Conversion Factors for Type I and II Resin Pockets

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Plantation Management Cooperative

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EXECUTIVE SUMMARY

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THE PROBLEM

Resin pockets are a major cause of degrade in boards cut from pruned radiata pine logs. Currently, the most reliable means of assessing the level of this defect involves sawing a sample of logs, and counting the frequency of resin pockets on exposed board surfaces. A less expensive method of is to count the frequency of such defects in crosscut log surfaces such as log ends or discs. However, there is currently no method of converting crosscut resin pocket frequencies to board surface frequencies.

COOP INITIATIVES

There have been a number of WQI projects that relate to this work. A series of evaluations of the relationship of lumber out-turn to standing tree resin categorisation also included log end resin feature identification (APP reports 12, 13, 19, 31, 42, & 52) and showed strong overall trends between these properties. This led to a further project investigating the potential for inclusion of log end resin features in log specifications (APP 52).

THIS PROJECT

All resin pockets in nine 290 mm x 40 mm x 2.4 m knot-free boards and six 400 mm slabs cut from pruned logs were exposed either by planing in 3mm steps or crosscutting in 7mm steps. The lengths, depths and widths of all resin pockets were measured. Based on these dimensions, conversion factors were derived for converting crosscut resin pocket frequencies to board surface and wood volume defect frequencies.

RESULTS

Analysis of resin pocket dimensions showed that crosscut defect frequencies can be converted into board surface frequencies by multiplying by a conversion factor of 0.21. This conversion factor applies equally to both Type I and Type II defects. To convert crosscut frequencies per m^2 into wood volume frequencies per m^3, they should be multiplied by 16.

IMPLICATIONS FOR THE COOP

Crosscut sampling either of log ends or discs provides an efficient and relatively inexpensive means of quantifying resin pockets. Crosscutting exposes five times as many resin pockets per m^2 as are found on surfaces of boards cut from the same log. The use of the conversion factors established in this study mean that board surface frequencies and wood volume frequencies can now be obtained from crosscut surface frequencies.

INTRODUCTION

Aim

To develop reliable factors for converting the incidence of Type I and Type II resin pockets in radiata pine assessed using crosscut sampling to board surface and volume incidence.

Background

Resinous defects in pruned radiata pine logs can seriously downgrade their value. The extent of the degrade depends on the frequency and size of the defects. Somerville (1980) provided a description of the types of resin pockets found in radiata pine, and of their typical dimensions. He described the following three types of resin pocket:

- Type I resin pockets. Contained, oval, lens-shaped defects lying in the longitudinal tangential plane and containing callus and free resin.
- Type II resin pockets. These may start as type I defects but rupture through the cambium layer. The resulting defects often have a greater radial component than Type I defects. They can contain dry resin, bark, callus, or occluded wood.
- Type III resin pockets. These resemble Type II defects, but lack a large, oval-shaped, tangential separation at the base.

Typical dimensions given by Somerville of these three resin pocket types are shown in Table 1.

Table 1. Range of resin pocket dimensions (mm) given by Somerville (1980)

Position	Type I	Type II	Type III
Tangential	20-50	10-40	3-10
Radial	3-6	15-35	3-10
Longitudinal	40-100	40-120	25-70

The type definitions proposed by Somerville are widely used. However, it is often difficult to distinguish between Type II and Type III defects. In practice, the main difference between these two types is their size, with Type III defects being smaller than Type II defects but otherwise similar. For this reason, Type II and III defects are often grouped into one class, and this approach was adopted in the current study. For simplicity, the grouped Type II and III defects are referred to as Type II defects in the remainder of this report.

Current methods of assessing resinous defects in trees generally involve some form of destructive sampling, although assessing external resinous legions on trees or logs is showing considerable promise as a surrogate measure of internal degrade (e.g. McConchie, 2003). The most direct method for quantifying resinous defects is to process logs through a sawmill, and to obtain the resin pocket frequency per m^2 of sawn board surface. Boards can also be graded and valued according to established grading rules. The level of degrade can be quantified by comparing the effect of grading with and without accounting for such defects (McConchie 2003; McConchie *et al.* 2003; McConchie 2004a, 2004b, 2004c, 2005).

Rather than processing logs through a mill, which is a complex and expensive operation, an alternative approach is to count the number of defects on exposed stem cross-sections such as log ends or discs. This also provides a count of defects per m^2 of exposed surface. However, there is no established procedure for converting from a crosscut defect count to a board surface defect count. It is thus difficult to know what level of crosscut defect frequency will correspond to a significant level of degrade in appearance grade sawn timber. The objective of this study was to establish factors for converting from crosscut resin pocket frequency to timber surface and wood volume defect frequency for both Type I and Type II resin pockets.

The values of such conversion factors will depend on the dimensions of typical defects. If a slab of wood contains a defect, the probability of a cut exposing that defect will be proportional to the length of the defect measured at right angles to the cut. Therefore, if the longitudinal length of a defect in a log is twice as great as its depth measured at right angles to the surface of a board cut, then the defect will be exposed twice as often per m^2 on a cross cut face than on a board surface. If all defects in a log are twice as long as they are deep, the factor for converting from crosscut defect frequency to board surface frequency will be 0.5. More generally, the expected frequency per m^2 of defects exposed by cross cutting divided by the board surface frequency will equal the sum of all longitudinal defect lengths within the log, divided by the sum of all defect depths measured at right angles to the board surface plane.

