Principles & applications of wood retification

Retification® is a mild pyrolysis process conducted under inert atmosphere which considera-bly improves wood dimensional stability, hygroscopy and resistance to decay. It does not use external chemicals and is an alternative to both wood impregnation and the importation of expensive or endangered species. It now reaches the industrial stage.

INTRODUCTION

Solid wood has numerous assets: its insulating capacity, its aesthetics, its strength to weight ratio... Ecologically speaking, it's an economical material, renewable and low in energy processing. Nevertheless, wood is handicapped by its natural origin: its dimensions change with moisture content and it degrades under the influence of insects and fungi. Such shortcomings are mostly overcome by chemical treatments (creosote or CCA impregnation, polymer composites...) or by the importation of species reputed for their stability (western red cedar, teak or tropical timbers).

There are growing concerns about wood classical impregnation: treatment plants may pollute soils and incineration of treated wood is problematic (the only incineration plant in France suited for wood waste containing metallic salts is not operational)... On the other hand, wood importation increases deficits and thoughtless exploitation leads to deforestation and unsustainable development.

Hence the interest of an environment friendly heat treatment (no chemicals needed) which permits the upgrading of fast-growth European species (fir, spruce, maritime pine, beech, poplar...). This process is called Retification® and is developed by the "Ecole des Mines de Saint-Etienne", in collaboration with the license owner "NOW S.A." and the kiln manufacturer "Fours & Brûleurs Rey".

1. PRINCIPLES OF RETIFICATION

1.1 Chemical modifications in retified wood

Wood is a three-dimensional polymeric composite made of cellulose, lignin an hemicelluloses, with a small amount of extractives and ashes. A mild pyrolysis (T<280° C) of wood mainly cracks hemicelluloses and begins to modify lignin. By products of hemicelluloses pyrolysis condense and polymerize on lignin chains hence the notion of reticulation (creation of chemical bonds between polymeric chains) which gave its name to "retification" (an abbreviation between reticulatio and torrefaction). These reactions create a new "pseudo-lignin" which is more hydro phobic and rigid than the initial one. An infrared spectroscopy study has indeed revealed a modification of chemical bonds in treated wood: the number of oxygen containing groups (mainly hydroxyl groups) decreased while the number of C= double bonds increased. Cellulose cristallinity does not seem to be affected [1] & [2]

1.2 Pilot-scale reactor

Experiments are carried out in a batch pilot-scale reactor (3001). it's basically a forced convection kiln with electric heating (up to 300° C). Retification consists in a progressive heating of wood boards up to pyrolysis temperature, followed by a rapid cooling (via an air driven double shell) to ambient temperature (figure 1).

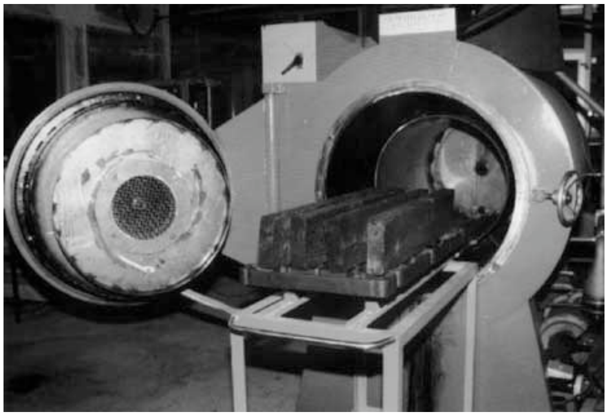


Figure 1. Pilot-scale reactor

1.3 Properties of retified wood

Wood dimensions change under the effect of humidity because cell wall polymers contain hydroxyl groups (and other oxygen-containing groups) that adsorb water through hydrogen bonding 13]. As a consequence, the cell wall expands till it is saturated with water (fiber saturation point or FSP). Cracking of hemicelluloses (the main causes of water adsorption) thus reduces both wood shrinkage and equilibrium moisture content (EMC).

Hemicelluloses removal and lignin modification prevent fungi enzymes from "recognizing" and hydrolyzing their nutrients (hemicelluloses at first). What is more, a lower EMC handicaps fungi development: they can not grow in wood unless wood moisture content is above 17% [4]. A combination of both factors may explain the improved durability of retified wood. Environmentally speaking, we never evidenced the presence of toxic chemicals generated by retification: fungi aren't killed but are unable to develop, and insects still attack retified wood.

Properties of retified wood are explained in a very similar way to those of chemically modified wood, for instance through acetylation processes. The main difference is that retified wood produces its very own reagents during pyrolysis, without any exterior chemical modifiers.

