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Development of Kiln Schedules to Eliminate the Development of Internal Checking in Radiata Pine Boards

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ABSTRACT

Kiln schedule development was based on two schedule phases, the first being to determine the maximum safe kiln temperature during the check prone initial stage of drying, with the second stage determining how to accelerate drying once the danger of checking had passed. This was achieved by using 38 mm thick boards which were pre-screened for susceptibility to internal checking, and then drying matched sample boards over a range of kiln temperatures.

Research has shown that below 50% MC there is no further risk of internal checking. However, difference in drying rate due to board width and the increased occurrence of wet patches in wide boards means that it is essential to modify the basic schedule according to the maximum board width.

A condition of 52/40 ^{0}C was selected for the checking-free initial kiln drying step and a 5-step kiln-schedule dried the boards from 109% to 8% MC for 72.5 hours without internal checking.

Key words: Drying schedule, radiata pine, internal checking.

INTRODUCTION

Internal checking of radiata pine (*Pinus radiata*) is a serious problem for the timber industry because a large investment in timber processing and transport can be made before the internal checking in boards is discovered during remanufacturing (Fig. 1). If boards are laminated into engineering products and then re-cut, a single board component containing internal checking can seriously downgrade the value of the entire product.

When sapwood dries the water in the cells develops a tension which causes the earlywood and latewood to contract. Because the latewood has thicker and stronger cells it contracts less than the earlywood. The differential contraction places the earlywood in tension and the latewood in compression. If the lignin "glue" that holds the cells together is not strong enough, the earlywood develops a crack extending radially within the earlywood, between adjacent latewood bands. As all the cells are connected together they can not collapse individually, but after a crack has formed, the cells adjacent to it can collapse. If this happens what would normally only be seen as a fine line in the wood will become a wide lens shaped crack (Booker 1994). Unfortunately collapse in radiata pine can not be completely removed by reconditioning. Why reconditioning of collapse is almost completely successful for hardwoods (Hart et al. 1992; Innes 1996), but not for radiata pine, is not understood.

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A previous study by NZFRI showed that internal checking occurs at the start of drying (Booker et al. 1993). It is also known that internal checking becomes more severe at higher temperatures (Chafe 1994 and 1995). The reason was thought to be that wood strength decreases as temperature increases.

The frequency of internal checking also increases with increasing board thickness and board width (Chafe and Carr 1998). Internal checking is particularly prevalent in material from certain forest sites. It is not clear whether this is caused by provenance, climatic conditions or soil deficiency, or an interaction among these factors.

Fig.1. Typical internal checks in kiln-dried board of radiata pine, developing from earlywood.

To develop a kiln drying schedule that will ensure that practically all boards are free from internal checking, but still dry sufficiently fast for the schedule to be economically viable. The aim of this study has been to develop a schedule to dry, with minimum degradation, the boards susceptible to internal checking.

MATERIALS AND METHODS

Four local mills sent 12-foot-long and 38-mm-thick boards selected on the basis that these boards were expected to be prone to internal checking. A 450 mm long section was cut from one end of each board and dried at a schedule of 120/70 ^{0}C (dry-bulb temperature / wet-bulb temperature). Each of these sections was cross-cut and the number of internal checks in the cross section counted.

Although no annual ring orientation was specified, all boards with the exception of one packet were flat-sawn (none of the quarter-sawn boards showed internal checking).

After the preliminary screening, 16 check-prone boards were chosen for the kiln schedule development experiment. From each of these boards another MC specimen was cut, followed by as many 600 mm sections as possible, followed by another MC specimen if possible. The 600 mm specimens were end-coated twice with a two pot epoxy aluminium paint and divided into charges of end-matched specimens. The charges were dried according to four low temperature straight through schedules to develop the initial kiln conditions for drying boards free from internal checking. A series of conditions were evaluated at 5^{0}C steps in wet-bulb temperature at a unity condition of 50% relative humidity. The wet-bulb temperature was used because during the time that internal checks form when the wood is at the wet-bulb temperature.

After the above charges had been dried and an appropriate schedule identified, another series of green boards were delivered from the same mills and were tested for internal checking propensity. They were all cut into 600 mm long sections and end-coated. All the charges were dried in a laboratory kiln (Fig. 2). Stickers of 13 mm thickness were used for stacking.