In this study, large numbers of resin pockets were exposed and measured by planing or cutting boards or log slabs. Each defect was measured for its length, depth and width, and conversion factors were calculated on the basis of these dimensions.

METHODS

Two sets of data were obtained using two different techniques for exposing and measuring defects. The first set was obtained by repeatedly planing boards while the second set was obtained by repeatedly crosscutting log segments. Although these two sets were measured differently, the two methods of measuring defect dimensions provided comparable results. Both processes were carried out in the Scion wood processing laboratories.

The first data set was obtained from nine boards sourced from the Tenon Taupo sawmill measuring 290 mm x 40 mm x 2.4 m cut from pruned radiata pine logs. The boards were selected on the basis that they showed considerable external evidence of resinous defects. Each board was planed using a bench planer in 3 mm steps, and at each step, all exposed defects were assessed. Planing continued until less than 5 mm of board thickness remained. Each defect was classified as Type I or Type II, and its maximum dimensions longitudinally and across the board were measured. From these measurements, the maximum extent of the length, width and depth dimensions of each defect was established. The depth was calculated as the sum of all planing thicknesses removed while the defect remained visible plus 3 mm to account for the depth missed on either side of the first and last thickness. Examples showing the process of measuring resin pockets in this data set are shown in Figs. 1-2.

Fig. 1. Surface of a board during planing showing the process of measuring two large Type I resin pockets

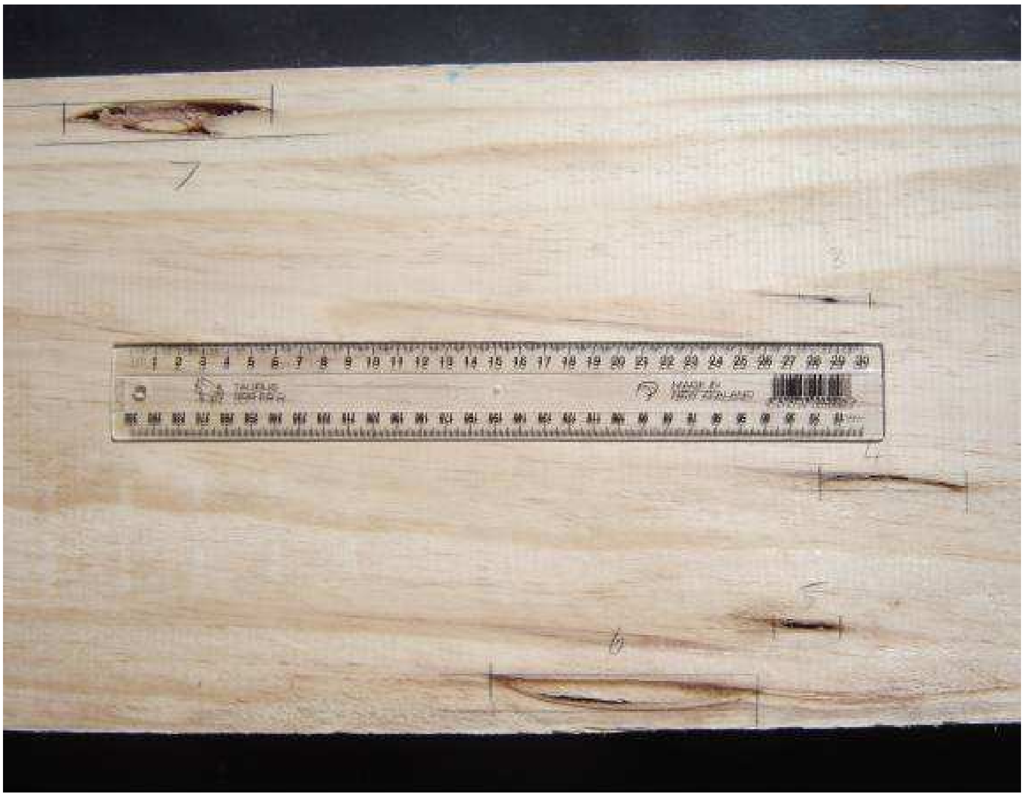

Fig. 2. Surface of a board during planning showing several mainly Type II resin pockets

The second data set was obtained from six 400 mm long half-diameter slabs cut from the butt-ends of pruned radiata pine logs. Slabs were cut from logs sourced from Tarawera Forest showing external evidence of resinous defects. Each slab was further cut into four sections to enable further processing. These sections were then cross cut repeatedly using a radial bench saw to reveal defects. Each cut exposed a new face about 7 mm below the previous cut, and cutting continued until the entire 400 mm long section had been processed. An example of a processed log section is shown in Fig. 3. All defects exposed at each cut were measured for depth and width in relation to the arbitrary axis formed by the base of the slab. The type of each defect and its maximum width, depth and length were obtained from these measurements. Length was calculated as the sum depths of all cuts exposing the defect plus 7 mm to allow for depths on either side of the initial and final cut.

