UTILISATION OF 25-YEAR-OLD *PINUS RADIATA*
PART 2: WARP OF STRUCTURAL TIMBER IN DRYING

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ABSTRACT

From a stand of 25-year-old *Pinus radiata* D. Don, 183 4.8-m-long logs were individually measured and sawn to 100×50-mm framing timber. After high-temperature drying, warp measurements were related to the individual log characteristics.

Twist was the major form of degrade; before planing 36% of the lengths had excessive twist and rejection from Framing 1 grade was 28%. Twist was most strongly related to log diameter, with corewood portion and spiral grain being the contributory factors. Twist also increased with log height class. Gauging halved the incidence of twist rejection.

The relationship between corewood proportion and twist and its effect on rejection could be incorporated into current stand growth models, thereby extending the profitability modelling capability of models from green sawn timber through to the final dry product.

Keywords: high-temperature drying; warp; twist; crook; bow; spiral grain; *Pinus radiata*.

INTRODUCTION

The problem of warp during the drying of timber sawn from young trees is well documented for *Pinus radiata* (Kloot & Page 1959), *P. taeda* L. and *P. elliottii* Engelm. (Balodis 1972), and *P. ponderosa* P. et C. Lawson (Shelly *et al.* 1979). There is general agreement that properties of juvenile corewood are significantly different from those of the outerwood (Fig. 1) thereby adversely affecting drying.

The corewood properties contributing to warp in the processing of young *P. radiata* are fibril angle (spiral grain) and longitudinal shrinkage. For *P. radiata,* corewood has been defined as the first 10 growth rings from the pith (Cown, McConchie & Young 1991). In this corewood zone, spiral grain increases to a maximum at 4–8 rings from the pith and then gradually decreases until at approximately 15 rings it reaches a minimum constant value (Cown, Young & Kimberley 1991). Typical average corewood spiral grain values are 5–7° (maximum 18°) whereas for the outerwood they are only 2°. Furthermore, spiral grain has been found to increase with height within the stem, typically increasing from an average of 2° at 0 m to 6° at 16 m. The high spirality of corewood is the major cause of twist in *P. radiata*,

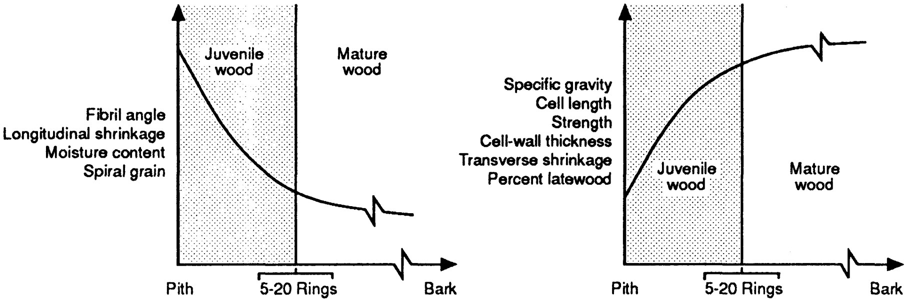

FIG. 1–Schematic representation of the gradual change in properties from juvenile wood to outer wood in conifers (from Bendtsen 1978).

although correct processing such as presteaming and high-temperature (HT) drying with stack restraint will reduce its severity (Christensen 1972; Mackay & Rumball 1972; Haslett & McConchie 1986). Longitudinal shrinkage is generally well below 1% except occasionally in corewood rings near the base of the stem where it can exceed 1% (Cown & McConchie 1983). In drying corewood, longitudinal shrinkage manifests itself as crook in quarter-sawn and bow in flat-sawn lengths, and here again HT drying can reduce its severity.

In New Zealand the commercial clearfelling age for *P. radiata* has recently been reduced from 50 years and older down to approximately 30 years and in the future it could be as low as 25 years. The reduced clearfelling age greatly increases the proportion of corewood, and thus the proportion of sawn timber rejected also increases because of warp associated with corewood (Table 1).

