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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2011
Brasov, 26-28 May 2011

STUDY CONCERNING THE INFLUENCE OF MILLING PARAMETERS UPON THE SURFACE QUALITY OF THE BIRCH AND PEAR WOOD

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Abstract: *This paper presents a comparative study concerning the surface quality resulted after processing birch and pear wood in longitudinal direction by means of two cutters with removable plates from SMC (sintered metal carbide), with different diameters: D80 mm, D120 mm. The variable parameters of the processing regime were: cutter diameter, speed, feed speed, cutting depth and cutting width. The samples were processed by milling using the two cutters, on the vertical milling machine type MNF10, endowed with a mechanical feed device. The study was based on assessing the quality of the processed surfaces by comparative analysis of the roughness parameters Ra, Rk and Rpk, resultant from roughness measurements along the cutting direction, by using an optical profilometer FRT (Fries Research Technology) made in Germany. After conducting the experimental research, it could be concluded that the best surfaces are obtained when using cutters with removable plates and larger diameters, through milling in longitudinal direction. The results of this research were used to formulate optimised processing regimes, through which very good surfaces can be obtained. In this way, the attitude of specialists from the wood industry regarding two species studied, can be changed, by promoting its use on extensive scale and so offering the possibility of broadening the raw material range of our country.*

So according with obtained study's results it can be observed differences between these two species. The values of the roughness parameter Rpk as the obtained results, after the longitudinal cutting of the birch wood, are double to those remarked for the pear wood. Consequently, the final conclusion is: pear wood has better surface quality than the birch wood

Keywords: *birch, pear, longitudinal milling, roughness parameters, cutter diameter, removable plates.*

INTRODUCTION

Considering the current global crisis, it is increasingly necessary to develop the basis of wooden raw materials, both globally and especially nationally. This determined more and more researchers during the last years to study the processing of species with limited area of distribution, but which nevertheless present a real use potential

Birch is part of the species with small area of spread in our country, but because it is a rapidly growing species, within naturally regenerated forests, with no special requirements for the soil, climate and forestry works, it deserves the attention of the wood processing specialists with a view to enlarge its use in the production of furniture and finished wood products.

Pear wood, is also part of the category of species with small area of distribution in our country, but requires a long time to increase compared with birch. It has a low share quantitative in our country but its wood is hard to break, is hard, elastic and easily bent. Wood of pear dries well and can be easily processed by the sculpture and lathing and planing, milling and sanding. Compared with beech, which is in a high percentage in our country, pear wood does not change size over time.

In this respect, manufacturers need clear and precise information on optimal milling regimes for this wood species, capable to lead to the production of furniture with good quality surfaces.

It is known that the milling operation was and remains probably the most important wood machining operation that captured the attention of all specialists in the wood industry, being rightly considered the „queen” of shape and size processing.

For this reason, many Romanian and foreign researchers focused their studies on wood machinability (Dogaru 2003, Iskra 2005) tools and machinery for milling wood (Ispas 2000), optimization of processing procedures (Costes 2002, Brenci 2006, Fotin 2009a, Fotin & other 2009b, Salca & other 2008,), in order to obtain high quality surfaces (Kilic 2005, Vega 2005, Moura 2007, Usta 2006, Keturakis 2007), all aiming to establish optimum parameters of the working regime.

The analysis of the surface quality obtained by milling was done by different methods of scanning the topography of the wood surface, through methods with and without contact, and by analyzing the different roughness parameters which are considered representative for wood: *Ra, Rz, Rk, Rpk, Rvk* (Sandak 2005).

Some researchers (Fujiwara 2004, Gurău 2004), believe that for the study of the surface quality of wood, the parameters *Rk* and *Rpk* are those who provide most information about the influence of processing upon the surface quality.

The objective of this work is oriented towards the influence of the variable parameters of the processing regime upon the surface roughness obtained by milling birch and pear wood with cutters with removable plates, of different diameter, seeking to establish optimal processing parameters, for the both species.