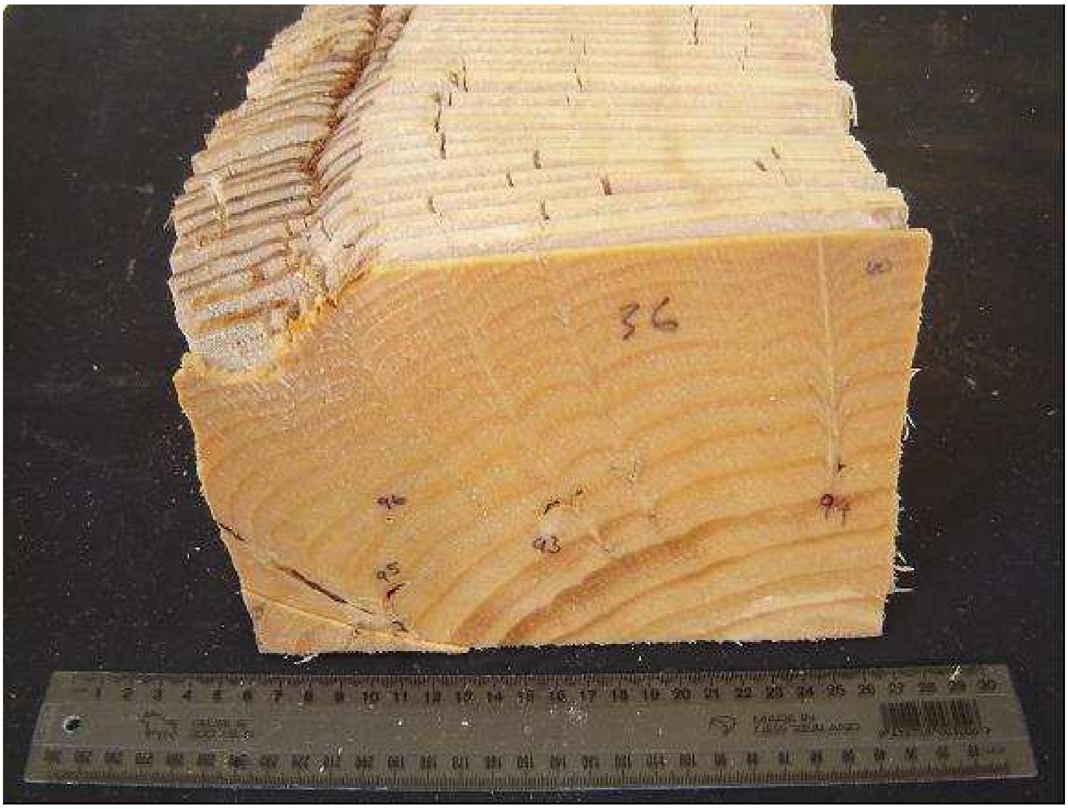

Fig. 3. Section of a log slab crosscut into slices. Several exposed resin pockets are visible on the front slice

Because the aim of this study was to develop conversion factors for board surfaces, depths and widths were assessed in relation to the board surface for the first data set, and to the base of the slab in the second data set, rather than in the radial or tangential direction. The orientation of depth and width measurements of typical defects is illustrated in Fig. 4. Therefore, the widths and depths obtained in this study cannot be compared directly with those given by Somerville (Table 1).

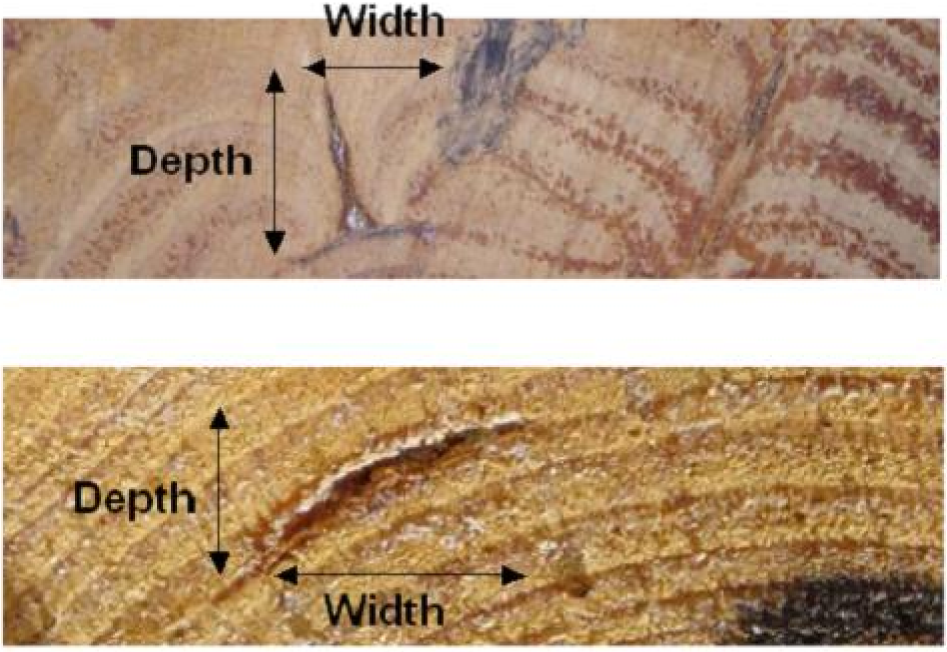

Fig. 4. Orientation of width and thickness measurements in relation to a board surface for typical Type II (upper) and Type I (lower) resin pockets

The analysis concentrated on estimating the typical depth to length ratio of defects, since this is the appropriate factor for converting from crosscut counts to board surface counts. It was also important to determine whether this ratio is typically constant, or varies with resin pocket type, defect length, or between trees. To examine this question, a quadratic regression without an intercept was fitted:

(1) $D = aL + bL^2$

where D is defect depth (mm), L is defect length (mm), and a and b are regression coefficients. Separate regressions were fitted for each defect type. The significance of the quadratic term b determines whether the D/L ratio is constant or alters with defect length. A value of b close to zero would imply that the ratio remains constant. Also, to test whether the ratio varied between resin pocket types, or between trees, the model was fitted using separate a coefficients for each pocket type, and for each board or slab.

