Ring Shake in Eastern Hemlock: Frequency and Relationship to Tree Attributes

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Abstract

Ring shake is a barrier to improved utilization of eastern hemlock, an important component of the total softwood timber resource in the Eastern United States and Canada. Ring shake is the lengthwise separation of wood that occurs between and parallel to growth rings, diminishing lumber yields and values. Evaluating the potential for ring shake is essential to improving estimates of tree and stand volume and value, and identifying forest management practices that could minimize the occurrence of ring shake. To assess the incidence and extent of ring shake in eastern hemlock, we sampled 377 trees containing 1,247 sawlogs from sites in Maine, New York, Pennsylvania, North Carolina, Tennessee, and Georgia. Results include relative frequencies of trees and logs with ring shake detected in dry and green lumber. Relationships between tree attributes and the occurrence of ring shake in dry and green lumber also are presented.

Introduction

Eastern hemlock (*Tsuga canadensis*) is one of the more commonly occurring eastern softwoods. In the 12 northeastern states, hemlock represents 22 percent of the softwood sawtimber inventory. More than half of the softwood sawtimber in Pennsylvania and Connecticut is eastern hemlock (Powell and others 1992). This species also extends west into the Lake States and south along the Appalachians into northern Georgia and Alabama (Burns and Honkala 1990).

The production of hemlock lumber is evenly distributed between the New England States, Middle Atlantic States, and the Lake States (FPL 1987) with lumber being used for building construction and the manufacture of pallets and containers. Properties that favor the use of hemlock lumber for framing and general construction include strength, moderately light weight, and straight grain. Due to the lack of resins, hemlock lumber also stains, paints, and glues well (USFS 1973). Properties damaging hemlock's image in the lumber market include brittleness, density variations, differential swelling, and ring shake (Gardner and Diebel 1995). The occurrence of ring shake, which is the lengthwise separation of wood between and parallel to growth layers, is one of the more serious problems affecting the utilization of hemlock. According to the standard lumber grading rules applied by the Northeastern Lumber Manufacturers Association (NELMA 1998), ring shake is not allowed in the better and more valuable grades of hemlock boards (C, D, Select, or 1 Common grades). The occurrence and extent of ring shake also reduce the grades of dimension lumber produced for structural framing and construction.

Koehler (1933) hypothesized that sudden changes in diameter growth rates that accentuated internal stress attributed to differences in the ratio of circumferential to radial growth could account for the occurrence of ring shake. Based on anatomical studies of ring shake in western softwoods, Meyer and Leney (1968) concluded that "shake is a natural occurring defect in standing trees caused primarily by a separation of contiguous latewood tracheids along the middle lamella," but they could not isolate the factors resulting in ring shake. Wilson (1962) cited several external stress factors such as wind and temperature extremes as possible causes of ring shake, but concluded from a study of hemlock stands in Massachusetts that ring shake was attributable to internal growth stresses. Shigo (1963) found a direct correlation between scars and decay resulting from sapsucker damage and the occurrence of ring shake in eastern hemlock. In a follow-up study, Jorgensen and Lecznar (1964) identified cell structure changes resulting from sapsucker wounds and associated with ring shake, concluding that internal stress contributes to the formation of shake defects.

Whereas these and other studies have attempted to identify the causes of ring shake, assessments of the occurrence and variability of ring shake have not been conducted on a broad geographical scale. Also, information linking site and/or tree attributes to the occurrence of ring shake is needed to improve assessments of wood utilization opportunities.

The objectives of this paper are to present preliminary results of a study conducted to: (1) evaluate the frequency and magnitude of ring shake found in hemlock trees sampled from stands located in six states ranging from Maine to Georgia; and (2) identify tree attributes that could indicate the likelihood of ring shake in hemlock lumber.

Methods

The ring shake related data used in this study were collected as part of a larger study conducted to improve hemlock lumber manufacturing processes through the development of eastern hemlock log and tree grades for estimating lumber grade yields. Because ring shake is one of the more important tree and log attributes affecting lumber yields, detection and evaluation of ring shake was an important aspect of this study. The data were collected from 1968 to 1971 but due to changes in research priorities from softwood to hardwood utilization, data analyses were not completed nor were results published. However, with the recent reductions in softwood harvests from public land in the West, there is renewed interest in utilizing eastern softwoods to meet the growing demands for wood and wood products.

