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Effect of thermal post-treatment on some surface-related properties of oriented strandboards*

Utjecaj toplinske obrade na neka svojstva površine iverice s orijentiranim iverjem

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ABSTRACT • *A very promising method for improving the dimensional stability of oriented strandboard (OSB) has been studied in Brazil since 2001. According to this method, the OSB is thermally treated under mild conditions using a hot-press, where it is reheated without high level of compression stress. The properties of the treated OSB panels are different from and enhanced compared to those untreated ones. It means that the treated OSB can be used in more severe uses, like concrete formwork. This paper aims to evaluate the effect of the proposed thermal treatment on nail-holding capability and on surface hardness of OSB. Samples from 42 commercials OSB were thermally treated according to two levels of temperature (190°C and 220°C) and three heating times (12, 16 and 20 min) using a single opening hot-press. For comparison, control panels were kept untreated. The following surface-related properties were evaluated: Janka hardness, nail-holding capability in a plane normal to the surface, in the edge of the panel, water absorption and thickness swelling (TS) of edge sealed samples, and four surface roughness parameters. According to the Dunnett test, there were significant differences between treated and untreated panels for nail-holding, dimensional stability and surface roughness. The factorial ANOVA identified that the temperature was the main factor governing these properties while the duration of the treatment had lesser effect. It was concluded that the proposed thermal treatment improved significantly dimensional stability and did not affect adversely the nail-holding capability and surface roughness of the treated OSB.*

Keywords: *oriented strandboard, surface properties, thermal treatment.*

SAŽETAK • *Vrlo obećavajuća metoda za poboljšanje dimenzijske stabilnosti ploča iverica s orijentiranim iverjem (OSB ploča) proučava se u Brazilu od 2001. godine. Prema toj metodi, OSB ploča se obrađuje toplinom u umjerenim uvjetima, uporabom vruće preše, pri čemu se ponovo zagrijava bez velikog pritiska. Svojstva toplinski obrađenih OSB ploča poboljšana su u odnosu prema neobrađenim pločama. To znači da se termički obrađene OSB ploče mogu rabiti i u zahtjevnijim uvjetima, npr. kao betonske oplate. Cilj ovog rada bio je procijeniti utjecaj metode toplinske obrade OSB ploča na čvrstoću držanja čavala te površinsku tvrdoću tretiranih ploča. Uzorci izrađeni od komercijalne OSB ploče toplinski su obrađeni u vrućoj preši na dvije razine temperature (190 °C i 220 °C) i tri vremena zagrijavanja (12, 16 i 20 min). Za usporedbu su uzeti kontrolni uzorci koji nisu obrađivani. Istraživana su*

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ova svojstva površine OSB ploča: tvrdoća prema Janki, čvrstoća držanja čavala u ravnini okomitoj na površinu i na rub ploče, upijanje vode i debljinsko bubrenje uzoraka izoliranih rubova te četiri parametra hrapavosti površine. Prema Dunnett testu, između toplinski obrađenih i neobrađenih ploča postoje signifikantne razlike u čvrstoći držanja čavala, dimenzijskoj stabilnosti i hrapavosti površine. Faktorskom ANOVA analizom ustanovljeno je da je temperatura glavni činitelj koji utječe na poboljšanje svojstava, a da vrijeme zagrijavanja ima manji utjecaj. Može se zaključiti da opisana metoda toplinske obrade znatno utječe na poboljšanje dimenzijske stabilnosti OSB ploča, a ne utječe negativno na čvrstoću držanja čavala i hrapavost površine tako obrađenih ploča.

Ključne riječi*: iverice s orijentiranim iverjem, svojstva površine ploče, toplinska obrada*

1 INTRODUCTION
1. UVOD

The oriented strandboard (OSB) is a wood based panel used mainly for structural purposes. It has very good mechanical, physical and technological properties when compared with other composite panels made of wood particles. In comparison with plywood, OSB has lower mechanical properties, but it has been replacing plywood mainly due to the possibility of using low quality species and logs and low availability of veneer logs.

The OSB dimensional stability is worst than that of plywood: its thickness swelling is 7 to 10 times higher than that of plywood. Consequently it is necessary to improve the OSB dimensional stability to raise its market share. Many researches on treatments for the improvement of dimensional stability have been made and they can be divided in three types according to the stage when they are applied: before panel consolidation (furnish pre-treatment); during hot-pressing (steam injection press, not exactly a treatment); or after pressing (panel post-treatment).

