Heat treatment of wood in Finland- state of the art

Production and classification of heat treated wood in Finland

Tuula Syrjänen,
Kestopuu Oy

Heat treatment of wood Better durability without chemicals

Saila Jämsä and Pertti Viitaniemi
Technical Research Centre of Finland
Building Technology

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PRODUCTION AND CLASSIFICATION OF HEAT TREATED WOOD IN FINLAND

Tuula Syrjänen
Kestopuu Oy

Introduction

In Finland heat treatment of wood started in early 90´s when the first treatment plant was built to Mänttä. During the first ten years the interest against this new material has grown and today there are eight so called traditional heat treatment plants in Finland. The research work started nearly at the same time. Today producers co-operate at the research projects, especially which aim to quality control and classification of heat treated wood.

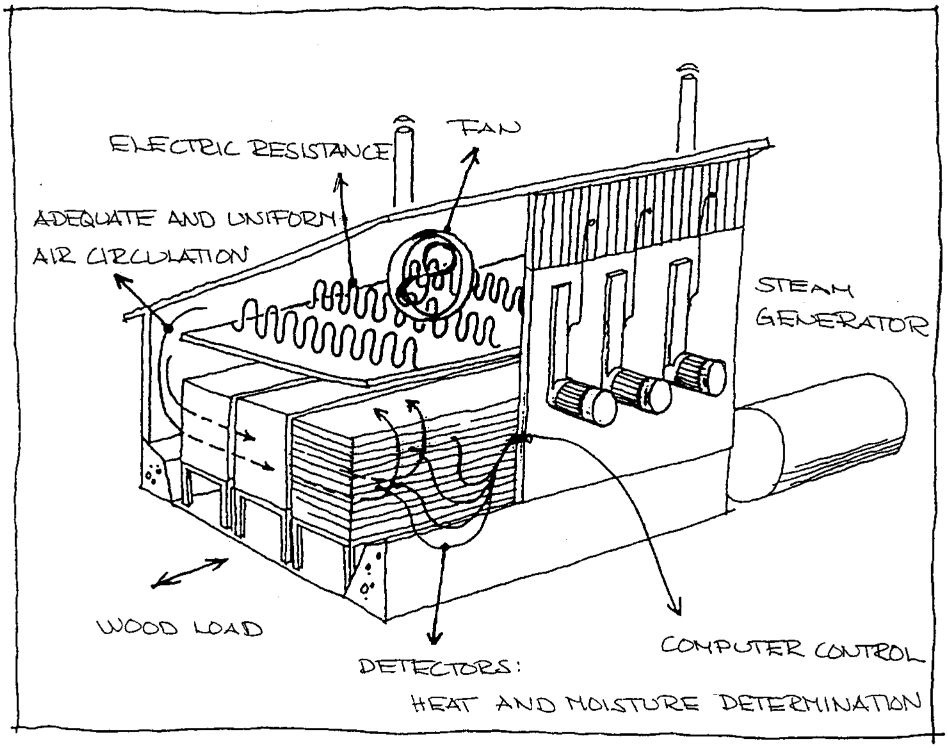
Heat treatment plants and equipment

Today there are eight heat treatment plants in Finland and one quite big plant is under construction. The capacity of these eight plants is little under 50 000 m^3/year (year 2000) and the production is around 35 000 m^3/year (year 2000). The treatment plants are so called traditional heat treatment plants. That means that chemicals or pressure are not used. Only heat and water vapour.

The principle of a heat treatment plant is shown in picture 1. In this picture the heat is produced with electric resistance. In industrial scale heat is usually produced with thin oil. In Finland there is already one heat treatment plant which uses bark, sawdust and plane dust to produce heat.

The fan makes the air circulation adequate (10 m/s) and the wood load must be lathed so that the air circulation is equal. The steam generator produces the steam needed. Water steam is needed to prevent the wood from burning (air content must be under 3-5 %) and it also affects the quality of heat treated wood.

There are detectors around the chamber to measure the heat and moisture content of air and wood load and the heat treatment plant is controlled by a computer. Computer control adjusts the heat treatment process according to the initial data and data gathered from treatment process. Because of the automation the process can be recorded and rechecked later.

