Study of overlength on red oak lumber drying quality and rough mill yield

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Abstract

Lumber stacking practices can directly affect drying defects, drying rate, and moisture content uniformity. The effect of overlength on drying is generally thought to be detrimental, yet large volumes of overlength lumber are used by secondary manufacturers. Managers of secondary manufacturing facilities need quantitative information to assist them in determining if overlength is beneficial or detrimental to their operation. The goal of this research was to compare the drying degrade, kiln capacities, and rough mill yields of red oak lumber with overlength to lumber that was precision-end trimmed. Degrade and rough mill yield studies where conducted at four manufacturing facilities located within Tennessee, Kentucky, and Virginia. Each facility used predriers prior to kiln-drying red oak. Differences in kiln capacities for precision end-trimmed vs. non-precision end-trimmed lumber were determined from company records for previous kiln charges that were composed of one or the other type of lumber. The results of the four mill studies demonstrated that: 1) drying degrade was not significantly different between the two trimming and stacking practices; 2) kiln capacity can be increased by an average of 4 to 12 percent for precision-end trimmed lumber; and 3) using lumber with overlength leads to an increase in rough mill yield. A modified version of the ROMI-RIP rough mill simulation software was used to determine theoretical yield differences for different lumber grades and cutting bills. Simulation results indicated that there was a definite increase in rough mill yield for 1 Common lumber regardless of the difficulty of the cutting bill. For 2 Common lumber, yields were either not significantly different or higher for lumber with overlength, depending on the cutting bill.

Stacking practices can directly affect lumber drying defects such as warp, staining, and end checking (Boone et al. 1991, Simpson 1991, Denig et al. 2000). When stacking practices permit the location of stickers flush or near the ends of lumber, cup, twist, and end checking are minimized (Simpson 1991). Stacking practices also have an influence on air velocity, drying rate, and moisture content (MC) uniformity (Eckert and Little 1999). The use of proper stacking methods has become more important as the risk of warp, especially cup, has increased due to small-diameter logs being processed in today's sawmills (Wengert and Denig 1995). The amount of lumber that can be loaded into a dry kiln is also affected by stacking (Bond 2000). Given the relationship between stacking practices and lumber degrade, stacking practices may be expected to have an effect on rough mill yield.

There are three primary stacking methods used by the hardwood lumber drying industry: 1) precision end-trimmed (PET) stacking; 2) even-one-end stacking; and 3) box piling. PET stacking uses lumber that has been trimmed to a specific length prior to stacking. PET lumber is typically manufactured such that all boards are usually cut in 1-foot increments with a trim allowance of 1 inch at either end. Even-one-end stacking methods consist of stacking the lumber such that one end of the stack is uniform and the opposite end has boards of varying lengths protruding. Boxpiling consists of stacking lumber of various lengths so that the entire stack is uniform in length with the ends of random-length boards alternated in the pack to allow good sticker placement and pack alignment. The alignment is achieved by keeping the outside boards in each course equal to the full length of the stack. Shorter boards in all courses are staggered from one end to another within a layer.

Overlength is the length of lumber in excess of the nominal (even foot) board length. While excessive trim allowance in logs is the root cause of most overlength, the main reason

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overlength is included in processed lumber is the absence of equipment for double-end trimming. The National Hardwood Lumber Association Rules for the Measurement and Inspection of Hardwood and Cypress (NHLA 2003) do not consider overlength when calculating volume or surface measure; however, it can be used in determining the size and number of cutting units in a grading cutting when grading a board. The average overlength in boards has been measured to be between 4 and 7 inches (Bond 2000, Wiedenbeck et al. 2003). Even-one-end and boxpiling are the most common methods used to stack lumber with overlength.

Advantages and disadvantages of stacking methods

PET lumber is expected to contribute to greater drying capacity, less lumber degrade, and easier material handling by drying operators and managers (Bond and Hamner 2003). The uniform length of the PET stacks helps forklift operators locate the stack ends, leading to reduced handling damage during the loading and unloading of dry kilns and predryers. PET stacking allows straight-ended lumber piles with sticker placement close to the ends, which promotes uniform airflow, reduced warp, and increased kiln capacity.

