

Full Length Research Paper

Effect of surface roughness on drying speed of drying lamellas in veneer roller dryer

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Lamellas, which are defined as top layers of multilayer parquet and favourable to wood veneer can be dried in jet ventilated automatic veneer roller dryer due to short drying period. The objective of this study is to determine the effect of surface roughness on the drying speed of the veneer roller dryer. *Quercus* spp., frequently used tree specie in Turkish solid wood and multilayer parquet industries was chosen as material in this study. Pre-dried lamella blocks were cut into 4 different machines. As a result, 4 test groups of lamellas displaying different surface roughness values were obtained. Lamellas which belong to each of these 4 test groups were also divided into 2 sub-groups and dried at 90 and 130°C drying temperatures. Drying was evaluated in relation to drying speed. Mitutoyo SJ 301 profilometer was used for determining surface roughness values. Drying speed of lamellas was expressed as: dividing difference of initial moisture content and final moisture content values to drying time value. The result of variance analyses showed differences between groups as surface roughness values. There was no difference between groups as drying speed were determined at 90 and 130°C temperatures. Furthermore, the relation between surface roughness values and drying speed was searched using correlation analysis and no significant relationship was found. Finally, it was determined that there was no effect of surface roughness on drying speed in radial cut, pre-dried lamellas, which have surface roughness values between 10.464 and 15.064 µm, drying in jet ventilated roller dryer, at 90 and 130°C temperatures.

Key words: Lamella drying, veneer roller dryer, surface roughness, drying speed.

INTRODUCTION

Air movement is the most important factor which influences drying speed in wood drying process. Effect of air movement on wood changes according to air movement speed and surface of drying material such as horizontal and vertical planes. Air movement is parallel to lumber surface in drying kilns. Contrary to this, air movement perpendicular to veneer surfaces are observed in veneer wood dryers. As air movement speed increases drying speed, also increases unrelated to air movement and drying time shortens at this rate (Hildebrand, 1979; Kantay, 1993; Unsal and Kantay 2002; Trübswetter, 2006). Since material (water) transfer is more difficult in rough surfaces, air movement

parallel to lumber surface is less effective in rough surfaces in drying kilns. For this reason, special ventilation systems in veneer drying were improved which are able to spray air perpendicular to veneer. Thus, equal, continuous and enough air movement can be supplied in every part of veneer surface that results with powerful air movement effectiveness on drying speed, time and quality, which cannot be obtained in horizontal ventilation (Kantay, 1983).

Vertical air movement (ventilation) systems were considered to decrease effect of surface roughness due to air spraying perpendicular to veneer surfaces. But no research has been completed about this so far.

According to TS EN 13489 (2004), lamella thicknesses were stated as at least 2.5 mm in multilayer parquet production. Since top limit for lamella thicknesses were not stated in TS EN 13489 (2004), 3 or 5 mm thicknesses

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are found to be put in practice at enterprises. These thicknesses are also agreeable to veneer thickness stated at TS 1250 (1974), Kantay (1983). For this reason, lamellas, in other words multilayer parquet top layer can be dried in vertical ventilation applied veneer wood dryers such as drum dryers and band dryers. Drum dryer was chosen for drying lamellas in this study because band dryer is appropriate for drying veneers thinner than 1 mm in plywood industry.

Lamellas are obtained usually from lamella blocks dried in lumber dry kilns. Dried lamella blocks are cut to lamellas by thin cutting frame saws. Drying time of lamella blocks is long. To shorten drying time, wet or pre-dried lamella blocks can be cut to lamellas and then lamellas can be dried in veneer wood dryers. Since high temperature is applied in drying for shortening drying time, colour changes can occur. Kollmann et al. (1951) stated that the most significant colour changes that occurred by drying came into existence due to temperature and moisture. They also determined that mentioned colour changes in drying veneers were not important. On the other hand, Kantay (1983) found that colour changes occurred in sliced veneers at high drying temperatures (150-190°C) and in drying times, emphasized as seconds (maximum 2 min). In this respect, Kantay (1983) recommended not applying drying temperatures above 150°C. A number of studies have been concluded on colour changes of veneer during drying (Lutz et al. 1974; Kantay et al., 1997; Aydın and Colakoglu, 2005). The purpose of drying lamellas in drum dryers is to shorten drying time. Drying speed (and consequently drying time) changes relative to tree species, drying temperature, veneer thickness and initial moisture content in these dryers. Surface quality of veneer effect was determined to be unknown on drying speed. The objective of this study is to determine the effect of lamella surface roughness on drying speed in vertical ventilation applied veneer wood dryers. Lamellas (multilayer parquet top layers) which are convenient to veneer definition as thickness value criteria were chosen as one of the materials for the present study.