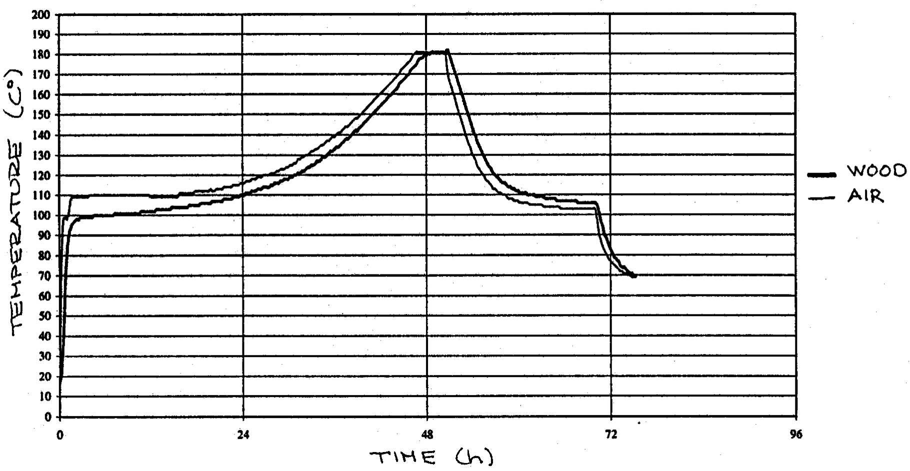


Picture 1. Principle of a heat treatment plant

Heat treatment process

The process used for the Finnish treatment method can be divided into three different steps:

1) temperature rise period (preliminary warm up (→ 100°C) + kiln dry at hot temperatures if needed (100 - 150°C) + temperature rise period (150°C →)), up to 48 hours
2) actual heat treatment (constant temperature of between 150-240°C), 0,5-4 hours
3) cooling + stabilizing, up to 24 hours



Picture 2 Example of a heat treatment process.

During the temperature rise period the temperature of the oven is raised to the temperature at which the actual heat treatment occurs. If the moisture content of the material is too high (> 10 %) before heat treatment a lot of splitting and colour differences may result. The kiln dry period can be integrated to the temperature rise period. The temperature rise period can take up to 48 hours.

The temperatures used for the actual heat treatment period range from 150 °C to 240 °C and during the actual treatment the temperature of the oven is kept constant. In heat treatment both the time and the temperature affect on the quality of the heat treated timber. The actual heat treatment takes from 0,5 hours to 4 hours.

During cooling and stabilizing the temperature decreases to normal. Cooling and stabilizing takes about 24 hours. During all these periods it is important that the temperature difference between the wood and the air is not too large. If the temperature difference is large the quality of treated wood is not good. It is also important that there is water vapour in the oven during the whole treatment cycle. The water vapour affects the quality of heat treated timber and it also acts as a protective atmosphere to prevent the material from burning.

Material

In Finland the most common wood species used for heat treatment are pine (*Pinus sylvestris*), spruce (*Picea abies*), birch (*Betula verrucosa/pubescens*) and European aspen (*Populus tremula*) although other species are also treated. The heat treatment process is different for each wood species and the final result is different because of the different chemical compositions and cellular structures. Usually softwoods are treated more strongly and hardwoods are treated more lightly. This is because of the different usage of the heat treated species.

The quality of wood which is going to be heat treated must be good. For example the knots are problem if they are dry and they drop out or crack. Also decayed wood may cause colour differences after treatment.

The final result is also affected by how the log is sawn. The conventional simple cut may result especially for softwoods a lot of peeling off and peeling of annual rings. In this case the annual rings are nearly horizontal to the surface. If the wood pieces are sawn so that the annual rings are at least in 45° angle to the surface the deformations will be smaller, the hardness of the surface will be stronger and the ”general looks” after heat treatment is better.

Usually softwoods are treated more strongly and are used in constructions which need moisture protection, for example in outdoor constructions. Hardwoods are treated more lightly and usually the most important property is the colour or good surface quality. Heat treated hardwoods are used indoors, for example in kitchen furniture, panelling and parquets.

Pine

Pine is a good material for heat treatments. Usually pine is used in outdoor constructions and because of this it is also treated quite hard. After treatment the knots of pine are mainly solid. The small and dry knots in butt logs may loosen when treated. The fresh knots in top logs stay solid and only in big knots there is some cracking. Especially for small dimensions there some torsion may occur because of big knots.

