ACCELERATING OAK DRYING BY PRESURFACING, ACCELERATED SCHEDULES, AND KILN AUTOMATION
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Abstract

Previous research has indicated that time savings can be obtained from presurfacing boards, accelerating schedules, and automating kilns. Northern red oak was dried according to various combinations of these processes. As a result of reduced drying times and minimal degrade observed in this study, further testing on a larger, semicommercial scale is justified.

Oak is probably the most important hardwood species in the United States. The oaks are also among the most difficult species to dry rapidly without degrade. Drying costs are therefore high, estimated to be between $30 to $50 per MBF. The U.S. Forest Products Laboratory has, during the past several years, been conducting research in many areas in order to reduce oak drying costs.

As a result of this research program, several possible methods of reducing degrade and costs for drying oak lumber were found in use or were developed:

(a) Presurfacing of rough lumber (6,12)\(^2,3\)
(b) Clamping or weighting the top courses of lumber (1,5,13,14)\(^3\)
(c) Accelerating conventional schedules (7,11)
(d) Improving air-drying practices (3,4,9,10)
(e) Automathg kiln drying (15)

\(^1\)Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
\(^2\)Underlined numbers in parentheses refer to Literature Cited at end of report.
\(^3\)Also observed at several drying operation in addition to the cited literature.

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Figure 1.—Three schedules used: T4-E2, C, and C smooth.
The purpose of the research reported here was to establish, on the basis of small kiln charges, what the time advantages would be in presurfacing, schedule accelerating, and kiln automating. This, in turn, would provide data to ascertain whether or not further research or pilot testing on a larger scale is worthwhile.

Procedure

Eight kiln charges of northern red oak were dried in a small kiln (15) using various combinations of rough or presurfaced lumber, conventional or accelerated schedules, and manual or automatic control (table 1). Capacity of the kiln was one thousand board feet (MBF).

Materials and Methods

Rough, random-width, flat-sawn, 4/4 lumber from a local tie mill was obtained for the study. To produce presurfaced lumber, nominal 4/4 rough lumber was run through a cabinet planer, surfacing to a thickness of 1.00 inch and attempting to eliminate the “saw marks.” A few boards still had saw marks at 1.00 inch; they were used in that condition.

Three different schedules were used, designated as T4-E2, “C,” and “C Smooth” (figure 1). Schedule T4-E2 is the recommended schedule in the Dry Kiln Operator’s Manual (8); the letters refer to tables 9 and 10 in that publication. The “C” schedule refers to Procedure C mentioned in Research Paper FPL 122, p. 12 (7). The “C Smooth” schedule is derived from the C schedule; the dry bulb temperature is determined by drawing a smooth curve through the peaks in the dry bulb temperature-moisture content plot of the C schedule and the wet bulb temperature is determined by drawing a smooth curve through the EMC-moisture content plot of the C schedule. It should be noted that T4-E2 is run on the wettest half of the samples; the other two on the average of all samples. Both “C” and “C Smooth” are experimental schedules.

All runs had sample boards, in accordance with the procedures in the Dry Kiln Operator’s Manual. If the sample boards were used to determine when schedule changes were made, the run was designated “manual.” If the schedule changes were made automatically, based on the average moisture content of the load as determined by a load weighing system, the run was designated “automatic.” It should be noted that “C Smooth” cannot be used without automation. The schedule changes for the manual runs were made only between 8 a.m. and 5 p.m., Monday through Friday, while the changes for the automatic runs were made at any time of the day, on any day. In both cases, the kilns ran continuously.
Table 1.--Summary of experimental combinations and drying times for drying northern red oak from 60 to 8% M.C.

<table>
<thead>
<tr>
<th>Run</th>
<th>Surface</th>
<th>Schedule</th>
<th>Control</th>
<th>Time$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>rough</td>
<td>T4-E2</td>
<td>manual</td>
<td>20.2</td>
</tr>
<tr>
<td>2</td>
<td>presurfaced</td>
<td>T4-E2</td>
<td>manual</td>
<td>18.1</td>
</tr>
<tr>
<td>3</td>
<td>rough</td>
<td>C</td>
<td>manual</td>
<td>10.9</td>
</tr>
<tr>
<td>4</td>
<td>presurfaced</td>
<td>C</td>
<td>manual</td>
<td>10.2</td>
</tr>
<tr>
<td>5</td>
<td>presurfaced</td>
<td>C</td>
<td>automatic</td>
<td>9.6</td>
</tr>
<tr>
<td>6</td>
<td>presurfaced</td>
<td>C</td>
<td>automatic</td>
<td>9.5</td>
</tr>
<tr>
<td>7</td>
<td>presurfaced</td>
<td>C Smooth</td>
<td>automatic</td>
<td>8.4</td>
</tr>
<tr>
<td>8</td>
<td>presurfaced</td>
<td>C Smooth</td>
<td>automatic</td>
<td>8.4</td>
</tr>
</tbody>
</table>

