Project No. PN02.1308

Resource Characterisation & Improvement

Australian Government

Forest and Wood Products Research and Development Corporation

Sawing Regrowth and Plantation Hardwoods with Particular Reference to Growth Stresses

Part B Survey Results

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Sawing Regrowth and Plantation Hardwoods with Particular Reference to Growth Stresses
Part B Survey results

Prepared for the

Forest & Wood Products
Research & Development Corporation

by

R. de Fégely

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SUMMARY

In deference to requests from sawmillers, companies have not been identified in this report and to protect further the identity of individual sawmillers, the report has been presented generically but with sufficient detail to ensure the information can be used by individual sawmillers as they see fit.

The first stage of Project PN02.1308 was a literature review, encompassing both Australian and international published and unpublished documents and was completed, presented to, and accepted by Forest and Wood Products Research and Development Corporation (FWPRDC) in November 2002. In the second stage, 40 hardwood sawmills in New South Wales, Queensland, Tasmania and Victoria, and three sawmill engineering companies, were visited by Jaakko Pöyry consultants[1] between November 2002 and February 2003. The consultants discussed and witnessed processing problems actually experienced by sawmillers, which could be associated with growth stresses, and the methods used to reduce their impacts. As part of this second stage, two questionnaires were used; one sent to all the sawmillers visited, the other to sawmill engineering companies. The questionnaires were useful in structuring the question and answer sessions during our visits.

All the mills visited were cutting regrowth, sometimes in mixture with mature wood. However, most of the regrowth logs were slow grown and more than 60 years old. Some could have been more than 100 years old. In general, growth stresses were not posing serious problems so that regrowth hardwoods, preferably as large a diameter as possible, were being sawn successfully to produce high grade, high value products. However, as the regrowth on offer from growers becomes younger and smaller this may need a different approach based on research, reliable information and the introduction of more appropriate technologies where this has not already occurred.

In total, at the mills visited, more than twenty different species were sawn.

The combined inputs of the regrowth sawmills visited by Jaakko Pöyry Consulting during the course of this study were:

State	Regrowth sawmill sawlog inputs m3	Regrowth sawlog input of the sawmills visited by the Consultants	Percentage of each State's regrowth sawlog input	Combined percentage of regrowth sawlog input
Queensland	350,000	120,000	34	
New South Wales	700,000	250,000	36	
Sub total	**1,050,000**	**370,000**		**35**
Victoria	750,000	475,000	63	
Tasmania	350,000	280,000	80	
Subtotal	**1,100,000**	**755,000**		**68**
Overall	**2,150,000**	**1,125,000**		**52**

[1] Brian Wall and Ken Groves

The most common species were coastal blackbutt and spotted gum in New South Wales and Queensland, the ash group in Victoria, and ash and messmate stringy bark in Tasmania. Only three mills were cutting a proportion of plantation-grown wood. Two in New South Wales were cutting small amounts of either flooded gum only or a mixture of flooded gum and coastal blackbutt to produce palletwood. One mill in Victoria was cutting mountain ash. These logs, as delivered to the mill, appeared to be of satisfactory quality but when opened up on the headrig displayed an array of faults, including extensive kino pockets and veins, knots and brown stain. Growth stresses were so severe that as sawn sections were unloaded from the headrig carriage they were splitting lengthwise on impact. While there are differences between wood quality in regrowth and mature wood, the differences are much less severe than those between the plantation grown mountain ash in Victoria and anything seen elsewhere in Eastern Australia. If these differences are repeated elsewhere, when more plantation grown sawlogs become available, we will indeed have a serious problem. The need for timely and well-directed research is discussed in the report.

Although raised as an issue in the literature review, brittleheart and saws binding in the cut did not pose serious problems in any of the mills visited.

The major problems encountered were:

- End splitting of trees and logs after felling and crosscutting, and during storage in mill yards
- Splitting of timber when sawing plantation grown timber
- Spring.

End splitting (known colloquially as popping) occurs either because of growth stresses or drying stresses or both combined. To reduce end splitting, sawmillers rely on a mix of log management practices, which are detailed in the report.

Sawmillers were not generally concerned about splitting when sawing regrowth in the green mill. However, as discussed above, it was a serious problem in sawing plantation grown ash in Victoria.

Most sawmillers identified spring as a problem. It is usually dealt with by putting in a straightening cut to provide a reference face from which subsequent pieces can be sawn accurately to wanted dimension; hence the practice is commonly known as face cutting. There are ways of limiting face cutting so as to improve recovery, which have been adopted by some Australian mills; these are discussed in the report. Spring is a greater problem in Victoria and Tasmania than the other States due to their species being prone to collapse. Collapse prone species largely have to be quartersawn[2] to permit recovery by reconditioning. In Tasmania, the proportion of logs from regrowth was less than in New South Wales and Queensland and the logs, in general, were larger. Spring was not as serious as we had anticipated in New South Wales and Queensland although this may reflect the nature of the resource, which, because it has less tendency to collapse during the early stages of drying, can be backsawn. Backsawing is most likely to give rise to bow, which can usually be ignored during milling.

[2] Quarter sawing is impossible in smaller regrowth e.g. < 40cm small end diameter.

The overall effect of splitting and spring is to reduce recovery. There are many factors influencing recovery, which accounts for the large variations reported of 24 to 45%. These factors are detailed in the report. In general, in Tasmania, because of the need to quarter saw and despite the larger logs, stated recoveries seemed low. One mill even claimed recoveries out of the green mill of only 24 to 28% from regrowth and 29% from mature logs despite average log diameters between 65 and 70 cm and the extensive use of bandsaws.

A range of milling equipment was inspected, used exclusively for back sawing in New South Wales and Queensland and mainly quarter sawing in Tasmania and Victoria (except east of Orbost). No two sawmills were alike. Each in its unique way had adapted to the species, gross annual volumes, log sizes and qualities available now and in the future, and to the sawing patterns required to service its markets, which, in themselves, are extraordinarily varied. However, there seems to be widespread agreement as to the best types of equipment for optimising productivity and reducing the impact of growth stresses. These are as follows:

- Small logs up to a maximum of 600mm centre diameter but with many logs less than 450mm centre diameter down to about 300mm:

  Twin edger headrig with the log fed into and through the saws by an overhead end-dogging carriage. The advantage of this method for highly stressed, small logs lies in the roughly equal stress relief on either side of a log provided by simultaneous symmetric cutting, resulting in the production of a centre cant with little warping. This cant can then be resawn on a centre splitting saw and the two halves further resawn into wanted dimensions.

- Large logs > 450mm centre diameter:

  Single saw headrig with line bar sizing carriage followed by one or two one-man semi automatic benches, depending on the level of production required. These saws can follow the spring, producing accurately dimensioned pieces and reducing the need for face cutting.

Jaakko Pöyry Consulting recommended research studies at the end of each major section of the report. These are not intended simply to confirm what individual sawmillers, through experience and trial and error, have discovered what is best for them. Rather they are intended to define the conditions under which certain practices have been beneficial, to ascertain if these practices can also be beneficial under different sets of conditions, at the same time defining the parameters within which the benefits can be realised.

