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MEASURING THE SURFACE ROUGHNESS VALUES OF EUROPEAN HOP-HORN BEAM (*OSTRYA CARPINIFOLIA* SCOP.) WOOD

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ABSTRACT

In this study, the samples obtained from European hop-horn beam (*Ostrya carpinifolia* Scop.) wood has been subject to cutting with circular saw, planing with a thickness machine and sanding with a caliber sanding machine (with no: 80 sand). After the specimens were processed in the machines in radial and tangential surfaces, their surface roughness values (R_a, R_y, R_z) have been determined in accordance with the ISO 4288 standard. According to the statistical results, the lowest roughness values have been achieved with the thickness machine. Similarly, the roughness values of tangentially cut surfaces have been found to be lower than the radially cut surfaces.

KEYWORDS: Surface roughness, *Ostrya carpinifolia* Scop., wood machining, cutting directions.

INTRODUCTION

Determination of surface roughness of wood material used in the furniture industry is quite important in the identification of the quality of the end products. Surface roughness directly affects both connecting (adhesion) products of wood origin and the top surface processes (polishing).

During the processing of wood with various machines, as a result of cutting cells which make up the wood with sharp tools, it has been stated that gaps are formed between these cells and that tree species, ratio of spring-summer wood and the cutting of the wood in a radial or tangential manner are effective in terms of the size of these gaps and this in turn effect the surface roughness of the wood (Stumbo 1963, Peters and Cumming 1970, Söğütlü 2017, Kilic et al. 2006).

Yearly ring width and wood density also affect surface roughness, depending on the conditions of the growing place of the wood material. The spring and summer wood ratio in the yearly ring is quite effective on surface roughness. It has been stated in the studies conducted that, the summer wood part in the yearly ring gives lower surface roughness values in comparison to spring wood parts (Gurau 2004, Ulusoy 2011, Tiryaki 2012). This is being associated with spring wood and summer wood cells' wall structures being different from each other (Ohashi et al. 2001). In addition, the cracks formed on the surface of the wood, cell dents, fiber ruptures, fiber length and knot, fiber curvature and formation of pressure wood which are regarded as the natural growth characteristics of wood have the effect of increasing roughness (Sieminski and Skarzynska 1987, Akbulut and Ayrilmis 2006). The processing direction of the wood also affects surface roughness. In general, tangential sections give less surface roughness in comparison to radial sections (Kilic et al. 2006, Burdurlu et al. 2006, Aslan et al. 2008, Tiryaki 2012, Kilic 2015, Söğütlü et al. 2016).

The surface quality of the wood is its most important characteristic which affects production processes such as adhesion strength and surface procedures. For this reason, numerous approaches have been put forward in order to measure surface roughness (Kilic et al. 2006, Bajic et al. 2008). The methods used in measuring surface roughness can be grouped under two categories. These are contact and non-contact methods (Aydin and Colakoglu 2003).

Contact stylus type profilometer method which is still being used is one of the most effective roughness measurement methods (Lemaster and Beall 1993, Hiziroglu 1996, Kilic et al. 2006, Kilic 2015, Pelit et al. 2015). However, there is no standard method which has generally been accepted to evaluate the surface roughness of wood (Zhong et al. 2013). In addition, each method has positive and negative aspects. For instance, contact stylus type profilometer method is quite simple in comparison to other methods. In this method, since scanning is performed with a stylus which has a sensitive tip, it is required to use a scanning stylus which is suitable for roughness measurements. On the other hand, in order to be able to achieve the surface roughness values with full precision, many measurements need to be done. Making of the measurements and the evaluation of the results cause a great loss of time. In this method, the scanning process is performed vertically on the fibers with a stylus (Bonac 1979, Aydin and Colakoglu 2003, Malkocoglu and Ozdemir 1999, Tiryaki et al. 2014, Kilic 2015).

Optical methods, which are one of the non-contact surface roughness measurement methods, are widely used in surface roughness measurements since they allow speedy area measurement. The greatest advantage of these measurement methods is that, they are non-contact and that they do not give damage to the surfaces. In addition, since this method is visual and microscopic based, it is much faster than the contact methods (Vorburger et al. 2007).

In the recent years, ultrasonic, video camera and scanning electron microscope methods for roughness measurements have been given weight to besides the other methods. Since the sample dimensions used in the scanning electron microscope method are very small, it has been stated that they are insufficient for roughness evaluations (Malkocoglu and Ozdemir 1999, Tiryaki et al. 2014, Tiryaki 2012).