MATERIALS AND METHODS

As research material, lamellas were cut from fresh *Quercus* spp. log, with 45 cm central diameter, selected from timber store of a lumber enterprise, which was transported from Demirköy Forest Service. Log was cut into slash sawn planks with 10 cm thickness by using plain saw method; then flat sawn lamella blocks with 120 cm length were cut from these slash sawn planks (Figure 1). As cutting of fresh lamella blocks generally was not found to be convenient in practice at enterprises, pre-air drying was applied to lamella blocks to obtain moisture content below 30%. Afterwards, these lamella blocks were divided into 4 groups. Then each group was cut into 30 lamellas in 4.2 mm thickness with different machines to obtain different surface roughness values. The objective of using different sawing machines in lamella manufacturing was to obtain different surface roughness. Machines and test group numbers of

machines used in lamella manufacturing are stated below:

- Group 1: Thin-cutting band saw¹
- Group 2: circular saw bench
- Group 3: thin-cutting frame saw²
- Group 4: planing machine

Where, ¹Tooth depth (h) 5 mm, tooth pitch(t) 12 mm, saw thickness (d) 1.1 mm, the set of the teeth (b) 0,25 mm, cutting speed (v_b) 3 m/sec, feed speed (v_f) 0.5 m/min; ²Tooth depth (h) 5 mm, tooth pitch (t) 14 mm, saw thickness (d) 0.8 mm, the set of the teeth (b) 0.2 mm, cutting speed (v_b) 3 m/sec, feed speed (v_f) 0.5 m/min. Material thickness is known to be one of the factors affecting drying speed. Efforts were made to obtain equal lamella thicknesses in order to eliminate effect of lamella thickness on drying speed for this study. Also, optimum care in every step of manufacturing was applied to obtain effect of lamella surface roughness on drying speed and to minimize effects on drying speed coming from natural tree structure.

Surface roughness test method

Surface roughness was determined on 30 cm length pieces cut away from edges of lamellas. At first, test pieces were conditioned at $20 \pm 2^\circ\text{C}$ and 65 ± 2 percent relative humidity. Surface roughness values of lamellas (R_a , R_y , R_z , and R_q) were measured on these lamella pieces at 12% moisture content.

Mitutoyo SJ-301 Profilometer was used for surface roughness. Tracing speed, stylus tip diameter, and tip angle were 10 mm/min, 4 μm , and 90° , respectively. The location of roughness measurements were randomly marked on the surface of samples. Measurements were made perpendicular to the fiber direction of samples. Average surface roughness (R_a), mean peak- to-valley height (R_z), and maximum roughness (R_{max}), which are the parameters characterized by ISO 4287, were recorded. The average roughness is the most commonly used parameter. Roughness values were measured with a sensitivity of 0.5 μm . A 15 mm tracing length (L), a 2.5 mm cutoff was used for measurements. The measuring force of the scanning arm on the surfaces was 4 Min (0, 4 g.), which did not result in any significant damage to the surface. Measurements were done at room temperature and the stylus pin was calibrated prior to the tests.

Lamella drying

After surface roughness test pieces were taken, lamellas were brought to Pelit Arslan Plywood Enterprise (Istanbul) for drying. Lamellas were dried in "Schilde" brand Veneer Roller dryer. As the purpose of the study is to determine the effect of surface roughness on drying speed, applying low or high drying temperature is not important. Since it was considered that surface roughness could also affect drying speed while different drying temperatures were applied, 2 different drying temperatures below 100 and above 100°C, such as 90 and 130°C were chosen for tests. 15 lamellas from each surface roughness group were dried in every chosen temperature. Drying tests were made in the jet ventilated (vertical ventilation applied) automatic roller veneer dryer. Pretests showed that drying times were determined to be 60 and 40 min for 30% initial moisture content to 10% final moisture at 90 and 130°C, respectively. For this reason, drying times, 60 and 40 min for 90 and 130°C, respectively, were applied.

