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HEAT TREATMENT: CAN IT REPLACE PRESERVATIVES?

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Abstract

This paper describes the attributes of heat treated wood as alternatives to wood preservatives treated wood. The improved dimensional stability and decay resistance resulting from heat treatment are attributed to the cross linking and esterification reactions that occur during the heat treatment. These reactions promote the decrease of some mechanical properties. Today, the use of heat treated wood is limited to above ground non structural applications where the insect attacks are absent.
Compared to traditional wood preservatives treatment of wood products, the investment and production costs are still not favorable to heat treated wood, the development of technology with high volume production, the reduction of damage created during the heat treatment to the mechanical properties and the increase of insect resistance may help alleviate the burden associated to heat tretament. However, environmental concerns such as the migrations of preservatives from treated wood, the management and disposal of waste and wood retired from service place heat treated wood above existing wood preservatives. Efforts in the reduction of the production cost and the control of the mechanical and physical properties combined with the environmental advantages will accelerate the development of heat treatment as alternatives to existing metal containing wood preservatives for specific niche market product.

Keywords: Heat-treatment, Retified, Pine, PLATO, THERMOWOOD, Oil, LE BOIS PERDURE Mechanical, physical and biological properties.

1. Introduction

Wood preservatives treated wood is under severe public scrutiny because of the potential risk associated with the leaching of preservatives in the surrounding environment. The concerns include health risks, the management of waste generated during treatment such as sludge and off cuts and the disposal of treated wood once retired from service.
Without protection, the utilization of wood will be reduced to low hazard environment like outdoors or alternative materials will replace wood. The uses of substitutes which require high energy for their manufacture may not be beneficial for the planet. The search for strategies to increase the durability of wood is an ongoing research effort throughout the world. Several methods such as biological, mechanical, chemical and physical modifications of wood and wood products are proposed. The potential improvement of the durability of wood, mostly for decay and insects resistance can be

achieved by using genetic manipulation. It is foreseeable in the near future to transfer genes responsible for the biological resistance to non durable species. Mechanical means such as compression has been proposed to increase the dimensional stability of wood products and the density of the low density Chinese fir (Jieying et al. 2000). Chemical modification such as acetylation or sillylation has been used to increase the durability of wood products, mainly for low volume high value products. Charring and light heat treatment considered as physical modification have been used for centuries in construction and boat manufacturing and still used in some places in Africa for farm posts and pickets. One of the objectives of wood drying is to increase the durability. The temperature during drying is seldom above 250°F. The application of heat at temperature higher than 220°C on wood products may yield a stable product but the quality is questionable.

High temperature heat treatment of wood products can improve some properties of timber on several aspects (Stamm 1956; Kollman and Schneider 1963; Kollman and Fengel 1965). The foremost advantages of heat treated wood are the remarkable resistance to fungal decay attack (Ruyter 1989) the noticeably improved water repellency, and the improved dimensional stability to moisture variations.

Stamm et al. (1946) reported that when wood is heated at elevated temperatures, the reduction in hygroscopy and in swelling and shrinkage are due to the formation of ether linkage by the splitting of two adjacent hydroxyl groups. They reported an appreciable increase in decay resistance and significant losses in strength at heat treatment temperature above 270°C. This temperature is closed to the exothermic decomposition temperature where the hemicelluloses and lignin are attacked, and the crystalline structure of cellulose modified.

The maximum temperature during the heat treatment varies from 200° to 280° C and for duration of 15 minutes to 96 hours depending on the process, wood species, and sample size, moisture content of the wood, the desirable mechanical properties, resistance to biological attack and the dimensional stability of the final product. The presence of air or oxidant during the heat treatment may accelerate the degradation of wood components. Inert or reducing atmosphere is reported to facilitate the heat-treatment because the rate of thermal degradation of wood polyoses in air is greater than in an inert environment. The chemical degradation of wood occurs. A limited decomposition of wood extractives, lignin and hemicellulose is observed at temperature as low as 220°C with the generation of organic acid such as acetic and formic acid, phenolic substances such as vanillin, formaldehyde, furfural, coniferaldehyde and syringyl aldehyde (Sandermann and Augustin 1964).

