TANGENTIAL SHRINKAGE OF *PINUS RADIATA* EARLYWOOD AND LATEWOOD, AND ITS IMPLICATION FOR WITHIN-RING INTERNAL CHECKING

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ABSTRACT

Tangential shrinkage of earlywood and latewood of *Pinus radiata* D. Don in wood from logs which had a severe propensity for within-ring internal checking was compared with wood from logs which showed no tendency to form internal checks. The samples were collected from nine 23- to 26-year-old trees of each category, with a total of 132 samples being assessed. These trees were chosen from three forests in the central North Island of New Zealand, denoted as Site A, Site B, and Site C.

The average tangential shrinkage from green to 12% moisture content was 3.68% for all the samples, with a standard deviation of 0.82%. Between-site variation for average shrinkage was less than 0.27% with an average value of 3.82% for Site B, 3.57% for Site A, and 3.55% for Site C. From the measured data, it was found that earlywood and the latewood shrink differently. However, for the severely checked rings, the tangential shrinkage of the earlywood layer was higher than for the latewood layer, and for the rings without checks the trend was the opposite.

Keywords: tangential shrinkage; earlywood; latewood; internal checking; *Pinus radiata*.

INTRODUCTION

Within-ring internal checking in kiln-dried *Pinus radiata* lumber (Fig. 1) is a defect which causes concern for appearance products (Miller & Simpson 1992; Booker & Haslett 1993). Internal checking occurs in earlywood layers in the radial direction, and studies have shown that it can occur in the early stages of drying when the moisture content is above the fibre saturation point (FSP) (30% moisture content at room temperature) or in the late stages of drying with the moisture content below the FSP. One of the possible causes for below FSP internal checking is the difference in tangential shrinkage between the earlywood and the latewood layers. However, published shrinkage data are the average values over several growth rings (Cown & McConchie 1980, 1983), and there are no data available on the shrinkage of individual earlywood and latewood layers of *Pinus radiata*. The objective of the work reported here was to examine the shrinkage differences between earlywood and latewood for logs in which dried lumber showed severe internal checking and for logs in

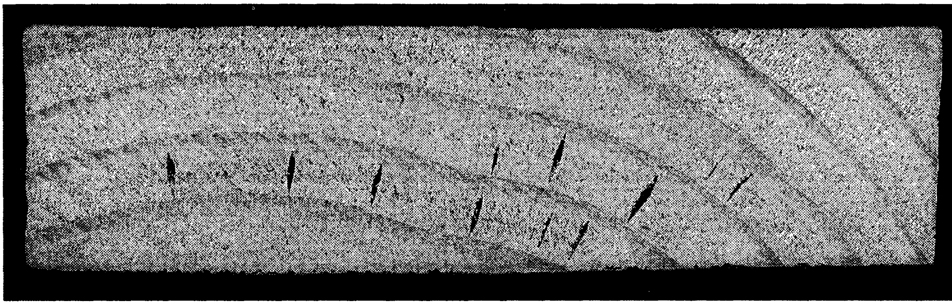

FIG. 1–Typical within-ring internal checking in kiln-dried lumber.

which no internal checking was observed in the dried lumber. In this project, the earlywood and latewood layers were separated and their shrinkage was measured.

MATERIALS AND PROCEDURE

Pinus radiata trees aged 23 to 26 years were selected and felled from three forests in the central North Island of New Zealand (Site A, Site B, and Site C). After felling, several stem discs about 100 mm in thickness were cut from each of these trees. One disc from the end of each pruned butt log was dried to identify whether the log was prone to internal checking. Then the severity was classified into categories based on the size and number of checks: severe, moderate, light, and no checking. Where checking occurred, the years in which the associated rings formed were also recorded.

For the shrinkage studies, three severely checked discs and three non-checked discs were chosen from each of the three forest sites. For the severely checked discs, three rings (1985 to 1987 for Site A and Site C) or five rings (1985 to 1989 for Site B) were identified as having the highest incidence of checking. For the non-checked discs, growth rings from the same year as those of the severely checked discs were used for comparison of the shrinkage.

