DEFECT REDUCTION IN LOW-VALUE WHITE OAK LUMBER USING RESTRAINED DRYING

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Abstract.—Increasing emphasis is being placed on alternative processing methods for low-value hardwoods. Extensive research has shown that drying softwood lumber using edge-wise restraint improves product and value yields. Currently, the effects of restraint drying on product and value yields from low-grade hardwood lumber have not been investigated. We evaluated the use of a modified restraint drying system on its potential to reduce bow, crook, twist, cup, and surface defects in low-grade white oak (*Quercus alba*) lumber. We found that the amount of crook was significantly lower in boards that were dried using pneumatic restraint versus those dried with top-loading only. These results suggest that restraint drying could help secondary processors increase yields and overall returns on low-grade lumber.

INTRODUCTION

In a recent survey of hardwood industry priorities, firms in West Virginia indicated that more research was needed on potential new products and processing technologies that use lower grade logs and lumber (Milauskas and others 2005). Many barriers limit the increased use of this resource. One significant obstacle is the difficulties related to drying low-grade lumber. The presence of high proportions of juvenile and mixtures of flat- and edge-grained wood can increase the tendency of warp during the drying process (Bowyer and others 2003). One of the main components of warpage is crook, which can reduce primary yields (Gatchell 1990). Lumber sawn from small-diameter logs also tends to be shorter in length. The tendency for oak to display crook after drying has been found to be greater for shorter length lumber (Wiedenbeck and others 2003). Furthermore, oak species are more susceptible to drying defects due to their refractory nature and the occurrence of large ray cells (Bowyer and others 2003).

Research has shown that adding weight to the top of a stack of lumber is an effective way to control warp during drying (Denig and others 2000). Top loading can reduce bow and twist, but is less effective at reducing crook (Simpson 1991). Recent research on edgewise restraint drying has shown promise for limiting drying defects in pine lumber (Erickson and Shmulsky 2005, Shmulsky and Butler 2005, Shmulsky and others 2005). Warp reduction was found to be significantly less in boards dried using the restraint system. While these results are promising, the effects of edge-wise restraint on reducing drying defects in hardwood lumber have not been investigated. The objective of this study is to determine the efficacy of using edge-wise restraint to reduce drying defects of low-grade hardwood lumber.

METHODS

Green, low-grade (No. 3 Common) white oak 4/4 lumber was obtained from a local sawmill in West Virginia. At delivery, the majority of this lumber was approximately 6 inches in width and 10 feet long. The lumber was ripped to obtain a uniform width of 5.625 inches. Mostly defect-free 4-foot sections of lumber were then cross-cut from the ripped boards. A total of 140 board sections from approximately 70

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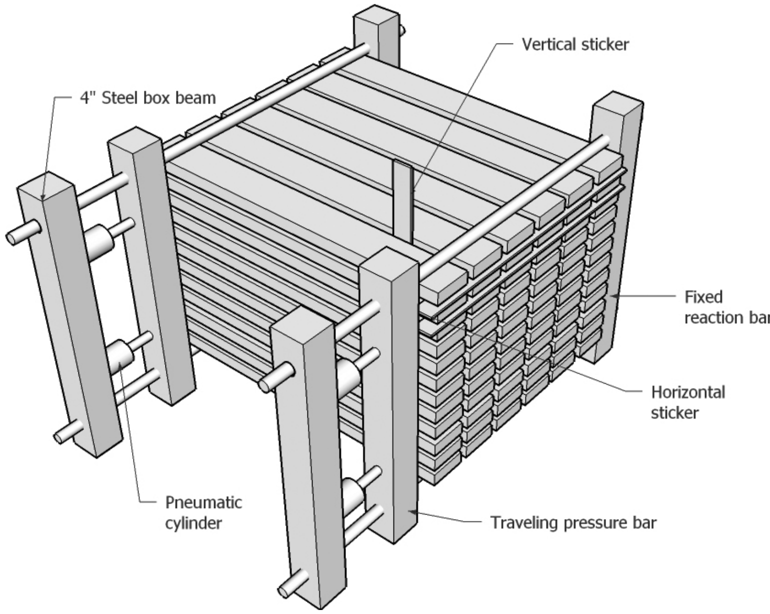

Figure 1.—Three-dimensional schematic of the edgewise restraint device used to assess the impact of restraint on the occurrence of drying defects.

boards were produced for this experiment. All board sections were enumerated and 70 were randomly selected for treatment and the remaining seventy were assigned to the reference group. Before drying, the extent of bow, crook, cup, twist, end-checks, and surface-checks were measured. Departure from the horizontal plane (crook, bow, and twist) was measured on a warp table, using a metal ruler and calibrated wedge. Measurements were recorded to the nearest 1/20 inch. Surface- and end-checks were measured to the nearest 0.125 inch using a metal ruler and/or caliper. The procedure used in this experiment to measure drying defects was modeled after Shmulsky and Butler (2005).

An edgewise restraint system similar to that used by Shmulsky and Butler (2005) was fabricated using a system of metal restraint and traveling bars powered by pneumatic cylinders (Fig 1). Boards were stacked 14 courses high in both the test and control charges. Horizontal stickers were placed on each end of each row, as well as at 12-inch spacings between ends. Because edgewise restraint would have forced the boards together, four sets of vertical ¼-inch x ¾-inch spacers were used uniformly along the length of the stack between each row of boards. The vertical spacers were used to separate the boards edgewise and to promote airflow through the reference and treatment lumber stacks.

