Research & Development Summary

Value to Wood

RDS 2009-06-E

High Temperature Treated Wood

Wood properties and performance can be enhanced through high temperature conditioning (typically 180 to 220°C) in the absence of oxygen for several hours. The resulting chemical changes to the wood result in a darkening of wood colour, improved dimensional stability, reduced water absorption and improved decay resistance. However, there is some loss in bending strength and other mechanical properties. There are several commercial processes for thermal modification of wood, based on drying and heating in steam or nitrogen environments, or submersion using hot vegetable oils as the heat transfer and oxygen excluding medium.

High temperature treated or thermally modified wood is a potential alternative to preservative treated wood, naturally durable wood, or wood-plastic composite lumber in exterior above-ground applications such as fences, deck boards and cladding. However, there are questions concerning the suitability of these processes for Canadian lumber species, optimal processing conditions and quality control for these processes.

The objectives of the projects described here were to evaluate the effects of different thermal modification processes on Canadian lumber species and to establish appropriate quality control procedures for these products. An additional objective was to investigate the feasibility of adding value to the process through incorporating additives such as waxes and pigments with a hot oil treatment.

Results

Potential of thermal treatment for Canadian species

Canadian wood species, including SPF and Douglas-fir, were treated by a number of commercial thermal modification processes and by various hot oil treatments, and the physical and mechanical properties evaluated. The treated wood characteristics depend on the time and temperature of treatment, with higher temperatures and longer times resulting in better decay resistance, dimensional stability and more colour development. The darkening response of higher temperatures and longer exposure times could be quantified by the L* (lightness) property measured by a CIE L*A*B spectrometer as a potential quality control measure. This colour change effectively masks blue staining fungi discoloration of wood. The dark coloring is susceptible to UV fading in exterior applications, but modified wood accepts stains and other protective coatings reasonably well.

However, bending strength (MOR), impact resistance, abrasion resistance and, for some thermal treatments, hardness are reduced by the treatment, although part of this strength loss is balanced by the lower equilibrium moisture content of treated wood, since drier wood is generally stronger. Results from hot oil treatments show that bending strength is reduced by about 20% and abrasion resistance and toughness may be reduced by 40 to 50% with treatment at 220°C for 2 hours. These strength losses are

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still acceptable for most anticipated applications such as decking, cladding and fencing. Bending stiffness (MOE) and wood density are not significantly affected.

Thermal modification reduces both free water and water vapour uptake by wood, resulting in reduced shrinkage and swelling and lower moisture contents at a given relative humidity. Because the treated wood is essentially oven dried by the treatment, there is high potential for wood degradation during the process. One phase of this study showed that internal defects could be identified by an ultrasonic device.

Results of hot oil thermal treatments

Thermal treatment in high temperature vegetable oil results in darkening of the wood and shallow penetration of oil into the wood surface (Figure 1).

Figure 1: Colour change in pine from thermal treatment in soybean oil at 220°C for 2 hours.

The use of oil and/or wax as the heat transfer medium results in low rate of water absorption both in laboratory soaking tests (Figure 2) and when exposed to natural weathering. Samples exposed vertically out-of-doors for about 1.5 years fluctuated less than 5% in moisture content compared to more than 20% for untreated or preservative treated wood. The reduced moisture content fluctuation in-service results in much lower surface checking compared to untreated or CCA preservative treated wood. The treated wood is more dimensionally stable (Figure 3) resulting in anti-shrink efficiencies ranging from 30% to 55% depending on the oil used and treatment conditions. (ASE = 50% means that wood shrinks or swells only one half as much as untreated wood.)

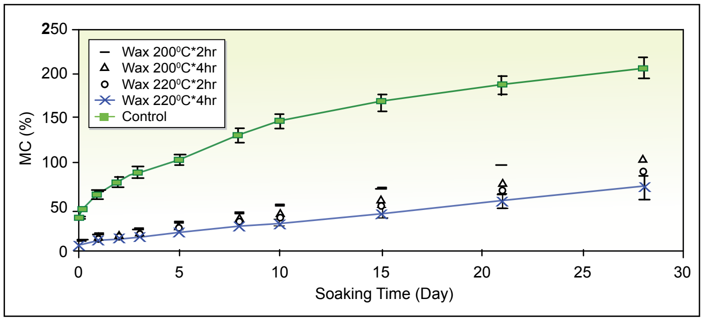

Figure 2: Effect of temperature and treatment time on water absorption of SPF wood.

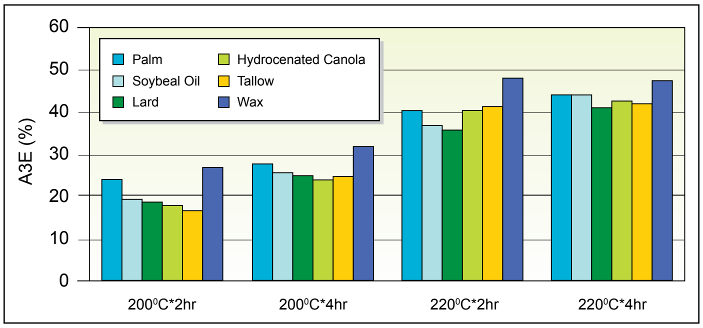

Figure 3: Anti-shrink efficiencies (tangential direction) of spruce samples exposed to different hot oil/wax treatments.