1 Add one day if conditioning is included. Add time if final M.C. is to be below 8% or if incoming M.C. is greater than 60%.

2 Honeycomb considered excessive.
The air velocity for all runs was a nominal 375 fpm. Three-quarter-inch stickers were placed 2 feet apart. The kiln loads in all runs were 4 feet wide and had the same number of courses. The number of board feet in each run was about 660 board feet (nominal).

Collection of Drying Data

The average initial moisture content of the various loads of lumber ranged between 65 and 85 percent; most were between 75 and 80 percent. In order to facilitate comparison of the runs, calculations of drying times were made starting at the point when the average moisture content of the load was at 60 percent. The average moisture content of the load was determined daily, except weekends, until the average was below 8 percent. Drying was continued until the wettest sample was below 7 percent, at which time the lumber was conditioned at 180° dry bulb, 170° wet bulb. Drying times below the average of 8 percent were not included in the data presented (table 1).

Lumber Quality and Degrade

The material used in these experiments, obtained from the tie mill, was unselected, and therefore of various grades. Only those boards with large areas of decay were eliminated from the experiments.

At the conclusion of drying, all boards in a load were sawn one and two feet back from one end to examine for honeycomb. Except for the rough load using the C schedule, honeycomb was found in about 10 percent of the boards in each load. The rough lumber dried using schedule C had honeycomb in 50 percent of the boards. Much of the honeycomb found was associated with a dark-colored area in the wood, an observation also made in earlier work (7). Some dark-colored areas were observed without honeycomb, however.

After completion of all the runs, the lumber from one rough run and four presurfaced runs was manufactured into residential flooring, 25/32 inches thick, following National Oak Flooring Manufacturers' Association specifications. Warp, primarily bow in some longer pieces, and honeycomb were observed, but neither presented any problem No thin boards were seen. No difference in the manufacturing process or product with respect to the different drying schedules was noted.

4Acknowledgment and appreciation is given to the Webster Lumber Co., Bangor, Wis.

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Discussion of Drying Time Data

The benefit of presurfacing alone, as indicated by these data (table 2) is a time saving of between 4 and 10 percent compared with rough lumber. This savings is due primarily to the reduction in thickness of presurfaced lumber and not the change in surface characteristics.

The time saving resulting from use of the C schedule compared with the T4–E2 recommended schedule was 46 percent for rough and 43 percent for presurfaced lumber, although the rough lumber had excessive honeycomb with the new schedule. These savings were considerably higher than those observed by McMillen with smaller loads (2). The saving from the schedule will not be quite as large if the final moisture content is lower and conditioning is included—perhaps a saving of 37 percent.

The saving from both presurfacing and using the new schedule amounts to 47 percent, and, as indicated by this study, this is without my noticeable increase in degrade.

Runs five through eight were made using automatic programming and control of the kiln—equivalent to having an experienced operator operating one kiln 24 hours a day. The advantage of automation is seen by comparing C, manual, with C, automatic (run 4 and runs 5 and 6, table 1). The indicated time saving is 7 percent (table 2). However, with the use of automation, new schedules such as “C Smooth” can be used. Taking full advantage of automation the saving in time is 18 percent (table 2). When compared with rough lumber dried using T4–E2, C Smooth results in a saving in time of 56 percent—the combined effect of presurfacing, automation, and the new schedule.

Economics

A great deal of caution should be used when developing economic data based on small experimental kiln charges. The primary reason for this statement is that in the laboratory, very close control is maintained throughout the entire operation—much closer than would be seen in a typical commercial drying operation. These data, however, are developed to provide guidelines.