A simple no-intercept linear model without the quadratic term was also fitted:

(2) $D = aL$

The coefficient a in this model is an estimate of the D/L ratio and can therefore be used as the required conversion factor. However, if the quadratic term in Model (1) is significant, this conversion factor could produce biased estimates if mean L is substantially different to the means in the study data. Although the ratio of width to length was of less interest Models (1) and (2) were also fitted using width (W) as the dependent variable.

Because the boards used to obtain the first data set were only 40 mm thick, a considerable number of defects intersected the board surface, either at the top or bottom on the board. For these defects, the measured depth was less than the true depth of the defect, although lengths and widths would be generally correct. The depth measurements were therefore underestimates of the true depths. Statistically, depths of defects that intersected the board surface are termed censored observations. Removing these observations from the analysis was not considered a valid option, as it would bias the data towards smaller and shallower defects. It was therefore necessary to use a method of data analysis that took account of censoring, as otherwise the D/L conversion factor would be underestimated. The SAS procedure LIFEREG can fit regressions to censored data and was therefore used to fit the above models. A lognormal error distribution was assumed. The log slab dataset did not include censored observations as the small number of defects that intersected the edges of the slab in either depth or length were not included in the analysis.

RESULTS & DISCUSSION

Both methods of sampling, i.e., planing boards and cross cutting slabs, provided good data. However, the board planing method was more laborious, with each board requiring about 12 man-hours to process, while slabs took about 4 man-hours. This was despite the fact that the slabs and boards were of a similar volume with the boards each being 0.028 m^3 and slabs averaging slightly more. The board sampling method produced many censored depth measurements, which complicated the analysis and reduced the precision of the estimated D/L ratios. Typing of defects was also simpler with crosscut sampling. For all these reasons, it is recommended that any future work of this nature use crosscut sampling of slabs rather than planing as a means of exposing defects.

In the combined data, similar numbers of each defect type were obtained, with 113 Type I defects and 97 Type II defects being sampled (Table 2). The boards had greater numbers of Type I than Type II resin pockets while the slabs contained more Type II than Type I defects. Numbers and types of defects varied considerably between individual boards and slabs. Overall incidence of defects per m^3 was similar for both data sets averaging about 500 defects/m^3 in the boards, and 470 defects/m^3 in the slabs.

Table 2. Mean dimensions of resinous defects

Defect Type	Data set	Number	Length (mm)	Depth (mm)	Width (mm)
Type I	Board	82	72.7	17.5[1]	20.0
	Slab	31	68.0	14.7	15.0
	Combined	113	71.4	16.7	18.6
Type II	Board	43	73.8	15.0[1]	17.2
	Slab	54	34.1	8.4	7.3
	Combined	97	51.7	11.3	11.7
Combined		210	62.3	14.2	15.4

[1] Mean depths for board samples have been adjusted to take account of censoring.

Mean dimensions of Type I defects were similar in both data sets with lengths averaging 71 mm and depths and widths averaging 15-20 mm (Table 2). Average dimensions of Type II defects were very similar to Type I defects in the board samples, but were smaller in all dimensions in the slab samples. This may reflect a difference in the source of sampled material. Alternatively, the manner of choosing boards for sampling, i.e., on the basis of large visible surface defects, could have led to a larger than average defect bias in these samples. However, although there were differences in average dimensions of Type II defects in the two data sets, the ratios of depth to length were similar in both.

As noted above, it was necessary to adjust for the effect of censoring of the depth measurements in the board data set, and the mean depths shown in Table 2 are adjusted to take account of this. Fifty-five percent of the depth measurements from the boards were censored. Unadjusted mean depths for the board data set were 10.4 and 12.5 mm for Types I and II defects respectively, but after adjusting for censoring these were increased to 17.5 and 15.0 mm respectively.

Mean depth was very similar to mean width for each defect type (Table 2). Because the measurement axis of the log slab data was completely arbitrary, mean widths and depths in this data set would be expected to be nearly identical. However, this would not necessarily be expected for the board data set. For example, given the that Type I defects are much shallower in the radial plane and wider in the tangential plane (Table 1), flat sawn boards would be expected to have wider but shallower Type I defects. However, as all boards in the study were approximately 3/4 sawn, the radial and tangential dimensions of the defects contributed equally to defect widths and depths in relation to the board surface, and mean widths and depths were therefore similar.

Cumulative distributions of defect lengths, depths and widths are shown in Figs. 5-7. These show that all defect dimensions were positively skewed, with large numbers of small defects and small numbers of larger defects. For example, the median length for Type II defects was 37 mm but the longest was 203 mm, nearly six times the median length. The Type I length distribution was less skewed, having a median of 70 mm and a maximum of 186 mm. Depths and widths were if anything more skewed than length. As expected from the similarity of their means, the distributions of depth and width were very similar.