Pre-treatments were evaluated by Paul *et al*. (2006), Pétrissans *et al*. (2003) and Goroyias and Hale (2002) and very good results have been obtained, but some adverse effects are common like decreasing of wood bonding, wood wettability and flexural properties. On the other hand, it is possible to use a post-treatment, as made by Suchsland and Xu (1991), where the board is treated after its consolidation.

A very promising post-treatment to improve the dimensional stability of the oriented strandboard (OSB) has been studied in Brazil since 2001. According to this method, the OSB is thermally treated under mild conditions using a hot-press, where the pressure is applied just to provide contact between press plates and surfaces of the board. The main difference from the well known thermal processes is in using lower temperature, but fast heating by conduction, and shorter time. Consequently, the results obtained so far show an improvement of the dimensional stability by reducing thickness swelling, equilibrium moisture content and permanent thickness swelling, as observed by Del Menezzi and Tomaselli (2006).

It has been observed that the treated OSB has longer service life than the untreated one because it has both higher resistance against fungi and better weathering behaviour as related by Del Menezzi (2006). These improvements could be obtained without any severe effect on mechanical properties, which always happens when wood and wood products are thermally treated for a longer time. Although the post-treatment is recommended to boards produced with thermal-resistant resins (phenol-formaldehyde, isocyanate), recently Okino *et al*. (2007) treated thermally urea-formaldehyde-bonded OSB and encouraging results have been obtained.

Consequently, the properties of the treated boards are enhanced and different from untreated ones. It means that the treated OSB can be used in more severe uses, such as concrete formwork. In this end-use two properties play an important role: nail-holding capability and surface hardness. These properties are not usually determined for wood based panels, but some studies dealing with these properties have been made (Falk *et al*. 2001, Viswanathan and Gothandapani 1999, Lee *et al.* 1996). The lack of that information is especially evident for wood and wood products that have been heat-treated. However, some works have related that thermal treatments can increase the corrosion of fasteners (Jermer and Anderson 2005) and decrease the surface hardness of wood (Brischke *et al*. 2005) or even improve it, depending on how intensive the applied treatment was, as argued by Syrjänen and Kangas (2000).

In this context, the present work aims to raise the technological information about this kind of treated material by evaluating the effect of the proposed thermal treatment on some surface-related proporties, which are important properties mainly when OSB is used in more severe uses.

2 MATERIALS AND METHODS
2. MATERIJAL I METODE

2.1 Wood material
2.1. Uzorci

Samples (50x50x1.25 cm^3) were cut from 42 commercials OSB panels and they had the following characteristics: made from *Pinus* sp, nominal density of 0.64 g/cm^3, three layers, 19 kg/m^3 solid resin (40% di-isocyanate resin on the core layer and 60% on the surface layer). The samples (boards) were kept in a conditioning room (65%; 20°C) until constant mass was reached.

2.2 Thermal treatment
2.2. Toplinska obrada

The thermal treatment was applied using a laboratory single-opening press. The boards were put into the press and repressed and re-heated, but without high level of compression stresses. The pressure was only enough to provide contact between the press plates and both surfaces of the boards. A preliminary study was carried out to evaluate the time needed for heating the boards above 170°C, which was set as the minimum temperature where the compression stresses could be released and some chemical degradation could occur. It is known as viscoelasticity transition temperature (T_g) and the wood matrix above this temperature losses its stiffness. In an OSB industrial plant, the pressing temperature varies from 190°C to 210°C, which is the range needed to promote the resin polymerization. Hence, two temperature levels were chosen: 190°C, industrial minimum; and 220°C slightly above the maximum. The results showed that the boards required at least 590s to reach the set T_g at 190°C and at least 400s at 220°C (Figure 1). It meant that the minimum treatment should be 8 minutes, provided that the board's temperature was kept for a certain time to release the compression stresses. The interval of at least 4 minutes was chosen, which was added to the required minimum.