Several authors (Stamm 1973; Suschsland 1968; Tjierdsma et al; 1998) suggested that the heat treatment enhances cross-linking and esterification reactions of formaldehyde generated during the decomposition of wood organic acids and the phenol units of wood lignin. Improved dimensional stability of heat treated wood is reported to be due to the loss of constitutional water in wood (Seborg et al., 1953).

Pilots trials were conducted in Europe particularly in France and in Finland in 1990's to produce heat treated wood with improved durability. The commercial heat treatment processes are: the Finnish THERMO WOOD, the Dutch PLATO WOOD, the French RETIFICATION and the German heated oil treatment. The Dutch and the German processes are still pilot trials whereas French and Finland technology are commercially available.

FINNISH

The Finnish process is a three steps process which includes an initial period of 0 to 48 hours with temperature rising to 150° C (Syrjanen 2001; Jamsa and Viitaniemi 2001). The second step is the actual heat treatment with temperature increasing from 150° C to 240° C in 4 hours and a final step where the wood is cooled and stabilized at 70° C during 24 hours. The Finnish process is expected to last for an average of 72 hours. It is estimated that four heat treatment units in Finland produced a total of 33.000 m^3 annually. Steam and heat are used to control the temperature and the relative humidity during the Finnish heat treatment.

PLATO

The Dutch process known as PLATO uses two-steps heat-treatment (Militz and Tjeerdsma 2001) . In the first step green wood is treated between 160° C and 190° C from 3 to 5 days under increased pressure to produce wood with less than 10% MC depending on species and sample size. In the second step dried wood is heated at 170° C -190° C during 14 to 16 hours and then conditioned for 2 to 3 days. The duration of the PLATO process varies from 6 to 8 days. Heat air and/or steam are used in the PLATO process.

FRENCH Processes

Two processes have been used to heat treated wood in France (Vernois 2001). One of the process known as RETIFICATION developed by the Ecole des Mines de Saint Etienne and commercialized by S.A. NOW consists in heating wood with a moisture content of about 12% in a chamber up to 240° C in nitrogen atmosphere with less than 2% oxygen. Nitrogen is used to control the color of the final products by limiting oxidation under high temperature.

The second process called “Le Bois Perdure” uses green wood instead of dried wood. In this process, wood is dried first and then heated at 230° C under steam atmosphere. Several commercial units with total capacity of 8000 m^3 per year are in operation in France.

The total production of heat-treated wood in France is about 8000 m^3 per year.

German Process

The German process is a thermal treatment of wood in a hot oil bath (Rapp and Sailer 2001). Wood is immersed in heated oil, raising the temperature of the wood. This process takes advantage of the fact that the boiling points of several natural oils and resins are lower than the temperature required to heat treat wood. This process uses wood dried at 6% MC with oil at temperature of 200-220° C. Oil with boiling point higher than the heat treatment temperature of 230° C can be used.

2. Important Parameters of the heat treatment

The critical parameters for heat treatment are:

The maximum temperature during the treatment which is comprised between 190 to 260° C dependent on the process, the species and the target applications and uses of the final products. The higher is the temperature the more durable and more strength reduction. The rate of the temperature increase and the duration are important parameters to control the color of the final products and some others properties such as strength and flammability. The control of the initial moisture content of wood, the size of the sample to be heat-treated and the species are very important for the quality of the final products. The quality of the wood to be heat-treated in terms of presence of knots, checks, splits, decay pockets or others natural characters marks will influence the quality of the final products. Heat treatment is desirable for wood with no defects. Heat treatment to improve the quality of low quality materials with knots and defects

3. Attributes of heat-treated wood

Hygroscopicity/Water absorption/Dimensional stability

Wood is known to absorb water from its surrounding environment until it moisture content is in equilibrium with the air. Typically, the equilibrium moisture content (EMC) of wood is close to 30% when exposed to 100% relative humidity at 25° C. After heat treatment, the equilibrium moisture content is reduced from 30 to 15%, representing 50% reduction. The 50% reduction is due to the cross linking and esterification of lignin and hemicelluloses during the heat treatment and the reduction of the hydroxyl sites available for water absorption. Heat-treated wood at temperature above 200°C results in reduction in swelling and shrinking of about 50%. However, heat treated wood dip in liquid water, absorbs liquid water faster than untreated wood because of the increase in the porosity, which is attributed to the removal of some wood extractives from the wood micro structure and the modification of some wood components.