The means given in Table 2, and the cumulative distributions given in Figs. 5-7 are based on the maximum dimensions of each defect, i.e., the dimensions giving the maximum extent of the fully dissected defect. In practice, a surface cut will usually expose less than the maximum dimension of a defect. In Table 3, the ratios of the maximum to the mean exposed dimensions of each defect are shown. To obtain this ratio for the length dimension from the board data set, the lengths of a defect measured for all planing steps when it was visible were averaged and divided by its maximum length. A similar calculation was made for width from the board data set, and for width and depth from the slab data set. Table 3 shows that the exposed length of a defect averaged about 75% of the maximum length. There was some discrepancy between the slab data set in which exposed widths and depths were about 80% of their maximum, and the board data set where this ratio averaged about 60%.

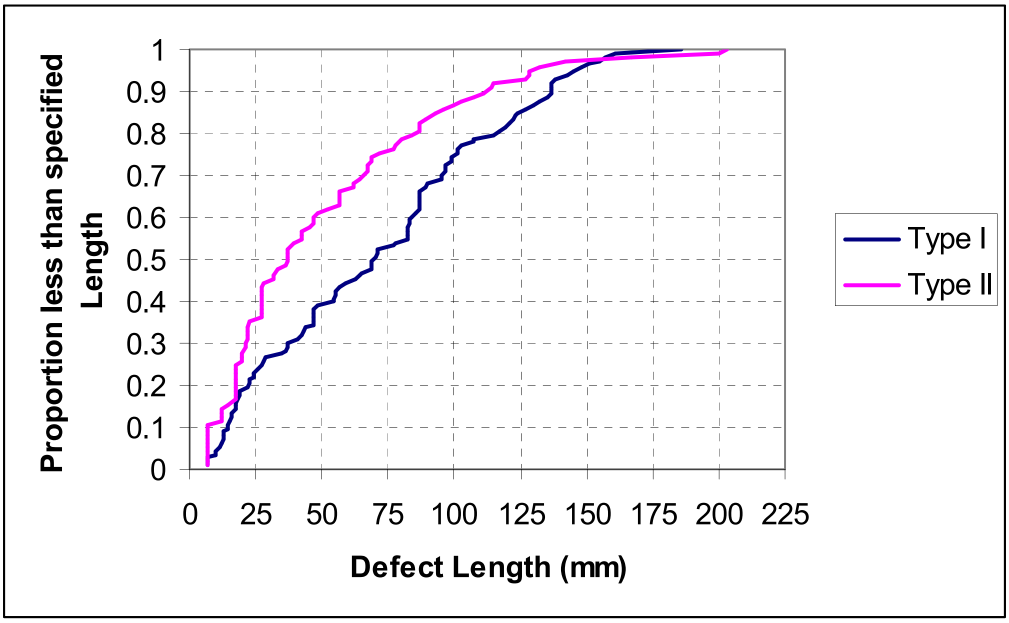

Fig. 5. Cumulative distribution of defect maximum lengths in the combined data

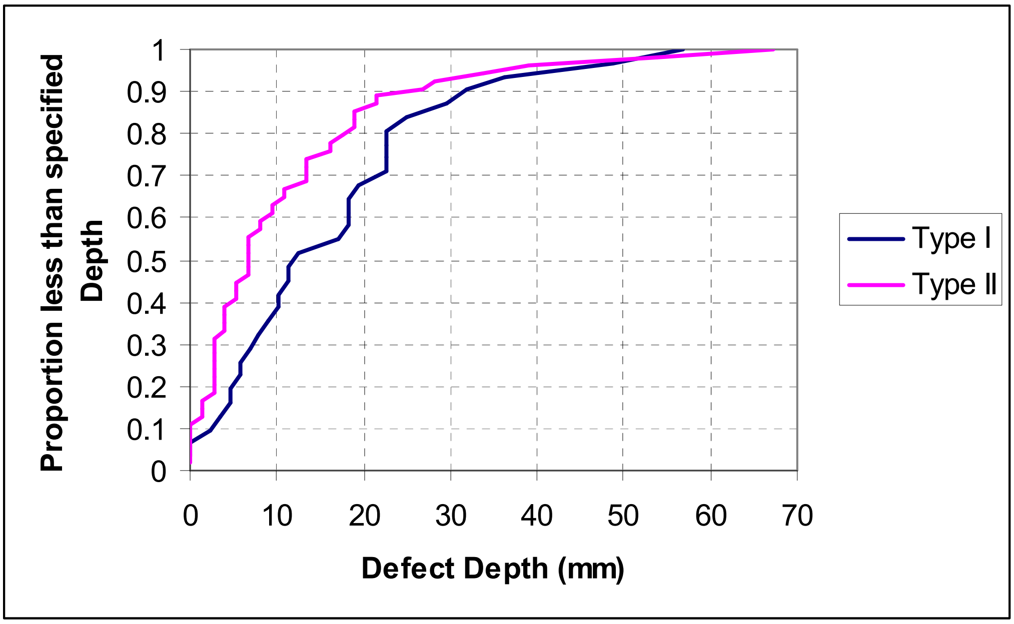

Fig. 6. Cumulative distribution of defect maximum depths. Because many of the measurements in the board data set were censored, only the slab data set was used for this graph. However, the measurements were adjusted to reflect the overall mean depth of the combined data shown in Table 2