Consequently, the boards were treated according to the following schedule: two temperature levels, 190°C and 220°C, during 12, 16 and 20 minutes. For

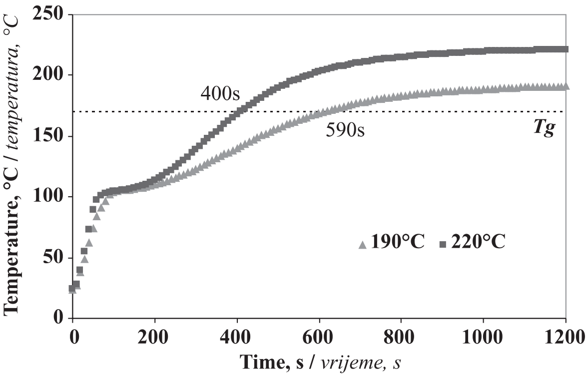

Figure 1 Temperature increase in the board when it is treated at 190 °C and 220 °C
Slika 1. Porast temperature u ploči kada se zagrijava na 190 °C i 220 °C

each temperature-time combinations, six boards were thermally treated and additional six boards were kept untreated (control samples), totalling 42 boards (Table 1). After the thermal treatment, the boards were returned to the conditioning room to cool down and to reach constant mass.

Table 1 Experimental design
Tablica 1. Podaci o eksperimentu

Treatment *Obrada*	**Temperature, °C** *Temperatura, °C*	**Time, min** *Vrijeme, min*	**Number of boards** *Broj ploča*
Control	-	-	6
T1	190	12	6
T2	190	16	6
T3	190	20	6
T4	220	12	6
T5	220	16	6
T6	220	20	6

2.3 Mechanical and dimensional stability properties
2.3. Mehanička svojstva i dimenzijska stabilnost

The following mechanical and dimensional stability properties were evaluated according to the ASTM D1037 (1999): nail-holding capability in a plane normal to the face (F⊥) and in the edge of the panel (E//), Janka hardness (JH), water absorption (WA) and thickness swelling (TS) after 2 and 24 hours. Both nail-holding tests were carried out on the same sample. To achieve the minimum thickness for the JH test, two pieces had to be glued so as to produce one sample. For each property, two samples were tested from each board, totalling 84 samples. For WA and TS, the four sample edges were sealed with wax, so that liquid water could only penetrate through the surface of the samples.

2.4 Surface roughness measurement
2.4. Mjerenja hrapavosti površine

The measurement of the surface roughness was carried out using the Surftest SJ-301 (Mitutoyo). It is a stylus type instrument which traces the minute irregularities of the board. The surface roughness is determined from vertical stylus displacement produced during the detector traversing over the surface irregularities (Mitutoyo, 1999). The device was set to measure surface roughness according to JIS (2001) and the evaluation length was 12.5 mm. The following surface roughness parameters were determined: R_a, the arithmetic mean of the absolute values of the profile deviations from the mean line; R_q, the square root of the arithmetic mean of the square of profile deviations from the mean line; R_z, sum of the mean height of the five highest profile peaks and the depth of the five deepest profile valleys measured from a line parallel to the mean line; R_t, the sum of the maximum profile peak height and the maximum profile valley depth over the evaluation length.

2.5 Statistical analysis
2.5. Statistička analiza

Initially the comparison between the treated and control board was evaluated for each mechanical property by running Dunnett test at 5% probability level. This test compares the means of the control and treated board, pair to pair, instead of comparing the whole treatments. To evaluate the effect of temperature (T_p), time (T_m) and its interaction (T_p x T_m), a factorial (3 x 2 levels) analysis of variance (ANOVA) was run without control values.

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

3.1 Comparison between control and heat treated boards
3.1. Usporedba kontrolnih i toplinski obrađenih ploča

Figure 2 presents the results of the properties of both control and treated boards. As shown in this figure, JH of the treated boards had slightly lower values than those observed for control boards, but the Dunnett test failed to identify these differences as statistically significant. The board moisture content was about 9.2%. It is well known that thermal treatment makes wood more brittle and degrades wood polymers of the cellular wall causing mass loss. These effects increase proportionally to the treatment temperature and length and if carried out in the presence of oxygen, as argued by Militz (2002). Brischke *et al*. (2005) observed decreasing of the Brinell hardness of thermally treated silver fir and beech wood. The higher the mass loss, the lower the Brinell hardness.

