# EFFECTS OF BARK REMOVAL ON ACOUSTIC VELOCITY OF DOUGLAS-FIR LOGS

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## ABSTRACT

The acoustic velocities of 81 Douglas-fir logs were measured before and after debarking in a log yard. Bark removal led to an average increase in acoustic velocity of 3.6%. A regression model for determining the effect of bark removal on the change in acoustic velocity was developed. This model predicted an increase in acoustic velocity of 4.6% if 100% of bark was removed. This is similar to increases in velocity found by other researchers for radiata pine logs.

**Keywords:** modulus of elasticity, wood properties, Douglas-fir, acoustics, harvesting practices.

## INTRODUCTION

Forest managers today operate in globally competitive forest product supply markets. These require that managers have good metrics of the quantity, quality and location of timber resources within their forests. These metrics can help the forest manager to ensure that: (a) wastage is minimized; (b) harvest and volume growth increments are balanced; (c) log products are optimally matched to markets; and (d) value of the forest is maximized at the time of harvest.

Traditionally, quality has been characterized by such external features as branch size, fluting, sweep, decay, and scarring. Consideration is now being given to intrinsic wood properties such as stiffness, strength, density, spiral grain, extractives content, and consumption of energy for processing (Andrews, 2002; Carter, et al., 2005; So, et al., 2002; Walker, 2000; Young, 2002).

Acoustic technologies have become widely accepted in the forest products industry for

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product grading and on-line quality control (Pellerin & Ross, 2002). Wang, Carter, Ross and Bradshaw (2007) comment that "the precision of acoustic technology has been improved to the point where tree quality and intrinsic wood properties can be predicted and correlated to structural performance of the final products". They summarise studies that show how acoustic technologies can be used at a number of places along the wood supply chain to successfully:

- sort logs for lumber quality based on strength and stiffness;
- sort logs for veneer quality based on stiffness;
- sort logs for pulp and paper quality based on average fibre length and energy requirements;
- monitor moisture changes in log stocks;
- verify log supply for visually graded lumber;
- measure wood properties (e.g stiffness and microbril angle) of standing trees;
- assess silvicultural treatment effects;
- assess young trees for genetic improvement; and
- evaluate plantation resources for wood quality based on stiffness.

Almost a decade ago, Arlinger and Wilhelmsson (1999) commented that the future would see wood properties of individual sawlogs and pulpwood bolts determined on site by a harvester's merchandising computer. Their comment was related to the prediction of wood properties based on regional variables and intra-tree models. Rather than using predictive models, Wang et al. (2007) commented that empirical acoustic measurement of wood properties could be obtained automatically now by sensors on the harvesting processor.

In a study of the relationship between average acoustic velocity of Douglas-fir [*Pseudotsuga menziesii* (Mirb.) Franco] logs and veneer recovery, Amishev and Murphy (in press) noted that veneer recovery from five stands which had been manually delimbed and bucked appeared to be higher grade compared with that from two stands which had been mechanically delimbed and bucked. It was noted that little of the bark had been removed when stems were manually processed whereas a large portion of the bark had been removed during mechanical processing. Both processors were fitted with spiked rollers, which tend to remove more bark than processors fitted with rubber rollers (Lee & Gibbs, 1996). It was hypothesized that bark removal affected acoustic velocity of logs.

In a review of the literature, we found only one study that evaluated the effect of bark removal on acoustic measurement of wood properties. Lasserre (2005) found that bark removal significantly influenced whole stem modulus of elasticity measured by acoustic resonance ($MOE_{res}$), increasing values by an average or 8.3% for *Pinus radiata* stems. He commented that the acoustic resonance method measures a volume-weighted $MOE_{res}$ and that bark adds mass to the stem without contributing much $MOE_{res}$.

This technical note reports the results of a brief study which evaluated the effects of bark removal on acoustic velocities of Douglas-fir logs.

# MATERIALS AND METHODS

The study was carried out in November 2007 in Georgia Pacific's log yard in Philomath, Oregon, USA. About 100 "run-of-bush" Douglas-fir logs were originally laid out in the yard ready for measurement. It appeared that many of the logs had been delimbed by a mechanical processor with spiked rollers. Logs had been delivered to the log yard less than 10 days prior to the measurements. It is unknown how long, prior to that, the trees had been felled and manufactured into logs.