MATERIAL AND METHOD

The machining was performed on both species specimens with 8% humidity, with 700 mm in length and variable width, for the processing in longitudinal direction (Fig. 1a).

a. Samples for processing in longitudinal direction.

b. Samples for processing in transverse direction.

Fig. 1.
The samples used within the experiments

The edges of the samples were processed by milling in longitudinal direction, with two cutters with removable SMC-plates, with different diameters MNF10 (Fotin 2009a, Marty 2010), provided with an attachable mechanical advance system (Fig.3).

Milling cutter with removable SMC-plates: D=80; B=50; d=30

Milling cutter with removable SMC-plates: D=120; B=50; d=40

D -outer diameter in mm
B - processing width in mm
d - bore diameter of the cutter in mm.

***Fig. 2.* Milling cutters with removable CMS plates used within the experiments.**

***Fig. 3.* Vertical milling machine type MNF10 with mechanical feed device.**

The variable parameters of the processing regimes for straight milling of the edges are presented in Table 1.

Table 1

Milling schedule parameters

Rotation speed, rot/min	6620, 9732
Feed speed, (u) m/min	9; 13,5; 18;
Cutting depth, (h) mm	1; 2; 3
Cutting width, (b) mm	30

After each milling, the processed areas of the specimens were cut into lamellas. The items obtained were used to measure the roughness parameters.

The lamellas were coded, packaged and stored for preservation until the roughness measurement was performed (Fig.4).

Fig. 4.
Cutting, coding and packaging of the samples obtained by milling.

To establish the experimental working principle, the program module PROGR was used (Laurenzi 2000), which was based on the factorial experiment method, for the three variables, namely: feed speed (*u*), cutting depth (*h*) and width of milling (*b*).

To measure the roughness of the processed surfaces, a MicroProf FRT milling device (Fig.5), was used, from the endowment of the Laboratory for Testing the Manufacturing Precision in Wood Industry - LTPFIL (with RENAR accreditation No. LI 665/2008) – from the Faculty of Wood Industry. This device is a standard measurement tool for assessing optical non-contact surface roughness (Fotin & other 2009b, Marthy 2010).

Fig. 5.
MicroProf FRT optical device

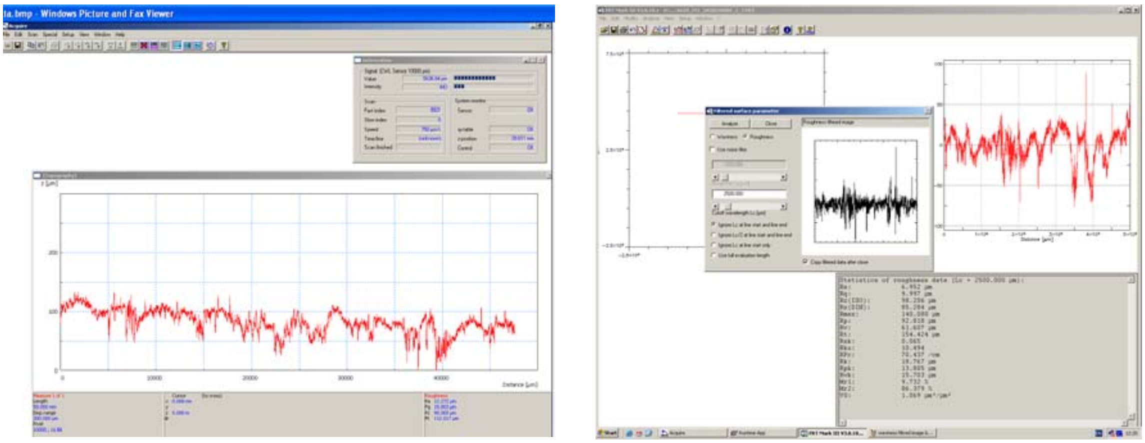
The roughness was measured parallel to the processing direction, the test-pieces being placed in a device to keep the same measurement position (Fig.5). On each test specimen, two measurements were performed, on different areas. The estimation of the roughness parameters was achieved by averaging the two measurements. The scanning parameters of the MicroProf FRT device are presented in Table 2.

