Linking Log Quality With Product Performance

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Abstract

In the United States, log grading procedures use visual assessment of defects, in relation to the log scaling diameter, to estimate the yield of lumber that may be expected from the log. This procedure was satisfactory when structural grades were based only on defect size and location. In recent years, however, structural products have increasingly been graded using a combination of visual estimation of defects, coupled with nondestructive evaluation of other parameters, to obtain a more precise estimate of product properties. Today, the most commonly used nondestructive evaluation parameter is modulus of elasticity (MOE). This paper summarizes the results of three studies that used longitudinal stress wave techniques to determine the MOE of logs prior to processing into lumber. The MOE of lumber was then determined by transverse vibration. A good relationship was generally observed between the MOE of logs and the average MOE of the lumber cut from an individual log. These results indicate that improved sorting of logs for structural products might be achieved using a combination of visual assessment and determination of the MOE of the logs using longitudinal stress wave techniques. Future research will quantify the improvement in log sorting efficiency relative to other nondestructive testing options.

Keywords: Log grade, longitudinal stress wave, modulus of elasticity, lumber, spruce, balsam fir, Douglas-fir, western hemlock, Southern Pine.

Introduction

Considerable savings in material and processing might be achieved if a better relationship could be established between log quality and the quality of products cut from the log. The capability to improve log sorting becomes especially important as the wood industry adapts to a resource base that includes more plantation-grown softwoods, nontraditional species, and small-diameter trees (Skog et al. 1995).

Log grades are used to relate log size and quality to the yield of products that can be cut from the log. Since the 1940s, the Forest Service and industry researchers have been developing log grades to estimate lumber yield (Gregory and Person 1946; Southern and Southeastern Forest Experiment Station 1953; Campbell 1964; Ostrander and Brisbin 1971). These log grading systems are based on visual estimation of the number, size, and type of knots and other defects in relation to log scaling diameter. The visual log grading systems generally work satisfactorily for estimating the yield of visually graded structural lumber that may be expected from a log (Gregory and Person 1946, Lane et al. 1973; Woodfin and Snellgrove 1976; McDonald et al. 1993).

Structural lumber, visually graded by standardized procedures, has been available in the United States since at least the early 1920s (Newlin and Johnson 1923). In the early 1960s, mechanically graded structural lumber also became commercially available. This lumber is graded by a combination of visual assessment of knots and other lumber characteristics and nondestructive evaluation of the relationship between lumber modulus of elasticity (MOE) and modulus of rupture (MOR). Nondestructive evaluation of MOE, along with visual assessment of surface characteristics and defects, is also used for sorting lumber for the production of glued-laminated beams (AITC 1993), structural lumber from hardwood species (Green et al. 1994), and laminated veneer lumber (Sharp 1985). Green et al. (1996) recently proposed that nondestructive evaluation of MOE be used to grade heavy timbers. Despite the increasing importance of grading structural wood products by a combination of visual and mechanical means, the relationship between log and lumber stiffness has generally not been investigated for U.S. species.

In a limited study with six Douglas-fir logs, Galligan et al. (1967) were able to rank lumber obtained from the logs with reasonable accuracy, using only the longitudinal vibration characteristics of the logs. Recently, studies in other countries have begun to evaluate the relationship between log and lumber stiffness. For example, Arima et al. (1990) found a 0.83 coefficient of determination between log MOE and the average MOE of lumber from individual Sugi (*Cryptomeria japonica*) logs using longitudinal stress wave techniques. Aratake et al. (1992) reported coefficient of determination values of 0.82 between log MOE and the average MOE of the lumber from a log for green lumber. The coefficient of determination value was 0.71 between log MOE and average lumber MOE for dry lumber without the pith present and 0.58 with the pith present. Sandoz and Lorin (1994) reported coefficient of determination values of 0.44 between log MOE and lumber MOR cut from 12 spruce logs.

In 1992, we proposed to evaluate the relationship between log and product properties for a range of species and products. The goal of our research is to access improved procedures for sorting logs, and eventually trees, for production of products graded by mechanical means. This paper summarizes some of the results from three of these studies.

Materials and Methods

The first study evaluated the relationship between log and lumber MOE using randomly selected eastern spruce and balsam fir logs (Ross et al. 1997). The second study evaluated the log MOE–lumber MOE relationship for Southern Pine sampled from both natural and plantation forests (Green et al. [in progress A]). The third study utilized Douglas-fir and western hemlock logs 660 mm (26 in.) and less in diameter (Green et al. [in progress B]). The procedures followed in all three studies were similar (Fig. 1).