Two 30-mm-wide strips were sawn from pith to bark of the chosen stem discs. From one of these strips, three or five full earlywood layers were sectioned out and from the other strip three or five full latewood layers were sectioned out. The ring numbers were again identified. In this way, 132 specimens were prepared (Table 1). The specimens were 100 mm long and 30 mm wide (tangential dimension), and thickness was that of one earlywood layer or one latewood layer (radial dimension).

TABLE 1–Distribution and number of specimens

	Forest site		
	Site A	Site B	Site C
Checked discs	3	3	3
Non-checked discs	3	3	3
Identified rings (year)	3 (1985–87)	5 (1985–89)	3 (1985–87)
Number of specimens	36	60	36

The green width of each specimen was measured in the tangential direction at three points using a dial gauge with a sensitivity of ±0.01 mm. All the specimens were then weighed using a laboratory balance with a sensitivity of ±0.01 g. After this, they were placed in the laboratory in front of a fan for a week before they were equilibrated for 6 weeks in an e.m.c. chamber at a temperature of 20°C and relative humidity of 52%. After equilibration, the width and weight of the specimens were remeasured, then all specimens were oven-dried and weighed again for determination of moisture content.

RESULTS AND DISCUSSION

From the measured dimensions of the specimens green and after equilibration, the tangential shrinkage (ε) was determined by using the following equation:

$$\varepsilon = -\frac{L_{eq} - L_{grn}}{L_{grn}} \times 100\% \tag{1}$$

where L_{eq} and L_{grn} are the specimen dimensions (in millimetres) after equilibration and green.

Final moisture contents calculated from the measured weights after equilibration and oven drying ranged from 12% to 15%. This was slightly higher than the predicted equilibrium moisture content of 12%. The average moisture content for all the earlywood was 13.95% and that for all the latewood was 14.12%. For comparison, the measured shrinkage was normalised to values at 12% moisture content by the following equation:

$$\varepsilon_{12\%} = \varepsilon \times \frac{(30 - mc)}{(30 - 12)} \tag{2}$$

in which mc is the actual moisture content of the specimens after equilibration.

The full data from the 132 specimens were analysed and the average values of the separate earlywood and latewood are given in Table 2 and Fig. 2 to 4. The overall average tangential shrinkage from green to 12% moisture content was 3.68% for all the specimens (s.d. 0.82%). Between-site variation was less than 0.27% (absolute shrinkage); Site B had the highest shrinkage at 3.82%, and the other two sites had similar values with 3.57% for Site A and 3.55% for Site C. When earlywood and latewood were compared in combined severely checked and non-checked logs, earlywood shrinkage (3.73%) on Site A was higher than that of the latewood (3.40%). However, at the other two sites latewood shrinkage was higher than earlywood.

From the measured data, an important trend was apparent on all three sites: in severely checked rings the earlywood shrinkage was higher than the latewood whereas in the non-checked rings the opposite happened, with the latewood shrinking more than the earlywood. This is clearly illustrated in Fig. 2 to 4, but particularly in Fig.2 where the average shrinkage of the earlywood in severely checked rings is more than 1% (absolute) higher than in the latewood, but in the non-checked rings the earlywood shrinkage is 0.4% (absolute) less than the latewood.

It was also apparent that the difference between the earlywood and the latewood varied with forest site and growth ring numbers. In fact, for checked logs on Site B (Fig. 3) the earlywood shrinkage was lower than that of the latewood in the 1985 and 1986 rings. However, further examination of the logs revealed that severe checking did not occur in these two rings but in 1987, 1988, and 1989 ones.

TABLE 2–Shrinkage variation with site and wood type (earlywood/latewood)

All sample average	3.68											
All sample std. dev.	0.82											
Forests	Site A				Site B				Site C			
Average	3.57				3.82				3.55			
Std. dev.	0.66				0.91				0.79			
Earlywood/ Latewood	EW		LW		EW		LW		EW		LW	
Average	3.73		3.40		3.63		4.01		3.41		3.69	
Std. dev.	0.51		0.76		0.80		0.99		0.78		0.80	
Checking/ No Checking	C	NC	C	NC	C	NC	C	NC	C	NC	C	NC
Average	4.02	3.44	2.97	3.84	4.22	3.05	4.10	3.92	3.89	2.92	3.84	3.54
Std. dev.	0.40	0.44	0.62	0.66	0.41	0.65	1.14	0.83	0.54	0.69	0.83	0.78

