MAINTAINING LUMBER QUALITY IN PRESS DRYING BY MANIPULATING SAWING PATTERNS[1]

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ABSTRACT

Lumber is traditionally dried in kilns by processes that often take several weeks to complete. Considerable research has been conducted on more rapid processes. Press drying can dry common 25-mm-thick lumber in 1 to 2 hours instead of several weeks. However, little success has been achieved with this technique because intolerable drying defects usually accompany such rapid drying. This paper reports on a press-drying technique that offers considerable promise in avoiding honeycomb that usually develops. In this technique the sawing pattern of boards from logs is changed from the usual flatsawn pattern to quartersawn. The honeycomb that usually develops occurs at interfaces of ray tissue and the surrounding tissue and is caused by internal tensile forces that develop during drying. With flatsawn boards the wide face, which makes contact with the platens during drying, is parallel with the critical internal tensile forces. By using a quartersawn pattern, the direction of the critical internal tensile forces is effectively rotated by 90 degrees. The critical internal tension is then perpendicular to the wide face of the board.

The hypothesis of the study was that the compressive pressure of the press therefore opposes the internal stresses and prevents honeycomb. In this study honeycomb in press-dried quartersawn red oak was significantly less than in press-dried flatsawn red oak. Small compressive forces of the platens were less effective than large forces in reducing honeycomb in quartersawn oak, thus verifying the hypothesis.

Keywords: Drying, press drying, high-temperature drying, rapid drying, oak, drying defects, honeycomb.

INTRODUCTION

This paper is a report on a recent development that appears to allow rapid drying with a minimum of structural damage.

Wood as formed in living trees has moisture contents ranging from 40 to over 100% (dry basis). For most end uses, lumber must be dried to 6 to 15% moisture content to perform satisfactorily in service. Lumber is usually dried commercially in batch processes in dry kilns that may hold from 75 to 250 m^3. It is usually dried by proven schedules of temperature and relative humidity that vary with species of wood and lumber thickness. The temperatures and relative humidities are changed throughout the drying process according to moisture content level and represent empirically determined compromises between drying as rapidly as possible, but not so rapidly as to cause structural damage. This sensitivity to structural damage has prevented the acceptance of rapid drying processes (usually requiring high drying temperatures where wood becomes weaker) that could reduce drying time from days or weeks to only 1 to 2 hours.

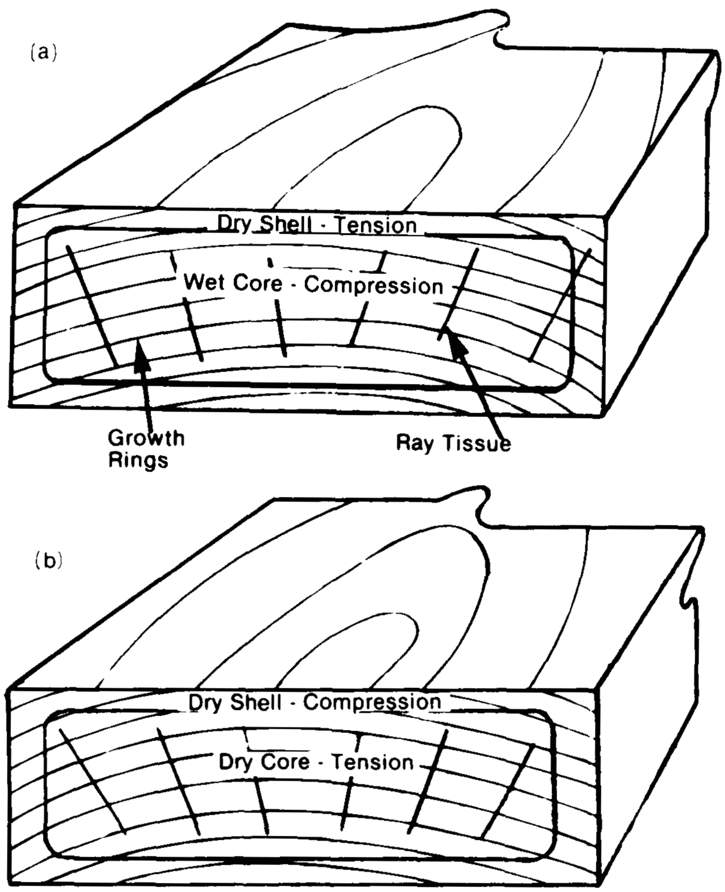

FIG. 1. End view of board showing development of drying stresses early in drying (a) and later in drying (b).

