

Research & Development Summary



Value
to
Wood

RDS 2009-05-E

Improving Wood Hardness and Dimensional Stability by Densification and Impregnation

Hardened and impregnated woods are new materials that present new market opportunities for the wood products industry. These new materials have properties that are different from the virgin wood, and therefore can be used for different applications.

Normally, in a conventional wood hardening and modification process, the wood is impregnated with polymer(s) or chemicals to fill voids in the wood cells or to crosslink (i.e. chemically react with) wood components. Filling voids will improve the wood hardness, and crosslinking will reduce wood hygroscopicity, leading to improved wood dimensional stability. The impregnation of chemicals and subsequent fixation are conducted batch by batch, which limits the production capacity and results in a high operational cost. This may be one of the reasons that there are few businesses in Canada that engage in wood modification.

The intent of this project was to characterize the properties of impregnated and hardened western hemlock, red maple, aspen, balsam fir, tamarack and white pine; and, identify and recommend appropriate end uses for each new material. Specifically, the project objectives were to: 1) develop a cost-effective process for improving wood hardness and dimensional stability; 2) evaluate the impact of different chemicals and treatment methods on wood hardness; and 3) evaluate the performance of the various chemically treated wood samples for different applications.



Method

Six different wood species (aspen, balsam fir, red maple, tamarack, western hemlock, and white pine) were treated with different processes: pre-compression, hot press compression, chemical impregnation, and post-hot compression. They were also treated with combinations of these four processes and phenol formaldehyde (PF) resin, melamine urea formaldehyde (MUF) resin and methyl methacrylate (MMA). Following treatment, samples were tested for chemical retention and distribution in wood specimens, sample surface quality, dimensional stability, hardness, mechanical strength, bond line quality, pull-off strength, wear resistance, volatile organic compound (VOC) emissions, and mold and decay resistance.

Table 1: Hardness (MPa) of different wood species samples with different treatments.

	Control	Treat1	Treat2	Treat3	Treat4	Treat5	Treat6	Treat7	Treat8
Aspen	2.22	4.04	2.3	7.97	12.34	6.43	3.23	3.09	2.09
Red maple	3.98			11.31			5.04	6.01	4.73
Balsam fir	1.19			2.96	4.36		1.50	1.18	1.19
White pine	1.48			3.46			1.86	1.44	1.56
Tamarack	2.20			2.77			3.79	2.65	2.94
Western Hemlock	1.48			4.99			3.13	1.74	2.49

Note: Treat1 PF resin impregnated by compression and cured by hot press compression
 Treat2 PF resin impregnated by compression and cured by microwave heating
 Treat3 MMA impregnation
 Treat4 MMA impregnation followed by hot press compression
 Treat5 MMA impregnation by vacuum process
 Treat6 Low molecular weight PF resin impregnation by vacuum process
 Treat7 High molecular weight PF resin impregnation by vacuum process
 Treat8 MUF resin impregnation by vacuum process

Results

The results showed that (Table 1), after it was subjected to a pre-compression-impregnation process, aspen had a 6% PF resin gain. After hot press compression, the treated aspen had a hardness of 4.04 MPa (Treat1), which is almost double the value of the untreated samples (2.22 MPa). Curing the resin-impregnated aspen samples in a microwave oven resulted in a 2.3 MPa hardness for the treated samples (Treat2). However, laboratory observation indicated that some of the aspen samples started to burn after 7 minutes of curing, while the resin in other samples was not cured, implying that the microwave energy was not evenly distributed. Curing resin-impregnated samples in a microwave oven was thus judged unsuitable, under the conditions tested.

When treating wood with 100% MMA, it was found that red maple had the greatest hardness, followed by aspen, red pine, western hemlock and white pine; balsam fir and tamarack had the lowest hardness (Treat3). In addition, treated aspen, red pine and western hemlock were found to be harder than untreated red maple (3.98 MPa). This showed the potential of using the MMA impregnation process for substituting underutilized softwood species for expensive hardwood species. The results also showed that after MMA was polymerized, further hot press compression of the MMA-impregnated wood increased the wood hardness, especially for aspen (Treat4).

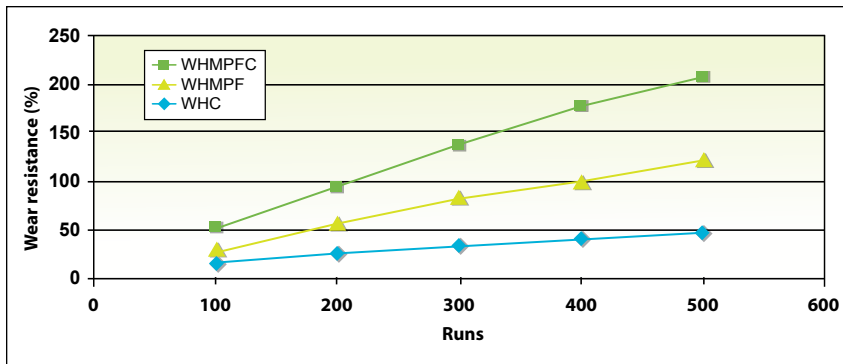
Among the treated samples of aspen under the same process parameters, MMA treatment produced the highest hardness, followed by low molecular weight PF resin and higher molecular weight PF resin; the use of 100% MUF resin resulted in the lowest hardness, comparing the hardness of aspen in Treat5 to Treat8. Among the samples treated with low molecular weight PF resin, red maple had the highest hardness, followed by tamarack, western hemlock and white pine; balsam fir had the lowest hardness, which indicates that the treated wood hardness was related to interactions between wood characteristics and process parameters (Treat6).