The 25-year-old stand used for this study represents the lower range of clearfelling for New Zealand forestry. Part 1 of this series of papers presented details of wood property relationships (Young *et al.* 1991) and Part 2 outlines the drying properties.

TABLE 1–Effect of felling age on rejection for excessive twist after HT drying

Felling age	Rejected for excessive twist* (%)	Source
14 years	37	Haslett & McConchie (1986)
20 years	19	Haslett & Patmore (1988)
30 years	5	Haslett & Patmore (1988)
>50 years	5	Haslett & Patmore (1988)

* Twist (lengths not gauged) in excess of NZS3631:1988, New Zealand timber grading rules

MATERIAL AND PROCEDURES

Full stand details have been given by Young *et al.* (1991). The silvicultural tending was typical of that expected in future sawlog stands in that it involved three pruning lifts to a total height of 5.8 m with a thinning to waste at the time of each pruning lift. The 50 test trees were selected to ensure that a full range of log grades was included in the study. The test trees were not intended to represent the stand as a whole but rather to highlight relationships between log and timber grades. The Forest Research Institute log grades (Whiteside & Manley 1985) were used (Table 2).

TABLE 2–Study sawlogs according to FRI log grades

FRI log grade	Small-end diameter (mm)	Largest single branch (cm)	Number of logs Included
S1	≥ 400	6	9
S2	300–399	6	25
S3	200–299	6	30
S4	150–199	6	5
L1	≥ 400	14	24
L2	300–399	14	46
L3	200–299	14	41
L4	150–199	14	3

Apart from eight unpruned butt logs, the study logs were fairly evenly distributed between second to fifth logs. Butt logs were largely excluded because it is unlikely that pruned logs would be sawn for structural use using the cant sawing pattern from this study.

A cant sawing pattern was used to maximise the recovery of 100 × 50 mm timber from the 4.8-m logs. All the 4.8-m lengths of sawn timber were machine-filleted into full kiln stacks at the Waipa Sawmill of the Forestry Corporation of New Zealand, in Rotorua. Each stack was 20 boards wide and approximately 40 layers high, with fillets at 60-cm intervals and top weighting of approximately 600 kg/m^2 according to normal commercial practice.

The timber was then HT kiln dried according to the following schedule:

dry	120°/70°C for 32 hours
cool	for 2 hours
steam	100°/100°C for 6 hours
cool	for 24 hours weights on

After HT drying, each length was measured for warp (crook, bow, twist) and moisture content. In addition log number, green timber grade (according to NZS 3631:1988), stack position, and presence of pith were also recorded. After gauging to 90×45 mm, a sub-sample of 148 lengths was measured for warp and planer skip to determine the reduction in warp attributable to gauging.

The influence of position in stack, both vertically and horizontally, on final moisture content and twist was assessed. Vertically the top four layers were compared to the bottom four layers, and horizontally the lengths were paired according to their number from the stack edge.

The statistical significance of the effects on twist of stack position and of factors such as log diameter, grade, and height class, and of timber grade, was tested by analysis of covariance, using final moisture content as a covariate.

RESULTS AND DISCUSSION

Twist was directly related to moisture content, with a 1% reduction in moisture content giving an average increased twist of 0.6 mm.

Overall the average moisture content was 10.8%. Although of high statistical significance ($p < 0.01$) the positional differences in moisture content between the top of the stack (10.6%)

and the bottom of the stack (11.6%) and from the edge (9.7%) to the mid-width of the stack (11.0%) were unlikely to be of commercial significance.

Vertical position in the kiln stack significantly affected twist ($p < 0.01$), with twist in the top and bottom four layers averaging 10.5 and 6.0 mm respectively. Compared to the top four layers in the stack, the weight of the additional 32 layers on the bottom four layers (an extra 720 kg/m^2 even at 12% moisture content) reduced twist, and clearly showed the reduction which could be achieved by increasing stack restraint above the 600 kg/m^2 used at the sawmill. Horizontal position across the stack had no effect on twist, there being no edge effect.