Table 2

Scanning parameters of the device MicroProf FRT

Parameter name	Modul 2D
Scanning speed	750 μm/s
Number of points per	10.000 points
Number of measuring	1
Evaluation length	50 mm
Sampling length	2,5 mm
Resolution	5 μm
Direction of measurement	Along the processing direction

The ACQUIRE software for data recording allowed the data rescue as *frt* and *txt* type files, but also the view of the surface topography under study, as shown in Fig. 5a. The roughness profile analysis was performed by calling the MARK III analysis software (Fig. 5b), which allowed saving the processed data as *log* type files. The roughness profile was obtained after a pre-filtering of the data with a Gaussian filter, which was automatically applied by the software when calling the analysis. The resulted *txt* type files were processed with conversion software, created in DELPHI (Fotin 2009a). After averaging the two measurements for each specimen, the experimental data were modelled using the software developed in DELPHI and called ***Modelare_simulare_date*** (Modeling_simulation_data), a program which used the mathematical regression method, with a non-linear II-nd degree model, expressed by the function: $Y = a+bx_1+cx_2+dx_3+ex_1x_2+fx_1x_3+gx_2x_3+hx_1^2+ix_2^2+jx_3^2$ - for that **three variables**, respectively *u, h* and *b* (Fotin & other 2010).



a - ACQUIRE window for data recording

b –MARK III window for data analysis

Fig. 6.
Soft windows of FRT profilometer.

Out of the parameters defined by SR EN ISO 4287:2003/AC:2009 only *Ra* was used in this study and out of those defined by SR EN ISO 13565-2:1999, *Rk* and *Rpk* were selected for analysis.

RESULTS AND DISCUSSIONS

This paper is a comparative study of the values of roughness parameters *Ra, Rk* and *Rpk*, obtained after from the surface quality measurements of birch and pear wood samples, processed by milling a longitudinal direction with cutters of two different diameters: D80mm and D120 mm, with SMC removable plates.

The comparative study on the values of roughness parameters obtained from the milling of the two species was achieved by milling width b = 30 mm, for three depths of cut and three feed speed (Fotin & other 2010).

In order achieve comparative study to drawn the families of curves for the three roughness parameters analyzed on the same graph for each experiment, the milling width of 30 mm for the both species.(Fig.7 and Fig.8);

The code presented in the title of each graph represents: cutter diameter measuring direction plate type rotation speed (rot/min) milling width (mm) and species that has been processed (Fig.7 and Fig.8).

Roughness parameters have been analyzed and different trends depending on cutter diameter, rotation speed, feed speed and cutting depth, for which they were determined.

In the case of birch wood milling the following results were obtained:

- For longitudinal processing at low speed rotation, D80 diameter cutter generated surfaces with: $Ra_{min}=2.90\ \mu m$, $Rk_{min}=6.69\mu m$, $Rpk_{min}=7.78\mu m$, while D120mm diameter cutter generated surfaces with $Ra_{min}=3.89\mu m$, $Rk_{min}=11.06\mu m$, $Rpk_{min}=6.28\ \mu m$ (for example it was considered processing regime with cutting depth h=1 mm and feed speed u=18m/min for a milling width b=30mm). The cutting depth of 2 mm, the two milling surfaces with roughness generated almost identical. In terms of raised grain characterization parameter (*Rpk*) better results were obtained by milling with larger diameter cutter (D120 mm) (Fig.9).
- The longitudinal processing, values of roughness parameters, which normally decreases with increasing diameter cutter, this time shows an increase at the same level of processing, becoming an inconclusive election cutter on the criterion of minimum roughness.
- For high speed rotation processing of the longitudinal direction, D80 diameter cutter generated surfaces with: $Ra_{min}=4.74\ \mu m$, $Rk_{min}=13.02\ \mu m$, $Rpk_{min}=8.48\ \mu m$, while D120mm diameter cutter generated surface with $Ra_{min}=4.73\ \mu m$, $Rk_{min}=13.84\ \mu m$, $Rpk_{min}=5.10\ \mu m$ (for cutting processing procedure with h=1 mm depth cut and feed speed u=18m/min)). The presence of raised grain it's noted at processed surfaces with D80mm the smallest diameter milling cutter, the value of *Rpk* is significantly higher than at processing with largest diameter milling cutter. The other two parameters were very close values (Fig.9).

