Heat treatment of wood in France –state of the art

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The poor dimensional stability of wood under variable atmosphere and the low durability of many species have originated research for stabilization treatment inducing the limitation of moisture absoption of the lignocellulosic material.

One of the process under study for the last decade in France and in Europe consists in submitting wood to heat treatment ranging from approximately 180°C to 250°C depending on the type of species and the physico-mechanical characteristics to reach.

The main objective is to reduce the hydrophilic behavior of wood by the tridimensional modification of the chemical structure of some of its components through heat treatment in controlled atmosphere as a soft pyrolysis reaction.

The way the pyrolysis is conducted and the selection of the various parameters involved in the process have an influence upon the characteristics of the final product.

Operating conditions are essential, and such parameters as atmosphere- temperature - processing time - rate of heating - species - weight and dimension of the pieces - original moisture of the wood should be taken into account for they can strongly affect the final properties. The aim is to reach the optimum balance between the improvement of the moisture resistance and the decrease of the mechanical characteristics depending on usage.

It has been observed that when submitted to heat treatment at high temperature, the kinetics of humidity absorption is noticeably modified resulting in a major reduction of the volume retraction and a lowering till a certain extent of some mechanical properties depending on the treatment applied.

Improved durability results from the combination of two factors induced by thermal treatment:

A noticeable reduction of moisture absorption. Rot fungi need a minimum of 20% of humidity to develop.

Elimination of some of the nutrients required by wood rotting fungi.

It should be noted that heat treatment induces chemical modifications in the wood which darken original color over the whole material.

Mainly two processes are in use at the present time in France.

The first one called Retification (Retified wood) has been developped by Ecole des Mines de Saint-Etienne and operating licences and patents have been acquired by the Company NOW (New Option Wood) (Also known as RETITECH).

The process consists in starting from wood previously dried around 12 % in humidity and to heat slowly in a specific chamber up to 210 – 240°C in a nitrogen atmosphere with less than 2 % in oxygen. The Industrial oven has been developed by the Company Four et Brûleurs REY, near Saint-Etienne.

Three Industrial Units are already in operation with a capacity of 3 500 m^3/year for each corresponding to a heat chamber of 8 m^3.

One more plant is already ordered and should be in operation new April 2001. A few others should be implemented next year in France.

The second Process is named "Le Bois Perdure" and the oven has been developped by the Company BCI-MBS.

Instead of starting from dry wood such a process allows to use fresh wood. The first step of the process consists in an artificial drying in the oven. Then the wood is heated up to 230°C under steam atmosphere (steam generated from the water of the wood).

Temperature used during the Process

In both cases there is a compromise between durability and mechanical properties-higher the temperature, better the durability and lower some mechanical properties as strength to rupture. The treated wood at 230 – 240°C is much more durable but can loose up to 40 % in Modulus of rupture and is more brittle.

At 210°C, the material, depending upon the species, can be less brittle with mechanical characteristics close to the original values but the durability could be improved only slightly.

It means that the heat treatment shall be adjusted in terms of rate of heating, duration of treatment and maximum temperature to reach according to the application on usage.

The processes are very sensitive to slight changes in temperature which shall be controlled with accuracy. For example, in the Retification Process it has been observed and published recently that 230°C corresponds to a define modification of the lignin leading probably to crosslinking. Under such a temperature the treated wood does not show the same behavior, in terms of durability, that at a temperature above 230°C.

Heating medium

The Retified wood is processed under inert nitrogen atmosphere, with the residual content of oxygen lower than two percents.

The "Bois perdure" is processed under saturated water vapor atmosphere.

Costs

Costs are very dependent upon the production level. The reprocessing of byproducts generated in some cases (for example: in the Retification process) should be taken into account in the cost as some of these byproducts constitute a certain pollution.

It is generally assumed that the cost of the Retification process is in the order magnitude of 150 – 160 EURO per treated cubic meter.

In the case of "Obis perjure" the supplier of the oven mentions costs of 100 EURO per treated cubic meter.

However, the yield is not the same for these two processes. We can easily understand that due to a better control of the raw material at the inlet of the oven and due to the fact that the wood is maintained under pressure during the process by a special device, the final yield is much higher in the Retification process than in the "Bois Perdure".

Plant – purchase cost

For the Retification process, with and oven of 8 cubic meters in capacity, which means an annual capacity of 3 500 cubic meters the total investment is in the range of 750 000 EURO.

