TanWood®: The Brazilian Process of Thermal Modification of Wood

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ABSTRACT

Thermal modification of wood has been scientifically studied for almost one century, although it was industrially consolidated in Europe only on the 1990's, where can be found in operation the most important industrial processes of the world, such as the Finnish ThermoWood® and the Dutch Plato®. The Brazilian company *TWBrazil* started its own research on thermal modification in 2006 and patented a process named TanWood®. The aim of this work was to describe the Brazilian process of thermal modification TanWood® and provide a general comparison to the European ones based on the bibliographic information. TanWood® is a hygrothermal process of thermal modification, which uses saturated steam as heating medium in a pressurized/closed system. TanWood® is similar to the European processes FirmoLin, Moldrup-SSP and WTT ThermoTreat 2.0. For a better comparison between the processes, it would be necessary more detailed information about the European ones, such as the heating system of the equipment used and the processing schedules. More research and development are required for the Brazilian process of thermal modification, in order to improve the equipment and the process, as well as to assess its impacts on the properties of the thermally modified wood.

INTRODUCTION

The Brazilian company *TWBrazil* (Treated Wood Brazil) is located in Ponta Grossa city, Paraná state, Southern Region. It works in the market of wood preservation with waterborne preservatives (eucalypt and pine), wood drying, wood frame, prefabricated wooden structures, fences, and decks.

In 2006, the company started its researches and development about the process of thermal modification of wood, resulting in the Brazilian process TanWood® (former VAPHolzSysteme®) and adopting the name *Thermally Modified Timber* or *TMT* to the products.

Regarding TMT, the company commercializes nowadays mostly teak (*Tectona grandis* L.f). as decks, table tops, garden furniture, wall coverings, and carpets. But tests with other species were already carried out, such as pine, eucalypt and even bamboo culms. The company also produces and commercializes the equipment which does the process.

Nowadays, the process is a reality, and at least six academic studies were carried out about the process (Batista 2012, Bellon 2013, Brito 2017, Griebeler 2013, Lengowski 2011, Menezes 2017).

Literature highlights important considerations about processes comparison (Hill 2006, Homan *et al.* 2000). For example, although thermal modification processes give the same qualitative effects on wood properties (hygroscopicity reduction, increased

dimensional stability, and biological resistance), the quantitative effects and the chemical nature of the modifications can be considerably different.
The aim of this work was to describe the Brazilian process of thermal modification of wood TanWood® and provide a general comparison to the European ones based on the bibliographic information.

MATERIAL AND METHODS

The Equipment used in the **TanWood®** *process*

The equipment is constituted basically by i) a steel cylinder/autoclave (pressure vessel) of 125 cm diameter, 850 cm length, with nominal capacity for six cubic meters of wood; ii) an instant steam generator (boiler) class B, with production capacity of 216 kgv.h^{-1}; iii) a water tank; iv) a programmable logic controller (PLC), which controls the variables of the process variables and; v) trails and trams for loading and unloading wood. In a general view, the equipment is similar to those used for wood preservation with waterborne products (Figure 1).

Figure 1: Equipment used in the* TanWood® *process of thermal modification of wood.

Description of the **TanWood®** *process*

Primarily, air-dried or kiln-dried lumber (approximately 15% moisture content) is stacked with stickers of 10 by 30 mm of cross-section and variable length (depending on the position in height) between the layers, and the stack gets the same shape as the cylinder. Stickering permits the steam to flow homogeneously through the lumber inside the cylinder. Figure 2 presents a charge of stacked wood ready to be loaded on a regular business day at the company.

Figure 2: Example of wood being loaded into the equipment.

Figure 3: Color patterns according to the common temperatures used in the* TanWood® *process. From left to right: untreated, 140 °C, 160 °C, and 180 °C Eucalyptus grandis

The final cycle temperatures normally achieved by the TanWood® process vary between 140 °C and 180 °C, but tests were already carried out up to 220 °C. Figure 3 presents the different colors of thermally modified fast-grown *Eucalyptus grandis* juvenile wood. TanWood® is divided into five phases and the duration is approximately eight hours with some more eight hours of cooling. A diagram of a theoretical program, with final cycle temperature of 160 °C, is presented in Figure 4, but the pressure is not shown and can achieve from 0.3 to 1.0 MPa in phase four, according to the final temperature.