The Ostrya species which is the subject of the study has about 7 types which have spread North and Central America and Europe and Asia. Among these, only *Ostrya carpinifolia* Scop. grows naturally. *Ostrya carpinifolia* Scop. is a tree of 15-20 height with a messy top and its bark which is dark grey colored and smooth at first becomes cracked in a longways linear manner like vine trunks. Its homeland extends from South France to Bulgaria and covers all Southern Europe, West of Syria, Anatolia and Transcaucasia. In our country, it is found in small groups in the forests of leaved trees in cities such as Zonguldak, Kastamonu, Sinop, Tokat, Trabzon, Erzurum, Antalya and Mersin (Gercek et al. 1998, Dogu et al. 2000, Korkut and Guller 2008).

It's very valuable, firm, thin textured, durable and dark colored wood is finished in Amasra and many different and quite beautiful touristic souvenirs are produced (Yaltirik and Efe 2000, Korkut 2009).

The physical and mechanic characteristics of *Ostrya carpinifolia* Scop. have been researched by Korkut and Guller (2008). However, no studies have been found in literature in which what the surface roughness values of *Ostrya carpinifolia* Scop. are when it is processed in furniture machines are indicated.

Thus, in this study, the fine stylus method was preferred to determine the surface roughness of machined wood samples prepared from *Ostrya carpinifolia* Scop. wood. The purpose was to determine the roughness of surfaces obtained by the most frequently used wood processing machines.

MATERIAL AND METHODS

The *Ostrya carpinifolia* Scop. trees used in the study have been obtained by being cut in accordance with the ISO 4471 standard from the Central Anatolia Forestry Research Institute Directorate Yaylacık Research Forests.

Ostrya carpinifolia Scop. trees have been obtained by being cut from an altitude of 1047 m. A total of 3 trees have been cut. After the trees have been cut, the branches on their trunks have been removed, the timbers have been taken starting from 0.30 m of height from the ground and the height and diameters at 1.30 m. have been measured (Tab. 1).

Tab. 1: Properties of experimental trees.

European hop-horn beam				
Tree number	Length (m)	Diameter at 1.30 m (cm)	Air dried density ($g\cdot cm^{-3}$)	Age (years)
1	21	34	0.87	68
2	20	32	0.86	64
3	23	27	0.85	74
Average air-dried density 0.86 $g\cdot cm^{-3}$				

The samples were cut in put 60 × 500 mm dimensions and were put in the environmental test chamber until the air dryness reached humidity (12%). The two cutting directions of tangential and radial in *Ostrya carpinifolia* Scop. have been performed and a total of 300 measurements and 50 tests have been performed in a repetitive manner on three different surface processing types used in furniture industry, namely cutting with a circular saw, planing and sanding (2 × 3 × 50 = 300).

The *Ostrya carpinifolia* Scop. samples have been processed in the most widely used machines in the furniture sector (thickness machine, circular saw and caliber sand machine) in a manner to form tangential and radial surfaces and it has been attempted to determine the surface roughness values of the tree samples which have been processed with these machines. Finally, planing has been done with the triple bladed thickness machine (4500 $rev\cdot min^{-1}$), cutting has been done with the 40 tooth circular saw machine (6000 rpm) and caliber sanding has been done with a caliber sanding machine (1400 $rev\cdot min^{-1}$) (with no: 80 sand paper). During the processing of these pieces with these machines, the feeding time has been set to 10 $m\cdot min^{-1}$. Finally, it was planned with a three-blade thickness machine.

In the determination of the surface roughness values, the measurements have been done in accordance with the requirements of the ISO 4288 through the surface roughness device which measures (Mitutoyo SJ-301 Series) with the "Contact stylus type profilometer method" (Fig. 1). Surface roughness was made across the grain.

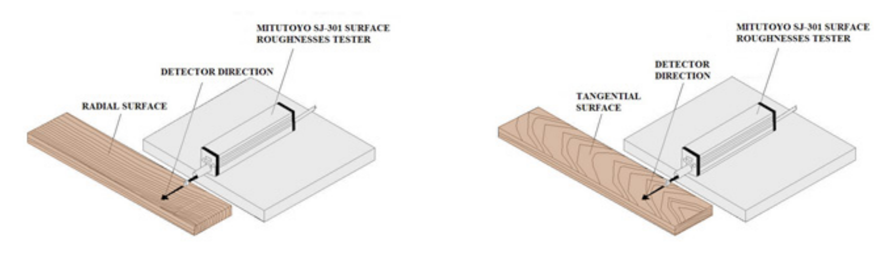

Fig. 1: Surface profilometer used in this study.