These recommended studies are complementary to the requirements of the Terms of Reference for Part Two of this study as provided by FWPRDC. These are:

To evaluate sawing patterns for reducing end splits for both back sawn and quarter sawn timber with appropriate equipment.

In the light of our Literature Review PN02.1308, this Report, and our visits to the mills, we have recommended to FWPRDC, **three** mills per State that are best suited to supporting such studies.

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GLOSSARY

Back sawn	A fully back sawn piece of timber is one in which the growth rings are roughly parallel to the face of the piece. However, in practice, provided the angle is less than 45^0, a piece of timber is regarded as back sawn
Band saw	An endless steel blade usually toothed on one edge only but occasionally on two. Band saws used on headrigs may be up to 40cm wide.
Barrel checking	These defects are the main types of fibre separation. A check is a separation that extends along the grain and results from stresses developed as the surface layers of wood lose moisture and shrink while the main body of material underneath is fully distended.
Bow	Curvature of the face of a piece of sawn timber along its length
Brown stain	A stain found particularly in mountain ash (Eucalyptus regnans) caused by micro-organisms invading the wood after injury
Canadian twin	A headrig consisting of two circular saws in the same plane, one a little behind but above the other, with their cutting edges overlapping. The second saw is smaller than the first and is used when sawing the biggest logs.
Chipper canter	A headrig of two parallel disc chippers which remove the outside of a log as chips and leave a parallel sided dimensioned cant which can then be sawn. A reducer bandsaw is a headrig consisting of a chipper canter immediately followed by twin or quad bandsaws.
Circular saw	A circular steel blade with cutting teeth on the rim
Collapse (abnormal shrinkage)	Flattening or buckling of the wood cells of some species in the early stage of drying i.e. at high moisture content. It manifests itself as excessive shrinkage of the early wood, causing “wash boarding” in quarter sawn timber and sometimes severe face and internal checking, especially in back sawn timber
Drying stresses	Stresses which occur in timber during drying largely caused by differential shrinkage
Face cutting	A lengthwise straightening cut in a piece of sawn timber to provide a reference face from which subsequent pieces can be sawn accurately to a wanted dimension

Grain	Grain is determined by the alignment of the fibres in the wood. If the fibres are aligned more or less parallel to the long axis of the tree and to each other the wood will be straight grained. In interlocked grain, the fibres of adjacent bands of growth are spirally inclined in opposite directions
Growth Stresses	Growth stresses are characteristic of normal growing trees. In hardwood trees, the outer wood is in tension stress as it develops, thus providing an efficient engineering solution to supporting themselves structurally.
Headrig	The main breaking down saw in a sawmill at which the process of converting logs to sawn timber begins.
Kino	A very dark reddish coloured, viscous exudate which occurs in eucalypts
Normal shrinkage	Shrinkage which occurs from the loss of bound water in wood in the late stage of drying i.e. below the fibre saturation point after all the free water has been removed
Quarter sawing	A fully quarter sawn piece of timber is one in which the growth rings are at an angle of not less than 80^0 to the face of the piece. However, in practice, provided the angle is not less than 45^0, a piece of timber is regarded as quarter sawn
Recovery	This is the volume of sawn timber produced divided by the volume of logs required to produce it. It is generally expressed as a percentage
Spring	1. Curvature of the edge of a piece of sawn timber along its length. 2. Bending in a log or flitch which occurs during sawing

1 INTRODUCTION

The first stage of Project PN02.1308 was a literature review, encompassing both Australian and international published and unpublished documents and was completed, presented to, and accepted by Forest and Wood Products Research and Development Corporation (FWPRDC) in November 2002. In the second stage, over 40 hardwood sawmills in New South Wales, Queensland, Tasmania and Victoria, and three sawmill engineering companies, were visited by Jaakko Pöyry consultants[3] between November 2002 and February 2003. The consultants discussed and witnessed processing problems actually experienced by sawmillers, which could be associated with growth stresses, and the methods used to reduce their impacts. As part of this second stage, two questionnaires were used; one sent to all the sawmillers visited, the other to sawmill engineering companies. The questionnaires were most useful in structuring the question and answer sessions during our visits. Appendix 1 contains pro-forma copies of each questionnaire.

In deference to requests from sawmillers, companies will not be identified in this report and to protect further the identity of individual sawmillers, the report will be presented generically but with sufficient detail to ensure the information can be used by individual sawmillers as they see fit.

The combined inputs of the regrowth sawmills visited by Jaakko Pöyry Consulting during the course of this study were:

Table 1-1:
Combined inputs of regrowth sawmills

State	Regrowth sawmill sawlog inputs m3	Regrowth sawlog input of the sawmills visited by the Consultants	Percentage of each State's regrowth sawlog input	Combined percentage of regrowth sawlog input
Queensland	350,000	120,000	34	
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Sub total	**1,050,000**	**370,000**		**35**
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Subtotal	**1,100,000**	**755,000**		**68**
Overall	**2,150,000**	**1,125,000**		**52**

With very few exceptions, there was excellent cooperation from all the sawmillers visited. Occasionally there was some initial suspicion about the aims and intentions but this soon disappeared after a detailed explanation of the nature of the Project.

All of the mills visited were cutting regrowth, sometimes in mixture with mature wood. However, most of the regrowth logs were slow grown and more than 60 years

[3] Brian Wall and Ken Groves

old. Some could have been more than 100 years old. In general, growth stresses were not posing serious problems so that regrowth hardwoods, preferably as large a diameter as possible, were being sawn successfully to produce high grade, high value products. However, if younger and smaller logs have to be processed in future, problems that are more serious may arise, although further research needs to be done before this can be substantiated.

In total, for the mills visited, more than twenty different species were sawn. In New South Wales the most important species were coastal blackbutt (Eucalyptus pilularis) and spotted gum (Corymbia maculata). In Queensland, blackbutt was much less commonly cut, the most important species being spotted gum with some ironbarks. In Victoria south of the divide and east of Orbost (plus one mill in New South Wales close to the Victorian border), the species mix was more variable, including messmate, blue leaf, yellow and white stringy barks (*E. obliqua*, *E. agglomerata*, *E. muellerana*, and *E. eugenioides*); silvertop ash (*E. sieberi*), coastal woollybutt (*E. longifolia*) and brown barrel, known locally as cut-tail (*E. fastigata*). West of Orbost and both north and south of the divide, the most important species were alpine and mountain ash (*E. delegatensis* and *E. regnans*), which are invariably processed and marketed together as Victorian ash; plus small quantities of other species such as shining gum (*E. nitens*), messmate, mountain grey gum (*E. cypellocarpa*) and, at two mills, manna gum (*E. viminalis*). In Tasmania, the most important sawlog species is messmate stringy bark, known locally as brown top, which is processed and marketed, together with mountain and alpine ash, as Tasmanian oak. In addition there are small quantities of other species sawn such as southern blue gum (*E. globulus*), myrtle beech (*Nothofagus cunninghamii*) and, at one mill, celery top pine (*Phyllocladus aspleniifolius*).