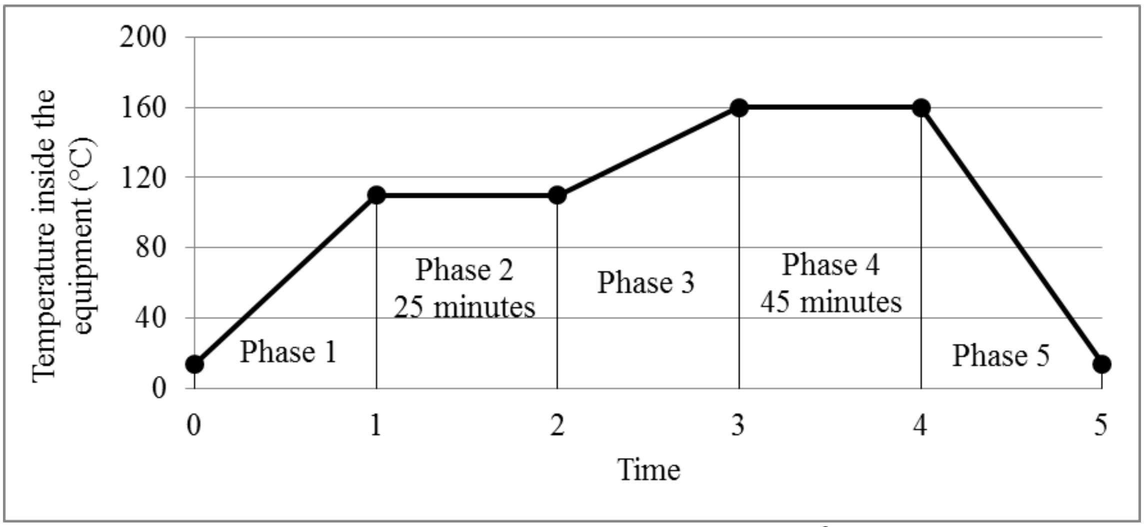

Figure 4: A theoretical example of a typical* TanWood® *process.

The description of each phase follows:

- Phase 1 – Initial heating: corresponds to the beginning of the process after lumber is loaded and the cylinder is closed. Steam is injected inside the equipment and the system is heated up to 110 °C, according to a predetermined heating rate (°C.min^{-1}). The duration of this phase is variable and depends on the heating rate adopted.
- Phase 2 – Constant temperature: after the initial heating, starts the first step of constant temperature, at 110 °C for 25 minutes, so the heating rate is nill in this phase. The goal is drying the wood.
- Phase 3 – Secondary heating: this is the second step of heating, and lengths until the system reaches the final cycle temperature, according to a determined heating rate (°C.min^{-1}).
- Phase 4 – Thermal modification: in this step occurs the thermal modification of wood, and the final cycle temperature is kept constant for 45 minutes.
- Phase 5 - Cooling: after phase 4, the equipment is turned off and the system cools down.

Literature review

Further, a literature review was carried out about the most consolidated and researched European processes of thermal modification of wood which are currently in operation in Europe (Esteves and Pereira 2009, Gérardin 2015, Hill 2006, Militz and Altgen 2014, Rapp 2001, Sandberg and Kutnar 2016, Xie *et al.* 2002).

RESULTS AND DISCUSSIONS

A general comparison between **TanWood®** *and the European processes*

After the description of the TanWood® process, it can be classified as hygrothermal, carried out in a closed system (Hill 2006) or under pressurized conditions (Gérardin 2015). According to the literature review, the Danish companies WTT (Wood Treatment Technology) and IWT/Moldrup develop processes with pressurized conditions (Gérardin 2015, Militz and Altgen 2014). According to Militz and Altgen (2014), the Dutch company FirmoLin Technologies enhanced the process and developed FirmoLin.

We visited the websites of these companies but found little information about the description of the processes (FirmoLin Technologies 2018, IWT/Moldrup 2018). On the WTT's website (WTT 2018), we found a presentation about the process (Klaas 2018) and also have some information directly with Ph.D. Thomas Venås, Director of Sales and New Product Development at WTT. We also found some information about this process in a paper (Dagbro *et al.* 2010). Regarding FirmoLin®, we found its description in the work of Willems (2009) and had some information directly with Ph.D. Wim Willems, the inventor of the process. Regarding Moldrup-SSP, we had the main information directly with Mr. Bror Moldrup.