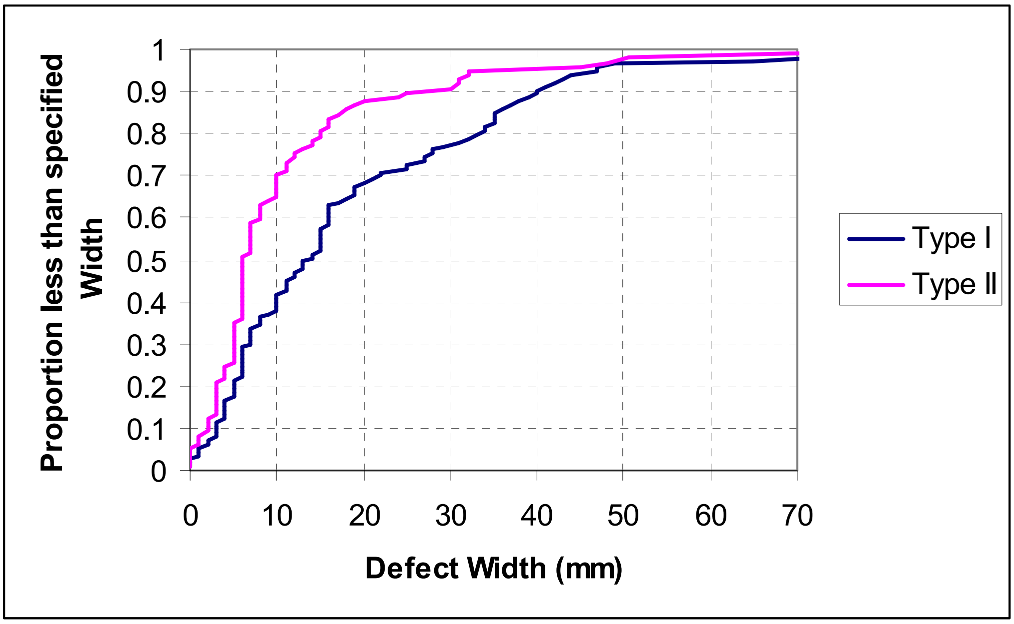

Fig. 7. Cumulative distribution of defect maximum widths in the combined data

Table 3. Mean ratios of defect maximum dimensions to visible dimensions

Defect Type	Length (Board data set)	Width (Board data set)	Width (Slab data set)	Depth (Slab data set)
Type I	0.75	0.59	0.79	0.75
Type II	0.68	0.59	0.88	0.90
Combined	0.73	0.59	0.86	0.83

The percentage of defects with visible dimensions greater than a specified length and width were calculated for the combined data sets (Table 4). This was based on actual measurements of mean visible dimensions for length from the board data set, and width from both data sets. For the slab data set, visible lengths were calculated as the maximum length multiplied by 0.74 on the basis of Table 3. Table 4 can be used to estimate numbers of defects of different visible sizes once the overall frequency is known, assuming size distributions similar to those in this study. For example, if the overall frequency of board surface defects is found to be 10 per m^2, Table 4 indicates that 8.5 defects per m^2 will be greater than 10 mm in length and 2 mm in width, and that 2.1 defects per m^2 will be greater than 50 mm in length and 10 mm in width.

Model (1) was fitted to determine whether the D/L and W/L ratios were constant. The quadratic coefficient *b* was not significant for the Type I defects, but was significantly negative for the Type II defects. This was true for both D versus L and W versus L. It was therefore concluded that for Type I defects, the D/L and W/L ratios are constant regardless of the size of the defect while, for Type II defects, the D/L and W/L ratios are lower for larger than smaller defects (Figs. 8 and 9). This implies that a simple conversion factor for Type II defects will tend to under-predict the board surface frequency in samples with smaller than average defects, but over-predict the frequency in samples with larger than average defects. Despite this, we believe that a simple conversion factor will give adequate results in most cases. It can also be seen from Figs. 5 and 6 that the D/L and W/L ratios are similar for both defects types, at least when lengths are less than 100 mm, suggesting that a single conversion factor may be appropriate for both defect types.

Table 4. The percentage of defects with visible length and depth greater than or equal to specified values

Defect length (mm)	Defect width (mm) 0-2	3-5	6-10	11-15	16-20	21-25	26-30	>30
0-10	100	90	65	26	8	4	2	1
11-20	91	85	63	26	8	4	2	1
21-30	68	66	56	25	8	4	2	1
31-40	58	56	49	24	8	4	2	1
41-50	46	45	40	23	7	4	2	1
51-60	35	34	33	21	7	4	2	1
61-70	28	27	27	18	5	4	2	1
71-80	20	20	20	13	4	3	2	1
81-90	11	11	11	10	3	3	2	1
91-100	9	9	9	8	2	2	2	1
>100	5	5	5	5	2	2	1	1

