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Using portable sawmills to produce high value timber from farm trees in the semi-arid zone

A report for the RIRDC/
Land & Water Australia/FWPRDC/MDBC
Joint Venture Agroforestry Program
and the Natural Heritage Trust

by P. Blackwell & M. Stewart

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Foreword

Australian farmers have generally embraced tree planting on their properties for environmental benefit for some time and these benefits are, more or less, well understood and accepted. However, over the last decade or so, there has also been a move to integrate trees more into the farming enterprise in commercial terms as well as for environmental amelioration. The production of wood from farm-grown trees has also become an issue of increasing interest for the community generally, both for its potential to broaden the economic base of rural communities as well as a perceived benefit in an alternative source of wood to native forests. This has given rise to many programs and initiatives to assist farmers in their endeavours to become tree growers and managers in addition to their more traditional farming activities.

However, for the adoption of commercial tree growing to succeed, farmers need to have information, and the matching skills, on the whole commercial chain of production from tree growing and management to the technical issues relating to wood and timber processing. The former has been reasonably well catered for – albeit it with a concentration in areas receiving more than ~600mm p.a. rainfall. Because of this concentration of activity in farm forestry, processing of farm grown trees has tended to be picked up by the larger established industrial operations – although not entirely. However, in the lower rainfall areas there is a scarcity of resource and little established processing infrastructure and the situation is not likely to change in the foreseeable future due to the scattered and diverse nature of any timber resource that does exist.

The major difference for farm forestry in the lower rainfall areas is that the species suitable for growing there – especially native species – tend to be much harder and denser than those commonly used for timber production in higher rainfall areas. This raises important issues with respect to the primary processing phase given that large processing infrastructure is unlikely to be established and hence the use of portable sawmills for this task has to be considered. There is a general lack of information on quality standards or processing operations relating to portable mills in these species and this project was set up to investigate the role of portable mills in processing the potentially high value wood grown in the lower rainfall areas to suitable quality standards. If this can be achieved then it should provide an essential step towards making it possible to capture the potentially high value, low rainfall resource for this purpose.

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This report, a new addition to RIRDC's diverse range of over 900 research publications, forms part of our Agroforestry and Farm Forestry R&D program, which aims to integrate sustainable and productive agroforestry within Australian farming systems.

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Simon Hearn

Managing Director

Rural Industries Research and Development Corporation

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Executive Summary

There is a perception by some within the sawmilling industry that portable sawmills cannot produce the sawing quality in hard high-density timbers that is required to be merchantable in the manufacturing industry – especially the higher value sectors such as furniture.

This study investigated the on-site processing of farm timbers from the semi arid regions of Australia using two different portable sawmills.

There were a limited number of plantations with sufficient quantity of suitable saw logs within the low rainfall regions of south-eastern Australia for sawing trials. The only plantations that had sufficient saw logs were of high-density eucalypt species. The four species selected were Brown Mallet (*Eucalyptus astringens*), Sugar Gum (*Eucalyptus cladocalyx*), Yellow Gum (*Eucalyptus leucoxylon*) and Swamp Yate (*Eucalyptus occidentalis*).

The portable sawmills selected for investigation were at the lower end of automation available on portable sawmills. Both mills required an operator to push and pull the power head along the log to produce sawn boards.

The mills used in the sawing trials were a single circular blade type sawmill, which was represented by a 'LucasMill™ Model 8' and a horizontal bandsaw type sawmill, which was represented by a 'Laidlaw® Farmill'.

Initial results showed the selected species produced dimensionally consistent 150 mm wide boards that could be used in the manufacture of furniture or other products.

The key criterion for investigation of sawing with both types of portable mill was the straightness of cut as the measure of sawing accuracy. This was measured with a modified straightedge and digital calipers. A total deviation or waviness in the cut of less than 1.5 mm was considered acceptable.

An investigation using the single circular blade sawmill sawing with four different width blade-tips revealed the 5 and 5.7 mm wide carbide tipped blades produced straighter cuts than the 4.5 and 5.4 mm wide carbide tipped blades in each of the trial species. The 5.0 mm blade also produced straight cuts with the fastest feed-speed in the majority of species while the 5.7 mm blade was the slowest sawing blade.

The use of a 5.0 mm tip-width blade on a single circular blade sawmill could be considered as the most versatile blade that is capable of producing more straight cuts and at the fastest feed-speed when sawing high-density hardwood species than other tip-width blades.

Investigation using the horizontal bandsaw sawmill and varying the blade parameters of hook angle, tooth set and blade tension showed the consistency in obtaining the blade tension was a major factor in accurate sawing. At low blade tension, the straightness of cut was adversely effected. The other variables revealed that at the widest tooth set the deviation along the cut increased with the faster feed-speed. The range of hook angles tested had no effect on cut straightness. It is possible that at higher hook angles problems might occur, as experience within the sawmilling sector suggests, but the range selected in this study, inadvertently, did not extend that far.

Investigation of three blade types with different tip construction and at different widths revealed the 32 mm wide Bi-Metal blade was the best general blade over the range of

species. Although this blade did not produce the straightest cuts in all the species the cuts were within the accepted tolerance of 1.5 mm. The carbon steel and carbide tipped blade did produce the straightest cuts in some species but were outside the acceptable range in other species.

A final trial to assess controlled feed-speed required the horizontal bandsaw to be modified with the attachment of a variable power feed unit to the sawing carriage. This modification allowed the feed-speeds to be doubled in most species without any reducing in the straightness of cut.

The production of quality timber is technically feasible using portable sawmills if the conditions and parameters of the blade, timber and mill are matched to meet the problems each log will demonstrate during the milling process.

1 Introduction

This study has investigated the sawmilling of four hardwood species grown in non-irrigated plantations harvested from regions of Victoria with rainfall between 400 and 600 mm. These species have traditionally not been considered suitable for commercial timber production and have generally been utilised for firewood, fencing and other utility grades. Due to their high-density and hardness they have been regarded as unsuitable for processing into high value timber. However, in the last five years or so, interest in these species for high value uses has started to evolve but the volumes available are small and scattered, in comparison to normal industrial operations, and it is unlikely that fixed sawmills would be interested in the resource. Work by Stewart and Hanson (1998) demonstrated that portable sawmills were well suited to dealing with small volumes of wood that has a high value and the distance to key markets was not a major deterrent. This seems to fit very well with the situation in the low rainfall zones where some the species that are grown are now recognised as potentially having high value (Hamilton, pers. comm.), generally occur in small disparate quantities and are a long way from major metropolitan areas.

Therefore it would seem opportune to investigate the role of portable sawmills in processing this wood, but recognising the potential value of the wood it is essential that the milling process is of high quality. It is considered that sawing accuracy is the yardstick of sawing quality and therefore the accuracy of sawing using two different types of portable mill was investigated in detail.

The use of four species from Victoria was not seen as a limiting factor for the project but were regarded as reasonably representative of species found in other areas of the low rainfall or semiarid zones of Australia.

1.1 Farm forestry development

Since the mid-1980s', there has been an increasing interest in farm forestry in Australia. The impetus for this has arisen from economic, social, political, environmental and community issues occurring concurrently. For example, the commencement of Landcare was a community-based response to tackling the problem of degraded privately owned land. In Victoria, in the late 1980s', the uptake of privately owned land for State plantation establishment prompted an investigation into the social impacts of that program on local communities against a backdrop of declining margins from farming and the subsequent decline of rural communities.

Since that time there has been a big increase in the number of programs supported or run by each level of government and education and training providers to foster in one way or another the development of farm forestry.

The semi-arid zone is classified as the areas with low rainfall (400-600 mm/yr) and not subject to irrigation. With the low and scattered volumes of available wood, in these lower rainfall areas, and the small-scale processing approach seemed to fit in very well with the conditions and requirements for farm forestry. Resulting from a growing interest in the farm forestry possibilities, this project was commenced to examine the processing of species grown in the semi-arid regions of Australia.

1.1.1 Government support

Examples of farm forestry programs at the federal level include:

- National Forest Inventory – which attempts to bring together a national inventory of all state and privately owned forest so that long term strategic planning is enhanced
- Plantations for Australia: The 2020 vision – which is designed to treble Australia’s 1996 effective plantation area by the year 2020
- The establishment of the Natural Heritage Trust which provides funds for a wide range of environmental programs. Under this umbrella the Joint Venture Agroforestry Program was established – bringing together research and development agencies with a common interest in farm forestry.

Following the completion of the Western Victoria Regional Forest Agreement (RFA) between the state and federal governments, the Victorian government has launched the Victorian Sawlog Farming project with aims just as its title suggests. The Victorian Government is also sponsoring, through its Department of Natural Resources and Environment, the “Commercial Farm Tree\$ Plan” – a program whereby landholders have access to subsidised farm tree plans for their property with an emphasis on commercial wood production.

1.1.2 Training support

In terms of training, there are a large number and variety of courses with the objective of improving landholders’ collective ability to manage trees on their properties. These programs exist within a wide range of provider frameworks. For example:

- Courses within the national accreditation system and funded through TAFE and higher education
- Units within broader natural resource and forestry degrees at university level
- Short course and fee-for-service programs funded outside federal or state training jurisdictions such as the Master Tree Grower program

The extension of these training activities into regional and local communities is often embraced through farm forestry networks and industry organizations such as the Australian Forest Growers. The common theme is the establishment of trees on farms for the range of benefits they can provide.

1.1.3 Concentration of activity

Whilst there has been a definite increase in interest over the years, farm forestry, especially farm forestry with a commercial focus, has tended to be concentrated within clearly defined zones. Most plantation activity in Australia occurs above the 600 mm annual rainfall isohyet as shown in Fig. 1.1. This is where most commercial farm forestry activity has also been concentrated, as landholders will obviously be looking to established infrastructure for processing and marketing.

However, given that one of the major drivers behind farm forestry development is that declining farm gross margins, from traditional farming enterprises, are causing farmers to look to the broadening of their economic bases it would seem there should be an even greater pressure in the lower rainfall areas.



Fig. 1.1: Location of major plantation areas within Australia (numbers represent rainfall).

In Victoria in 1999 the Shire of Buloke and the Wimmera and North Central Catchment Management Authorities, which are located within the lower rainfall zones of north and north-central Victoria, combined forces to commission a Farm Forestry Feasibility Study [The Virtual Consulting Group, 1999 #50]. The impetus behind this was to investigate the opportunities for broadening the farm enterprises of those regions through farm forestry.

The Virtual Consulting Group [, 1999 #50] reported that some increased potential from farm forestry was feasible but noted that farm forestry activity would most likely be small-scale and localised in comparison to the more industrial models developing in the higher rainfall areas. In particular, processing of wood products was seen as likely to be small scale, initially at least, with little or no immediate potential for large-scale farm forestry development within the region. The reasons why this conclusion was reached relate to issues of resource uncertainty and the relative lack of local processing infrastructure.

1.2 Resource issues

At the larger national level, the National Forest Inventory [, 1998 #63] process of gathering information on all privately owned forests is limited by the lack of knowledge on resource locations. While large plantation estates are visible and easily picked up in the inventory process, it relies more and more on information from smaller and localised sources as the forest areas become smaller. Obviously a point will be reached at which this particular inventory process will cease – as small plantations contribute proportionally less to the value of the information and the distinction between forest, plantations, woodlots and shelterbelts becomes somewhat blurred.

This is precisely the problem in the lower rainfall areas where plantings of species that are potentially suitable for timber production already exist – but almost exclusively as small, scattered, disparate woodlots and farm shelter plantings. This is not to say that recognisable plantations will not be developed (some small areas already exist) but they are not common at present in the lower rainfall region.

This raises several key resource issues for the planning of future development:

- Uncertainty regarding immediate volume availability and longer term availability based on the age structure of existing plantings
- Inconsistency in terms of species and product mixes and a disparity in management of the tree plantings
- Distances to the main processing and market zones are greater due to the more remote locations of the lower rainfall areas.

1.3 Processing issues

Species that occur in the lower rainfall areas are not normally sawn into timber – their major usage to date has been for firewood and fencing timbers. However, there has been recent interest shown in the species grow in these zones. For example, Blakemore *et al.* (2001) found that certain Victorian low rainfall plantation species have the potential to produce high value sawn timber.

In terms of the problems of processing plant and the distance that suitable sawlogs would have to be carted to established sawmills an alternative exists in the form of portable sawmills. Stewart and Hanson (1998) showed that the economic viability of portable mills is most affected by the price received for the sawn timber and least affected by the distance to the market. The difference between the distance to market for portable sawmilling and the straight out selling of saw logs at the stump is that the former delivers a product closer to its finished condition rather than raw material still needing considerable processing for the market end-users.

Both these factors (prices and distance to market) seem to suggest a suitable solution to the issue of processing in the lower rainfall zones:

- Market observation suggests the species grown have the potential to attract much higher prices than the high productive species grown in the higher rainfall areas. This is a combination of both the physical features of the various wood species as well as relatively low availability.
- The long distances to market are not the impediment that may at first appear.

It is possible that small-scale processing could provide the link between the disparate and small volumes that characterize the low rainfall areas and the end-users in the major markets. It is a matter of speculation whether this will be sufficiently successful that expanded farm forestry will result – it is certainly hoped by those with an interest in farm forestry in the region that this will be the case. However, if small-scale processing of timbers from the low rainfall areas is to produce the desired outcomes then it must be able to at least match the existing quality standards for higher value timbers – such as furniture timbers – throughout the production process. Given the potentially high value of the timbers grown in the region it could be argued that standards have to be correspondingly higher.

There are several issues that are considered fundamental to portable sawmilling to achieve the status needed for reliable supply of timber from these low rainfall zones.

1.3.1 High standards in processing – sawing accuracy

High standards in processing are essential to minimize wastage of the resource. With such potentially high value, every piece of timber becomes important to maximizing the value of the resource. Sawing techniques will affect the final product value and the factor that is considered of most importance in quality terms is the accuracy of the sawn finish. Issues such as grading the timber into different product lines are incidental to this – it can be presumed that timber will be graded correctly once the market requirements are clearly defined. Sawing accuracy is considered a critical factor at this stage for two reasons:

- Species that grow in the low rainfall region tend to be hard and dense and by nature therefore difficult to saw accurately. This has to be overcome if farm forestry is to have a future in the region.
- Wood that is not accurately cut can normally be dressed back to finished size. However, experience with some furniture makers is that dressing back over-dimension wood of these very hard species is very costly – multiple thin passes through a thicknesser have to be made. The extra time consumed and the blunting of the blades seriously reduces their life, which adds considerably to the cost of preparing the wood for final use. The result is the value of the wood to the buyer is seriously reduced.

Sawing accuracy with portable mills is therefore seen as a critical first step in capitalizing on the potential value of species grown in the low rainfall region as it establishes reliability of product quality and credibility so essential to market development.

1.3.2 Comparison of different mill types

For this study, the semi-automated portable sawmills were considered inappropriate because of the lower volumes of timber available and that the chainsaw mill (generally an attachment fitted to a chainsaw) would not meet the quality specifications. After excluding the chainsaw mills, the single blade circular saw portable mills and the horizontal bandsaw portable mills were found to be the most economical for lower volumes of timber (Stewart and Hanson, 1998). It was then decided that this study would only consider these types of mills. These two broad groups of portable mills have also been found to be the most popular amongst portable mill operators – the horizontal bandsaw and the single circular saw type mills (Stewart and Hanson, 1998). These need to be investigated to determine their relative merits and disadvantages. In particular, the ability to saw accurately and any differences between the two types of mill have to be determined. However, operational aspects of the mills during sawing also need to be investigated – such as rate of cut – so that some guide as to likely economic performance can also be provided for those operating the mills.

Understanding operational and quality issues of portable sawmilling will be an essential first step towards capturing the potential value from species growing in the low rainfall areas. This is the underlying purpose of this research.

1.4 Structure of the research project

The research project is constructed in four main parts.

1.4.1 Literature review

Chapter 2 is a literature review that looks into:

- General forest product supply and markets in Australia, with a special emphasis on high value timbers.
- Wood characteristics of dense hard timbers likely to be grown in the study area.
- Sawing technology and the implications for this research.
- Portable sawmills – current role of portable mills in the wood industries and possible implications for primary processing in the study area.

1.4.2 Materials, methods and benchmarking

Chapter 3 details and tests the materials, equipment and methods used throughout the research project. This involves conceptualising or defining and quantifying what the term accuracy means in respect of sawing through a log.

Chapter 4 describes the initial trials to ascertain the current status and performance of two types of portable mills in sawing a selection of hard, dense timbers. The results of this part of the project set the scene for the direction of the subsequent research and act as a benchmark for improving portable mill performance.

1.4.3 Testing the two types of mills

Chapters 5, 6 and 7 investigate the running of the two mill types with the emphasis on the factors that can affect accurate sawing and the optimum-operating blade configurations for each when sawing high-density timbers.

Chapter 8 brings together the data collected during the running of the detailed trials to make operational inferences under actual sawing conditions and examine a constant feed-speed device on the horizontal bandsaw.

1.4.4 Conclusion

Chapter 9 draws the conclusions from the research and provides recommendations on what should be done given the new information and recommendations for future research and development in light of any unanswered questions or new found problems.

2 Literature Review

2.1 The supply and markets.

In Australia, the forest industries have traditionally sourced much of their timber requirements from the logging of native forests. However, in recent years, there has been much controversy about logging of native forests, and many of these areas have been placed under permanent conservation status (Smorfitt *et al.*, 1998). These areas of 'reserves and parks' are no longer available for logging, which has placed greater strains on the available native forest resource and the need for alternative sources of timber supply.

Following the release of the Report of the Board of Inquiry into the Timber Industry in Victoria (Ferguson, 1985), the marketing of native hardwoods moved from lower valued green framing timber to higher priced value added products.

The advances in kiln drying techniques and equipment have allowed a refocusing of the sawmilling industry, from the traditional method of sawing logs and selling the green timber only, to now following this with the drying of the sawn boards. Sawmillers have used these changes in direction to increase the percentages of their production that is further value added (National Forest Inventory, 1998).

2.1.1 Plantations and farm forestry

Throughout Australia, and especially in Victoria, the majority of the native forests consist of hardwood species. Softwood species are limited in their natural occurrence (National Forest Inventory, 1998). In the 1870s', plantations were established to supplement timber supplies, with mainly softwood species planted.

Since the 1960s, forest services in all states have undertaken programs to establish plantations to supply the majority of the future timber requirements (National Forest Inventory, 1998). In conjunction with the public sector, there has also been an increase in private sector plantation establishment during this period, most of which has been associated with establishment of industrial softwood plantations.

During the 1990s', many parts of Western Australia, South Australia and Victoria converted farmland to hardwood plantations, planting species that are suitable for wood chips. While these species are suited for wood chips and the export market, in the short term, they may have poor prospects for milling into solid timber.

Recently there has been a number of initiatives designed to facilitate farm-based forestry including a number of joint venture schemes in New South Wales, Victoria, Western Australia, South Australia and Queensland, and a number of subsidized tree planting schemes (National Forest Inventory, 1998; Smorfitt *et al.*, 1998).

The major plantations and farm forestry activities within Australia are in the regions with rainfall over 750 mm per annum. These areas are along the eastern seaboard, the south-eastern region of South Australia and the south-western region of Western Australia, although some plantations have been established in highland and tableland regions of New South Wales and Victoria (Stephens *et al.*, 1993).

The area of softwood and hardwood plantation established in each five-year period from 1940 to 1994 is shown in Fig. 2.1. Most of the areas of softwoods planted before 1960

have been harvested and some of the more recent plantings are on those previously harvested areas (National Forest Inventory, 1998).

Fig. 2.1 shows the area of plantation establishment. This is based on companies with a minimum of 1000 hectares of plantation which eliminates most smaller farm plantings (National Forest Inventory, 1998). There is new research being carried out by the Bureau of Rural Studies which will report on both farm forestry plantings and commercial plantations. This report will give the areas of plantation down to a 40-hectare size rather than only the large organizations represented in the plantation data.

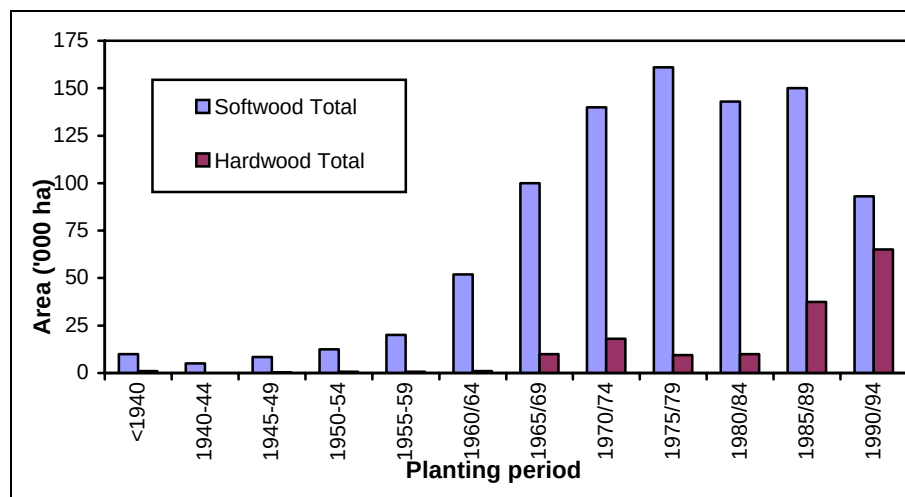


Fig. 2.1: Area of plantation established in each five year period from 1940 to 1994: softwoods and hardwoods. Source: (National Forest Inventory, 1998)

The smaller-scale farm-based forestry ventures require the maximum value from the timber produced to return a profit to the farmer, while larger operations may be able to work on an economy of scale and accept a smaller return per unit of production (Stewart and Hanson, 1998).

2.1.2 Semi-arid zone

The concentration of farm forestry interest in the regions with medium to high rainfall has tended to create the perception that farm forestry in the lower rainfall zones has little, or at best limited, commercial potential. This view is starting to be challenged and in 1999 local government and state agencies involved in the Wimmera and North Central regions of Victoria jointly conducted a farm forestry feasibility study to explore farm forestry options for those regions. The consultants engaged, (The Virtual Consulting Group, 1999) concluded there are two main reasons why farm forestry would seem to have an important role in those regions.