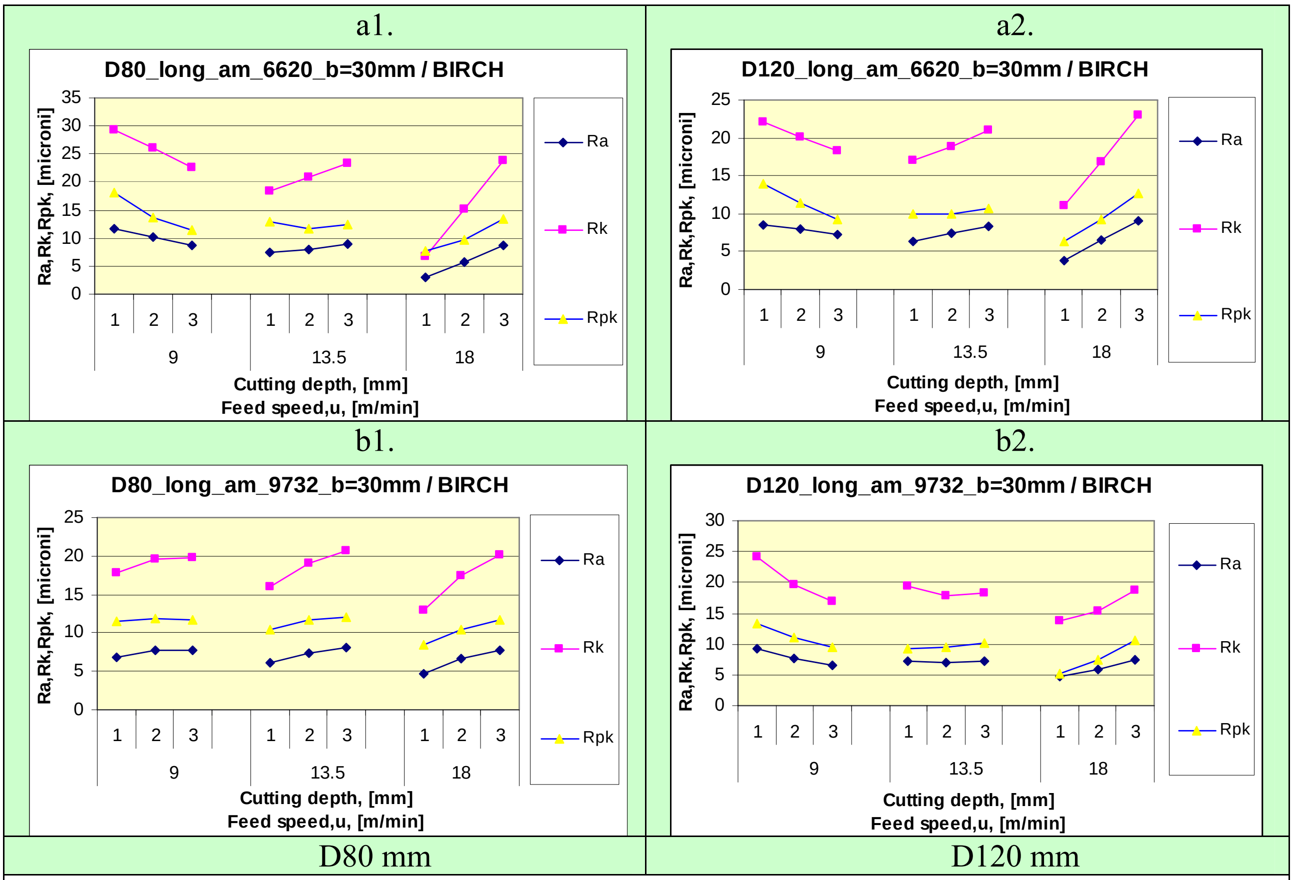


Fig. 7. Variation of roughness parameters Ra, Rk şi Rpk (μm), at the longitudinal milling of birch wood by means of cutters with removable plates, with diameter: D80mm (a1 and b1), and D120mm (a2 and b2)

