proportion of the crystalline cellulose, in which the hydroxyl groups are not easily accessible to water molecules; and crosslinking of the lignin network, which might hinder the accessibility of free hydroxyl groups to water. The relative weight loss includes the evaporation of water as well as evaporation of extractives, degradation of wood components especially hemicelluloses and evaporation of degradation products.

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