Firstly, there is a greater need to look for expansion of the economic base for farming communities in the lower rainfall regions as they tend to be areas where farming margins are lower than in higher rainfall areas (The Virtual Consulting Group, 1999). Secondly, from a wood production perspective, the species best suited to growing in these regions tend to be slow growing and hard but there is evidence that these species have considerable potential for very high value end uses (Eugene Dimitriadis, pers comm). In particular, by using small-scale processing such as portable mills, much of the capture of this value could be made at the local level.

As previously stated, the semi-arid zone is classified as the areas with rainfall of 400-600 mm/yr and not subject to irrigation. The areas in Australia that are classed in this rainfall category are shown in Fig. 2.2. The rainfall categories on this map included the areas under irrigation which are excluded from this study.

Trees grown in this area are potentially suitable for appearance products but have generally smaller diameters and relatively poor form due to lack of management and slower growth rates than more productive forests (Blakemore *et al.*, 2001). These species traditionally produce low timber volumes per hectare which works against an economy of scale and therefore reduces the financial return to the property owner or grower.

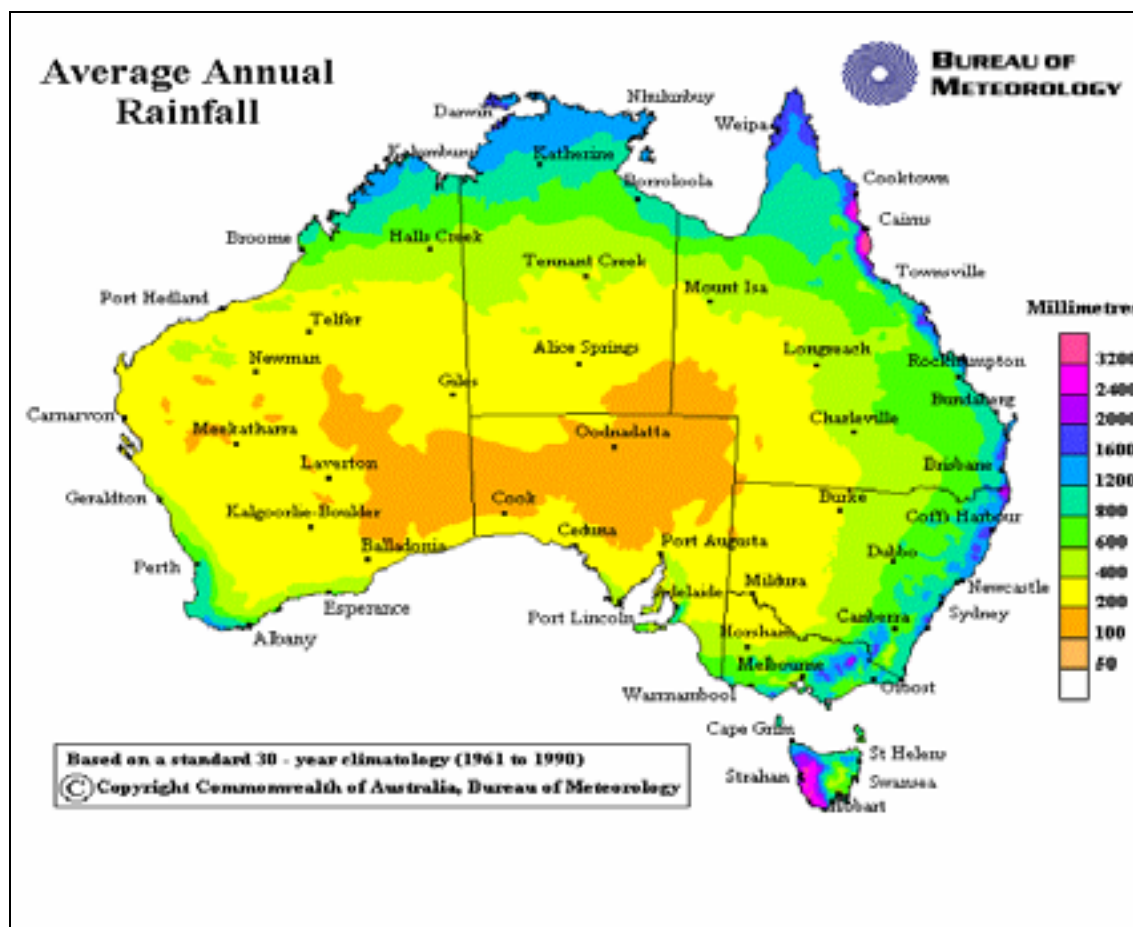


Fig. 2.2: Rainfall map showing rainfall zones throughout Australia. (Reproduced with permission, Bureau of Meteorology)

2.1.3 Trends

The trade in wood products depends on a range of factors which include world prices, domestic demand and supply conditions (Hossain *et al.*, 1989). The domestic demand and consumption of sawn hardwood is forecast to decline due to its substitution by softwood for structural applications (Love *et al.*, 1999).

Australia imports 25 per cent of timber used domestically while the exports of sawn timber are negligible (National Forest Inventory, 1998). However, the unit value of the export sawnwood, especially the hardwood, is at the higher end of the value range (ABARE, 2001).

Sawn timber consumption within Australia has remained relatively constant over the past 25 years at around 4,000,000 m³ per annum. This usage is made up of timbers obtained from native hardwood forests (32%), local softwood and hardwood plantations (53%) and from imported timbers (15%) (National Forest Inventory, 1998).

The use of Forestry Certification may be a tool to enable market penetration by plantation or farm-grown timbers that have been managed and produced by an environmentally sustainable method. "The international acceptance of National Certification Systems may lead to, not only market acceptance, but the market demand for forest products to be certified" (Fordyce, 2000).

2.1.4 Infrastructure and employment

The areas that have been specified as the semi-arid zone are mainly involved with farming with some regional towns as service centres for these agricultural enterprises. The enterprises in these areas are generally based around the industries operating in the region. For this reason, existing forestry operations are very limited and any new infrastructure will allow for additional employment for the region.

Employment within this sector of the industry will not be high since a two-man portable sawmilling operation with a kiln could cut and dry 3-4000 cubic metres of logs per year (Stewart and Hanson, 1998). That's very much at the high end – given a range of volumes.

The infrastructure and capital outlay for portable sawmills can range from \$600 to \$98,000 depending on the type and size of machine and its level of automation (Stewart and Hanson, 1998). The purchase price of portable mills varies according to the degree of automation. The cheapest machines are attachments to a chainsaw while the most expensive are transportable mills that are almost fully automated.

Both types of mill are commonly available for contract work throughout Australia with Stewart and Hanson (1998) quoting prices of \$25 to \$60 per hour.

These mills can be set up adjacent to the trees that are to be sawn so making it unnecessary to cart logs long distances to a mill. These mills are very easy to relocate and can be moved around a property if required. Although no buildings are required for the mills a shed or canopy, if available, increases the operators' comfort, providing them with protection from the sun or rain.

To produce timber of a higher value it is necessary, in most cases, to kiln dry the boards before they can be supplied to the majority of the commercial markets. This is an added cost to the producer however contract-drying facilities are available and may be worth considering to reduce the initial capital outlay especially when large volumes of timber are not available.

The use of cooperatives to mill, dry and market the timber may be a viable option in areas where existing timber industries are not established.

2.1.5 High Value Timber

High value solid timber is obtained from those species that can produce boards which will dry well, remain stable over a long period and with a uniqueness of grain and appearance without excessive contrast. The promising eucalypt species from the semi-arid zone produce high-density wood with attractive features and colours (Blakemore *et al.*, 2001). These species are the same as those reported in this study and described in chapter 3.4.1.

These species do not have great prospects for being mass-produced and entering the standard building or construction market. The products that have unique properties would be better suited for markets where limited supplies are an advantage rather than a handicap. Niche markets can give the greatest return as a limited supply of raw material can drive the price to a higher level than available in larger markets.

"An analogous situation exists in Australia where farmers who grow trees as a means of ameliorating chronic salinity problems are often disappointed at the low rate of return provided by the sale of woodchips and are seeking to penetrate more profitable markets for solid timber" (Crompton and Turnbull, 2000).

For a farmer growing trees for added income there is little chance of obtaining the higher value available from solid timber sales because the processing of the logs is out of their control. However, with the use of portable mills value adding is possible at the farm level (The Virtual Consulting Group, 1999).

To gain the maximum value from these timbers, processors will be required to produce a consistent and accurately dimensioned quality product. Sawing, drying and grading of boards add value to the product. The limited supplies of suitable tree species should ensure a specialist market should be established without the intervention of large companies that will control prices and markets.

Brennan *et al.* (1997) concluded after study on three Western Australian species, that a promising future exists for a value adding industry to supply specialty and craft wood timbers from the W.A Wheat Belt. Many of these Western Australian Wheat Belt species are well suited to the climatic conditions of Western Victoria.

2.1.6 Market Requirements

As the supply of timber from the lower rainfall region increases, in the longer term, there may be opportunities to develop new markets for these timbers that previously have not been available or to capture some of the existing markets by product substitution.

The use of short length boards has traditionally been avoided by the joinery industry. Joinery shops would prefer to buy longer length timber and dock or cut to the required lengths. As the demand for higher value timber increased and the suppliers applied policies that placed a premium price on the longer length boards the industry turned around and now consider shorter lengths as an economical option (VTITC, 1999).

Studies of Jarrah (*Eucalyptus marginata* Donn ex Sm.) used in the Western Australian furniture trade indicated that the maximum solid timber length required was 2200 mm, with 84% of lengths less than 1000 mm (Challis, 1989). Although the furniture industry actually uses the majority of their timber in short lengths, a report by CALM (1990) indicates manufacturers believe the small piece size and range of colours within species are a major problem.

Japan and North America look for colour and consistency of colour in the timbers they use (Beall, 2000; Davison, 2000). This may be a limitation to the sale of eucalypts into the export markets unless careful grading and colour matching is carried out by the manufacturer before export.

The Japanese market is difficult and time consuming to break into. They require the highest standard of quality, consistency and presentation of the product plus a reliability of supply before they will accept a supplier or new product (Davison, 2000).

2.1.7 Market size

The major markets for wood are firewood, timber for construction, furniture timber and wood chips. The markets available to timber from the semi-arid zones are limited because of the low volumes of wood available, inconsistency and uncertainty in the wood resource and their distance from existing industry.

However, the distance the timber resource is from markets may not be a problem, as Stewart and Hanson (1998) found distance to markets is not a significant factor affecting the cost structure of producing and supplying timber from portable sawmilling operations.

Low volumes of timber produced in the lower rainfall areas will require landholders to maximize the value of the timber they grow and by engaging in on-site processing with the use of portable sawmills this can be achieved (Stewart and Hanson, 1998; The Virtual Consulting Group, 1999).

Generally, the species grown in the lower rainfall areas have a higher density than faster grown species in higher rainfall regions. The demand for firewood produced from high-density timbers will remain high but the financial return to the growers may be very low (Sonogan, 1998).

The low quantity of wood suitable for high value processing available from the semi-arid zones will be a limiting factor in the establishment of large-scale operations. It will not be possible in the short or medium term to set up and compete with the fast growing eucalypts from the higher rainfall regions of Victoria, Tasmania or Coastal NSW.

The larger producers set market prices, for construction timber, and there is very little opportunity for small operators to introduce new species or gain market share in this highly competitive market.

The supply of furniture timber has some niche markets and utilizes both high and low value timbers. Premium prices can be paid for relatively small quantities of decorative or distinctive timbers such as Ironbark or Red Gum.

The value of furniture manufactured from wood in Australia in 1996-97 was \$1205.2 million which was 23% higher than the previous year (FIAA, 1999).

Higher financial returns can be obtained from supplying sawn dry timber to the furniture market than by selling green timber to the construction markets. The wholesale prices from Matthews Timber in Vermont, Victoria for select furniture grade Brush Box from NSW or the South African replacement product Danta is \$2600 to \$3000 per cubic metre. The timbers from the semi-arid zones should be able to compete in this market by supplementing the supplies of Brush Box and helping with the import replacement of Danta. This is meant as an example of the pricing and usage of high-density timber with prices as high as \$4000 per cubic metre quoted by some sources (Stewart and Hanson, 1998).

2.1.8 Marketing

The use of common names for many species is a drawback to the marketing of their timber. An example is Sugar Gum where the public perception is that it can only be used for firewood. Some manufacturers are suggesting that the name "Murray Mahogany" be used for furniture manufactured from Sugar Gum in an attempt to overcome the negative connotations that the public and potential purchasers have with this species (Eugene Dimitriadis, pers. comm.).

While the use of common names may be an advantage for the marketing of timber, producers must use the botanical name when selling to manufacturers and processors, as a common name may relate to different species in other regions or countries. There have been many examples where a timber has been sold under the common name to a client who believed that this was a different species to the variety actually supplied.

CALM (1990) claims markets have not been established that can handle a large influx of high quality furniture timber. This does not appear to be a problem in the semi-arid regions as it is not envisaged that the supply of high-density timbers will be in quantities that could flood the market. The reverse would be more likely where over the next 15 to 20 years, a reliable supply of timber may be too low to establish viable markets.

As the barriers increase to the use of some tropical rainforest timbers, the potential for plantation and farm grown timbers to replace this market increases (Beall, 2000).

In North America, the marketing of hardwood is through a complex distribution system of distribution yards, concentration yards, wholesalers, brokers and secondary processors. An avenue for the marketing of Australian timber in North America is the use of distribution yards, where kiln-dried timber is purchased and sold in small quantities. In addition, within this market, the price structure is difficult to define since it varies with species and grades according to market demands and raw material availability (Beall, 2000).

Alternative marketing systems are being developed through the Internet. At present, buyers can bid through an auction on the Internet, for specified parcels of timbers. These types of operations for the trading of timber claim to be enhancing the trading relationship between buyers and sellers (TIMBERWeb's, 2001).

Until currently non commercial species, which include the high-density hardwoods from the study area, are produced and graded to an agreed standard, the marketing will rely on the goodwill of the supplier and customer. This may lead to disputes over quality and grade which is usually expensive for the supplier and a hassle to the consumer.

2.2 Wood Characteristics

2.2.1 Species

Traditionally many of the high-density species have only been used for firewood. In Victoria and N.S.W. the most popular species for this purpose are Red Gum (*Eucalyptus camaldulensis*) followed by Red Box (*E. polyanthemos*), Yellow Box, (*E. melliodora*), and Ironbark (*E. sideroxylon*) (Driscoll *et al.*, 2000). The use of these high-density timbers in value adding and manufacturing of timber products has been very limited. Some small-scale manufacture of furniture by artisans has been carried out, with individual units being manufactured usually for their personal use rather than commercial production. The timber for this furniture was often gathered from trees that had died and dried naturally on the ground.

Many areas of the Western District of Victoria have planted Sugar Gum (*E. cladocalyx*) as a source of firewood. These plantings can be seen along roadways and as windbreaks along farm fence lines. When Sugar Gum is used for firewood the trees are harvested, the stumps will coppice and regrow so that an ongoing supply of wood is available.

There are many other species of high-density hardwoods, from the semi-arid region, that could be investigated as potentially valuable timbers. For these species, the plantings cannot be found in large enough quantities to be commercially harvested. This is mainly

due to many small-scale plantings with a variety of species used on a site. This does not produce enough timber of any one species to be commercially practical to harvest.

2.2.2 Drying

Any application that requires the timber to be stable would require further processing such as air drying, kiln drying or a combination of both.

Although the drying of the high-density species is not being investigated in this study, it is still an important aspect in the value adding process. Without good drying procedures the markets for any furniture timbers will not be established and if established will not be maintained.

Washusen *et al.* (1998) reported relatively fast drying rates, in lower density and lighter colour wood in 40 –50 year old plantation grown trees. The differences in drying rates may be due to the younger age of the plantation trees when compared to those from traditional native forest. This also could point to a relationship of ease of drying and density.

During the drying process most Australian hardwoods are prone to collapse and the formation of surface checks, particularly on the backsawn face, although advice from the Timber Training Centre (TTC) is that the dense hardwoods typical of the low rainfall zone are not prone to collapse (Rob Rule, pers. comm.). Checks are acceptable in structural timber, but are considered as severe defects in appearance products (Ozarska, 1998). While the industry may consider checks a severe defect, the Australian Standard for appearance grade timber, AS 2796-1999, permits checks in all grades except for clear grade.

The moisture content for any species of timber that will be used in furniture housed in an air conditioned or heated building must be at a maximum of 11 percent.

Trials by Langrish *et al.* (1997) have shown that to reduce the downgrade and shorten drying times kiln drying should start at low temperatures and high humidities then, as the timber loses water, the temperature is increased while at the same time reducing the humidity. These results could well apply to other high-density timbers from the study area. The purpose is to heat the water within the timber before any drying in the timber takes place. This prevents a hard dry layer on the outside of the board and a wet core where water is trapped. This problem is called casehardening.

The moisture content of any furniture timber must be 11 percent according to the Australian Standards (SAA, 1999). A moisture content of below about 16 can only be achieved with kiln drying after a period of air-drying.

Surface checking was discussed earlier as a problem in higher grades of timber. Surface checking commences as soon as the timber is sawn. It is therefore critical to cover the boards immediately after they are milled and ensure that the boards do not lie in the sun (Charlie Bovalino, pers. comm.) .

2.2.3 Density

Timber density is reported in three ways; green density, basic density and air-dry density.

Green density is the density of the wood at the time the living tree is felled. The green volume and green weight are used to calculate green density (Walker and Butterfield, 1993). This density will vary with the season, age of the tree and weather conditions which cause the quantity of water contained within the wood to vary. Due to variability in the

results of green density, it is generally only used for assessing weight for the transport of logs (Bootle, 1983).

Basic density is the density of timber calculated from the green (or fully saturated) volume of a test piece of timber taken from a tree and the oven dry mass of the test piece (SAA, 1981; Walker and Butterfield, 1993).

Air-dry density is “an expression of the mass of timber at equilibrium moisture content, standardized at 12 per cent, per volume of timber at the equilibrium moisture content” (Walker and Butterfield, 1993, SAA, 1981). This density can vary with the age of tree, and climate factors or other factors that affect the growth conditions of the tree (Bootle, 1983).

2.2.4 Hardness

Hardness is not directly related to workability but is a measure of the resistance of the wood to indentation (Bootle, 1983). The hardness figures used in this report are obtained from a Janka hardness test which involves the measurement of the force required to press an 11.3 mm steel ball into the specimen until the ball has penetrated half its diameter (National Timber Industry Training Committee, 1987).

Results of work by Oliverira (2000) reveal no direct relationship between hardness and timber density in a selection of Eucalypts and other species from Brazil. While contradictory findings are reported by Kollmann and Cote (1968) who quote Janka (1906) and Lorenz (1909) as saying, “the hardness is approximately proportional to the density of the wood”. Kollmann and Cote (1968) also quotes Ylinen (1943) who found a linear relationship between the Brinell-hardness and oven-dry density. This reflects that the higher the density the harder the timber.

2.2.5 Dimensional Stability and Glueability

Higher density timbers tend to have a larger unit-shrinkage than the lower density timbers. This means that for the same increase in moisture content for two given species (one low density and one high density), the higher density species will swell more than the low density. The converse is also true that for a reduction in moisture content the timber will shrink.

Dimensional stability is of major importance to the furniture industry. Timber produced from species with a high unit-shrinkage presents a problem for gluing and maintaining tight joints in climates where high variations in humidity occur. The performance of various adhesives is species dependent (Ozarska and Ashley, 1998).

An adhesive manufacturer suggested that recent research is showing promising results from new generation polyethylene glue in bonding the high-density timbers. These adhesives work on chemical reactions rather than the traditional mechanical bonds. Epoxy adhesives are satisfactory in situations where no movement occurs in the timber however if the timber moves either due to a physical flexing or a change in moisture content the glue lines will break and a failure of the bond will occur.

2.3 Potential products from the trees

2.3.1 Sawn Timber

Sawn timber or boards are the most versatile of the uses for timber. Boards can be produced in a variety of cross-section sizes and can either be further processed by drying or used in the green state.

In Australia, the cross-sectional size of a board is expressed as the widths by the thickness. The commercial width for timber are generally produced in 25 mm multiples and the thicknesses available are 12 mm, 16 mm, 25 mm, 38 mm, 50 mm, 75 mm and 100 mm with the two thickest sections not readily available. These sizes are nominal and when sawing an additional size allowance must be made to cover the drying shrinkage of the species. The shrinkage due to drying of the high-density species used in this study is discussed in Chapter 3. The lengths of boards are generally supplied in 300 mm multiples and the price based on the next lowest 300 mm from the actual lengths. However, a few manufacturers are selling timber with the price in 100 mm multiples.

The importance of sawing accuracy is highlighted with harder timbers where the density of the wood and subsequent difficulties in the sawing of boards have led to the moulding, joinery and furniture industries facing difficulties in obtaining accurate dimensions of sawn materials (Loehnertz *et al.*, 1996). The supply of vastly oversized or even slightly undersized boards is no longer acceptable to industry that wants the size that was ordered and not just what the sawmiller felt like milling.

Timber grading is an important part in the supply of sawn timber to the commercial markets. There are Australian standards for the visual stress grading of structural timbers (SAA, 1979) and for appearance grade timber (SAA, 1999).

Suppliers of sawn timber will not be able to obtain the maximum price, when they supply to the commercial markets, without the ability to ensure the timber is to the specifications as described in the appropriate standard.

The timber grading rules have been developed over the years to meet the structural or strength requirements of the sawn boards or the appearance characteristics desired for the end use. The grading rules are different for both types of use. A characteristic, in the timber, that may be considered as an unacceptable defect in one grade may be an acceptable feature when a different end use or difference grading rule is used to assess the features / defects. While checks are acceptable in structural timber, they are considered as severe defects in appearance products (Ozarska, 1998).

The supply of wide sawn boards to a manufacturer allows them to re-saw the boards into smaller sections or machine the boards into a profile. This makes the production of sawn boards a very good option for the operators of small sawmills, as this would give them the ability of supply a 'graded product' into the existing markets.