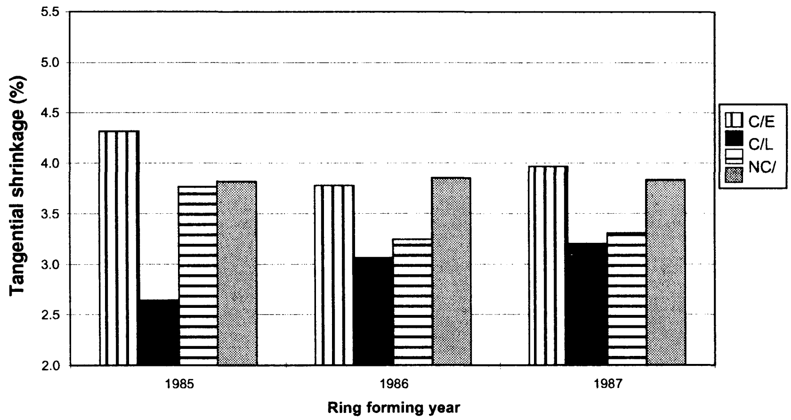

FIG. 2–Tangential shrinkage of earlywood and latewood of severely checked logs and non-checked logs (Site A). In Fig. 2–4, C = checked logs, NC = non-checked logs, E = earlywood layer, and L = latewood layer.

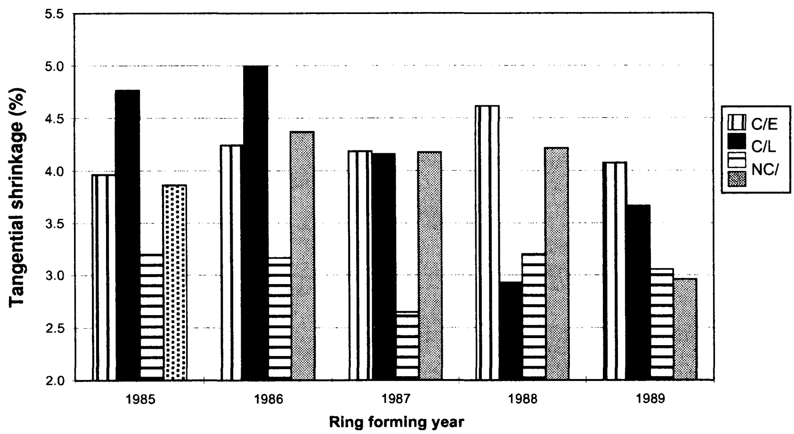

FIG. 3–Tangential shrinkage of earlywood and latewood of severely checked logs and non-checked logs (Site B).

The fact that the earlywood shrank more than the latewood in the severely checked rings was contrary to traditional theories that predict a higher shrinkage (excluding collapse) for the latewood than the earlywood (Kollmann & Côté 1968). For normal wood, a positive correlation between shrinkage and wood basic density has been observed where earlywood shrinks less than latewood because the earlywood has a lower density than the latewood (Kininmonth & Whitehouse 1991). The abnormal behaviour in tangential shrinkage of the severely checked rings may be due to several factors such as microfibril angle and the way the bond water is held by the wood. As discussed in the Materials and Procedure section, the specimens were exposed to mild conditions and thus the collapse was expected to be minimised.

The difference in tangential shrinkage between the earlywood and the latewood can be used to help explain the occurrence of internal checking when the moisture content is below

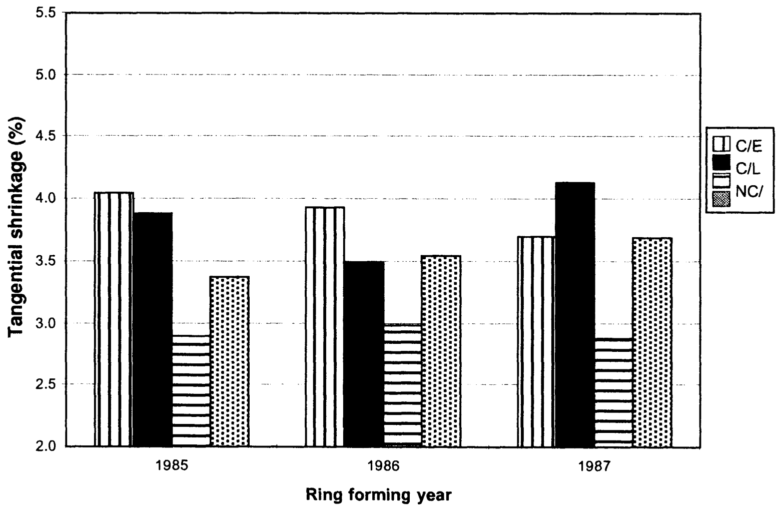

FIG. 4–Tangential shrinkage of earlywood and latewood of severely checked logs and non-checked logs (Site C).