The thermal treatment was applied under comparatively mild conditions in comparison with to the well known thermal wood processes, such as: opened system, atmosphere pressure, low moisture content and fast heating. Recently, Okino *et al*. (2007) applied the same thermal treatment on UF-bonded OSB and JH values were also slightly lower, although not statistically. According to Del Menezzi (2004) the permanent mass loss for this process is less than 5%, and it is much lower than those observed in others processes, which can explain the results observed here.

On the other hand, according to Figure 2 the treatment seems to be suitable for OSB because of the improvement of both F⊥ and E//. However, these improvements were statistically significant only for the boards treated at 220°C, while at 190°C the values observed were similar to those of control boards. Some explanation of these results can be given.

It is well known that wood based particle/fibre products like OSB, PB and MDF have unequal distribution of density through the thickness: higher density on the surface, while on the core it is lower. This characteristic is called vertical density profile (VDP) and is generated during hot-pressing. As the surface layers are hotter than the core layer during the early stages of hot-pressing, it is compressed more intensively because of the stiffness loss of the wood matrix, while on the core it remains still stiffer and is compressed in this way later.

It can be said that the thermal treatment used here acted as a re-pressing stage and it could improve the density of the surface layers. The F⊥ test was carried out on nail driven through the sample from surface to surface, and in this way those higher density regions probably helped to retain the nail, improving their values. It can also be supposed that some core densification took place because of the improvement of E// values. Nevertheless, these suppositions cannot be used to explain the observed JH values as well.

Figure 3 presents the results of the dimensional stability properties. The results of the physical properties indicated that the method provided an improvement of the dimensional stability of the treated panel. It can be observed that WA and TS were positively affected by the thermal treatment and that the dimensional stability of the treated board could be achieved. However, the improvement of the dimensional stability was more evident in longer contact with water (24h). It seems that for shorter water exposure (2h) the thermal treatment was not effective in reducing WA. For longer water exposure (24h), WA could be reduced only when higher treatment temperature was used. On the other hand, for both 2h and 24h of water exposure the TS values were reduced even when a lower temperature was applied. The values of TS2h were reduced up to 51%, and for TS24h to 55%

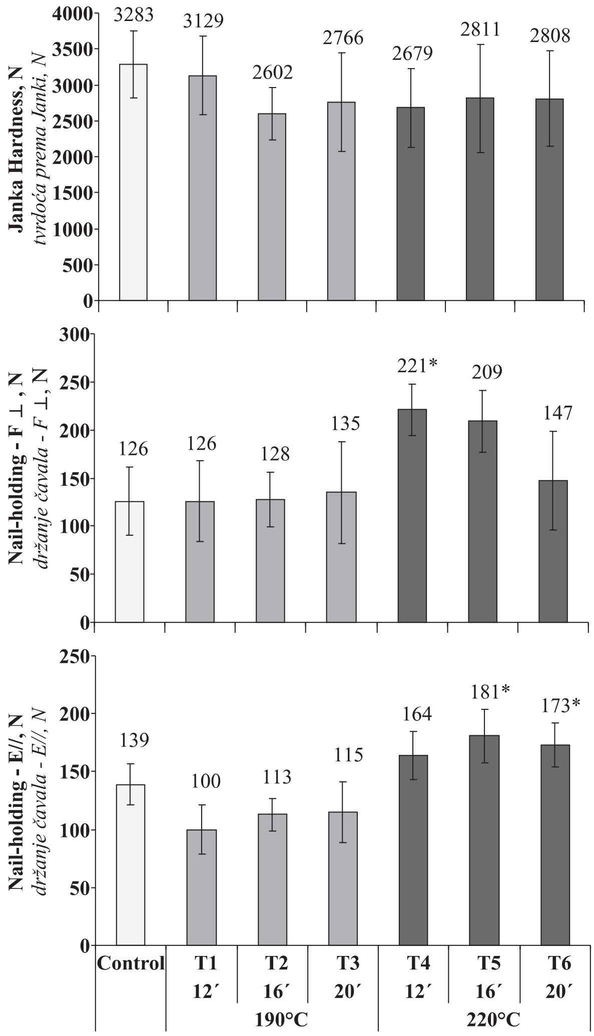

Figure 2 Janka hardness and nail-holding capability of control and thermally treated OSB (* statistically significant according to Dunnett at 5% probability)

Slika 2. Tvrdoća prema Janki i čvrstoća držanja čavala kontrolnih i toplinski obrađenih OSB ploča (* statistički signifikantno prema Dunnett testu na razini signifikantnosti 5%)

The results of surface roughness parameters are presented in Figure 4. The effect of the proposed thermal treatment was not as clear as for dimensional stability properties. Consequently, according to the Dunnett test only the treatments T2 and T4 were positively affected by the thermal treatment. For these groups the parameters R_a, R_q and R_z were reduced, which means an improvement of the surface quality. R_t was not affected by the thermal treatment.