In 1970, it was estimated that direct kiln operating costs ranged from $1.35 to $1.80 per day per thousandboard feet (MBF)—the higher figure is for an 8-day run, the lower for 20—for well-run kilns processing hardwoods in the northern

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These figures are only for direct kiln operating costs and do not include such things as stickers, depreciation, degrade, and general selling and administrative expenses.
Table 2.--Percentage time savings \( \frac{B-A}{A} \cdot 100\% \)

<table>
<thead>
<tr>
<th>A</th>
<th>:</th>
<th>B</th>
<th>:</th>
<th>Savings $^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4-E2 (R)$^2$</td>
<td>:</td>
<td>T4-E2 (P)$^3$</td>
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<td>10%</td>
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<tr>
<td>C, manual (R)</td>
<td>:</td>
<td>C, manual (P)</td>
<td>:</td>
<td>7%</td>
</tr>
<tr>
<td>T4-E2 (R)</td>
<td>:</td>
<td>C, manual (R)</td>
<td>:</td>
<td>46%</td>
</tr>
<tr>
<td>T4-E2 (P)</td>
<td>:</td>
<td>C, manual (P)</td>
<td>:</td>
<td>43%</td>
</tr>
<tr>
<td>T4-E2 (R)</td>
<td>:</td>
<td>C, manual (P)</td>
<td>:</td>
<td>47%</td>
</tr>
<tr>
<td>C, manual (P)</td>
<td>:</td>
<td>C, automatic (P)</td>
<td>:</td>
<td>7%</td>
</tr>
<tr>
<td>C, manual (P)</td>
<td>:</td>
<td>C Smooth (P)</td>
<td>:</td>
<td>18%</td>
</tr>
<tr>
<td>T4-E2 (R)</td>
<td>:</td>
<td>C Smooth (P)</td>
<td>:</td>
<td>56%</td>
</tr>
</tbody>
</table>

$^1$Based on original data in hours. May vary slightly if Table 1 data are used.

$^2$R = rough.

$^3$P = presurfaced.

Table 3.--Estimated kiln operating cost savings/MBF

<table>
<thead>
<tr>
<th>Surface</th>
<th>:</th>
<th>Schedule</th>
<th>:</th>
<th>Control</th>
<th>:</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Presurfaced</td>
<td>:</td>
<td>T4-E2</td>
<td>:</td>
<td>manual</td>
<td>:</td>
<td>1.00</td>
</tr>
<tr>
<td>:</td>
<td>C</td>
<td>:</td>
<td>manual</td>
<td>:</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>:</td>
<td>C</td>
<td>:</td>
<td>automatic</td>
<td>:</td>
<td>10.50</td>
<td></td>
</tr>
<tr>
<td>:</td>
<td>C Smooth</td>
<td>:</td>
<td>automatic</td>
<td>:</td>
<td>11.50</td>
<td></td>
</tr>
</tbody>
</table>

AS COMPARED WITH T4-E2 (R) COST OF $26.25/MBF

AS COMPARED WITH C, MANUAL (P) COST OF $16.25/MBF

Presurfaced : C Smooth : automatic : 1.50
Using these data, the operating costs per MBF for an eight-day run are $14.40; 10 day, $16.00; 15 day, $21.75; and 20 day, $27.00. With these data and the drying times from table 1, the estimated cost savings (table 3) were developed.

For a closer approximation, these estimated cost data should be modified to include such presurfacing benefits as increased kiln capacity (approximately 12 percent), lower shipping weight per MBF, and so forth, and such presurfacing costs as machinery investment, operator, and so forth. Although a more thorough study on economics is underway, it is believed that these latter benefits and costs are about equal. Hence, the costs in table 3 are estimates of net savings compared with rough lumber dried using T4-E2.

The economic advantages of automation are less clear than the advantages of presurfacing. The cost of the automated controls at FPL was over $5,000. The possible benefits of automation are reduction of labor costs, human errors, and operator turnover problems, and a reduction in drying time worth about $1.50 per MBF (table 3). It might also provide a method of determining moisture contents in high-temperature kilns. Maintenance, insurance, and the other costs may be higher than those for manual operations. A thorough analysis of the costs and benefits of automation is underway. It is expected that this analysis will show that automation would be beneficial for some, but not all, operations.

**Conclusions**

As a result of reduced drying time and minimal degrade, further research or pilot studies appear to be worthwhile in order to establish the commercial feasibility of presurfacing, drying with a new kiln schedule, and automation.
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