

INFLUENCE OF THE PROCESSING PARAMETERS UPON THE BIRCH WOOD SANDED SURFACES

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Abstract:

The main objective of the experimental research was to assess the quality of the birch wood surfaces after sanding them with 60, 80, 100 and 120 grit sizes, by analyzing the roughness parameters of the sanded surfaces in each phase. The birch wood specimens were sanded parallel, perpendicular and inclined with 45 degrees against the wood grains. The variables of the sanding process were considered to be the feed speed and the cutting depth. For conducting the research, the samples were sanded in an industrial mode on a wide belt sanding machine, at SC NIKMOB SA Company, in Nehoiu, Buzau county. The equipment used to measure the roughness of the sanded surfaces was an optical profilometer FRT-MicroProf type (German production) with results in roughness parameters that characterize the quality of that surface. Among all the parameters obtained for this study, two roughness parameters were chosen, namely: R_k , the parameter that estimates the machining roughness and R_{pk} parameter, which estimates the raised fiber - for the two areas of the specimens with and without wetting. Data processing after measuring and recording the quality of the surface in terms of roughness parameters was achieved by nonlinear regression method, using a second-order equation with two variables. In order to assess the quality of the sanded surfaces, the results were compared by varying the grit sizes, machining direction, feed speed and the sanding depth for the two distinct areas of the specimens, respectively with and without wetting. The results were also interpreted by ANOVA test for two separate variables, namely the sanding depth for wet and dry method, in case the speed feed was constant. The data were processed for each sanding schedules and each direction of processing. The results have shown that the quality of the wet surfaces was higher than that of the surfaces sanded prior wetting, disregarding of the direction of processing. It was also found that for the final grit size of 120, the best results were obtained in case of prior sanding with other two different grit sizes. The results of the present research can be successfully applied in the wood industry, for birch wood furniture production, in order to reduce the material consumption and to improve the sanding process by using appropriate technology with results in the high quality of the surface obtained.

Key words: roughness; birch wood; sanding process; sanding parameters.

INTRODUCTION

The surface sanding is different from other wood machining methods by the fact that the chip detachment is achieved by multiple small cutting edges of the grit abrasives glued on the sanding belt, whilst generally a single cutting edge is used for the other processing methods. Sanding operation is one of the most important ones because it prepares the surface for finishing and eliminates irregularities occurred during the previous processing operations are removed.

As proved, a well sanded surface is half finished. For this reason, many researchers in the field have studied the wood sanding surface in terms of working method influence upon the surface quality. Among those who have dealt with the influence of the abrasive grit size are as follows: (Pahlitzsch 1970) (Pop 1979a, 1979b) and (Cotta 1982), who had confirmed that the roughness of the sanded surface increases with the abrasive grit size. (Carrano *et al.* 2002) (Moura and Hernandez 2006), (Ratnasingam and Scholz 2006) stated the same, namely if the grit size is smaller, than the quality of the surface is better. (Sinn *et al.* 2004) have established a linear positive correlation between the abrasive grit size and the roughness of the surface. (Cotta 1982) was the one who studied the roughness of the sanded surface of various species of wood (spruce, beech, lime and oak) obtaining the best results when sanding the oak surfaces.

(Gurău 2006) have also studied the quality of the surface in case of sanding oak, beech and fir wood using different processing parameters. As regards the method of wetting and drying the surfaces before sanding, (Beganu 2001) considers it to be more efficient than the method of sanding the surfaces without wetting. Instead, (Pop 1979) considers that, due to the fact that the results of the surface quality using the two methods mentioned above are not significantly different, the wetting operation can be eliminated for economic reason. The method of sanding parallel to the wood grains is supported both by (Cotta 1982) and (Beganu 2001) based on the aesthetic reasons.

(Pop 1979) have recommended the use of wide belt sanding machine for wood sanding operation and also have considered that developing of sanding regimes for each species of wood is compulsory. (Pop 1979) concluded that the grit size of abrasive belts have a great influence upon the quality of the surface. It is also proved that the roughness of the sanded surface decreases slightly with the decreasing of the feed speed and the performance of the abrasive tools depends on the grit type and its size, as well as on the time of using the abrasive. (Gurău 2005) found in the research of the wood sanded surfaces that the grit size of the abrasive belts had a significant influence on the quality of the surface, fact that determined the researcher to make recommendations regarding the assessment of the surface roughness of the sanded wood.

