Mississippi Forest Products Laboratory
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Wood Composites are Enhancing Our Quality of Life

In the past decade the availability, size and quality of trees used for manufacturing wood products have declined significantly. This change has resulted in a substantial increase in the use of glued-wood composite materials such as oriented-strand board (OSB–flakes or strands of wood arranged so as to add greater strength), particle board, fiber board and veneer board products. The trends were recognized early on by scientists at the Mississippi Forest Products Laboratory (MFPL) and a series of research projects has been carried out to address the major issues concerning composite wood products.

This research has resulted in:

* use of natural products as a partial substitute for petroleum-based phenol in adhesives;
* development of new fillers for plywood adhesives;
* widespread use of under-utilized wood species in composite products; and
* an understanding of the adverse effects of some adhesives that influence the performance of wood products

These developments have had a significant impact on the Mississippi composite and laminated products industry and they result in annual savings of several million dollars each year.

Adhesives from Renewable Resources

Up to the 1930's all adhesives were natural products. More recently, synthetic resins from petrochemicals have become the predominant binders for wood composites. Since the United States imports the bulk of its oil, it would be desirable to find domestic substitutes, preferably from renewable resources. One possible source of feedstock for adhesives is lignin. Since lignin is a by-product of the pulping and other wood-processing industries, it is

Professor Terry Sellers (c) discusses a laminated wood product and its properties with Mississippi Legislators touring the Forest Products Laboratory

a readily available renewable resource.

The first breakthrough came in 1981 when scientists at the Mississippi Forest Products Laboratory and the Masonite Corporation developed a method for using a lignin-based waste product from Masonite's steam explosion process (and other processes) as a partial substitute for phenol in the synthetic phenol-formaldehyde binder. This development not only resulted in annual savings in excess of $1 million, but also added value to a waste product. (Note: Masonite decided to use lignin from sulfite-pulping liquor instead of their own steam-explosion lignin.)

Additional research has shown that other lignin by-products are suitable substitutes for phenol. Dr. Terry Sellers, Jr. recently investigated the possibility of using lignin from an organic solvent pulping process. The results were extremely good and showed that up to 40 percent of the phenol in a phenol-formaldehyde adhesive could be replaced by this lignin waste.

Recently, it was demonstrated by Dr. Sellers and Dr. Moon Kim that the lignin from waste newspapers was satisfactory as a partial substitute for phenol in phenol-formaldehyde binders. This work was carried out as a cooperative project with the Tennessee Valley Authority utilizing the residue from its acid hydrolysis process, which produces sugars and ethanol from waste newspapers. Up to 35 percent of the phenol can be replaced by this lignin.

These studies clearly demonstrate that a substantial amount of the petroleum-based phenol in phenol-formaldehyde adhesives can be replaced by renewable resources.

Under-Utilized Wood

Trees around the world, including those in Mississippi, are being grown and used more quickly for faster return on investment. This means, of course, that trees are not allowed to grow so large. But the more rapid use increases the amount of wood fiber from that usually produced on an acre. The smaller stem wood, especially numerous kinds of hardwoods, must be cut and used for paper manufacture or glued-wood composites. An officer of the American Plywood Association, which recently changed its name to The Engineered Wood Association, remarked that the MFPL study on under-utilized hardwoods "...was the most important work ever conducted for the Plywood Research Foundation" (subsidiary of APA).

This research showed the suitability of an array of medium- and low-density hardwoods for veneer products such as structural plywood and parallel-laminated veneer lumber. That wasn't all: the information was transferrable to the more recent introduction of structural-oriented strandboard products, which use an even wider number of hardwood species in combination with southern pines. This research has further helped forest owners recover greater value from their timber resources.

About half of a tree can be converted to lumber, or some 70 percent can be used in veneer products. But up to 90 percent can be made into strandboards (or flakeboards as they are generally termed). Today, wood residues from lumber and veneer production
are used to make paper and wood composite products, and the tree bark typically is burned to provide energy for the mill or is used as mulch

Problems and Potential of Nutshells

What's in a nutshell would surprise most people who don't know much about the makeup of this product. Most wood is very porous, with void distances

greater than the polymers used to bind or coat them.