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Table 1.—Sample tree attributes by study site.

State	No. of trees	Dbh		Age		Tree volume[a]	
		Mean	Range	Mean	Range	Mean	Range
		inches		*years*		*board feet*	
PA	126	17.4	9.0 - 30.7	141.2	46 - 244	339.8	40 - 1,079
NY	29	16.2	10.1 - 26.0	131.4	105 - 200	227.9	48 - 593
ME	91	15.6	9.9 - 31.7	98.6	48 - 220	204.3	25 - 850
TN	40	24.9	13.4 - 46.3	217.5	79 - 415	709.4	55 - 2,667
NC	49	25.7	13.2 - 45.6	191.8	92 - 491	880.5	58 - 3,432
GA	42	22.7	13.1 - 44.3	149.5	75 - 309	725.2	86 - 2,970

[a]Lumber tally

Sampling

Data were collected from a total of 377 hemlock trees in three general geographic areas: the Northeast, Pennsylvania, and the southern Appalachians. The northeastern samples were collected at two sites in Maine near Naples and Belgrade and one site in New York on the Pack Demonstration Forest near Warrensburg. The Pennsylvania samples were collected at four sites: Williamsport, Renova, Coudersport, and Emporium. The southern Appalachian samples were collected at one site in each of three states: Tellico Plains, Tennessee; Robinsville, North Carolina; and Clayton, Georgia.

Sampling was conducted on active timber sales located on diverse sites with respect to slope and aspect. Sample trees were selected to include a relatively wide range of tree diameters at breast height (Dbh), ages, and quality classes. Identical sampling procedures were applied at each site. These included measuring and assessing site and stand attributes, measuring tree attributes before and after felling each tree, measuring sawlog attributes after felled stems were bucked into sawlog lengths, and tracking each log through the sawmill to measure and grade all lumber sawn from each sawlog. With the exception of the trees and logs sampled in Maine, lumber was air dried before it was measured and graded. Lumber sampled in Maine was measured and graded green. Because the study did not compare lumber shake in green and dry lumber from the same boards or logs, we could not reliably determine the effects of air drying on the detection or occurrence of ring shake in lumber. As a result, ring shake in green and dry lumber are reported separately.

Lumber grading included evaluation of each board sawn for the presence of ring shake. Following felling and bucking, sawlogs were evaluated for ring shake by examining log ends and recording the length, width, and estimated depth of ring shake, and recording the number of log end quarters showing indications of ring shake. From the large array of tree attributes collected, those relevant to this study include: Dbh, age, number of abrupt changes in growth rates, total lumber volume obtained from all logs in each tree, and the occurrence of occluded or closed bird peck.

Analyses

Data analysis included calculating the total volume of lumber with ring shake sawn from each sample tree, calculating percent shake or volume of lumber with shake as a percentage of total tree lumber tally, and the frequency or percent of all sample trees with at least 1 percent shake. To evaluate the reliability of visible ring shake indicators in log ends as indicators of ring shake in the lumber sawn from those same logs, number of logs with and without shake found in the lumber were calculated for logs with and without shake indicators visible in log ends. To help explain the variation found in the frequency of ring shake found between sample sites and to link tree attributes to the occurrence of ring shake, a probit analysis was conducted (Greene 1997). This analysis was used to estimate the relationship between a binary dependent variable Y coded 1 if 1 percent or more of the lumber volume sawn from the tree contained shake defect, or zero if it did not; and variables that measured tree and site characteristics (X'B), and a random disturbance, e.

$$\text{Prob}(Y=1) = \text{Prob}(e<X'B) = F(X'B) \quad [1]$$

Results

Sample Tree Attributes

The largest and oldest trees were sampled on the southern Appalachian sites, where all three sites had trees larger than 40 inches Dbh and older than 300 years (Table 1). Maine sites had the lowest average tree diameters and ages, 15.6 inches Dbh and 98.6 years, respectively. Because of the old age and large Dbh of many sample trees, especially those on the southern Appalachian sites, mean tree volumes ranged from 204.3 to 880.5 board feet lumber tally. Maximum tree volumes ranged from 593 to 3,432 board feet per tree (Table 1).