Previous studies of (LeMaster and Beal 1996, Taylor *et al.* 1999, Moura and Hernández 2005, 2006) concluded that the roughness of the processed surface (assessed by the roughness parameters) is the main criterion for the quantitative assessing the quality of the sanded surfaces. (Williams and Morris 1998) are those who concluded that any sanding process has to begin with a rough sanding, achieving a fast and deep machining afterwards, being followed by several fine sanding with the role of preparing the surfaces for lacquer finishing. As regards to the purpose of each phase of the sanding process, both (Williams and Morris 1998) and (Lihra and Ganev 1999) concluded that the irregularities obtained in the previous sanded phase must be reduced so to be no longer visible in the finishing stage.

Numerous researchers have been concerned with the optimization of the wood sanding process. For this purpose they have analyzed the grit size of the abrasive belt (Carrano *et al.* 2002, Sinn *et al.* 2004, de Moura and Hernández 2006, Ratnasingam and Scholz 2006), the machining direction against the wood grain orientation (Taylor *et al.* 1999, Carrano 2002) and sanding feed speed (Carrano 2002, Moura and Hernandez 2006). (Carrano 2002) and (Moura Hernandez 2006) established that the feed speed has a significant influence on the quality of the sanded surface. Thus, they proved that rough surfaces were obtained after sanding the wood at higher feed speeds, fact explained by the reduced number of marks on the surface caused during the process (Carrano 2002), which generates a higher sanding belt oscillation on the surface (de Moura and Hernández 2006).

The quality of the sanded black alder wood surface was analyzed by (Salcă and Hizirolu 2012) on the three processing directions (parallel, perpendicular and inclined with 45 degrees against the wood grain orientation), with and without wetting, where feed speed and cutting depth were the variables.

In order to assess the quality of the surface, the roughness parameters R_k and R_{pk} were compared. No improved quality of the alder wood surface was obtained after wetting and drying the surface before sanding (Salcă and Hizirolu 2012). In terms of processing direction, a slightly better quality was obtained for the inclined 45 degrees and parallel directions against the wood grains, compared with the perpendicular direction.

The main objective of this work was to quantify the influence of the processing parameters and to establish an optimum sanding technology for a good quality of finishing.

OBJECTIVES

The objective of this paper is to assess the quality of the birch wood sanded surfaces, by analyzing the roughness parameters R_k and R_{pk} . The specimens were sanded on three directions (parallel, perpendicular and inclined with 45 degrees against the wood grains), using the grit sizes of 60, 80, 100 and 120, grouped in various technologies. All groups of technologies ended with 120 grit size sanding. This study is a part of the PhD thesis, where aspects of milling and sanding of birch wood have been analyzed (Fotin 2009).

MATERIALS AND METHODS

The main objective of the paper is to assess the quality of the sanded surfaces. The specimens used for the tests were made of birch wood (*Betula pendula*), with sizes of 300x95x16mm, at a moisture content of 8%, being prepared for sanding operation after cutting, gluing and planing the solid wood. The sanding operation was done at SC NIKMOB SA, of Nehoiu, Buzău county, on wide belt sanding machine – upper contact, namely SANDINGMASTER machine, with two sanding belts (Fig.1.), and the second belt with pressing bar was used for the final sanding of the solid wood surface.



Fig. 1

SANDINGMASTER Wide belt sanding machine – upper contact.

The above sanding machine is provided with an oscillation pneumatic system and a dust extraction system of the abrasive belt. The main characteristics of the wide belt sanding machine are presented in Table 1.

Table 1

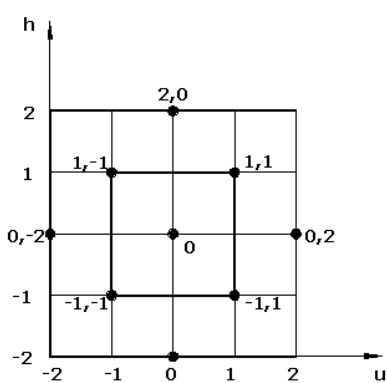
Technical characteristics of the wide belt sanding machine

Parameter	Value
Width, mm	1100
Abrasive belt sizes, mm	1900 x 1130
Sanding speed (opposite to feed speed), m/s	16
Pressure, barr	4,5
Feed speed, m/min	4...20

