The use of log geometry variables to determine the stiffness of Sitka spruce

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Abstract

A key limiting property in the utilisation of British grown Sitka spruce is its lower stiffness when compared to slower grown softwood from northern Europe. With better knowledge of the variables affecting timber performance, better sorting regimes might be determined. Three dimensional log shape scanners are used in many sawmills to optimise volumetric recovery. These scanners also have the potential to be used to indicate timber quality.

In this paper the relationship between axial position within the stem, log shape variables (taper, ovality, pith eccentricity) and MOE as indicated by Cook Bolinder grading machine and static bending tests to EN 408 are examined for sample batches of Sitka spruce. A particular feature noted is the existence of a zone of low stiffness material near to the butt. The low stiffness was determined to be due to high microfibril angle (MFA), and not other factors such as low density or slope of grain. The effect was noted to be variable between the individual trees and stands of material.

1 Introduction

Sitka spruce (*Picea Sitchensis*) is the UK's most important commercial species, providing over half of the total volume of softwood timber produced. British-grown Sitka spruce trees reach maturity relatively quickly; as a consequence the timber differs significantly from slower grown softwoods imported from northern Europe. British-grown Sitka spruce tends to meet a lower structural grade than imported softwood, which can exclude it from certain markets. For example, none at present is used for trussed rafters.

Although density has, historically, been considered one of the main properties influencing the mechanical performance of timber, Brazier (1986) questioned its significance for Sitka spruce. He identified two features of greater influence, grain inclination and presence of juvenile wood.

Brazier (1991) found in a study on the effect of spacing on the vigour of 41 Sitka spruce trees that the timber at the base of the tree was of poorer quality (*i.e*. was less stiff), and that stem size had no apparent effect on structural wood performance. He suggested that the reason for the low performance of the near butt wood might be due to a combination of low density, irregular grain associated with a buttressing effect from the roots, and possibly also "unusual"

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cell microstructure. In more recent work, Ping and Walker (2004) assembled stiffness profiles from pith to bark and from butt to the upper top logs for Radiata pine (*Pinus radiata*), and identified a zone of high MFA within the base of the trees. Like Brazier, they advocated segregating this material.

2 Method

For this work around 500 battens of Sitka spruce were obtained from two localities - Lochaline and Benmore in Scotland. The logs were scanned by a Pronyx™ 3D laser scanner in a sawmill prior to being converted, enabling log shape variables to be obtained (Figure 1).

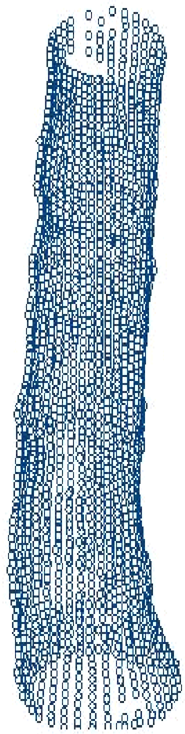

Figure 1: Log shape data obtained from industrial 3D laser scanner, from which variables such as *Log taper* were obtained.

The timber was sawn into three nominal sizes - 200 x 47 mm, 150 x 47 mm, 100 x 47 mm - which are commonly used in construction. Variables which were recorded included tree height, tree diameter at breast height (*DBH*), density, knot content (in terms of total area of knots/area of batten faces), ring width, juvenile wood content, slope of grain, ring width, radial and axial position within the stem and compression wood content based on surface appearance. This paper reports the results of observations on the influence of axial position or *Cut ht*. (defined as the distance from ground level to the lower end of the batten) and the log shape variable *Log taper* (defined as base diameter/top diameter over 3 m). The battens were machine strength graded using a Cook Bolinder to obtain detailed values of stiffness (E_{cb}) along the board lengths. This device obtains an indicative stiffness parameter using three-point bending via a system of rollers (Figure 2), based on a nominal batten size. Values of stiffness and strength (*i.e.* $E_{m,g}$ and f_m) were also determined by tests to EN 408.