Drying speed

Drying speed was found by dividing difference of initial moisture

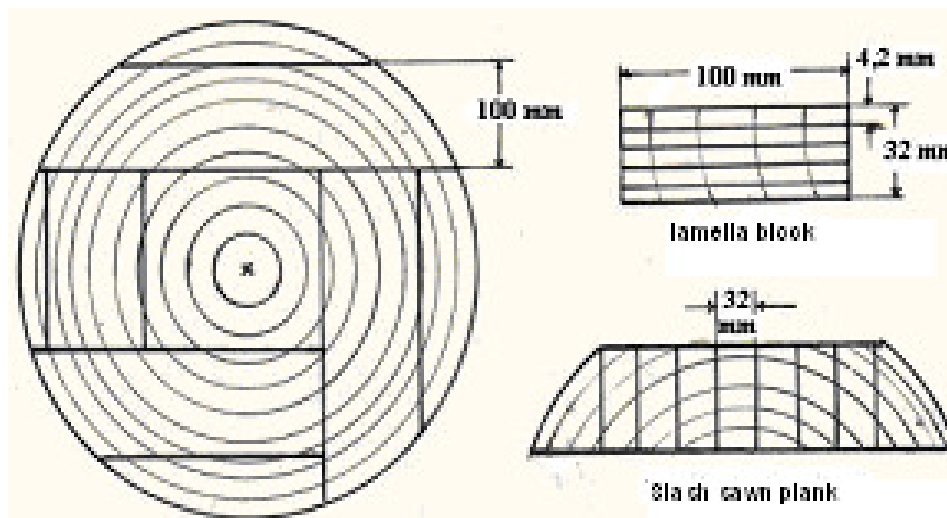


Figure 1. Obtaining lamella blocks and lamellas from log.

Table 1. Statistical data of surface roughness values (Ra)

| Statistical data | Planing 90 | Planing 130 | Band 90 | Band130 | Circular 90 | Circular 130 | Frame 90 | Frame 130 |
|-------------------------|------------|-------------|---------|---------|-------------|--------------|----------|-----------|
| Arithmetic mean | 11.127 | 11.016 | 10.566 | 10.465 | 15.064 | 14.584 | 11.155 | 11.337 |
| Standard deviation | 2.408 | 1.287 | 2.562 | 1.260 | 2.175 | 2.142 | 1.126 | 1.569 |
| Variance | 5.797 | 4.205 | 4.325 | 2.324 | 7.542 | 4.457 | 4.925 | 5.461 |
| Coefficient of variance | 21.637 | 11.683 | 24.249 | 12.040 | 14.435 | 14.685 | 10.091 | 13.839 |
| Maximum | 17.400 | 15.570 | 15.980 | 14.170 | 21.490 | 19.100 | 16.350 | 19.970 |
| Minimum | 6.440 | 6.310 | 7.400 | 6.940 | 7.920 | 10.510 | 7.030 | 7.670 |

content (U_b) and final moisture content (U_s) to drying time (min) and can also be expressed as moisture loss per unit time (%/min) (Kantay, 1983).

Measurement of moisture content

Moisture content of lamellas were measured in 3 points, such as 2 points 30 cm inner from lamella edges and 1 point from the middle of specimen favorable to TS EN 13183 - 2 (2002). Final moisture measurements were made in same points with initial moisture measurements. "Gann Hydromette HT 85 T" electrical resistance type moisture content measurement device was used in which tree specie and temperature adjustment can be applied.

Evaluation method

Statistical data belonging to sample groups relating to surface roughness and drying speed (arithmetic mean, standard deviation, variance, coefficient of variation, range of variation) were determined using the statistical package for the social sciences (SPSS). One-way analysis of variance (ANOVA) was made to establish the existence of difference between groups for each surface roughness and drying speed. Significant differences between the test groups were determined using Duncan's multiple range tests. Also, statistical relationships between surface roughness and drying speed were

tested by correlation analysis.