The problem in treating pine is that the resin comes out of the wood. It causes problems with heat treatment equipment if they are not cleaned between fillings. Also planing is difficult because of resin. But the good thing is that when the resin comes out many new uses can be found for heat treated pine.

Spruce

Spruce is also mainly used at outdoor constructions. Spruce is not that good material for heat treatment as pine. This is because of the knots and annual rings which loosen very easily. Already at low temperatures the fresh knots crack and loosen during treatment more often than for pine. Planing makes the annual ring rise up. Also the resin is a problem for spruce as it was for pine.

Birch

The aim of treating birch is not the better decay resistance but the other benefits. Birch has had an important role for Finnish carpentry industrial as such and now when it is heat treated it gives more interesting opportunities. Birch is treated usually more lightly than pine and spruce. Already the chemical construction requires lower temperatures as for softwoods. The most important properties for treated birch are usually the colour or good surface quality. Birch is used indoors, for example in kitchen furniture and parquets.

The biggest problem with birch is twisting. The big knots, curves at logs and tension wood makes it difficult to predict how the sawn timber is going to behave when treated.

Aspen

The heat treated aspen is used indoors and especially as wood material for sauna furnishing. A problem is that the colour is not always equal and a lot of splitting may result. Splitting results especially when there is decay in the wood or when there is both sapwood and heartwood in one piece or a lot of internal cracking. But when the treatment is done right and the treated material is good the colour of aspen is beautiful after treatment and the characteristic strong curling is decreased essentially.

Use

The improved characteristics of heat treated timber offer the timber product industry many potential and attractive new opportunities. The most important property compared to untreated wood is that the equilibrium moisture content of the heat treated wood is reduced and as a consequence of this shrinkage and swelling of the wood are also reduced. The best way of utilizing heat treated timber is to make use of these improved properties. Wood species having no commercial value as such can be heat treated and in this way a new use found for these species.

Heat treated pine and spruce are mainly used for outdoor constructions, for example garden furniture, windows, doors and wall or fence boarding. When better weather and decay resistance is desired the temperatures used for the heat treatment process must be over 200°C. At these temperatures the strength properties also decrease, a factor which has to be taken into account. Although the decay resistance improves when the timber is heat treated strongly it is not recommended to use heat treated timber in ground contact.

Heat treated birch and aspen are used indoors. The most important property of heat treated birch and aspen is dimensional stability (due to moisture content changes) but also very beautiful but selectable shade of colours varying from light brown to almost black. For indoor use the treatment temperatures are under 200 °C. Birch and aspen are used for furniture, kitchen furniture, parquets, panelling and sauna furnishing.

The effect of heat treatment to wood

The extent of the change in timber properties during heat treatment depends on

- the maximum temperature and the maximum length of the actual heat treatment period
- the temperature gradient
- the maximum length of the entire heat treatment
- the use and amount of water vapour
- the kiln drying process before the actual heat treatment
- the wood species and its characteristic properties

Temperatures over 150°C alter the physical and chemical properties of wood permanently. Heat treatment darkens the colour of the wood. It reduces the shrinkage and swelling of the wood and improves the equilibrium moisture content of the wood. At the same time the strength properties begin to weaken. Very high temperatures improve the resistance to rot and also reduce the susceptibility to fungal decay.

The improved characteristics of heat treated timber offer the timber product industry many potential and attractive new opportunities. Also wood species having no commercial value as such can be heat treated and in this way new uses can be found for these species.

Classification

The classification of heat treated wood is based on standard EN 335-1 (Wood and wood based products - Definition of hazard classes of biological attack - Part 1: Solid wood). In the Finnish Wood Preserving Association’s project the heat treated wood was classified into three heat treatment classes which are shown in table 1. In Finland heat treated timber is not recommended for use in hazard class 4.