3.2 Effect of temperature and time
3.2. Utjecaj temperature i vremena zagrijavanja

The results of factorial ANOVA are presented in Table 2. As expected, JH and WA-2h were not affected by the treatment, while F⊥, E//, WA-24h, TS-2h and TS-24h were. For the fastening properties, it can be said that only temperature affected the results and the higher it was, the higher were both nail-holding capacities.

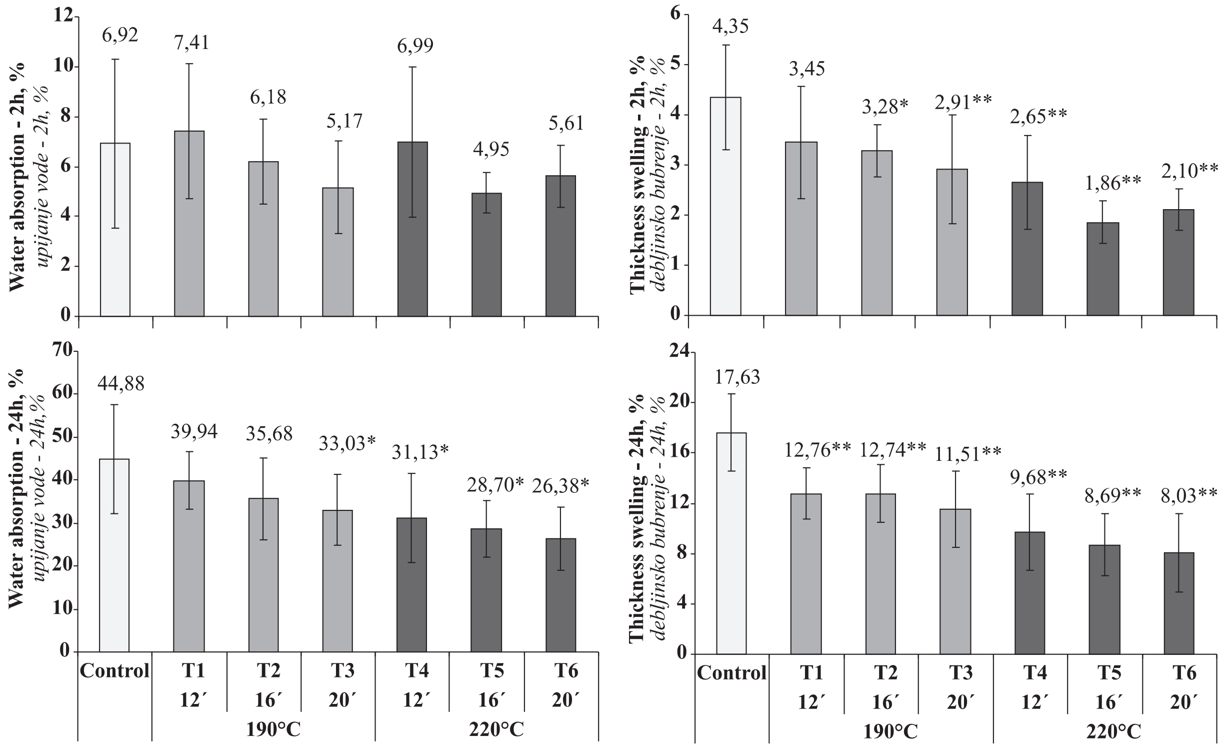

Figure 3 Dimensional stability of control and thermally treated OSB (**,* statistically significant according to Dunnett at 1% and 5% probability)

Slika 3. Dimenzijska stabilnost kontrolnih i toplinski obrađenih OSB ploča (**, * statistički signifikantno prema Dunnett testu na razini signifikantnosti 1 i 5%)