Table 2

The values of the parameters of the processing mode in case of sanding operation

Code	Designation of	Value of parameter				
		-2	-1	0	1	2
x_1	Feed speed, u (m/min)	4	8	12	16	20
x_2	Cutting depth, h (mm)	0,1	0,2	0,3	0,4	0,5



In order to establish the experimental program, the factorial experiment (Laurenzi 2000) with two variables (feed rate and depth of processing) was used. It allowed to use a limited number of parts for sanding operation, which was intended to be carried out with various operating modes, obtained by combining the five values of the feed speeds and cutting depths listed in Table 2, on three processing directions (parallel, perpendicular and inclined at 45 degrees against the wood grain orientation). The correspondence between the coordinate points and the above mentioned variables is shown by the drawing of Table 2 (Fotin 2008).

After applying the algorithm for factorial experiment with two variables, 13 specimens were required. The samples were coded and half of the surface was wetted before each sanding phase, in order to further analyze the influence of the moisture content on the roughness of the sanded surface (Fig. 3a). In order to ensure the direction of sanding processing, special devices were used (Fig. 3b and c). The samples were wetted prior each sanding phase, only on a half of the surface, namely on the first half, where the code number is written on the edge of each part, in order to identify the number of the specimen in the set, then the processing mode and the direction of processing together with the technology of sanding.

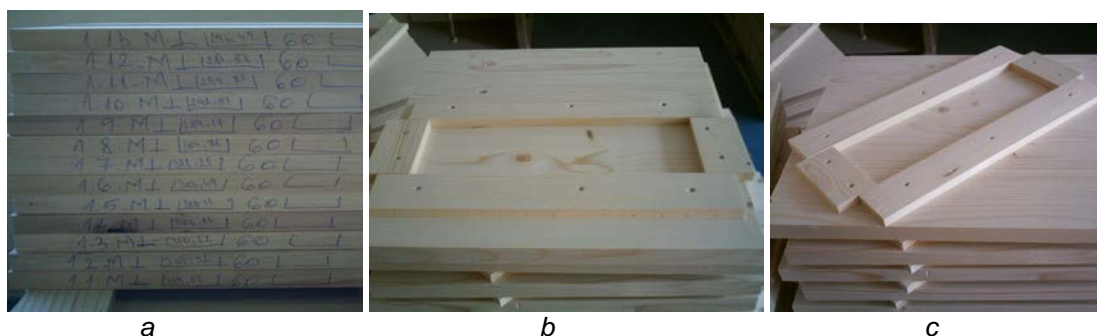


Fig. 3

Code number of the specimens and devices required for tracking the sanding direction:
a - specimens' code number; b - device for sanding parallel – perpendicular to the wood grains direction; c - device for sanding inclined at 45 degrees against the wood grains direction.

The abrasives used for the sanding tests were made of corundum abrasive grit sizes of 60, 80, 100 and 120. All samples were initially sanded with 60 grit size sanding paper, at a feed speed of 12m/min and a cutting depth of 0.3mm and then sanded according to the technologies described in Table 3. The common characteristic of the three programs of sanding technology is the fact that the final sanding was performed with the same 120 grit size.

Table 3

Matrix of the tests during the sanding processing

	Parameter	Values		
1	Feed speed, m/min	8	12	16
2	Cutting depth, mm	0,1	0,2	0,3
3	Processing direction	Inclined at 45° against the wood grain orientation	Parallel to the wood grain orientation	Perpendicular to the wood grain orientation
4	Method	prior wet		
		no wet		
5	Sanding technology program and grit sizes	No.4	No.8	No.11
		60, 80, 120	60, 100, 120	60, 120

ROUGHNESS MEASUREMENT OF THE SAMPLES

The measurement of the roughness of the sanded surfaces was performed by standard equipment Micro Prof FRT type which scans with light beam the roughness profile of a surface as illustrated in Fig. 4. In order to maintain a constant measuring direction of the roughness, namely perpendicular to the direction of processing, the device in Fig. 4 was used. Two measurements of the surface roughness of each sample were performed: the first one on the prior wetted surface (coded with index 1) and the other one on the non-wetted surface (coded with index 2). Codes 1 and 2 attached after measuring the roughness in the situations of wetting (1) and no wetting (2) are valid for all sanding operations that follows the 60 grit size sanding. The scanning parameters of MicroProf FRT equipment were set up according to Table 4.



a.



b.