Two sets of restraint bars applied a total compressive force of 1,962 pounds to the test charge. Pressure was applied near the end of the boards approximately 3.5 feet apart. This force provided sufficient edge-to-edge pressure to deter tangential movement of the boards during drying. The restraint-system is designed to continue applying equal pressure to the board edges as they shrink in width. The maximum metal-to-wood contact pressure was approximately 18 pounds per square inch. This pressure is far less than the crushing strength of white oak and therefore no damage occurred to the edges of the boards (Green and others 1999). Both charges received approximately 450 pounds (45 pounds/ft^2) of top weight. Sample boards were placed with the kiln charge so that moisture content could be measured (Simpson 1991). The charges were dried in a commercial dehumidification kiln following the moisture content steps recommended for white oak (Simpson 1991). When the average moisture content of the sample boards reached 8 percent, they were allowed to cool to room temperature and the edgewise pressure was released. Following drying and conditioning, we again measured the extent of bow, crook, cup, twist, end-checks, and surfaces-checks on the boards.

Table 1.—Total amount of bow, twist, crook, cup, and number of surface and end checks found in white oak lumber that was dried with and without restraint

	Measured Defect (Inches)	Pre-drying	Post-drying	Difference (Post-Pre)
Reference	Bow	0.15	2.18	2.03
	Twist	3.10	7.83	4.73
	Crook (in^2)	0.00	124.30	124.30
	Cup	0.00	3.03	3.03
	# Surface Checks	10.00	96.00	86.00
	# End Checks	4.00	80.00	76.00
Treatment	Bow	0.33	3.03	2.70
	Twist	2.25	9.13	6.88
	Crook (in^2)	3.72	68.39	64.67
	Cup	0.00	3.77	3.77
	# Surface Checks	3.00	87.00	84.00
	# End Checks	1.00	48.00	47.00

Boards were considered the experimental unit in this study. The following variables were used in the analyses to determine the effect of edgewise restraint on drying defects: bow, twist, crook, cup, average length of surface defects, total length of surface defects, average length of end defects, and total length of end defects. Crook was calculated by determining the triangular area using the maximum length and width of departure from the straight plane. The magnitude of each defect for each board before drying was subtracted from the corresponding measurement of defect after drying to construct the variables for analyses. This allowed us to ascertain the amount of defects due to drying alone. The Shapiro-Wilk test was used to assess the normality of the defect data. Because of the small sample size and the Poisson nature of the defect distributions, the Wilcoxon non-parametric two-sample test of mean dispersion was used in the analysis.

RESULTS AND DISCUSSION

The number and extent of defects was similar in the treatment and reference groups before drying (Table 1). After drying, large increases in the total amount of crook and end checks were noted in the reference group.

Erickson and Shmulsky (2005) and Shmulsky and Butler (2005) found significant reductions in crook, bow, and twist in edge-restrained pine lumber. Following a similar protocol, we found less crook in restrained white oak (0.95 vs. 1.77 square inches; p-value=0.004). Only 22 boards in the restraint dried sample exhibited crook, as compared to 38 boards in the reference group. We found no difference in the amount of twist or bow (Table 2).

Neither Erickson and Shmulsky (2005) nor Shmulsky and others (2005) investigated the effect of edgewise restraint on checking because this is not usually considered a problem when drying pine lumber. However, checking is one of the most common forms of defect in oak lumber. In our study, although not significant, there was weak evidence of an increase in the average total length of end checks in unrestrained versus restrained lumber (p-value=0.102)(Table 2). Further research on the effect of restraint placement on the distribution of surface- and end-checks in oak lumber may be warranted.

Table 2.—Average, with standard deviation in parenthesis, measurement of drying defects in boards dried with and without restraint. P-values generated from Wilcoxon two-sample rank sum test for comparison

Defect	Treatment (restrained)	Reference (unrestrained)	P-value
	-----------------------inches-----------------------		
Bow	0.04 (0.12)	0.03 (0.08)	0.6532
Twist	0.10 (0.14)	0.05 (0.14)	0.3750
Crook (in^2)	0.95 (2.53)	1.77 (2.65)	0.0043
Cup	0.05 (0.05)	0.04 (0.05)	0.2643
Average Length Surface Checks	0.75 (0.87)	0.53 (0.63)	0.1872
Total Length Surf Checks	1.56 (2.37)	1.37 (1.87)	0.5695
Average Length End Checks	0.49 (0.72)	0.66 (0.96)	0.2774
Total Length End Checks	0.89 (1.37)	1.57 (2.82)	0.1018

Drying-induced warp has the potential to significantly decrease yield in hardwood lumber (Gatchell 1990, Wiedenbeck and others 2003). We found that the use of edge-wise restraint during drying of white oak lumber has the potential to decrease the amount of crook, thereby increasing dimensional yields. This is an important finding since the single most important barrier sited among secondary wood processors for the increased use of low-grade lumber is low yield (Pohle and others 2002). Revised techniques for applying edgewise restraint during drying should be investigated since we found some evidence that checking could be reduced using these methods. Likewise, further research should be conducted to see if the use of edge-wise restraint could decrease drying degrade when using accelerated kiln schedules, when drying other species, and when drying higher grade white oak lumber.

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