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The influence of machining process on wood surface roughness

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Abstract

In this research, the effect of different machining processes on wood surface roughness was studied. There were applied three main furniture manufacturing processes, respectively planning, routing and sanding. The sanding process was applied twice, respectively with 100 and 120 grit sandpapers. The study was focused on two main native wood species, beech (Fagus sylvatica L.) and fir (Abies alba Mill.). The specimen samples were sawn with dimensions 90×8×2 cm, with 11% moisture content. For each machine were processed two specimens from each species. Routing process was carried out after planning, as well as sanding. Sanding process with 120 grit paper was conducted after the 100 grit process, respecting so the processing line applied by manufacturing sector. For measurement of surface roughness was applied the direct contact method. This method reproduces the surface profile by means of contact stylus profilometer, making so possible the calculation of arithmetic mean deviation of the profile, maximum two point height of the profile, mean roughness depth and root-mean-square deviation of the profile. The measurements were performed in ten different clear wood points for each specimen. Results showed that fir wood gave the same class of roughness for all machining processes, respectively 8. Regarding to beech wood, planning and routing processes gave the same roughness class, equal with those of fir, while sanding gave a higher class for both numbers of sandpapers, respectively 9. The results obtained present useful information for furniture manufacturing sector, by the cost effective viewpoint.

Keywords: machinig, wood, furniture, surface, roughness class.

1. Introduction

The complexity of wood as a substrate appears to be a crucial element to guarantee the gluing quality. Studies have shown that rough veneer reduces the bond quality by as much as one-third comparing to the smooth one [3]. It is proved that the strength of adhesive joints is influenced by surface roughness [16]. The same situation appears to be related to wood finishing quality as well. For smoother surfaces the finishing performance is improved and the consume of the paint is lower [21].

The roughness of wood surface can be considered as result from combination of deformations caused by anatomical structure of wood with irregularities caused by machining process.

In the first category are included various factors such as wood anatomy (cell structure), grain figure, wood density (wood porosity), moisture content, annual ring variation and latewood/earlywood ratio.

A study on beech and oak sanded surface shows that the wood anatomy increases the roughness parameters, indicating in this way a surface rougher than in reality. As the grit size becomes finer, the biasing effect of wood anatomy is stronger, tending to obscure the processing, especially in the case of a ring porous species as oak and is less in case of a diffuse porous species as beech. The spacing parameters are greater when contained the anatomy and are clearly biased as their values are greater than the mean grit diameter. While processing roughness parameters are consistently greater for beech than for oak, the total roughness parameters has unpredictable trends because of the variable anatomy [8].

During machining anatomical elements of wood are cut or separate by the tool and a new heterogen surface is created. The quality of this surface is determined by the grain patterns and dimensions as well as by the orientation of machining process with respect to the grain. Studies show a strong relation between grain angle and surface quality5. Cutting along the grain provides a better surface quality than cutting across the grain, where the effects of moisture content, rake angle, depth of cut and edge sharpness were studied decades ago [4,11,23]. Cutting in 90°-90° direction provides lower quality surface (higher roughness) than 0°-90° and 90°-0° directions [6]. Wood surface roughness in the case of across the wood grain is 1.46 times larger compared to that of along the wood grain and 1.06 times higher in comparison to wood grain in the angle of 45° respectively [24]. Furthermore cutting at angles with and against the annual growth rings the surface roughness results lower in the first case than in the second one [7].

Other researchers analyzed the influence of the moisture content of the wood, at three different levels, on surface quality, determined by the method of mechanical probing move [19]. Statistically significant differences were observed on roughness between the three levels of moisture. It was observed that with the increase in the moisture content occurred an increase of roughness.

Different surface roughness is obtained in the late and early wood areas. Early wood roughness is higher than late wood [15].

In the second category are included factors related to kinematics of the cutting process such as cutting directions, tool geometry, cutting speed and feed speed as well as factors related to machine conditions such as design of the machine and its vibrations, tool wear and its maintenance (quality of sharpening, joining of the cutting knives), strength of the positioning of the work piece and stiffness of the tool holder.