Fig. 4

Experimental set-up: a - MicroProf FRT equipment for measuring the roughness; b - the device of positioning the parts on the table.

Table 4

Scanning parameters of MicroProf FRT equipment set on

	Parameter	2D profile method
1	Scanning speed, $\mu\text{m/s}$	750
2	Scanned points	10.000
3	(x) assessed length, mm	50
4	Sample length, mm	2,5
5	Measuring resolution, μm	5
6	Measuring direction	Perpendicular to the processing direction

Processing of the data

The **Acquire software**, which records the data measured by the equipment, saves *prt*, *bmp* and *txt* file types and shows the surface topography of the scanned surface. The analysis of the profile roughness was performed by **Mark III** software, which allows the recording of the processed data as *log* file type. The roughness profile was obtained after filtering the data by a preliminary Gaussian filter, automatically applied by the software. The data were then processed in several stages using programs created in Delphi. A nonlinear regression by second-order equation with two variables was applied. Among all roughness parameters defined by technical specifications, which are recommended and used for wood surfaces, just two of *Rk* type (*Rk*, *Rvk* and *Rpk* according to ISO 13565 2:1999) were selected for the present analysis, namely *Rk* and *Rpk*, and also *Ra* parameter, according to ISO 4287:2001. *Rk* parameter defined by the technical specification is considered by (Gurău 2004a, 2007), after removing the influence of anatomy and also by (Sandak 2005), as the most useful processing indicator of the roughness.

It was found in the literature in the field that a single roughness parameter for describing and assessing the quality of the wood surfaces is not enough, so that *Ra*, *Rk* and *Rpk* roughness parameters were chosen for this study, due to the following reasons:

Ra is the most common parameter used to assess the roughness of the surface. The roughness parameter *Ra* is considered to be the most appropriate one to assess the quality of the wood surface which has spread pores (Hiziroglu and Graham 1998) and, for a more accurate analysis, it must be accompanied by other parameters, because it doesn't provide enough information about the area;

Rk is considered to be the most useful roughness indicator of the process, if the wood surface has small pores and no pilling on it, being insensitive to the variation of the wood species, yet. This parameter is representative when the processing quality must be expressed only by a single parameter (Gurău 2004);

Rpk, one of the *Rk* family parameters is used to assess the presence of the raised fiber (Gurău 2004).

The results of the study upon the roughness of the surface are presented for all three parameters taken into consideration (*Ra*, *Rk*, *Rpk*) on individual technology programs and directions of processing, for both variants of wetting and no wetting the surface, but also for the case of compared technologies of the final grit size sanding in a full factorial experiment or removing the extremes, case for which the results were analyzed.

RESULTS AND DISCUSSION

Based on the results of the present study, the values of the roughness parameters registered both tendencies of increasing and decreasing with the variations of the feed speed between 8 and 16 m/min and of the depth of sanding from 0.1 to 0.3mm (Fig. 5 and Fig. 6).

Processing at 45 degrees

The wet sanding technological program no. 4 (60, 80, 120 grit sizes) provided surfaces with better results of the roughness parameters compared with the case of non-wet one of the same technological program. Thus, the values of Ra ($5,46\mu\text{m}$) and of the Rk parameter ($17,14\mu\text{m}$) for the same processing mode, at a speed feed of 8m/min and a cutting depth of 0,1mm are to be noticed. The increasing tendency of Ra parameter against the feed speed is similar to that of Rk parameter. It is also noticed the increasing of Rpk parameter (the raised fiber characteristic) against the increasing of the cutting depth, at the same feed speed. The wet sanding technological program no. 8 (60, 100, 120 grit sizes) provided the best quality of the surface at a feed speed of 16m/min and cutting depth of 0,1mm, the values being $6,03\mu\text{m}$ for Ra , $17,97\mu\text{m}$ for Rk and $8,81\mu\text{m}$ for Rpk .

When processing with sanding technological program no. 11 (60 and 120 grit sizes), the resulted roughness parameters were better for the case of non-wetting technology, so that, at a feed speed of 16m/min and a cutting depth of 0,1mm, the values of the roughness parameters were of $5,36\mu\text{m}$ for Ra , $17,26\mu\text{m}$ for Rk and $7,16\mu\text{m}$ for Rpk . But in comparison with the value of Rk mentioned before, the sanding technological program no. 4 is to be mentioned as a representative one, considering the minimum value of the roughness processing parameter.