The measurement speed of the surface roughness device which has been used was 0.5 mm·sec^{-1}., its limit wave length (λc) was 0.8 mm (0.8 mm x 5 rows) and its detector measurement length was (lt) 21 mm (diamond tip stylus, tip angle 90°/tip radius 2 μm). As a result of the surface roughness measurements, each piece's R_a, R_y, R_z (μm) values have been determined.

RESULTS AND DISCUSSION

R_a (Average roughness)

The statistical values calculated for average surface roughness (R_a) have been given in Tab. 2.

Tab. 2: R_a statistic values.

Source of Variation	Sum of squares	Degrees of freedom	Mean squares	F	P
Machine (A)	64.483	2	32.242	47.749	0.00*
Cutting Direction (B)	7.815	1	7.815	11.574	0.00*
A*B	10.516	2	5.258	7.787	0.00*
Error	198.518	294	0.675		
Total	6413.345	300			
ns=(not significant) *=<0.05 important					
Cutting direction	Number of samples	Mean	Standard deviation	Minimum	Maximum
Tangential	150	4.35	0.999	4.19	4.52
Radial	150	4.68	0.914	4.53	4.83
Machine	N	α=0.05			
		1	2		3
Thickness	100	3.91			
Sanding	100		4.60		
Circular saw	100				5.04

When Tab. 2 was analyzed, it has been observed that besides the machine types and cutting directions affecting the R_a values, their double effects also carry importance statistically in terms of R_a value as well.

When the statistical values for the cutting directions (Tab. 2) were analyzed, it has been seen that the average surface roughness values of samples which have been cut tangentially were lower compared to the samples which were cut radially ($R_{a\text{Tangential}}$ = 4.35 µm, $R_{a\text{Radial}}$ = 4.68 µm).

According to the results of the Tukey's test carried out to compare the averages, the smoothest surfaces have been achieved with the thickness machine (R_a=3.91 µm) and it is being followed successively by the sanding machine (R_a=4.60 µm) and the circular saw machine (R_a=5.04 µm) (Tab. 2).

The average surface roughness have similarly been found to be lower in the thickness machine and in general in tangential surfaces in some previous studies (Tab. 3) as well Ilter et al. 2002, Ilter and Balkiz 2005, Burdurlu et al. 2006, Aslan et al. 2008, Kilic 2015).

Tab. 3: R_a values determined in previous studies.

Wood Types	**Cutting direction**	**Machine**		
		Thickness 2 blade	**Thickness 3 blade**	**Sanding No.**
		10 m·min^{-1}	**10 m·min^{-1}**	**80**
***Eucalyptus camelduensis* Dehn.** (Ilter and Balkiz 2005)	Radial	5.839	5.496	6.733
	Tangential	5.429	4.971	6.672
***Bornmullerian* Fir** (Ilter et al. 2002)	Radial	3.885	4.551	8.410
	Tangential	4.073	4.084	7.816
***Pinus brutia* Ten.** (Burdurlu et al. 2006)	**Circular Saw**		-	-
	Radial	6.770	5.550	5.740
	Tangential	6.640	4.480	5.320
Pinus nigra Arnold. (Kilic 2015)	Radial	7.17	5.11	5.48
	Tangential	6.86	4.41	4.63
***Ostrya carpinifolia* Scop.**)	Radial	4.27	4.82	5.13
	Tangential	3.55	4.38	4.95

It has been seen that, when compared to the surfaces achieved in radial cuts, the surfaces achieved in tangential cuts were smoother. The reason for this might be the use of the cutting method along with an increase or decrease in the tissue voids emerging as a result of the angle of the fiber cutting (Kılıç 2015).

R_y (R_{max}) (Maximum roughness)

The statistical values calculated for one of the surface roughness values R_y have been shown in Tab. 4.

Tab. 4: Statistical values for R_y.