Table 1   Heat treatment classes

Heat treatment classes	Hazard class EN 335-1	Situation in service	Description of exposure to wetting in service	Moisture content of untreated wood	Classification of impregnated timber
1	1	Above ground covered (dry)	permanently dry	permanently under 18 %	
2	2	aboved ground, covered risk of wetting	exposed to occasional wetting	occasionally over 20 %	
3	3	above ground not covered	exposed to frequent wetting	frequently over 20 %	AB (HC3/P8) B (HC3/P5)
	4	in contact with ground or fresh water	permanently exposed to wetting in contact with ground or fresh water	permanently over 20 %	A (HC4/P8)
	5	in salt water	permanently exposed to wetting by salt water	permanently over 20 %	M (HC5/P8)

Class 1

Very slight heat treatment. Mainly colour changes. Recommended to be used as untreated wood. Usage in constructions above ground covered and in conditions where the equilibrium moisture content of untreated wood will remain permanently under 18 % during service.

Class 2

Slightly heat treated timber. To be used in constructions above ground where is a risk of accidental wetting or condensation and the equilibrium moisture content of untreated wood occasionally exceeds 20 %. For example, kitchen furniture, parquets, windows and doors. The strength properties are slightly poorer as for untreated timber.

Class 3

Strongly heat treated timber. To be used in constructions above ground in situations where the timber will be continually exposed to the weather or to other sources of wetting such as condensation during service, but where the wood will not be in contact with the ground. The timber can be expected to have a moisture content of above 20 % repeatedly. To be used in constructions where the very good dimensional stability and lower moisture content are good properties. The strength properties have decreased.

Quality control

The Finnish heat treatment plants inform that they have their own internal quality control. All the plants are computer controlled and they can recheck the process after treatment. Test pieces are taken out of the wood loads and checked if there are internal cracks or external cracks, if the wood looks good, etc. Buyers have usually own standards according to which the control is done. In Finland there is not yet external control or marking/labelling requirements.

R&D-projects

In Finland there are four different research centres which have studied heat treated timber. These research centres have carried out research work for the producers of heat treated timber but not very much for the general public. Finnish Wood Preserving Industry Ltd began to co-ordinate the research work among the producers and research centres in December 1997 and launched a project in which the aim was to assess the quality of heat treated timber in Finland. Another aim was to produce the basic values for a classification scheme and for quality control in heat treated timber.

This project is extended with a second project *Long term durability and painting of heat treated wood*. The objective of this project is to focus classification system, to write quality control instructions and painting instructions (schedule July 2000 - July 2003)

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HEAT TREATMENT OF WOOD
Better durability without chemicals

Saila Jämsä and Pertti Viitaniemi
VTT Building Technology

Introduction

Heat treatment of wood has an effect on wood's chemical composition and through that on the properties of wood. The effect of heat treatment on wood's properties was already known by our forefathers when heating the edges of fence posts to increase durability. In addition to better durability the advantages of heat treated wood are reduced hygroscopicity and improved dimensional stability.

Many methods of thermal modification of wood have been reported in the literature. The first articles concerning wood heat treatment were found in literature from 1920's. After this the method has been developed in Germany /1-4/, France /5,6/, Finland /7-9/ and Netherlands /10,11/.

The reason why heat treatment method has not been commercialized earlier is mainly because the processes were complicated in large scale production due to high temperature needed to get good biological durability. The problem has been wood's burning if shielding gas is not used. There have also been problems in getting the heat effect evenly inside the wood without surface charring. Also treatment decreased wood's strength making it too brittle for many applications.

VTT has developed together with Finnish industry an industrial scale wood heat treatment process, Thermowood T^{o}W. Pilot scale production of Thermowood T^{o}W has been started by the developers of the process, Enso Timber Ltd, UPM-Kymmene Timber and Valmet UTEC Ltd in Finland. One of the first applications in full scale can be found in the latticework of the headquarters of Mac Donalds in Helsinki.

VTT process

The Thermowood T^{o}W is based on heating wood at high temperatures, 180 - 250 ^{o}C, by using a water vapour as shielding gas. While heating wood at temperatures over 200 ^{o}C wood undergoes a large number of chemical changes, like degradation of wood hemicelluloses. The VTT method differs from other methods that these methods often use nitrogen as shielding gas and some processes are done under pressure.

The process has been divided into three parts. The first is the rise of temperature, the second is the treatment time and the third is the decrease of temperature /12,13/. Many things have an effect to total treatment time. It will depend on kiln size, kiln loading amount, dimensions of wood species and the temperature decrease during cooling.