Comparing the three sanding technological programs, namely P4, P8 and P11 for the inclined processing direction of 45 degrees against the wood grains, the technological program no. 4 (60, 80 and 120 grit sizes) with prior wetting is recommended, because it provided surfaces with good results of the studied parameters, namely $5,46\mu\text{m}$ for Ra , $17,14\mu\text{m}$ for Rk and $10,15\mu\text{m}$ for Rpk , at a feed speed of 8m/min and the cutting depth of 0,1mm.

Paralel processing

For the sanding technological program no. 4 (60, 80 and 120 grit sizes), the sanding with prior wetting was the one that provided minimum values of the roughness parameters. At a feed speed of 16m/min and a cutting depth of 0,1mm the following values of Ra , Rk and Rpk were obtained, namely $3,82\mu\text{m}$, $12,08\mu\text{m}$ and $8,46\mu\text{m}$. The value of Ra parameter ($3,9\mu\text{m}$ at a feed speed of 16m/min and a cutting depth of 0,2mm) is very close to that obtained for maple wood in case of parallel processing (by Moura and Hernandez 2005). It was noticed in this case that sanding with 80 grit size, followed by sanding with 120 grit size brought significant reduced values of the roughness parameters.

In case of sanding technological program no. 8 (60, 100 and 120 grit sizes) the prior wetting does not improve the quality of the surface, because the minimum values of the roughness parameters were obtained for the non-wet surface, namely $5,29\mu\text{m}$, $16,08\mu\text{m}$ and $9,86\mu\text{m}$, for Ra , Rk , respectively Rpk parameters, at a feed speed of 8m/min and a cutting depth of 0,2mm. However, relatively close values were obtained for two of the three parameters (Ra and Rk) and a lower value of the raised fibre roughness parameter (Rpk of $6,42\mu\text{m}$) was obtained in case of sanding technological program no. 8 (60, 100 and 120 grit sizes), with prior wetting. So, with this conclusion is difficult to choose the optimum sanding program for this direction of processing.

As regards to the sanding technological program no. 11 (60 and 120 grit sizes), it was noticed that at a cutting depth of 0,1 to 0,2mm the raised fibre does not occur and at a feed speed of 8m/min and a cutting depth of 0,1mm the studied roughness parameters had minimum values, but higher than when sanding with technological programs no. 4 and 8.

Comparing the technologies, the optimum one in case of final 120 grit size was the 4th one (60, 80 and 120 grit sizes) with prior wetting, on parallel processing direction. The 8th sanding program (60, 100 and 120 grit sizes), in similar processing conditions had lower values of the raised fibre roughness parameter, but Rk , as a processing parameter remained at minimum values for the 4th sanding program (Rk $12\mu\text{m}$ instead of $18\mu\text{m}$ for the 8th program).