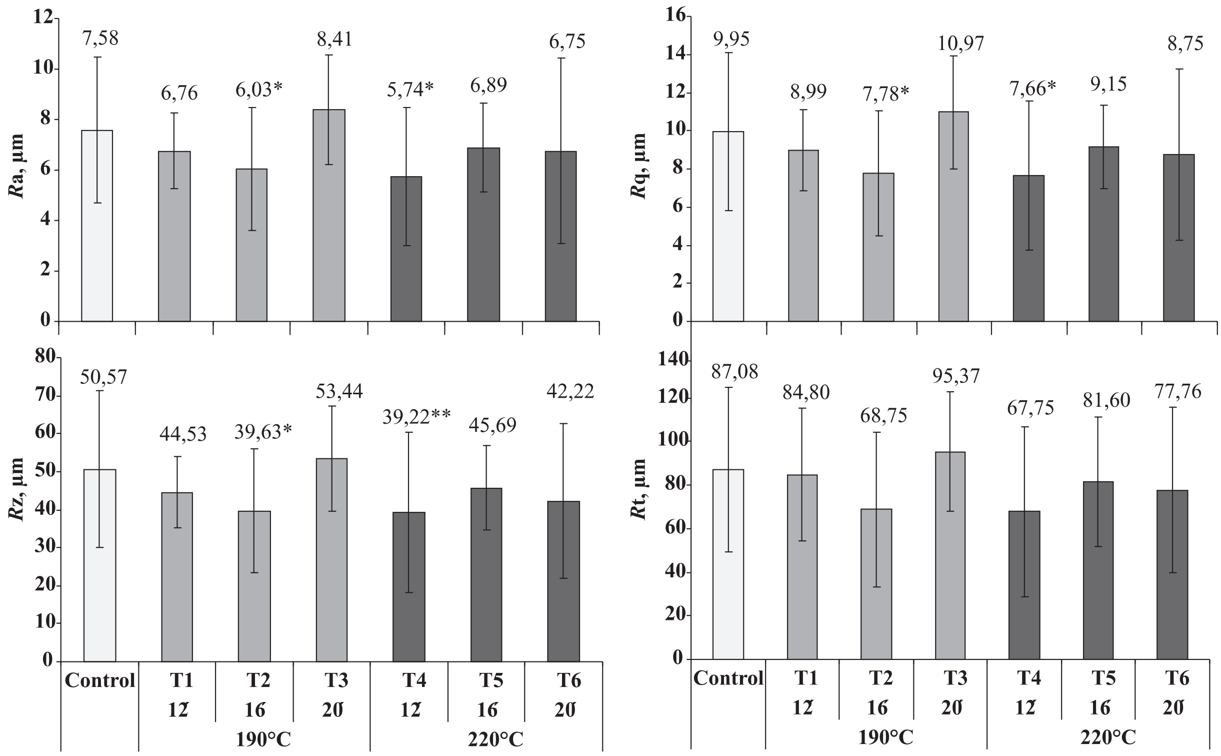

Figure 4 Surface roughness parameters of control and thermally treated OSB (**,* statistically significant according to Dunnett at 1% and 5% probability)

Slika 4. Parametri hrapavosti površine kontrolnih i toplinski obrađenih OSB ploča (**, * statistički signifikantno prema Dunnett testu na razini signifikantnosti 1 i 5%)

The dimensional stability properties were affected by treatment temperature, while TS-2h was also affected by treatment time.

Consequently, utilization of the higher temperature improved the dimensional stability of the OSB. For TS-2h the longer the treatment the lower the observed

Table 2. Summary of the factorial ANOVA analysis of variance for properties affected by thermal treatmen
Tablica 2. Sažeti podaci faktorske analize ANOVA varijanci za svojstva na koja utječe termička obrada