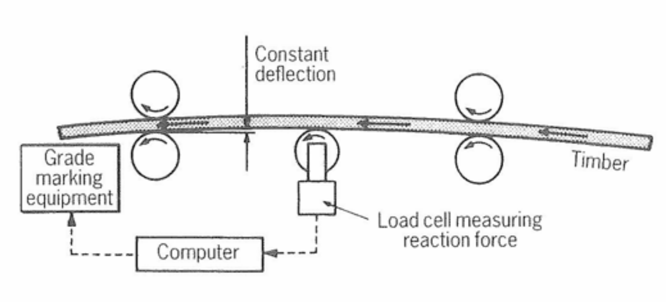

Figure 2: Schematic of Cook Bolinder strength grader.

Since the position of every batten was known within each tree stiffness profiles both axially and radially could be established. MFA measurements were carried out on samples from selected butt log battens using microscopic examination of cross-field pit angle relative to the axis of the cell wall. In addition, MFA measurements on batten cross sections were also obtained on several battens using the Silviscan™ instrument at STFI-Packforst, Sweden, which measures MFA based on X-ray diffractometry. A full description of the operating principle of this device is given by Evans (1997).

3 Results and discussion

Figure 3 shows an example of tree stiffness profiles assembled from Cook Bolinder grader data. For the Benmore material (stand nos. FR3 and FR4), in particular, there was a marked tendency for low stiffness material to be evident at the butt; however this feature was noted to be variable between individual trees.

Figure 4 shows E_{cb} plotted against *Cut ht*. (*i.e.* axial position) for the FR3 150 x 47 mm butt log subgroup. A similar effect was noted in other (but not all) butt log subgroups. Figure 5 shows E_{cb} plotted against *Log taper* for groups of upper log and butt log material. It can be seen that the butt log battens are generally of lower stiffness than the upper log material.

Microscopic examination of material taken from a number of boards which showed particularly marked trends for lower stiffness towards the butt indicated that this effect was related to MFA (Figures 6 and 7). Marked differences in the MFA trends from pith to bark between butt and upper sections were also obtained in several other battens using the Silivscan™ instrument.