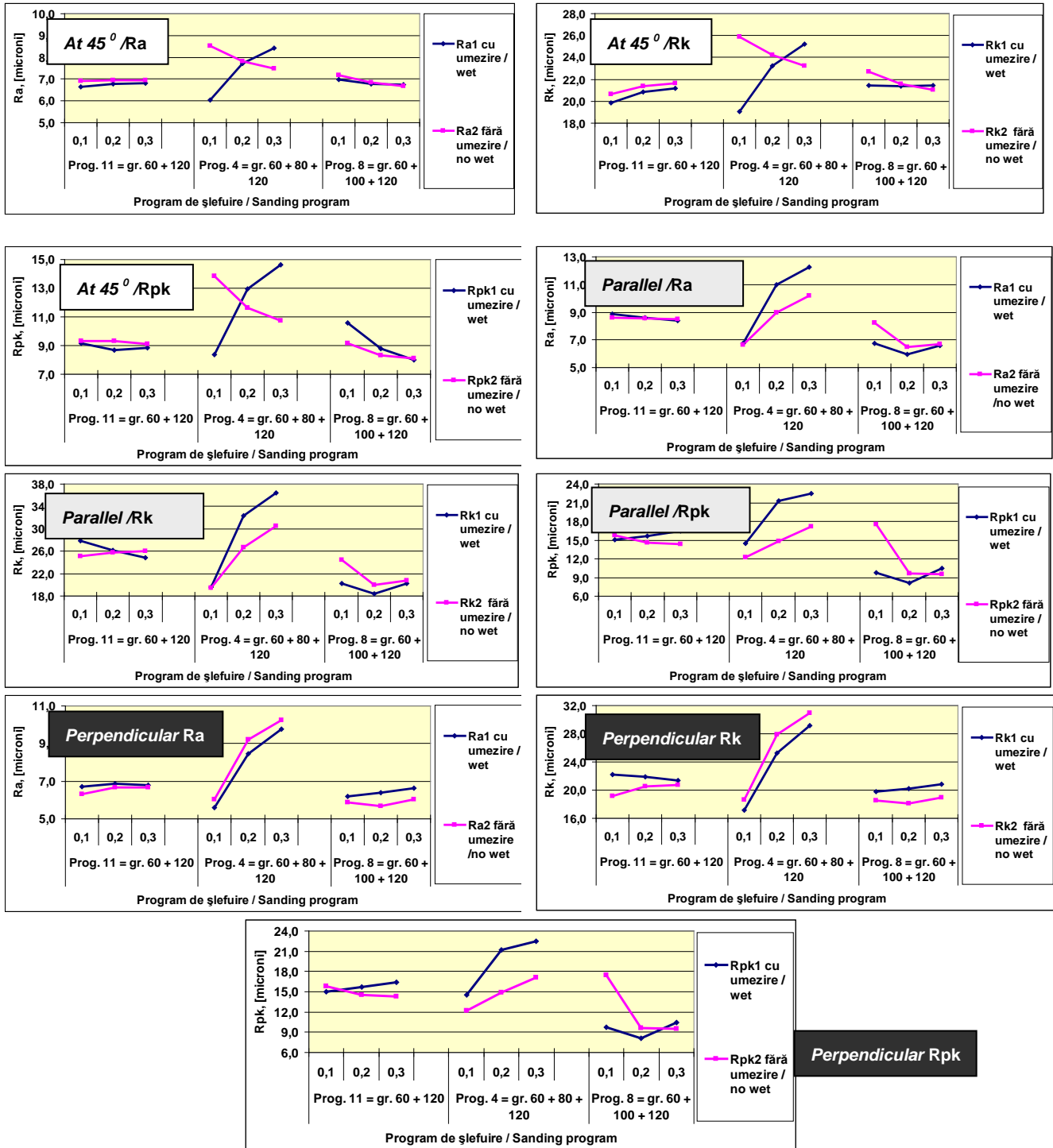


Fig. 5

The variation of Ra, Rk and Rpk parameters on the three directions of processing, namely inclined with 45°, parallel and perpendicular to the wood grains, for a feed speed $u = 12$ m/min and three cutting depths.