Logs were numbered on the largest end, and then measured for length [glass fibre tape], large end diameter [callipers], and acoustic velocity [Fiber-gen HM200]. An estimate was also made by two observers of the amount of bark present; estimates were rounded to the nearest 5% of each log's surface area, e.g. 85%. The logs were then taken to the log yard debarker, debarked and returned for remeasurement of acoustic velocity within one hour of the pre-debarker acoustic velocity measurement.

When first discussing the study with log yard personnel, we envisioned that most logs would have most of their bark present. However, prior handling by mechanized equipment meant that high levels of bark removal had already occurred on many of the logs. Logs were rejected from the study if they had less than 40% of their bark present prior to log yard debarking. Logs were also rejected if greater than 5% of their bark was still present after log yard debarking. About half of the logs were rejected. Additional logs were brought from the log stacks until more than 80 logs were available for analysis.

# RESULTS AND DISCUSSION

Table 1 summarises the key statistics for the 81 logs included in the study. Log lengths ranged from 3 to 7.5 m and diameters from 26 to 71 cm. Average acoustic log velocity was 3.82 km/sec prior to debarking and 3.96 km/sec after debarking. The average increase in acoustic velocity after debarking was 3.6%.

A number of regression models were explored to determine the effect of bark removal on the change in acoustic velocity. These included: (1) acoustic velocity after debarking (m/sec) as a function of bark presence and acoustic velocity before debarking(m/sec); (2) change in acoustic velocity (m/sec) as a function of bark presence; and (3) change in acoustic velocity (%) as a function of bark presence. The presence of an intercept in each model was also evaluated. The best model found was:

$$\text{Change (\%)} = 0.0046 \times \text{Bark Presence}$$
$$R^2 = 0.92$$

where Change (%) is the percent increase in acoustic velocity after bark has been removed, and Bark Presence is the percentage of bark present prior to debarking. Initial analyses indicated that the intercept was not significant so the regression model was forced through the origin.

TABLE 1. Statistics from Log Acoustic Measurement Study

| | Length (m) | Large End Diameter (cm) | Prior to Debarking | | After Debarking | | Change in Acoustic Velocity (%) |
|---|---|---|---|---|---|---|---|
| | | | Bark Presence (%) | Acoustic Velocity (km/sec) | Bark Presence (%) | Acoustic Velocity (km/sec) | |
| Mean | 5.45 | 50.3 | 78 | 3.82 | 1 | 3.96 | 3.6 |
| Range | 3.00 – 7.47 | 25.9 – 70.6 | 40 – 100 | 2.94 – 4.27 | 0 – 5 | 3.05 – 4.45 | 0 – 7.4 |
| Standard Deviation | 0.70 | 10.4 | 12.8 | 0.27 | 1.6 | 0.28 | 1.1 |

The ANOVA model is shown in Table 2. The standard error for the coefficient was 0.00015. We note that coefficients may have changed slightly if an objective, rather than subjective, measure of bark presence had been used.

TABLE 2. ANOVA analysis of Bark Removal Model

| ANOVA | | | | | |
|---|---|---|---|---|---|
| | *df* | *SS* | *MS* | *F* | *Significance F* |
| Regression | 1 | 0.107083 | 0.107083 | 938.7 | <0.0001 |
| Residual | 80 | 0.009126 | 0.000114 | | |
| Total | 81 | 0.11621 | | | |

The above model implies that if 100% of the bark was present prior to debarking, the increase in acoustic velocity, after debarking would be 4.6%.

As noted above, Lasserre (2005) found an increase in $MOE_{res}$ of 8.3% after stems were debarked. Since $MOE_{res}$ = density x velocity$^2$ and density was held constant in Lasserre's calculation, the implied increase in acoustic velocity from his research was 4.1%. This is similar to the increase found in this present study.

Past interest in determining what factors affect bark removal has usually been related to surface damage and fungal bluestain in logs. At two Corsican pine (*Pinus nigra*) study sites (Thetford and Inverness) in Great Britain, Lee and Gibbs (1996) found that there was much less bark removal on logs that had been manually delimbed and processed

(13% and 1%), than on logs that had been mechanically delimbed and processed with rubber rollers (29% and 6%), or with spiked rollers (39% and 8%). The authors commented that the higher bark removal at the Thetford site was likely to have been due to the thinner bark at this site.