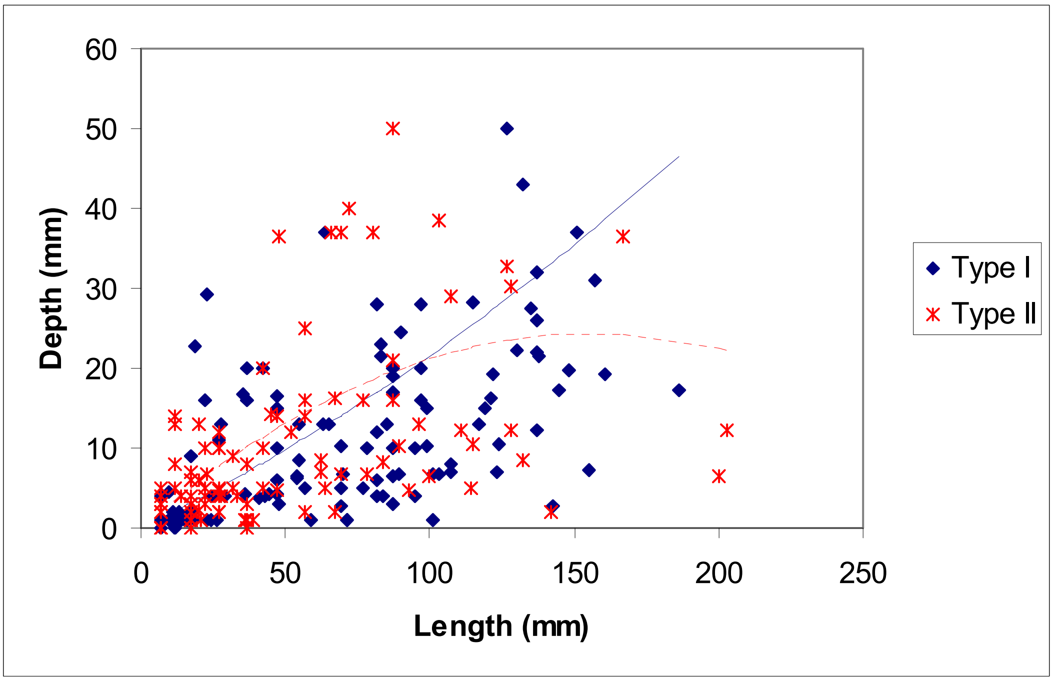

Fig. 8. Defect depth versus defect length for Type I and II defects. Fitted lines using Model (1) are shown for Type I defects (solid line) and Type II defects (dashed line). Note that depth measurements of some of the data points on this graph are censored and are therefore less than their true value. However, the fitted lines take account of this censoring

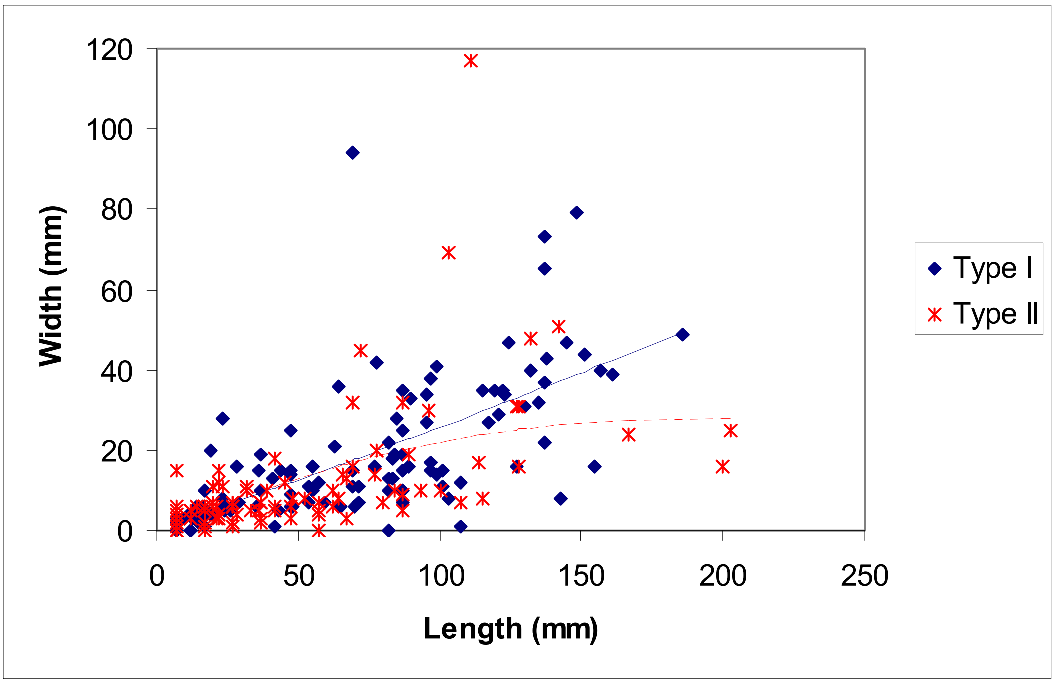

Fig. 9. Defect width versus defect length for Type I and II defects. Fitted lines using Model (1) are shown for Type I defects (solid line) and Type II defects (dashed line)

Model (2) was fitted to provide estimates of the D/L ratio. Initially, separate estimates were obtained for each board or slab (Table 5). These showed that there was considerable variation in the ratio between individual boards and slabs, presumably reflecting variability between individual trees from which each sample was obtained. There was also considerable variation in the precision of the estimates, mainly because of large differences in defect sample numbers between individual boards or slabs. Combined estimates of *a* were therefore obtained by weighting each by the inverse of its variance. The combined estimates were 0.20 and 0.18 for Types I and II defects respectively (Table 5). Confidence intervals of the combined estimates were then obtained using the variation between boards or slabs as the basis of the calculation. These indicated that the mean D/L ratio for Type I defects is between 0.15 and 0.25, and the mean for Type II defects is between 0.10 and 0.26. The widths of these intervals reflect the considerable variation in the D/L ratio between trees. Although further sampling would give more precise ratios, for the purposes in which they will generally be used very high precisions are probably not required, and these estimates may therefore be of sufficient accuracy.