RESULTS

Surface roughness values (Ra) of lamellas obtained by using 4 different sawing machines are given in Table 1 according to sawing machine types and drying temperatures. One-way analysis of variance (ANOVA) test, establishing the existence of difference as lamella (obtained by means of using 4 different sawing machine) Ra values between groups for each according to sawing machine type and drying temperature are given in Table 2. The result of ANOVA showed that the difference between Ra of the lamellas obtained by using 4 different sawing machines was significant at 95 and 99% confidence level with respect to sawing machine type and drying temperature. DUNCAN test was used to show the difference determined with ANOVA. Test results are given in Table 3. Table 3 shows that there was a statistical difference between surface roughness values of the lamellas dried in 90°C cut with circular saw, surface roughness of the lamellas dried in 130°C cut with thin-cutting frame saw,

Table 2. One-way analysis of variance (ANOVA) test of surface roughness values (Ra)

| Source of | Degree of | Total | Variances | F-ratio | F-ratio | Confidence |
|----------------|-----------|-----------|-----------|---------|---------|------------|
| Variation | Freedom | Variances | | 95% | 99% | level |
| Between Groups | 7 | 1048.779 | 149.826 | 30.706 | 30.706 | |
| Within Groups | 352 | 1717.555 | 4.879 | > | > | (%95) S* |
| Total | 359 | 2766.334 | | 1.938 | 2.511 | (%99) S** |

Table 3. Duncan test results belonging to surface roughness values (Ra).

| Parameters | Circular 130 | Frame 130 | Frame 90 | Planing 90 | Planing 130 | Band 90 | Band 130 |
|--------------|--------------|-----------|----------|------------|-------------|---------|----------|
| Circular 90 | 0.480 | 3.727 | 3.910 | 3.937 | 4.048 | 4.498 | 4.599 |
| Rp | 0.922 | 1.106 | 1.215 | 1.291 | 1.350 | 1.396 | 1.436 |
| Circular 130 | | 3.247 | 3.430 | 3.457 | 3.568 | 4.018 | 4.119 |
| Rp | | 0.922 | 1.106 | 1.215 | 1.291 | 1.350 | 1.396 |
| Frame 130 | | | 0.182 | 0.210 | 0.321 | 0.771 | 0.872 |
| Rp | | | 0.922 | 1.106 | 1.215 | 1.291 | 1.350 |
| Frame 90 | | | | 0.028 | 0.138 | 0.589 | 0.690 |
| Rp | | | | 0.922 | 1.106 | 1.215 | 1.291 |
| Planing 90 | | | | | 0.111 | 0.561 | 0.662 |
| Rp | | | | | 0.922 | 1.106 | 1.215 |
| Planing 130 | | | | | | 0.450 | 0.551 |
| Rp | | | | | | 0.922 | 1.106 |
| Band 90 | | | | | | | 0.101 |
| Rp | | | | | | | 0.922 |

Table 4. Statistical data of drying speed.

| Statistical data | Planing 90 | Planing 130 | Band 90 | Band 130 | Circular 90 | Circular 130 | Frame 90 | Frame 130 |
|-------------------------|------------|-------------|---------|----------|-------------|--------------|----------|-----------|
| Arithmetic mean | 0.288 | 0.477 | 0.247 | 0.480 | 0.234 | 0.419 | 0.265 | 0.442 |
| Standard deviation | 0.018 | 0.016 | 0.026 | 0.036 | 0.017 | 0.035 | 0.021 | 0.020 |
| Variance | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.000 |
| Coefficient of variance | 6.307 | 3.398 | 10.690 | 7.453 | 7.455 | 8.454 | 8.075 | 4.613 |
| Maximum | 0.321 | 0.501 | 0.279 | 0.513 | 0.256 | 0.468 | 0.325 | 0.478 |
| Minimum | 0.261 | 0.448 | 0.206 | 0.377 | 0.196 | 0.328 | 0.243 | 0.396 |

the lamellas dried in 90°C cut with thin-cutting frame saw, the lamellas dried in 90°C planed with planing machine, the lamellas dried in 130°C planed with planing machine, the lamellas dried in 90°C cut with thin-cutting band saw and the lamellas dried in 130°C cut with thin-cutting band saw at 95 and 99% confidence level. It was also determined that a statistical difference was found between surface roughness values of the lamellas dried in 130°C cut with circular saw and surface roughness of the lamellas dried in 130°C cut with thin-cutting frame saw, the lamellas dried in 90°C cut with thin-cutting frame saw, the lamellas dried in 90°C planed with planing machine, the lamellas dried in 130°C planed with planing machine, the lamellas dried in 90°C cut with thin-cutting

band saw, the lamellas dried in 130°C cut with thin-cutting band saw at 95 and 99% confidence level.