Log characteristics and timber warp are summarised in Table 3, first by log diameter and then by log grade. Twist was clearly the major form of warp. Of the No. 1 timber grade lengths, 28% were rejected for excessive warp (Table 4). In a similar study involving 14-year-old trees, 37% of the No. 1 grade lengths were rejected for excessive warp (Haslett & McConchie 1986).

As log diameter decreased the proportion of corewood increased, and so did the spiral grain angle, resulting in an increase in twist and rejection ($p < 0.01$) with decreasing log diameter. Detailed twist modelling currently being investigated at the New Zealand Forest Research Institute (W. Miller, W. Joe pers. comm.) indicates not only that twist of individual boards is dependent upon spiral grain but that the radial position of the board within the log is also important. However, for the purpose of modelling the effect of forest practices and log characteristics on the profitability of sawing and drying timber, a broader approach is advisable initially. It has already been shown that decreasing log diameter increases twist,

TABLE 3–Summary of warp by log grade and log diameter

	Logs		Timber								
	Corewood volume (%)	Spiral grain angle (°)	No. of lengths	Mean mc (%)	Mean warp			Lengths rejected for warp*			
					Crook (mm)	Bow (mm)	Twist (mm)	Crook (%)	Bow (%)	Twist (%)	All (%)
Log diameter (mm)											
≥ 400	47	3.8	499	–	–	–	6.7	–	–	22	22
300–399	57	4.4	745	–	–	–	8.7	–	–	35	35
200–299	78	4.8	372	–	–	–	12.1	–	–	53	53
150–199	93	5.2	19	–	–	–	18.2	–	–	79	79
Log grade											
L1	48	4.3	358	10.7	8.2	10.4	7.1	1	0	23	23
L2	67	5.0	476	10.0	8.2	10.7	9.2	1	0	37	37
L3	80	5.3	205	10.6	7.8	11.1	12.1	0	0	55	55
L4	91	6.4	9	10.6	8.8	11.6	19.0	0	0	89	89
S1	44	2.5	141	11.8	8.8	11.4	5.6	1	0	18	18
S2	50	3.2	269	10.7	7.4	10.4	7.9	0	0	31	31
S3	75	4.1	167	10.4	7.7	11.4	12.1	1	0	51	51
S4	99	4.5	10	10.9	4.1	16.4	17.5	0	0	70	70
All log grades	–	–	1635	10.6	8.0	10.8	9.0	1	0	35	36

* Maximum warp permissible in 4.8-m length of 100 × 50-mm timber (NZS 3631:1988) is: twist 10 mm, crook 30 mm, bow 60 mm.

– Data not available

TABLE 4–Effect of timber grade and log branch diameter on twist after drying

Timber grade	No. of lengths	Mean twist (mm)	Rejected for twist (%)
All branch sizes			
No. 1	305	7.6	28
No. 2	674	9.6	39
Box	656	9.0	35
Small branch logs*			
No. 1	204	6.8	25
No. 2	270	9.2	38
Box	103	10.2	41
Large branch logs*			
No. 1	99	9.1	34
No. 2	394	9.6	39
Box	546	8.6	34

* Lengths from S4 and L4 log grades not included.

but diameter alone would be inadequate to predict twist. Because an older butt log has a lower proportion of corewood, a butt log from a slow-grown 35-year-old tree will give less twist than a butt log of similar diameter from a fast-grown 15-year-old tree. Regression analyses of the data for the 183 logs yielded the following relationships between corewood and twist:

$$\text{mean twist} = 0.194\ (\text{corewood } \%) - 2.13 \qquad r^2 = 0.41$$

$$\text{percentage rejected for twist} = 1.11\ (\text{corewood } \%) - 28.76 \qquad r^2 = 0.39$$

Much of the unexplained variation in the above equations is due to differences between individual trees, e.g., by incorporating separate intercepts for each tree in the equation for mean twist, the r^2 was increased to 0.76. This suggests that there may be scope for breeding trees which produce timber less prone to warp, presumably by selecting for low levels of spiral grain.