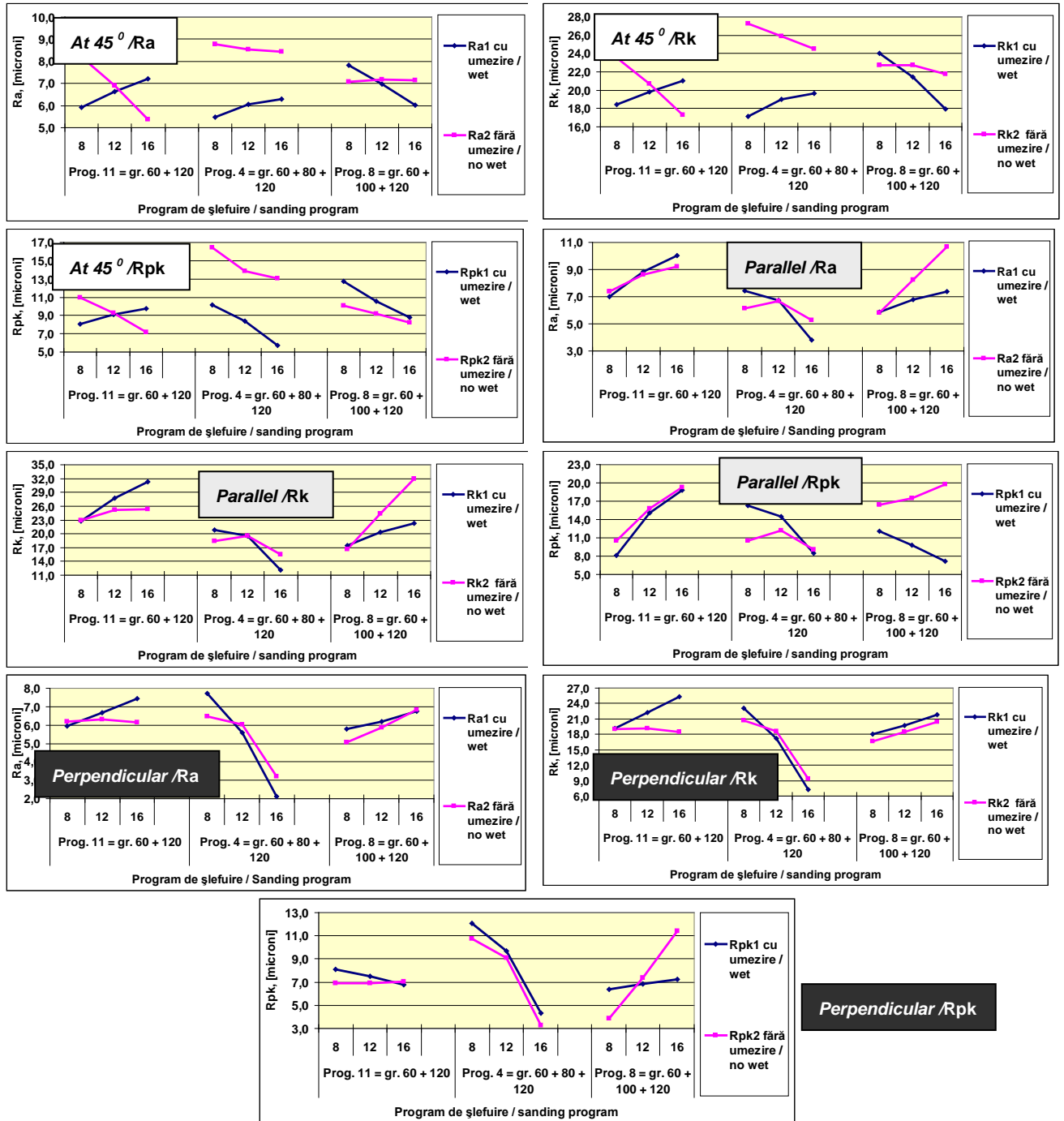


Fig.6.

The variation of Ra, Rk and Rpk parameters on the three directions of processing, namely inclined with 45°, parallel and perpendicular to the wood grains, for three feed speeds (u = 8, 12 and 16 m/min) and cutting depth of 1mm.

Perpendicular processing

The sanding technological program no. 4 (60, 80 and 120 grit sizes) gave close values of the roughness parameters for prior wet and without wet method, in similar conditions, but the minimum values of Rk parameter (7,31µm), was obtained for wet method, at a feed speed of 16m/min and a cutting depth of 0,1mm.

For the sanding technology program no. 8 (60, 100 and 120 grit sizes), the best surfaces were obtained without prior wetting.

In case of sanding technology program no. 11 (60 and 120 grit sizes), both methods of sanding have as results high values compared with the other two sanding technology programs.

Comparing the sanding technology programs P4, P8 and P11, perpendicular to wood grains, having 120 as final grit size, the program no. 4 (60, 80 and 120 grit size) stands out for the minimum values of the roughness parameters (R_a 2,12 μ m, R_k 7,31 μ m and R_{pk} 4,31 μ m), for prior wetting method, at a feed speed of 16m/min and a cutting depth of 0,1mm. The resulted values are lower than in the case of parallel and inclined direction of processing, due to the fact that the scan was done perpendicular to the direction of sanding.

In order to determine the significant influence of processing conditions on the roughness parameters, the two-factor ANOVA test was done. (Table 5).