Only three mills were cutting a proportion of plantation-grown wood. Two in New South Wales were cutting small amounts of either flooded gum (*Eucalyptus grandis*) only or a mixture of flooded gum and coastal blackbutt to produce palletwood. One mill in Victoria was cutting mountain ash (*E. regnans*), aiming to produce F17 structural timber. These ash logs, as delivered to the mill, appeared to be of satisfactory quality but when opened up on the headrig displayed an array of faults, including extensive kino pockets and veins, knots and brown stain. Growth stresses were so severe that as sawn sections were unloaded from the headrig carriage they were splitting lengthwise on impact. While there are differences between wood quality in regrowth and mature wood, the differences are much less than those between the plantation grown mountain ash in Victoria and anything seen elsewhere in eastern Australia. These differences will be discussed in a separate section. The comment that most experienced sawmillers in Australia "consider plantation eucalypts to be too difficult to process because of growth stress related distortion during sawing and drying degrade" would seem to have some justification. These are "seen to be so severe that the resulting poor quality products are not suited for the manufacture of anything other than low-quality packaging products" (Waugh and Northway 2002)[4]. However, according to CSIRO media release 2003/100 of June 19, quarter sawing of plantation grown shining gum in one series of trials in NE Victoria

[4] Page 22 of Literature Review PN02.1308

produced more encouraging findings, i.e. that “distortion during sawing was well contained”, that “much of the timber produced from the plantation-grown logs was of similar quality to wood from the much older native forest logs” and that, “with thinning and pruning, future plantations should give even better results”.

Jaakko Pöyry Consulting has recommended research studies at the end of each major section of this report. These are not intended simply to confirm what individual sawmillers have discovered, through experience and trial and error, suit them but rather to define the conditions under which certain practices have been beneficial, to ascertain if these practices can also be beneficial under different sets of conditions, at the same time defining the parameters within which the benefits can be realised.

These recommended studies are also not intended to replace the requirements of the Terms of Reference for Part Two of this study as provided by FWPRDC. These are:

To evaluate sawing patterns for reducing end splits for both back sawn and quarter sawn timber with appropriate equipment.

Since one year has been allocated by FWPRDC for Part Two, and involve detailed studies in two mills per State, the recommendations we have made in this report can be incorporated within these studies. After discussions with FWPRDC, we will recommend confidentially, in the light of our Literature Review PN02.1308, this Report, and our visits to the mills, three mills per State that are best suited to supporting such studies, including those recommended in this report. Appendix 2 gives our research program for Part Two as contained in our original proposal to FWPRDC.

2 END SPLITTING OF TREES AND LOGS

End splitting (known colloquially as popping) occurs either because of growth stresses or drying stresses or both combined. If end splitting occurs immediately or soon after felling a tree and/or crosscutting it into logs, growth stresses are the most likely cause. If the end splitting takes a longer time to occur, drying stresses are the most likely cause. These drying stresses arise through differences in tangential and radial shrinkage[5], combined with very rapid drying out through the end grain. Sometimes the two types of stress may act together, in which case end splitting may be even more pronounced.

Reducing growth stress levels in standing trees by direct intervention e.g. ringbarking or defoliant sprays, or by genetic and/or silvicultural manipulation, as discussed in the literature review for this Project[6], was not practised by forest owners and, with one exception, sawmillers were unaware of the possibilities and/or thought they were of little consequence. The exception had asked Queensland Department of Primary Industries to conduct trials on poisoning trees to defoliate them but this had been refused. However, all sawmillers were very aware of the problem and, where they could, managed their log supplies to reduce its impact. No one had accurate figures for losses due to end splitting. One sawmiller in Tasmania, cutting residue logs for palletwood, claimed a 10% loss through end splitting while also claiming a 43% recovery based on green sawn size. The more usual figures for losses through end splitting varied from 1 to 5%, more commonly about 3%.

Sawmillers rely on a mix of management practices to reduce end splitting. These include:

- Reducing to a minimum the time between felling and delivery to the log yard and then holding the logs in the millyard for as short a time as possible. This is especially so in New South Wales and Queensland where logs are not sprayed with water to keep them fresh and to reduce the impact of barrel checking, as they commonly are in Tasmania and Victoria. However, the decision as to when to saw logs may be driven more by what has to be cut to avoid deterioration not only by end splitting but by other agencies such as attack by Lyctus and longicorn beetles. In northern New South Wales and south-eastern Queensland, there are significant seasonal variations in how long logs can be held in storage without deterioration of one sort or another; as little as a month in summer to as much as 4 months from late autumn to early spring. In Tasmania and Victoria, seasonal variations are not so important because of the prevalence of water spraying. Nonetheless, storage times in log yards vary greatly; from no storage time at all in the case of one small mill in Tasmania to three to five months for the largest mills in both States with a range of other times in between, depending on a number of factors. These include the need to build up stocks to ensure the full entitlement can be taken and to insure against non-deliveries because of adverse weather

[5] Tangential shrinkage is usually between 1.5 and 2.5 times the radial.
[6] Pages 16 to 18 of Literature Review PN02.1308

during the winter months. The periodicity of spraying log stocks with water also has a bearing; this will be discussed in more detail below.

- Delivering and storing logs in the millyard in as long a length as possible, e.g. in Tasmania 11m, only crosscutting to mill lengths just before milling. Sawmillers in New South Wales indicated dissatisfaction with log deliveries from State Forests in that these were commonly harvested with fully mechanised systems and some logs were delivered in mill lengths. This had two disadvantages for sawmillers:

  - they couldn't crosscut mill logs from long length logs to their own best advantage
  - they could not delay crosscutting to mill lengths until they were ready to saw them.

In addition, in Tasmania, several sawmillers complained that, where regrowth could be mechanically harvested, they had to accept some logs 5.5m long or shorter, and there was significant fibre damage and increased end splitting. However, one sawmiller said the quality of logs, which were mechanically harvested, had improved over the last few months. A manager of a Victorian harvesting company also commented that there was less end splitting when regrowth logs were felled with a felling head, although there is some evidence that leaning on trees with harvesting equipment can contribute to end splitting. Also, slabbing off can occur when crosscutting with a mechanical harvester. He also commented that skills were diminishing as experienced operators left the harvesting industry.

- Sorting into small and big logs in the millyard. The smaller logs are then cut as quickly as possible since they have the highest stress gradients and are, therefore more likely to split. However, where mills only cut to specific orders, as in the first four mills visited in Queensland, the logs best suited to meet those orders were selected for milling.

- Sorting by species. There are species variations and, while there are differences of opinion about the impact of these variations on the tendency to split, species having wavy or interlocked grain e.g. spotted gum and the ironbarks are less likely to split than species having straight grain e.g. blackbutt in New South Wales and Queensland and the ash species in Victoria and Tasmania. However, there are 'within species', possibly provenance, variations e.g. spotted gum which can be straight grained. Again, sawmillers in New South Wales indicated dissatisfaction with log deliveries from State Forests in that they had no certainty with respect to the mix of species or where the logs were coming from.