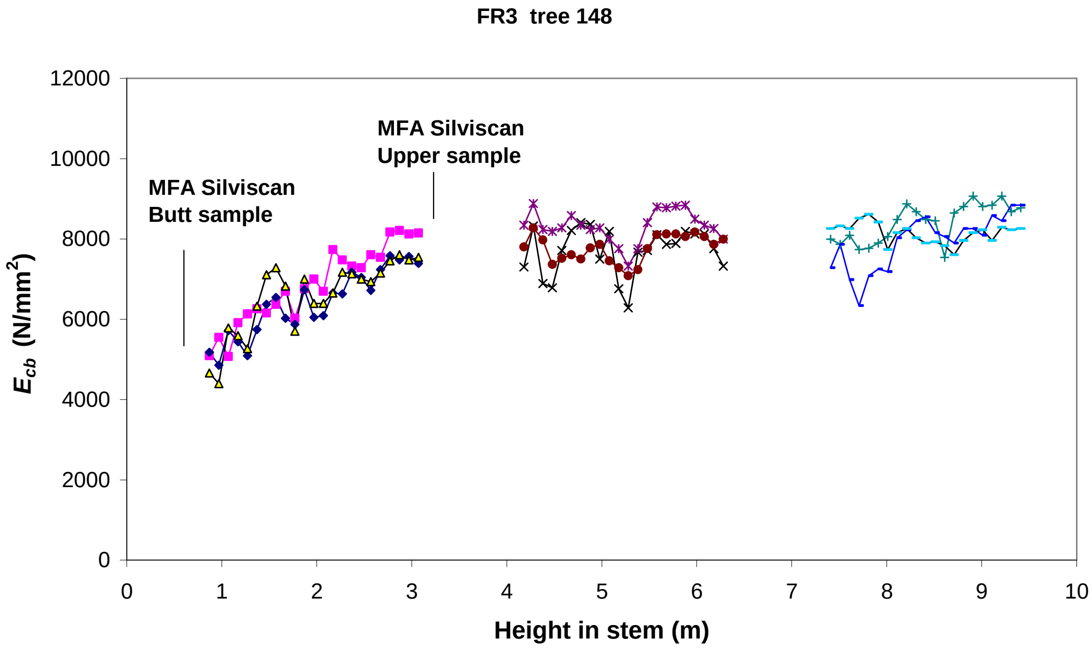

Figure 3: E_{cb} data plotted against height in stem, with position of MFA measurements shown.

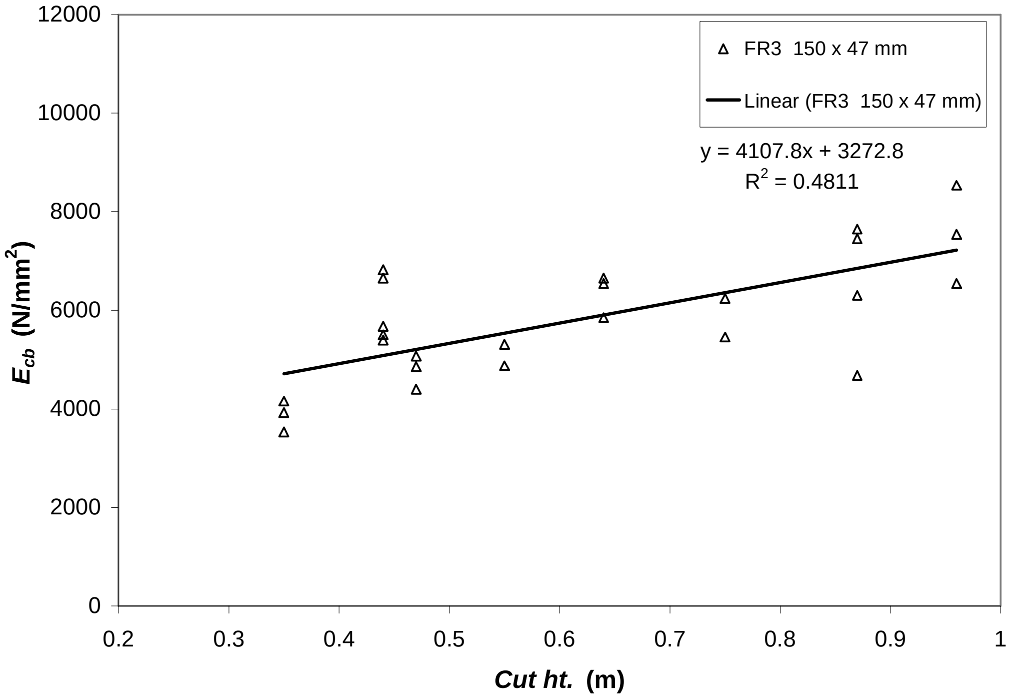

Figure 4: E_{cb} plotted against axial position *i.e*. *Cut ht*. (FR3 150 x 47 mm butt logs).