For the analysis of internal checking after drying, all 600 mm board sections were cross-cut into slices which consisted of one end slice 10 mm thick, 18 slices 29.5 mm thick, followed by another 10 mm end slice (Fig. 3). The number of internal checks were counted in all these slices, but only two measures of checking propensity are recorded, and these are: the number of internal checks in the central cross-section of the board section (at slice 10); the sum of the total number of checks in slices 4 to 17, ie. the sum of the internal checks in all the slices except those within about 90 mm from the ends.

To be able to safely accelerate the schedule starting at 52/40 ^{0}C it was first necessary to conduct an experiment to determine the drying rate and the MC variation of boards. Two series of six end-matched boards were prepared and one series was placed in the kiln. The length of the two series was 600 mm, and the width of each series was 320 or 430mm. At first the six 430mm-wide boards were stacked in the kiln and dried. After 20 hours, the first board was removed and replaced with one from the second series. The removed board was weighed, and cut into 20 slices as Fig. 3. The slices were visually examined and marked at wet patches and oven-dried to measure moisture content except a slice cut in the middle of the board. It was split into pieces to measure the variation of MC across the width (Fig. 5). The boards of 320mm and 430mm widths made, respectively, 16 and 22 pieces.

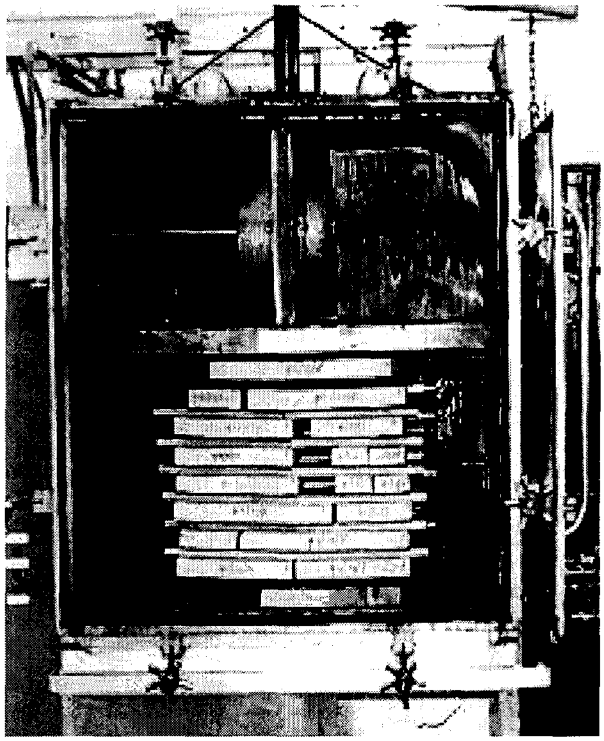

Fig.2. The laboratory kiln used for this study.

Next boards were removed at the intervals of 9-16 hours and the procedure for the first board was repeated until finally all 600 mm boards had been dried. The second series of boards that were progressively placed in the kiln were similarly sectioned to determine the moisture content variation during drying.

The MC variation across each board cross-section and along the length of the board was investigated for a range of drying times from the experiment of two series of six end-matched board sections.

Based on the results from kiln-drying the boards with the 52/40 ^{0}C schedule, four full schedules were developed and tested. The kiln-dried boards were slided as Fig. 3 and checks on the slides 4-17 were counted.

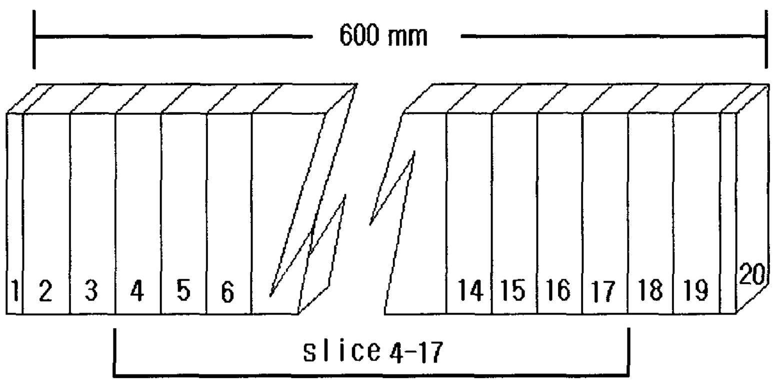

Fig.3. Diagram of preparing MC slices from a 600-mm-long section.

