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Development of New Microwave-Drying and Straightening Technology for Low-Value Curved Timber

National Fire Plan Research Program USDA Forest Service

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Abstract

A considerable amount of small-diameter, branched, or curved timber is currently left standing, bucked and left on the ground, chipped, or burned after logging or thinning operations. Most North American mills are not equipped to handle this low-value material. In many areas of the western United States, such forest residue does not decompose and becomes susceptible to forest insects or disease, especially if the material is partially damaged or injured during logging. The USDA Forest Service Forest Products Laboratory is conducting a comprehensive research program to add value to biomass derived from small-diameter, branched, and curved timber. This paper describes the development of new microwave-drying and straightening technology.

Keywords: wood-based, structural, small-diameter, forest fuel, fuel reduction, composite, thermal softening, microwave heating.

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Development of New Microwave-Drying and Straightening Technology for Low-Value Curved Timber

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Introduction

"Whole site" forest management promotes sustainable forests and reduces insect infestation, disease, and forest fires. Utilization research at the Forest Products Laboratory (FPL), funded under the USDA Forest Service National Fire Plan (Hunt 2000), is developing economically viable processes and products that can utilize small-diameter timber, forest undergrowth, and whole tree trimmings from logging operations. The overall goal of this project is to help maintain healthy and sustainable forests by developing uses for low- or no-value curved and cull small-diameter trees (Hunt and Winandy 2002). Several technologies are being combined to determine if this material can be used for value-added structural products (Hunt and Winandy 2002, 2003). Economical options for low-value material encourage rural development and reduce costs to the Federal government in terms of improved forest ecosystem health and mitigation of fire risk.

This paper describes recently developed technology for microwave-drying and straightening of curved lumber (Fig. 1). At this time, the laboratory-scale technology processes one board at a time. However, larger machines with greater capacity seem plausible given the development of a fundamental understanding of the critical physical and engineering concepts involved in this new process.

Figure 1—Low-value curved wood from thinned stand: (a) small-diameter curved and cull material left after logging; (b) curved material removed from woods for project. Curvature and cull features render trees valueless for standard sawing practices.

Background

In living trees, warp is primarily caused by compression wood in softwood and tension wood in hardwood. In lumber, warp takes four forms: bow, crook, cup, and twist. Bow is defined as a deviation flatwise from a straight line drawn from end to end of a piece (Fig. 2a). Crook is a deviation edgewise from a straight line drawn from end to end of a piece (Fig. 2b) (Southern Pine Inspection Bureau 1977).

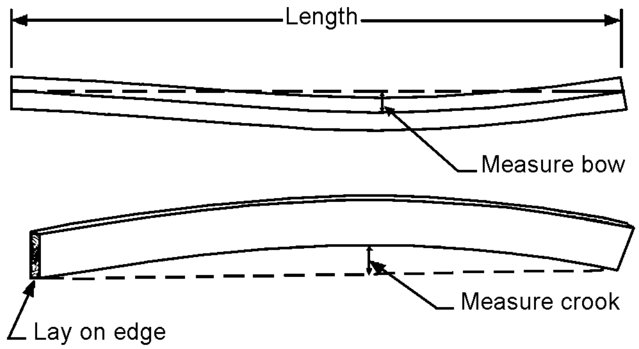

Figure 2—Schematic of bow and crook measurement.

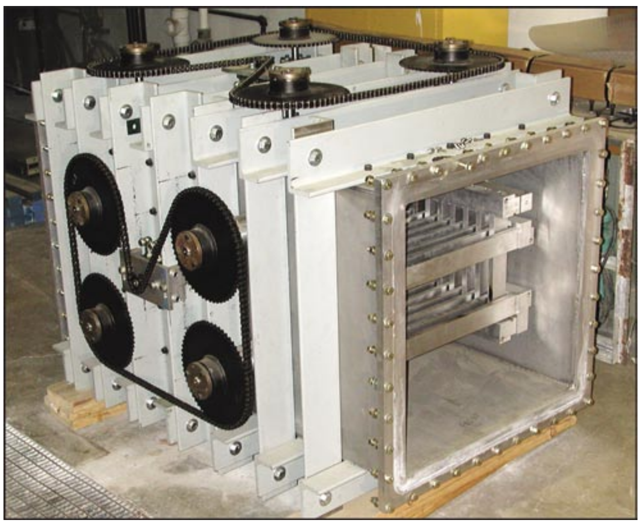

Figure 3—Internal view of microwave drying chamber showing pressing bars used to straighten and hold curved lumber during drying.

One FPL project involves the utilization of small-diameter, bowed timber in laminated structural lumber by developing new sawing, drying, straightening, and laminating processes (Hunt and Winandy 2003). Current research is exploring alternative methods to reduce the curved shape of cut boards through the use of microwave heating and longitudinal compressive clamping during drying. We are developing a prototype microwave press-dryer (Fig. 3), with both integrated compressive restraint and microwave heating, capable of straightening curved sawn lumber during the drying process. While research and development work is ongoing, advancements in microwave drying and straightening technology have already been achieved.