Shake in Log Ends as an Indicator of Ring Shake in Lumber

Of the 998 hemlock logs with lumber graded dry, 387 logs or 39 percent produced lumber with ring shake (Table 2). Of these 998 logs, 269 or 27 percent showed indicators of ring shake in log ends. However, less than half of the logs producing lumber with ring shake also showed visible indicators of ring shake in log ends. In addition, approximately one-third of logs with shake indicators in the log ends did not produce lumber with ring shake.

Table 2.—Number and percentage (in parentheses) of hemlock sawlogs by shake status of log ends and dry lumber.

Shake indicators in log ends	Shake in lumber Yes	Shake in lumber No	Totals
Yes	181 (67.2)	88 (32.7)	269 (27)
No	206 (28.3)	523 (71.7)	729 (73)
Totals	387 (38.8)	611 (61.2)	998 (100)

Of the 249 hemlock logs with lumber graded green, only 22 logs or 9 percent produced lumber with ring shake (Table 3). Twelve percent of these 249 logs showed indicators of ring shake in log ends. Thirty-one percent of the logs yielding green lumber with shake also showed visible indicators of ring shake in log ends, but approximately 69 percent of logs with shake indicators did not produce green lumber with ring shake. These results imply that the visible indicators of ring shake in the ends of green hemlock logs were not reliable predictors of ring shake in the lumber sawn from these logs.

Table 3.—Number and percentage (in parentheses) of hemlock logs by shake status of log ends and green lumber.

Shake indicators in log ends	Shake in lumber Yes	Shake in lumber No	Totals
Yes	9 (31.0)	20 (69.0)	29 (12)
No	13 (5.9)	207 (94.1)	220 (88)
Totals	22 (8.8)	227 (91.2)	249 (100)

Frequency and Magnitude of Ring Shake in Dry and Green Lumber

The analysis of ring shake frequency and magnitude included only trees with 1 percent or more shake. This level of ring shake in dry lumber occurred in 73.1 percent of trees (Table 4). The frequency of ring shake varied from 52.4 percent of trees sampled in Georgia to 89.6 percent of trees sampled in New York. For the remaining three states where lumber was graded dry, 73.8 to 77.5 percent of trees sampled had shake.

The volume of dry lumber with ring shake averaged 62 board feet per tree (Table 4), ranging from 40.6 to 78.8 board feet per tree. Maximum volumes of lumber with shake varied by site, ranging from 175 to 355 board feet per tree (Table 4). The lumber volume with shake averaged 14.7 percent of the lumber sawn from trees with 1 percent or more shake. For the five states with lumber graded dry, the average proportion of lumber with ring shake ranged from 5.0 percent in Georgia to 34.0 percent in New York (Table 4).

Nineteen percent of the trees sampled in Maine had 1 percent or more shake in green lumber. Ring shake affected an average of 35.4 board feet or 11 percent of the lumber sawn from trees with shake.

Tree Attributes Associated with Ring Shake

The variables included in the probit analysis that link tree attributes with the incidence of ring shake are defined in Table 5. With the exception of the dummy variable indicating the condition of lumber when graded green or dry, the initial choice of explanatory variables was based on tree attributes reported in the literature and thought to be associated with ring shake. It was anticipated that lumber graded green could be different compared to lumber graded dry.

The results of the probit analysis are presented in Table 6. The signs of the coefficients indicate direction of change in probability resulting from an increase in a particular explanatory variable. Positive coefficients were obtained for all variables indicating that shake was more likely: the older the tree, the more times the growth rate changed abruptly, if occluded bird peck was present, and if shake was assessed in dry rather than green lumber. The latter effect is confounded with the location of the sample because only lumber cut from Maine trees was graded green.

The model correctly classified 104 of 151 trees without shake and 198 of 226 trees with shake (Table 7) for an overall accuracy rate of 80 percent.

Discussion

This study is unique in that the results are based on direct evaluations of lumber sawn from trees, permitting analyses of both the frequency of occurrence of ring shake in lumber and the actual lumber volumes affected. Results indicate that ring shake in eastern hemlock can be a serious wood utilization issue because it occurs frequently and often affects a significant portion of the lumber sawn when it does occur. Results also indicate that significant levels of ring shake occurred over a wide range of site conditions and geographic locations that spanned much of eastern hemlock's native range. This widespread occurrence lends support to Wilson's (1962) conclusion that ring shake in eastern hemlock is not strongly linked to site attributes and location.

Although determining the causes of ring shake was not a primary objective of this study, the results of the probit

Table 4.—Percent of trees with shake in dry lumber, and actual and relative volumes of lumber with shake for trees with 1 perecnt or more shake in dry lumber.