Corewood proportion has an important, although indirect, effect on twist through log height class (Table 5). Although log diameter is a major characteristic in explaining twist, there is an additional log position effect, with logs from higher positions producing timber

TABLE 5–Influence of log height on twist (4.8-m log lengths)

Log diameter (mm)	Log height class	No. of lengths	Average twist (mm)	Rejected for twist (%)	Rejected overall (%)
≥ 400	Butt	75	5.4	13	15
	Second	352	6.8	22	23
	Third	72	7.3	24	24
300–399	Butt	36	6.3	11	11
	Second	233	8.3	37	37
	Third	378	8.7	33	34
	Fourth	98	10.9	43	43
200–299	Second	34	8.6	38	38
	Third	67	10.8	42	42
	Fourth	182	12.1	54	54
	Fifth	89	14.3	65	65

with significantly more twist within any log size class ($p < 0.01$) (Fig. 2). The effect of log height holds true for both small- and large-branched logs. This relationship follows the increase of corewood proportion and spiral grain with height within the stem.

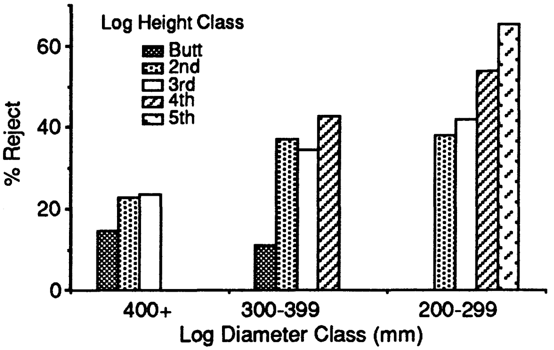

FIG. 2–Influence of log diameter and log height on twist

Overall there was no significant relationship between timber grade and average twist or rejection after drying (Table 4). The visual timber grades are based largely on knot size and location, rather than the presence of pith or corewood, which explains the absence of a relationship. However, when small branch logs (S1–S4) were considered separately there was a significant ($p < 0.05$) relationship between timber grade and twist, the lower grades showing worse twist.

The effect of gauging on warp is summarised in Table 6. The percentage rejected for twist was more than halved after gauging. However, there was a slight drawback associated with gauging in that planer skip of 30 cm or greater, due to twist, would have necessitated end docking of 18 of the lengths assessed. Clearly, though, gauging reduced the severity of twist.

TABLE 6–Comparison of warp before and after gauging (148 lengths)

Warp	Before gauging		After gauging	
	Mean warp (mm)	Rejected* for warp (%)	Mean warp (mm)	Rejected* for warp (%)
Twist	8.7	38	5.3	16
Crook	7.5	1	6.0	1
Bow	10.9	0	8.9	0

* Maximum warp permissible in a 4.8-m length of 100 × 50-mm timber (NZS 3631:1988) is: twist 10 mm, crook 30 mm, bow 60 mm.

CONCLUSION

Warp could be a major problem in the drying of structural timber sawn from trees less than 30 years old, with twist being the most important form of warp.

High-temperature drying gives less warp than other types of drying and there are indications that increasing the stack restraint above 600 kg/m^2 should produce further reductions in twist. Twist is also inversely related to final moisture content and so sawmillers must minimise overdrying of young twist-prone material.

As far as log characteristics are concerned, twist is due largely to corewood proportion and grain spirality, both of which increase with decreasing log diameter. Log height, not only through its effect on diameter and corewood proportion but also because of increasing spirality, has an important influence on twist.

From the viewpoint of both forest managers and researchers, the New Zealand Forest Research Institute STANDPAK growth model can already predict log grades, including diameter, and it should be possible to modify the model to include corewood proportions for each log grade. From the log grades and corewood proportion provided by STANDPAK, the existing SAWMOD model could then be extended to take the sawn timber recovery from the green state on to the dry stage. This could allow silvicultural decisions such as thinning intensity and rotation length to be better assessed in terms of their impact on sawn timber processing and profitability.

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