We present in Table 1 a summary of the main processing conditions of TanWood® and the other closed system/pressurized processes, according to the information we found in the above-mentioned sources. If some information is wrong, the authors take the complete responsibility.

Although the Oil Heat Treatment is a process in a closed system, we did not provide any comparison with it because the wood is immersed in plant oil for thermal modification, making it a very different process from any other currently in operation. The same for Plato®, because only one of its four phases is carried out in pressurized condition (0.6 – 0.8 MPa) (Esteves and Pereira 2009, Militz and Altgen 2014, Rapp 2001; Sandberg and Kutnar 2016, Xie *et al.* 2002). Then we compared only the processes where all the phases are carried out under pressurized conditions/closed system.

The four processes are similar regarding the initial moisture content, where pre-dried wood (10-15%) is demanded in order to avoid drying defects, such as cracks. The temperatures used are similar, around 160 and 190 ºC, lower than the commonly applied in open system processes (Rapp 2001). Processes duration is also similar, ranging from 8 to 24 hours. Lumber thickness and maximum temperature influence on it, but closed system processes tend to be shorter than open system ones, what is an important characteristic to be considered regarding costs ($\$/m^3$).

Pressure seems to be higher in the WTT ThermoTreat 2.0 process than in the other three. Final moisture content is higher in the Brazilian process, where for the European ones it ranges from 3 to 7%. Although the equipment seems to be similar for all processes, there is a marked difference between the European ones, because they can have a fan inside the autoclave for steam circulation and homogenization.

Other marked difference in the European processes is the use of an initial pre-vacuum phase. It aims to evacuate the autoclave and the wood from oxygen to ensure the process is carried out in an atmosphere free of air to prevent self-igniting. The vacuum also reduces the boiling point of the water, permitting the use of lower temperatures for drying the water at the beginning of the process.

Table 1: Comparison of the main processing conditions of pressurized processes

Information	Processes			
	Firmolin	TanWood	Moldrup-SSP	WTT ThermoTreat 2.0
Company, country	FirmoWood, the Netherlands	*TWBrazil*, Brazil	IWT/Moldrup, Denmark	WTT, Denmark
Year	2008	2006	1999	2005
Equipment	Two connected pressure compartments: autoclave and boiler	Autoclave	Autoclave	Autoclave
Moisture content (%): initial/final	12/6	12 – 15/13 – 16	10 – 12/3 – 5	10 – 15/5 – 7
Temperature (°C)	160 – 190	140 – 180	Around 180	160 – 180
Process duration (h)	19 – 22	8 – 16	12 – 23 (for 25 mm thickness)	8 – 24
Pressure (MPa)	0.6 – 1.0	0.3 – 1.0	Up to 1.2 MPa	1.4 –2.0
Atmosphere/heat transportation media	Superheated steam	Saturated steam	Wood moisture is transformed in steam through heating by radiators filled with thermal oil	Saturated steam or nitrogen
Remarks	Pre-vacuum (0.01 MPa). Control of the relative humidity through a ratio of 0.75 between the actual steam pressure and the saturated steam pressure at the actual temperature.	Divided into five phases, as described in the Material and Methods.	Pre-vacuum. Radiators (filled with thermal oil) heat the air in the beginning phase; after, moisture evaporated from wood is transformed in steam. If necessary, additional water can be injected in the autoclave for steam production. After the pre-vacuum, pressure and temperature are thoroughly increased until their maximum values. Use of water-mist for conditioning the wood during the process.	Divided into five phases: Pre-vacuum (up to 0.3 bar); Heating (temperature increases up to 110-120 °C); Drying and thermal modification (160-180 °C, for 0.5-1.5 h); Cooling (40-70 °C); Pressure normalization.

CONCLUSIONS

TanWood® is a hygrothermal process of thermal modification, which uses saturated steam as heating medium in a pressurized/closed system.

TanWood® is similar to the European processes FirmoLin, Moldrup-SSP and WTT ThermoTreat 2.0. For a better comparison between the processes, it would be necessary more detailed information about the European ones, such as the heating system of the equipment used and the processing schedules.

More research and development are required for the Brazilian process of thermal modification, in order to improve the equipment and the process, as well as its impacts on the properties of the thermally modified wood.