Radially sawn wood has lower surface roughness than tangentially sawn wood [1]. It is determined that surface roughness decreases when the feed speed and the cutting depth decreases and increases when the number of the knives on the cutter heads decreases [23]. Also, increasing cutting speed or rpm a lower surface roughness is obtained [17,18].

With regard to tool geometry, it is found that saw blades produce the highest surface roughness comparing to planer knifes and sand papers. Planed and sanded with 60 grit sandpaper wood surface roughness was comparable [12]. It is noticed, that using a finer size grit sanding paper, wood surface roughness started to decrease in all three directions of wood grain, but strict linear dependence was not estimated [24,10]. Roughness parameters can be used to monitor the tool and the machine. The relationship between surface roughness and tool wear is well known [11].

Except factors mentioned above other factors can influence on surface quality such as air humidity, temperature, chemical or biological degradation of the surface, different damages or treatments. So, the surface roughness decreases when the wood is treated in high temperatures [9].

Taking into consideration that surface roughness can be used for process control; this study is focused on the effect of different machining processes on wood surface roughness, respecting processing line applied by manufacturing sector.

2. Material and Methods

Wood material for production of samples was selected from pieces of kiln dried beech (*Fagus sylvatica* L.) and silver fir (*Abies alba* Mill.) boards, with moisture content from 10 to 12%. These species were selected taking into account that are the most common and used species in Albania. Furthermore, beech wood is the main wood used as raw material for solid wood based panels, not only in Albania but and in many other countries, while fir wood is one of the main species for production of glued laminated and cross laminated timber.

Selected pieces were trimmed to 90 cm long, 8 cm wide and 2 cm thick samples, without any knots, deformations or structure defects, or any grain distortions. Average density of the samples was 0.73 g/cm^3 for beech and 0.43 g/cm^3 for silver fir. The test design considered surface roughness of planed, routed and 100-, 120 grit sandpaper samples. Two samples of both beech and silver fir were selected for each machining process. All samples were conditioned till to constant weight prior to be machined. Planing was carried out by means of a planer with 3 knives cutterhead, revolution 5100 rpm, feed speed 7 m/min and depth of cut 1.5 mm. Routing process was carried out after palning using a vertical router with 2 knives cutterhead, revolution 3500 rpm, feed speed 7 m/min and depth of cut 1.5 mm. Regarding to sanding process it was carried out after planing by means of sanding machine with feed speed 7 m/min and sending pressure 6 Bar. Sanding with 120 grit paper was carried out after that of 100 grit paper, respecting so the line applied by production sector. Each sample was run once through the sander.

Evaluation of surface roughness of the samples was carried out by means of a surface roughness tester, type MITUTOYO, model SJ-201P (Japan). This instrument applies the direct contact technique, using a pick-up stylus which traces irregularities of the surface, reproducing in this way its 2D profile and calculates its roughness based on respective standards. Nowadays, this technique is the most popular for roughness assessment, although it presents some important limitations regarding to contacting in principle (possible damage of the surface), non-zero tip radius (missing fine irregularities), cone angle of the tip (sliding on the steep fragments of the profile) and slow feed (limitation for in-process evaluation) [22]. The stylus traverses the surface at a constatnt speed 0.5 mm/s applying on the surface a negligible measuring force 4 mN. The instrument can use PC50 (Gaussian) filter to separate the primary profile (P-Profil) of the surface into two profies, roughness (R-Profil) and waviness (W-Profil) profiles (figure 1).

