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HYGROSCOPIC PROPERTIES OF THERMALLY POST-TREATED OSB

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Abstract:

OSB (oriented strandboards) made from Scots pine (Pinus sylvestris) were thermally post-treated at three different maximum treatment temperatures in the laboratory thermal treatment chamber of the Institute for Wood Technology Dresden (IHD). The OSB were supplied by a European manufacturer of OSB and bonded with methylene diphenyl diisocyanate (MDI).

Post-treatment means that rather than thermally treating wood or strands before panel production, cut industry panels, i. e. 650mmx1200mm, were modified in IHD's lab kiln.

The main goals of the thermal post-treatment of full-sized OSB were to improve the hygroscopic properties, i. e. to reduce the thickness swell (TS) and the equilibrium moisture content (EMC), as well as to improve the long-term properties creep behaviour and dimensional stability, without significantly reducing further mechanical properties like e. g. internal bond (IB) or bending properties, however.

It was observed that the thermal post-treatment of the aforementioned OSB had a very positive effect on the moisture-related properties TS and EMC. The modified OSB showed far better values for said properties than the respective untreated ones.

In can be concluded, that the thermal modification of OSB panels is possible and leads to very positive effects regarding their hygroscopic properties.

Key words: *MDI; OSB; Scots pine; thermal post-treatment; thickness swell.*

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INTRODUCTION

The thermal treatment of solid wood has been intensively investigated in the last decade (e. g. Andersons *et al*. 2007, González-Peña *et al*. 2009a & 2009b, Gunduz *et al*. 2010, Sernek *et al*. 2010, Yilgör *et al*. 2010). It is established that thermal treatment improves the moisture-related properties thickness swell (TS) and equilibrium moisture content (EMC) and also the biological durability (Plaschkies et al. 2010). Moreover, internal stresses are reduced (Bächle *et al*. 2007). Disadvantages of thermal treatment are, among others, impaired mechanical properties and increased brittleness (Grossmann 2002).

Furthermore, previous studies by Bonigut and Stephani (2009) and Bonigut *et al*. (2012) have shown that the thermal post-treatment of phenol-formaldehyde (PF) - bonded OSB and MDF (medium density fibreboards) positively influences the hygroscopic properties of said wood-based materials. However, the influence of thermal treatment on wood-based composites is still not yet fully understood (Del Menezzi *et al*. 2006, Ayrilmis *et al*. 2009), whilst Paul and Ohlmeyer (2005) showed, that the thermal treatment of particles and the subsequent production of particleboards with the use of said treated particles resulted in good technological panel properties with an improved thickness swelling and sorption behaviour as well as suitable internal bond strength.

The goal of this work was to investigate whether the hygroscopic properties, i. e. TS and EMC of MDI-bonded OSB could be improved without at the same time significantly reducing further mechanical properties like e. g. IB or bending properties, however.

MATERIAL AND METHODS

Oriented strandboards

MDI-bonded OSB from a European industrial manufacturer made from Scots pine (Pinus sylvestris) as raw material for the OSB production were sourced (type OSB/3). The OSB were three-layered and the MDI content was 4.5% in the outer layers and 5% in the middle layer, with reference to bone-dry strands. The hydrophobing agent was paraffin-based, whilst its amount was 1.5% (solids, with reference to bone-dry strands).

Thermal treatment

The thermal treatment took place in IHD's laboratory 1m^3 thermal treatment chamber (see Fig. 1) according to industrial settings with the following parameters. Heating and cooling down speed, respectively: 0,33Kmin^{-1}, holding time at temperature maximum: 4h, temperature maxima: 160°C (total time 20h), 175°C (total time 21.5h) and 190°C (total time 23h). Whilst water vapour was introduced into the process, the treatment took place at ambient pressure and atmosphere.

Fig. 1
IHD's 1m^3 laboratory thermal treatment chamber.

The thermally treated panels turned darker – as well known from thermally modified timber (TMT, Klement *et al*. 2009) – than the untreated ones and the colouration was equally distributed over the material cross section (see Fig. 2).

Fig. 2
Cross sections of thermally post-treated (top) and untreated (bottom) OSB.

Testing of the short-term properties

The testing of the short-term properties of the treated and untreated OSB followed the thermal treatment. The necessary test specimens were cut from the treated panels and stored in a climate of 20°C/65% RH until they reached moisture equilibrium and then were tested according to the European standards listed in Table 1 afterwards.