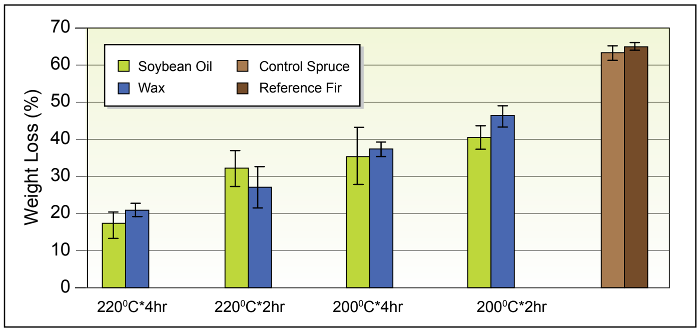

Figure 4: Effect of treatment conditions on resistance to decay (AWPA E10).

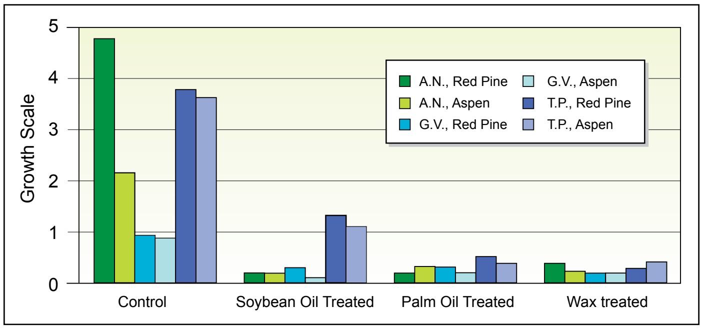

Figure 5: Comparison of growth of various molds exposed in the laboratory to untreated wood and wood thermally modified in different oils for 2 hours at 220°C. Note the mould fungi tested were Trichoderma pseudokoningii (T.P.), Gliocladium virens (G.V.) and Aspergillus niger (A.N.).

Resistance to biodegradation

Thermal modification provides moderate resistance to decay fungi, with improved decay resistance at higher temperature and longer duration thermal treatments. A comparison of decay rate for a common brown rot fungus (Gloeophyllum trabeum) in a soil jar test is shown in Figure 4 for soybean oil and slack wax treated samples. Similarly, attack by mold (Figure 5) was reduced by thermal treatment in various oils. However, the thermally treated wood was not resistant to attack by the Eastern subterranean termite (Figure 6).

Figure 6: Termite choice test. Termites showed no preference between untreated wood and thermally treated wood.

Environmental implications

Both wood and vegetable oils are renewable materials with environmental costs associated with their growth, harvesting and processing. The two main environmental costs of hot oil thermal modification process are the costs of energy to heat the oil and the eventual need to dispose of degraded oil. We observed that the viscosity of aged oil increased rapidly with time used resulting in solidification of the cold oil that would present processing difficulties for storage and transport. This viscosity effect is minimal as long as the oil remains heated. Furthermore, a number of potential additives, including slack wax and sage and rosemary dried spices were effective anti-oxidants to reduce the rate of oil degradation and increase the working life of the oil. For example, 50% slack wax more than doubled the effective life of the oil, while the dry herbs at only 0.75% of the oil weight were nearly as effective as the slack wax.

Potential Benefits and Application

High temperature modified wood has improved dimensional stability, water absorption properties and decay and mold resistance making it a potential substitute for preservative treated wood, naturally durable wood species and wood-plastic lumber for some exterior applications. The thermally modified material has reduced environmental impacts because the process uses natural renewable materials, although processing energy requirements are higher than for preservative treatments. For difficult-to-treat Canadian species, it offers the advantage that wood is modified equally throughout its depth. Because the treatment is less effective than preservatives against fungi and is not resistant to termites, it should be considered for low decay hazard uses such as fence boards, decking, cladding and other above-ground appearance products.

Use of hot oil as the heat transfer medium offers certain benefits including the ability to enhance the wood properties by use of additives. Slack wax was an effective additive that could be mixed with vegetable oil (for example 50:50) to reduce water uptake, reduce oil degradation and reduce the overall cost of treatment. Micronized pigments could also be suspended in the oil to provide some colour enhancement and UV protection. The low water absorption during exposure to weather protects the wood from excessive surface checking and warping in-service.

Treatment in soybean oil amended with low cost slack wax at 220°C for two hours provides a good balance of properties, with acceptable strength loss and good longevity of the oil due to anti-oxidant properties of the wax.

As a result of the above described property enhancements, modified wood maintains its aesthetics longer than untreated or pressure treated wood and has a longer effective service life. The main operating costs for this treatment are related to the need to dry wood to a relatively low moisture content (10 - 15%) prior to treatment, oil consumption (absorption and spoilage) and the energy required to heat the oil and maintain it hot. The estimated cost of processing is about $325/Mfbm which will still make the treated product cost competitive with untreated cedar lumber and plastic lumber products.

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Full reports are available from the Value to Wood website (www.valuetowood.ca).

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Value to Wood Research Program Partners

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