"Without fillers to block these voids, the wood would take up great amounts of adhesives," says Sellers, who is an MFPL expert on wood composites. "To keep adhesives and coatings on the surface of the wood substrates as they are being made into wood products, various fillers are added.

"Fillers are the materials in a multi-million dollar business which affect multi-billion dollar products of trade. The research of the MFPL on adhesive fillers such as nutshells has helped develop new products, reduce filler shortages and demonstrate the characteristics of fillers."

One company (Agrashell, Inc.) wrote the MFPL: "You previously did some extensive work for us as we were developing a new (nutshell filler) product to service the southern pine plywood market. The product is now well established and accepted in the marketplace." This company's filler processing plant is operating at capacity and selling products in Mississippi and throughout the western United States. The use of nutshells as filler also puts another value-added product on the list of residues that have historically been under-utilized.

The Dynamics of Tool Wear

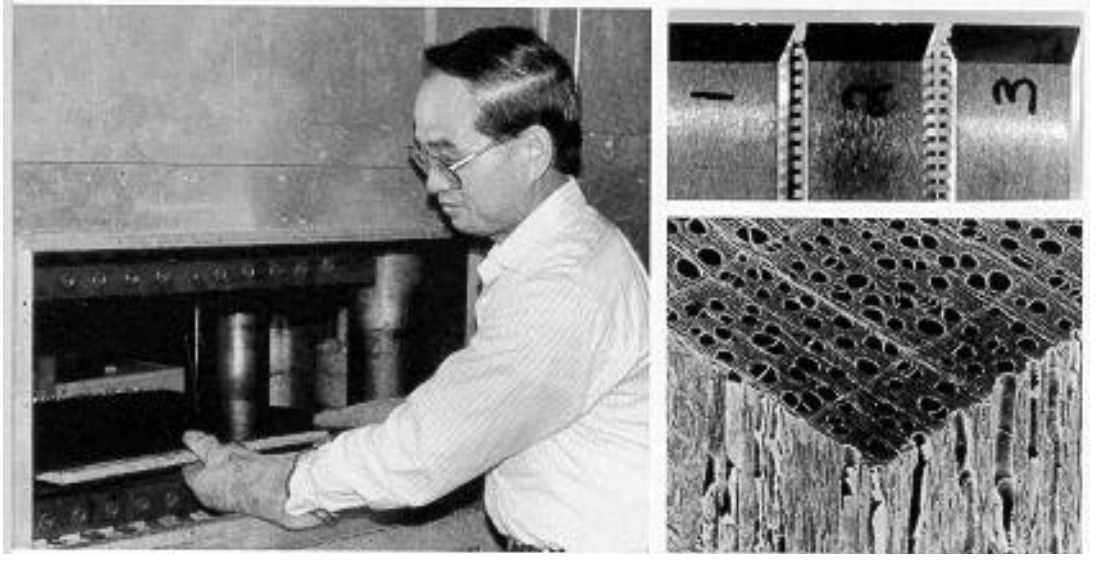
When wood-cutting tools and wood surfaces are in close contact, temperatures and pressure forces are involved; these result in tool wear and possible wood-surface changes. Research to find the causes of tool wear and ways of reducing it go on constantly at the MFPL. This research is especially important in processing wood composites into furniture and other items.

The research involves not only the wood in wood composites, but other materials, too-chemical binders and other additives, such as fillers, waxes and catalysts which are part of the bonded products. Fillers may be made from nutshell flours, agricultural chemical-process residues or inorganic minerals and clays. Research at the MFPL has shown which sources of materials cause the greatest wear of tools made of different metals. So, higher quality fillers have been promoted and wood-shaping tools with improved metals have been developed. These developments have already reduced the machining costs in wood manufacturing significantly. It is anticipated that further implementation of this technology will save the industry several million dollars annually.