Biological performance

Insects

Heat treatment does not modify the susceptibility of wood against longhorn beetles neither termites nor marine borers**.**

Decay Fungi

Decay resistance was improved from hazard class Use category UC1 or H1/ to Use category UC3 or H3. UC3 is for above ground not cover with frequent wetting. Due to the increased permeability and porosity of wood after treatment and the potential susceptibility to insects attacks like beetle, the use of heat treated wood may require further protection against insects and also to be installed vertically to reduce the accumulation of water.

Strength properties

Mechanical properties including flexural bending of heat-treated wood are affected. The decrease of the modulus of rupture is varies from 10 to 50% depending on the process. The maximum temperature and the rate of increase of the temperature are critical to control the reduction of the mechanical properties. The decrease of modulus of rupture of heat-treated pine was reported to vary from 10 to 40% for the French process, 20 to 40% for the Plato process, 5 to 15% for the Finnish process, and 20 to 30% for the German oil treatment. The reduction of the strength is attributed to the embrittlement of the heat treated wood.

Other properties

The color of heat-treated wood varies from light brown to dark brown depending on the species and the processes. A strong smokey odor can last up to six month on heat-treated wood. The gluability and paintability of heat-treated wood is not well documented, surface preparation is needed to increase the wettability and the adhesion on the surface. When exposed outdoors under sunlight and rain, the color of the surface goes from brown to light grayish, confirming the weathering of heat-treated wood.

4. Applications

Heat treated wood is mostly used for above ground non load bearing applications where insect attacks is absent. Outdoors applications include:

- Siding, Cladding
- Above ground decking and flooring members
- Garden furniture
- Children playground
- Window and doors frame

It can be used indoors for specific applications where the color is desirable or where the dimensional stability is highly required such as musical instrument, windows, flooring, doors, etc…

5. Quality control

One of the present challenges of the heat treated products is how to control the quality of the final products. Unlike preservatives products, the quality control of heat treated products is rather a process characterization. The performance of heat treated wood depends on the process used, the maximum temperature, the rate of temperature increase and the species.
Some studies reported a correlation between the color of wood and the performance.

Costs
Advantages of heat treated wood
Heat treated

- Dimensional stability
- Disposal, leaching and waste
- Environmental issues
- Non structural applications
- Value added products for specific products and niche market
- Performance UC1 to UC3 (H1 to H3)
- Residential products with human contact, low environmental risk
- Color
- Process control

Preservatives

- Low costs
- Available in volume
- Plant capacity
- Insect and decay resistance

- Performance UC1 to UC5 (H1 to H5)
- Mechanical properties
- Structural applications
- Commodities
- Low grade wood
- Product specification

6. Conclusions

Heat treatment processes with maximum temperature close to 240° C can be used to increase the dimensional stability and the decay resistance of wood products without addition of chemicals. The reduction of some mechanical properties and the susceptibility of heat treated wood limit their uses to above ground and no load bearing applications. Further work is needed to reduce the duration of the relatively long treatment cycle, to limit the degradation of wood strength, to enhance the insect resistance and the treatment cost in order to compete with existing preservatives. However, heat treatment can be considered as a complementary treatment for specific niche market where preservatives is non-desirable, such as residential products with frequent humans contact.

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Table: Cost comparison (Euros)

	Finland Thermowood	Plato (Netherlands)	France (Retifie and Bois Perdure	Germany
Investment	-	10-15 M	0.75M	0.45M
Production, m^3	35 000	75 000	3 500	8 500
Production Cost per m^3	-	120	130-200	100-180
Operational costs per m^3		20	100-160	60-90
Plants	8	1	5	-


Heat treatment Oven Larochelle, France


Above ground applications


Retified wood (Switzerland)


Retified wood (Poplar, Pine)