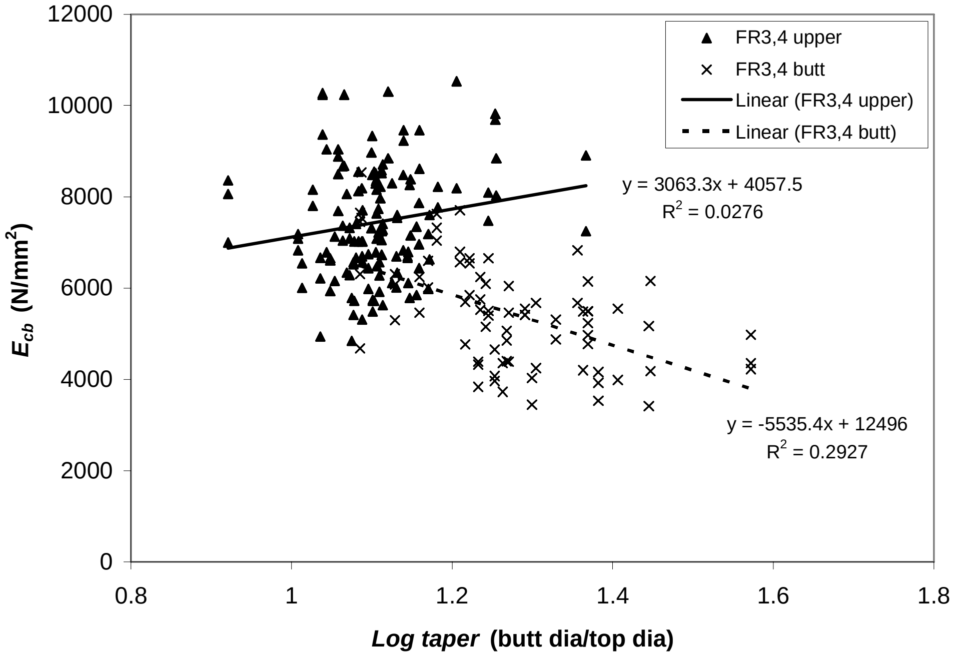

Figure 5: E_{cb} plotted against *Log taper* for groups of butt and upper logs.

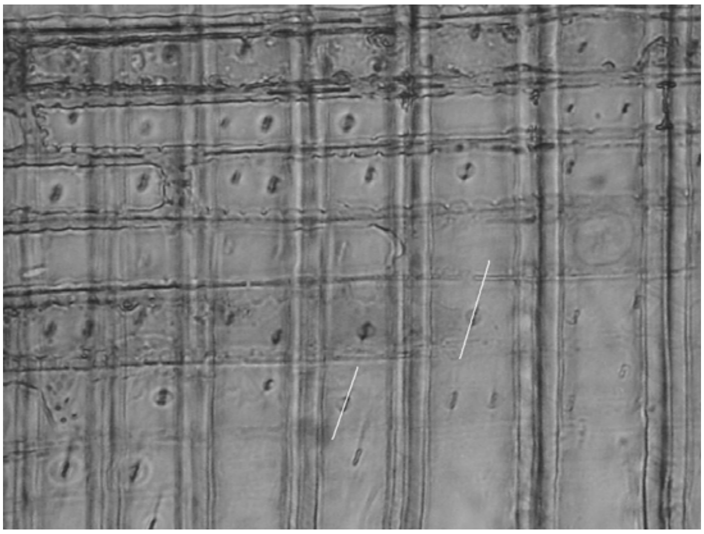

Figure 6: MFA indicated by cross-field pit angle, from upper section.

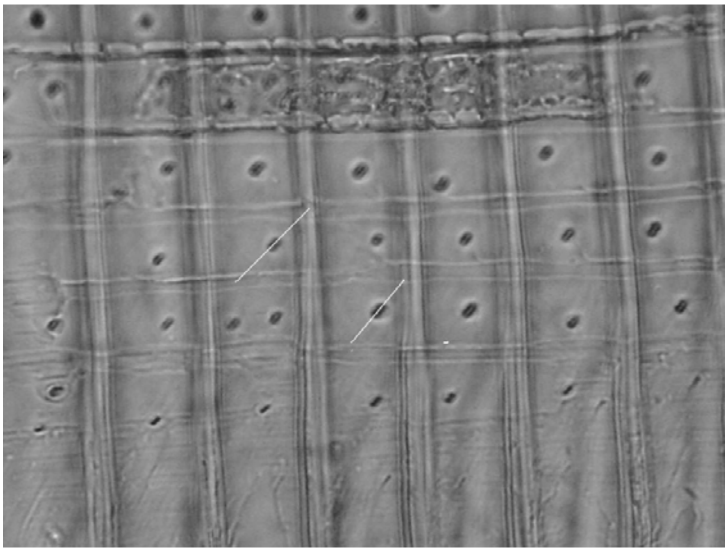

Figure 7: MFA indicated by cross-field pit angle, from butt end.