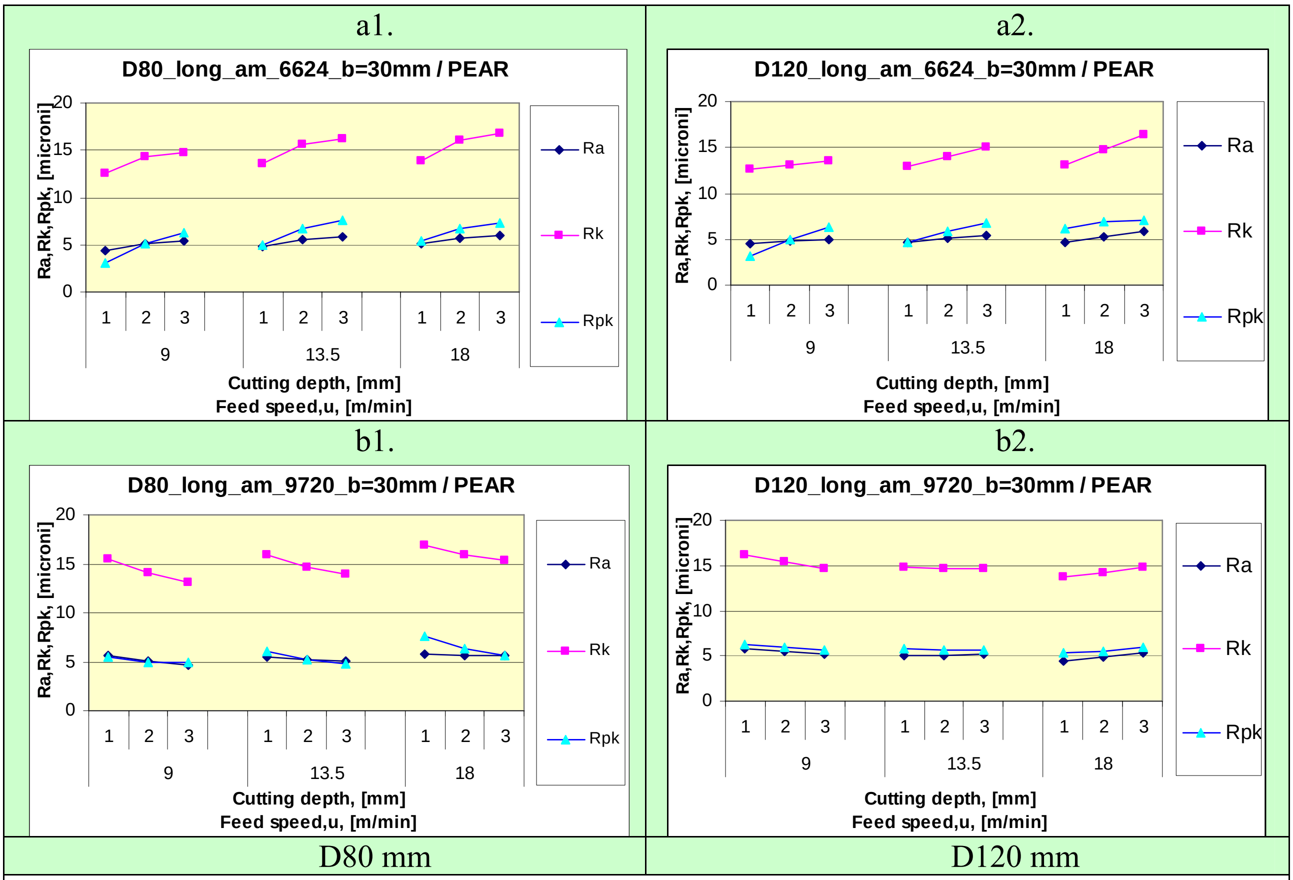


Fig. 8. Variation of roughness parameters Ra, Rk and Rpk (μm), at the longitudinal milling of pear wood by means of cutters with removable plates, with diameter: D80mm (a1 and b1), and D120mm (a2 and b2)