2.3.2 Furniture

Until the 1960's the furniture industry in the both the United States and Australia relied exclusively on solid timber and plywood as a source of raw material (Blackwell pers. comm.; Cohen and Goudie, 1995). With the advent of composite products like hardboard, particleboard and medium density fibreboard (MDF) the markets have changed.

More recently, high quality solid timber has mainly been used for the visible components in furniture, with lower quality timbers or alternative species used in the carcass or covered areas.

Research has been centred on the higher volume commercial timbers grown along the east coast and in the southwest region of Australia. These timbers are of lower densities (below 750kg m⁻³) and traditionally come from forest ecosystems dominated by tall, relatively closely spaced trees (Tickle *et al.*, 1997; Turnbull and Pryor, 1978). The use of dense timbers for high value products such as furniture has been limited.

Australian hardwoods that could be used for appearance products have high densities, high stiffness, and good strength characteristics in comparison to imported hardwoods typically used for furniture (Ozarska, 1998). But many of these timber species may cause problems that will result in the timber being difficult to work i.e. turn, nail or the susceptibility to split because of the high-density and interlocking grain (Bootle, 1983).

Davison (2000) claims there is a potential niche market for furniture manufactured from Australian Hardwoods in Japan. However any enthusiasm must be tempered as colour and consistency of timber features are an important issue for the Japanese market, and the high-density species tend to vary more than the faster grown species (Beall, 2000; Davison, 2000).

2.3.3 Bark

The use of the bark from hardwood species has often been overlooked as an additional source of revenue by most of the Australian timber industry.

Pine bark has been converted into a potting mix for many years but hardwoods have not been traditionally used for value adding. With the use of composting systems hardwood bark can be converted into growing media and mulch which are used in the horticultural industry (DeCamp, 1980).

Bark mulch is a superior reclamation material in the rehabilitation after strip-mining. It significantly modifies spoil microclimate factors such as temperature and moisture in a favourable manner. The cost associated with bark mulching is less than for many other systems while it has the benefit of adding large quantities of organic material (Graves and Carpenter, 1980).

Brown Mallet (*E. astringents*), one of the species selected for trials within this project, has bark which contains 40 to 57 per cent tannins (Bootle, 1983). These tannins can be extracted and used in industrial applications especially as extenders for resins and adhesives. Current research at the University of Melbourne indicate the use of a Pyrolysis processes may give greater possibilities for the recovery of many products from bark which was previously discarded as waste (Vinden, pers comm.).

2.3.4 Fuelwood

A traditional use for farm trees has been firewood or fuelwood. The suitability of high-density tree species for fuelwood is because they have higher calorific values than the less dense species (Hendricks, 1980).

Many species that are sought for fuelwood also have the potential to be converted into high value timber. Potentially high value species like Red Gum, Bull Oak, Ironbark and many box species have been cut for fuelwood since Europeans first settled Australia. The use of

high value timber for fuelwood is not limited to Australia; research in South Africa showed some high value timbers were used by local communities for firewood (Dyer,undated).

When fuelwood is used for cooking, lower density timbers burn faster but generate heat quicker, while for slower cooking dense species can maintain a steady heat over a longer period. "This would be particularly advantageous where fuelwood is used for heating" (Crompton and Turnbull, 2000) thus giving a greater strain on the supply of timber from high-density species as most fuelwood in Australia is required for heating.

Timber growers should not consider a tree as either sawn timber or firewood but as a combination of both. As little as 20 per cent of a tree is converted into sawn boards, this leaves the majority of a tree available for fuelwood (Stewart and Hanson, 1998). A market for fuelwood would be a desirable option for farmers milling high-density timbers. Sawing offcuts and tree branches could be utilized and sold as fuelwood to increase the return from their trees.

2.4 Sawing Technology

A critical ingredient in the successful evaluation of the use of solid wood products is to understand the markets that use the higher valued timber components in their products (Cohen and Goudie, 1995). While an understanding of the market is important, having the technical ability to produce a raw material that meets the market requirements cannot be overlooked.

Due to the low volumes of wood available in the semi-arid regions of Australia, it is uneconomical to build a sawmill at a central location to mill the small number of available logs. Thus it is suggested that a portable sawmill is the most feasible option to obtain the financial value contained within the farm trees of the semi-arid region.

2.4.1 Standards

Before looking at the processing of logs, the terms used in the industry must be understood. Definitions vary between countries, companies and within local regions and for this reason a uniform terminology is required.

A range of terms for use with portable mills is described in the glossary. These are based on The Australian Standard 4491-1997 and Learner Guide for Sawing Hardwood ABL 052. (Australian National Training Authority, 1997; Bootle, 1983; SAA, 1997; SAA, 1975; Walker and Butterfield, 1993).

The concluding report on the Small Eucalypt Processing Study (CALM, 1990) states,

Most of the difficulties in dressing, gluing, resawing and sanding from regrowth eucalyptus relate to the piece size and not the wood property variations. Colour matching, when required, is adversely affected by the often wide range of colours within a single board of regrowth wood. Processing costs are adversely affected by small piece size.

2.4.2 Sawing

Very little information could be found on the sawing of high-density timbers and even less on the use of portable sawmills for these timbers. A study by Loehnertz *et al.* (1996) concluded that the problems of sawing tropical timbers are:

- the density of wood and occurrence of silica,
- the poor understanding of the sawtooth geometry and wear characteristics of bandsaw blades,
- the lack of training for saw doctors or sawfilers (as known overseas).

These findings may bear little relationship to Australian hardwood, since the silica content is not reported as significant in the timbers from regions outside the tropics.

2.4.3 Sawing Theory

The history of the saw goes back to early man and the basic concept has not changed. A sharp tooth cuts or pulls the fibres loose and these fibres fall into the gullet and are removed from the cut as sawdust.

The major factor that affects the sawing of any piece of timber whether with a portable mill or larger conventional mill, band or circular saw, is the sawblade.

While some work has been carried out on wide bandsaw blades and circular sawblades, Australian distributors are unable to advise of any literature on the design and cutting characteristics of narrow bandsaw blades.

Sawblade theory is similar for band and circular saws, where a combination of factors contribute to produce a good cut. The common factors are (Folkema, 1992; Frankson, 1977; Harris, 1973; Quelch, 1977; Williston, 1989):

- blade speed,
- blade tension,
- blade thickness,
- blade width,
- clearance angle,
- face angle,
- feed speed,
- gullet depth,
- gullet shape,
- hook angle,
- sharpness or tooth angle,
- side clearance,
- tooth design,
- tooth pitch or spacing,

These factors will be discussed in later chapters.

The alteration of any one of these factors may have an effect on the ability of the saw to produce straight boards. When the balance of factors is at an optimum the saw will run at its most efficient, with lowest energy usage, highest production, and high quality cuts for the maximum time between blade sharpenings.

2.4.4 Blade construction, hook angle, tooth set

This section will relate to sawblade theory with the differences between circular saws and bandsaws discussed when appropriate.

Sawblades are manufactured from high quality steel which is essential to ensure good performance. Some of the performance characteristics required of sawblades include good durability, resistance to wear, high resistance to fatigue, ability to keep its tension and not stretch during sawing, and an ability to remain flat and straight.

Blade materials range from carbon steels with the carbon content around 0.75%, to steels with added manganese or nickel to increase toughness and alter mechanical properties. Hardening or tempering of blades is common to alter the molecular structure of the steel and increase the blade hardness. Carbide or stellite tips can be welded to the tooth to increase wear resistance and prolong blade life between sharpenings (Frankson, 1977).

The set on a sawblade gives a clearance between the body of the sawblade and the timber. This set can be achieved using different methods. The traditional method is called spring set where a tooth or the tip only of a tooth is bent to the side. By bending alternate teeth, the set is produced on a blade. Different combinations of bent and straight teeth can be achieved. A common set for circular saws is left-right set, while for bandsaws a left-right-raker is common. The raker tooth is not bent and may stand slightly higher than the teeth which have the set on them.

Swage set is a method used on wide bandsaw blades. This is a method which requires the tip of the tooth to be pushed back into the hook; with nowhere for this metal to go it is pushed out to the sides of the tooth tip and this makes the tip wider than the blade, thus giving a clearance. The swage is put on the tooth with a device that clamps onto the blade and controls the extent the metal of the tip can move sideways.

2.4.5 Feed speed

The feed speed is the speed at which the saw is passed through the timber. Faster feed speeds increase the chip size, while slower speeds reduce the sawdust or chip size to the size of fine sand. This has the effect of heating the blade, causing sawdust spillage between the blade and wood, increasing wear on the tip and causing wavy or snaky sawing (Frankson, 1977).

Every tooth has a maximum and minimum bite or chip size which is based on the feed speed, the blade pitch, gullet area and speed the blade is travelling at the cutting tip (Quelch, 1972).

For wide blade bandsaws and large diameter circular saws the maximum and minimum feed speed can be determined using formulas defined by Quelch (1972). These formulas are only for wide bandsaw blades and during this study they could not be shown to be relevant to narrow blades.

2.4.6 Sawdust

To reduce saw tooth width and therefore potentially increase recovery Quelch (1972) states "It would appear that one of the main controlling factors is the ability of the gullet to convey the sawdust out of the cut." On average, lightly packed sawdust occupies a volume three times greater than the timber from which it was formed (Harris, 1973). The bite of an individual tooth into the timber should not be less than the clearance on the side of the blade (Quelch, 1977).

Quelch (1972) expresses the underlying premise on which the industry has based its sawmilling practices:

For maximum efficiency, a tooth must never bite less than the clearance on the side of the saw plate. When this occurs, the chip is smaller than the opening (swage, less plate ga. $\div 2$), and spills out of the gullet. This is not only equivalent to reducing the clearance and causing heat, but owing to the grain in the wood and lead in the saw, sawdust rarely if ever spills evenly on each side. By spilling more on one side than the other, it tends to crowd the saw out of line. Sometimes spillage has been considered necessary to gain gullet capacity in deep cuts. We know some sawdust will spill, but every effort should be made to prevent it. Sawdust should be carried out of the cut and discharged at the bottom.

The design of portable sawmills generally relies on a horizontal cut. This is in contradiction with the quote above and this study will endeavour to clarify the difficulties encountered without the gravitational advantage of vertical sawing.

2.5 Portable milling

Alternative handling and production methods are required to reduce the distance to existing processing facilities and thus make farm forestry ventures more economically viable.

Stewart and Hanson (1998) state

“there is considerably more to owning a portable sawmill than the actual cost of the sawmill itself, however a number of factors must be considered before an appreciation of the true costs of owning a portable sawmill can be gained. These factors include matching the sawmill to the available resource, the potential markets for the sawn timber, and the additional equipment that is often required before sawmilling can commence”.

For this very reason portable sawmills can be used in those areas where niche markets are available, or where log supplies are so fragmented that it is not financially viable for the fixed-site sawmill to operate, such as in a declining or emerging market (Smorfit *et al.*, 1998).

Landowners within the areas that have been defined as semi-arid (rainfall between 400-600 mm per annum) are being encouraged to plant and develop trees in conjunction with their existing agricultural activities. These areas will not produce timber volumes at the same rates as land with higher rainfalls but the lower volumes and with the use of portable mills they can be profitable (Stewart and Hanson, 1998; The Virtual Consulting Group, 1999).

2.5.1 Different types of portable mills

Portable sawmills can be divided into three basic categories:

- Chainsaw mills
- Circular sawmills
- Horizontal bandsaw mills (Laidlaw, 1997).

Stewart and Hanson (1998) include two extra categories by dividing the circular sawmills into single and twin circular sawmills plus an additional category of one-person bench-type mills.

2.5.1.1 Chainsaw mills

The chainsaw mill consists of a chainsaw and a lightweight frame that is attached to the chainsaw. The frame is used to gauge the slabs as the chainsaw is worked down the log.

The chainsaw mill is very portable and relatively cheap compared to other types of portable mill but is limited in operational performance for the following reasons:

- Lack of automation which makes the chainsaw mill extremely labour intensive.
- The higher cut width which results in substantial sawdust losses and therefore lower recovery rates.
- The slower feed-speeds which result in a lower production rate (Laidlaw, 1997; Stewart and Hanson, 1998; The Virtual Consulting Group, 1999).

2.5.1.2 One-person bench-type portable sawmills

The one-person bench-type mill is the most sophisticated of the portable mills and can be supplied with many features such as hydraulic log handling, holding tables for flitch resawing and other automations.

The one-person bench-type mill is the least portable and most expensive compared to other types of portable mills and for these reasons it has been excluded from the study (Laidlaw, 1997; Stewart and Hanson, 1998).

2.5.1.3 Financial viability of portable sawmills

The financial viability of portable sawmills is mainly dependent on the availability of sufficient volumes of sawlogs and the price received for the sawn timber (Stewart and Hanson, 1998). Therefore, an operator who is milling hardwood may be profitable with lower volumes of timber than if milling softwood purely due to the higher price paid for hardwood than for softwoods.

Stewart and Hanson (1998) found that a 10% changes in the mill running cost, distance to markets or productivity had less impact on the profitability of portable mills than did a similar change in the market price for the sawn timber.

The smaller break-even volume for hardwood enterprises in all cases highlights the benefits of targeting high value species. However, the technical limitations of milling certain species (such as small eucalypt logs) may make the processing of sufficient quantities of high value sawn timber difficult (Stewart and Hanson, 1998).

3 Sawing Equipment and Timber Species

3.1 Portable Sawmills

It was decided that the type of sawmill to be used in these trials should be affordable to farmers and small operators and be commonly used. Stewart and Hanson (1998) showed that the cost of mills increases with the level of automation and the most common types of mills in use were those in the price range up to about \$20,000. This range includes the single circular saw and horizontal bandsaw mills, which seemed to be the most popular among users.

These two types of portable mills, with manual feed operations, were selected as these required the least timber throughput to be economically viable and would therefore suit operators with small volumes of logs (Laidlaw, 1997; Stewart and Hanson, 1998; The Virtual Consulting Group, 1999). The two different types of mill also vary considerably in the sawing of wood and this is considered to provide the variety in operation suitable for the purposes of the project.

3.1.1 Single Circular Blade Sawmill

Personal observation and experience of portable mill users suggests that the single circular blade mills are able to cut dense hardwoods accurately in contrast to horizontal bandsaw mills which seem to have consistent problems with wavy cuts along the log being sawn. It was therefore decided that this type of mill could act as an initial benchmark for investigating other mills.

There are several manufacturers of single circular blade portable sawmills. For operational reasons the availability of a Lucas Model 8, 25 HP Portable Sawmill, located at the Timber Training Centre (TTC) was used for this part of the project (Fig. 3.1).

The Lucas mill has a sawblade that can be swivelled or rotated from a vertical to a horizontal position thus allowing sawing in both directions along the log (Fig. 3.2 and 3.3).

The operator performs a vertical cut by pulling the saw carriage and power head along the log while a horizontal cut is carried out by the operator pushing the saw carriage unit back along the log.

The sawdust is blown out of the back of the power-head carriage, away from the operator.

Removal of the cut board is easiest after the horizontal cut is completed when the operator is next to the log and the carriage is past the log. If the final cut to produce the board is made vertically, then the operator is on the opposite side of the saw carriage and power head unit to the board and log. The operator must walk around the saw to get to the board or use a second person to remove the boards and off cuts. The two-man operation is the recommended method by the manufacturers where the saw carriage is on the operator side of the log therefore both the operator and their assistant are not in the same working space (Lucas Mill Pty Ltd, 1999).



Fig. 3.1: Lucas Mill set up for sawing at the TTC, Creswick.



Fig. 3.2: (left) The Lucas mill with the blade in the horizontal position.



Fig. 3.3: (right) The Lucas mill with the blade in the vertical cutting position.

3.1.1.1 Blades

During these trials, most logs were milled using the standard Lucas blades. The blades used on the Lucas mill are manufactured with five Carbide-tipped teeth. The 530 mm diameter blade (cut up to 215 mm) is supplied with a 3.25 mm thick base material and with the tip width of 5.4 mm or 5.7 mm (Fig. 3.4).

Only one log (SG04) was milled using the larger diameter blade. This 575 mm diameter blade (cut up to 235 mm) has a base material thickness of 3.55 mm and a tip width of 6.1 mm. This larger diameter blade can be fitted to the later model mills by attaching some modifications to the riving knife and a spacer behind the sawblade.

This larger diameter blade was used at an early stage in the project when there was a requirement by the TTC that only their trainer should operate the saw and he was unwilling to refit the 215 mm cut blade. Later in the trials, our operator was allowed to use the Lucas mill, after he had completed the Small Scale Sawmilling Training Course conducted by the TTC.

The blade manufacturer can produce blades with narrower and wider tips. The blades used in each trial will be detailed in the relevant chapters.

3.1.1.2 Sharpening

The Lucas mill is supplied with a grinder to sharpen the carbide teeth while the blade is on the saw. The grinder is set up with the diamond wheel parallel to the face of the tooth (Fig. 3.5).

Sharpening is achieved by gently pressing the tooth on the face of the diamond wheel while using a side-to-side motion of the grinder. This removes a small amount of carbide from the face of the tooth and creates a sharp cutting edge on the point of the tip.

Grinding reduces the width of the carbide tip. The tooth is manufactured with tapered sides to give a clearance behind the cutting edge. As the face of the tooth is ground, the width of the tooth is reduced slightly, about 0.02 mm, for a little cleanup of the tooth face. This would reduce the width of the tip from 5.7 mm to 5.4 mm in about 15 light sharpening. Extending the time between sharpening may reduce the sawblade life, as more aggressive sharpenings will be required, as the tip point wears.



Fig. 3.4 (left): Lucas mill with the guard removed and the blade in the vertical position. (Insert shows the saw with the guard in place). NB: The saw should not be used without the guard in place.

Fig. 3.5 (right): Sharpening the 5-tooth saw-blade

Any build-up of resin on the blade or tooth reduces the effectiveness of the cutting tip. A build-up in the gullet will affect the sawdust removal and cause spillage out of the gullet that may lead to overheating of the blade.

As resin build-ups on the tip it will reduce the clearance between the side of the tip and the timber. This will create increased friction during the sawing process thus the increased heat will reduce the length of time a tip will remain sharp and distort the blade during sawing.

Examples of resin build-up on the tip are shown in Fig. 3.6 and 3.7.



Fig. 3.6 (left): Blade before sharpening, build-up on the face of the blade at the base of the gullet and behind the carbide tip.

Fig. 3.7 (right): Blade with no build-up on the face but slight build-up on the top edge of the tip face.

3.1.1.3 Lubrication during sawing

Water is used as a lubricant to reduce resin build-up on the sides of the blade which causes heat build-up due to side friction. The recommended flow-rates are five litres every one-to-two hours (Lucas Mill Pty Ltd, 1999). In reality, higher flow rates were needed due to the resinous nature of the species used in this project. Fig 3.8 shows the results of high resin build-up on the underside of the blade when insufficient water was used.

The total build-up was 0.3 mm on the under side of the blade. This reduced the side clearance from 1.0 mm to 0.7 mm and would have been significant on the horizontal cuts.



Fig. 3.8: Blade showing the direction of the water flow from the centre of the blade to the gullet and extensive build-up at the back and base of the gullet.

3.1.1.4 Other Blades

While only Lucas blades were used on the mill for this project there was much advice given by many people on what type of sawblade to use. This section is for further interest and is not related to any experiments or research but reflects opinions of some people within the industry.

Fig. 3.9 shows three blades that have been used on dry timber with no lubricant used in the sawing process. A high level of resin build-up is apparent on all the blades especially on the first two blades.



Fig. 3.9: Different blades used on Ecosaw to resaw dry high-density timbers.

The first two blades have black lines drawn around the area where cracks have formed in the blades. The cracks on the first blade have appeared in front of the chip breakers on three of the teeth. The chip breaker is designed to reduce the size of the sawdust that gets past the gullet.

All these blades were manufactured for a sawmiller using steel blanks from which the blade profile was laser cut. The cutting tips were produced by welding carbide inserts onto the profiled blade. The sawmiller stated that in their experience the laser cut blanks produced cracks very quickly and that the profiles required grinding to final shape. It was suggested that the laser cutting caused a hardening of the metal along the cut edge and that the grinding removed the hardened material and left a uniform base metal (Venn, pers. comm.).

3.1.2 Horizontal band mill

A horizontal bandsaw mill is the simplest of the bandsaw type mills as the logs generally do not have to be raised a great height from the ground. A vertical band sawmill requires the logs to be lifted on to a platform at least the height of the diameter of the wheels. This requires lifting equipment and a substantial frame to support the log and saw carriage and generally requires the log to be moved past the cutting band.

Bandsaw mills require the blade, or band, to be tensioned on the machine to hold the blade straight during the cut. Every band manufacturer has a recommended tension for their blade and operators should observe these tensions when setting up a mill.

Manufacturers of bandsaws have different methods to achieve band tension and these are often very different and cannot be translated between machines.

Two portable horizontal bandsaw mills were used during this project. The first was a Wood-Mizer LT15 then after it was no longer available; a Laidlaw Farmmill was used.

Water was used on both mills as a blade coolant and to assist with the removal of sawdust. Many operators used other products to reduce resin build-up on the sawblades. Traditionally diesel has been used as a lubricating compound but with the proven health risks this is no longer an option. Proprietary lines are becoming available where sawblade manufacturers are producing products that are reported to improve sawing performances.

The logs were rolled onto the base with the larger or butt end facing the sawing head. The initial cut was made after the smaller end of the log was raised and secured to produce a cut parallel to the pith or centre of the log

3.1.2.1 Wood-Mizer

A Wood-Mizer LT15 horizontal bandsaw at the TTC was used for initial bandsaw trials (Fig. 3.9). A power head is moved along the sawing bed by turning a handle on the frame which is attached to a rope and pulley arrangement. This set up does not give the operator a good feel for the forces during the sawing process and also limits the speed of cut to the speed the handle can be turned.