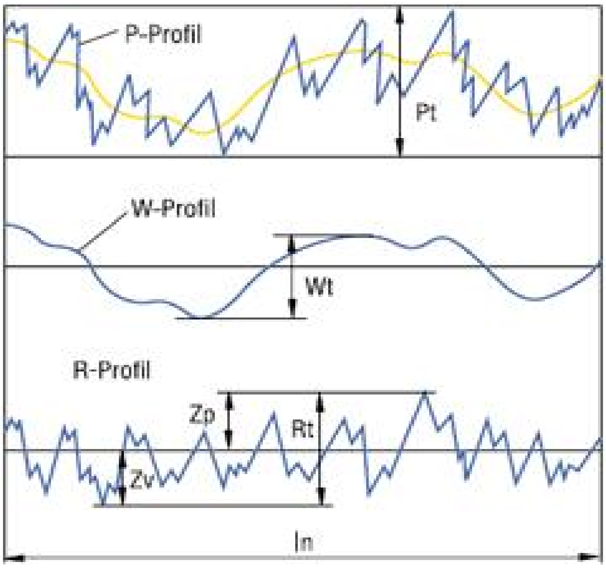

Figure 1. Separation of primary profile into waviness and roughness profiles

3. Results and Discussion

Mean values of surface roughness of machined samples, together with respective standard deviations (in parentheses) of both beech and fir are shown respectively in Tables 1 and 2.

Table 1. Mean roughness of machined beech samples

Roughness parameters (μm)	Planing	Routing	Sanding 100 grit	Sanding 120 grit
Ra	5.10 (1.44)	4.98 (1.52)	3.71 (0.96)	3.28 (0.88)
Ry	41.87 (10.18)	41.48 (9.72)	24.54 (7.16)	24.25 (7.12)
Rz	35.76 (8.78)	35.71 (8.59)	20.57 (6.49)	20.33 (6.35)
Rq	6.32 (2.22)	6.30 (2.31)	4.75 (1.36)	4.23 (1.19)

Table 2. Mean roughness of machined silver fir samples

Roughness parameters (μm)	Planing	Routing	Sanding 100 grit	Sanding 120 grit
Ra	6.36 (2.18)	4.96 (1.71)	4.76 (1.37)	4.61 (1.22)
Ry	53.04 (12.07)	48.16 (11.38)	33.41 (7.97)	32.81 (7.38)
Rz	44.19 (9.76)	39.36 (9.08)	25.41 (7.07)	23.72 (6.42)
Rq	6.95 (2.63)	6.64 (2.36)	6.15 (1.99)	5.91 (1.48)

With regard to beech wood, no significant difference was observed between planed and routed surface roughness at a 95% confidence level. The difference between roughness parameters as function of these two operations was respectively 2.4% and 1% for *Ra* and *Ry*, while for two other parameters was less than 1%. On the other hand for sanded surfaces the difference as a function of grit number resulted respectively 11.6% and 11% for *Ra* and *Rq*, while for other two parameters 1.2%. This phenomenon can be related to clogging effect (compression) of the profile due to sanding process [14]. This is a special cutting process using a more or less round edge profile and negative rake angle, which play an important role in exerting compressive stresses in the surface avoiding grain pull-up [20]. When roughness parameters of planed and routed samples were compared to those of sanded, significant differences were determined to 95% confident level, varying from 25% to 42.5%. The differences in *Ry* and *Rz* values referring to planing and 100 grit sanding were too high comparing those between 100- and 120 grit sanding. In general, roughness values have a decreasing trend passing from planing to routing as well as from planing to sanding.

With regard to silver fir wood significant difference was observed between planed and routed surface roughness at a 95% confidence level. The difference between roughness parameters as function of these two operations was respectively 22%, 9.2% and 10.9% for *Ra*, *Ry* and *Rz*. Only *Rq* presented a difference less than 5% (4.5%). On the other hand for sanded surfaces the difference as a function of grit number resulted within 95% confidence level, respectively 3.2%, 1.8% and 3.9% for *Ra*, *Ry* and *Rq*, while for other parameter *Rz* resulted 6.7%. When roughness parameters of planed and routed samples were compared to those of sanded, significant differences were determined to 95% confident level, varying from 7% to 46.3%. Only *Ra* values of routing and 100 grit sanded surface made an exception (4%). The differences of all parametres values referring to planing and 100 grit sanding were too high comparing those between 100- and 120 grit sanding. As wood beech, roughness values have a decreasing trend passing from planing to routing as well as from planing to sanding.