In each study, logs were selected at a mill and measurements were made of log length, scaling diameters, and visual grade. For each log, longitudinal speed-of-sound stress wave transmission was determined using accelerometers fixed to the ends of the logs. A stress wave was introduced into the specimen through a hammer impact on one end and the signal obtained from the opposite end. The stress wave signal was recorded on an oscilloscope to obtain the transit time from the distance between signal peaks (Ross et al. 1994). Although a preliminary study indicated that equivalent measurements could be obtained with stacked logs, all stress wave measurements were taken with the logs removed from the stack (Fig. 2) (Ross et al. 1997). The logs were then sawn into lumber, with

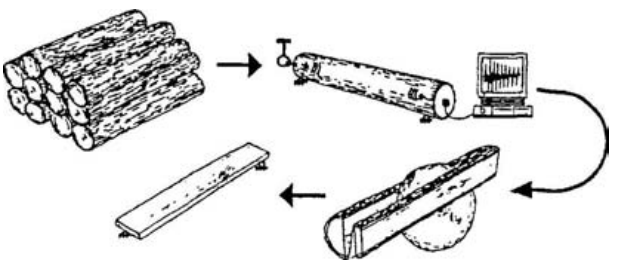

Figure 1- Flow chart of log–lumber correlation studies.

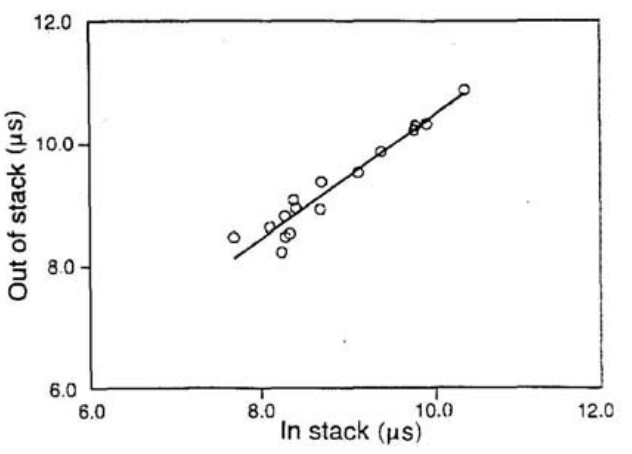

Figure 2—Results obtained from stress wave transmission measurements made in logs in and out of the stack for eastern spruce and balsam fir (Ross et al. 1997).

special care taken to ensure that individual lumber specimens could be traced to the log from which they were sawn. Flatwise MOE was determined for each lumber specimen using transverse vibration techniques (Ross et al. 1991).

Results and Discussion

Linear regression was used to evaluate the relationship between the lumber MOE values and the MOE of the logs (Table 1). The log–lumber MOE relationship was evaluated two ways. First, the correlation was determined between log MOE measured by stress wave techniques and the MOE of each individual board in the logs measured by transverse vibration (called "individual boards" in Table 1). Second, the correlation was established between the log MOE and the average MOE of all boards obtained from a given log (called "average of boards" in Table 1). In general, a good correlation was found between log MOE and the average MOE of the lumber cut from a log for eastern spruce, Southern Pine, and Douglas-fir (Figs. 3–5). For these three species, coefficients of determination ranged from 0.50 to 0.82. Significant, but lower, correlations were found with balsam fir and western hemlock (0.33 and 0.13, respectively). The low coefficient of determination for western hemlock was probably a result of having a limited range in log MOE values in the sample selected. The range in MOE values was about half that expected from tests of dimension lumber. The western hemlock was sampled primarily from trees growing at lower elevations (Green et al. [in progress A]). When combined with Douglas-fir, the log MOE–average lumber MOE correlations were excellent. The reason for the low correlation between log and lumber MOE for balsam fir could be similar to that for western hemlock (Ross et al. 1997). However, the low correlation could also be a result of the frequent occurrence of bacterially infected wood in balsam fir (Ward and Pong 1980). Additional research on western hemlock and balsam fir is needed to clarify the relationship.