The flitch is held from moving by metal lugs welded to the sawing bed on the blade exit side of the flitch and adjustable screw clamps on the blade entry side. The adjustable screw clamps are pictured in Fig. 3.9 at the base of the flitch.

The blade tension on this mill is achieved by turning a handle attached to a screw mechanism that has a pointer mounted on it. When the pointer is in the recommended position the correct tension is applied to the blade. Fig. 3.10 shows the two band guide rollers. The right hand roller is fixed in position while the left hand roller is adjusted by the operator to close the throat or width of cut down to minimize band deviation.

Water was used as a blade coolant and to assist with the removal of sawdust.



Fig. 3.9 (left): Wood-Mizer cutting sugar gum flitch at the TTC.

Fig. 3.10 (right): View of band cutting into a flitch.

3.1.2.2 Farmill

A Laidlaw Farmill was used for this trial and was set up in the University of Melbourne's Wood Technology Park at Creswick, Victoria.

The Farmill comes with a factory fitted 13hp Vanguard motor (Fig. 3.11). The sawing head, motor and carriage were standard but the owner had made some modifications to the bed. These modifications had no effect on the performance of the saw and were only for easy set up and log handling. Special adjustable brackets were manufactured to hold a flitch securely, during sawing, and these do not require the flitch to come into contact with the sawing carriage.

The engine had a tachometer fitted to measure engine speed, in rpm, and engine running hours.

Tension on the blade on the 'Farmill' is applied by a nut on a threaded rod attached to the slide plate on the idler wheel. As the nut is turned, the idler wheel moves in or out, applying or releasing tension on the blade. The torque applied to the nut is measured with a torque wrench and this torque reading is used as an indicator of the tension applied to the blade.



Fig. 3.11: Laidlaw 'Farmill' at School of Forestry, Wood technology Park, Creswick.

The position of the blade on the wheel or "tracking of the blade" needs to be adjusted each time a different length blade is used. This process determines the amount of blade that protrudes in front of the wheel. If a blade protrudes too far forward, the blade will not have an even tension and may not cut straight. If the blade is back past the gullet with the teeth in contact with the wheel, the set can be removed. The optimum position is with the bottom of the gullet at the edge of the wheels and only the teeth protruding in front of the wheels (Wirth, pers. comm.).

A threaded rod and nut arrangement on the rear bearing adjusts the tracking of the blade on the wheels; this is similar to the tensioning device on the front bearing (Fig. 3.12).

3.1.2.3 Blades

Manufacturers are making claims about different blades for example, "this blade cuts faster and lasts longer than carbon steel blades"(American Saw and Mfg Company, 1999) or "wider widths for more beam strength and stability" (Simonds, 1996). During these trials three different styles of blade were used and at two different widths to test some of the claims made by the manufacturers (Table 3.1).

The six blades used were:

Pacific Saw International 32 mm (1¼") blade carbon steel (Made in Australia).

Lenox® Bi-Metal 32 mm (1¼") blade (Made in USA).

Simonds® 32 mm (1¼") bevelled Carbide-tipped blade (Made in USA).

Pacific Saw International 50 mm (2") blade carbon steel (Made in Australia).

Lenox® Bi-Metal 50 mm (2") blade (Made in USA).

Lenox® 50 mm (2") variable pitch Carbide-tipped hogged and beveled blade (Made in USA).



Fig. 3.12 (two pictures): Tension adjuster (viewed from above) on the front bearing behind the idler wheel of the Farmill.

The different blade characteristics are detailed in Table 3.1 where the basic type, pitch and manufactures specifications are shown.

3.1.2.4 Carbon steel

Pacific Saw International, formerly CBS Saws Australia, who manufacture in Australia, supplied the carbon steel blades. Both the 32 mm and 50 mm wide blades were manufactured from a 1.1 mm thick band material. The band material was ground to profile then the set was applied to the teeth after which the band was heat hardened to a hardness of 42 Rockwell. After hardening, the bands were tempered and then roll tensioned to the manufacturers' design (this information is not available and will be part of the trade secrets that have one manufacturer differing from the next). The finished band had a hook angle of 10° and a set between 0.48 to 0.57 mm (0.019" to 0.022"). The set was with a left-right-raker tooth pattern that produced a face angle on the tooth of about 85°.

The face angle is achieved by grinding when the tooth is in a vertical position before applying the set. A face angle, other than 90°, is difficult to reproduce when field sharpening, as the set must be removed before sharpening, the blade sharpened and then the set reapplied. This method of manufacture also produces a slightly higher raker tooth than the left-right set teeth. The horizontal bending of the tooth, to produce the set, reduces the vertical height slightly.

Unless special grinding equipment is available, the tooth height is changed with on-site grinding. This makes all the teeth the same height and produces the same face angle.

These alterations to the manufacturer's design could be a factor in the wear characteristics of the blade and the subsequent power required for cutting after on-site sharpening.

Table 3.1: Blade descriptions and parameters used in this trial.

Manufacturer or Brand	Construction	Blade Width	Blade Gauge	Tooth Spacing	Tooth Set	Sawing Kerf
Pacific Saw International	Carbon Steel	32 mm	1.1 mm	19 mm	0.5 mm	2.1 mm
Pacific Saw International	Carbon Steel	50 mm	1.1 mm	19 mm	0.5 mm	2.1 mm
Lenox®	Bi-Metal	32 mm	1.1 mm	25 mm	0.5 mm	2.1 mm
Lenox®	Bi-Metal	50 mm	1.1 mm	25 mm	0.5 mm	2.1 mm
Lenox®	Carbide Tipped	50 mm	1.1 mm	25 mm 32 mm 38 mm	0.4 mm	1.9 mm
Simonds®	Carbide Tipped	32 mm	1.1 mm	19 mm	0.25 mm	1.6 mm

3.1.2.5 Bi-Metal

Both the 32 mm and 50 mm wide Bi-Metal blades were Lenox® Woodmaster "B" blades manufactured by American Saw and Mfg. Co and supplied by one of their Australian agents, Henry Bros., NSW. The Bi-Metal blade has a different base metal design from the carbon steel blades but the subsequent manufacturing method is similar.

Bi-Metal blades have a backing material or blade body with a hardness of 42-44 Rockwell to which a "High Speed Steel" strip is Electron Beam Welded to the backing material, and then heat-treated to 66-68 Rockwell on the tooth tip.

The Bi-Metal and Carbon bands was milled on a milling machine to produce the profile. After milling the teeth profile, the blade has a softer metal in the body of the blade and a very hard tip to the tooth, which is the same width as the backing material.

The harder tip is difficult to see from the backing material, as the thickness is the same across the blade. Grinding of these blades should be kept to a minimum, as the hardened tip is very small and easily removed by excessive or aggressive grinding.

The final blade configuration of hook, set, thickness and face angles is similar to the carbon steel band material.

3.1.2.6 32 mm Carbide Tipped

The 32 mm Carbide-tipped (CT) band was manufactured by Simonds Industries Inc. and their local agents Excision Saws and Supplies, Ballarat then fabricated the blades to the specified length.

The Carbide-tipped blades are a standard carbon steel bands with a very hard carbide tip. The backing material is 45-47 Rockwell while the tip is 90 Rockwell C hardness.

The gullet and tooth profiles are ground in a similar manner to the other blades; in addition, a socket is milled into the tip of the blade. A round section of carbide is placed into this socket and welded into position.

The Carbide-tipped inserts and tooth tips are then ground as shown in Fig. 3.13.

A side clearance is obtained by grinding the insert on a taper from the wider section at the tip to almost the same thickness as the backing material where they meet (Fig. 3.13(a)(i)). This shape of tooth is called a swage tooth, as it resembles the conventional method of swaging a bandsaw tooth to produce the set clearance (McKenzie, 2000).

Each tooth is ground to produce a tooth hook angle of 1° and lined up with the gullet that was previously ground (Fig. 3.13(c)). In addition, a positive face angle of 5° is ground into the Carbide-tipped tooth (Fig. 3.13(b))

The clearance angle is ground on the back edge of the teeth. Alternate teeth have slightly more metal ground off the back of the teeth (Fig. 3.13(c)) (approx. 0.1 mm); the exact specifications are not available.

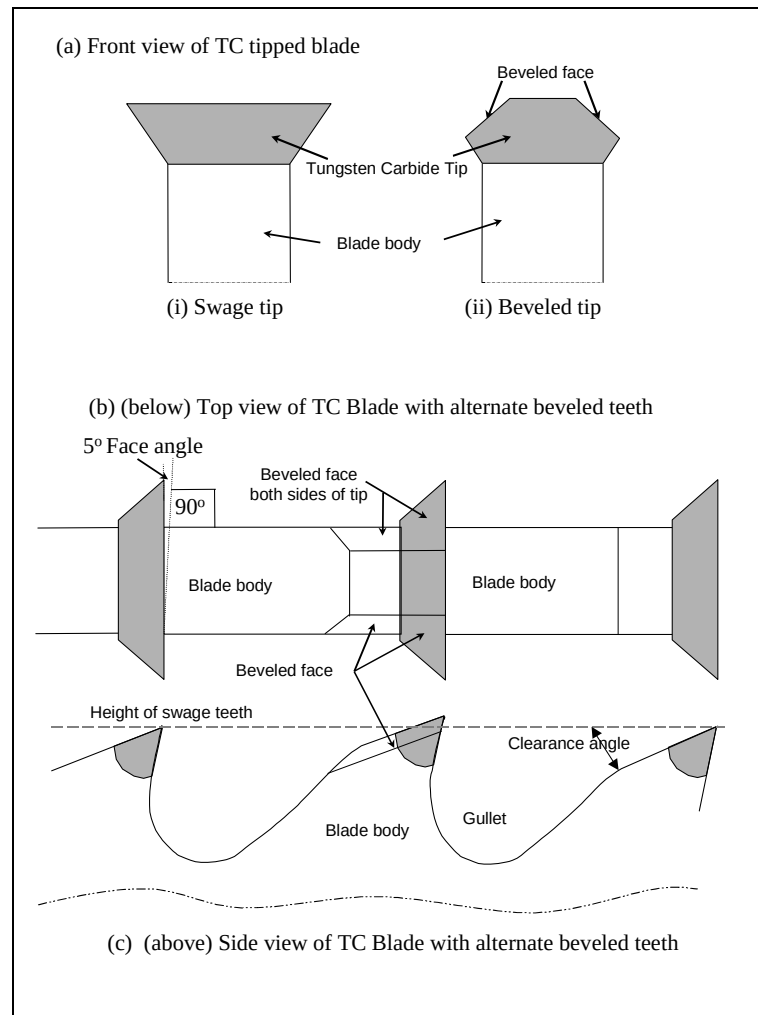


Fig. 3.13: Description of alternate bevelled tooth design of 32 mm Carbide-tipped blade. (a)(i) Front view of swaged tip (ii) Front view of bevelled tip. (b) Top view of swaged and bevelled teeth. (c) Side view of swaged and bevelled teeth.

Alternate teeth are then bevelled. These are the higher teeth after grinding the clearance angle. A 45° angle or bevel is ground on each side of the teeth along the clearance angle

grinding line at a distance of one third the width of the distance across the face of the tip insert (Fig. 3.13(a)(ii)). This produces an alternating tip pattern with a tooth that has a flat section in the centre third of the tooth cutting face and with a 45° bevel each side (bevelled) followed by a slightly lower tooth that has the full width of the carbide tip (swaged). Then the pattern is repeated along the band.

3.1.2.7 50 mm Carbide Tipped

The 50 mm Lenox® Woodmaster CT (Carbide Tipped) bands had a variable tooth pattern. The tooth pitch of these bands was different with a pattern of 25 mm, 32 mm, 50 mm then 32 mm before the pattern repeated itself.

The manufacture of this band material was similar in method to that described for the 32 mm CT bands but with the band tooth profile being totally ground.

The hardness of the tooth is 94 on a "RAD" scale that is used for measuring carbide hardness.

3.2 Equipment

3.2.1 Measuring equipment for sawing deviation

A straightedge manufactured from a 50 mm x 40 mm x 4 mm thick aluminium rectangular tube section 2.4 metres long was used for measuring saw deviation along the cut line. Screwed to this was a 40 mm x 50 mm x 3 mm thick aluminium tee section (Fig. 3.14) to provide rigidity. A 12 mm aluminium block was attached to the under side of the straightedge at each end (Fig. 3.14). This meant the straightedge sat on each end of the log rather than at some unknown highest point along the cut surface.

To ensure the pair of callipers, which were used to measure the deviation, were being held vertically at each measuring position holes were drilled at 90 degrees to the face of the aluminium at 100 mm centres (Fig. 3.15). The positioning of these holes allowed the movable centre strip of a pair of digital callipers to be used as a depth gauge (Fig. 3.16).

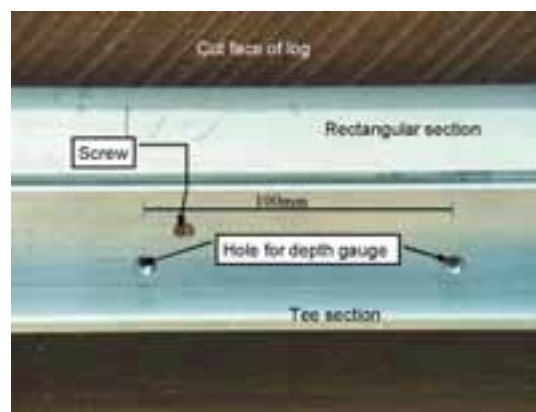


Fig. 3.14 (left): End section of straightedge with spacer block to clear log.

Fig. 3.15 (right): Holes in straightedge for depth measurements.

In addition, an aluminium block was manufactured to clamp to the base of the digital callipers. This block ensured the callipers were held vertically and provided sufficient weight to contact the straightedge (Fig. 3.16).

Care was taken not to apply excess force on the upper finger of the callipers, as this could cause deflection in the straightedge (Fig3.17).

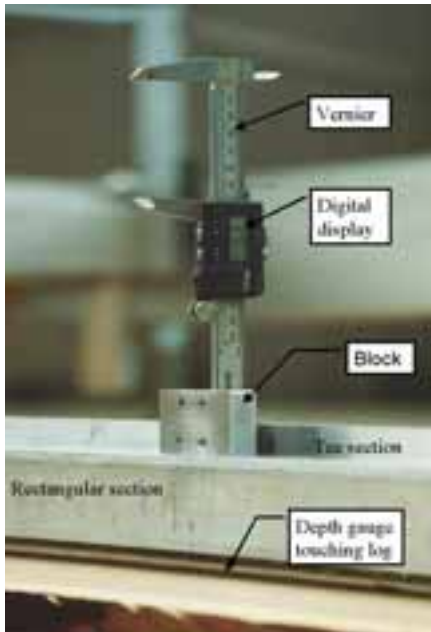


Fig. 3.16 (left): Calliper used as a depth gauge to measure the distance from the straightedge to the cut surface.

Fig. 3.17 (right): Measuring the deviation along a log with the straightedge and calliper

3.2.2 Measuring Band Tension on Horizontal Bandsaw.

The actual mechanics each mill manufacturer used for blade tensioning were discussed earlier in this Chapter (3.1.2.1 and 3.1.2.2).

A method was developed to measure the blade tension using a wire rope, load cell and weight indicator. The wire rope was used to go around the drive wheels of the bandsaw and was then attached to a load cell. This load cell was connected to a weight indicator. As the drive wheels were moved to tension the wire rope, the relevant force was recorded on the indicator in kilograms. This method allowed a force calculation equivalent to that applied on the blade for each machine irrespective of the particular tensioning method used by the mill (Fig. 3.18). This meant that the same tensions could be used on the blade for both the Wood-Mizer and Laidlaw portable mills even though the methods used to tension the blade were totally different.

Later in the trial, a Lenox tension meter was used to measure the strain or tension applied on the blade. This instrument measures the stretch in the blade and displays this deflection on a dial gauge as a force per unit area (psi.) (Fig. 3.19).

The tension meter used in these trials was supplied by the manufacturer. The meter worked by a screw on the fixed arm which was tightly screwed down onto the blade, the pivot arm was adjusted to move the dial one revolution and then the screw on the moving arm was

tightened onto the blade. This ensured there was no slack in the arms and any stretch in the blade would have show on the dial.



Fig. 3.18 (right): Load cell and weight indicator attached to the Laidlaw mill to measure the tension.



Fig. 3.19 (left): Lenox Tension Meter on 32 mm Bi-Metal blade.

3.2.3 Sharpening Bands for Horizontal Bandsaw.

The sharpening of the bandsaws was carried out on site with a Dino® Bandsaw Profiler. This machine is Australian-made and has a 12-volt motor to turn a grinding wheel. The blade is positioned on the base frame and the grinding wheel as shown in Fig. 3.20 is adjusted to the hook angle. By turning the handle manually, the blade is moved under the grinding wheel. A set of cams, within the machine, raises and lowers the grinding wheel as the handle is turned and the blade is moved by the pushing arm.

Fine adjustments are possible with this machine to either clean up or lightly grind the back of the tooth only or the face of the tooth. This method was employed in some of the trials where only light grinding was required.

3.2.4 Setting Bands for Horizontal Bandsaw.

The bandsaws were set using a 'Dino Bandsaw Setter' (Fig. 3.22). This machine gives a left-right-raker profile i.e. one tooth tip bent to the left, the next bent to the right and the third straight or not bent. By manually turning a handle the blade would move to the exact position where an arm with an adjustable screw would contact the tooth tip. As the handle was turned a cam would push the arm and therefore the tooth in the direction required.



Fig. 3.20 (left): Dino Bandsaw Sharpener viewed from the front



Fig. 3.21 (right): Dino Bandsaw Sharpener viewed from the rear

The adjustable screw on the arm determined the distance the tooth was bent or set.

This machine required manual checking of the set. Fig. 3.23 shows the set of a tooth being checked. By adjusting a cam in the machine, teeth could be changed from a left to a straight or right raker and vice versa. This was used when reducing the set in some trials.



Fig. 3.22 (left): Dino tooth setter



Fig. 3.23 (right): Checking the set on a bandsaw blade.

3.3 Sawing procedures

The sawing procedures for the circular saw and the bandsaw are different but every attempt was made to be consistent in the operation of the sawing process to allow for comparisons between the two types of saws. The numbering and recording for each machine was similar although the setting up of the machines was different.

3.3.1 Circular Saw

Debarked logs were set up on bearers within the frame of the Lucas Mill. The side bars were adjusted to be parallel with the pith both horizontally and vertically i.e. the frame was moved or the log was moved so that the pith ran parallel to the side bars then each end. The ends were adjusted until the height was parallel to the pith. The initial sawing was to get a flat face on the top of the log and a good edge to start a board. To ensure a sharp blade was used for each trial the blade was changed or sharpened.

To check any movement in the log due to growth stresses or other internal log movement a long tapered wedge was used as a fine gauge between a bearer which was clear of the log in the centre and the underside of the log.

Figure 3.24 shows the wedge and vertical timber which was attached to the bearer. After each cut the distance of the vertical timber to the log was measured and by moving the wedge in and out from under the log until it came into firm contact with the log a fine adjustment could be obtained. There was a 30:1 ratio of the horizontal movement to the vertical. Therefore, after a cut, if the wedge could be moved in horizontally by 30 mm this would indicate a 1 mm vertical movement in the log.

An example of the sawing pattern used for horizontal cuts is shown in Fig 3.25.

Recording of the results included the following data recorded for each cut:

- Log number
- Cut width

- Tip width
- Orientation of cut
- Cut number
- Board number (also recorded on the board with a paint pen)
- Minimum engine speed during the cut
- Duration of cut in seconds
- Log movement



Fig. 3.24 (left): Log set up with the wedge to check any log stress movement.



Fig. 3.25 (right): Typical log showing sawing patterns for Lucas mill

3.3.2 Horizontal bandsaw

The sawing trials were carried out in a regular process to ensure a high level of consistency. For each set of cuts the key constants were:

- The log was positioned on the carriage bed and secured in place with tapered stops each side and at each end of the log.
- The smaller diameter end of the log was raised till the centre of the log was parallel to the blade each end. This was achieved by lifting the log and inserting the tapered stops closer to each other.
- The moving parts on the blade tensioner were sprayed with WD40
- The tension was set using the torque wrench and the weights.
- The motor was started, run for a few seconds to ensure the blade was correctly positioned and the back bearing was adjusted to give the desired tracking of the blade.
- The tension was again set using the torque wrench and the 11.5 kg weights and the blade tension measured using a Lenox tension meter (after this equipment became available)

- The throttle was set so that the engine was running at 3600 rpm (manufacturer's specifications).
- The water was turned on to give a small trickle onto the sawblade.
- The blade was lowered or raised to the desired cutting position.
- The power-head and carriage were pushed along the log, which allowed the blade to saw a wing from the log.
- The throttle was returned to idle, the water turned off and the sawblade raised slightly.
- The off-cut wing was removed before returning the carriage to the start of the log.
- The log was then rotated and a second cut carried out using the same method as the first cut.
- Subsequent cuts were required to produce a 150 mm wide flitch.
- The 150 mm flitch that was to be used in a trial was clamped into position on the carriage bed to ensure it did not move during the sawing process.
- A sharpened blade was fitted to the saw and the sawing was carried out as per the method shown above and to the specifications discussed in each chapter.

Fig. 3.26 shows a Yellow Gum (*E. leucoxylon*) log being broken down and prepared for sawing, within a trial. The number of each cut is on the end of the log. These two flitches were produced after Cut5 and both upper surfaces were together before the right-hand flitch was turned over to expose the common face. The left-hand flitch (150 mm high) is ready to be stood vertically for sawing while the right-hand flitch requires two cuts to reduce it to 150 mm wide.

Recording of the results included the following data recorded for each cut:

- Log number
- Cut width
- Blade tension
- Blade number
- Cut number
- Board number (also recorded on the board with a paint pen)
- Minimum engine speed during the cut
- Duration of cut in seconds

Fig. 3.26 shows a typical log being prepared for trial with the breaking down with the cut numbers on the log end. Left-hand flitch (150 mm high) is ready to be stood vertically for sawing. Right-hand flitch requires two cuts to reduce it to 150 mm wide.