Model (2) was also fitted to the pooled measurements from each data set, and to the combined data across both data sets (Table 6). These estimates differ slightly from the estimates in Table 5 partly because of the different method of calculation, but also because the method used in Table 5 was unable to provide an estimate for Type II defects from one board because all depths in that board were censored. The values in Table 6 are therefore more complete that those in Table 5.

Table 5. Estimates of the D/L ratio estimated using Model (2) for each board or slab

Data set	Board/Slab	Type I			Type II		
		No. defects	*a*	std. error	No. defects	*A*	std. error
Board	1	12	0.26	0.06	8	0.31	0.09
	2	6	0.18	0.05	1	0.03	0.22
	3	12	0.23	0.03	3	0.28	0.11
	4	15	0.22	0.08	0		
	5	6	0.13	0.05	0		
	6	4	0.18	0.08	0		
	7	4	0.79	0.22	0		
	8	13	0.39	0.06	6[1]		
	10	10	0.10	0.03	25	0.15	0.02
Slab	5	0			1	0.06	0.47
	6	24	0.20	0.02	33	0.17	0.03
	7	0			1	0.03	0.12
	8	2	0.21	0.06	10	0.47	0.05
	9	5	0.24	0.05	0		
	10	0			9	0.07	0.11
Combined			0.20 ± 0.05[2]			0.18 ± 0.08[2]	

[1] no estimate of *a* was possible for this board because all depths were censored

[2] 95% confidence interval of combined estimate based on variation between boards and slabs

Table 6 shows that the D/L estimates were similar for both types of defects from both data sets. The pooled data gave an estimate for D/L of 0.21 for Type I and 0.22 for Type II defects. The values for W/L were similar to those for D/L. Given the similarity of the ratios for the two types of defect, and given the variability in the estimates demonstrated in Table 5, there seems to be no justification for using different factors for Types I and II defects, and it is proposed that a common factor of 0.21 should be used for both. This factor implies that crosscutting a log will reveal nearly five times as many resin pockets per m^2 as board surface sampling.

Table 6. Mean estimates of coefficient *a* for Model (2)

Defect Type	Data set	D vs. L	W vs. L
Type I	Board	0.24[1]	0.27
	Slab	0.20	0.21
	Combined	0.22[1]	0.26
Type II	Board	0.24[1]	0.22
	Slab	0.22	0.21
	Combined	0.21[1]	0.22

[1] Coefficients adjusted to take account of censoring.

The defect dimension data obtained in this study also allows us to estimate a factor for converting from a crosscut frequency to a wood volume frequency. Although crosscut sampling produces an area count, effectively this method samples a wood volume equal to the surface area times the average defect length. The factor for converting from crosscut frequency to volume frequency is therefore the inverse of the average defect length. Given that the average length of all defects in the study was 62 mm (Table 2), this conversion factor is therefore 1/0.062 or 16.

As an example of the application of these conversion factors, suppose that crosscutting a sample of logs reveals 10 defects per m^2. By applying the board surface conversion factor we can estimate that the board surface frequency will be 10 × 0.21 or about 2 defects per m^2. The volume conversion factor implies that the volume frequency is 10 × 16 or 160 defects per m^3. Table 4 can be used to estimate the frequencies of defects of various sizes if required.

The factors derived in this report for converting from crosscut frequencies to board surface frequencies and wood volume frequencies, will be valid for a population as long as the defect dimensions found in this study hold in that population. The board surface conversion factor depends on the D/L ratio while the wood volume conversion factor depends on the average length of defects. The conversion factors will give incorrect results in stands or regions where the D/L ratio or the average defect length varies from the values found in this study. The fact that the D/L ratio remains fairly constant across a range of defect sizes and is similar for both Types I and II defects, suggests that this ratio may be fairly robust. However, if the factors are applied in regions where resin defects are different in dimension to those in the Central North Island, these factors may not give correct results. Validation of the factors in another region such as Canterbury might therefore be worthwhile.

CONCLUSIONS

- Analysis of defect dimensions showed that crosscut frequencies of resinous defects can be converted into board surface frequencies by multiplying by a conversion factor of 0.21.
- This conversion factor is derived from the fact that the dimension of a resinous defect in the longitudinal plane of a log is typically almost five times greater than its depth at right angles to the surface of a board cut from that log.
- This conversion factor can be applied equally to both Type I and Type II defects.
- Cross cutting exposes about five times as many defects per m^2 as found on a board surface cut from the same log.
- Crosscut frequencies per m^2 can be converted into wood volume frequencies per m^3 by multiplying by 16.
- The crosscut method of assessing resin pockets is more efficient than the planing method.

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