Table 1
Conducted tests for determination of short-term properties of thermally post-treated and untreated OSB

Test	**Unit**	**Standard**	**No of specimens *n***
Density	kg/m3	EN 323	15
Panel thickness dry and after 2 h boiling	mm	EN 324	15
IB (dry)	N/mm²	EN 319	15
IB (after 2h boiling)	N/mm²	EN 319, EN 300	15
Modulus of rupture MOR	N/mm²	EN 310	12
Modulus of elasticity MOE	N/mm²	EN 310	12
Thickness swell after 24h	%	EN 317	21
EMC	%	EN 322	15

Testing of the long-term properties

The European prestandard ENV 1156 constitutes a procedure to determine the creep value with a four-point bending set-up with constant load in a steady climate. The creep specimens then were loaded with a force equal to 25% of their respective mean F_{max} values. In this work, the testing of the creep behaviour took place in a climate of 20°C/85% RH, in order to evaluate the behaviour of thermally post-treated OSB with regard to potential uses in exterior applications in environments with high humidity, for a period of 105 days.

The dimensional stability describes the distortion of a flat-shaped material due to its hygroscopic changes when both its surfaces are simultaneously exposed to two different climates. The testing of the dimensional stability took seven days according to an internal IHD standard, the edges of the OSB panels were sealed. The test specimens were floatingly positioned into a separation wall between the two climates of 20°C/35% RH and 20°C/85% (see Fig. 3). The test results were calculated from six measurement points and extrapolated to 1m in diagonal panel direction.

Fig. 3
Set-up for testing dimensional stability; left: test specimens positioned in separation wall between 20°C/35% RH and 20°C/85% RH; right: measuring equipment to determine potential warping / cupping.

RESULTS AND DISCUSSION

Thickness

While the thickness (dry) of the industrial OSB made from Scots pine does hardly change, the thickness values after 2h boiling look quite different (see Fig. 4). The thickness of the untreated variant increases dramatically, whilst the treated variants remain at a low level.

As is the case for solid wood, it is assumed that the treatment temperatures destroy the points of the wood, where water can adsorb, i. e. the OH-groups of mainly the hemicelluloses, and thus less swelling occurs.

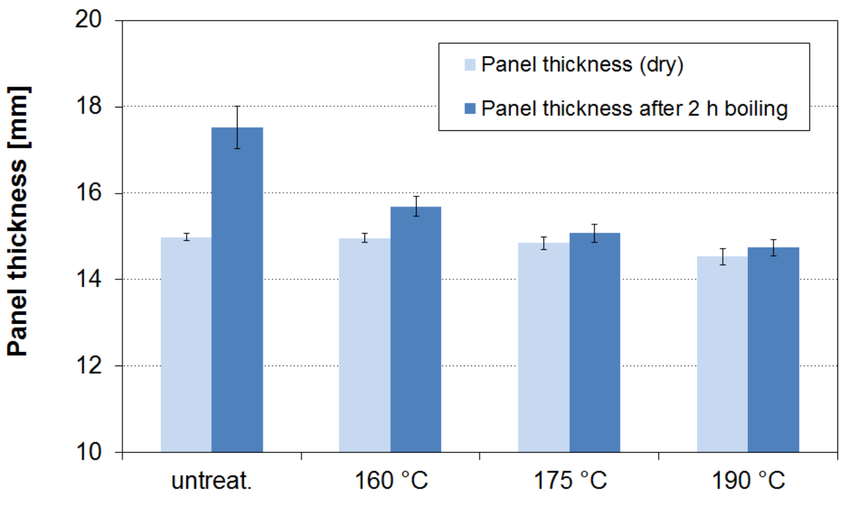

Fig. 4
Panel thickness of industrial Scots pine OSB versus thermal modification temperature in comparison to an untreated variant.

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Internal bond (IB)

For the IB (dry) of the industrial OSB made from Scots pine, the untreated variant exhibited the highest value, while the variants treated at 160°C and 175°C were on about the same level and the values of the variant treated at 190°C decreased significantly (see Fig. 5).

For the IB after 2h boiling the untreated variant and the ones treated at 160°C and 175°C showed about the same level, while the variant treated at 190°C decreased only slightly.