From inspection of the relative content of juvenile wood at the butt end of the battens compared with the top end of the batten, it could be seen that the change in stiffness from one end to the other for these battens was due a change in the nature of the juvenile wood, rather than a simple increase in its proportion. It was also determined that there was little difference in density between samples taken from the butt and top of these battens. A strong negative correlation (r^2 = 0.78) was observed between *MOE* and *MFA* was observed for the small clear samples obtained.

Table 1 shows the correlations obtained for E_{cb}, $E_{m,g}$ and f_m for the 150 x 47 mm FR3 and FR4 butt and upper log battens (*i.e.* a combined group) for which corresponding measurements are available.

Table 1

r	E_{cb}	$E_{m,g}$	f_m
E_{cb}	1	.667**	.576**
$E_{m,g}$	.667**	1	.687**
f_m	.576**	.687**	1
Cut ht. (axial position)	.593**	.298*	.202
Log taper	-.680**	-.428**	-.383**
Density	.310*	.405**	.273
Pith Distance (radial position)	-.034	.125	-.074
Ring width	-.394**	-.540**	-.449**
Juvenile wood content	-.216	-.377**	-.158
Knot area (%)	-.603**	-.409**	-.413**

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
N = 51

From the above table it can be seen that E_{cb} is more strongly related to *Log taper* and *Cut ht.* than $E_{m,g}$. This is likely to be due to the nature of the test set up whereby for butt log battens the Cook Bolinder effectively measures the stiffness at the lower end near to the ground, whilst the EN 408 determined stiffness using a four point bending arrangement is more biased towards the middle of the batten. The relationship between E_{cb} and $E_{m,g}$ is quite poor (r^2 = 0.44), probably due to the random arrangement of the battens with respect to the position of knots. Inaccuracies within the grader derived stiffness values are likely due to batten distortion and the use of nominal rather than precisely determined batten dimensions. The battens are also bent about different axes.

However, it can be seen that E_{cb}, $E_{m,g}$ and f_m all correlate negatively to knot content, albeit very weakly, whilst correlations between E_{cb}, $E_{m.g}$ and f_m are poor for both density and radial position. No correlation between these mechanical properties and either compression wood content or slope of grain, or *DBH* was observed. No significant relationships between these mechanical properties and log shape variables based on ovality, pith eccentricity or arc (*i.e.* curvature) were observed. Batten knot content was noted to be related positively to log taper (r^2 = 0.46).

It appears probable that the axial variation in stiffness observed, and the variation of this effect between individual trees, causes relationships between stiffness and other variables such as batten knot content, juvenile wood content, density, radial position and ring width to be poor – and hence ineffective sorting parameters in an industrial setting where upper and butt log material would likely be mixed.

4 Conclusions

This work identified the causal relation between MFA and the relatively low stiffness of butt wood material observed in the Cook Bolinder derived E_{cb} trends, and is in agreement with recent work by McLean (2007). This feature was, however, noted in some of the earliest Forest Products Research Laboratory studies on British grown Sitka spruce. In particular the relationship between stiffness and *Log taper* reported in this work indicates that 3D log shape scanners, which are currently used to maximise recovery in terms of quantity by optimising the cutting pattern, also have the potential to be used to sort timber on the basis of quality (*i.e*. stiffness). Logs containing near butt wood material of lower stiffness could be readily identified, and the battens processed into non-structural sizes. In particular, butt logs with both high levels of taper and knot content should be avoided. The absence of radial variation in both stiffness and strength for the batten size examined means that it is not only the central batten containing pith that should be avoided. Forest practice which involves felling trees close to ground level may risk reducing structural timber quality. The variation in the so-called weak butt effect observed between individual trees and stands warrants further investigation.

Acknowledgments

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