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Contact thermal post-treatment of oriented strandboard to improve dimensional stability: A preliminary study

Abstract The oriented strandboard (OSB) has less dimensional stability than plywood, but they are competitive panels and have been used for similar ends. The wood-water relation variables, such as thickness swelling and water absorption, express this OSB dimensional instability and can be explained by two main factors: wood hygroscopicity and imposed hot-pressing stresses. The objective of this present paper was to propose a thermal post-treatment as a method to improve OSB dimensional stability by decreasing wood hygroscopicity and releasing hot-pressing stress. OSB panels from *Pinus taeda* wood were produced in laboratory, and their characteristics were: single layer, 0.8 g/cm^3; 8% phenolic resin and without wax. The OSB panels were treated in a laboratory press at 250 °C for about 4, 7 and 10 minutes. The wood-water relation variables, thickness swelling (TS), water absorption (WA), equilibrium moisture content (EMC) and springback or permanent thickness swelling (PTS) were determined and compared with untreated panels. The results showed that the proposed thermal treatment was effective to reduce TS, EMC and PTS, but didn't affect WA which was affected by panel density reduction. The longer the treatment the higher the dimensional stability, and panel weight loss could be used as predictive variable for the efficiency of the treatment.

Kontaktwärme-Nachbehandlung von OSB zur Verbesserung der Dimensionsstabilität: Voruntersuchung

Zusammenfassung OSB hat zwar eine geringere Dimensionsstabilität als Sperrholz, aber dennoch ist es für viele Verwendungen ein wettbewerbsfähiges Produkt. Parameter wie Dickenquellung und Wasseraufnahme verdeutlichen die Dimensionsstabilität von OSB. Diese lässt sich durch zwei Hauptfaktoren erklären: zum einen durch die Hygroskopizität von Holz und zum anderen durch die beim Heißpressen eingebrachten Spannungen. Ziel dieser Veröffentlichung ist es, eine Wärmenachbehandlung als ein Verfahren zur Verbesserung der Dimensionsstabilität von OSB vorzuschlagen, welche die Hygroskopizität des Holzes verringert und die Spannungen durch das Heißpressen abbaut. Labor-OSB-Platten aus *Pinus taeda* Holz wurden mit folgenden Eigenschaften hergestellt: einschichtig, 0, 8 g/cm^3; 8% Phenolharz, kein Wachs. Diese Platten wurden in einer Laborpresse bei 250 °C für ungefähr 4, 7 und 10 Minuten behandelt. Die Parameter Dickenquellung (TS), Wasseraufnahme (WA), Gleichgewichtsfeuchte (EMC) sowie reversible und irreversible Dickenquellung (PTS) wurden bestimmt und mit den Werten von unbehandelten Platten verglichen. Die Ergebnisse zeigten, dass mit der Wärmebehandlung zwar die Parameter TS, EMC und PTS verringert werden konnten, WA jedoch davon nicht beeinflusst wurde. Diese wird durch die abnehmende Rohdichte der Platte beeinflusst. Mit zunehmender Dauer der Wärmebehandlung verbesserte sich die Dimensionsstabilität. Der Masseverlust der Platten ist ein gutes Maß für die Wirksamkeit der Behandlung.

1 Introduction

In the countries where oriented strandboard (OSB) is manufactured it competes with plywood. This is due to technical, economical and environmental reasons. However, OSB has still not overcome its main limitation in comparison with plywood: its low dimensional stability. When OSB has contact with water it swells much more than plywood. There are two main factors for this excessive thickness swelling (TS): the inherent hygroscopicity of the wood and the stress imposed to the mattress of particles during hot pressing. Thus, when the panel has contact with water, the wood swells and stress is released, causing an increase in the thickness of the panel.

There are several treatments that impose transformation or alteration of the properties of solid wood. The main objective

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of this treatment is to improve wood dimensional stability. According to Rowell and Youngs (1981) and Stamm (1964) all the treatments can be divided into five different types: cross-laminating, coatings, reduction in hygroscopicity, bulking treatment and cross-linking. Thermal treatment is a kind of treatment that reduces the wood hygroscopicity, which means reduction in dimensional instability.

The application of heat to modify the wood characteristics has been used and the process is known as thermal rectification. It consists of thermal treatment of the wood at a temperature above 120 °C for periods of time that can vary from 30 minutes to 72 hours, depending on the process. Thermal rectification is being extensively studied according to works by Militz (2002), Welbacher and Rapp (2002), Pincelli (1999), Bourgois et al. (1989), Bourgois and Guyonnet (1988) and others. The thermal treatment is also recognized to improve wood decay resistance (Tjeerdsma et al. 1998). These studies involve methods considered severe to wood mechanical behavior that can be negatively influenced by about 10 to 40%.

