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FURFURYLATION OF WOOD OVERVIEW

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Summary

Furfurylated wood is resistant to biodeterioration and non-toxic. It has some enhanced physical and mechanical properties. Recently developed technologies for producing it, extensive properties testing and an operating commercial production plant have made it a fairly mature alternative for uses in harsh environments. New generations of furfurylated and other polymer modified woods are being developed.

1. Introduction

"Furfurylated wood" is a fairly recent name for wood modified with polymerized furfuryl alcohol. The earliest furfurylated wood was made using zinc chloride-catalyzed furfuryl alcohol. The product was a highly-loaded, dark, dense material resistant to decay, acids and bases (Goldstein 1955). It was used for laboratory countertops, knife handles and walkways in acid plants.

Early workers called the material "wood polymer combinations" and later "wood polymer composites." But the term "wood polymer composites" has recently been used for thermoplastic polymer-wood fiber composites. "Polymer modified wood" is perhaps the best current name for wood modified with furfuryl alcohol polymer, acrylic polymers and styrene.

For those familiar with the preservative industry, perhaps some differences and similarities will help understanding. Furfurylation has similarities to both salt and creosote treating.

- Salt, creosote and fufurylation use a vacuum-pressure treating process.
- Salt and furfurylation use concentration in water to control retention.
- Creosote and furfurlation retentions are similar
- Creosote and furfurylation use heat in the process

But there are major differences between furfurylation and any conventional preservative.

- Furfurylated wood is non-toxic.

- Combustion products of furfuylated wood are similar to wood alone.
- Water leachate from furfurylated wood is non-toxic.
- Furfurylation improves some physical and mechanical properties of wood.

This paper outlines the origins, properties and uses of the newest generation of furfurylated wood.

2. Methodology

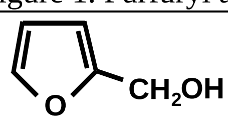
The author is the inventor of much of the technology described. He used his research and commercialization experience as the basis for this descriptive article requested by the Canadian Wood Preservers Association for presentation at its 2007 annual meeting.

3. Results and Discussion

Furfuryl alcohol is the main chemical used in wood furfurylation. It is made from furfuryl aldehyde (furfural). Furfural is a breakdown product of pentosans (5-carbon sugars) in plants. Wood destructive distillation produces furfural in low yield. Sources like oat hulls and sugar cane bagasse produce furfural in much higher yield and are the commercial source of the chemical. Plant decomposition in nature produces some furfural, so it is a ubiquitous substance. It is present in coffee, fermented foods like beer and is used as flavouring. There is a 358 page textbook about furfural available (Zeitsch 2000).

Furfural and furfuryl alcohol molecules contain 4 carbons in a ring with 1 oxygen, and a pendant carbon upon which either the aldehyde or alcohol group attached. The ring has 2 double bonds and 3 single bonds in a resonant structure. It is illustrated in Figure 1. Upon aging or polymerization, the rings change to visible light chromophores, producing a brown color. The color depth is dependent on chromophore concentration.

Figure 1. Furfuryl alcohol molecule



Furfuryl alcohol (FA) is produced from furfural by hydrogenation. FA can be auto-polymerized to a hard, dark, crosslinked polymer. The polymerization and crosslinking is possible because FA is multi-functional. The alcohol group is reactable and the ring can open to provide further functionality. Furfural requires a co-reactant like urea to polymerize. It also is multifunctional and produces a similar polymer to FA.

Soaking in furfuryl alcohol or furfural causes wood to swell. Some of the swelling remains after curing. Furfurylated wood also has reduced hygroscopicity. So furfurylated wood is permanently more dimensionally stable than untreated wood.

Conventional full cell pressure treating cycles are used for the impregnation part of furfurylated wood production. The mechanism for controlling loading is the concentration of FA in a water treating solution.

The water-based treating solution penetrates easily-penetrated woods, like southern yellow pine, well. It penetrates moderately refractory woods, like Scots pine, somewhat less uniformly but with generally useful penetration. Refractory woods and heartwood is penetrated poorly or not at all.

Curing takes place at elevated temperatures, usually in the range of conventional kiln drying. Typically, drying and curing are carried out as an integrated process in a single chamber.

Treating and fire-retardant compounds like borax can be dissolved in the furfurylated wood treating solution. They are then carried into the wood with the solution. After polymerization they are resistant to leaching.

Recent advances in furfurylation technology have allowed lower, controlled levels of loading. This makes the product more wood-like and allows properties to be adjusted to requirements. Its density slightly increases, it has a light brown color, but it looks and feels like wood rather than plastic. The main attractive feature is resistance to deterioration by fungi, termites and marine borers.