In the case of pear wood milling the following results were obtained:

- For low speed rotation longitudinal processing, the two mills have generated surfaces with very close minimum values of roughness parameters, the differences for processing regime were insignificant h=1mm depth of cut and feed speed u=9m/min (D80mm/D120) (Ra_{min} = 4.32µm/4.51µm, Rk_{min} = 12.52µm/12.69µm and Rpk_{min}=3.06 µm/3.10 µm)
- At the high speed rotation longitudinal processing were found large differences in terms of processing regime between the two mills for obtained minimum values were, respectively: D80 mm cutter surfaces generated with minimum values (Ra_{min}=4.69 µm, Rk_{min}=13.06 µm, Rpk_{min}=4.76 µm) to low feed speed processing (u = 9 m / min) and large cutting depth (h = 3mm), while D120mm cutter, generated surfaces with close minimum values (Ra_{min}=4.50 µm, Rk_{min}=13.68 µm, Rpk_{min}=5.31 µm but for high feed speed (u = 18 m / min) and small cut depth (h = 1mm) (Fig. 9).
- Consequently, because the minimum values of roughness parameters are very similar, the differences were insignificant, even in *Rpk* parameter (parameter that signifies the presence of raised grain) implies inconclusive mill choice according with minimum roughness criterion at the high speed processing.