Uzonovic et al. (1999) also reported much less bark removal from Corsican pine with manual delimbing and processing (< 5%) than with mechanical delimbing and processing with rubber rollers (5 to 45%). Bark removal also appeared to be greater on logs delimbed in late spring than in mid-summer. Others have noted that bark is more easily knocked off stems and logs in spring, when the sap is rising, than at other times of the year (Nevill, 1997).

Granlund and Hallonborg (2001) report that bark removal by five harvesters, all fitted with rubber rollers, ranged from 0 to 5%. This is considerably lower than was noted by the authors in field work carried out in the summers of 2006 and 2007. It is also considerably lower than noted when selecting logs for the brief trial reported in this paper; up to 95% of bark was missing on some logs. As noted above, logs with less than 40% of bark present were rejected from the study.

## CONCLUSION

Bark removal increases the acoustic velocity of Douglas-fir logs compared with non-debarked logs. Bark removal should be considered when predicting $MOE_{res}$, and timber and veneer grade recoveries. Factors, such as harvesting season, timber location, and harvesting system, can affect the amount of bark removed in the forest.

The percentage increase in acoustic velocity for Douglas-fir logs was similar to that found in radiata pine logs. Further studies should be undertaken to determine whether the same level of increase is observed for other conifer species and also for hardwoods.

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# REFERENCES


Amishev, D. & Murphy, G. (in press). In-forest assessment of veneer grade Douglas-fir logs based on acoustic measurement of wood stiffness. *Forest Products Journal.* (accepted July 2008).

Andrews, M. (2002). Wood quality measurement – *son et lumiere. New Zealand Journal of Forestry, 47* (3), 19-21.

Arlinger, J. & Wilhelmsson, L. (1999). *Wood Analysis – an aid to meeting the needs of the mills.* Results No 1. 1999, 4 pp. Uppsala, Sweden: Skogforsk.

Carter, P., Briggs, D., Ross, R. J. & Wang, X. (2005). *Acoustic testing to enhance western forest values and meet customer wood quality needs.* (PNW-GTR-642, Productivity of Western Forests: A Forest Products Focus pp. 121-129). Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

Granlund, P. & Hallonborg, U. (2001). *Latest harvesters are gentle on the wood.* Results No 5. 2001, 4 pp. Uppsala, Sweden: Skogforsk.

Lasserre, J.P. (2005). *Influence of initial stand spacing and genotype on Pinus radiata corewood properties*. Unpublished Master of Forestry Science thesis (107 pp.). University of Canterbury, Christchurch, New Zealand.

Lee, K. & Gibbs, J. N. (1996). An investigation of the influence of harvesting practice on the development of blue-stain in Corsican pine logs. *Forestry, Vol. 69* (2), 137-141.

Nevill, R. J. (1997). *A review of tree wounding.* (Technology Transfer Notes Number 3, 4 pp), Victoria, British Columbia: Pacific Forestry Centre, Canadian Forest Service.

Pellerin, R. & Ross, R. J. (2002). *Nondestructive evaluation of wood* (210 pp.), Madison, WI: Forest Products Society.

So, C. L., Groom, L. H., Rials, T. G., Snell, R. , Kelley, S. & Meglen, T. (2002). Rapid assessment of the fundamental property variation of wood. In Outcalt, K. W. (Ed.) *Proceedings of the 11th Biennial Southern Silvicultural Research Conference* Report SRS-48 (pp. 176-180). Asheville, NC: USDA Forest Service, Southern Research Station,.

Uzonovic, A., Webber, J. F., Pearce, A. J. & Dickinson, D. J. (1999). The role of mechanized harvesting in the development of bluestain in pine. *Canadian Journal of Forest Research, Vol. 29*, 242-251.

Young, G. G. (2002). Radiata pine wood quality assessments in the 21st century. *New Zealand Journal of Forestry, 47* (3), 16-18.

Walker, J. (2000). Dream merchants: why forestry practices will change. *New Zealand Journal of Forestry, 45* (3), 27-33.

Wang, X., Carter, P., Ross, R. J. & Brashaw, B.K. (2007). Acoustic assessment of wood quality of raw forest materials – a path to increased profitability. *Forest Products Journal, 57* (5), 6-14.