Since the testing of IB generally is a sign of the quality of the adhesive bond, a damage of the MDI due to the high temperatures during the thermal post-treatment must be assumed. The only slight decrease of the values after 2h boiling can be explained with the destruction of the hemicelluloses during the temperature treatment and the material's subsequent inability to adsorb water and thus less swelling potential. This means there are two overlapping phenomenons at work: while for the treated variants the MDI has been damaged during the thermal treatment, the large swelling of the strands of the untreated variant is responsible for damaging the adhesive bonds between the strands. At the same time the strands of the treated variants do not swell nearly as much (see Fig. 4).

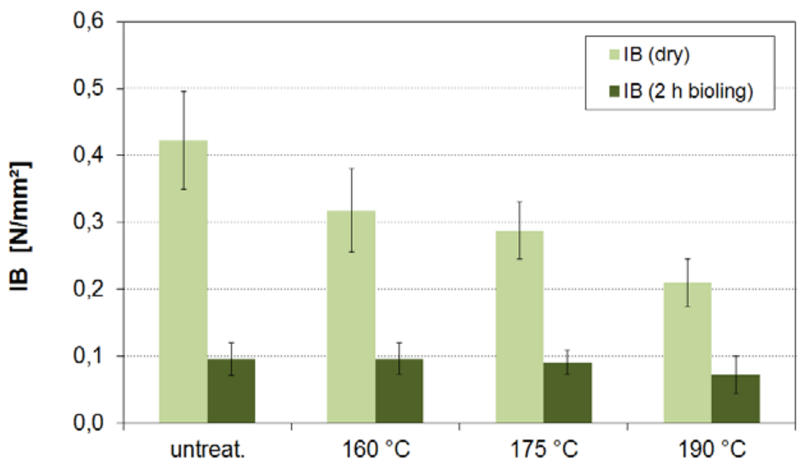

Fig. 5
IB of industrial Scots pine OSB versus thermal modification temperature in comparison to an untreated variant.

MOR / MOE

Since the investigated industrial OSB were three layered, with the orientation of the middle layer being perpendicular to the outer layers, the bending properties have to be looked at in the direction of production (major axis) and perpendicular to the direction of production (minor axis). For the purposes of this work, MOR and MOE have only been tested in the direction of the major axis.

The testing of the MOR and MOE resulted in smaller values the higher the treatment temperature, whilst the MOE decreased just little (see Fig. 6). Bekhta *et al*. (2003) also found a decrease in MOR for OSB at treatment temperatures of 140°C. Sinha *et al*. (2011) explained this reduction of MOR with the fact that OSB is a composite material that contains strands and an adhesive. Even if the wood does not deteriorate at temperatures of ≥100°C, the adhesives used in OSB production might deteriorate which would in turn cause a degradation in the strength of the composite.

As Scheiding and Gecks (2009) explained, the MOE of thermally treated solid wood rises in most cases, due to the reduction of the EMC (see Fig. 8) and the decrease of the hemicellulose content. In this case the MOE does not rise, but at the same time it does not decrease at the same rate as the MOR does.

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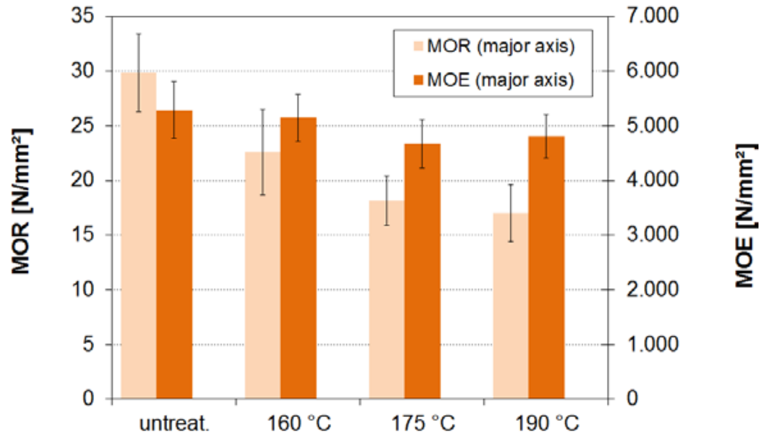

Fig. 6
MOR and MOE (major axis) of industrial Scots pine OSB versus thermal modification temperature in comparison to an untreated variant.