Specifically for wood-based panels, there are several methods of treatment or strategies to improve dimensional stability which can be divided into three different means of application: pre-treatment, post-treatment and production technology. In the first group are the methods that involve treatments applied to furnish before panel hot-pressing, such as: particle pre-steaming (Sekino et al. 1999, Irle et al. 1998) and particle chemical modification. In the second group are the methods applied to the consolidated panel, and thermal treatment is the most usual (Suchsland and Xu 1991, Hsu et al. 1989). Finally, the production technology methods involve those that are related to improving resin content (Hashim et al. 2001), application of water repellents (Winistorfer et al. 1992), and mat-forming type (Avramidis and Smith 1989). However, for these kinds of methods and strategies, there are two common objectives: to reduce the wood hygroscopicity and to release compression stress.

This way, the present work aims to propose a thermal treatment, milder than those cited above, to improve the dimensional stability of OSB panels produced from *Pinus taeda* wood, and concomitantly to evaluate the effect of this treatment on the physical characteristics of the panels.

2 Material and method

2.1 Production of the panels

The single layer oriented strandboard (OSB) panels were produced with wood from *Pinus taeda* in the dimensions of 450 × 450 × 12.5 mm (w×l×t), with nominal density of 0.8 g/cm^3, 8% of phenolic resin, without wax. The hot pressing conditions were: 190 °C for 8 minutes with 60 s of press closing time, at 3.2 MPa. The boards were trimmed to 420 × 420 mm and were conditioned (20 °C, 65% humidity). After this, 20 samples were obtained according to ASTM D1037-96 for thickness swelling (TW) and water absorption tests (WA). However, with one modification: the samples dimension was 76 × 76 mm.

2.2 Time/temperature and treatment application

The thermal treatment consisted of heating the samples in a laboratory press to 250 °C for different time periods (4, 7 and 10 minutes). Each temperature-time combination was considered as a different treatment: T2, T3 and T4, respectively, with 5 replications for each one. Five samples remained untreated (T1) and they were the control samples. The applied pressure (0.17 kPa) was only to provide the contact between the sample's surface and the press plate. The moisture content (MC) of the samples at the treatment was admitted as being the same as of the untreated panel (T1).

2.3 Evaluation of the effects of the treatment

After the treatment, the samples were reconditioned (20 °C, 65% humidity). Then they were measured and weighed to determine the loss of weight (LW), the dimensional changes (width, thickness and volume) and the density (D). After that, the samples were tested for thickness swelling (TS) and water absorption (WA). The evaluations of TS and WA were made in 1/2, 1, 2, 18 and 24 hours. After the tests, the samples were again conditioned until reaching constant mass. The samples were measured again so that the permanent thickness swelling (PTS) could be calculated. PTS was the relationship among the sample's thickness before and after the TS/WA test. Finally, the samples were dried at 103 ± 2 °C to determine their moisture content which was considered as equilibrium moisture content (EMC).

The evaluated properties (TS, WA, D, PTS and EMC) were submitted to the analysis of variance (ANOVA) and, following it, Tukey's test at the level of 5% of probability was conducted to determine differences among the treatments. Pearson's correlation between some properties was calculated and regression models were obtained to evaluate the effect of the duration of treatment (T) on the TS, WA, PTS and EMC.

3 Results and discussions

3.1 Effect of the treatment on the physical characteristics of the panel

The thermal treatment provided a darkening of the surface of the panels that also reached the internal part, as it could be observed on the sides of the panels. Hsu et al. (1989), working with thermal treatment of panels, also made this verification. It is believed that the darkening, and consequent aesthetic change, doesn't cause great problems regarding the commercialization of the panels. The thermal treatment imposed loss of weight (LW) and reduction of the dimensions of the panels. The averages of the treatments are presented in Fig. 1. It is observed that the reduction was larger the longer the treatment duration was.