Drying speed values of the lamellas (multilayer parquet top layers) obtained from 4 different saw machines are given in Table 4 according to sawing machine type and drying temperature. ANOVA test, establishing the existence of difference as lamella (obtained by means of using 4 different sawing machine) drying speed values between groups for each according to sawing machine type and drying temperature are given in Table 5.

The result of ANOVA showed that the difference between drying speed of the lamellas obtained by using 4 different sawing machines was not significant at 95 and 99% confidence level with respect to sawing machine type an

Table 5. One-way analysis of variance (ANOVA) test of drying speed values.

| Source of variation | Degree of freedom | Total variance | Variance | F-ratio 95% | F-ratio 99% | Confidence level |
|---------------------|-------------------|----------------|----------|-------------|-------------|------------------|
| Between groups | 7 | 0.406 | 0.058 | 0.587 | 0.587 | |
| Within groups | 112 | 11.053 | 0.099 | < | < | (%95) S* |
| Total | 119 | 11.45842 | | 2.016 | 2.663 | (%99) S** |

Table 6. Statistical data of surface roughness values (Ry).

| Statistical data | Planing 90 | Planing 130 | Band 90 | Band 130 | Circular 90 | Circular 130 | Frame 90 | Frame 130 |
|-------------------------|------------|-------------|---------|----------|-------------|--------------|----------|-----------|
| Arithmetic mean | 116.755 | 116.988 | 100.031 | 99.537 | 129.330 | 128.996 | 104.400 | 104.711 |
| Standard Deviation | 18.979 | 25.209 | 22.167 | 28.225 | 26.648 | 25.950 | 21.157 | 32.214 |
| Variance | 360.214 | 635.516 | 491.358 | 796.676 | 710.102 | 673.377 | 447.621 | 1.037.745 |
| Coefficient of Variance | 16.256 | 21.549 | 22.160 | 28.357 | 20.605 | 20.117 | 20.265 | 30.765 |
| Maximum | 158.800 | 174.700 | 158.250 | 160.000 | 182.000 | 196.200 | 157.000 | 181.100 |
| Minimum | 74.140 | 73.980 | 57.380 | 7.070 | 78.460 | 87.260 | 63.280 | 12.920 |

Table 7. Statistical data of surface roughness values (Rz).

| Statistical data | Planing 90 | Planing 130 | Band 90 | Band 130 | Circular 90 | Circular 130 | Frame 90 | Frame 130 |
|-------------------------|------------|-------------|---------|----------|-------------|--------------|----------|-----------|
| Arithmetic mean | 81.200 | 78.528 | 70.234 | 69.050 | 92.116 | 90.366 | 74.549 | 74.757 |
| Standard Deviation | 11.330 | 15.654 | 10.477 | 11.473 | 18.398 | 13.761 | 12.383 | 16.687 |
| Variance | 128.372 | 0.000 | 57.138 | 118.638 | 79.652 | 66.816 | 108.108 | 228.487 |
| Coefficient of Variance | 13.953 | 19.934 | 14.917 | 16.615 | 19.972 | 15.228 | 16.610 | 22.321 |
| Maximum | 102.100 | 126.900 | 97.710 | 92.610 | 117.300 | 113.900 | 97.120 | 131.700 |
| Minimum | 56.280 | 47.630 | 52.120 | 50.710 | 8.230 | 44.430 | 43.990 | 47.000 |

drying temperature.

Surface roughness values (Ry) of the lamellas (multilayer parquet top layers) obtained from 4 different saw machines are given in Table 6 according to sawing machine type and drying temperature. Surface roughness values (Rz) of the lamellas (multilayer parquet top layers) obtained from 4 different saw machines are given in Table 7 according to sawing machine type and drying temperature. Surface roughness values (Rq) of the lamellas (multilayer parquet top layers) obtained from 4 different saw machines are given in Table 8 according to sawing machine type and drying temperature. Correlation analysis was made for the determination of the effect of surface roughness on drying speed and obtained results are given in Table 9. As can be seen in Table 9, there was no significant relationship between surface roughness of lamellas and drying speed of the lamellas at both 90 and 130 °C at 95% significant level.