	Temperature – T_p *Temperatura*		**Time – T_m** *Vrijeme*		**T_p x T_m**	
Property *Svojstvo*	***F***	**Significant** *Signifikantno*	***F***	**Significant** *Signifikantno*	***F***	**Significant** *Signifikantno*
Janka hardness *Tvrdoća prema Janki*	0.054	0.817	0.742	0.480	2.169	0.123
Nail-holding - Face ⊥ *Držanje čavala – površina ploče ⊥*	5.091	0.028*	0.525	0.594	0.865	0.426
Nail-holding - Edge // *Držanje čavala – rub ploče //*	16.604	0.000**	0.353	0.704	0.042	0.959
Water absorption – 24h *Upijanje vode – 24h*	13.444	0.001**	3.295	0.043	0.183	0.834
Thickness swelling – 2h *Debljinsko bubrenje – 2h*	30.483	0.000**	5.728	0.005**	2.725	0.073
Thickness swelling – 24h *Debljinsko bubrenje – 24h*	28.188	0.000**	2.478	0.092	0.242	0.786
*R*a	11.958	0.007**	3.726	0.030*	3.077	0.053
*R*t	1.593	0.212	1.847	0.166	3.373	0.041*
*R*q	1.596	0.211	2.972	0.059	3.576	0.034*

***, * significant at the level α=0.01 and α=0.05*
***, * Signifikantno na razini signifikantnosti α=0,01 i α=0,05.*

value. In fact, for thermal treatments the temperature has been identified as a very important factor affecting the extent of changes in thermally treated wood (Del Menezzi 2004, Militz 2002, Syrjänen and Kangas 2000).

It is well-know that utilization of high temperature has a positive effect on dimensional stability and an adverse effect on mechanical strength. None of the evaluated mechanical properties were affected by time and this agrees with the study previously done by Del Menezzi (2004) who evaluated several mechanical properties of thermally treated OSB. It means that if even a shorter treatment were applied (12 min.) it would be already possible to improve these properties.

Within surface roughness properties only *R*a was affected by temperature and time of the treatment separately. In general, severe treatment (higher temperature) contributed to the improvement of the surface quality by reducing roughness. On the other hand, *R*t and *R*q were affected by the interaction between temperature and time of the thermal treatment. It means that the temperature effect depends on the time of the treatment. Figure 5 presents this behaviour. For *R*q parameter, at 190°C the longest treatment improved the quality of the surface, whereas at 220°C an opposite pattern was identified. However, the behaviour was not so clear for *R*t, but it might be concluded that at both temperatures the prolongation of the treatment had an adverse effect on the surface quality.

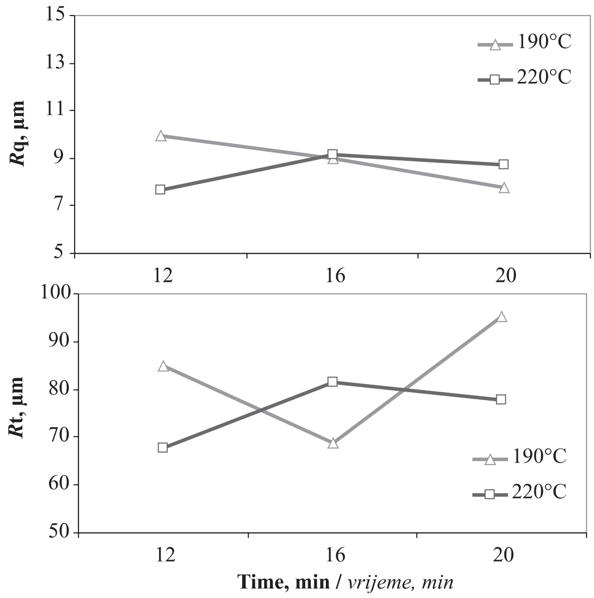

Figure 5 Combined effect of temperature and time of thermal treatment on *R*q and *R*t surface roughness parameters of OSB
Slika 5. Kombinirani učinak temperature i vremena zagrijavanja na parametre *R*q i *R*t hrapavosti površine OSB ploča

4 CONCLUSIONS
4. ZAKLJUČAK

Significant differences between treated and untreated boards for nail-holding, dimensional stability and surface roughness were identified. The temperature was the main factor governing these properties modifications while the duration of the treatment had less effect. It was concluded that the proposed thermal treatment improved significantly dimensional stability and did not affect adversely the nail-holding capability and surface roughness of the treated OSB, and could even improve it. The results for the nail-holding and surface hardness confirm those obtained for other previously investigated mechanical properties. Additional tests will be made to evaluate the effect of this thermal treatment on joints made with others fastenings.

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