With the reduction of the thickness and of the width of the panels, a density increase was expected. However, with the increase of the duration of the treatment (T), the panel lost more mass, and at the end its density (D) was reduced. The reduction of density can mean reduction of the mechanical properties. A significant

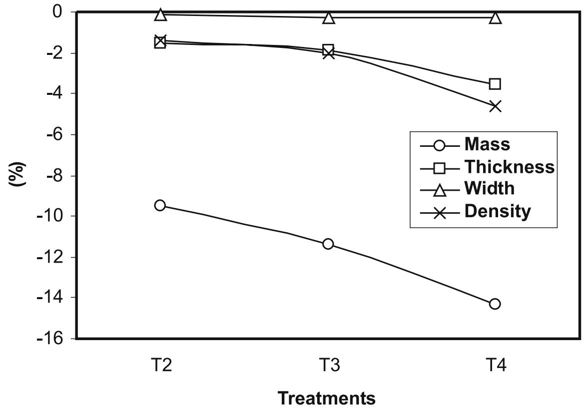

Fig. 1 Decrease values for physical characteristics of the treated panels (T2–T4)
Abb. 1 Veränderung der physikalischen Eigenschaften der Platten mit zunehmender Behandlungsdauer (T2–T4)

improvement of the quality of the panel's surface was also observed, although empirically. The surface changed from a thick to a smooth texture. The improvement of the surface is a great advantage and it indicates the possibility of using the panel as concrete mold, with fewer marks on the concrete.

3.2 Effect of the treatment on the dimensional stability

Figure 2 shows the results for TS and WA tests. It can be observed that the thermal treatment reduces TS of the treated panels in comparison with the untreated ones. The reduction is larger the longer the duration of the treatment was. The results show that TS for T4 treatment (10 minutes) was 50% smaller than the control boards (T1). The TS average in 24 hours was 14.7% for T4. This means that the panel meets the Canadian Standard (CSA) which determines a maximum value of 15%. For the analysis of Fig. 2, it is also clear that after a test of 30 minutes, the treatment shows almost the same value for TS. With the continuity of the TS test, T1 begins to distance from treated panels, until reaching the largest TS among all of the treatments at 24 hours. These TS values can be considered larger than those observed for OSB panels. The reason for this can be that the *Pinus taeda* wood has a low density (0.42 g/cm^3) compared with the target panel density of 0.80/cm^3 and this condition promotes a very high compaction ratio (1.9). Then, more compressive stress is present in the mat, and TS can be higher. However, this hypothesis has not been unanimous, as appointed by Kelly (1977).

For WA the behavior was very different from that observed for TS. It was observed that the shorter the treatment, the smaller the absorption of water. This way, by increasing the duration of the treament, the treated boards absorbed more water, and had inferior behavior than untreated boards. These results suggest that WA wasn't influenced by thermal treatment the same way as it was observed for TS. It could be evaluated that the panel density (D) was the main property affecting WA (Fig. 4).

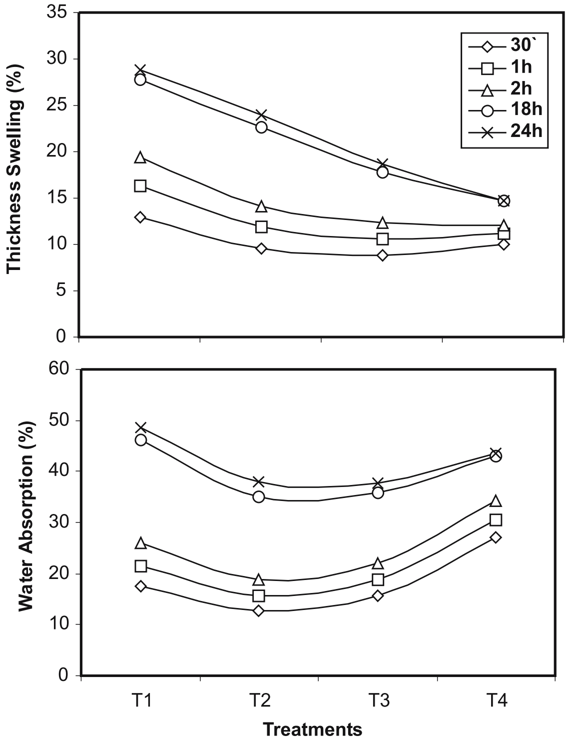

Fig. 2 Thickness swelling and water absorption of the untreated (T1) and the treated panels (T2-T4)
Abb. 2 Dickenquellung und Wasseraufnahme der unbehandelten (T1) und der behandelten (T2) Platten (T2–T4)

It is believed that TS reduction was due to the compression stress realease and because the thermal treatment changed the panel's hygroscopicity. When the wood is heated above a certain temperature the polymers, mainly lignin, reduce the stiffness, and the compression stress can be released and rearranged to a new level at the mattress while the heating treatment is applied. This temperature is known as viscoelasticity transition temperature (Tg) and is influenced by many factors (moisture content, chemical composition), and can range from 90 to 170 °C. The duration of the treatment had great influence on this reduction, as can be seen from the following.