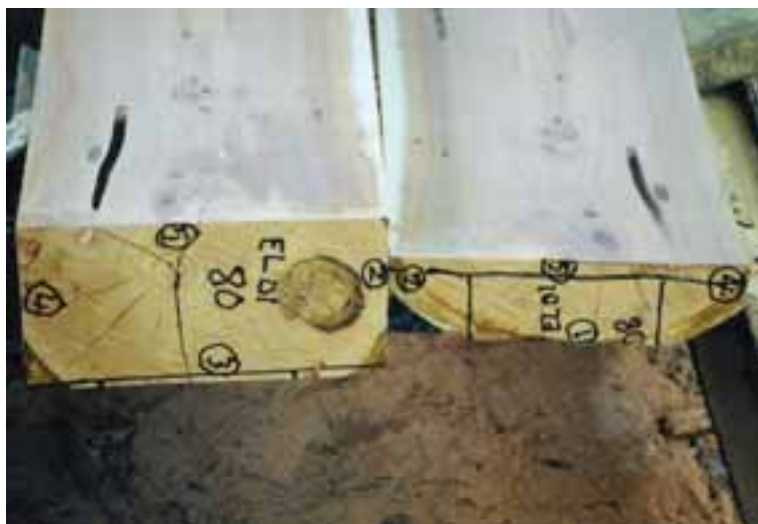


Fig. 3.26: A typical log showing sawing sequence

3.3.3 Measuring Sawing Straightness

After sawing and prior to measuring the deviation the flitch would be cleaned of any sawdust on the face and the straightedge placed in the centre on the flitch. Measurements were taken at the ends and every 200 mm along the straightedge and recorded on a tally sheet.

This process was repeated eight times before removing the blade then replacing it with another blade with a different tip construction or blade width.

After each pass, the straightedge was laid on the freshly sawn face of the log and measurements were taken at the end then every 200 mm with a final reading at the other end of the straightedge using the depth gauge on the callipers. These readings were later adjusted by the end depth readings to determine the actual deviation from the straight cut line – the supposed zero position.

Care was taken not to apply excessive force on the upper finger of the callipers, as this could cause deflection in the straightedge while some pressure was applied to the lower finger to ensure good contact with the cut face of the log.

The measurements for each cut were taken from the digital display on the digital callipers and recorded on a tally sheet.

3.4 Species selection criteria

The selection of logs and species was carried out in collaboration with Commonwealth Scientific and Industrial Research Organization (CSIRO) as part of a parallel project funded by Forest and Wood Products Research and Development Corporation (FWPRDC).

The trees were selected on the following criteria

- Existing plantations located in areas with rainfall 450 mm to 600 mm per annum
- A plantation was required to supply at least 16 harvestable trees of a species.
- Trees required a minimum DBHOB of 280 mm.
- Trees required suitable form to obtain at least a three-metre sawlog.

- Where additional trees were available in a plantation, the better form trees were selected.
- Harvesting constraints were considered in the tree selection process.

3.4.1 Species

The selected logs were obtained from four species at three sites in the Wimmera region of Victoria.

The following four species were available in large enough quantities to trial during this project (Blakemore *et al.*, 2001).

- Sugar Gum (*Eucalyptus cladocalyx* F. Muell.) is a widely planted farm tree predominantly used for firewood and fencing. The dry density is reported to be around 1025 kg/m³ (Ozarska and Ashley, 1998). Some trial samples were obtained from the Wail Nursery Plantation 1971-73 plantings. Additional trees were sourced from Majorca Plantation via Talbot
- Swamp Yate or Flat-top Yate (*Eucalyptus occidentalis* Endl.) is one of the very few eucalypts that is salt tolerant and can survive in moderate to low rainfall areas (Raper, 1998). There is no relevant literature on the properties or characteristics of Swamp Yate. The Swamp Yate was obtained from The Barrett Reserve with the selected trees being planted in 1959 (Fig. 3.28).
- Brown Mallet (*Eucalyptus astringens* Maiden (Maiden)) was an important timber in Western Australia where the bark is used as a source of tannin. The bark contains 40 to 57 per cent tannins. The wood has a green density of 1120 kg/m³ and an air-dry density of 980 kg/m³ (Bootle, 1983). All logs were obtained from two sites in the Glen Lee State Forest which were planted in 1955 (Fig. 3.27).
- Yellow Gum (*Eucalyptus leucoxylon* F. Muell.) is found naturally occurring in Western Victoria and into South Australia with green density around 1200 kg/m³. Bootle (1983) claims Yellow Gum is a species that is slow to dry with little downgrade. All logs used in the trials were obtained from Wail Nursery Plantation 1956-60 plantings.

These species will, from hereon, be referred to by their common names.

In the first week of February 2000, sixteen (16) Swamp Yate, Yellow Gum and Brown Mallet trees were harvested and a 3.1 metre log was obtained from each tree. Although the criteria required 16 trees the Sugar Gum plantation only had 12 trees of an acceptable size and therefore only 12 logs were obtained. Immediately after falling and cutting to length, both ends of the log were painted with a wax emulsion which is manufactured as a timber end sealer to reduce drying from the ends of the log. During that week, Department of Natural Resources and Environment (DNRE) employees transported all the harvested logs to the Wail Nursery.

The logs were stored in the shade but not under water spray and two weeks later, all logs were transported to the Timber Training Centre at Creswick.

The logs were allocated between this project and CSIRO on a random selection basis. Ten Sugar Gum logs and eleven of each of Yellow Gum, Brown Mallet and Swamp Yate were used for CSIRO sawing and drying trials. This allowed two Sugar Gum and five of each of Yellow Gum, Brown Mallet and Swamp Yate available for these sawing trials. Additional Sugar Gum logs were obtained from the Majorca Plantation. Details of these logs are discussed in the chapter relevant to their use.



Fig. 3.27 (left): Brown Mallet plantation at Glen Lee State Forest, near Nhill, Western Victoria.



Fig. 3.28 (right): Swamp Yate plantation at the Barrett Reserve, near Warracknabeal, Western Victoria

3.4.2 Log storage and processing

The logs used for these trials were stored under water spray at the TTC log yard and transported to the Wood Technology Park when required. After debarking, the logs were broken down into 150 mm wide flitches in a method described earlier in this chapter Fig 3.26. The flitches were stored under wet carpet underfelt until they were required for sawing. This was to prevent them from drying out while waiting to be resawn.

Fig. 3.29 shows a Swamp Yate log that was allowed to dry in storage when the water system was turned off for a period of time.



Fig. 3.29(two pictures): End sections of log that was allowed to dry and then re-wet. The watermarks indicate the extent of surface cracking.

After the water was turned on again this log was selected for sawing and disks were cut from each end to obtain the desired length. These cuts reveal the extent of surface cracking on the log and why rewetting the timber will allow water to penetrate the surface but not repair any cracking.

3.5 General characteristics of species used in trials

Wood properties of the species used in these trials were determined and can be used as a baseline in any comparisons with other species. Although this is not an extensive list of properties they cover some factors than can affect the final uses for timber, especially for use in furniture or appearance products.

Brown Mallet was not included in some of this section of the report, as at the time of sampling the available logs had large sections of rot which excluded bark to bark measurements. An internal report by Brennan *et al.* (1997) presented some physical properties of Brown Mallet which have been included in this report where other results were not available.

3.5.1 Moisture Content, Density and Shrinkage

Three samples 150 mm long and 40 mm wide by the board thickness were cut from each 150 mm wide board. The boards had a 200 mm section cut from each end and then a 150 mm sample taken from each end. The centre of the board also had a 150 mm sample taken (Fig. 3.30).

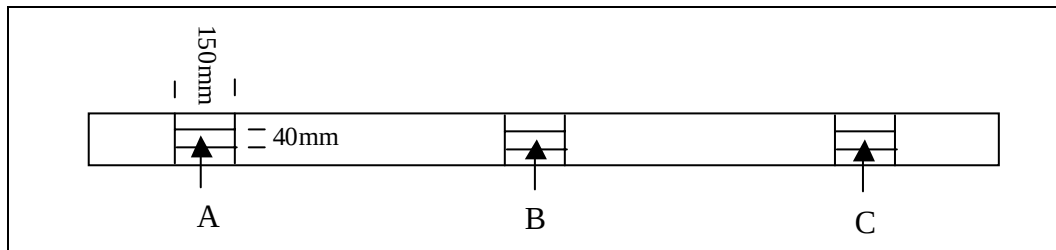


Fig. 3.30: Board showing the location of the three sample blocks

These samples were further cut down with approximately 40 mm cut from each side giving samples from the centre of the boards. These samples were labelled with the board number with A, B and C, then weighed and measured before being oven dried to constant weight.

After constant weight was achieved, the samples were again weighed and measured. The moisture content, green density and air-dry densities were calculated as per AS 1080.1 and AS1080.3.

Moisture content was determined by the following formula (SAA, 1997):

$$MC = \frac{Mi}{Mo} \times 100$$

where

MC = percentage moisture content of test piece

Mi = initial mass of test piece

Mo = oven-dry mass of test piece.

Basic Density and Air-dry Density were calculated by the following formulas (SAA, 1981; SAA, 1998):

$$P_b = \frac{M_t}{V} \times \frac{100}{(100 + W)}$$

and

$$P_{12} = \frac{M_t}{V} \times \frac{(100 + 12)}{(100 + W)} \times \frac{100}{(100 - (r + t)(W - 12))}$$

where

P_b = basic density, in kilograms per cubic metres

M_t = mass of test piece at time of test, in kilograms

V = volume of test piece in cubic metres

W = moisture content of the test piece based on oven dry method, in percentage units

P_{12} = air-dry density, in kilograms per cubic metre

r and t = unit shrinkage percentage in the radial and tangential directions respectively.

Unit shrinkage was based on the percentage change in dimension divided by the initial moisture content. This is the average percentage change in dimension per one per cent decrease in moisture content

Three samples from each of the resulting boards in the Sugar Gum log were prepared for testing moisture content and density.

Figure 3.31 shows a clear moisture gradient with higher moisture contents in the centre of the log that reduce toward the outer edge of the log. This trend is opposite to the basic density, which is higher on the edges and lower in the centre.

The average oven-dry moisture content of all 150 mm wide boards in each of the logs is shown in Table 3.2.

Table 3.2: The mean and standard deviation oven-dry moisture content of each 150 mm board by log.

Log No.	Mean Oven dry moisture content (%)	Standard deviation	Coefficient of variance
SG01	33.6	3.6	10.7
SG02	41.8	4.7	11.2
SG04	33.8	4.4	13.0

The basic density (the mass of wood per unit volume excluding water) was higher in the boards produced from the outer regions of the log and lower in the boards from the centre of the log (Fig. 3.31). These results are consistent with work by Lima (2000).

The green density, which includes the moisture contained in the sample, was relatively uniform across the width of the log (Fig. 3.31).

This would suggest that the green boards would weigh approximately the same when cut and before drying. More fibre, tannins, non-removed extractives or wood material in the outer region of the log than at the centre could explain the higher basic density.

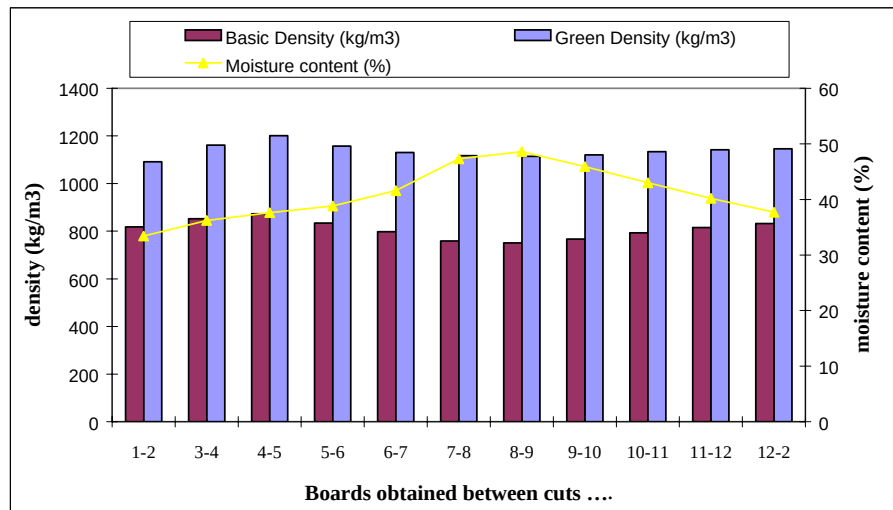


Fig. 3.31: Basic Density, Green Density and Moisture Content for boards across log SG03

Log SG01 that was a butt log from the tree had basic density of 901 to 935 kg/m³ in boards cut from the outer section of log. This is 10% higher than Log SG03 that was from high up the tree. This is consistent with the literature, which states density decreases with height up the tree (Lima, 2000).

The mean green density of the Logs SG01-05 was 1153.80 kg/m³ (1123.44-1184.26) while the mean basic density of the boards was 839.24 kg/m³ (792.71 -885.77) and the mean air-dry density was 1396.12 kg/m³ (1316.19- 1476.05).

The basic density of Log SG05 ranged from 883 kg/m³ in the first board closest to the bark to 723 kg/m³ from the board closest to the pith. There were similar trends in the spot samples taken in other logs. Log SG01 had readings in boards cut from the outer section of log at 901 to 935 kg/m³.

The mean moisture content, nominal or green density, basic or conventional density and density at 12% moisture content of the samples produced from strips taken from each end of the log are shown in Table 3.3. The standard deviation of the mean calculation is show below each result in brackets.

The mean moisture content of the top and bottom sample strips for three species is shown in Fig. 3.32. The graph lines are smoothed to show gradients in moisture content from the bark or log edge through the centre area of the sample disk to the opposite edge of the log.

Table 3.3: Mean Green density, Basic density, Air-dry density (12%) and moisture content of Sugar Gum, Yellow Gum and Swamp Yate. Standard deviation of test samples is in brackets ().

	Green Density (AS 1080.3-2000)	Basic Density (AS 1080.3-2000)	Density @ 12% MC (AS 1080.3-2000)	Moisture Content (AS 1080.1-1997)
Sugar Gum	1130kg/m ³ (65 kg/m ³)	740 kg/m ³ (85 kg/m ³)	1040 kg/m ³ (75 kg/m ³)	34.7% (4.0%)
Yellow Gum	1150 kg/m ³ (70 kg/m ³)	730 kg/m ³ (85 kg/m ³)	1065 kg/m ³ (75 kg/m ³)	36.6% (3.3%)
Swamp Yate	1115 kg/m ³ (45 kg/m ³)	735 kg/m ³ (80 kg/m ³)	1070 kg/m ³ (60 kg/m ³)	34.1% (5.2%)
Brown Mallet *	1130 kg/m ³ * (45 kg/m ³)	865 kg/m ³ * (40 kg/m ³)	1060 kg/m ³ * (45 kg/m ³)	N.A.

(* Results sourced from Brennan *et al.*)

The centre of each log is not exactly in the same position and Figs. 3.32, 3.33 and 3.34 should not be used to measure differences between logs but for general trends in moisture content and shrinkage.

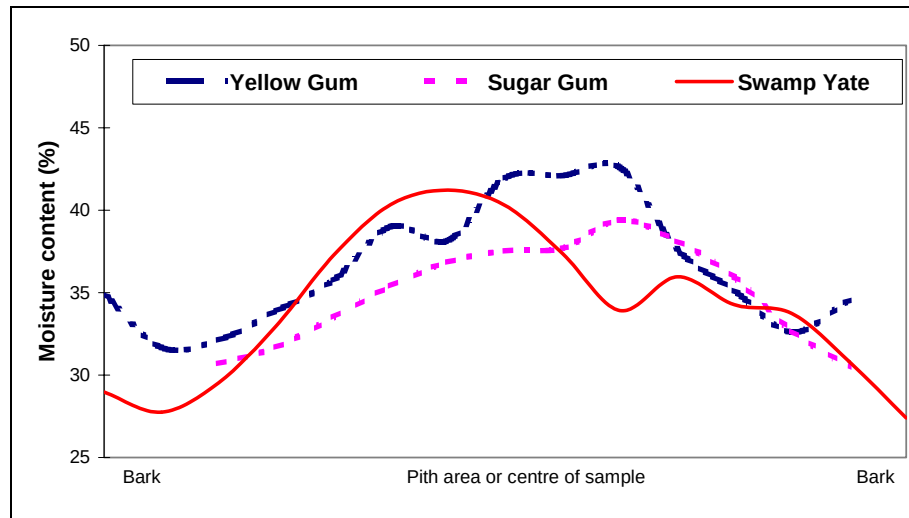


Fig. 3.32: Moisture content of samples taken across the log section.

The mean unit shrinkage for each end of the log for three species in the radial direction is shown in Fig. 3.33. Unit shrinkage is the percentage change in a dimension per 1% change in moisture content.

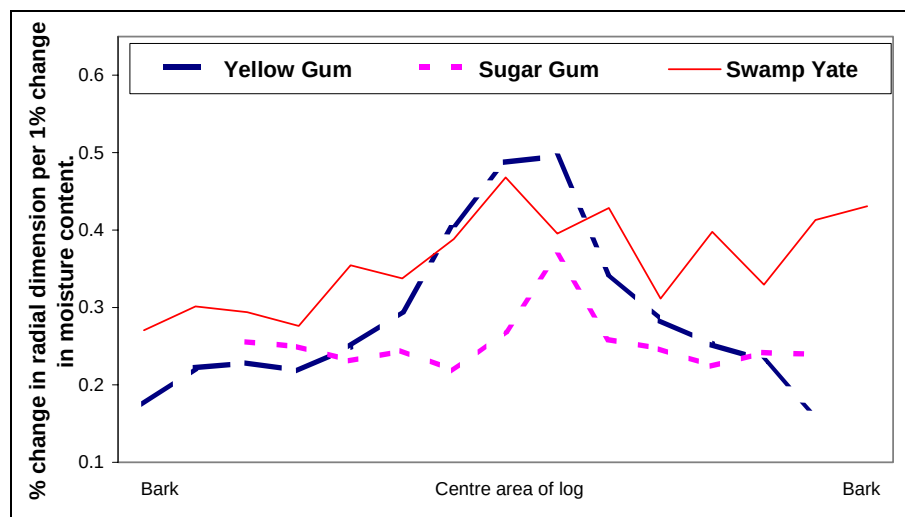


Fig. 3.33: Mean unit shrinkage in the radial direction of samples taken from both the butt and top of the log. Samples were prepared from bark to bark disks.

The mean unit shrinkage for each end of the log for three species in the tangential direction is shown in Fig. 3.34.

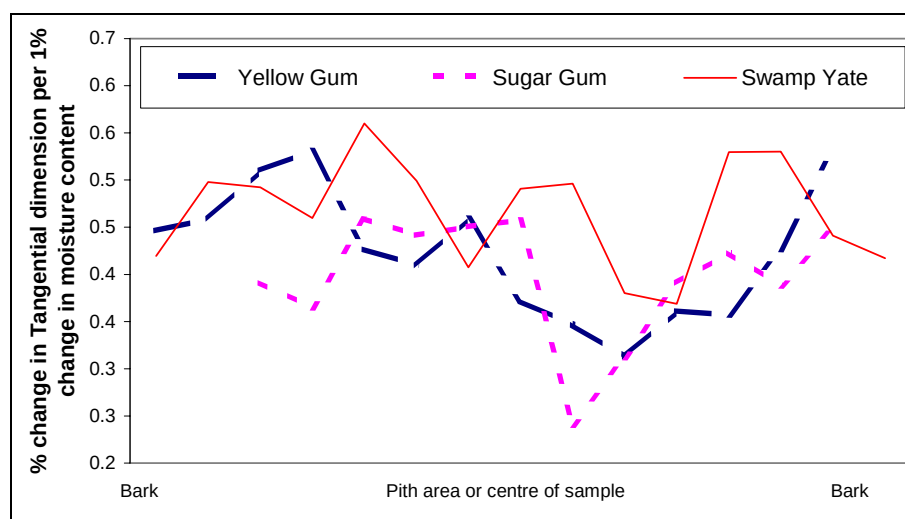


Fig. 3.34: Mean unit shrinkage in the tangential direction of samples taken from both the butt and top of the log. Samples were prepared from bark to bark disks.

Brennan *et al.* reported Brown Mallet to have a shrinkage of 6.6% tangentially and 3.3% radially. This shrinkage was determined by:

$$\frac{\text{Green dimension} - \text{oven dry dimension}}{\text{Green dimensions}} \times 100$$

3.5.2 Hardness

A range of samples from boards across Log SG04 and SG05 was selected for hardness testing. The Janka hardness test was used at two points on each of the 20 mm wide sides of the sample and an average of the four readings was calculated for each piece.

The Janka hardness test was carried out on a machine that pushes an 11 mm steel ball 5.64 mm into the surface of the timber and graphs the force required over the full 5.64 mm penetration. The maximum force in Newtons was recorded for each reading.

The mean hardness of the boards on the outer edge of the log was 6.45 kN while in the centre the mean board hardness was 3.75 kN in Log SG05.

The hardness decreases with the distance from the outer edges of the log and is lowest at the pith. The relationship between sawing characteristics and hardness needs to be examined further.

3.5.3 Features and Appearance

Fig. 3.35 shows a Swamp Yate log partly sawn by the Lucas Mill. The log shows some self-pruning effects where the centre section of the log contains a knotty core. This self-pruning produces a section of relatively clear wood from the knotty core to the outer edge of the log. The timber color in the Swamp Yate is a red-brown with darker patches associated with the late wood found in the growth rings.

The sapwood is a lighter colour towards a cream compared to the heartwood or truewood.

End grain sections were prepared for each of the trailled species and placed under a microscope then photographed. These photos are shown in Fig. 3.36, 3.37, 3.38 and 3.39. The lines at the top of each photo are the scale with each line being 1.0 mm graduation.

The colours of these photos are not true representations of the timber colours as the photographic lights altered the colour appearance but the interesting features are the vessels which contain tyloses.



Fig. 3.35: Swamp Yate showing the grain found in many logs

Tyloses develop from protoplasmic material that proliferates into the vessels. This material may include starch, proteins, oils, fats, tannins and inorganic substances recognizable in the form of crystals (Kollmann and Cote, 1968).