Table 5

The ANOVA comparison between the roughness parameters (R_k) obtained after applying sanding technology programs P4, P8 and P11, with and without prior wetting

Direc- tion	u = feed speed	Factors	F			Fcritic
		h= cutting depth,	P4	P8	P11	
Inclined at 45°	8 m/min	h = 0,1;0,2;0,3 mm	0,217152273	606,0072548	0,07513175	19,0000
		No Wet/ /wet	1,252868692	249,9237121	4,23747763	18,5128
	12 m/min	h = 0,1;0,2;0,3 mm	0,162566035	1,117854668	34,4598551	19,0000
		No Wet/ /wet	0,563687605	0,497091319	28,4936042	18,5128
	16 m/min	h = 0,1;0,2;0,3 mm	0,087348199	1,137237982	2,14106032	19,0000
		No Wet/ /wet	0,553755917	4,116693876	2,77878875	18,5128
Parallel	8 m/min	h = 0,1;0,2;0,3 mm	48,81809453	48,99543449	2,37484694	19,0000
		No Wet/ /wet	16,81763139	2,638859675	6,78764378	18,5128
	12 m/min	h = 0,1;0,2;0,3 mm	18,37577829	3,010195788	0,30194249	19,0000
		No Wet/ /wet	4,125220959	3,86662774	0,36827481	18,5128
	16 m/min	h = 0,1;0,2;0,3 mm	9,453786288	3,818834273	0,77405439	19,0000
		No Wet/ /wet	0,71489989	5,376198045	1,68100087	18,5128
Perpendicular	8 m/min	h = 0,1;0,2;0,3 mm	3,10105932	55,71512412	0,00053768	19,0000
		No Wet/ /wet	0,182037235	73,58713359	1,62471765	18,5128
	12 m/min	h = 0,1;0,2;0,3 mm	444,3023277	3,955269259	0,18796316	19,0000
		No Wet/ /wet	32,05053034	47,61266604	6,11161749	18,5128
	16 m/min	h = 0,1;0,2;0,3 mm	73,54466766	3,459825443	0,01764693	19,0000
		No Wet/ /wet	0,005244242	41,48987297	5,20486888	18,5128

The differences between the average of the roughness parameters obtained in certain conditions are not significant in case of null hypothesis (H_0) and are significant in case of alternative hypothesis (H_1).

CONCLUSIONS

Based on the findings in this work, the conclusions are as follows:

- The best results were obtained when applying the prior wetting method.
- For the final sanding with 120 grit size, the preferred sanding program is the 4th one (60, 80 and 120 grit size), with prior wetting, where the roughness is two times lower than in the case where no wet is applied.
- The best quality of the surface resulted for parallel and 45 degrees inclined processing, for a feed speed of 8m/min and a cutting depth of 0,1mm.
- If the best quality of sanded birch wood surfaces is obtained when applying the prior wetting method, (Salcă 2012) has obtained best results in case of alder wood for the sanding surfaces without prior wetting. The sanding process and the roughness measurements were done in the same conditions.
- The results of R_k parameter (12 μ m for parallel processing) are quiet close to those obtained by (Salcă 2012) for alder wood (22 μ m), fact that confirm the influence of density upon the quality of the surface, in terms of increasing the quality against the increasing of wood density.

After processing the data with ANOVA test and analyzing the values obtained for test F compared with $F_{critical}$, the following results are to be mentioned:

For inclined processing:

- for a feed speed of 8m/min and for sanding program no. 8, the cutting depth and also the wet or no wet method have a significant influence on the quality of the surface.

- in change, for a feed speed of 12m/min, the cutting depth and also the wet or no wet method have a significant influence on the quality of the surface only for P11 sanding program.
- for the rest, the quality of the surface is not affected by the sanding method or cutting depth.

For parallel processing

- for a feed speed of 8m/min, just the cutting depth has a significant influence upon the quality of the surface in case of using sanding programs no. 4 and 8, but for the rest, no factor has influence on the quality of the surface, as long as the value of F test is lower than the value of Fcritic.

For perpendicular processing

- for P4 sanding technology program, at the feed speeds of 12m/min and 16m/min, the cutting depth has a significant influence on the quality of the surface.
- in case of P8 sanding technology program, the state of the surface (wet/no wet) has a significant influence on the quality of the surface, no matter of feed speed or cutting depth, except the feed speed of 8m/min, where the cutting depth is the factor of influence.
- in case of P11 sanding program, no factor has a significant influence on the quality of the sanding surface.

The results of the present research can be successfully used for using birch wood in furniture manufacturing, having as main objective to increase the efficiency of sanding process, by obtaining surfaces with a high quality in conditions of low materials consumption, both for sanding and finishing operations and low manpower. The fact of obtaining the high-quality surfaces with minimal effort can lead to the increasing of using birch wood on an industrial scale in furniture manufacturing field, thus expanding the raw material base of wood industry in Romania.

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