Objective

Our goal was to straighten the curved boards in the drying process using a newly developed microwave dryer and lumber straightener (Figs. 3 and 4). The objective of this paper is to document the recently developed equipment and show its capabilities.

Material and Methods

Several single-curved 102-mm- (4-in.-) thick lodgepole pine (*Pinus cortina*) slabs were shipped to FPL for microwave drying and straightening. Approximately 2.4-m- (8-ft-) long boards were curve-sawn green from the slabs and stored at 2°C (36°F), 82% relative humidity, for about 2 years before testing. The 2.4-m (8-ft) boards were cut into 1.2-m- (4-ft-) long boards before testing to fit the microwave dryer.

In this first series of microwave drying and straightening tests, we examined two parameters—initial heating temperature and pressing time—on the effect of straightening a 1.2-m- (4-ft-) long curved board. The experiment was designed with three levels for each parameter:

> **Temperature**—(1) No heating before pressing, (2) heating to 98°C (208°F) by microwaves before pressing, and (3) heating to 140°C (284°F) by microwaves in a pressurized chamber before pressing.
>
> **Pressing time**—5 s, 5 min, and 15 min.

Boards were pressure soaked with water before testing to bring moisture content to near fully saturated conditions. We also subjected a dry board to a combined heating and pressing schedule to explore more efficient and effective ways for straightening.

Results and Discussion

Both heating temperature and pressing time had significant effects on straightening of the boards. The higher initial heating temperature and longer pressing times resulted in

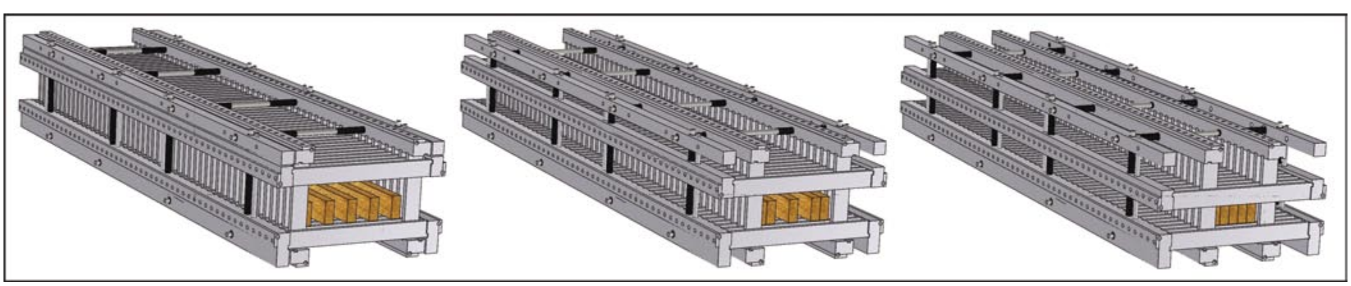

Figure 4—Drying chamber pressing bars in three positions: (left to right) open, half closed, and closed.

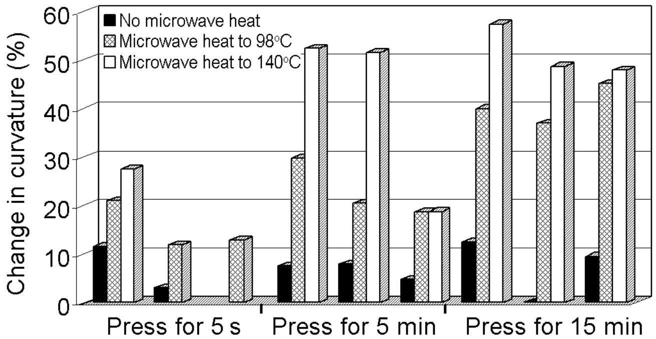

Figure 5—Deflection change in curvature under different heating and pressing conditions.

better straightening. Figure 5 shows changes in curvature with different heating temperatures and pressing times. Three samples were tested for each conditioning, except for the 5-s press, where fewer replicates were used. Microwave heating a board to a high temperature may thermally plasticize wood components, such as lignin and hemicellulose, causing these components to "flow" and the material to be easily pressed into the desired shape. Pressing for a longer time provides a chance for the thermally softened lignin and hemicellulose to cool and set while in the straightened form.

Figures 6 and 7 show test boards processed by two different microwave heating and pressing approaches. Compressive pressing without microwave heating had virtually no effect on straightening the lumber (Fig. 6). In contrast, initial heating to a high temperature, followed by compressive pressing, was effective in reducing the curvature (Fig. 7).

The result of processing a dry board (8% moisture content) by a combined heating and pressing schedule were impressive (Fig. 8b). After removal from the microwave chamber, the straightened specimen was exposed on a laboratory workbench for about 48 h at approximately 20°C (68°F) and 25% to 35% relative humidity. The specimen remained straight, as shown in Fig. 8c; visual examination revealed no damage (e.g., cracking or splitting) of the board.