The tyloses appear to have filled all the vessels in the Swamp Yate (Fig. 3.36) and Brown Mallet (Fig. 3.39) samples while in the Yellow Gum (Fig. 3.37) is a thickening around the edge of the vessels with only a few vessels completely filled.

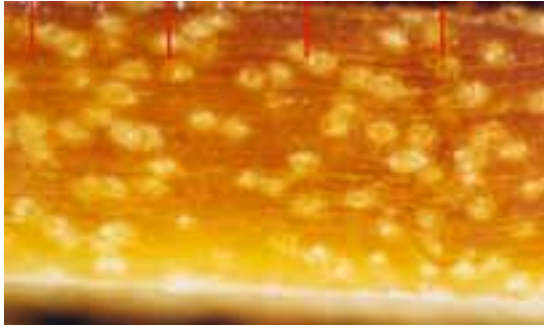


Fig. 3.36 (left): A section of Swamp Yate viewed under a microscope (The lines are 1 mm graduations)

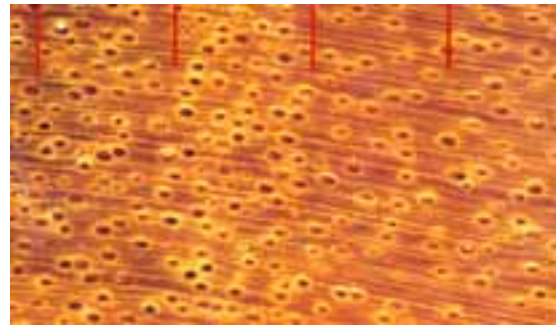


Fig. 3.37 (right): A section of Yellow Gum viewed under a microscope (The lines are 1 mm graduations)

In the Sugar Gum (Fig. 3.38) all the vessels are filled and the tyloses are said to resemble soapsuds, being frothy and shiny (Kollmann and Cote, 1968).

This section has given an overview of the equipment and machinery used in the trials. Details of the specific variations used in a particular trial are discussed in the relevant chapters.

This chapter has also shown some of the properties of the species selected as examples of high-density timbers from the semi-arid regions of south-eastern Australia.

The following chapters discuss the actual sawing trials and the sawing results. Some of the generic results have been included in this chapter, as they were common to all the trials or species used for this project.

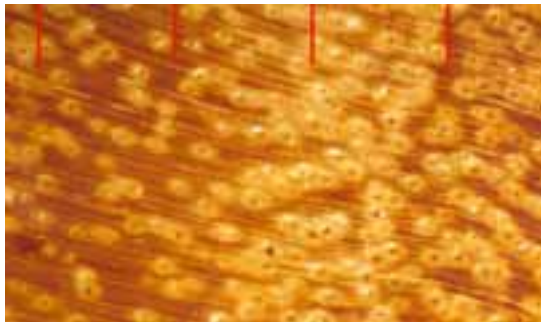


Fig. 3.38 (left): A section of Sugar Gum viewed under a Microscope (The lines are 1 mm graduations)

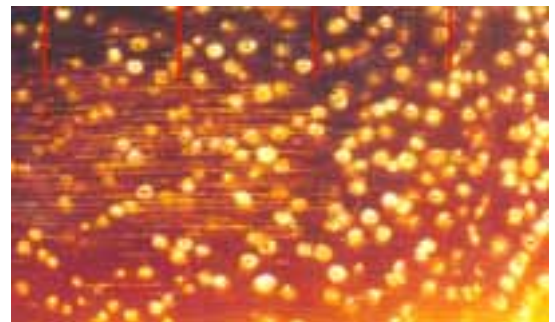


Fig. 3.39 (right): A section of Brown Mallet viewed under a Microscope (The lines are 1 mm graduations)

4 Initial Sawing Trials

4.1 Introduction

The high density of the wood of species grown in the low rainfall areas and subsequent difficulties in the sawing of boards have led to the moulding, joinery and furniture industries facing difficulties in obtaining accurate dimensions of sawn materials (Loehnertz *et al.*, 1996).

The determination of "what is straight" or how much variation is acceptable must be based on customer requirements.

In this trial, a tolerance of 1 mm for the straightness of cut was chosen. The decision to set this tolerance for straightness of cut (1 mm) was deliberately, if somewhat arbitrarily, made to ensure high quality cutting performance. In reality, the Australian standard for hardwood timber is less severe. Australian Standard AS 2796.3–1999, titled "Timber – Hardwood – Sawn and milled products: Part 3 Timber for furniture components" specifies that:

"for sawn boards, at the time of grading the actual dimensions shall be not more than 2 mm below an ordered nominal size or, where specified, not less than the agreed cross section size" (SAA, 1999).

This 'standard' refers to dried timber – but not dressed. Obviously, timber will shrink as it dries and achieving this standard in the green form does not necessarily ensure the timber will finish up within standard in the dry form. However, the quality of drying practice has a major impact on the result and poor practice could completely ruin a well-sawn batch of timber. This cannot be accounted for in this trial and the approach was to at least produce the green sawn timber within the specified standard.

It has been discussed that less than a 2 mm total variation in board thickness is the desirable standard. This relates to a 1 mm variation along the face of the cut along a log as it is being sawn as this could be doubled if the next cut has a variation in the opposite direction.

4.2 Aim

There is anecdotal evidence that single circular blade portable sawmills can cut logs of high-density timber straight while horizontal bandsaw mills have considerable difficulties in achieving straight cuts in the same species.

The aim of these trials was twofold:

- to quantify the sawing performance of a 'Lucas' single circular saw-blade mill on a high-density hardwood species (Sugar Gum) and establish this as a benchmark
- to observe and measure the extent of the perceived problems and difficulties encountered by a horizontal bandsaw mill in sawing the same species of timber and to determine the controllable parameters that may affect sawing performance

4.3 Materials and methods

Although the nature of portable sawmills allows them to be set up in the area where the trees have been felled, it was decided that for these trials logs would be collected and returned to Creswick. It was thought that the measuring and analysis would be easier and more convenient at Creswick than in more remote locations.

Descriptions and details of the Lucas and Wood-Mizer mills are given in Section 3.1.

Five logs were used in this trial to test the suitability of the equipment and the experimental design - three for the Lucas trial and two for the Wood-Mizer trial.

4.3.1 Sawing Tolerances

Although much of the project was carried out using the sawing tolerances referred to in the Introduction, shortly after sawing trials commenced it became apparent that the initial assumption on how tolerances translate into variations in board thickness appeared to be incorrect.

Using a tolerance of 1 mm on the cut surface would allow for the thickness variation within a board to be up to 2 mm, if at both positions along the cut the deviations were in opposite directions – as discussed earlier. However, close examination of the data revealed that most deviations were upwards of the cut line (for reasons that were not able to be adequately explained). The example shown in Fig. 4.7 and 4.8, where there was downwards deviation, was in fact not common. Therefore, the likelihood of there being deviations in matching positions but opposite in direction was low. For this reason, it was decided that a tolerance of 1.5 mm in the cut face of a flitch should also be considered, as this would still give a total variation in the thickness of the board of 2 mm. This was done and the results for the trials were recalculated and included in this report.

4.3.2 Measuring sawing straightness

The straightness of cut was measured with the straightedge and vernier as described in Section 3.2.1.

The initial sawing (refer to Results in Section 4.4) in the first two logs showed the maximum size that could be cut in one pass on the ‘Lucas’ Mill to be 150 mm. A wider board could be produced if multiple passes were used to achieve a cut up to 215 mm deep.

To break down the logs using a horizontal bandsaw required some wide cuts. These cuts produced a flitch from which uniform width boards could be sawn. For example, Log SG05 (Fig. 4.4 and Table 4.1) milled with the Wood-Mizer required two 400 mm wide cuts and these cuts were within the tolerance of 1.5 mm. Even though these wider cuts were required to break down the log, it was decided that 150 mm would be used as a standard width cut for consistency in the trials, for both saw types, from here on.

4.3.3 Logs

It was decided that because of its availability only Sugar Gum (*Eucalyptus cladocalyx*) would be used as an example of dense timber in these initial trials.

Two trees, about 40cm DBHOB, were selected from a Sugar Gum plantation at Majorca (near Talbot) in Central Victoria. After falling, each tree was cut into three sections each 2.5 metres long (Fig 4.1). Each section was free of branches and was relatively straight.

The six logs were transported to the Timber Training Centre (TTC) Creswick (Fig 4.2). All logs were stored, in the TTC log yard, under water spray until required.

The logs were coded with the first letter of the common name and a consecutive number. These six logs were coded SG01 to SG06 being Sugar Gum and log number 1 to 6.

4.3.4 Circular Saw Sawing Specifications

The target size for materials used in the initial trials was 150 mm x 20 mm. Although 20 mm may not be a standard size for commercial use, this decision was based on the need to obtain a sufficient number of saw cuts to produce a statistically valid sample rather than the commercial value of the boards



Fig. 4.1: (left) Sugar Gum after cutting into sections.



Fig. 4.2: (right) Logs loaded on trailer.

A backsawn sawing pattern was used on Logs SG01, SG02 and SG04. Fig. 4.3 shows a typical backsawn sawing pattern, which was used on Log SG04. The recovered boards were numbered from 01 to 21 and prefixed by the log number (e.g. SG04/14).

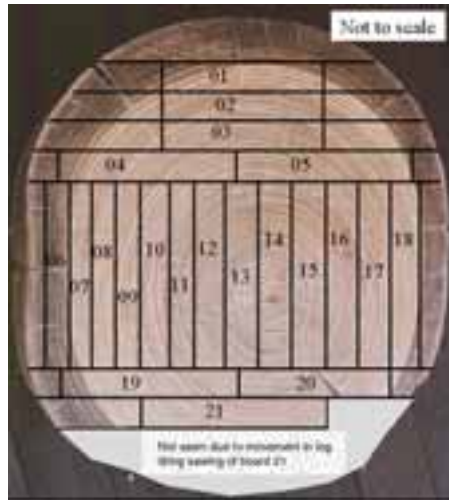


Fig. 4.3: Cutting layout for Log SG04, typical for backsawn boards on single blade circular sawmill.

Logs SG01 and SG02 were sawn with a 530 mm blade which had 4.5 mm wide carbide tips. This blade produced a width of cut or nominal kerf of 4.5 mm. Log SG04 was sawn with the 575 mm blade which had 6.0 mm carbide tips with a nominal kerf of 6.0 mm.

4.3.5 Bandsaw Sawing specifications

A Wood-Mizer LT15 horizontal bandsaw was used for initial bandsaw trials at the TTC. The measuring equipment and methods were as described in Chapter 3.

A new “Wood-Mizer Frozen Wood” blade was used to saw both logs used in this trial. The blade or band was 32 mm (1 ¼”) wide, 1.3 mm (0.049”) thick with a gullet depth of 4 mm (0.214”) and teeth spacing of 18 mm (0.886”). This blade was supplied by Wood-Mizer who stated that it was designed to saw frozen logs in North America and Europe.

The target size for boards sawn in these trials was 150 mm x 20 mm as discussed above. The same board and cut identification system was used as for the circular saw trials.

The first log (SG03) was sawn or ‘broken down’ in a pattern to produce a 150 mm wide flitch from the centre of the log with wide boards being sawn from each side of the log. The remaining 150 mm wide flitch was then sawn into 20 mm thick boards.

The second log (SG05) was broken down with two wide cuts to produce a 150 mm flitch through the centre then the ‘wings’ were re-sawn to produce 150 mm cants as shown in Fig. 4.4. These side cants were then sawn into the nominal 20 mm thick boards.

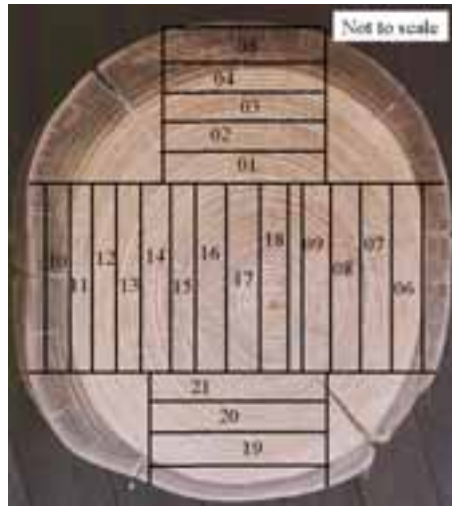


Fig. 4.4: Cutting layouts for Sugar Gum Log SG05, typical for backsawn boards on horizontal bandsaw.

4.4 Results

Using the Lucas Mill, Logs SG01 and SG02 were sawn to produce boards 50 to 200 mm wide. It was during this work that the problems of sawing wide boards, referred to earlier, became apparent. These problems relate to the sawblade climbing out of the wood and almost stalling the motor. Following this, Log SG04 was sawn to produce only 150 mm wide boards (Fig. 4.3 and Table 4.1).

Using the Wood-Mizer, Log SG03 was sawn to produce boards from 150 to 300 mm wide. In Log SG05, with a target board width of 150 mm, two cuts 400 mm wide were required to break down the log (Fig. 4.4 and Table 4.1).

The measurement of the two 400 mm wide cuts showed maximum and minimum deviations of +0.92, -0.83 mm and +1.19, -0.83 mm for the two cuts. This produced total deviations of 1.75 mm and 2.02 mm respectively.

Table 4.1: Number of cuts by width of cut in Logs SG01-05 and the type of mill used for the sawing.

Nominal Cut width (mm)	Sugar Gum Log Number				
	SG01	SG02	SG03	SG04	SG05
	Type of mill used				
	Lucas	Lucas	Wood-Mizer	Lucas	Wood-Mizer
50	1	1			
75		4			
100		6			2
125	2	2			3
150	11	6	14	22	23
200	2		3		
250			3		
300			1		
400					2

4.4.1 Lucas Mill - Straightness along 150 mm wide cuts

Straightness was assessed on the 150 mm cut face only of Logs SG01, SG02 and SG04, which were sawn using the Lucas single circular blade sawmill. Cuts were carried out in both the vertical and horizontal orientations and deviations were recorded.

Analysis of variance of the deviation from straight showed there was a highly significant difference between the logs ($p < 0.001$) and at positions along each log ($p < 0.001$) but not between vertical and horizontal cuts ($p = 0.017$) when using all three logs (Fig.4.5 and 4.6).

The average deviation along the logs for the horizontal cuts was slightly over 1.2 mm and for the vertical cuts it was 1.3 mm. These results appear to be within the 1.5 mm range, which is considered acceptable (Fig. 4.5 and 4.6).

When examining Log SG04 without including the first two logs, there was a highly significant difference in deviation in the straightness of cut between the cuts in the horizontal and vertical orientations ($p = 0.007$). There were nine horizontal cuts with an average deviation of 1.54 mm with five of these cuts above 1.5 mm deviation (Fig. 4.7). While the 13 vertical cuts had an average deviation of 1.09 mm only two of the cuts were above 1.5 mm (Fig. 4.8).

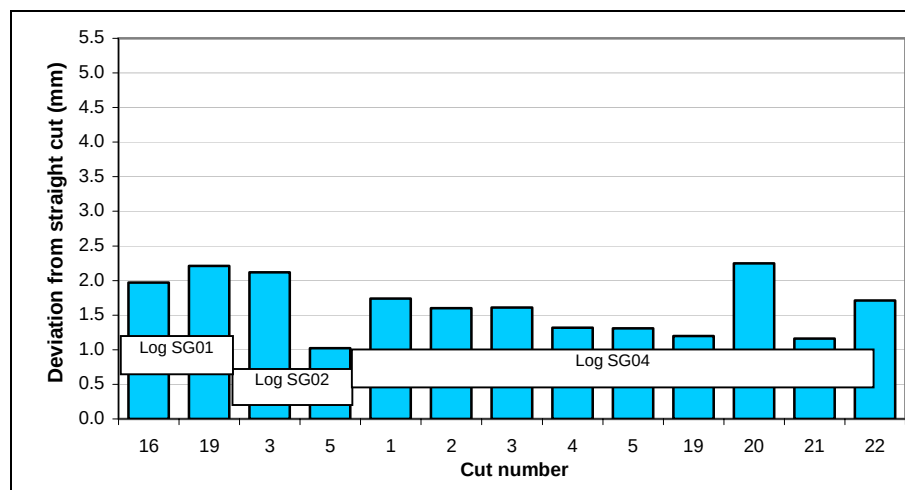


Fig. 4.5: The total deviation along each 150 mm wide horizontal cut in Logs SG01, SG02 and SG04.

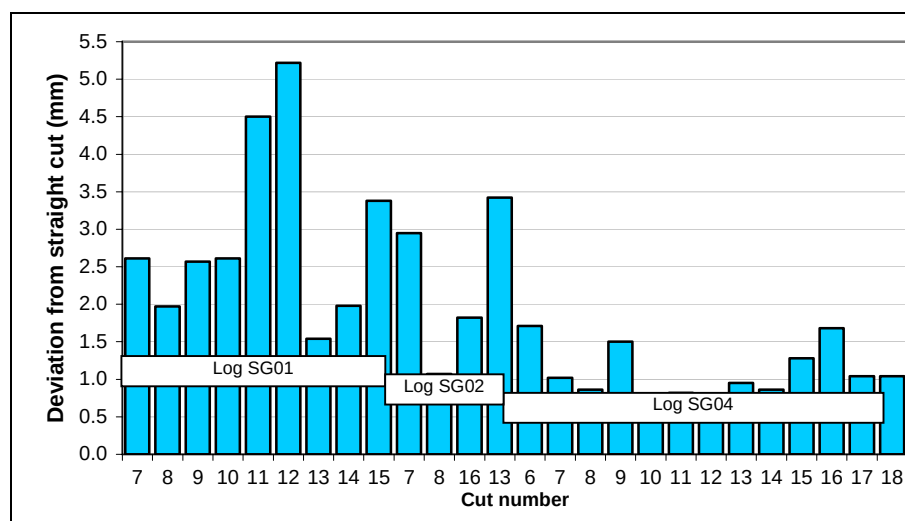


Fig. 4.6: The total deviation along each 150 mm deep cut vertical in Logs SG01, SG02 and SG04.

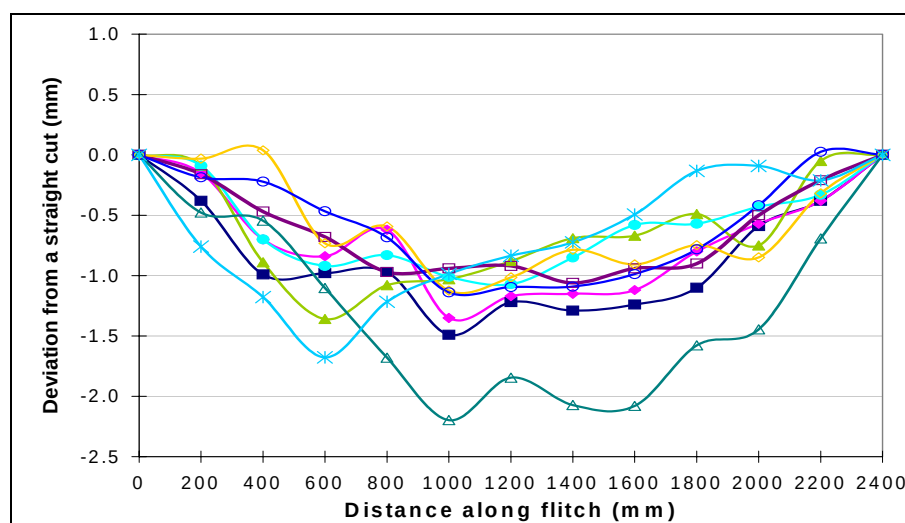


Fig. 4.7: The deviation and shape of horizontal cuts in Log SG04

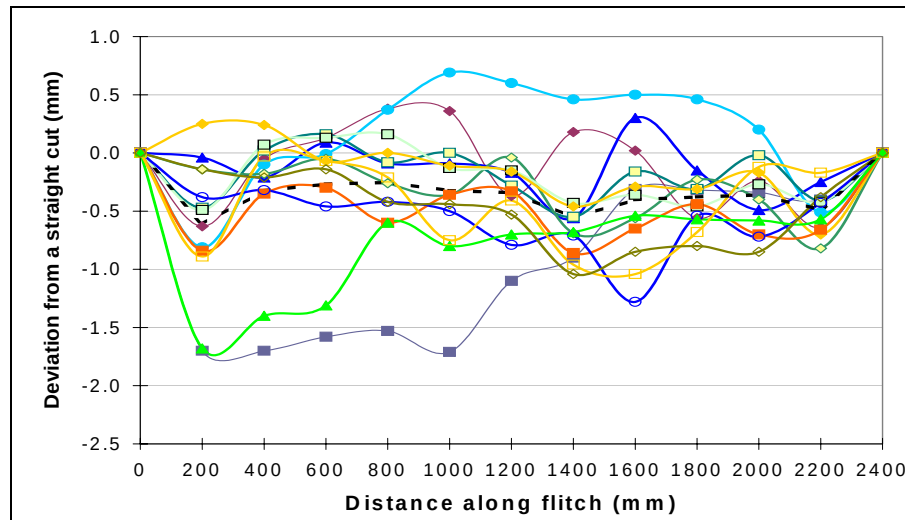


Fig. 4.8: The deviation profile of vertical cuts in Log SG04

4.4.2 Wood-Mizer - Straightness along 150 mm wide cuts.

The sawing deviations for the 150 mm wide cuts in Log SG03 are shown in Fig. 4.9.

Cuts1 and 5 showed a large deviation, Cuts2 and 4 were more than 1.5 mm while the remainder were clustered around a straight cut (0.0).

The speed of Cuts1-5 was between 2.01 and $2.95 \text{ m}\cdot\text{min}^{-1}$ with the average $2.48 \text{ m}\cdot\text{min}^{-1}$ and these produced four of the five cuts outside the acceptable tolerance of 1.5 mm.

The sawing deviations for the 150 mm wide cuts in Log SG05 are shown in Fig. 4.10.