- Cutting random lengths in products such as flooring and decking so the effect of end splitting could be minimised by docking the splits as required.

None of the mills visited in New South Wales and Queensland either watered the logs or sealed their ends with sealant. The general opinion was that logs were held in mill yards for too short a period to justify the expense. However, one miller in Queensland suggested the possibility of storage under shade cloth plus spraying with water and claimed he would be installing such a system in the future. Another miller in southern New South Wales normally stored logs under shade cloth plus intermittent water sprays[7]. Of the twenty-four mills visited in Tasmania and Victoria, only four did not spray and/or use sealant. However, in practice, there were some differences in the approach to spraying; including total spraying all through the year, summer spraying only, spraying according to weather conditions, and spraying intermittently e.g. 20 minutes every two hours for 24 hours a day. While spraying is effective in maintaining high moisture content in the logs and reducing barrel checking caused by drying stresses at the surface of the logs, there were some differences of opinion with respect to its effectiveness in reducing growth stresses. Research reported on in Literature Review PN02.1308, showed mean longitudinal growth stresses (8.14 to 9.65 MPa) in mountain ash stored under water sprays for six months dropped by 16-25%[8]. Whether this was sufficient to have a measurable effect during subsequent sawmilling was not stated. It was suggested by one Tasmanian sawmiller that such stresses could be more significantly reduced by total immersion in water in a log pond for as long as possible. This has yet to be tested on a commercial scale.

End sealants are also widely used in Victoria and Tasmania to reduce the incidence of end splitting. They do so by reducing the drying rate from the end grain, which, in turn, reduces the drying stresses. They can have no direct effect on the growth stresses, although there may be linkages between drying and growth stresses, which could moderate the effect of the latter. However, to be effective, Tasmanian evidence suggests they must be applied within an hour of felling i.e. in the forest or at the forest roadside. Hence, the harvesting contractor must normally do this. One sawmiller indicated that, in his case, this was not satisfactory since the contractor was either not applying enough sealant or putting it on too late or both.

2.1 Recommendations for further investigations on end splitting of felled trees and logs

1. Where sawmillers are concerned about end splitting, its extent and severity and the resultant loss of usable log and sawn timber volume should be measured through a statistically designed research program which would take into account at least the following factors:

    - Species
    - Provenance
    - Small end diameter
    - Large end diameter
    - Estimated age of logs
    - Unsprayed logs

[7] Normally half an hour per hour for 24 hours a day, although this had been modified because of water restrictions.
[8] Page 20 of Literature Review PN02.1308

- Sprayed logs[9]

- End coating trees with sealant immediately after felling or logs treated within one hour of felling

- Logs coated with end sealant after arriving in the mill yard

- Uncoated logs

- Elapsed time between felling and conversion

- Estimated cost of spraying

- Estimated cost of treatment with sealant

- Estimated increase in grade and volumetric recovery by spraying with and without using sealant

- Estimated increase in recovery by using sealant with and without spraying

- Benefit cost analysis of spraying

- Benefit cost analysis of treating with sealant

- Any other important variable.

Discussions with some sawmillers have revealed support for some aspects of such a research program to the extent they might be willing to help fund it. Such a program would be complicated, at the fundamental level, by the need to distinguish between end splitting caused by growth stresses and that caused by drying stresses. Quick 'popping' would be due to growth stresses, slower 'popping' could be due to either or both. However, pragmatic applied research could still be useful.

2. Where sawmillers are concerned about the quality of logs produced using mechanical harvesters, this should be investigated and the extent and severity of damage quantified. It has been said that some machines such as modified excavators are worse than others. Inherent problems should be defined and ways of overcoming them recommended including, where appropriate, modifications to machines and operating techniques, and better operator training. Support for such investigations, if shown to be necessary, should be sought from manufacturers and distributors of such machines. Such investigations could be especially important for plantation grown eucalypts expected to produce sawlogs since they are most likely to be harvested using mechanised systems.

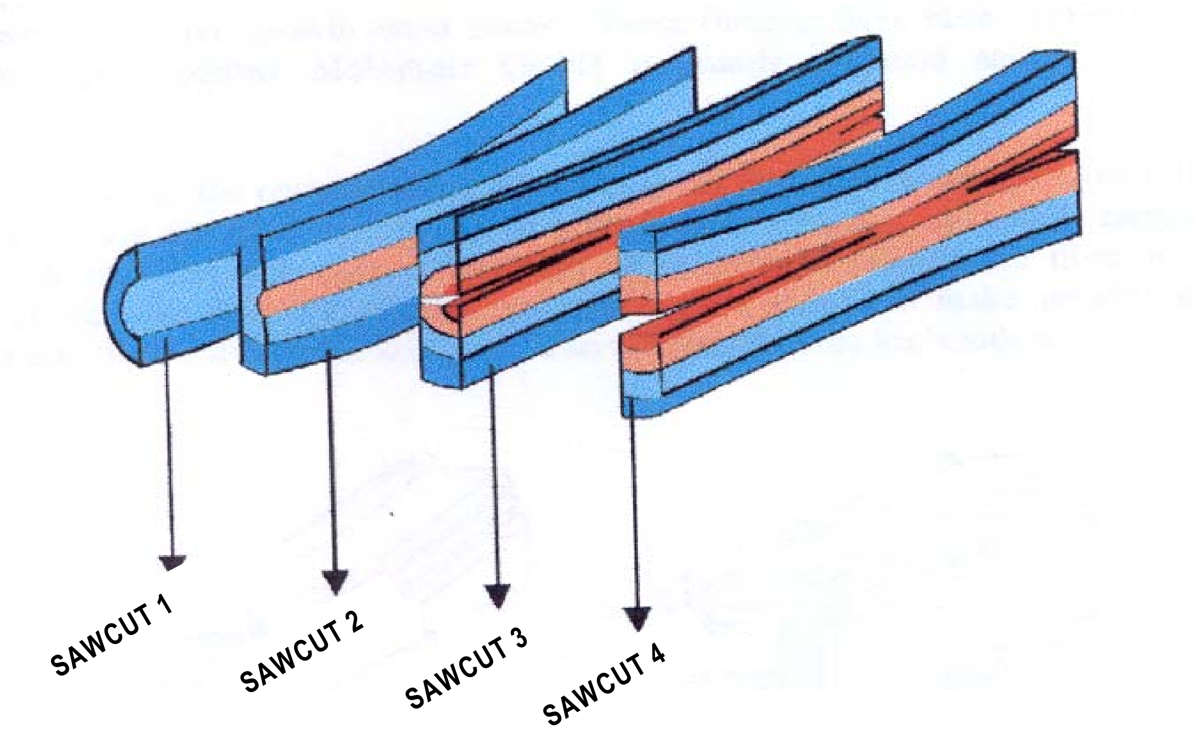
[9] CSIRO Forest Products Newsletters 245 September 1958, 281 December 1961 and 298 July 1963, report on spraying and the use of sealants but these need to be updated.