The extra inches of lumber contained in overlength sections is considered by many secondary processors to be extra or "free" material (Bond and Hamner 2003). It has been documented that more overlength than PET lumber is used by secondary processors. Most of this overlength lumber is stacked using the even-one-end method (Bond and Hamner 2003). It has been suggested that even-one-end stacking also leads to excessive warp and end checking, longer drying times, reduced drying capacity, and reduced airflow in predyers and dry kilns (Eckert and Little 1999, Denig et al. 2000, Lamb 2000).

While PET lumber and box piling have been stated to produce the highest quality of lumber, even-end lumber stacking is widely practiced by the secondary wood products industry in Tennessee (Bond and Hamner 2003) as well as other eastern states. When industry personnel were questioned as to why they used various stacking methods, many different opinions where given (Bond and Hamner 2003). With so many varying opinions on best practices in stacking, it is clear that managers of hardwood lumber drying and processing facilities need accurate, quantitative information to help them distinguish between the options; therefore, a study to quantify these differences was undertaken.

Objectives

The goal of this study was to quantify the drying and manufacturing differences that exist between PET lumber and lumber with overlength. The term overlength will be used throughout the remainder of this paper to refer to lumber containing overlength that was stacked for drying using the even-one-end method. Our research objectives were to evaluate the differences in: 1) drying degrade; 2) kiln capacities; and 3) rough mill yields for red oak lumber with overlength and PET lumber.

Methodology

Secondary manufacturing operations that contained both lumber-drying facilities and rough mills were contacted in Virginia, Tennessee, North Carolina, and Kentucky to determine their interest in being a research partner for this project.

Table 1. — Lumber grade mix used at each participating mill.

Mill number	Product	Grade mix
1	Dimension parts for cabinets	80% 1 Common, 15% 2 Common, 5% FAS
2	Molding and millwork	80% 1 Face, 20% 1 Common
3	Stair parts	90% 1 Common, 5% 1 Face & Better, 5% 2 Common
4	Flooring	64% 2 Common, 26% 3 Common, 10% 1 Common

Red oak was chosen since it is considered a difficult species to dry, is susceptible to warp and checking, and is used in large volumes by several different manufacturing sectors. Four mills participated in this study and all lumber used was 4/4-inch thickness. Attempts were made to assure that the distribution of grades, widths, and lengths of lumber be uniform between sample groups (PET and overlength).

Each participating mill dried lumber using a predryer prior to kiln-drying and produced a different finished product: millwork, cabinet dimension parts, flooring, and stair parts. Each mill also used a different grade mix. The product type and desired grade mix for each mill are listed in **Table 1**.

All lumber was graded by a certified lumber grader provided by each manufacturing facility prior to stacking using the National Hardwood Lumber Association's (NHLA) grading rules (NHLA 2003). All lumber was dried in a predryer until the lumber reached an MC between 22 and 25 percent and then dried in a conventional dry kiln to between 6 and 8 percent MC according to each mill's drying schedule. After drying, the lumber was regraded by the mill's lumber grader to determine grade and volume losses during drying.

Lumber degrade was determined by measuring lumber volume and grade for all the lumber in the green condition and then regrading it after the drying process. A value for the dried lumber was determined using lumber prices from the September 4, 2004 Hardwood Market Report (Hardwood Market Report 2004). After adjusting the green lumber volume for shrinkage, changes in lumber grade and value were compared after kiln-drying

The lumber was then run through the rough mill at each manufacturing facility and the rough mill yields were calculated. Yields were determined by calculating the percentage of parts out of the rough mill given the input of dried lumber. The tests where conducted using between 10,000 and 82,000 board feet (BF) of lumber in each experimental group. While each manufacturer used a different cutting bill, the same cutting bill was used between the two sample groups.

To determine the kiln capacity differences between the two lumber groups, company records from previous internal studies were analyzed. Records of previously conducted trials at two of the participating mills and at three other mills with drying operations were used for determining the volume differences between full kiln charges of overlength and PET lumber. The differences in kiln capacities were based on records from 14 kiln runs so that 7 comparisons could be made.

To clarify and substantiate the in-mill yield study results, theoretical rough mill yield studies were conducted using simulation. ROMI 3, rough mill simulation software developed by the USDA Forest Service, Forestry Sciences Labora-

Table 2. — Difference in average board size between the two sample groups for 1 Common and 2 Common lumber data sets used in simulations. Differences reflect the increase in surface area associated with adding overlength sections to PET boards.