Source of variation	Sum of aquares	Degrees of freedom	Mean squares	F	P
Machine (A)	3207.363	2	1603.682	27.146	0.00*
Cutting Direction (B)	77.358	1	77.358	1.309	0.00*
A*B	434.669	2	217.335	3.679	0.00*
Error	17368.458	294	59.076		
Total	431836.690	300			
ns=(not significant) *=<0.05 important					
Cutting direction	Number of Samples	Mean	Standard Deviation	Minimum	Maximum
Tangential	150	36.49	8.879	35.06	37.92
Radial	150	37.51	7.884	36.23	38.78
Machine	N	α=0.05			
		1	2		3
Thickness	100	32.79			
Sanding	100		37.58		
Circular Saw	100				40.68

When Tab. 4 was analyzed, it has been observed that besides the machine types and cutting directions affecting the R_y values, their double effects also carry importance statistically in terms of R_y value as well.

When Tab. 4 was analyzed, it has been observed that besides the machine types and cutting directions each affected the R_y value, their double effects also carry importance statistically in terms of R_y value as well.

When the statistical values of cutting directions were analyzed (Tab. 4), it has been seen that the average maximum profile height values of samples cut tangentially were lower compared to radially cut samples ($R_{yTangential}$=36.49 µm, $R_{yRadial}$=37.51 µm). Similar results have also been reached in Kilic's (2015) study on *Pinus nigra* wood.

According to the results of the Tukey's test carried out to compare the averages, the smoothest surfaces have been achieved with the thickness machine (R_y=32.79 µm) and it is being followed successively by the sanding machine (R_y =37.58 µm) and the circular saw machine (R_y =40.68 µm). Similar results have also been reached in Kılıç's (2015) study on *Pinus nigra* wood.

R_z (Mean peak-to-valley height)

According to Tab. 5, it has been observed that besides the machine types and cutting directions each affecting the R_z values, their double effects also carry importance statistically in terms of R_z value as well.

Tab. 5: Variance analysis for R_z.

Source of variation	Sum of squares	Degrees of freedom	Mean squares	F	P
Machine (A)	861.552	2	430.776	35.176	0.00*
Cutting Direction (B)	279.368	1	279.368	22.813	0.00*
A*B	497.510	2	248.755	20.313	0.00*
Error	3600.364	294	12.246		
Total	234379.924	300			

ns=(not significant)
*=<0.05 important

Cutting direction	Number of samples	Mean	Standard deviation	Minimum	Maximum
Tangential	150	2.,67	4.46	26.110	27.234
Radial	150	28.60	3.65	28.040	29.164

Machine	N	α=0.05		
		1	2	3
Thickness	100	25.55		
Sanding	100		27.64	
Circular	100			29.70

When the statistical values for the cutting directions were analyzed, it has been seen that the average ten point height values of samples which have been cut tangentially were lower compared to the samples which were cut radially $R_{z\text{Tangential}}$=26.67 μm, $R_{z\text{Radial}}$=28.60 μm) (Tab. 5).

According to the results of the Tukey's test carried out to compare the averages, the ten point height values (R_z =25.55 μm) have been achieved with the thickness machine on the lowest surfaces and these are followed successively by the sanding machine (R_z =27.64 μm) and the circular saw machine (R_z =29.70 μm) (Tab. 5). The R_z results achieved in this study are in line with the findings obtained in precious studies (Ilter et al. 2002, Ilter and Balkiz 2005, Kilic 2015).

CONCLUSIONS

In this study, the surface roughness values of European hop-horn beam in three most widely used machines in the furniture sector (circular saw, thickness, sanding machine) have been determined. After the tangential and radial surfaces achieved from the European hop-horn beam were processed in three machines (sawing with a circular saw, planing with a thickness machine, and sanding with a sanding machine: No. 80 sandpaper), their surface roughness values have been measured (R_a, R_y and R_z). The smallest surface roughness values have been obtained in surfaces planed in the thickness machine. The surface roughness values of tangential surfaces (R_a, R_y and R_z) have been found to be lower in comparison to radial surfaces. The average surface roughness values (R_a) of European hop-horn beam have been found to be lower in comparison to *Pinus nigra* Arnold and *Pinus brutia* Ten which have been processed with the same machines (Tab. 3). It is thought that diverse factors, such as the anatomic structure of the wood, which influences the surface roughness of the wood material, its specific gravity, hardness, spring -summer wood and heartwood - sapwood ratios could have significant effects. It is suggest that these characteristics be taken into consideration in studies to be conducted in the future.

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