3 SPLITTING OF TIMBER DURING SAWING

Sawmillers were not generally concerned about splitting when sawing regrowth in the green mill. However, as more plantation wood becomes available, such splitting will become more of a problem and it may be necessary to consider the tendency to split during sawing in species selection, if it can be shown that this differs between species (or provenances) and/or sawing patterns (and product output) may have to be changed to reduce the tendency to split. Certainly, in one sawmill we visited in Victoria that was cutting plantation grown mountain ash, severe splitting occurred during sawing.

Figure 3.1 illustrates what could occur when sawing a log by a series of parallel cuts e.g. with a single bandsaw[10].

Figure 3-1:
Sawing with a sequence of parallel cuts



Dark blue:	High to moderate tension stress
Light Blue:	Moderate tension stress to no stress
Light orange:	No stress to moderate compression stress
Dark orange:	Moderate to high compression stress

Source: Executive Summary of Cooperative Research Project FAIR 98-9579 1999-2001 (EU).[11]

The first saw cut is made through the outer part of the wood, which has a gradient of diminishing tension stress from the periphery inwards, to produce a round back which is backsawn and bows away from the saw. If the stress distribution in the uncut log is as shown in Figure 3.1, the greatest stress gradient in the round back will be along the

[10] See also Pages 11,12 and 13 of Literature Review PN02.1308
[11] No Hardwood sawmiller in Australia uses this sequence of cuts. It has been used here simply for illustration.

extrapolated horizontal centre line of the log; the least at right angles to this line along the sawn face, assuming the distance from the sawn face is shorter in the former than in the latter. Because of the greater tension stress at the periphery, stress relief occurs because the fibres at the periphery shorten more than those on the inside of the round back which thus becomes concave on the bark side and convex on the sawn face, i.e. the bark side actually shortens in length and the sawn face lengthens. At the same time, the remaining log has a tendency to shorten on its uncut side.

The second saw cut produces a parallel-sided slab, which is mixed sawn and has a rather more complex stress distribution. In this case, the maximum stress gradient could occur at right angles to the horizontal centre line of the flitch depending on its thickness. Most of the fibres in this flitch were still under high to moderate tension stress before sawing and will shorten after sawing; however, the fibres in the light orange portion were under moderate compression and will lengthen after sawing. We now have a combination of "tension pull" and "compression push" the most likely net effect of which is again to cause the flitch to bow away from the saw cut.

The third saw cut produces another slab, which is mostly quartersawn and has an even more complex stress distribution. In this case, the maximum stress gradients would occur in two opposite directions from the centre of the flitch towards the bark. In theory, these would manifest themselves by a combination of "tension pull" and "compression push" as spring towards the bark. In practice, this is impossible in a bark-to-bark flitch *unless the flitch splits sufficiently in the middle to enable both halves to move independently*. Otherwise stress relief may only occur when the flitch is resawn, enabling separate pieces to spring towards the bark.

The fourth saw cut produces a fully quartersawn slab in which the effects are similar to those in the previous flitch but with greater stress gradients arising during sawing and a greater likelihood of splitting and spring towards the bark.

From the above theoretical analysis, splitting is most likely to occur in fully quarter sawn slabs extending over the entire diameter of a log. In practice, where splitting could be a problem, especially in smaller logs, some sawmillers saw through the middle of a log on a headrig or the middle of a log which has been turned on to an opening or spotting cut. The flitches produced are then sawn on a bench. These procedures do not eliminate spring, the effects of which can be offset by face cutting, but they will certainly reduce splitting.

Figure 3-2:
Possible stress relieving cuts in small logs

Single cut up the middle

Spotting cut followed by a cut up the middle of the flitch

One sawmiller commented that an overhead feed with end dogging for twin log edgers aggravated splitting because of the impact when the cant was dropped after sawing. However, end dogging in itself may cause splitting so that further investigations will be necessary to clarify this. Different types of transfer and conveyor systems in green mills should also be investigated particularly where sawn pieces are dropped e.g. off a carriage or from a transfer deck to a conveyor or into a pocket sorter.

3.1 Recommendations for further investigations on splitting in green sawn timber

1. Sawmillers were not generally concerned about splitting when sawing regrowth in the green mill. However, plantation grown wood may pose much more serious problems as evidenced by the mill in Victoria cutting plantation grown mountain ash. We would, therefore, recommend that the extent and severity of splitting of green sawn timber and the resultant loss of usable sawn timber volume should be measured through a statistically designed research program which would take into account at least the following factors:
   - Provenances, families and clones in the plantations
   - Soil types on which the plantations are growing
   - Aspect and slope
   - Thinning details where these differ sufficiently between stands
   - Small end diameter of logs
   - Estimated age of logs
   - Unsprayed logs

- Sprayed logs[12]
- End coating logs with sealant immediately before sawing[13]
- Uncoated logs
- Measurement of splitting before starting seasoning
- Measurement of splitting after completing seasoning
- Estimated cost of spraying
- Estimated cost of treatment with sealant immediately before seasoning
- Estimated increase in grade and volumetric recovery by spraying with and without using sealant
- Estimated increase in recovery by using sealant with and without spraying
- Benefit cost analysis of spraying
- Benefit cost analysis of treating with sealant
- Any other important variable.

Part of the study would be purely observational i.e. observing where the splitting occurs and under what conditions.

[12] See footnote 7

[13] Sealant will not reduce splitting caused by growth stresses. It may, however, reduce splitting during seasoning.

4 SPRING

Spring is bending of both edges of a piece of sawn timber to form part of the circumference of a rather large circle and, as part of the process of stress relief, is most likely to occur in quartersawn timber during sawing. Since spring cannot be removed by force in normal usage, it is usually dealt with by putting in a straightening cut to provide a reference face from which subsequent pieces can be sawn accurately to wanted dimension; hence the practice is commonly known as face cutting.

Spring is more of a problem in Victoria and Tasmania in their collapse prone species largely because these have to be quartersawn[14] to permit recovery from collapse by reconditioning although, in Tasmania, the proportion of logs from regrowth was less than in New South Wales and Queensland and the logs, in general, were larger. One sawmiller in Victoria claimed that spring was only a problem in small logs. It was not as serious as we had anticipated in New South Wales and Queensland although this may reflect the nature of the resource, which, because it has less tendency to collapse during the early stages of drying, can be backsawn. Backsawing is most likely to give rise to bow (bending of both faces of a piece of sawn timber along the length of the piece). Bow can be nullified more easily by force than spring and it is not necessary to correct for it during milling. In most cases, seasoning in a weighted stack can flatten bowed boards.

Growth stresses in sawn timber can cause variable thickness of products. This was never mentioned as a problem specifically by sawmillers; where the consultants raised it, there were different reactions. Some felt it was of little concern; others agreed it was a problem, dealt with by cutting in as short lengths as possible and face cutting as required. However, since it is less obvious than distortion and end splitting, it may be more serious than is generally believed. It may also be more or less prevalent depending on the processing technologies used. It should be investigated further in any future research.