The use of the low molecular weight PF resin normally resulted in a higher hardness than the use of the higher molecular weight PF resin (Treat6 and Treat7).

Comparing the hardness of samples treated with MUF resin (Treat8) with that of samples treated with low or higher molecular weight PF resin showed that the hardness value of the samples treated with MUF resin was low and did not vary much. Except for red maple treated with MUF resin, PF resins and tamarack treated with low molecular weight PF resin, none of the resin treated samples of any of the wood species studied were harder than untreated red maple.

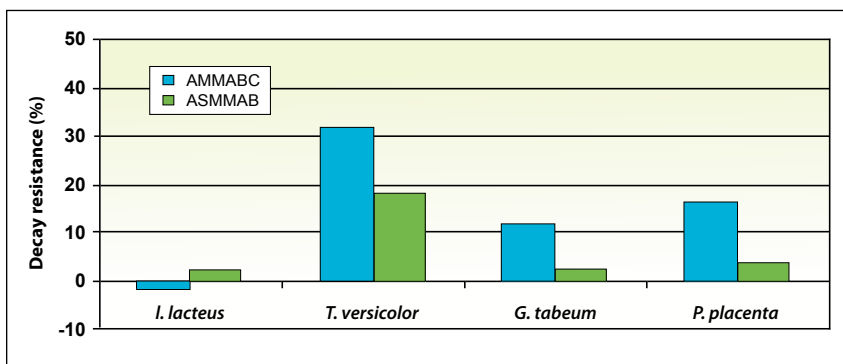
Impregnating a mixture of MMA and PF resin decreased the wear resistance of the treated samples, while further hot press compression increased the wear resistance of the treated sample, compared to the control samples (Figure 1).

Normally, the faces were more mold resistant than the sides. The mold growth on the control samples occurred later and was less abundant within 7 weeks incubation than on the samples treated with MUF resin and Bardac, a commercially available wood preservative component, but occurred faster and was more abundant than on the samples treated with MMA and Bardac after 9 weeks. Hot press compression delayed the mold growth on samples treated with MUF resin and Bardac.



WHMPFC: Sample impregnated with MMA+PF resin and hot press compressed
 WHMPF: Sample impregnated with MMA+PF resin and then hot pressed
 WHC: Western hemlock control

Figure 1: Wear resistance of different western hemlock samples



AMMABC: Aspen impregnated with MMA+Bardac by pre- and post-hot press compressed
 ASMMAB: Aspen impregnated with MMA+Bardac by pre-hot pressed

Figure 2: Decay resistance of treated aspen

The effect of hot press compression on decay resistance of treated aspen samples depended on fungi used. Of the samples treated with MMA and Bardac (Figure 2), for example, pre-compression, followed by hot press compression increased decay resistance to white rot fungus *T. versicolor*, but this treatment did not yield any resistance to the other white rot fungus, *I. lacteus*. It had some improvement on the resistance to the brown rot fungi, *G. trabeum* and *P. placenta*. Pre-compression of MMA- and Bardac-treated aspen without hot press compression reduced the decay resistance of aspen to three fungi but tended to increase the resistance to *I. lacteus*.

Under the same impregnation process, red maple had the greatest treatment efficiency, followed by aspen and western hemlock, while white pine had the lowest treatment efficiency. This experiment showed that white pine, balsam fir and tamarack should not be considered in the chemical impregnation process, while the hardness of red maple, aspen, and western hemlock are increased using this process, within the process parameters used.

For the same wood species (aspen), varying the impregnation process parameters (vacuum and pressure) shows that, when the chemical retention reached a certain level, further increase in chemical retention did not increase the wood hardness. The main factor affecting the change in the wood hardness was found to be the extent of the vacuum.

When different chemicals, different wood species and different impregnation process parameters were considered together, it was found that MMA did not show an obvious advantage over the other chemicals. The most efficient use of the different chemicals to achieve the optimal hardness value was found to be:

- PF Resin: treatment by dipping or coating for aspen, balsam fir, tamarack and western hemlock; vacuum treatment for red maple; treatment with both vacuum and pressure for white pine.
- MUF Resin: dipping or coating treatment for balsam fir and western hemlock; vacuum treatment for tamarack, red pine and white pine; treatment with both vacuum and pressure for aspen.
- MMA: aspen should be vacuum-treated.

Applying the Results

The study showed that different wood species and types of wood products require different processes, process parameters and chemicals. Optimization of the wood modification process should be based on the specific mill situation and materials selected. If the wood species and type of product have been selected, one can work on process parameters and chemicals selection.

Potential Benefits for Manufacturers

- To develop a cost effective process based on wood modification concepts, one needs to understand product requirements, wood properties, chemicals and the process used and their interactions so that one can use this information to optimize the final production operation. This project has shown ways this could be achieved.

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Potential Benefits for Manufacturers cont'd.

- Based on 2007 prices, there could be a financial benefit to producing chemically impregnated wood flooring, compared with engineered wood flooring, which needs to be optimized in a mill situation.
- It has been determined that aspen is an excellent candidate for wood modification process.

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