DRYING DEFECTS

Drying defects from structural failure can be traced to either differential shrinkage, stresses caused by liquid tension forces, or both. Differential shrinkage between the shell and core of lumber during drying results when the outer fibers in the shell dry and attempt to shrink. However, the core has not yet begun to dry or shrink, and consequently the shell is restrained from shrinking by the core. The shell thus goes into tension and the core into compression (Fig. 1a). If drying in the shell progresses too rapidly, it is stretched beyond the elastic limit and dries in a permanently stretched condition without attaining full shrinkage. Sometimes surface fractures occur during this stage of drying. As drying progresses, the core begins to dry and attempts to shrink. However, the shell is set in a permanently expanded condition and prevents normal shrinkage in the core. This causes the stresses to reverse—the core goes into tension and the shell into compression (Fig. 1b). The internal tension stresses may be severe enough to cause or contribute to internal fractures commonly termed honeycomb. Honeycomb can occur in conventional kiln-drying as well as in the more rapid drying processes.

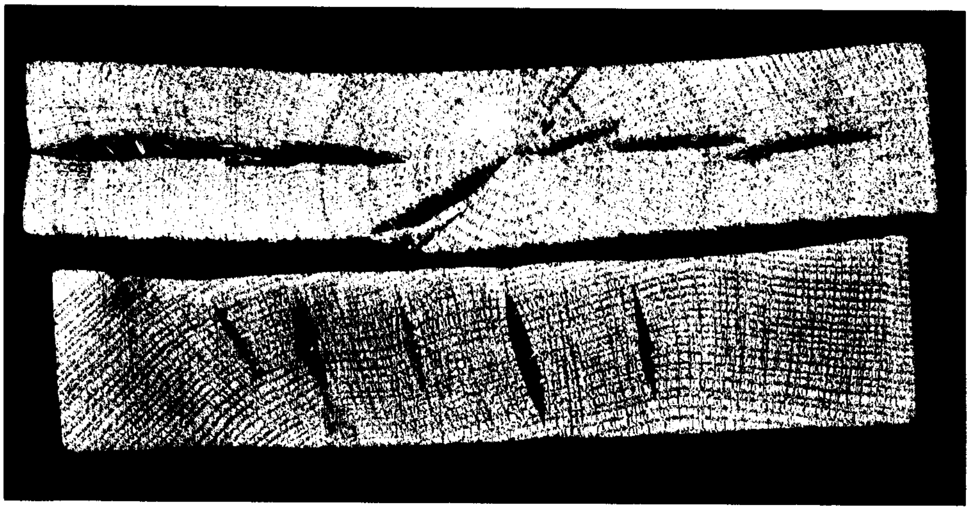

FIG. 2. Collapse and orientation of honeycomb fractures in quartersawn (top) and flatsawn (bottom) lumber.

Liquid tension forces lead to a drying defect known as collapse, and also contribute and may even be a major cause of honeycomb. Some of the cells of wood contain both air bubbles and water in the lumens and some contain only water. Liquid tension is set up in these cell lumens according to the capillary pressure equation:

$$p_o - p = 2\sigma/r \quad (1)$$

where
p_o = air pressure,
p = liquid pressure,
σ = surface tension of liquid, and
r = radius of air-water interface.

When a cell lumen contains no air bubbles, the air-water interface becomes the pit openings in cell walls. As evaporation progresses from the menisci of these pits, large tension forces develop according to Eq. (1) and pull inward on the cell walls, collapsing them and often causing honeycomb. Both honeycomb and collapse are illustrated in Fig. 2.