Comparing both woods to each-other was noted that fir wood presented higher roughness than beech for almost all parameters as well as for all machining processes. The only exception was routing process, which presented almost the same *Ra* value. This is related to different anatomical structures of two species. Routing process presented less difference in comparison to other machines (Figure 2).

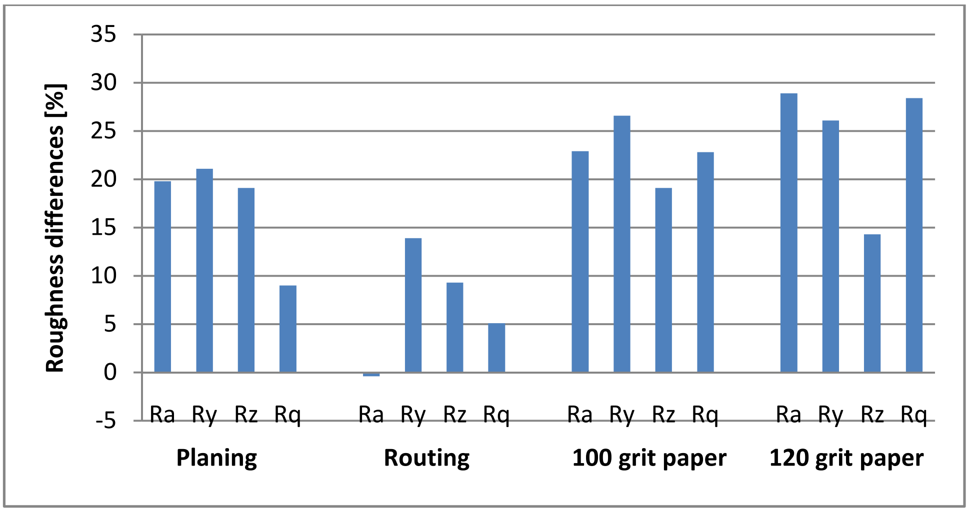

Figure 2. Increment of fir surface roughness referring to beech wood

Actually wood processing industry applies a system of 10 classes of surface roughness based on *Ry* parameter (table 3). Results showed that fir wood gave the same class of roughness for all machining processes, respectively 8. Regarding to beech wood, planning and routing processes gave the same roughness class, equal with those of fir, while sanding gave a higher class for both numbers of sandpapers, respectively 9.

Table 3 Surface roughness class [2]

Class symbol	Ry [µm]
Δδ 1	1250-1600
Δδ 2	800-1250
Δδ 3	500-800
Δδ 4	315-500
Δδ 5	200-315
Δδ 6	100-200
Δδ 7	60-100
Δδ 8	30-60
Δδ 9	16-30
Δδ 10	16

4. Conclusions

Based on results presented above we can say:

there are no significant differences referring to values reported by respective literature;

both woods presented different surface roughness for all machining processes, but for routing the difference was lower;

with regard to beech wood roughness has a moderate decreasing trend passing from planing to routing, while for sanded surfaces has a stronger decreasing trend passing from 100 grit to 120 grit papers;

with regard to fir wood roughness has a significant decreasing trend passing from planing to routing and a moderate trend passing from 100 grit to 120 grit papers;

in general, roughness values have a strong decreasing trend passing from planing to sanding;

fir wood gave the same class of roughness for all machining processes, respectively 8;

beech wood gave the same roughness class for planning and routing processes, equal with those of fir, while for sanding gave a higher class for both numbers of sandpapers, respectively 9.

Taking into account that surface quality does not always tend to reduce the “roughness” by any cost, it is enough those roughness parameters to be within certain limits. In this framework, in order to evaluate planed, routed and sanded surface roughness effectively, it is recommended to perform laboratory tests on their gluing and finishing performance.

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