1.4 Process parameters

The Retification process is mainly driven by transport phenomena (heat & mass transfer) and pyrolysis kinetics. We distinguish 3 kinds of influencing parameters:

• wood characteristics: wood components differ from broad-leaved to resinous trees, from one species to another, from one region of origin to another... As a consequence, wood properties (heats of reaction for pyrolysis, specific gravity, permeability...) strongly vary, which leads to different retification schedules (exactly as for drying processes). The initial moisture content and its homogeneity within the load also affect total duration and quality,

• geometrical parameters: for thickness above 1 mm, transport phenomena aren't negligible any more. Additionally, secondary reactions occur in wood

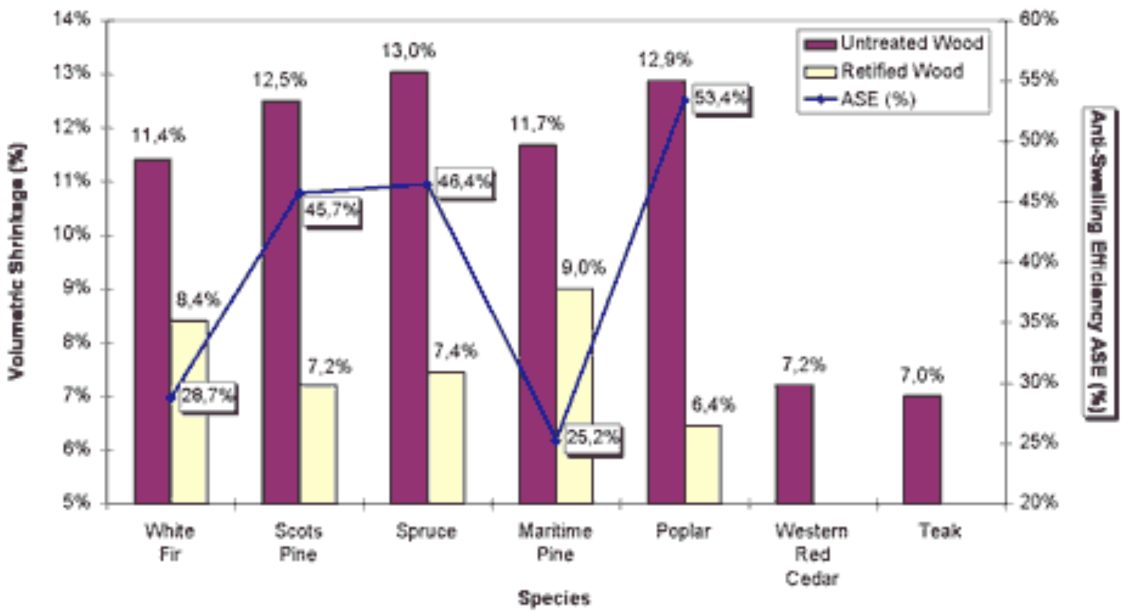
• during pyrolysis as a consequence of the interaction of hot pyrolysis vapors with decomposing wood solid [5]. Wood dimensions are thus crucial to determine a good schedule. The number of boards and pile stacking also affect forced convection and the homogeneity of heat treatment within kiln,

• process parameters: temperature and duration of pyrolysis obviously determine the quality of retified wood.

2. RESULTS AND APPLICATIONS OF RETIFIED WOOD

2.1 Results

We present here the results concerning common species in Europe and compare them with imported species reputed for their stability (western red cedar, teak). Measurements were carried out according to French standards [6], [7l, [8], [9] and [10]. Fungi used to determine wood durability were *Poria placenla* for resinous trees and *Serpula lacrymans* for poplar.

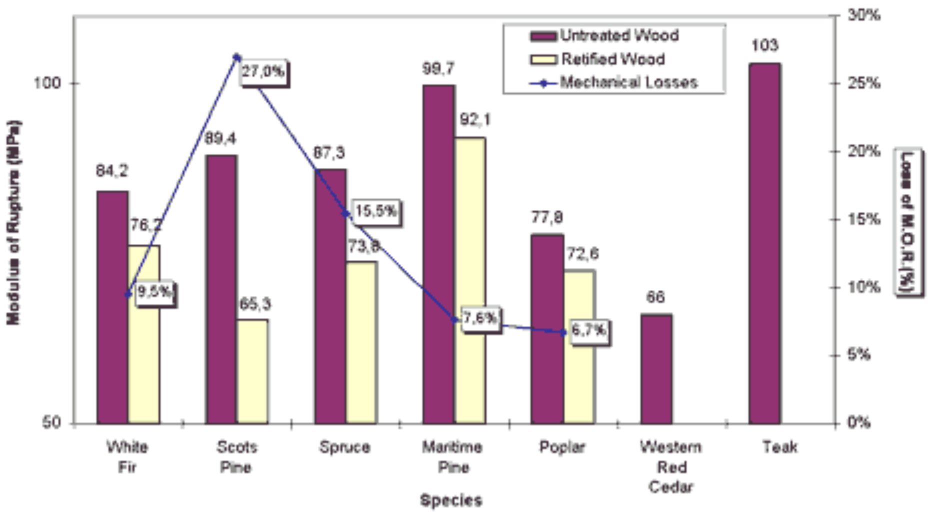


Reduction of volumetric shrinkage

Western red cedar and teak are classified from very durable to moderately durable (respectively 2-3 and 1-3). Retified wood dimensional stability and resistance to decay are very competitive with those of these species. We even succeed in upgrading fir and poplar from non durable (5) to very durable (1).