Thickness swell and EMC

The largest improvements due to the thermal post-treatment of the industrial Scots pine OSB were achieved for thickness swelling and EMC. For the thickness swelling, the untreated variant exhibited far higher values than the thermally treated ones.

The dramatic decrease in thickness swelling is due to changes in the chemical composition of the strands, more precisely of the cell wall. As mentioned before, the hemicelluloses (starting from 140…150°C) and the cellulose (starting from 150°C) degrade. Furthermore the lignin is also degraded and partially restructured, which leads to an increase in the relative lignin share, whilst volatile accessories (e. g. resins) are expelled (Scheiding 2012). The most significant effect is the clear reduction in the number of OH-groups and the thereby connected inability of the wood particles to adsorb water and thus swell.

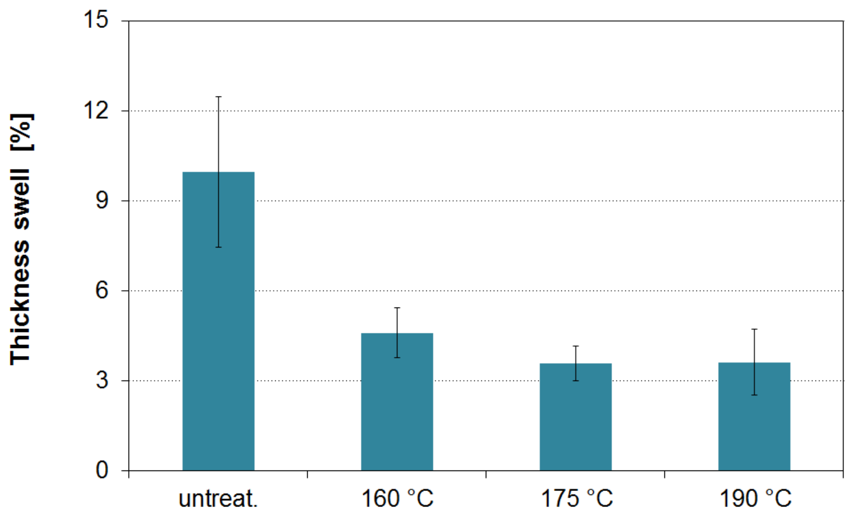

Fig. 7
Thickness swell of industrial Scots pine OSB versus thermal modification temperature in comparison to an untreated variant.

The EMC was reduced by about 35% from the untreated variant to the one treated at 190°C (see Fig. 8). Before determining the EMC, the test specimens were climatised to constant mass in a standard climate of 20°C/65% RH.

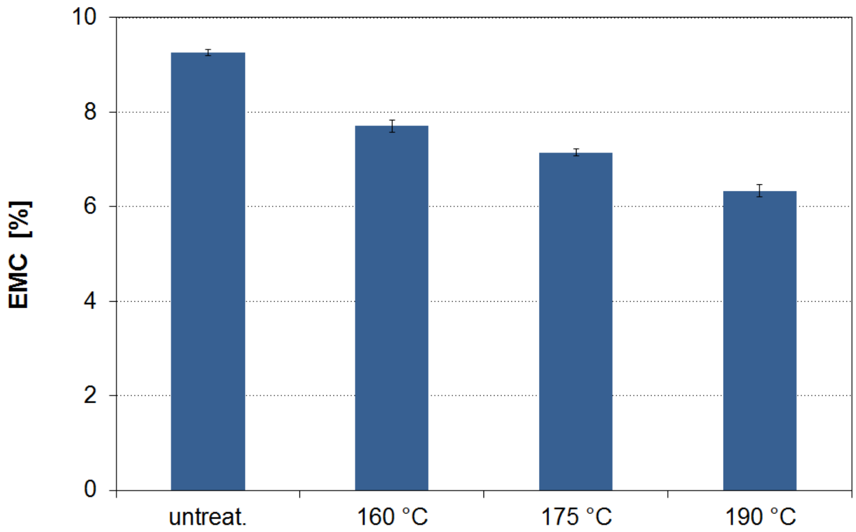

Fig. 8
EMC of industrial Scots pine OSB versus thermal modification temperature in comparison to an untreated variant.

Creep behaviour

The creep behaviour tests in accordance with ENV 1156 show that the creep values of the thermally post-treated MDI-bonded Scots pine OSB are essentially improved. The OSB treated at the highest temperature (190 °C) has the best (i. e. lowest) creep behaviour (see Fig. 9).