the fibre saturation point (FSP). When the earlywood layer shrinks differently from the latewood layer, constraint strains are generated within both the earlywood layer and the latewood layer. The magnitude of these strains can be calculated by the following equations which have been derived from Fig. 5:

$$\varepsilon_{\sigma e} = (\varepsilon_e - \varepsilon_l)\,\frac{E_l \cdot \delta_l}{E_e \cdot \delta_e + E_l \cdot \delta_l} \tag{3}$$

$$\varepsilon_{\sigma l} = -\,(\varepsilon_e - \varepsilon_l)\,\frac{E_e \cdot \delta_e}{E_e \cdot \delta_e + E_l \cdot \delta_l} \tag{4}$$

in which ε, E, and δ are the tangential shrinkage, the modulus of elasticity, and the layer thickness. Subscript e represents the earlywood layer, l the latewood layer, and σ is stress-related strain. The positive strain in the above equations indicates tension and the negative strain compression. When the tension strain reaches the fracture limit, the material breaks and internal checking occurs. Because the latewood is much stiffer than the earlywood

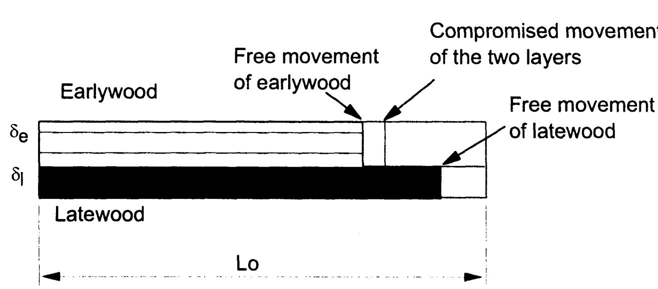

FIG. 5– Diagrammatic representation of the compromised movement of the earlywood and latewood layers when they shrink differently. Lo is the original dimension before the wood shrank.

(higher values for E), the earlywood is likely to have a higher strain than the latewood, particularly where the adjacent latewood layer is thick. Therefore, internal checking is most likely to occur in the earlywood layers where the earlywood shrinks more than the latewood and the latewood layer is stronger and thicker. Although only one earlywood layer and one latewood layer are illustrated in Fig. 5, the layer thickness can be the total thickness of two or three layers of the same type of wood (earlywood or latewood).

Statistical analysis of the experimental data has confirmed that within-ring internal checking is significantly related to the shrinkage difference between the earlywood and the latewood layers. In addition, the probability of internal checking occurring is increased with green moisture content and the average shrinkage value over the growth ring (including one earlywood layer and one latewood layer).

However, within-ring internal checking is more complex than outlined above. For example, within-ring internal checking is often found in the early stage of drying when the average moisture content is well above the FSP. This type of checking is attributed to collapse mechanisms rather than normal shrinkage as the thin-walled earlywood cells are unable to withstand the hydrostatic tensions generated by removal of the free water. Further studies are currently being undertaken in order to fully understand the phenomenon.

CONCLUSION

Tangential shrinkage of *Pinus radiata* wood from green to 12% moisture content was measured on 132 specimens representing 18 logs collected from three forest sites in the central North Island of New Zealand. The earlywood and the latewood shrank differently when losing moisture below the FSP, but the trend for the severely checked rings was opposite to that of the non-checked rings. For non-checked rings, the earlywood layer shrank less than the latewood layer, but for severely checked rings the earlywood shrank more than the latewood. This helps explain why internal checking occurs in the earlywood layers and in the radial direction. However, within-ring internal checking can occur above the FSP. Further studies are needed in order to fully understand the phenomenon so that internal checking in *P. radiata* lumber during drying can be prevented.

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