After the initial breaking down of the log and cutting of the first five boards the blade was removed and sharpened. After Cut6 the same blade was used, without being sharpened, for Cuts7-23. There were large deviations in Cuts1-6, which are highlighted in Fig. 4.10. The remaining cuts (7-23) were within the set tolerance and showed only small variations in straightness (0.19 to 1.03 mm) measured along the cuts (Fig. 4.10).

Speed of cut for Cut1 was omitted in Log SG05, as it did not have a recorded time. The feed-speeds for Cuts2-5 were 2.01 to $2.95 \text{ m}\cdot\text{min}^{-1}$ and for Cuts7-23 feed-speeds were between 1.69 and $3.50 \text{ m}\cdot\text{min}^{-1}$.

When the blade was refitted after Cut5, Cut6 was faster, with a cutting rate calculated at $4.65 \text{ m}\cdot\text{min}^{-1}$ compared to an average of $2.42 \text{ m}\cdot\text{min}^{-1}$ for the previous four cuts. This cut wandered severely, finally diving 17 mm from the straight cut line, at the end of the flitch (Fig. 4.10). The final 'dive distance' was calculated by moving the blade back over the end of the flitch, measuring the distance from the cut surface to the underside of the blade then subtracting the blade set. This prompted a review of the measuring technique, which is discussed later in this Chapter.

Bandsaw blade tension was checked indirectly by using the load cell. The tension applied to the band blade by the Wood-Mizer tightening mechanism, as shown in Fig. 4.11, was 650 - 660 kg or 6.37 - 6.47 kN.

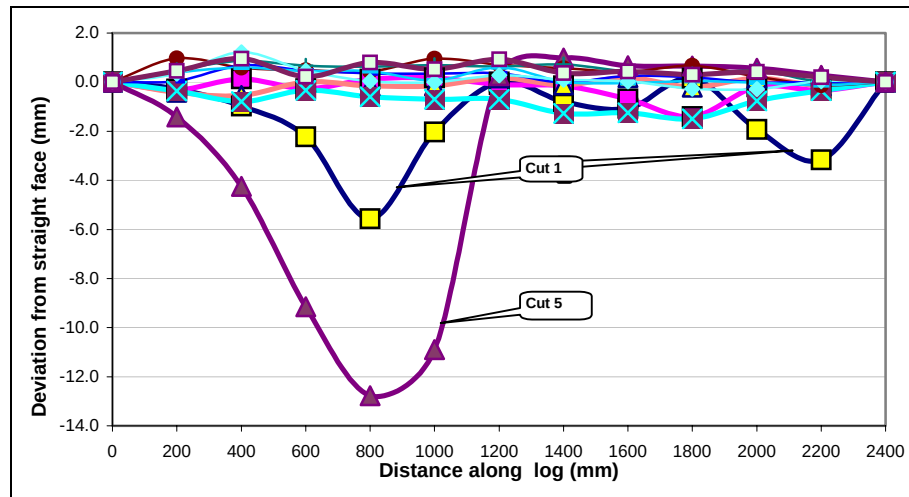


Fig. 4.9: The deviation profile of 150 mm wide cuts in Log SG03.

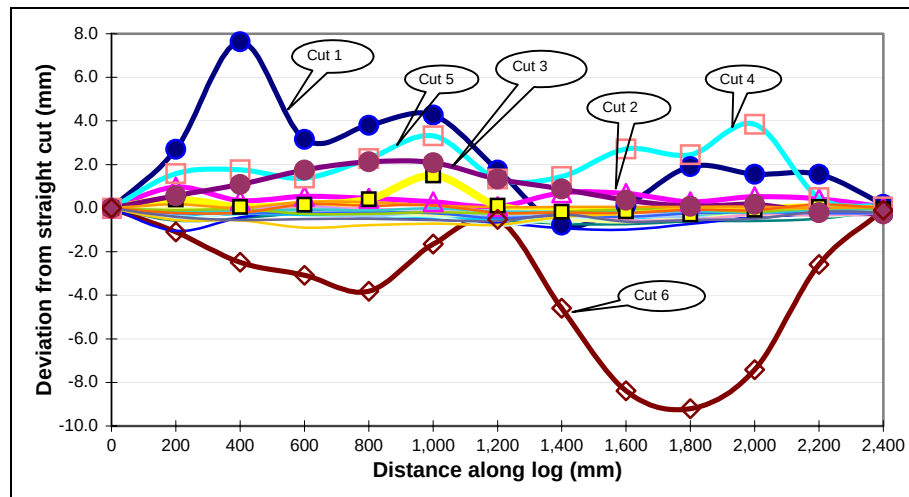


Fig. 4.10: The deviation profile of 150 mm wide cuts in Log SG05.

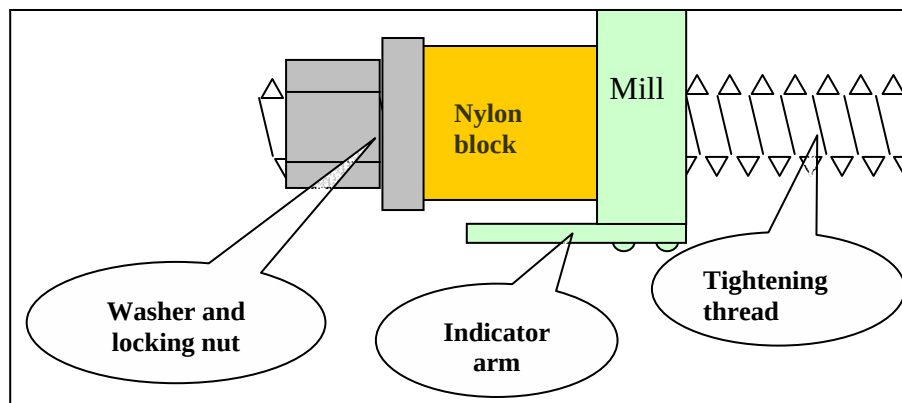


Fig. 4.11: Principle of the tensioning mechanism on Wood-Mizer horizontal bandsaw.

A short straightedge was used to align the washer and indicator on the tightening mechanism to ensure the same tension was applied each time. When the washer was 0.3 mm from the indicator, the tension was 50 kg or 0.47 kN below the final reading.

4.5 Discussion

4.5.1 Standardization of board size

Initial sawing with the single circular saw showed cuts over 150 mm to be unsuitable as the engine was not able to maintain the cut, the engine speed fell sharply, and the sawblade tried to exit the timber. This caused the mill frame to be pushed sideways as the blade tried to climb out of the cut i.e. cut at a reduced depth. The action of the blade pulling out of the log put a greater side force on the log and moved the log on the wedges. This process distorted the cut and ruined the board. The log was required to be repositioned and a new face cut to remove the damaged surface. Cuts greater than 150 mm can be obtained using a two cut method where the first cut is 100 mm, the saw carriage is returned and the depth adjusted to give a second cut 100 mm deeper than the first. This method was excluded from the trial as the second cut would affect the measurement of the first cut face thus the measurements would only be useful from one cut. It was decided that a 150 mm wide board would be the standard trial size cut from here on as both types of saw could produce material at that width in the high-density timbers.

4.5.2 Measurement Technique

The measurement technique showed a deficiency when the bandsaw blade dived at the end of Cut6 in Log SG05. The blade exited the cut 17 mm below the straight cut line. By placing the straight-edge on both ends of the cut surface, as was the procedure, the readings for deviation from the straight cut line would have been understated because the straight-edge would have actually been following the average line of downward movement of the blade over the length of the cut. The actual deviation therefore had to be measured by returning the blade over the flitch and measuring the distance from the face of the flitch to the underside of the blade. At the maximum deviation, around 1800 mm along the flitch, the deviation using the straightedge resting on the flitch was approximately 9.5 mm. After an adjustment for the 17 mm run off at the end of the flitch the maximum deviation was around 22 mm, almost 2.5 times greater.

This problem is highlighted in Fig. 4.12 which shows the difference in the measuring systems of:

- gauging of the flitch at both ends and
- gauging of the flitch at the start of the cut and the sawblade at the end of the cut.
- Following this experience, care was taken to assess whether the blade was exiting at higher or lower than the expected cut line. If this variation were greater than 5 mm, the end of the straightedge would be adjusted to allow of it. Any movement less than 5 mm would not show up in the precision of the measurements.

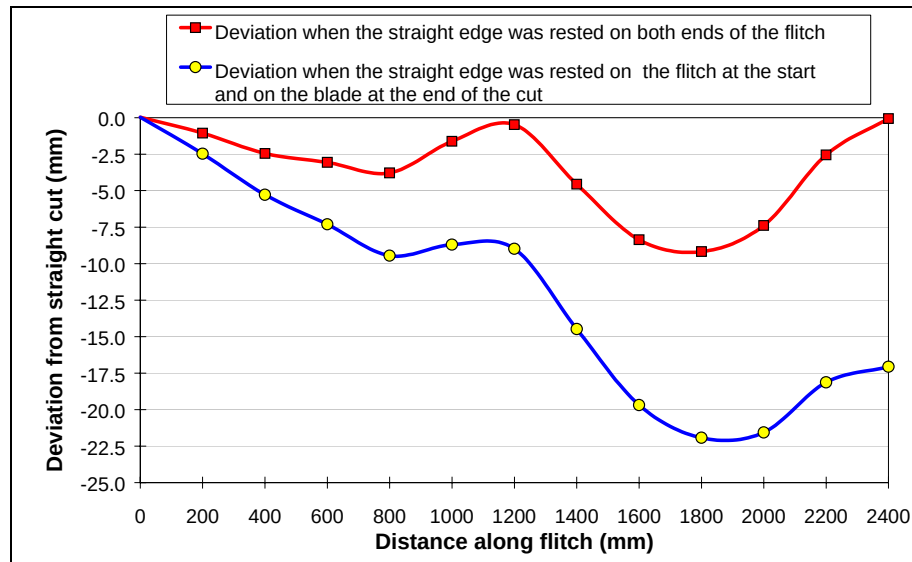


Fig. 4.12: Comparison of deviation measurements using the entry height as exit height and the exit saw cut (i.e. of the blade or of the flitch).

4.5.3 Straightness of cut using the single circular saw

The Lucas mill was set up with the vertical supports 5.4 metres apart. This was to allow for the milling long logs.

During sawing, deformation of Logs SG01, SG02 and SG04 occurred in the vertical direction. Deformation of logs was in the vertical direction due to the stresses being relieved from the top down. As each board was sawn, more internal stresses or compression was relieved at the centre of the log where the maximum deviation should have been encountered. The movement in the logs was 2.1 mm, 2.2 mm and 1.6 mm respectively. The release of stresses was so low that it was not considered large enough to affect the results in any single measurement because of the large number of cuts made.

As the initial sawing of Logs SG01 and SG02 did not have controlled speeds and only a few cuts were made at the 150 mm width the results for these logs should be excluded and Log SG04 used for any analysis. This assumption was supported when the deviations for the first three logs were combined, there was no significant difference between the horizontal cuts and the vertical cuts due to the very large variance in the deviation of the cuts. This was partly due to the trial not constraining feed-speed and the faster feed-speeds causing an increase in the deviation.

In Log SG04 there was a highly significant difference in the deviation along the log ($p < 0.001$) between the vertical and horizontal cut orientations. Deviations in the vertical cuts (Fig. 4.8) show a diversity of sawing lines with no particular pattern to the cuts. However, deviations in the horizontal cuts (Fig 4.7) show a consistent dip through the centre of the log. Individual cuts may vary from end to end but the differences between each cut are less than the vertical cuts.

The long span between supports may account for the movement in the sawing head and therefore the deviation in the horizontal direction due to gravity. However, there might also be a problem with the sawdust removal. Where the blade is unable to remove the sawdust it can build-up heat in the blade thus causing sawing problems (Quelch, 1977).

4.5.4 Straightness of cut using a horizontal bandsaw.

Discussions with experienced users of horizontal bandsaws indicated that there were several key factors influencing the accuracy of cut with this type of mill. In particular, blade tension, sharpness of the blade and the feed-speed of the sawing head through the log seemed to stand out. These were investigated, to varying degrees of intensity as opportunity provided, to gain some initial insight into how these factors need to be further analysed.

4.5.4.1 Blade tension

Although blade tension is considered an important factor in bandsaw blade behaviour, this could not be tested on the Wood-Mizer mill due to limitations placed on the study by the operators of the sawmill. The testing of the tension on the blade using the load cell showed a tension of 660 kg weight when tightened according to the manufacturer's specifications.

The calculated strain on the Wood-Mizer Frozen Wood blade was between 518 kg and 598 kg to obtain a tension of between 1830 and 2110 kg force per cm² (26000 and 30000 psi) which is the manufacturer's specified blade tension range.

The recommended method to tension the blade was to align an indicator arm with an outer face of the metal washer by screwing the tensioning handle as shown in Fig. 4.11. It was difficult to align the parts by eye and until a short straightedge was used, the correct positioning could not be determined. If the operators of a portable mill rely on the eye to align the critical parts then unpredictable variations could occur in the blade tension.

4.5.4.2 Blade sharpness

The cause and nature of saw dulling was not measured or tested in these trials. The process where a sawblade becomes blunt is a combination of many factors such as friction, heat, chemical reaction of acids in the wood and the fibre or wood structure. At this stage, it was not practicable to assess these factors although logically they would be expected to play an important part in the sawing process and deserve further investigation.

Blade sharpness was therefore considered a factor that could best be controlled in further trials by consistency in the amount of sawing work undertaken between each sharpening of the blade.

4.5.4.3 Feed-speed

Feed-speeds for the Wood-Mizer were based on the operator's hearing – noting that when the engine speed dropped the motor was heavily loaded, so less forward pressure was applied to compensate. This was not a satisfactory method to use for any quantitative comparisons.

Log SG03 (Fig. 4.9) was measured with the straightedge before the 10 mm blocks were fitted. The magnitude of the variations should be accurate while the $\pm$ measurement may not be a true representation of the actual direction of the variation. The first five cuts in Log SG03 were at a similar feed-speeds. Cuts1 and 5 (3.96 m·min⁻¹) had a large deviation in straightness while Cuts2, 3 and 4 (3.61 m·min⁻¹) had much lower deviations.

The remainder of the log (Cuts6- 11) was sawn with feed-speeds of 1.25 to 2.87 m·min⁻¹ and averaging 2.28 m·min⁻¹ and with a deviation of 1.50 mm for Cut10 being the only cut outside the acceptable range.

Figure 4.10 shows Cut6 in Log SG05 with a very large deviation from the centre of the cut to the end. The actual magnitude of the variation is not apparent until the 17 mm deviation from the blade to the log was calculated back along the cut as represented in Fig.4.12.

The remaining cuts (7-23) were with the same blade as for Cut6, which were well within tolerance and had very small variations in straightness.

The horizontal bandsaw mill appears to have a critical feed-speed. It appears that there is a speed above which the straightness cannot be maintained. The low power output of the motor (11 hp) is a limiting factor to maintaining engine speed, especially during heavy cutting work, but this could not be confirmed as the Wood-Mizer was not fitted with an engine rpm counter. The engine speed is used as an easy way of measuring the blade speed and are also references to a reduction in engine rpm also a reduction in the blade speed. It is understood that feed-speed and engine rpm or blade speed are directly related.

The balance of engine rpm and feed-speeds needs to be understood to determine their effect on the straightness of saw cut.

It may be suggested from these initial results that, for accurate cutting, the critical feed-speed difference may be very small. This means that an increase of only $0.35 \text{ m}\cdot\text{min}^{-1}$ in feed-speed above a maximum or critical speed, could be the difference between producing a cut with an acceptable or unacceptable tolerance.

The variability in the rate of which the handle was wound to move the power head along the carriage bed may cause variations in the feed-speeds. These variations would not be measured but would be averaged as the feed-speed was derived by using the total duration of the cut and the flitch length. Any changes in the cutting rate along the flitch would be averaged out.

Chapter 8 explores the feed-speed of cut in more detail.

4.6 Conclusion

These were initial trials designed to achieve two broad outcomes:

- to test the measuring equipment and evaluate the analytical process
- to establish the parameters that affect cutting accuracy in each type of mill and how these might be quantified for detailed analysis

The results indicate that there are differences between the two types of saws in terms of their ability to saw accurately although the features that affect each are specific to the saw type. However, both the single circular blade sawmill and the horizontal bandsaw portable mill used in this initial trial produced the majority of cuts within an acceptable tolerance of 1.5 mm. The research now needs to examine the factors that are causing a minority of cuts to be unacceptable.

4.6.1 Measuring equipment

Suitability of cut was determined by the magnitude of deviation from a theoretical straight cut line which was represented by a straightedge.

The measuring technique, using a modified straightedge and callipers, appeared to give a good representation of the deviation along the cuts. Care needed to be taken to ensure the exit blade height was the top of the cut face. If the blade dived at the end of the cut, the straightedge needed to be lifted to the straight cut line i.e. the underside of the blade.

A tolerance of 1.5 mm total deviation was considered the maximum deviation or variation in straightness of sawn face that would be considered acceptable to meet a desired straightness in sawing in high-density timbers.

4.6.2 Single circular saw

With the single circular blade sawmill, the maximum cut depth obtainable in one pass in Sugar Gum was 150 mm. All subsequent sawing was based on a maximum cut width of 150 mm.

The single circular sawmill saws in both the horizontal and vertical blade orientations. The final Sugar Gum log produced horizontal cuts with a mean deviation of 1.54 mm. These were not as straight as vertical cuts with a mean deviation of 1.09 mm.

The first two Sugar Gum logs showed no differences in straightness between the blade orientations but the spacing of the support frame was greater than acceptable for the log length and allowed excessive side movement.

4.6.3 Horizontal bandsaw

In these initial trials, the only parameter tested in any way was feed-speed – and this was more by default than by controlled trial i.e. the feed-speed was determined after the event rather than being set beforehand. While feed-speed showed up in these trials as possibly being the most critical factor, that would seem to be more an artefact of the nature of the trial where there was less than satisfactory control over the testing of the various parameters. However, logic would suggest that other features pertaining to the sawblade have to be right first before feed-speed can be considered. At this stage it was not possible to draw solid conclusions on feed-speed other than to say it was an obvious factor that should be further investigated once the blade conditions required for accurate cutting are determined.

With blade tension, no conclusions could be drawn from the trials thus far. However, experience from other users and advice from bandsaw manufacturers suggests that blade tension were also very important. A technique has been devised for predicting or estimating blade tension and this needs to be further tested.

Other blade configuration parameters such as set and hook angle were considered to be issues relevant to the successful milling of high-density timber and require further investigating.

4.6.4 Uncontrollable factors

There is also uncontrollable variability within and between logs in terms of moisture content, density and hardness. These three factors are features of the wood or log, which cannot be changed. They have been discussed in Chapter 3.

The critical issue is to understand if the variability inherent within logs will adversely affect the sawing and if one particular sawblade can handle all the uncontrollable variables. To this end, all necessary data were recorded to allow for possible future analysis.

The future trials were directed toward finding the blade parameters that would produce the straightest cut in a range of high-density timber species.

5 Circular Sawmill – Sawing depth, Tip width and Species

5.1 Introduction

The decision in the earlier chapters to saw all boards to 150 mm wide is actually outside the Lucas Mill manufacturer's recommendation with respect to horizontal cuts. In the owner's manual, it states; 'horizontal cuts larger than 100 mm are generally best done in two successive passes'. This raised the question: 'What width cuts are required to saw high-density species?'

As operators of portable mills try to increase production and productivity, they begin to explore methods to reduce waste and increase sawn recovery. One of the methods used by industry to increase sawn recovery (i.e. the volume of sawn timber as a percentage of the volume in the original log) is to reduce the thickness of the blade therefore reducing the amount of sawdust removed with each saw cut. This sounds great in theory but there is a point where the blade becomes too unstable to sustain a straight cut. There appears to be no scientific research into different width carbide tips on blades to saw any species, let alone the difficult-to-handle high-density species, and what effect these blades have on the straightness of cut.

5.2 Aim

There were two separate aims to these trials:

- Firstly to quantify the effect of the depth of cut and blade orientation on the straightness of cut for a 'Lucas' single circular saw-blade portable mill
- Secondly to determine the straightness of cut in four species of high-density hardwoods that are commonly grown in the low rainfall zone or are suitable for that region (Sugar Gum, Yellow Gum, Brown Mallet and Swamp Yate) using four different width tips (4.5 mm, 5.0 mm, 5.3 mm and 5.7 mm) on a 'Lucas' single circular saw-blade portable mill.

5.3 Materials and methods

The logs and mill were set up in the method discussed in Chapter 3.

For all trials using the Lucas mill the sawblade was pushed through the flitch so that engine speed was kept as close as possible to 3500 rpm. As the engine speed dropped below 3500 rpm, the forward pressure being applied by the operator on the saw carriage was eased i.e. the carriage was pushed slower while attempting to keep the carriage moving forward at all times during the cut. This meant the speed along the cut did vary slightly but it was not a stop-start sawing action. Conversely, as the speed increased above 3500 rpm, the speed the carriage was pushed through the cut was increased until engine speed dropped back to 3500 rpm.

A brief investigation on the use of water on the sawblade was performed and on the blade temperature during cutting. These were not extensive and are included in the discussion later in this chapter.

5.3.1 Effect of blade orientation and cut depth on straightness of cut

For this part of the trial only Sugar Gum was used – which was obtained from the Majorca plantation.

The log was sawn using a standard five tooth Lucas blade with a nominal tip width of 5.4 mm. This blade size is considered a standard size general-purpose blade and is supplied with the saw.

Sawing was carried out generally in a backsawn pattern at 75, 100 and 150 mm depths with the blade in the horizontal orientation and at 75 and 150 mm with the blade in the vertical orientation. The choice of three horizontal width cuts was to examine the combination of two 75 mm cuts against one 150 mm cut for both average time and straightness of cut, then with the 100 mm cut to compare its straightness with the 150 mm to see if the manufacturer's literature is correct (Lucas 1999).

The average time was calculated from the actual sawing time for one cut and the length of the log to calculate the number of metres of cut that can be sawn per minute (m.min^{-1}). With these calculations there was no allowance for the non-productive return walk between successive cuts which is required when sawing multiple width cuts.