Figure 6—Effect of compressive pressing (15 min) without initial microwave heating on bow of 1.2-m- (4-ft-) long board with 6.5% initial bow: (a) before pressing; (b) immediately after removal from microwave chamber. Board showed virtually no reduction in bow.

Figure 7—Effect of initial microwave heating to 140°C (284°F) in pressurized chamber and subsequent compressive pressing for 15 min on bow of 1.2-m- (4-ft-) long board with 7.5% initial bow: (a) before microwave heating; (b) immediately after removal from microwave chamber. Board showed approximately 50% reduction in bow.

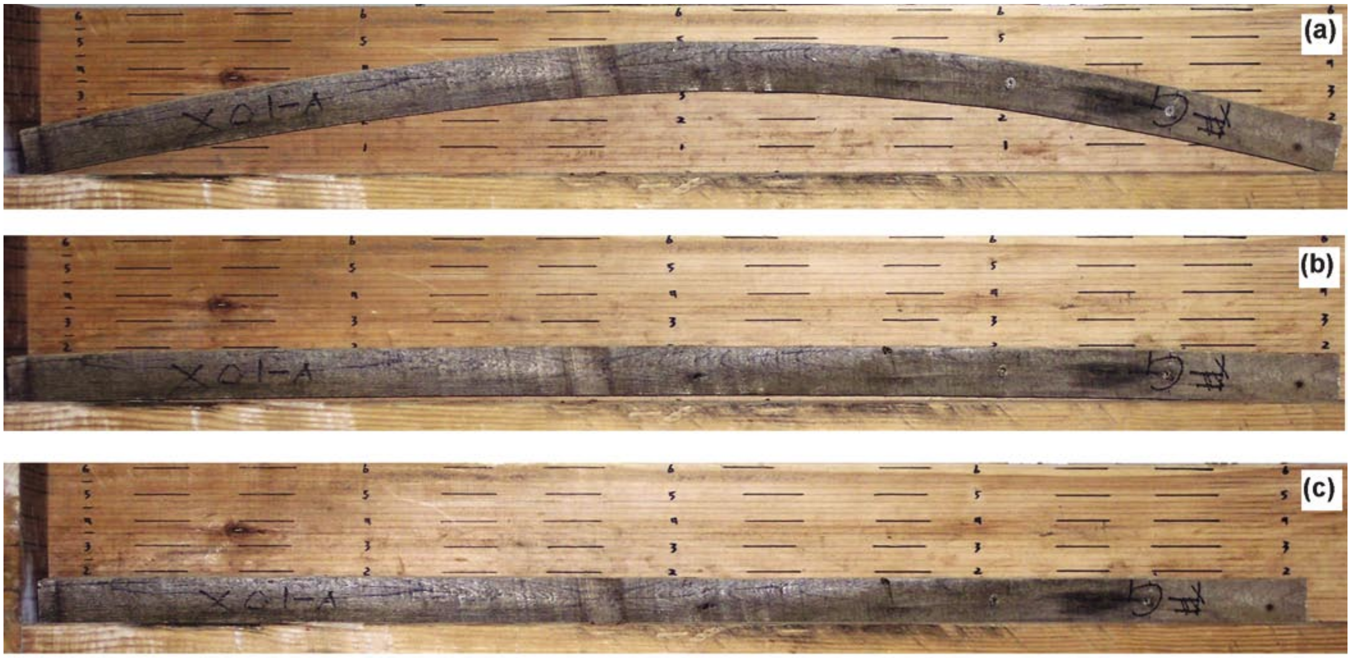

Figure 8—Effect of microwave heating and compressive pressing on bow of 1.2-m- (4-ft-) long board with approximately 10% initial bow: (a) before microwave pressing; (b) immediately after heating at 150°C (302°F), holding at 150°C (302°F) for 5 min, pressing with continued microwave heating for another 10 min, and cooling for 15 min in closed platen; (c) after 48 h exposure to 20°C (68°F), 25%–35% relative humidity environment.

We will formally test the schedule used for the dry board in our next series of experiments with green boards.

- Microwave heat lumber to approximately 150°C (302°F).
- Hold temperature for 10 min.
- Apply closed internal two-dimensional pressure (i.e., straightening) platens within press and continue microwave heating for an additional 10 min.
- Turn off heat and keep pressure platens closed for an additional 15 min.
- Open press and remove lumber from chamber.

Concluding Remarks

Although this research requires significant development, some economic and utilitarian value can clearly be recouped for low-grade curved lumber. Government and industrial partners are working in cooperation to assess the engineering and economic feasibility of new microwave-drying and straightening technology for processing curved and cull material for structural applications. The Forest Products Laboratory is directing the research to fully develop this new microwave drying and straightening technology. Future work will evaluate the potential for removing bow, crook, and possibly twist.

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