DISCUSSION

In this study, it was determined that surface roughness of lamellas obtained from four different machines were

different according to values of variance analysis. It was thought that the effect of surface roughness on drying speed could be changed with temperature. Two different temperatures were applied at 90 °C under the boiling temperature and 130 °C above the boiling temperature. It was shown that surface roughness was more efficient under the boiling temperature. It is worth noting that water in wood move in liquid phase at temperature below 100 °C and in steam phase at temperature above 100 °C in normal pressure during drying. Analysis of variance was made to determine the effect of surface roughness on drying speed with relation to temperature changes. As a result, it was found that there was no effect of surface roughness on drying speed.

Four different machines were used to obtain different surface roughness values in this research. Thin-cutting frame saw and thin-cutting band saw were used in practical manufacturing. The biggest and the lowest surface roughness values of lamellas obtained from the two machines were Ra: 11.337 and 10.464 µm.

These values were close to the surface roughness in practice. Gungor (2008) found that surface roughness average of oak parquet obtained from different mill was 9.19 µm. In another study, Unsal and Kantay (2002)

Table 8. Statistical data of surface roughness values (Rq).

| Statistical data | Planing 90 | Planing 130 | Band 90 | Band 130 | Circular 90 | Circular 130 | Frame 90 | Frame 130 |
|-------------------------|------------|-------------|---------|----------|-------------|--------------|----------|-----------|
| Arithmetic mean | 16.692 | 15.920 | 14.085 | 13.734 | 20.136 | 19.593 | 14.913 | 15.089 |
| Standard Deviation | 3.505 | 2.911 | 2.156 | 2.438 | 3.125 | 3.590 | 2.943 | 3.080 |
| Variance | 12.283 | 0.000 | 5.153 | 6.770 | 8.119 | 17.584 | 0.748 | 4.804 |
| Coefficient of Variance | 20.996 | 18.287 | 15.306 | 17.749 | 15.521 | 18.321 | 19.735 | 20.411 |
| Maximum | 23.640 | 24.930 | 20.820 | 20.800 | 27.800 | 28.860 | 22.320 | 27.140 |
| Minimum | 8.160 | 10.340 | 10.890 | 9.820 | 13.850 | 10.250 | 10.100 | 9.590 |

Table 9. Correlation analysis for the determination of the relation between surface roughness values (Ra) and drying speed.

| Parameters | Sample size | Correlation | Significant level |
|---|-------------|-------------|-------------------|
| Roughness planing 90 & speed planing 90 | 15 | 0.296 | 0.284 |
| Roughness planing 130 & speed planing 130 | 15 | 0.061 | 0.828 |
| Roughness band 90 & speed band 90 | 15 | 0.084 | 0.765 |
| Roughness band 130 & speed band130 | 15 | -0.134 | 0.635 |
| Roughness circular 90 & speed circular 90 | 15 | -0.335 | 0.223 |
| Roughness circular 130 & speed circular 130 | 15 | -0.028 | 0.921 |
| Roughness frame 90 & speed frame 90 | 15 | -0.081 | 0.775 |
| Roughness frame 130 & speed frame 130 | 15 | -0.144 | 0.607 |

determined surface roughness values of solid oak parquet cut in radial and tangential manufactured in Turkey as Ra: 5.07 and 5.18 μm . Also they found surface roughness values of imported solid parquet as Ra: 8.90 and 10.11 μm , respectively.

Lamellas used in this research were cut from pre-dried lamella blocks cut in radial direction. Lamellas cut in radial direction have been preferred by parquet manufacturers due to dimensional stability. Cutting lamellas from fresh lamella blocks is not required by most producers. But there are some machines that cut fresh materials. It can be shown that different result could be determined in drying freshly cut lamellas compared to those of pre-dried. Since it is known that drying occurs with constant speed above fiber saturation point, it can be said that the results would not change. There was no significant difference among the surface roughness of lamellas obtained from four different machines. The lowest Ra value was 10.464 μm which was obtained from thin-cutting band saw, while the biggest Ra value was 15.064 μm obtained from circular saw. Finally, it was determined that there was no effect of surface roughness on drying speed in radial cut, pre-dried lamellas which have surface roughness values between 10.464 and 15.064 μm , drying in jet ventilated roller dryer, at 90 and 130°C temperatures. Broader range of surface roughness values effect on drying speed can be shown. It is possible that this may be determined in new researches. It may be stated that surface roughness of lamellas does not affect drying speed in lamellas used in top layers of multilayer

parquet drying because surface roughness values of lamellas obtained from thin-cutting frame saw and thin-cutting band saw were under the surface roughness value stated above (Ra: 11.337 μm).

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