RESULTS AND DISCUSSION

Initial kiln-drying schedule

Table 1 shows the results from the experiment for the development of the initial kiln conditions. Because the occurrence of internal checking is very unpredictable, the total number of checks in just one cross-section from the central part of a board is less reliable than the sum of the checks in slices 4 to 17. Table 1 shows a regular progression in the number of internal checks from 0 to 3 to 17 to 27 with increasing severity. Thus the 52/40 ^{0}C schedule was selected for the initial kiln-drying step.

Table 1. Kiln schedules and the number of internal checks for developing the first drying step, arranged in order of increasing drying severity

Dry-bulb temperature (^{0}C)	Wet-bulb temperature (^{0}C)	Number of checks in	
		Slice 10	Slice 4-17
52.0	40	0	0
57.3	45	0	3
64.7	50	4	17
69	55	1	27

Visual examination of wet patches on boards

When a slide was cut from a board, wet patch was clearly seen to mark if available (Fig. 4). This marked photo envisages MC distribution along the length and width of a board. The area of wet patch is correlated with the MC of the slides. Fig. 4 shows how free is removed from the flat-sawn board during drying. The wet patch in the center of a board vanishes at the first and finally they are isolated in the latewood at the wings.

Another water patch picture (Fig. 5) was obtained to visualize how free water moves in a board. The slides in Fig. 5 were the eighth ones taken from the six end-matched boards. The wet patch disappears between 67.3 and 38.2% MC, thus it could be postulated that 50% MC be a critical point for wood-moisture relationship. Research has shown that below 50% MC there is no further risk of internal checking.

MC distribution on boards dried with the 52/40 ^{o}C schedule

The drying rates of two series of six end-matched boards were plotted in Fig. 6. The drying rate of 430mm was higher than

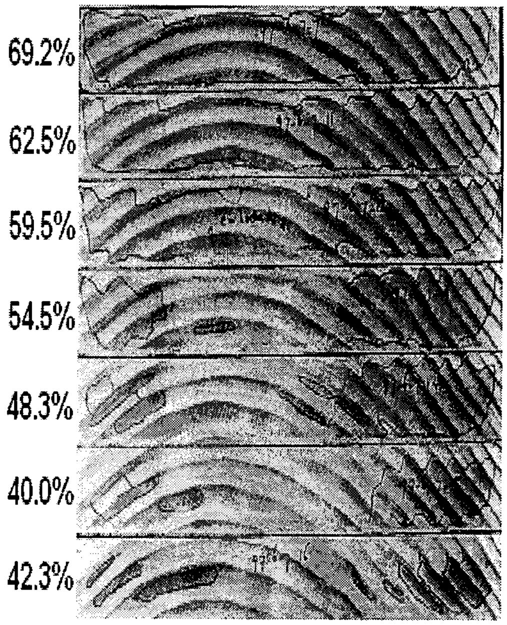

Fig.4. A series of slices cut from a board dried with the 52/40℃ schedule. Water patched are marked on the cross-sections of the slices, showing the variation of MC distribution along the length and width.

that of 320mm above 60% MC, which may be attributed to the facts that a wider flat-sawn board has more tangential surface than a narrower and that moisture moves in the radial direction faster than in the tangential direction.

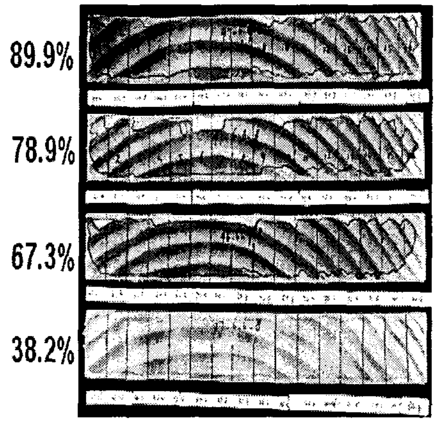

Fig.5. Four #8 slides taken from a series of the 320mm wide boards. It shows how water patch changes as drying. These slides were split into pieces to measure the variation of MC across the width.