Although most of the logs were from regrowth, most were slow grown and more than 60 years old and, because of the prevalence of backsawing, spring was less evident than bow. However, the nature of the resource e.g. species, size classes, log quality and age, should be investigated in more detail for reliable conclusions to be drawn. Furthermore, available resources vary greatly within and between States. One Queensland sawmiller, having a press button linebar sizing carriage on the headrig and a one man semi automatic bench, claimed that neither warping nor splitting was of any concern during milling, mostly for boards; a claim, which from a lack of face cutting and our inspection of his circular sorting table, would seem to be justified. However, he was cutting an unknown proportion of mature logs and, while not less than 75% of log input was from regrowth, much of this was “old” regrowth, i.e. more than 80 years old. A New South Wales sawmiller, cutting mainly spotted gum and coastal blackbutt, was marketing green timber (framing, subfloor joists and bearers, roof truss components, lintels, rafters etc.) as dead straight with “bow and spring

[14] Quarter sawing is impossible in smaller regrowth e.g. > 40cm small end diameter.

stresses relieved during milling". We were unable to inspect his mill to ascertain exactly how he did this.

There are ways of limiting face cutting, which have been adopted by some Australian mills; these will be discussed in the next section. However, face cutting is still common and causes a significant loss of recovery[15]. Recovery data from the survey are patchy, they are sometimes unreliable and, in any event, loss of recovery cannot be ascribed solely to face cutting. There are many factors influencing recovery including the following:

- Log size (diameter and length)
- Log form (taper and sweep)
- Log quality (especially important in terms of grade recovery)
- The distribution and severity of growth stresses
- Normal shrinkage and the extent to which this has to be allowed for in the overcut allowance in width and thickness
- Recovery from collapse
- Whether quarter sawing or backsawing
- The types of saws and infeeds used in a mill
- Whether optimising systems are used e.g. log scanners and optimising edgers
- The product mix.

In general, in Tasmania, because of the need to quarter saw and despite the larger logs, stated recoveries seemed rather low. One mill even claimed recoveries out of the green mill of only 24 to 28% from regrowth and 29% from mature logs despite average log diameters between 65 and 70 cm and the extensive use of bandsaws. At best, most mills reported recoveries of between 30 and 33% for mature logs and recoveries from regrowth invariably less than 30%. In Victoria, by contrast, where quarter sawing is also most common except east of Orbost, linebar carriages and one-man semi automatic benches are more prevalent than in Tasmania, recoveries were normally from 35 to 42%. One mill, which kept separate figures for ash and mixed species claimed it dropped from 38% for the former to 33% for the latter. In New South Wales and Queensland, despite the smaller logs than in Victoria and Tasmania, recoveries generally varied from 33 to 45%. Some of this can be ascribed to backsawing but more modern technology in processing smaller logs, such as chipper canters and twin edger headrigs, also helped.

Some mills dry unedged slabs rather than dimensioned pieces to reduce the impact of spring and the need for face cutting in the green mill. Pieces of wanted dimensions are then produced after drying by passing the slab through a straight-line edger to produce a reference face from which subsequent pieces can be sawn accurately.

[15] Recovery in hardwood mills in Australia is based on nominal size i.e. the assumed average size of rough sawn timber after seasoning but before dressing.

There are some disadvantages to doing this, e.g. kiln capacity is effectively reduced and, if the slabs have been cut close to the heart, drying degrade may be more severe since significant differential drying and shrinkage may occur. The loss of drying capacity may be offset to some extent by edging the slabs, removing wane and taper with twin saws before drying but leaving the final dimension cutting until after drying. The best option can only be determined by experience, conditioned by the facilities available at each mill.

Of the mills visited in New South Wales, all sawn timber is dimensioned at the green mill. The same applies in Queensland although one of the larger millers said he used to dry slabs but kiln-drying capacity became too small to continue doing this. However, with new kilns to be installed, the company was thinking about going back to slab drying. In Tasmania one miller does clean up the edges of slabs to avoid reducing his drying capacity too much but cuts no dimension stock until after drying. In Victoria, two mills were slabsawing, one mill mostly slabsawing and another mill cutting both slabs and dimension timber, the latter mostly F17 structural grade. All these Victorian mills were large with a majority of ash in their input.

4.1 Recommendations for further investigations of spring in sawn timber

1. Comparative recovery studies when slab sawing and dimension sawing, with particular emphasis on loss of recovery due to spring. Since one mill in Victoria was very successfully sawing both slab and dimension, optimisation of several mixes for defined marketing strategies should also be analysed.

2. Benefit/cost analyses of slab sawing compared to dimension sawing at mills where kiln-drying facilities are available.

5 TYPES OF SAWMILLING EQUIPMENT USED IN EASTERN AUSTRALIA

The consultants inspected a whole range of equipment, used exclusively for back sawing in New South Wales and Queensland and mainly quarter sawing in Tasmania and Victoria (except east of Orbost). The mills seen included the following:

5.1 Headrigs/log breaking down units

- Conventional sizing carriages feeding Canadian twin saws or a bandsaw (all States). In one mill the headrig also had scribing (horizontal) saws.
- Two linebar carriages feeding Canadian twin saws (Queensland and Tasmania) and five in Victoria feeding either Canadian twin saws or bandsaws. One sawmill manager commented that linebar carriages were most suitable for backsawing so it seems odd that we only saw one in Queensland and even moreso when the number of linebar carriages in Victoria, where quarter sawing is widely practised, is taken into account. This apparent contradiction needs to be investigated further. One sawmiller in Tasmania is currently converting from a conventional carriage and Canadian twin to a linebar carriage.
- Sizing pony carriage feeding either a band or circular saw (two in Tasmania, one in Victoria).
- Twin circular saw log edgers either with central end dogging and overhead carriage, front end top dogging and chain feed, and sharp chain feed (one each in Queensland and Victoria, four in New South Wales).
- Twin band log edger with end dogging overhead carriage (one in Tasmania).
- Chipper canter in tandem with a twin bandsaw (Reducer bandsaw) (New South Wales).
- Chipper canter in tandem with quad circular saws (Reducer circular saw with four sawblades) (New South Wales).

5.2 Resaws

The resaws were circular unless otherwise stated.

- One-man circular saw benches with linebar and hob feed. These were common. Where there was more than one they were set up either in parallel or in line (all States).
- Two, three and four man benches (all States).
- Twin board edgers including one optimising edger for seasoned boards (all States). One sawmiller used a twin board edger to clean up the waney edges of slabs but did not cut to dimension (Tasmania).

- Combination (i.e. fixed and movable) circular multisaws (all States).

- One-man recovery benches (all States).

- Four band resaws, two with roundabouts, plus one slant band resaw and one centre splitting band (Tasmania); one twin band resaw, two band resaws with pony carriages and linebars, two band resaws with linebars and two band resaws (Victoria).

- One straight-line edger for resawing seasoned slabs (Victoria).

The above summary of equipment indicates the wide range used in hardwood sawmilling in the eastern Australia. No two sawmills are alike. Each in its unique way has adapted to the species, gross annual volumes, log sizes and qualities available now and in the future, and to the sawing patterns required to service its markets, which, in themselves, are quite extraordinarily varied. However, there seems to be widespread agreement as to the best types of equipment for optimising productivity and reducing the impact of growth stresses.