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REFERENCES

Batista, D.C. (2012). Modificação térmica da madeira de *Eucalyptus grandis* em escala industrial pelo processo brasileiro VAP HolzSysteme®. *PhD Thesis, Universidade Federal do Paraná, Curitiba, Brazil. [In Portuguese]*.

Bellon, K.R.R. (2013). Modificação térmica da madeira de três espécies de florestas plantadas pelo processo VAP HolzSysteme®. *MSc. Dissertation, Universidade Federal do Paraná, Curitiba, Brazil. [In Portuguese]*.

Brito, T.M. (2017). Efeito da modificação térmica nas propriedades da madeira juvenil de *Eucalyptus grandis* W.Hill. e *Tectona grandis* L.f. *MSc. Dissertation, Universidade Federal do Espírito Santo, Jerônimo Monteiro, Brazil. [In Portuguese]*.

Dagbro, O., Torniainen, P., Karlsson, O., Morén, T. (2010). Colour responses from wood, thermally modified in superheated steam and pressurized steam atmospheres. *Wood Material Science & Engineering*, **5**, 211-219.

Esteves, B. M. and Pereira, H. M. (2009). Wood modification by heat treatment: a review. *BioResources*, **1**(4), 370-404.

FirmoLin Technologies. (2018). Available on: <http://www.firmolin.com/index.php/nl-nl/.>. Accessed on: 13 jun. 2018.

Gérardin, P. (2015). New alternatives for wood preservation based on thermal and chemical modification of wood – a review. *Annals of Forest Science*, DOI 10.1007/s13595-015-0531-4.

Griebeler, C.G.O. (2013). Colorimetria da madeira de *Eucalyptus grandis* W.Hill ex Maiden modificada termicamente. *MSc. Dissertation, Universidade Federal do Paraná, Curitiba, Brazil. [In Portuguese]*.

Hill, C. (2006). *Wood modification: chemical, thermal and other processes.* John Wiley & Sons, West Sussex, UK.

Homan, W., Tjeerdsma, B., Beckers, E., Jorissen, A. (2000). Structural and other properties of modified wood. In: *Proceedings of the Fifth World Conference on Timber Engineering*. Whistler, Canada.

IWT/Moldrup. (2018). Available on: <https://www.moldrup.com/>. Accessed on:13 jun. 2018.

Klaas, P. (2018). An Intro to WTT ThermoTreat 2.0. Available on: <https://wtt.global/wp-content/uploads/2018/01/ThermoTreat-2.0_Product-Presentation.pdf>. Accessed on: 13 jun. 2018.

Lengowski, E.C. (2011). Efeito da termorretificação nas propriedades anatômicas, físico-mecânicas e químicas das madeiras de *Pinus taeda*, *Eucalyptus grandis* e *Tectona grandis*. *Undergraduate Monograph, Universidade Federal do Paraná, Curitiba, Brazil. [In Portuguese]*.

Menezes, W.M.M. (2017). Efeito da modificação térmica em escala industrial na qualidade da madeira de *Tectona grandis* Linn.F. *Ph.D. Thesis, Universidade Federal de Santa Maria, Santa Maria, Brazil. [In Portuguese]*.

Militz, H., Altgen, M. (2014). Process and properties of thermally modified wood manufactured in Europe. In: Schultz, T. P., Goodell, B., Nicholas, D.D. Deterioration and Protection of Sustainable Biomaterials. Washington, D.C.: American Chemical Society. Chapter 16, p. 269-285.

Rapp, A.O. (2001). Review on heat treatments of wood. *Proceedings of Special Seminar*, Cost Action E22, Antibes, 66 p.

Sandberg, D., Kutnar, A. (2016). Thermally modified timber: recent developments in Europe and North America. *Wood and Fiber Science*, **45** (2015 Convention Special Issue), 28-39.

Willems, W. (2009). A novel economic large-scale production technology for high-quality thermally modified wood. In: *Proceedings of the 4th European Conference on Wood Modification*, Stockholm, p. 31-35.

WTT. (2018). Innovative heat treatment solution for wood. Available on: <https://wtt.global/products/thermo-treatment/>. Accessed on: 13 jun. 2018.

Xie, Y., Liu, Y., Sun, Y. (2002). Heat treated wood and its development. *Journal of Forestry Research*, **13**(3), 224-230.