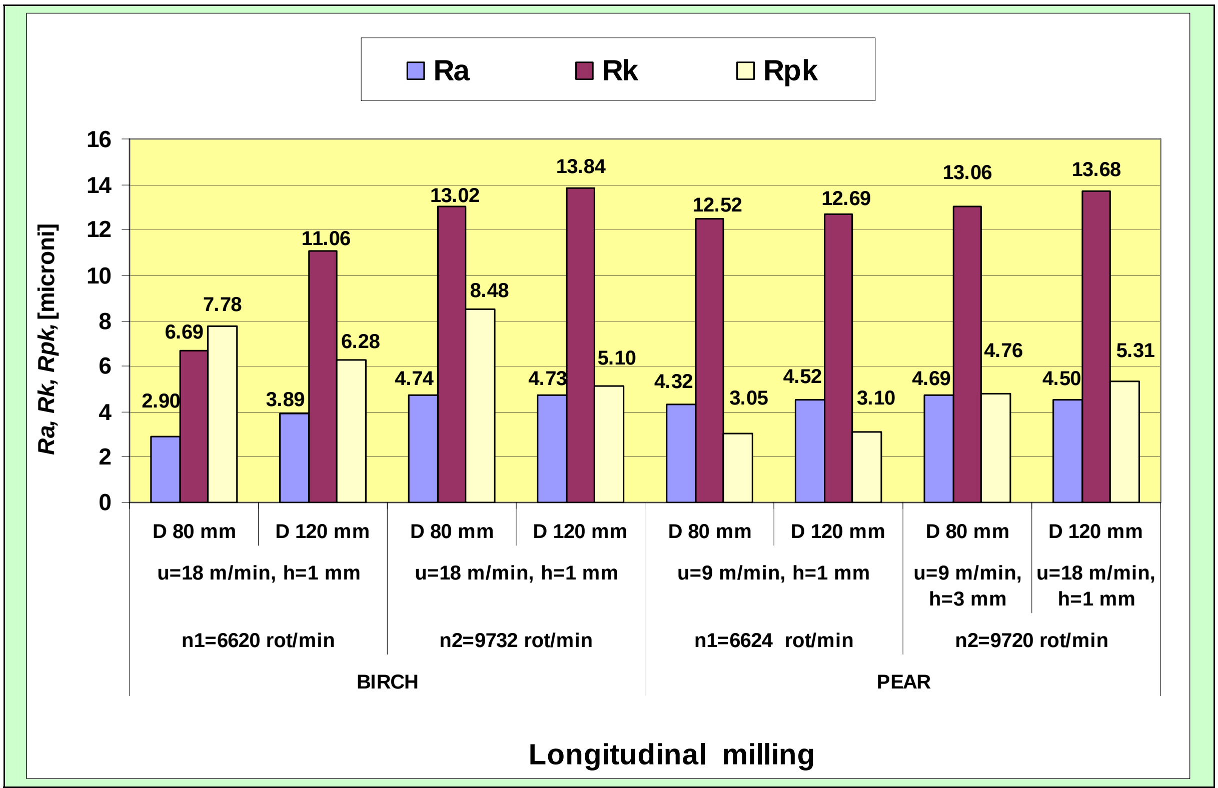


Fig. 9

The minimum values of roughness parameters *Ra, Rk* and *Rpk (µm)*, at the longitudinal milling birch and pear wood with removable plates of milling cutter with diameters: D80 mm and D120 mm at n1=6620 rot/min and n2=9732 rotation speeds, for milling width of 30 mm.

CONCLUSIONS

The conclusions on the influence diameter of cutter and cutting regime on the quality of processed surface of birch and pear wood, with removable plate from SMC mills with the diameters D80 mm and D120 mm, are:

- in case birch of wood, at the longitudinal processing the minimum value of roughness parameters were obtained, the processing at large feed speed and small cutting depths, for both mills at low speed rotation (6620 rpm) (Fig. 9);
- As regards the presence or absence of raised grain from processing birch wood with the two mills, the best results were obtained when processing with large diameter cutter (D 120mm) at high speed rotation (n2 = 9732 rpm);
- At longitudinal pear wood processing were obtained minimum values of roughness parameters on both milling feed speeds processing and small depths of cut (u = 9m/min h = 1mm) for speed rotation n1. At n2 speed rotation, the minimum values were obtained differently for the two mills, at D80mm milling process, processing regime was u=9m/min; h=1mm and for D120mm milling process regime was as birch to, high feed speed (u = 18m/min) and depth of cut h = 1 mm (Fig. 9);
- the minimum values of roughness parameters *Ra* and *Rk* were lower at birch wood in comparison with the minimum values obtained to the same degree of processing for the pear wood;
- regarding the *Rpk* parameter values (high value of the parameter signifies the presence of raised grain), the best results (lowest values) were obtained in all cases at the woodworking of the pear;
- at the pear wood processing, the best results were obtained, for both mills, at n1=6620 rot/min speed, the difference being insignificant (*Rpk*=3.05 μm for D80 mm mill processing and *Rpk*=3.10 μm for D120 mm mill processing) and for birch wood processing the lowest *Rpk* parameter values were doubled as of the pear wood processing, the best being obtained with large cutter diameter (D 120mm) at high speed rotation (n2);
- High quality of pear wooden surfaces compared to those of birch wood is due to the density influence of processing, birch being with a lower density (640 kg/m3) as pear (710 Kg/m3);

In conclusion, at longitudinal processing with low speed rotation, having regard the results obtained with the two mills are relatively close, it can choose smaller cutter diameter, D80 mm, thus reducing tools cost. When processing at high speed rotation even if supposed costs increase, it is choice preferred the large diameter milling , D120 mm, because the resulted surfaces presented fewer defects and raised grain after processing (Fig.9).

Results of study in design work can be based working arrangements Machining surfaces of birch and pear wood, taking as a criterion of optimization results in surface quality processing parameter of importance in terms of consumption of labour and energy consumption for subsequent technological operations of milling.

By using two working mills with diameters of 80 and 120 mm and two drive speeds actually obtained an analysis of influence of cutting speed (introduced in rose-wood contact area), of the resulting surface quality, knowing that with increasing cutting speed, the phenomenon of "stiffening" of wood fiber occurs much more conclusive can clearly influence the process of formation and detachment of the chip.

By offering industry study, optimal conditions for achieving industrial system processing by milling the wood of birch and pear, conditions can be analyzed in the field of wood processing companies.

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