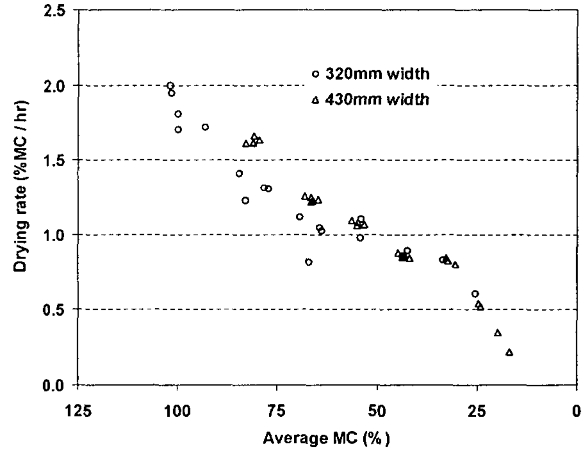

Fig.6. Plot of drying rate vs. average MC for two series boards with two different widths.

The large variation of MC along the length of the boards was observed above 50% MC (Fig. 7). But below 50% the MC distribution was pretty uniform except the ends. In spite of end-coating the ends of the board dried faster than else. There was no difference in longitudinal MC distribution between two widths.

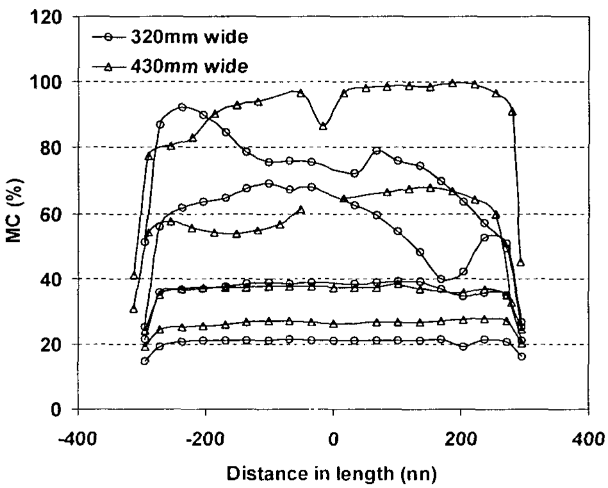

Fig.7. MC distributions along the length of the 320mm and 430mm wide boards.

The MC distribution across a cross-section was shown to vary considerably depending board width. The experiment showed that it is impossible to design a single schedule that will cover all widths of boards as wide boards dry more slowly than narrower boards. Moreover, the central part of a wide board dries faster than the edges, so that the centre may already be close to the fiber saturation point while the wings are still at a MC well above the fiber saturation point (Fig. 8). It is noticeable that the MC distribution changes around 50% MC for both widths.

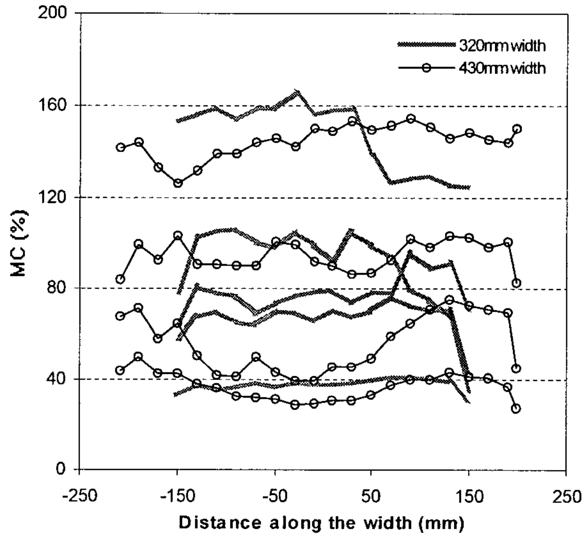

Fig.8. MC distributions along the width of the 320mm and 430mm wide boards. The edges of the 430mm board had higher MC than the ends at around 60% MC.

Kiln-schedule development

The results from four kiln charges are listed in Table 2. The boards dried with the first two kiln-schedules had internal checks, but no checks were found on the boards dried with 4-step and 5-step kiln-schedules, which run for 100 and 72.5 hours, respectively.

The 5-step kiln-schedule is shown in graphical form in Fig. 9 on which the average and maximum MCs of each step are recorded. The boards of this charge were dried from 109% to 8% MC in average.