During the thermal treatment, the water loss of the panel is very quick and it can implicate the occurrence of fissures in the particles that also help to release compression stress. Lu and Pizzi (1998) observed improvement in some UF-particleboards properties, included TS, when these panels were postcured at a temperature lower than pressing temperature and for a short time. The authors explain this by molecular level rearrangements of the cured adhesive network observed in the modern, lower formaldeyde content of UF adhesives. This important appointment changed the older one, where higher formaldeyde content of UF adhesives are less resistant to degradation by heat. In a similar way, Ohlmeyer and Kruse (1999) observed a reduction of the TS for the PF and UF-particleboard after hot-stacking. The authors argued about the adhesive post-curing that improves internal bonding and consequently reduces TS.

Hsu et al. (1989) got reduction of TS of up to 67% depending on the thickness of the panel. The authors applied the thermal treatment (240 °C; 2 to 10 minutes) 5 minutes after panel hot-pressing. Although they do not present the data, considering the present author's practical experience, it can be supposed that the panels are still hot. Thus, it can be supposed that the application of the thermal treatment in panels that are still hot propitiates an improvement in the dimensional stability. In other words, the thermal treatment is more effective, mainly regarding transfer and distribution of the heat in the internal areas of the panel.

After the tests, if the panel is reconditioned in the same environmental conditions as before the test, the panel tends to return to the original thickness. However, this return is not alone due to the wood contraction. The compression stress is released during the test and the thickness of the panel does not return when it is reconditioned. Consequently, the panel tends to remain permanently thicker than before the test. This characteristic is the springback or permanent thickness swelling (PTS) and the more intense its values, the higher the compression stress imposed during hot pressing.

Figure 3 shows the PTS values for the treatments. It can be observed that the thermal treatment reduced PTS meaning that the compression stress was reduced. The reduction was larger the longer the treatment. PTS also expressed a definitive increase in the panel thickness. This effect is very important because it means more panel integrity, which is very usefull for several panel end-uses. Additionally, if the PTS is smaller for treated panels, their density remains more constant or closer to the density before the test. Great PTS involves a bigger panel volume, which reduces the panel density, and consequently the mechanical properties.

Figure 3 shows EMC of the untreated and treated panels and it is evident that the thermal treatment reduced the hygroscopicity of the treated panels. This reduction is very advantageous and it means that the panels are more stable in environmental variations. The reduction of EMC happens because of the hemicelluloses, the more hygroscopic polymer of the cell wall and also the most heat sensitive between the wood components (Rowell and Youngs 1981). Besides, at the temperature of the treatment (250 °C), the hemicelluloses degradation has already started, while the other polymers remain practically intact. The degree of degradation of the polymers can be determined by loss of weight (LW). Thus, the bigger the LW, the larger the amount of polymers removed and consequently the treated panel became less hygroscopic. Del Menezzi (2004) observed that the total amount of hemicelluloses was reduced by about 20% for the OSB panels treated at 220 °C for 20 minutes. The amount of arabinose and galactose was completly eliminated from the samples when these were evaluated using high performance liquid chromotography (HPLC) analysis.

Figure 2 shows the WA for the panels for the different treatments. It is observed that the increase of the time of treatment provides increase of WA. Therefore, the thermal treatment reduced TS and it increased WA. However, a direct relationship exists between WA and TS, in other words, with increasing WA, TS increases also. The presented results are conflicting. However, the WA is a phenomenon also strongly influenced by the specific mass. With smaller specific mass there are more empty spaces, and, consequently, the absorption of water is larger (Kelly 1977). As can be observed in Fig. 1, the thermal treatment provided a reduction of the panel density. Thus, the treated panels became more porous, allowing the easiest water penetration and increasing WA. The relationship between WA and panel density (D) was very close, as can been seen in Fig. 4.

Table 1 shows the analysis of variance (ANOVA) and the result of the Tukey's Test for the mean comparison between treated (T1) and untreated panels (T2-T4). It is evident that the thermal treatment reduces TS of the panels significantly within 1 hour of test. However, no significant difference was detected for WA in any of the evaluated test durations. It is observed that statistical equality was detected between T3 and T4 for TS during the entire duration of immersion. This suggests that the reduction of the duration of the treatment from 10 (T4) to 7 minutes (T3) would result in the same TS. However, TS can meet OSB norm only for T4, which establishes 15% as maximum TS in 24 hours.