5.3 Equipment for sawing small logs to reduce the impact of growth stresses

Small logs are defined as those with diameters down to 300mm and with the majority of them having centre diameters of less than 450mm. The equipment regarded most favourably is a twin edger headrig with the log fed into and through the saws by an overhead end-dogging carriage. The advantage of this method for highly stressed, small logs lies in the roughly equal stress relief on either side of a log provided by simultaneous symmetric cutting, resulting in the production of a centre cant with little warping. However, there is a danger of splitting if the distance between the parallel sawn surfaces of the centre cant becomes less than about two thirds of the original diameter of the log, particularly if the cant is dropped from the carriage. If a squared cant is produced (within the two thirds constraint and without splitting), this may then be resawn on a centre splitting saw and the two halves further resawn into wanted dimensions.

Twin edger systems could be appropriate for small, highly stressed logs from plantations as well as smaller regrowth and small salvage logs. In this context, the overhead end dogging carriages developed in Australia also have advantages including the following:

- They hold logs very firmly through the saws, thus ensuring accurate sawing

- They lend themselves to scanning for optimising log and saw positions to give maximum volumetric recovery, provided the input volume is sufficient to justify this level of technology

- They can be used with twin or quad band or circular saws or with chipper canters.

They are not very flexible with respect to grade recovery.

The most common suggestions regarding resaws following a twin edger headrig were a combination multisaw plus a one-man semi automatic bench or simply a one-man semi automatic bench, depending on the level of production required.

5.4 Equipment for sawing large logs to reduce the impact of growth stresses

Large logs are defined as those with diameters greater than 450mm centre diameter. The equipment regarded most favourably is a single saw headrig with line bar sizing carriage followed by one or two one-man semi automatic benches, depending on the level of production required. One sawmill visited in Tasmania, which the miller said had been built specifically for large regrowth, consisted of a Canadian headrig with linebar carriage followed by a one-man semi automatic bench and an edger with one fixed and two floating saws.

5.5 Recommendations arising from the types of sawmilling equipment used in Eastern Australia

Since Part Two of this Project (Appendix 1) involves detailed milling trials in sawmills in each State we recommend the mills selected should be representative of best practice and most up-to-date technology within each State. For each mill the following should be investigated:

- The sawing patterns used for each size class of log and the factors causing variations to these patterns for a specific size class e.g., extent and nature of defect, market requirements etc.

- The sawing sequence followed for each sawing pattern used. This is useful in assessing the benefits of using multiple saws rather than single saws.

- The operating parameters for the type of equipment used, including feed speeds and feed systems, rim speeds, type of blade, tooth profiles (angle of hook, pitch, gullet configuration, whether saws are swage or spring set, gauge and kerf etc.).

- Sawing accuracy including a statistical analysis of the relationship between the green target size sawn and the nominal size required.

- Problems at the headrig e.g. any splitting after sawing, distortion such as spring and bow. The extent of splitting and distortion such as spring and bow should be measured, where practicable, and the extent of face cutting identified.

- Re-sawing and edging patterns downstream of the headrig.

- Problems at each saw e.g. face cutting required, and the extent of any further splitting and distortion after re-sawing.

- Overall green mill recovery (based on green and nominal sizes) for each defined size class, log grade and species.

In a normal production environment, it will be impossible to conduct some of the above investigations. This will have to be investigated before agreeing on a final research program, including the extent to which sampling and observation can be used.

Brittleheart and saws binding in the cut did not pose serious problems and so, regarding these, we make no recommendations. Sawmillers removed brittleheart either by sawing around when using carriage headrigs or cutting it out at the bench or benches when using twin edger headrigs or when the sawing pattern used at the headrig made it more convenient to remove brittleheart at the bench e.g. when quarter sawing smaller flitches. Binding occurred occasionally but could readily be dealt with at the time.

6 CONCLUSIONS

While most sawmillers are clear about how to manage their log supplies and the best equipment to use on regrowth, they are not at all clear about the quality they can expect from plantation grown logs and the best equipment to process them. However, since conducting our investigations for this report, the comments quoted in the Introduction about the difficulties of processing plantation eucalypts because of growth stress related distortion during sawing would seem to be justified.

Thus, one of the most important conclusions of this study is that sawmillers are continuing to operate profitably as they move more and more into regrowth. In other words, the problems posed by growth stresses when milling regrowth are manageable at present though the solutions do not necessarily maximise returns and the problems may become less manageable if greater volumes of smaller regrowth have to be processed. Milling plantation grown logs poses much more serious problems, some of which are caused by growth stresses, others by defects such as dead and green knots, kino deposits, stains and decay, and possibly by the presence of lower basic density wood from short rotation stands and of more reaction wood. Very recent research (Autumn 2003 edition No. 40 of Onwood, CSIRO) on 13 species of backsawn eucalypts, 12 to 18 years old, taken from species/provenance trials at Mount Gambier, South Australia concluded:

> "*... the quality of the solid timber recovered from the young logs was generally poor, mainly because of a high incidence of dead knots, green knots and decay*" and that "*distortion of boards during both sawing and drying was another major problem*". Of the three best performers in the trials (*E. globulus*, *E. nitens* and *E. sieberi*), "*the recovery of standard and better grade wood as a proportion of total sawn material for these species ranged from 12% to 18%*". Assuming a 35% recovery of all sawn timber, this implies a recovery of roughly 4 to 6% of log volume in standard grade and better.

If we are to succeed in growing sawlogs in eucalypt plantations, we must research the fundamental properties of selected species of plantation wood and their cultural, processing, utilisation and marketing requirements and options with the same dedication as we did for radiata pine. The most recent edition of Australian Forestry[16] has published twelve papers presented at the 'Prospects for Australian Forest Plantations 2002' conference at the ANU. Not one of these papers deals with the problems of growing eucalypt sawlogs in plantations and processing them successfully.

[16] Volume 66 No 1 March 2003

APPENDIX 1

Questionnaire on growth stresses for sawmillers

Introduction

This questionnaire is based on a detailed review by Jaakko Pöyry Consulting Pty Ltd (Jaakko Pöyry Consulting) of results published around the world of research and harvesting and sawmilling experience relating to growth stresses. The work was commissioned by the Forest and Wood Products Research and Development Corporation, which now want Jaakko Pöyry Consulting to go to the next stage of evaluating what is actually happening in selected Australian mills.

The questions are based on the results of the review and sawmillers may perceive some of them to be unimportant or irrelevant, in which case this should be stated in the reply. Alternatively, some questions may be relevant but cannot be answered because of a lack of information. Again, this should be stated in the reply. One of the aims of this questionnaire is to establish priorities for further research and development.

The last two questions are general and may already have been answered previously. They have been included to ensure that, as far as possible, nothing of importance to individual sawmillers has been left out of the questionnaire.