	Untreated Wood		**Retified Wood**	
	Weigh Loss (EN 113)	Classification (EN 350-1)	Weigh Loss (EN 113)	Classification (EN 350-1)
White Fir	18,0%	4	2,1%	1
Scots Pine	21,7%	5	4,1%	2
Maritime Pine	21,2%	5	5,9%	2
Poplar	26,8%	5	1,1%	1

Nevertheless, retification may lightly decrease wood mechanical strength because of the modification of its chemical components. On the other hand, a carefully driven retification schedule requires a very good quality pile stacking within kiln: imposing such rules to wood industrialists should lead to an overall improvement of dried wood quality and, as a consequence, to retified wood quality.



Evolution of mechanical properties

2.2 Applications

The uselessness of storage time for retified wood after treatment (in contrast to wood trented by chemical means) is a decisive advantage: retified wood is ready for machining immediately after treatment. Retification also applies to wood species which can not be impregnated with metallic salts (spruce) [11]

Solid retified timber can be destined for outdoor uses:

• cladding, soundproof wall: affordable conifers could replace expensive imported species. Retified MARITIME PINE or FIR have both good dimensional stability and resistance to decay,

• floor coverings, terrace, duckboards, boat decking. Retified BEECH favorably compares to TEAK as far as mechanical properties and dimensional stability are concerned. BEECH is considerably cheaper,

• garden furniture. Retified ASH and BEECH could be suited for this application because of their appearance and surface hardness,

• window and door frames. Glued laminated window frames made of FIR have proved successful,

• children's play areas, street furniture, forest cabins, wooden gates, fencing...

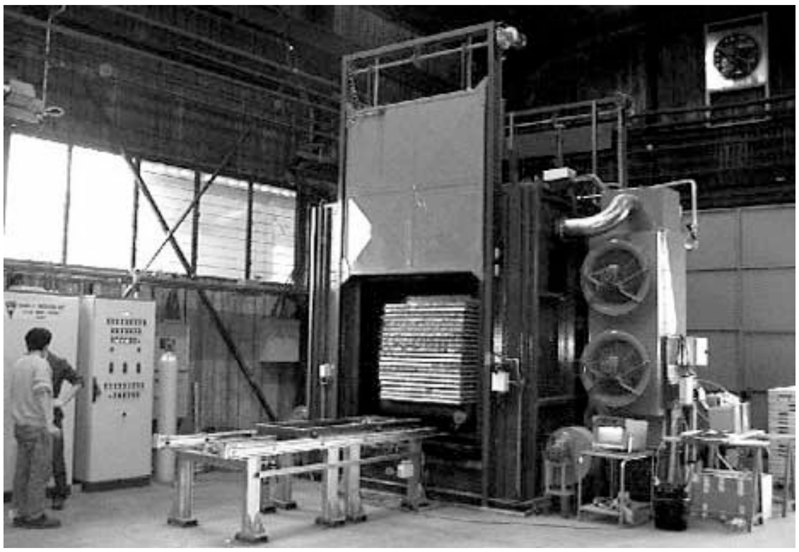
It can also be used for indoor uses (parquet flooring, furniture, interior decoration) and we could even consider musical applications, for which dimensional stability ensures consistent acoustic properties. Fragmented retified wood may be used to manufacture composite materials in association with glass, fiberglass, hydraulic or calcic binders (cement, plaster...): this should lead to a smart valorization of the unavoidable wastes occurring during retification or machining.

3. UP-SCALING AND INDUSTRIALISATION OF RETIFICATION PROCESS

Our partner "Fours & Brûleurs Frey" has built an industrial-scale reactor enabling the treatment of large amounts f wood (2 m3, which represents up to 240 three-meter long boards). Current researches deal with the up-scaling of the schedules of our pilot-scale reactor to this preindustrial kiln.

As in the pilot-scale kiln, final quality of retified wood depends on initial characteristics of wood (humidity homogeneity, warping...), pile stacking, heat treatment… Quality procedures are elaborated in order to ensure a reproducible and homogeneous treatment. We both focus on statistical samplings and non-destructive evaluation of wood quality to implement a process as simple and robust as possible. Modeling and simulating of transport phenomena will also allow us to improve the management of the process and to generate automatic schedules for wood retification.

Such an industrial size reactor is a powerful tool to show demonstration products (for instance spruce claddings in the "Village industriel" of Chenit, Switzerland... and to interact with wood actors for matters such as wood machining or finishing.



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