The "Bois Perdure" process seems to be less costly of 500 000 EURO.

Plant operation cost

The main operation costs are as follows:

- investments
- energy consumption
- nitrogen consumption (for the Retification process)
- maintenance
- treatment of effluents
- cost related to licence fees (patents)
- labor costs.

Retification process uses electrical energy

"Bois Perdure" uses gas energy. It should be noticed that, in that case, the VOC gases are reinjected in the burner to minimize air pollution as well as to improve the global energy consumption.

Documented properties

All properties are very dependent upon the wood species, the type of process, the final temperature reached.

However, in all cases, the material turns brownish in color, higher the temperature reached, darker the final product.

Smell

Wood treated at high temperature has always a strong smell just after treatment. After few days, such a smell decreases in intensity but could remain for several months.

Mechanical properties

As mentioned above, mechanical properties are very dependent upon the control of the process, the final temperature, the wood species etc.

The parameters to take into account are numerous and very sensitive to slight modification. In any case, the material becomes more brittle. At 230°C, quite often, a decrease of MOR in the range of 30 to 40 % can be measured with a very brittle behavior. (Catastrophic failure, without creep).

According to previous testing, mechanical properties after heat treatment are not strongly affected for poplar as they are for other species like pine trees.

This means that the density is not the only parameter involved.

Paintability

Surface tension of the wood is drastically affected after heat treatment.

Any kind of painting and finishing usually used for untreated wood cannot be used. However, it is possible to find some formulation and paints adequate on a surface of heat treated wood. If needed surface tension can be adjusted by additives. The main problem can arise from exudation of the resin from the resinous species.

Gluability

Proper glues have to be applied with heat treated wood. Research projects are presently carried out in CTBA Bordeaux on that topic.

Weathering properties

Wood treated at high temperature turns grey in colour after exposition to sun and UV, for few weeks. It is generally assumed that such grey colour is more homogenous than for untreated wood. Cracking, due to dimensional motion is reduced in comparison with natural wood.

Hygroscopicity

Wood treated at high temperature has less hygroscopicity than natural wood. It stabilises around 4 – 5 % in humidity instead of 10 to 12 %. This low hygroscopicity is of importance on biological durability (rot, stains, mould).

However, the material presents a certain porosity and when dipped in water it can absorbe more than 20 % of water. But when dried again the water can take out quite easily. Such behaviour is of importance for building materials.

Dimensional stability and cracking

It is known that heat treatment at a temperature above 200°C reduces by factor two dimensional movements. However, dimensional stability is largely dependent upon the process, the final temperature, the wood species.

Wood species

Species of high density are more difficult to process than low-density species. With species of high density (mostly hardwood) heat treatment has a tendency to induce cracking lowering drastically mechanical properties. Poplar seems to be interesting to process giving good results in terms of physical properties and durability. A large study on maritime pine has been carried out in France and the main results will be commented.

Durability

Durability is very dependent upon several factors:

- wood species
- type of process
- control accuracy of the process
- process time

maximum temperature reached and duration of time at such temperature.

Should we refer to natural durability or durability induced by chemical additives?

CTBA decided to refer to natural durability in terms of testing, standardisation, and requirements.

Industrial production

If plants have a theoretical capacity of 3 500 m3/year most of them are producing at around 50 % of their capacity. Total present industrial production in France is in the order of magnitude of 8 000 m3/year.

How many plants are in commercial use?

Six units are already in operation. Two others are expected and already announced for 2001.

Quality control and quality assurance

Each production unit has its own quality control. There is no quality assurance up to now and CTBA has been asked to insure such quality assurance in a future.

Production control of the plant

The raw material is checked according to internal specifications (dimension – moisture content) for each process. Each step of the process is recorded (heating time, percentage of oxygen, heat plateau, maximum temperature etc).

External control

Up to now there is no external control. However, such an external control could be part of quality assurance in the future.

Marking/labelling requirement

There is no marking and labelling today. There is a real need for such a labelling taking place after full quality assurance.

Quality testing after leaving the plant

In any case, we will have to find a non-destructive testing after heat treatment to insure that the treatment has been carried out properly according to the specifications required for the final usage. A simple test has to be found for industrial use. Few labs in France are already working on that topic.

R&D projects

Most of these projects are related to a specific process (for example: Retification). Hereunder are the present R&D topics:

- heat treatment of new wood species
- understanding of heat transfer in the material
- understanding of physico-chemical modification of lignin at high temperature.
- machinability of heat treated wood.