These results indicate that the duration of the treatment has a strong influence on the properties evaluated (TS, EMC, PTS and LW). This way, Pearson's correlation (r) among these properties was calculated. This correlation indicates the linearity

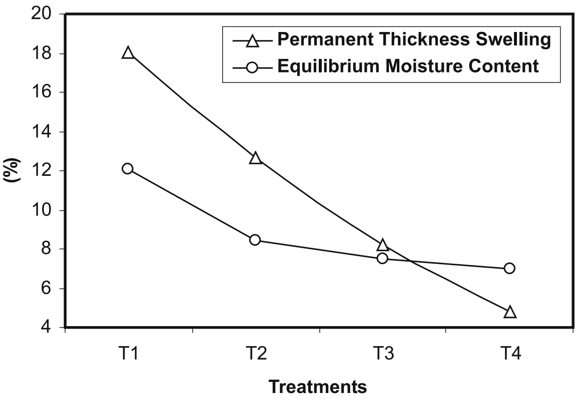

Fig. 3 Permanent thickness swelling and equilibrium moisture content of the untreated (T1) and the treated panels (T2–T4)

Abb. 3 Permanente Dickenquellung und Gleichgewichtsfeuchte der unbehandelten (T1) und behandelten (T2–T4) Platten

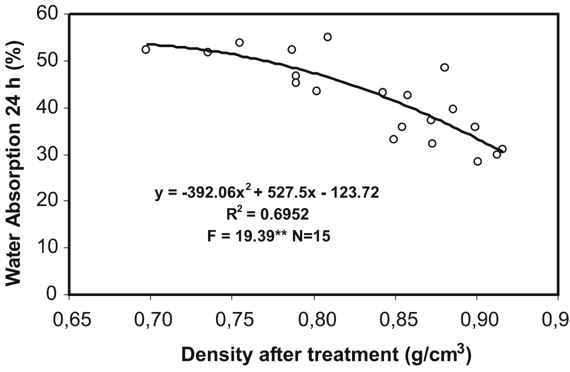

Fig. 4 Relationship between water absorption and density of the treated panels (T2–T4)

Abb. 4 Verhältnis zwischen Wasseraufnahme und Dichte der behandelten Platten (T2–T4)

Table 1 Summary of the analysis of variance of the treatments
Tabelle 1 Ergebnis der Varianzanalyse der Behandlungen

Property	F	Significant	Tukey Test T1	T2	T3	T4
D	0.54	0.663 ns	–	–	–	–
PTS	11.91	0.000 **	a	ab	bc	c
EMC	26.76	0.000 **	a	b	bc	c
TS30	2.97	0.063 ns	–	–	–	–
TS1h	3.99	0.027 *	a	ab	b	b
TS2h	5.00	0.012 *	a	ab	b	b
TS18h	8.71	0.001 **	a	ab	bc	c
TS24h	9.31	0.001 **	a	ab	bc	c
WA30	2.84	0.071 ns	–	–	–	–
WA1h	2.78	0.075 ns	–	–	–	–
WA2h	2.70	0.070 ns	–	–	–	–
WA18h	2.16	0.133 ns	–	–	–	–
WA24h	2.11	0.139 ns	–	–	–	–

*, ** significant at the level of $\alpha = 0.05$ and 0.01 respectively; ns: not significant; different letter in the same line involves that means are different; D: density; PTS: permanent thickness swelling; EMC: equilibrium moisture content; TS30, TS1, TS2, TS18, TS24, WA30, WA1, WA2, WA18 and WA24: thickness swelling and water absorption after 30 minutes, 1, 2, 18 and 24 hours.

degree among two variables, and the results are presented in Table 2.

The number of observations was for all the variables the same (20), apart from LW which was 15, because LW expressed the mass loss in function of the treatment and for T1 no mass loss occurred. It can be observed that LW is an excellent variable to estimate the direct effect of the treatment. In Table 2, it can be observed that there is a strong relationship among the time of treatment and the analyzed variables, with the exception of WA. However, the occurrence of a high correlation among two variables doesn't mean that the linear model is the better one. Therefore, regression models with the time of treatment as an independent variable were estimated.