The log MOE–average lumber MOE correlation is one indication of the potential of using log MOE values as an additional factor to incorporate into a log grading rule to improve the prediction of the yield of mechanically graded lumber. Another indicator is the log MOE–individual board MOE correlation. If the variability in MOE of individual boards within a log is too large, this might negate the benefit of sorting the logs by MOE. As would be expected, the correlation of log MOE and individual board MOE is less than that between log MOE and the average MOE of the boards (Table 1). As shown in Figure 6, there appears to be

Table 1- Summary of log–lumber correlations between log MOE and the MOE of lumber cut from individual logs

Species	Number of logs	Coefficient of determination (R^2): Individual boards	Coefficient of determination (R^2): Average of boards from a log
Eastern spruce	98	0.50	0.82
Balsam fir	95	0.17	0.33
Combined	193	0.30	0.55
Southern Pine	98	0.31	0.63
Douglas-fir	100	0.30	0.50
Western hemlock	100	0.13	0.34
Combined	200	0.54	0.74

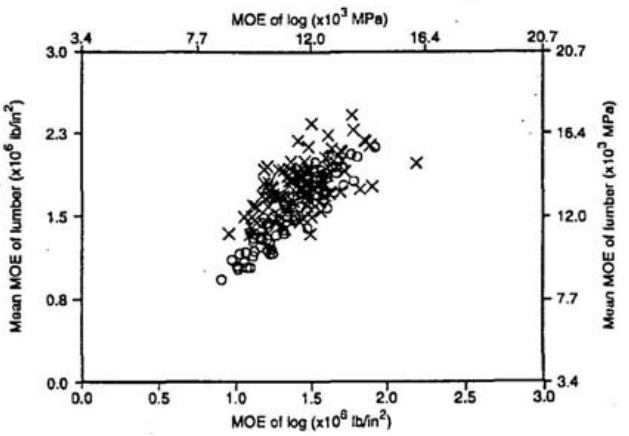

Figure 3–Average MOE of lumber from a log as a function of MOE of logs for eastern spruce and balsam fir (0 = eastern spruce; X = balsam fir) (Ross et al. 1997).

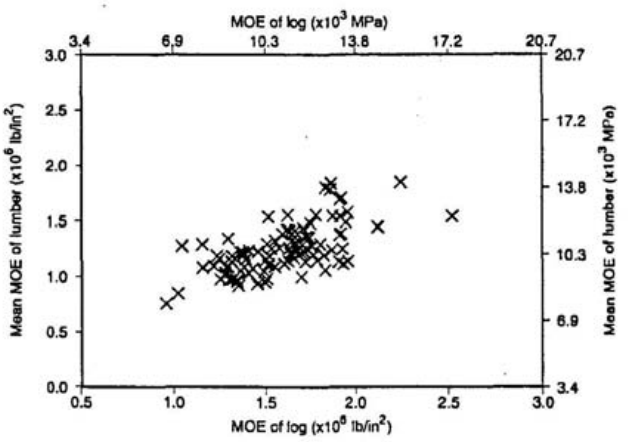

Figure 4- Average MOE of lumber from a log as a function of MOE of logs for Southern Pine (Green et al. [in progress A]).

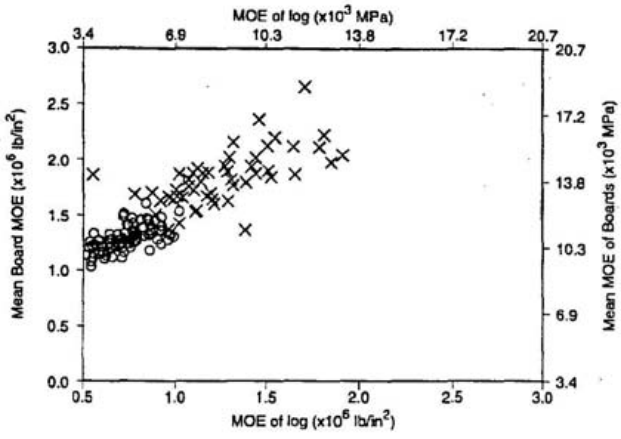

Figure 5- Average MOE of lumber from a log as a function of MOE of logs for Douglas-fir and western hemlock (X = Douglas-fir; 0 =western hemlock) (Green et al. [in progress B]).