When raising or decreasing the temperature a special adjustment system is used in order to prevent inside cracking. The temperature rise in the kiln is regulated by the wood's inside temperature. The difference between kiln and wood temperature is dependent on the dimensions of the wood specimens.

Raw material can be green or kiln dried wood. If the process starts from green wood the wood can be dried in a very quick steam drying process developed by VTT. Quick drying is possible because we do not have to care for the colour changes and because resins will anyway flow from the wood in heat treatment process.

During the heat treatment wood degrades and the degradation products are mainly acetic and formic acid, a small amount of phenolic compounds and other aromatic compounds and wood extractives. The gases which evolve during treatment are mainly carbon monoxide and carbon dioxide and methanol. This means that the equipment has some special requirements, it must be built of acid resistant stainless steel and it needs a washing system where the degradation products are absorbed.

Wood properties

The properties of heat treated wood are dependent on the treatment process: treatment time and temperature. Temperature has greater influence on many properties than time. Treatment in lower temperatures for longer times does not bring corresponding properties.

All heat treatment processes used today are not similar and so the properties of heat treated wood may also vary a lot. The colour of wood changes easily and colour changes do not tell anything about how much the other properties have changed compared to untreated wood.

VTT has clarified how the properties of Finnish pine, spruce and birch are modified by heat treatment. The following results were reached /7/:

<u>Colour change into brown or dark brown</u>

> The colour of wood changes already in a mild heat treatment. The colour is not stable for UV-light.

<u>Reduction of equilibrium moisture content of wood by 50 %</u>

> Heat treatment slowers water uptake and wood cell wall absorbs less water because of the decrease of the amount of wood's hydroxyl groups.

<u>Reduction of shrinking and swelling 50 - 90 %</u>

> As a consequence of the reduced number of hydroxyl groups the swelling and shrinking are lower.

Improvement of biological durability

The biological resistance in a laboratory test EN 113 showed very good durability depending on the treatment temperature and time. In order to produce wood which has good decay resistance temperature over 220 ^{o}C has to be used. The treatment time in that temperature is at least 3 hours.

The resistance in ground contact is not acceptable.

The improved biological durability is based on the chemical degradation in wood components and formation of new compounds. The essential changes in wood chemistry are not exactly known.

Decrease of wood mechanical properties by 0 - 30 %

The higher is the treatment temperature the better is wood's biological durability. But at the same time more weakened are wood's mechanical properties. A negative consequence is that the wood becomes more brittle, and bending and pulling strength decrease by 10 % to 30 %. No changes were found in compression and impact strengths and surface hardness. As also the dry knots are loosened, the use of heat-treated wood in load-bearing constructions is restricted.

Other properties:

Heat conductivity decreases by 10 - 30 %

Resin flows out of wood

Wood looses some of it's weight (5 - 15 %)

Heat treated wood as material

The performance of heat-treated wood differs from that of normal wood. Several considerations have to be kept in mind when using the new material.

As the wood has become brittle, sharp blades have to be used to prevent the wood from ripping. Wood dust coming from the process is very finely divided and dry. It can irritate respiratory tracks.

Heat-treated wood absorbs slowly water and water based glues, such as PVAc. That is why longer pressing times are needed, making the glueing more difficult. Suitable glues for heat-treated wood are resorcinol-phenol, polyurethanes, and other two-component glues. In assembling lower compression pressures should be used, because the material is brittle.

The darkened colour created in the process is not durable in UV-light, unless the surface is treated with UV-resistant coating. Normal painting processes present no problems, but when electrostatic painting is used, heat-treated wood requires extra moisturising.

Applications

It is possible to tailor the process for different end uses. There are multiple correlations between the properties like dimensional stability, decay resistance and strength, so if e.g. small reduction in strength is sought the dimensional stability will be less pronounced.

Due to it's good weather resistance, thermowood is suited for outside applications such as external cladding, window frames and garden furniture. It is also suited for end uses where it is an advantage that resin has flown out of wood and heat insulation has increased like interiors in bathrooms and saunas. Because of the dimensional stability the treated wood gives better durability for coating. If the material is to be used for furniture and furnishing the process can be modified to give the desired degree of colour change.

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