Two senior consultants (Ken Groves and Brian Wall) from Jaakko Pöyry Consulting will visit each mill. However, it would be useful, and more cost and time effective, if replies to the questionnaire could be received before the visits take place.

Questionnaire

1. What method(s) do you use to reduce end splitting in felled trees and logs during handling and transport from the forest to the mill and during mill storage? Are logs stored under sprays; if so please give details i.e. are the logs sprayed continually or periodically? If the latter, what time intervals are involved, including seasonal differences if any.

2. Please give estimates of the following:

    - The average time between felling a tree and delivering it to the mill; and

    - The range of times over which logs would be held in storage in the mill yard e.g. from 4 to 6 weeks, from 8 to 16 weeks etc. If there are seasonal or other differences, please give details.

3. Please provide log input data over the last 12 months for which information is available by forest type e.g. over mature and mature, regrowth or plantations; species; log dimensions including length and diameter or girth; volumes; and grades. Wherever possible, approximate ages would also be useful.

4. Was your mill purpose-built to deal with regrowth/plantation material or does it have to deal with a broad range of timber?

5. Detail the type of sawing equipment you use e.g., single saw headrig with conventional sizing carriage; single saw headrig with line bar carriage; twin log edger headrig; one, two, three or four man breast benches; multi saw edgers etc. A simple flow diagram of the green mill would be useful.

6. Indicate target-sawing patterns for each species and size class of logs (by length and diameter or girth if possible) and whether your aim is to produce mostly back sawn or quarter sawn material.

7. Identify the major problems you experience *during sawing* which you believe are due mainly to growth stresses. What steps do you take to reduce their impact?

8. Does brittleheart pose any problems during sawing?

9. Identify the major problems you experience *after sawing* which you believe are due mainly to growth stresses. What steps do you take to reduce their impact?

10. If you could change all or some of your sawing equipment what would you select?

11. What has been your final volume recovery and grade output by product classes over the last 12 months for which information is available?

12. Do you have any estimates for loss of log input through end splitting?

13. Do you have any estimates for loss of sawn timber recovery through warping and splitting during sawing?

14. Do you have any problems with saws binding (a) in the green mill (b) in the dry mill?

15. Do you season rough sawn finished sections or in the slab?

16. Has anything been done by the forest owner to reduce stress levels in standing trees e.g. by ring-barking or defoliant sprays, or through tree breeding and/or silvicultural treatment?

17. Do you use any of the following for felling trees and crosscutting in the forest:

    - Feller bunchers or other types of mechanised processors

    - Chainsaw operators who have had training in felling and crosscutting to minimise damage

- Cutting a circumferential groove on either side of the crosscutting plane before actually crosscutting

- Metal bands, gang nail plates, S or C hooks or PVC rings on the ends of logs?

18. If you have used or do use any of these methods, please comment on their effectiveness in reducing end splitting.

19. What problems do you have because of growth stresses?

20. What do you do to overcome these problems? Please give as detailed an account as possible.

Questionnaire for sawmill engineers on the importance of growth stresses in milling regrowth and plantation grown hardwoods

Introduction

This questionnaire is based on a detailed review by Jaakko Pöyry Consulting Pty Ltd (Jaakko Pöyry Consulting) of results published around the world of research and harvesting and sawmilling experience relating to growth stresses. The work was commissioned by the Forest and Wood Products Research and Development Corporation, which now want Jaakko Pöyry Consulting to go to the next stage of evaluating what is actually happening in selected Australian mills.

The questions are based on the results of the review and you may perceive some of them to be unimportant or irrelevant, in which case this should be stated in the reply. Alternatively, some questions may be relevant but cannot be answered because of a lack of information. Again, this should be stated in the reply. One of the aims of this questionnaire is to establish priorities for further research and development.

Two senior consultants (Ken Groves and Brian Wall) from Jaakko Pöyry Consulting will visit you as arranged. However, it would be useful, and more cost and time effective, if replies to the questionnaire could be received before the visits take place.

Questionnaire

1. What do sawmillers indicate to you as major problems when milling regrowth or plantation grown hardwoods.

2. Have you designed, or designed and installed, a mill or an item or items of equipment, to deal specifically with regrowth/plantation hardwoods?

3. If the answer to question 1 is yes could you please provide details of the type of sawing equipment you designed or installed e.g., single saw headrig with conventional sizing carriage; single saw headrig with line bar carriage;

twin log edger headrig; one, two, three or four man breast benches; multi saw edgers etc. A simple flow diagram of the installations would be useful.

4. Indicate your recommended target sawing patterns for each species and size class of hardwood logs (by length and diameter or girth if possible) which you have designed and installed, and whether the sawmiller wanted to produce mostly back sawn or quarter sawn material.

5. Identify the major problems you have experienced in designing suitable equipment to deal with growth stresses *during sawing*. What specific design and operating characteristics do you take into account to reduce their impact?

6. Does brittleheart pose any problems in equipment design?

7. If you could change all or some commonly used milling equipment to reduce the impact of growth stresses in regrowth and plantation grown timber what equipment would you select for removal. Please give reasons for your selection.

8. If you have any comments on problems not covered by the questionnaire, please give us the benefit of your knowledge and experience.

APPENDIX 2

Extract from Jaakko Pöyry Consulting's Proposal to FWPRDC

Part Two, Detailed Mill Studies

This work would be carried out preferably at a commercial sawmill (or sawmills) which has the equipment identified in Part 1 as the best for the purpose and can adjust its sawing patterns and sequences, if necessary, to facilitate the investigation. It will not be possible to do this without some interference with the normal running of the mill but the exact details will have to be worked out in consultation with the miller and his staff and after conducting pilot studies. The variables to be described and the parameters to be measured could include the following subject to agreement between the FWPRDC, the sawmiller concerned and the researchers:

- The origin, species and age of trees to be removed and their measurements immediately after felling including any apparent defects.

- The harvesting system used i.e., tree length, multiple log length, saw log length or random lengths as delivered to the mill. The time between felling and delivery to the mill for each tree and log removed.

- The time for which logs are held under water sprays in the mill yard before milling.

- The extent of end coating used, the product applied and when.

- The time period after crosscutting when saw log lengths are milled.

- After converting to final length sawlogs, the small end diameter, length of each log and apparent defects should be measured.

- Sawing pattern for each size class of log and whether the aim is to produce mostly back sawn or quarter-sawn material.

- The sawing sequence followed for each sawing pattern used. This is especially important in assessing the benefits of using multiple saws rather than single saws.

- Precisely defining the type of equipment used, including feed speeds and feed systems, rim speeds, type of blade, tooth profiles (angle of hook, pitch, gullet configuration, whether saws are swage or spring set, gauge and kerf etc.).

- Identifying problems at the headrig e.g. splitting as the saws cut through the log and subsequent segregation of split and whole pieces from randomly sampled logs for investigation and measuring the extent of splitting and distortion, the latter in terms of the appropriate Australian Standard for spring, bow etc. Measured pieces should be marked so that they can be subsequently identified and, if necessary, further measurements done on them to check their stability through the mill.

- Tracking sawn pieces downstream, identifying re-sawing and edging patterns and