The choice of the best model was made according to the largest R^2. In the hypothesis of very close R^2, the model that presented the largest calculated F, was chosen, which means larger significance level. Figure 5 presents the best models for the

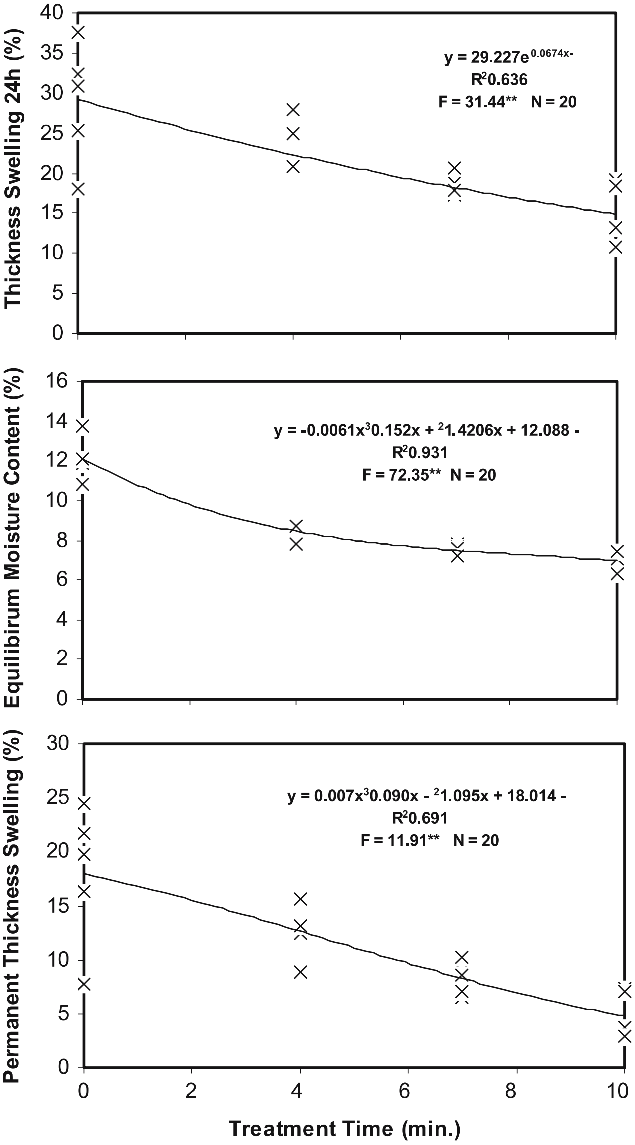

Fig. 5 Relationship between the treatment time and some properties analyzed
Abb. 5 Verhältnis zwischen der Behandlungsdauer und einigen untersuchten Eigenschaften

Table 2 Pearson's correlation (r) between properties affected by the thermal treatment and time of treatment
Tabelle 2 Korrelationskoeffizienten nach Pearson zwischen den von Wärmebehandlung beeinflussten Platteneigenschaften und der Behandlungsdauer

Property	D	Time	LW	EMC	PTS	TS2	T24	WA2	WA24
D	–								
Time	–0.248								
LW	–0.594*	0.881**	–						
EMC	–0.096	–0.878**	–0.713**	–					
PTS	0.374	–0.863**	–0.874**	0.763**	–				
TS2	0.063	–0.408	–0.402	0.509	0.664**	–			
TS24	0.481	–0.820**	–0.885**	0.695**	0.970**	0.726**	–		
WA2	–0.882**	0.588*	0.834**	–0.282	–0.596*	–0.077	–0.642**	–	
WA24	–0.912**	0.307	0.621*	0.013	–0.276	0.182	0.359	0.924**	–

*, ** significant at the level $\alpha = 0.05$ and 0.01. D: density; Time: duration of the treatment; LW: loss of weight; EMC: equilibrium moisture content; PTS: permanent thickness swelling; TS2, TS24, WA2, WA24: thickness swelling and water absorption after 2 and 24 hours

tested variables. For TS and LW, the best model was the exponential, while for PTS and EMC it was the cubic. This way, although linearity exists among the analyzed variables, as seen in Table 2, the linear model was not the best one to explain the effect of the duration of the treatment.

4 Conclusions

The proposed thermal treatment, milder than those known, reduced the thickness swelling (TS), the equilibrium moisture content (EMC) and the permanent thickness swelling (PTS) of *Pinus taeda* oriented strandboard. The longer the treatment the higher this reduction. It was observed that the treatment releases compression stress imposed during hot-pressing. Water absorption and density were not directly influenced by the treatment, but it had been reduced with the increase of the duration of the treatment. The weight loss is an excellent variable to evaluate the efficiency of the treatment, and it was inversely proportional to the TS, EMC and PTS.

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