PAST RESEARCH IN RAPID DRYING

High frequency electrical energy, hot presses, and jet impingement drying have all been used in research on rapid drying processes. Schmidt (1967) press dried 25-mm-thick European beech from 80% moisture content to 7% at temperatures of 150 to 170 C in 1 to 2 hours. As long as tyloses were not present, the beech blanks were free from drying defects. Hittmeier et al. (1968) press dried nine hardwood species at 170 C platen temperature to 6% moisture content in from 20 to 200 minutes, depending on thickness (12 or 25 mm) and species. All species showed drying defects, ranging from minor for some of the lower density hardwoods 12 mm thick, to major for the higher density hardwoods 25 mm thick.

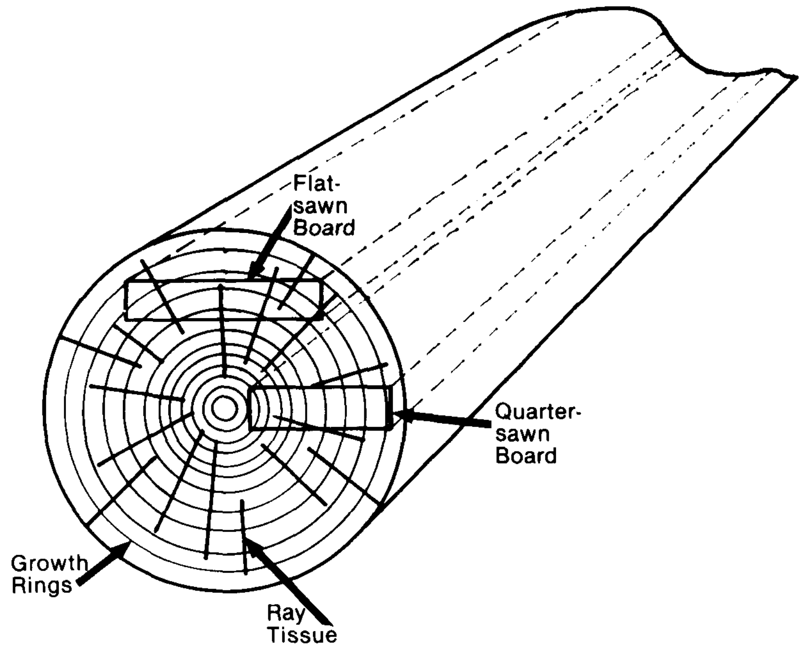

FIG. 3. Cross-sectional schematic of a log showing orientation of flat- and quartersawn lumber to growth rings and ray tissue.

Haygreen and Turkia (1968) press dried aspen and paper birch at 170 C in from 80 to 130 minutes and noted major defects in aspen heartwood. Quality of the paper birch was apparently acceptable. Wang and Beall (1975) press dried small 150-mm squares of red oak and noted moderate honeycombing and end checking. Chen (1978) press dried 25-mm-thick walnut and noted the presence of honeycomb. Alternating ambient air drying with press drying significantly reduced the occurrence of honeycomb but extended the drying time and did not completely eliminate honeycomb. Chen and Biltonen (1979) showed that prefreezing reduced but did not eliminate honeycomb in press-dried walnut. Chen (1980) did further press-drying work on American beech and yellow-poplar (12 and 25 mm thick × 100 mm × 254 mm) and found no occurrence of honeycomb. Rosen and Bodkin (1978) jet dried 25- and 50-mm-thick silver maple at air temperatures ranging from 107 to 204 C and air velocities of from 5 to 45 m/s. Drying times ranged from 1.2 to 37 hours. Honeycomb was present and severe in all 50-mm boards. It was less severe in 25-mm boards, but still present in 25 to 40% of the boards. Ward and Anderson (1964) reported complete freedom from any defects in drying 25-mm-thick red oak in 15 minutes by high-frequency electrical energy. Simpson (1980) found severe honeycomb and surface checking in high-frequency drying 25-mm-thick red oak.