The mechanisms that cause resistance to deterioration appear to be chemical grafting and crosslinking which prevent deterioration organisms from recognizing the material as wood or using it for food. It is essentially a biologically inert material . Since the furfuryl alcohol is polymerized to a solid, insoluble polymer, there is little to leach out into the environment. It has been found that water leachate from furfurylated wood is not toxic. Air-borne volatiles are below safe levels and are reduced quickly over time. Furfurylated wood is non-toxic and has been treated by the US EPA and the European Union as non-biocidal wood protection.

Furfurylated wood combustion products are similar to those of wood, so the material can be burned for disposal under the same conditions as wood.

With all these attributes, why has furfurylated wood not been more widely used in situations susceptible to decay and other biodeterioration? There are probably several reasons:

- Salt preservatives are cheaper and can be used at lower levels
- Furfurylation requires a heat curing step after impregnation
- Until recently, the only furfurylation technology available produced high loading that changed wood properties dramatically and made it more like plastic
- Useful furfurylation technologies are fairly new and are sufficiently different from conventional preservative technologies to not be embraced quickly by the preservation industry

Recent developments that have made furfurylation more practical and attractive as a method of protecting wood include:

- Furfurylation level (retention) can be controlled to match requirements
- Process and chemical formulation parameters that produce quality product have been developed
- Results of many performance and environmental influence tests on the material are available
- Certifying agencies in Europe and the USA have or will soon accept the material
- A pilot and small commercial plant producing and selling decking and other outdoor wood product has been in operation since 2003.
- A small commercial production facility making highly-loaded flooring material has been operating since 1997.
- A larger production plant is designed and construction began this year, for startup in 2008.

Test results show the following about furfurylated wood properties (Lande, Westin & Schneider 2004), (Lande & Westin 2004):

- Decay resistance test results ongoing for 9 years show that moderate levels (30% to 35% WPG or about 100kg/cu m or 6 lb/cu ft retention) furfurylated wood has comparable resistance to CCA
- Marine borer samples treated to 30% and 50% WPG (about 100kg/cu m to 150kg/cu m or 6 lb/cu ft to 9 lb/cu ft retention for 500kg/cu m or 32 lb/cu ft density wood) were sound after 5 years exposure and performed equally to CCA
- Furfurylated wood is resistant to subterranean and Formosan termites
- Relationships between loading (retention) and protection levels for several organisms and use conditions have been determined
- Tests have shown that leachate from furfurylated wood is non-toxic
- Tests have shown that furfurylated wood combustion products are virtually the same as those from wood
- Combustibility tests have shown that furfurylated wood and untreated wood behave similarly in a fire
- Mechanical properties, except impact resistance, are enhanced when wood is furfurylated
- Mechanical properties and dimensional stability are related to loading levels

Wood furfurylation technology is protected by several patents filed by myself or jointly with my colleague, Jonathan Phillips. Two technologies for making furfurylated wood from furfuryl alcohol are being commercialized by a Norwegian company, Kebony ASA (formerly Wood Polymer Technologies ASA) (Kebony ASA 2007). They are:

- Highly-loaded, dark, hard furfurylated wood currently used for flooring that simulates tropical hardwood but does not fade as much

- More lightly-loaded furfurylated wood currently used as decking, siding, roofing and outdoor furniture

Also, Kebony ASA has two other patented wood-improvement technologies. Ties made using these technologies are in test railway tracks around the world:

- Styrene impregnated timber with high mechanical properties and decay resistance
- Styrene-furfurylated wood with high mechanical properties and superior decay resistance

Two technologies for making furfurylated wood from furfural are currently being commercialized by a New Brunswick company, Infinity Wood Ltd. These technologies produce material similar to the highly-loaded and the more lightly-loaded furfuryl alcohol technologies but use cheaper chemicals that penetrate refractory wood better.

A new generation of shell-loaded polymer modified wood is being developed by Infinity Wood Ltd. Loadings are restricted to the shell zone ranging from fractions of a millimeter to several millimeters deep. Penetration can be controlled by the formulation, process variables and wood type. A surface-reinforced material is produced. Hardness, paint-holding and weatherability can be improved. The treated shell is resistant to biodeterioration. Continuous process equipment is in the design stage.

4. Conclusions

Furfurylated wood for general use in harsh environments is a relatively new material. However, there are now several years of test results available. There is also commercial experience producing it. Its properties are attractive and it should soon become a well-known and widely-used material. There are now several variations on the technology and more are being developed. This shows that furfurylation is an adaptable technology that will evolve as requirements change.

There is a new generation of treated wood in development that will have a treated shell only and that can be made in a continuous process.

5. References

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