Table 2. Multi step accelerated low temperature schedules

Schedule	Step	Step type	Temperature (°C)		Duration (hrs)	Total time (hrs)	No. of checks (slice 4-17)
			DB	WB			
1	1	drying	52	40	8	140.9	5
	2	drying	52	40	64.4		
	3	ramped in 20 minutes					
	4	drying	70	60	68.5		
2	1	drying	52	40	72	94	9
	2	ramped in 20 minutes					
	3	drying	90	60	22		

3	1	drying	52	40	10	100	0
	2	drying	52	40	38		
	3	ramped			32		
	4	drying	90	60	20		
4	1	drying	52	42	5	72.5	0
	2	drying	52	40	19		
	3	ramped			32		
	4	drying	75	60	2.5		
	5	drying	90	60	14		

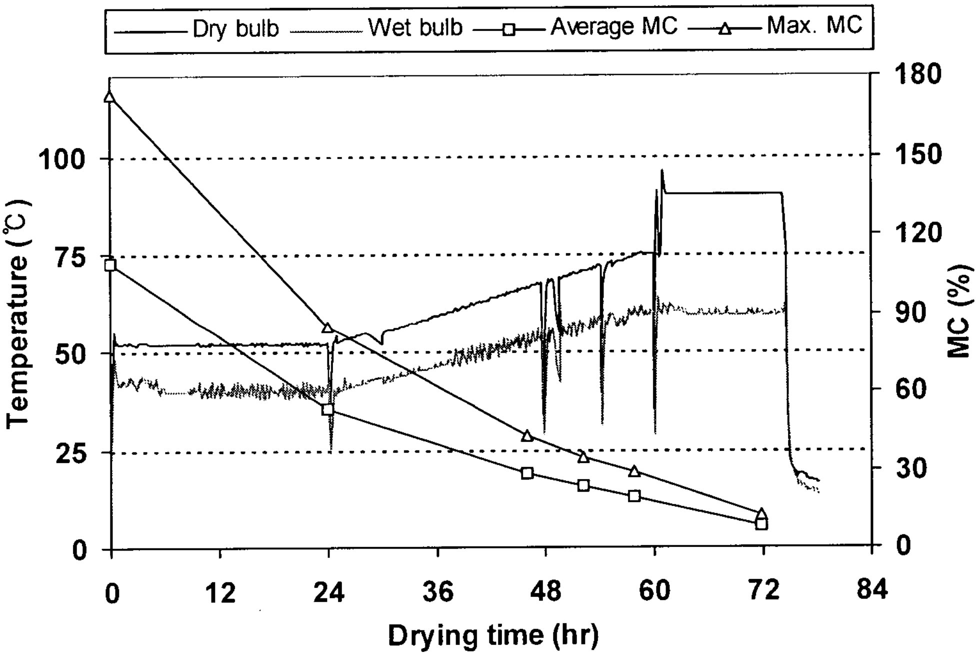

Fig.9. Plots of dry-bulb and wet-bulb temperature, and drying curves of maximum and average MC.

SUMMARY

Internal checking of radiata pine is a serious problem for the timber industry. Developing checking-free kiln-schedule was conducted by using 38 mm thick boards which were pre-screened for susceptibility to internal checking.

For the analysis of internal checking, all 600 mm boards were cross-cut into slices, which consisted of one end slice 10 mm thick, 18 slices 29.5 mm thick, followed by another 10 mm end slice.

The MC variation across each board cross-section and along the length of the board was investigated for a range of drying times from the experiment of two series of six end-matched board sections. The MC variation was visualized by marking wet patches on the slices.

The wet patch on the slices disappears between 67.3 and 38.2% MC, thus it could be postulated that 50% MC be a critical point for wood-moisture relationship. Research has shown that below 50% MC there is no further risk of internal checking.

The MC distribution across a cross-section was shown to vary considerably depending board width. The drying rate of 430mm was higher than that of 320mm above 60% MC, which may be attributed to the facts that a wider flat-sawn board has more tangential surface than a narrower and that moisture moves in the radial direction faster than in the tangential direction.

A condition of 52/40 °C was selected for the checking-free initial kiln drying step. Four different kiln-schedules for the second phase were developed. Among them two were revealed to be checking-free and 5-step kiln-schedule dried the boards faster than the other from 109% to 8% MC for 72.5 hours.

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