SAWING PATTERN AND RAPID DRYING

How lumber is sawn from logs and how some of the key anatomical features of wood relate to sawing patterns are critical to defect development in lumber during drying. Figure 3 shows a cross section of a log and the two common sawing

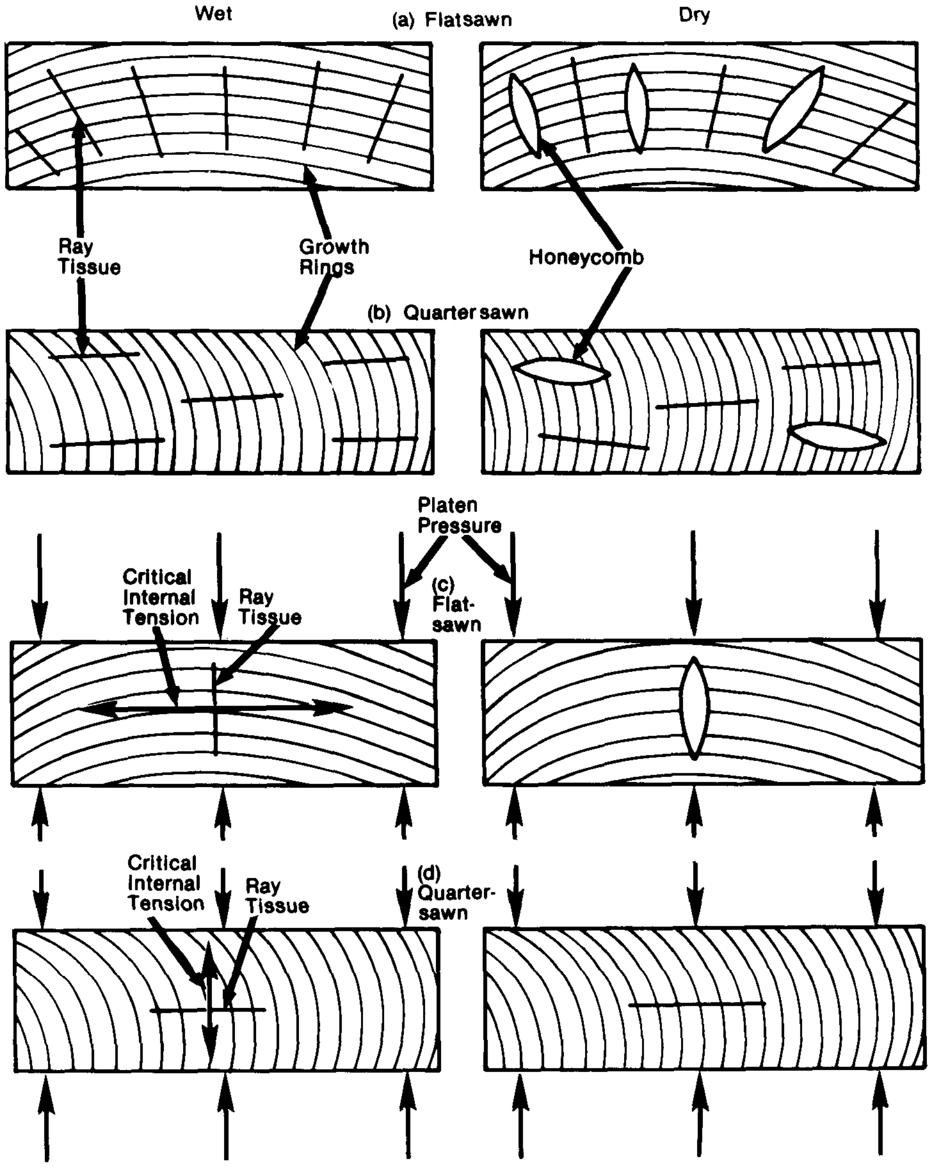

FIG. 4. Schematics showing how honeycomb can be avoided in press drying by manipulating sawing pattern: flatsawn board developing honeycomb (a), quartersawn board developing honeycomb (b), press-dried flatsawn board developing honeycomb (c), press-dried quartersawn board free of honeycomb (d).

patterns (flat- and quartersawn). Because of processing and yield efficiencies, most lumber is flatsawn, i.e., the growth rings are parallel to the wide face of the board and the ray tissue is perpendicular to the wide face. The less common sawing pattern produces quartersawn lumber where the growth rings are perpendicular to the wide face of the board and the ray tissue is parallel to the wide face.

Honeycomb fractures usually occur in ray tissue or at the interface of ray tissue