Since the creep value describes the time-dependent increase of deflection under load in relation to the initial elastic deflection, the value thus changes in dependency of the time under load, the stress level (usually 25% of F_{max}) and the ambient climate, i. e. the materials moisture content. Since the moisture content of the thermally treated variants is lower compared to the untreated variant (see Fig. 8) the thermally modified variants exhibit smaller, i. e. better, creep values.

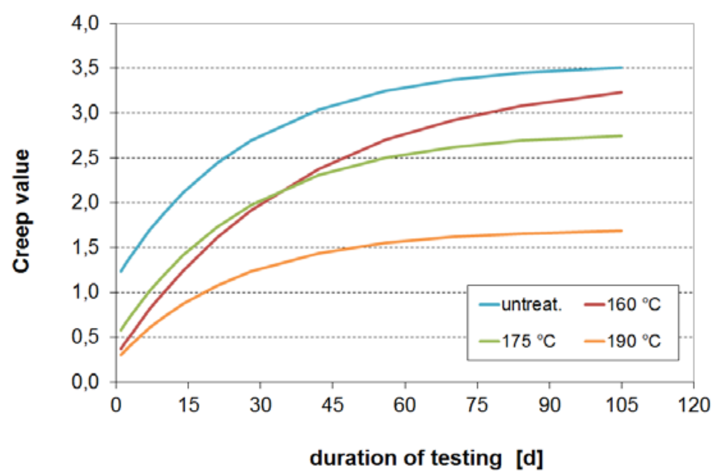

Fig. 9
Creep values of industrial Scots pine OSB versus time under load and thermal modification temperature in comparison to an untreated variant (test climate: 20 °C / 85 % RH).

Dimensional stability

Much the same as for creep goes for dimensional stability. The warping and cupping is due to changing moisture gradients in the material, which is sandwiched between a dry (20°C/35% RH) and a moist (20°C/85%

RH) climate. However, since the thermally treated variants have a much smaller capacity to shrink and swell due to the aforementioned thermal destruction of hemicelluloses and celluloses, the dimensional changes are also smaller (see Fig. 10).

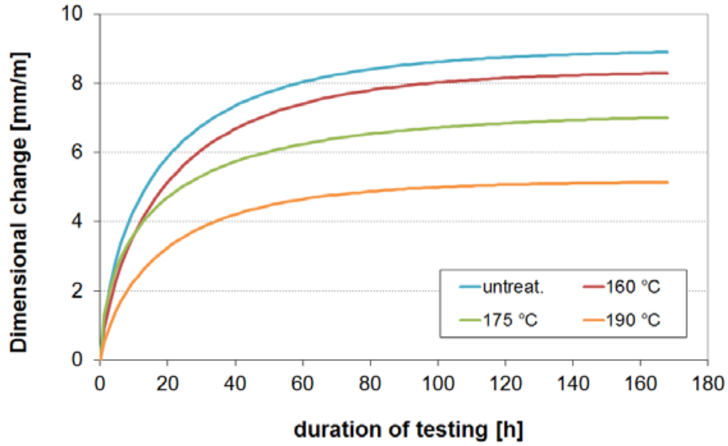

Fig. 10

Dimensional stability of industrial Scots pine OSB versus time under load and thermal modification temperature in comparison to an untreated variant (test climate: chamber 1 20°C/35% RH, chamber 2 20°C/85% RH).

CONCLUSIONS

With the presented method of thermally post-treating MDI-bonded Scots pine OSB it is possible to improve moisture related short-term as well as long-term properties of heat-treated variants in comparison to untreated ones. Especially thickness swelling was about halved, whilst the EMC was also steadily lowered with increasing maximum treatment temperature. Another positive effect concerning short-term properties was the decrease of the panel thickness after 2 h boiling. Regarding the long-term properties creep behaviour and dimensional stability it is apparent that in both cases the untreated variant showed the highest (i. e. worst) results compared to the post-treated ones.

However, while the IB after 2 h boiling did not change much, the dry IB results as well as the MOR showed an almost linear decrease with increasing treatment temperature. Thus further research is needed to e. g. establish thermal treatment regimes in order slow down or even prevent the decrease of properties like IB (dry) and MOR, respectively, since the goal of this research work was to investigate whether the hygroscopic properties could be improved without at the same time significantly reducing further mechanical properties like aforementioned properties.

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