Lumber grade	Average board size
	(ft^2)
1 Common	
PET	6.30
Overlength	6.49
Difference	3%
2 A Common	
PET	6.10
Overlength	6.44
Difference	5%

tory in Princeton, WV, was used to predict the theoretical yield differences (Weiss and Thomas 2005).

The current lumber databank (Gatchell et al. 1998) of lumber used to run the simulations contains only PET material; therefore, a method was developed to create overlength boards using the current databank information as a basis.

The method of adding overlength to boards consisted of determining how much overlength would be added, to which end it would be added, how defects located with increased length regions would be affected, and then regrading the boards. The amount of overlength added to a board was determined using the distribution of overlength from Wiedenbeck (2003). The overlength was then applied randomly to the right end, left end, or both ends of the board based on randomly generated numbers. If both ends of the board had additional length added, another random generator was used to determine how much overlength to add to each end.

Length was added to defects that occurred at the ends of the original boards for those defects that would typically extend into the trimmed-off portion: splits, shakes, decay, or wane. Other defects, such as knots, that occurred near the ends of the original boards were not extended into the newly created overlength sections. Once the boards and defects had been increased in length, they were regraded using UGRS: the Ultimate Grading and Remanufacturing System (Moody et al. 1998). If a board changed grade after having overlength added, it was removed from the sample set, and another board of the same grade, length, and width was selected from the red oak lumber databank, grown, regraded, etc. until board files containing 150 boards were composed for each lumber grade.

For the PET lumber, the unaltered red oak databank was used. Only boards having 2 inches or less overlength were included. The overall length and width distributions were kept the same for both study groups since both length and width distributions have been shown to affect simulated rough mill yields (Hamner et al. 2002, Clement and Bond 2005). In fact, the same boards were used in the same order of occurrence for both the PET and overlength data files with the only difference being that the overlength boards were lengthened as described earlier. **Table 2** lists the difference in average board surface area between the two sample groups for 1 Common and 2 Common lumber; for the overlength lumber samples, the surface areas shown in **Table 2** are based on the lengths of the boards after they were extended or "grown." ROMI-3 also

Table 3. — Volume and value changes between the green and dried lumber for mills in the study.

Mill number	Volume loss		Drying degrade	
	PET	Overlength	PET	Overlength
	(%)		(% change in value)	
1	8.4	7.2	2.3	1.5
2	7.6	8.3	4.1	5.9
3	7.5	7.3	0.2	−0.2
4	8.3	10.3	1.7	0.6

had to be modified to measure surface area using the method described by the NHLA grading rules (NHLA 2003). A new version of ROMI-3 that calculates yield properly was created by the USDA Forest Service for this project.

Since the difficulty of a cutting bill can affect rough mill yields and the actual rough mill yields in the earlier phase of this study were determined with different cutting bills, several different cutting bills were used in the yield simulations. All of the simulation tests were conducted using rip-first processing. Two hard cutting bills that contained a higher proportion of larger sized parts, two easier cutting bills that contained a higher proportion of shorter and narrower parts, and one flooring bill that contained random lengths were simulated. The cutting bills used in this study are detailed in earlier publications and briefly outlined below:

Two hard cutting bills:

One with random width panel parts (Gatchell et al. 1999)

One without (Steele et al. 1999)

Two easy ("Cabinet") cutting bills:

One with random width panel parts (Gatchell et al. 1999)

One without (Steele et al. 1999)

Flooring cutting bill:

Same width (1-5/8 in), random lengths 11 to 83 inches

Three board files were created for each lumber group (PET and overlength) and three simulation runs were conducted for each cutting bill for both 1 Common and 2 Common lumber. A minimum of 150 boards was processed for each simulation. For each cutting bill, part requirements were scaled back proportionally so part quantities would be met given the size of the input lumber data sets. This was not necessary for the flooring cutting bill since all parts were the same width (2.625 inches). For each simulation, the complex diamanic exponent part prioritization method (Thomas, 1996) was used with constant part updates and no orphan parts (those not specified by the cutting bill) were allowed.