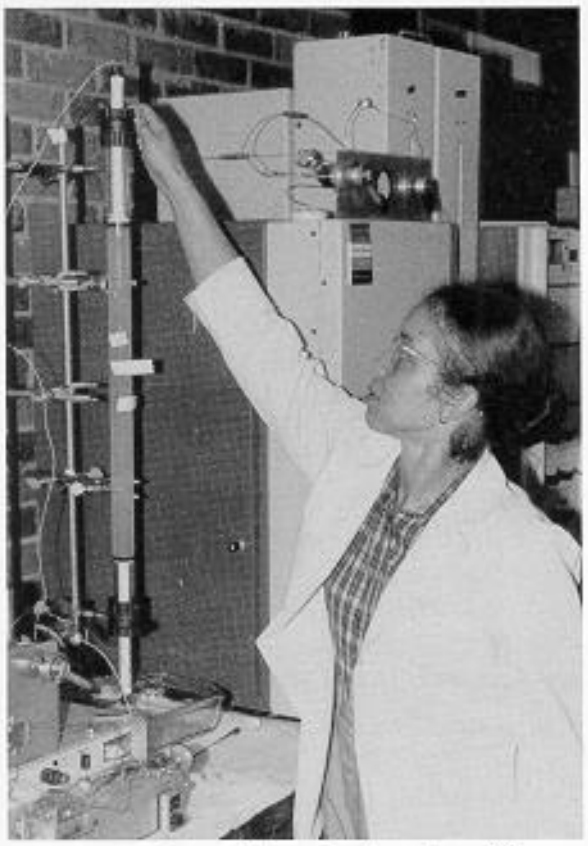
Important Molecules

For over 75 years, the thermosetting phenol-formaldehyde (PF) polymers have been of considerable commercial importance for bonding exterior-type wood composites. Today, in excess of 1.5 billion pounds of these resin adhesives (liquid form) are used to bond wood composites, including structural plywood and oriented strandboard.

A chromatography (fingerprint) procedure developed for determining the molecular characteristics of the PF resin and phenolic-like natural compounds such as lignin (from wood) and tannin (from tree bark) has been developed by the MFPL. The technique is useful to researchers and to industrial operations in Mississippi and elsewhere for comparative evaluation of similar resin adhesives, of potential adhesive raw materials and of production audits. Eventual correlation of molecular data of resin adhesives to end-use performance of bonded wood composites is a likely goal.



Dr. Moon Kim removing composite panel bonded with an adhesive containing lignin from whole newspapers (l). Different adhesive fillers wear tools differently (top r). Red maple at 75 times (bottom r) is shown to be very porous.



Research Associate determines "fingerprint" by chromatography of an adhesive.

Sellers with his Plywood and Adhesive Technology book; other works are nearby.

Turning Out Future Employees

Any review of the role of the MFPL at Mississippi State University would be incomplete without a mention of preparing students as future employees of industry, government and academia. Some students specialize in researching adhesives for wood composites. These graduates have made successful contributions to such resin-adhesive companies as Borden Packaging and Industrial Products, Dyno Industries, Franklin International, Georgia Pacific Resins and Southeastern Adhesives. Their work on behalf of industries involves various types of adhesive, including vinyls, ureas, melamines, phenolics and natural polymers. Some graduates are now professors in academic institutions in various parts of the United States and in other countries. Other graduates who studied specific subjects dealing with wood composites are now technical directors, marketing specialists, operational researchers and managers of wood composite operations in Mississippi and the nation.

Information Transfer

The MFPL is an internationally known center for wood technology. It has achieved this recognition by addressing state and national research priorities in the field, producing usable results and communicating these results in books, bulletins, articles and presentations. Dr. Sellers has authored a materials science book on Plywood and Adhesive Technology. Laboratory personnel researching composites have also produced a USDA Forest Service Bulletin on Gluing Eastern Hardwoods and more than 50 articles on research results on various aspects of composites. Scores of invited presentations have been made on these subjects at conferences and seminars. Most publications were written in standard international metric as well as English units of measure to help address the increasing importance of the international market.

A Billion Dollar Market

About 60 percent of the state of Mississippi is covered with woodlands. The timber and value-added wood products in Mississippi comprise a multi-billion dollar market. As trees are harvested in a faster rotation, the importance of wood composites and their attendant adhesive hinders increases. In 1994, there were more than 30 wood composite mills in Mississippi. Two resin-adhesive plants in the state and several more in nearby states support the binder needs of these composite mills in Mississippi. The billion-dollar furniture industry in the state is increasing its use of wood composites, and some composite mills are exporting 15-60 percent of their value-added products to other countries. The MFPL is continuing its research in wood composites to sustain the state's forests and their supply of products to provide continuing quality of life for its citizens, both materially and environmentally.