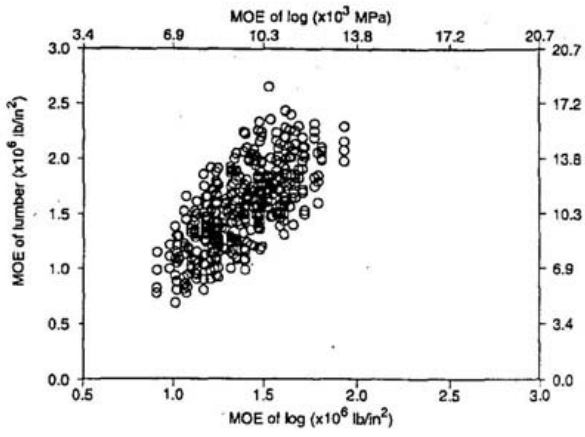

Figure 6- MOE of individual pieces of lumber from a log as a function of MOE of log for eastern spruce (Ross et al. 1997).

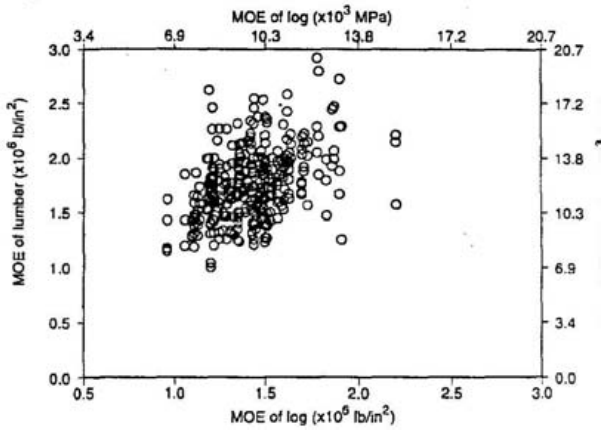

Figure 7–MOE of individual pieces of lumber from a log as a function of MOE of log for balsam fir (Ross et al. 1997).

good potential for sorting eastern spruce logs using this approach. With other species, such as the balsam fir shown in Figure 7, the potential is questionable. As discussed previously, additional work is needed before deciding to abandon this approach with balsam fir and western hemlock.

A detailed discussion of the log MOE–lumberMOE correlations for the species discussed in this paper will be given in the full reports (Ross et al. 1997, Green et al. [in progress A and B]). In addition to the three studies previously noted, several studies are nearing completion that evaluate the correlation between log and lumber properties for other species. Also nearing completion are studies that relate the MOE of logs to the MOE of veneer cut from those logs. Future studies will develop alternatives, using the stress wave based approach, to incorporate log properties into log grading rules and compare these results with existing rules based solely on visual assessment or density.

Concluding Remarks

Based on the results to date, we conclude the following:

- There is a good correlation between log MOE and the average MOE of the lumber cut from an individual log for eastern spruce, Southern Pine, and Douglas-fir. Correlations are not as good for balsam fir and western hemlock. However, a limited range of MOE values in our samples may have reduced the correlations for the latter two species.

- With eastern spruce, Southern Pine, and Douglas-fir, the correlation between log MOE and the MOE of individual boards cut from the log appears to be high enough so that within log variability would not negate the benefits of sorting logs by log stiffness. Additional work is needed to quantify this assumption.

- Results indicate that improvements in log sorting capability may be possible for predicting the yield of structural products that use MOE as part of the grading criteria.

- Additional research is needed to establish the log–product MOE relationship for other species and products and to evaluate the incorporation of log MOE values in log grading rules.

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Role of Wood Production in Ecosystem Management

Proceedings of the Sustainable Forestry Working Group at the IUFRO All Division 5 Conference, Pullman, Washington, July 1997

International Union of
Forestry Research
Organizations

National Project on
Wood Utilization for
Ecosystem Management

Abstract

The presentations at this symposium discussed concepts of ecosystem management and sustainability as viewed by various levels of government and private land managers. The theme was to integrate ecology, silviculture, forest operations, wood products, and economics to find ways to develop healthy sustainable ecosystems under financially sound management practices. Speakers discussed ways to manage disturbance to create landscapes with the desired level of diversity and resilience to fire, disease, and insects. Others identified technical aspects of improving the options for producing wood and promoting healthy ecosystems. The feasibility of the various modes of forest operation were considered along with methods to evaluate the financial aspects of activities in different stand types. Lastly, the concept of sustainability was discussed, both in theory and through case studies. A full paper is presented for the majority of presentations; an abstract is included for others.

Keywords: Ecosystem management, sustainable forestry, wood utilization, small-diameter timber, silviculture, forest operations, economic feasibility, wood quality, pulp quality

July 1997

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