Results and discussion

For the four mills in the study, there was no significant difference ($\alpha = 0.05$) in degrade between the PET lumber and the lumber containing overlength. **Table 3** shows the lumber grade and volume changes between the green and dried lumber. The average reduction in lumber value due to degrade was 2 percent and ranged between an increase of 0.2 percent and a decrease of 6 percent. The lack of a significant difference in the amount of degrade associated with lumber drying between the two stacking practices was unexpected. It had been hypothesized that lumber with overlength would suffer more degrade due to warp since overlength sections are not supported by stickers and package weight. We attribute the

Table 4. — Rough mill yield differences between overlength and precision end trimmed lumber for mills in the study.

Mill no.	Product	Yield increase obtained from overlength lumber
		(%)
1	Cabinet parts	1.0
2	Moldings	2.0
3	Dimension	0.5[a]
4	Flooring	1.2

[a]There was a change in cutting bill between sample groups; 1.88% significant theoretical difference based on simulation-based study.

lack of difference in degrade to be associated with the use of good stacking practices, predriers prior to kiln-drying, and how warp is interpreted when grading kiln-dried lumber. It is well known that good stacking practices and properly operated predriers can lead to significantly lower degrade than typical air-drying prior to kiln-drying. When operating a predryer conservatively, there is typically less degrade due to surface checks and end checking.

It is more difficult to measure the true impact of warp, which is the greatest expected increase in degrade for overlength lumber. NHLA grading rules state that for FAS and Select grades that "boards must be flat enough to surface two sides to the standard surfaced thickness" (NHLA 2003). Slight cup in boards allows both sides to be planed; however, cup may still be present and affect how the board is processed in the rough mill. For lower grades, warp is only considered in the cutting unit used to determine grade. This is a difficult task for graders to perform and is open to much interpretation. Post-experiment discussions with graders and NHLA inspectors indicated that the effect of warp on kiln-dried lumber grade is not fully accounted for.

Kiln capacity

Records from 7 kiln trials, 14 kiln charges total, were used to determine differences in kiln capacities between the 2 lumber groups. A 4 to 12 percent (9% average) increase in kiln capacity was calculated for PET kiln trials compared to overlength kiln trials.

Rough mill yield studies

While drying improvements are important to secondary wood manufacturing operations, improvement efforts are typically focused on increasing rough mill yields. Therefore, any comparison of stacking methods should include information on the effect on rough mill yield. It has been stated that drying defects are the single most common reason for loss of yield and profit in the rough mill; therefore, any reduction in drying degrade should result in increased rough mill performance.

The mills that agreed to participate in the study preferred not to be named and asked that actual rough mill yields not be published; therefore, actual rough mill yields will be discussed in terms of percent differences between lumber groups.

For the study in mill 1, an operation that produced cabinet parts, each sample group contained approximately 20,000 to 23,000 BF of lumber. The lumber group that contained overlength produced an overall yield of parts that was 1.0 percent higher than the PET lumber (**Table 4**). However, it was determined that the PET study group contained a higher percentage of longer length lumber than did the overlength study group. Since longer length lumber is known to have a positive influence on rough mill yields (Hamner et al. 2002), it is expected that the actual increase in yield for lumber with overlength would have been substantially greater if the two groups had included the same length material. While the exact yield difference could not be determined, this result indicates that lumber with overlength leads to greater rough mill yields.

The second mill study was conducted at a millwork manufacturing facility. All lumber was determined to contain the same length, width, and grade distributions of lumber. There was approximately 10,000 to 11,000 BF in each sample group. The manufacturing process at this particular plant allowed us to determine yields at each machine center. At the ripsaw, lumber containing overlength produced a yield that was 2.7 percent higher than PET lumber. When the material was processed at the chopsaw, the lumber containing overlength produced a 2.6 percent higher yield than PET. When salvage was taken into consideration, the overall yield for lumber containing overlength was 2.0 percent higher than the overall yield obtained from the PET lumber (**Table 4**).

In the third mill, a rough dimension manufacturing operation, the study was also conducted with a strictly controlled lumber grade, length, and width (i.e., the same for both groups of lumber). Unfortunately, during this test, the cutting bill of the rough mill was changed between sample groups, such that smaller part sizes were required during the cutting of the PET lumber. While this change made it impossible for us to determine actual yield differences, the results strongly support the findings from mill 2 – lumber containing overlength produced higher rough mill part yields. Considering the effect that the smaller part sizes would have on overall yield for PET lumber (causing an increase in yield compared to the longer cutting bill), it is likely that the overlength lumber would have exhibited an even larger yield difference than was measured (0.47%) had the cutting bill not been altered (**Table 4**). The change in cutting bill that occurred during this study prompted our interest in being able to determine the theoretical yield differences between PET lumber and lumber with overlength. A study to determine theoretical yields was thus undertaken and will be discussed in a later section.