State	Trees with shake in lumber	Lumber volume with shake: Actual mean	Actual range	Relative mean	Relative range
	percent of trees	board feet/tree		percent of lumber	
PA	73.8	56.3	3 - 239	15.4	2 - 45
NY	89.6	62.8	7 - 175	34.0	5 - 100
TN	77.5	78.8	13 - 238	11.7	2 - 32
NC	75.5	78.8	11- 355	8.6	1 - 20
GA	52.4	40.6	8 - 197	5.0	1 - 14
ALL	73.1	62.0	3 - 355	14.7	1 - 100

Table 5.—Summary of variables included in the probit analysis.

Variable	Definition
Age	Age of tree in years from growth ring analysis
Growth	Number of abrupt changes in growth rate over the life of the tree from growth ring analysis
Bird peck	Coded 1 if occluded bird peck was present on the tree bole; 0 otherwise
Dry[a]	Coded 1 if shake degrade was recorded on dry lumber; 0 otherwise

[a]Shake was evaluated for green lumber in Maine and in dry lumber for all other study locations.

Table 6.—Probit analysis results.

Explanatory variable	Coefficient	Standard error	Mean in sample (N=377)
Constant***	-2.1128	0.2448	1
Age***	0.0085374	0.001810	145.76
Growth*	0.10601	0.06124	3.0663
Bird peck**	0.38109	0.1529	0.45623
Dry***	0.92189	0.1994	0.75862

*significant at the 10% level
**significant at the 5% level
***significant at the 1% level

Likelihood ratio statistic = 142.75 (4 d.f)

Table 7.—Frequencies of actual and predicted numbers of trees with and without shake using the probit model.

Actual	Predicted: No shake	Predicted: Shake	Total
No shake	104	47	151
Shake	28	198	226
Total	132	245	377

analysis linking shake occurrence to tree age, numbers of growth rate changes, and presence of occluded bird peck, support the findings and hypothesis reported in the literature. Wilson (1962) found a strong, positive correlation between tree age and ring shake when observing ring shake found in stumps of harvested eastern hemlock. Koehler (1933) theorized that sudden changes in radial growth rates could contribute to stresses causing ring shake, and that the dehydration of parenchyma cells that occurs over time would also contribute to internal stress resulting in ring shake. The relationship between parenchyma cell dehydration and ring shake was observed by Jorgensen and Leczner (1964) in their study of cell structure changes related to bird peck damage. In an earlier study, Shigo (1963) reported finding ring shake associated with bird peck scars in all 25 trees dissected to determine the effects of old yet visible bird peck wounds.

In their evaluation of marketing opportunities, Gardner and Diebel (1995) indicate that the shortage of western softwoods and the declining quality of lumber from alternative eastern softwood species are improving the market potential for eastern hemlock. They also cite utilization practices adopted by the industry to deal with ring shake; including sorting lumber to exclude boards with shake and chipping versus sawing lumber from the first 100 to 200 inches of the tree stem. Because of the confounding effects of sample locations, we could not conclude from the results of our study that lumber drying made ring shake detection easier. However, the results appear to indicate that sorting lumber to exclude ring shake would likely yield better results with dry versus green lumber. Insofar as detecting shake in the felled tree stem or bucked logs to guide utilization decisions such as chipping versus sawing, study results show that indicators in ends of green logs are not reliable predictors of shake in green or dry lumber. However, results of the probit analysis indicate that including tree age, presence of occluded bird peck, and number of growth rate changes to assess the likelihood of ring shake in a log or stem section could improve wood utilization decisions.

Estimated relationships between tree attributes and the occurrence of ring shake also could be applied to assess potential wood quality in specific stands of eastern hemlock based on knowledge of stand history or increment borings to determine age and number of growth rate changes and the observed frequency of occluded bird peck. These results can be implemented in forest management guidelines when wood quality and value are important management objectives. Because of the effects of age and abrupt changes in growth rates on ring shake occurrence, managers should avoid long rotations and frequent and/or heavy thinnings and partial cuts when managing hemlock stands for quality wood production. When forest management objectives dictate long rotations, old growth conditions, or retention of residual hemlock trees in heavily cut stands to enhance aesthetic or wildlife values, managers should be aware of the likely tradeoffs that include reduced wood quality and value due to ring shake.

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