The fourth participating mill produced flooring. The study conducted in this mill had the largest lumber sample, approximately 82,000 to 83,000 BF per group. At this mill, the lumber with overlength produced approximately 1.2 percent more yield than did the PET lumber.

Thus, all four manufacturing facilities obtained higher yields from the lumber with overlength than from the PET lumber (**Table 4**). This result supports the point of views of those managers who prefer to process lumber with overlength, providing, of course, that there is no increase in lumber degrade during drying (as we found to be the case in this study).

Rough mill simulations

Since drying degrade differences between the two lumber types were not significant, it was feasible to determine the theoretical rough mill yield differences between the study groups (overlength and PET) using digital lumber data and simulation. Simulation analysis allowed for determination of the greatest potential utilization of the extra length in lumber.

Table 5. — Rough mill simulation results for five cutting bills; yield differences shown in bold were found to be statistically significant between lumber groups.

Cutting bill	Average difference increase in yield obtained from overlength lumber compared to PET	*p*-value
	(%)	
FS hard—random panel parts		
1 Common	**1.68**	**0.013**
2 Common	0.91	0.251
FS hard		
1 Common	**1.63**	**0.027**
2 Common	−0.45	0.409
FS easy—random panel parts		
1 Common	**2.16**	**0.007**
2 Common	0.34	0.257
FS easy		
1 Common	**1.15**	**0.024**
2 Common	**1.40**	**0.007**
Flooring		
1 Common	**1.96**	**0.0001**
2 Common	**1.50**	**0.008**

The results of the rough mill yield simulations are given in **Table 5**. It is clear that lumber with overlength provides significantly higher simulated rough mill yields for the 1 Common lumber regardless of the difficulty of the cutting bill. For the easy cutting bill without panel parts and for the flooring cutting bill, higher rough mill yields are also achieved from the 2 Common overlength lumber compared to the 2 Common PET lumber. The average increase in rough mill part yield obtained from the overlength lumber was approximately 1.7 percent for 1 Common and 1.45 percent for 2 Common lumber. This average was calculated by adding together the yield differences for each of the cutting bill tests that proved significant and dividing by the number of significant tests (5 for 1 Common and 2 for 2 Common).

The increase in yield associated with the overlength lumber can be directly attributed to the extra material contained in these boards. The extra inches per board permits additional and/or long cuttings to be captured in cuttings at the ends of these boards. Referring back to **Table 3**, 1 Common overlength boards had, on average, a 3 percent greater surface area than did their twin PET boards. For the five cutting bills simulated in this study, 56 percent of this extra area was captured in cuttings (1.7% ÷ 3.0%). A smaller percentage of the extra area contained in the overlength lumber was captured in cuttings for the 2 Common simulation runs – 29 percent (1.45% ÷ 3%). This seems logical since 2 Common lumber, by definition, contains fewer larger clear areas than does 1 Common lumber. Comparing the results of the rough mill simulations with those obtained in the actual rough mill studies leads us to deduce that higher yields, regardless of cutting bill difficulty, can be obtained when using overlength lumber rather than PET lumber and that the higher the grade of lumber used for the cutting bill, the greater the opportunity for increased rough mill yield.

Conclusions

Mill trials conducted at four manufacturing facilities were used to determine differences in drying degrade, kiln capacity, and rough mill yield between lumber with overlength and PET lumber. It was found that the use of PET lumber increased dry kiln capacity by 4 to 12 percent. Lumber degrade was not significantly different between the two types of stacking practices. For the four mills studied, it was determined that lumber containing overlength and stacked using even-one-end methods provided 1 to 2 percent higher rough mill yield than PET lumber.

Future work is needed to determine if the same degrade and rough mill yield differences would be experienced with lumber that is air-dried prior to kiln-drying. Air-drying is a less controlled process and it is likely that the unsupported ends of lumber containing overlength will indeed lead to increased degrade and therefore cause a reduction in rough mill yields for overlength lumber.

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