5.3.2 Effect of blade thickness on straightness of cut for different species

For this part of the trial, the four species were used. The sample logs came from the batch from Western Victoria (Wimmera region).

For each species six vertical and six horizontal cuts were made for each of the four blade thicknesses – a total of 48 cuts required for each species.

Due to the small diameter of some logs (235 to 315 mm small end diameter), three logs were required to obtain the required number of cuts in Brown Mallet, Sugar Gum and the Yellow Gum. For Swamp Yate only two logs were required as the diameter of the logs was slightly larger (320 and 410 mm small end diameter).

A blade of diameter theoretically capable of making a 215 mm deep cut was used for each blade tip width.

Figure 5.1 shows a Swamp Yate log set up for sawing. The marks on the end show the sawing pattern that was followed. The heart in the centre of the log are boxed out and both vertical and horizontal cut orientations 150 mm wide or deep have been shown.

The target size for boards was 150 x 5 mm for the trial using the various tip width blades. This board thickness was chosen simply to maximize the number of cuts that could be made from the limited resource. In the third log, thicker boards were sometimes cut if the amount of timber available allowed. These thicker pieces up to 30 mm by 150 mm were used for drying trials separate to this project.



Fig. 5.1: A Swamp Yate log that has been sawn with horizontal cuts and is ready for measurement.

5.4 Results

5.4.1 Variation in saw tip widths

The stated tip widths, or thicknesses, of the blades are, in some respects, nominal terms. It was found that thickness does vary slightly. Measurements were taken both before any work is carried out and after sharpening.

The blade used for the first part of the trial, the 5.4mm blade, had actual tip widths of 5.33, 5.39, 5.37, 5.33 and 5.36 mm. After sharpening the blade twice, the widths of carbide tips were 5.34, 5.33, 5.30, 5.33 and 5.33 mm. The average reduction in tip width was 0.03 mm – or approximately 0.015 mm per sharpening. This reduction in width is not considered important as it is well below the level of precision used for straightness of cut measurement.

Similarly, blades used for the second part of the trial had tip widths as follows:

- Nominal 5.7 mm – actual average 5.67 mm then 5.63 mm after one sharpening.
- Nominal 5.4 mm – actual average 5.36 mm to 5.33 mm after two sharpenings and 5.3 mm after use by other operators between the two sections of this trial.
- Nominal 5.0 mm – actual average 4.86 mm, 4.85 mm and 4.84 mm after sharpening on three consecutive occasions.
- Nominal 4.5 mm – actual average 4.44 mm with no recorded difference after one sharpening.

The blades were not measured after every sharpening. These are the measurements taken toward the end of the trial.

5.4.2 Various width and depth of cuts

There was a statistically significant difference in the deviations from straight ($p = 0.027$) between the vertical cuts with the 75 mm deep cuts straighter than the 150 mm deep vertical cuts. The means and standard deviations are shown in Table 5.1 and Fig. 5.2.

There was no significant difference in deviation from straight between the 75 mm, 100 mm and 150 mm wide horizontal cuts. The means and standard deviations are shown in Table 5.1 and Fig. 5.2.

Table 5.1: Mean, standard deviation and number of samples in the deviation in straightness for different depth vertical and horizontal cuts in Sugar Gum.

Size and direction of cut	Mean	sd	n
75 mm vertical	0.85	0.27	6
150 mm vertical	1.15	0.26	15
75 mm horizontal	1.02	0.28	16
100 mm horizontal	0.89	0.16	24
150 mm horizontal	0.93	0.17	9

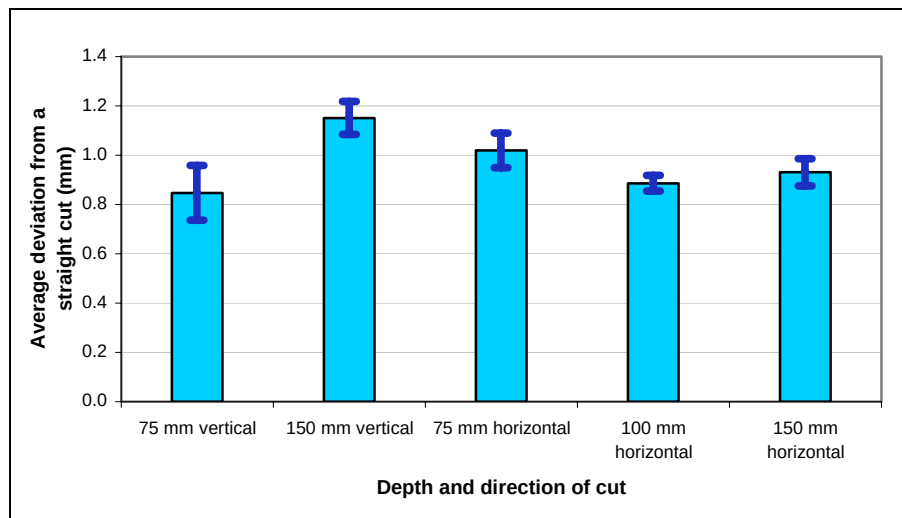


Fig. 5.2: Deviation from a straight cut from different depth cuts for both horizontal and vertical directions in Sugar Gum log. The bars = Standard Error (S.E.).

5.4.3 Effect of various width and depth of cuts on sawing speed

The Lucas owner's manual suggests that horizontal cuts over 100 mm wide should be made in two passes (Lucas Mill Pty Ltd, 1999). It was considered that this could have an effect on sawing speed.

For a combined depth of two 75 mm vertical cuts, one above the other, to produce a 150 mm deep cut, the actual sawing time, excluding set up and the return walk times, averaged 2.8 m.min^{-1} . This was made up of a first cut at an average speed of 6.0 m.min^{-1} and a second cut at an average of 5.2 m.min^{-1} . This compared to a 150 mm deep cut in one pass at an average of 2.9 m.min^{-1} . The single 150 mm pass was actually 3.2% faster but not

significantly different than the total sawing time for the combined double 75 mm vertical cuts whose processing time excluded the non-productive return time between cuts.

Similarly, the average of the first horizontal cut was 6.0 m.min^{-1} and the average of the second cut was 6.6 m.min^{-1} . This gave a mean average feed-speed, for the 75 mm cuts combined, of 3.5 m.min^{-1} . The average feed-speed for a 150 mm cut in a single pass was 3.3 m.min^{-1} . The single 150 mm wide cut was actually 5.4% slower but not significantly different than the total sawing time for the combined double 75 mm horizontal cuts. As for the vertical cuts these times exclude the non-productive return time between cuts which must be included to get accurate feed-speeds or a production rate.

5.4.4 Varied species, tip width and blade orientation

When combining all cuts and examining the different sawing orientation there was a very highly significant difference in the straightness of cut between the vertical and horizontal orientated cuts ($p < 0.001$). The mean deviation of the horizontal cuts was 1.57 mm while for the vertical cuts the mean deviation was 0.91 mm (Fig.5.3).

Analysis of the deviation of all cuts against the four different species showed there was no statistical difference ($p = 0.203$) in straightness of cut between species (Fig. 5.4).

Figures 5.5 and 5.6 show the deviation for the vertical cuts and the horizontal cuts respectively by species. There was no significant difference in the deviation in the vertical cuts between species. For the horizontal cuts, there was a significant difference ($p = 0.034$) with the mean deviation of Sugar Gum (1.79 mm) higher than all the other species whose mean deviations were less than 1.49 mm.

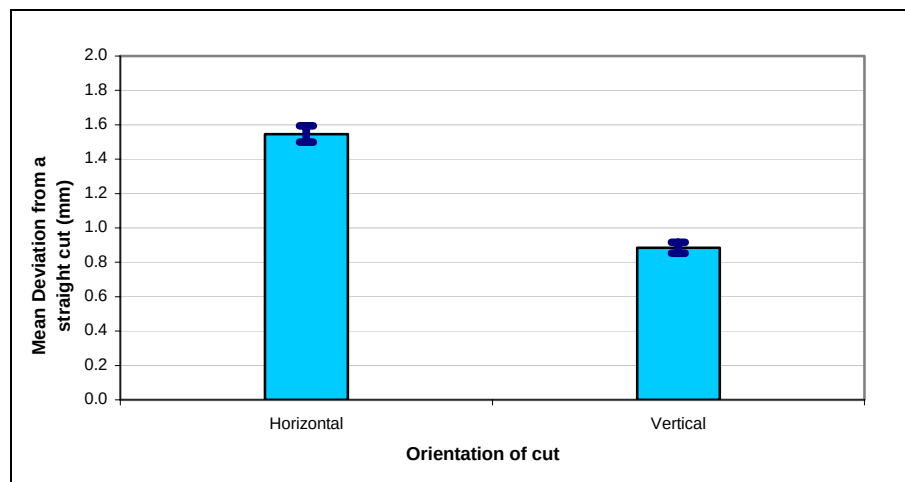


Fig. 5.3: Straightness of cut against total vertical and total horizontal cuts with all species combined (bars = S.E.).

The number of cuts that were within the acceptable tolerance for the cuts in the vertical orientation was 93 out of 96 total cuts. For the horizontally orientated cuts, only 52 out of the 96 cuts had a deviation of less than 1.5 mm (Table 5.2).

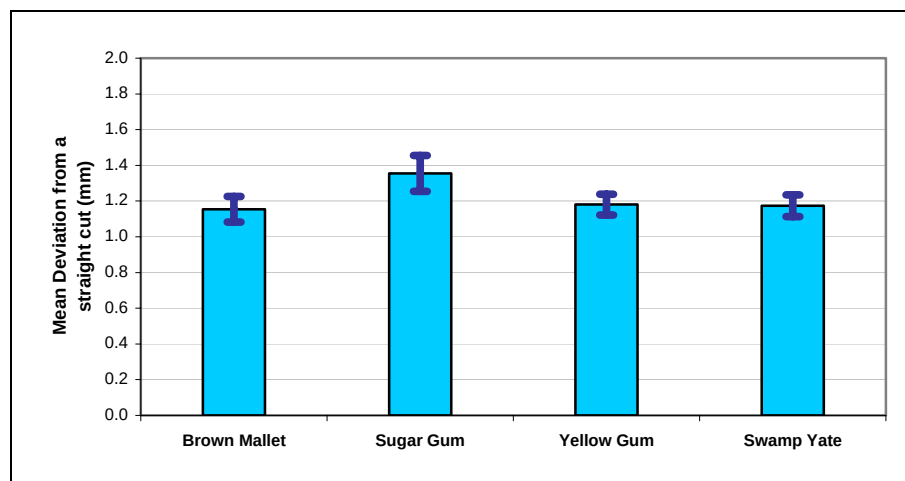


Fig. 5.4: Deviation from a straight cut for combined saw tip width by species (bars = S.E.)

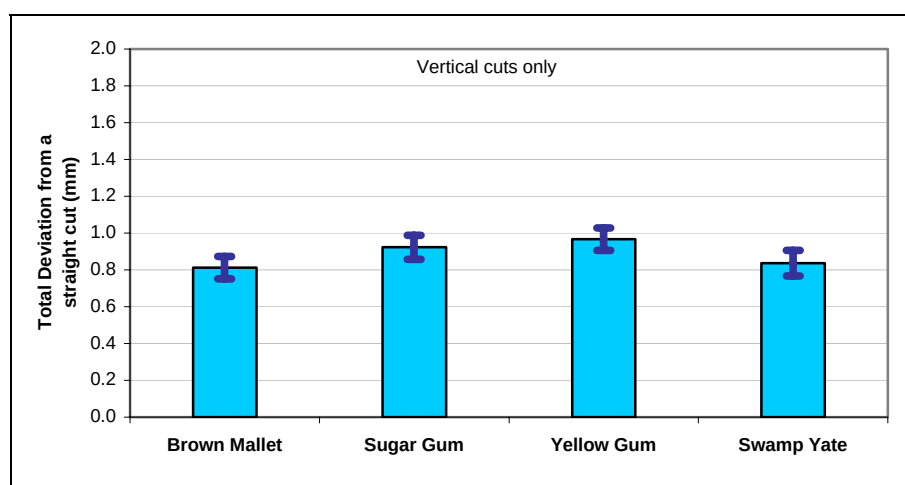


Fig. 5.5: Deviation from a straight cut for vertical cuts only by species (bars = S.E.).

Analysis of the mean deviation of all cuts by the four different blade tip widths, showed no significant difference ($p = 0.061$) (Fig. 5.7).

Analysis of the straightness of cut for the horizontal cuts while using the four different blade tip widths revealed there was a very highly significant difference ($p < 0.001$). The 4.5 mm blade produced significantly more deviation in the cuts than did the 5 mm and the 5.7 mm blades. There was no significant difference between the 5 mm and 5.7 mm tip width blades. The 5.4 mm tip width blade produced cuts with a lesser deviation than the 4.5 mm tip width blade but more than the 5 mm and 5.7 mm tip width blades (Fig. 5.8).

Table 5.2: Number of 150 mm cuts by species and saw orientation that are within or outside the 1.5 mm deviation tolerance.

Species	Blade orientation	Less than 1.5 mm	Greater than 1.5 mm
Brown Mallet	Horizontal	14	10
	Vertical	23	1
Sugar Gum	Horizontal	12	12
	Vertical	24	0
Yellow Gum	Horizontal	10	14
	Vertical	23	1
Swamp Yate	Horizontal	16	8
	Vertical	23	1

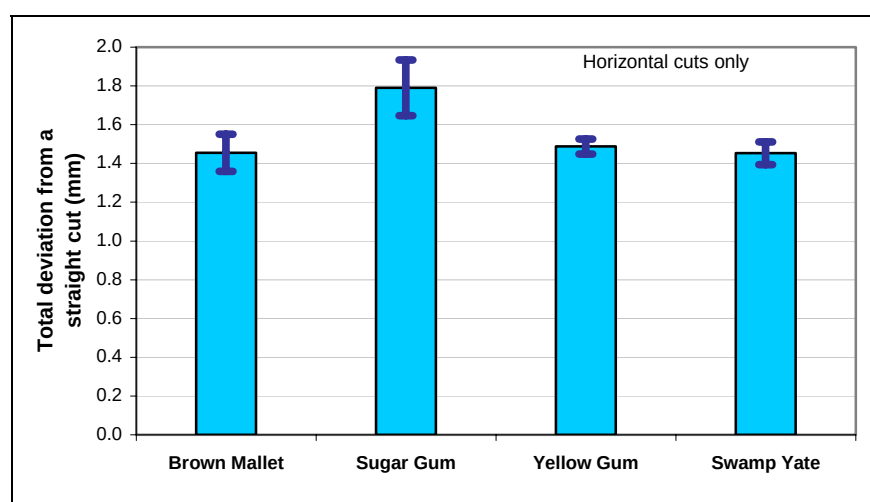


Fig. 5.6: Deviation from straight for horizontal cuts only by species (bars = S.E.).

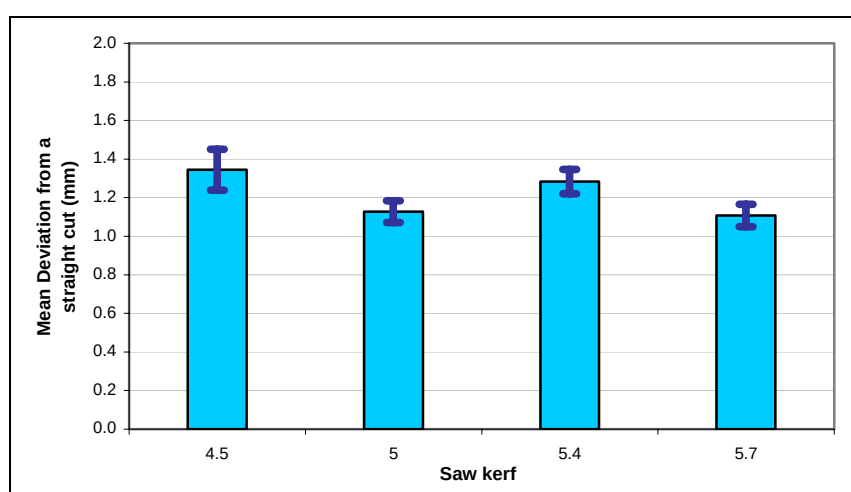


Fig.5.7: Deviation from straight cut for combined horizontal and vertical orientation by width of saw tip (bars = S.E.).



Fig. 5.8: Deviation from straight cut for cuts in the horizontal orientation by saw tip width (bars = S.E.).

Analysis of the deviation of vertical cuts against the different blade tip widths revealed there was no statistical difference in the straightness of cut (Fig.5.9).

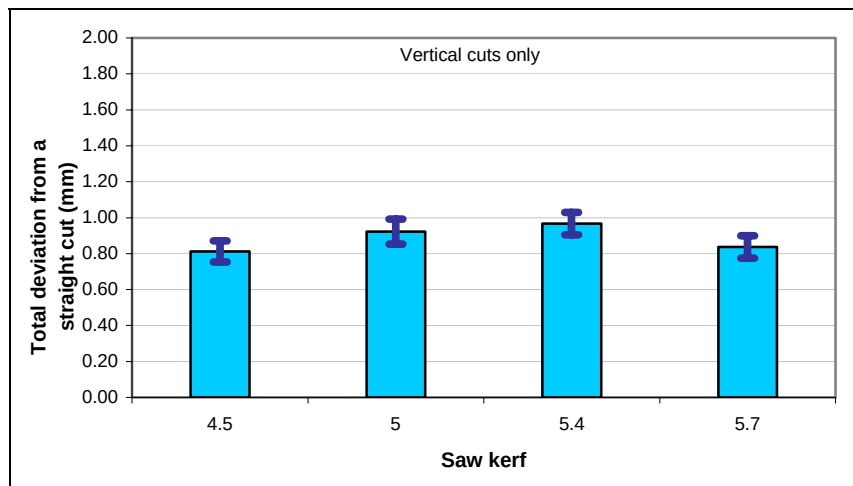


Fig. 5.9: Deviation from straight cut for cuts in the vertical orientation by saw tip width (bars = S.E.).

5.5 Discussion

5.5.1 Blade orientation and cut depth

There was a significant difference between the straightness of cut in the vertical and horizontal orientation. The horizontal cuts averaged 1.57 mm deviation which is above the acceptable limit while the vertical cuts averaged 0.91 mm. This could be explained by the sawdust being trapped under the blade in the horizontal cut and not being fully removed in the gullet of the sawblade as with the vertical cuts. This sawdust build-up or spillage causes heat in the blade and can even produce a physical distortion of the blade if it is allowed to continue.

The problem of sawdust entrapment is why the sawmill manufacturer suggests a maximum of 100 mm horizontal cut in one pass. When undertaking a double depth cut the sawblade will remove the first 100 mm of wood and even though the second cut is at a depth greater

than 100 mm there is less sawdust being removed and therefore less spillage of sawdust around the blade and into the clearance between blade and timber (Fig. 5.10-5.11).

This saw dust spillage might be a bigger problem in species with a high sawdust expansion factor, where the sawdust expands as the saw tooth removes the wood into the gullet.

The double cuts were difficult to achieve in the vertical orientation (Fig. 5.12-5.17). The nature of the Lucas Mill did not make it easy to carry out two consecutive vertical cuts exactly aligned above each other. The mill is designed for fast movement in a horizontal direction while doing either a vertical or a horizontal cut and then the lowering of it requires the turning of the handles on the side poles. This is not as accurate as the sideward movement of the power head in the frame.

To test this, four vertical cuts were made 10 mm apart. The frame was then lowered and reset to give a cut directly below the previous cuts. The lining up of the cuts was very difficult, as shown in Fig. 5.13, 5.15 and 5.17. The vertical offset at the start of the cuts was acceptable i.e. very little difference, but along the cut there was up to 1.6 mm difference in the widths. This would make this form of sawing unacceptable and above the tolerances acceptable for the high-density timbers. It should also be noted that it was not significantly faster to do the two cuts compared to one cut and especially if the return and set up time was included then it would be significantly slower doing the double vertical cut to get a 150 mm deep cut. This may be necessary if cuts greater than 150 mm are required. In the initial trials, a 200 mm deep cut could not be produced due to the blade bogging into the timber and jamming the saw.

The deeper of the double 75 mm vertical cut did show a significantly straighter cut than the 150 mm vertical cut but this did not allow for the step in the finished faces shown in Fig. 5.13, 5.15 and 5.17. This step in the face was actually greater than the deviation along the cut therefore the double vertical cuts require at least as much machining or planning to produce a smooth face as the single 150 mm cut.



Fig. 5.10 (left): Sugar Gum log with double 100 mm wide horizontal cut showing a step in the face.



Fig. 5.11(right): Close-up of fig. 5.10 showing teeth marks on cut face.

Some saw vibration was observed during the horizontal cut and the saw carriage and frame would oscillate in a sideward direction. On several occasions, the logs moved during sawing even though they were wedged into position. This was more noticeable with the smaller diameter logs and was overcome by recessing the bearer rather than through the use

of wedges, which was an alternative method, suggested in the Lucas owners manual (Lucas Mill Pty Ltd, 1999).

The trial showed there was no significant difference in the cutting straightness between the 75 mm and 150 mm horizontal cuts ($p = 0.097$) and no saving in time. These results, although true and accurate may not be representative for all logs. While demonstrating the sawing of Sugar Gum at a field-day held in Lismore during September 2001, the author, using the same Lucas mill as in the trials was unable to saw a 150 mm wide horizontal cut. The saw became very hard to push and was inclined to pull back into the saw cut. The sawblade was backed out of the cut a little distance and when the sawing re-commenced the same problem reoccurred. The depth of cut was reduced to 75 mm and the sawing continued without a problem. The subsequent 75 mm cut to get the final 150 mm depth also had no problems. The resultant board showed steps in the face where the blade had dived and then straightened after the blade was backed out of the cut.



Fig. 5.12 (left): Two 75 mm vertical cuts. Photo taken before the horizontal cut.



Fig. 5.13 (right): Face of timber showing double cut.



Fig. 5.14 (left): Cut log after removing 5.12.



Fig. 5.15 (right): Face of timber.



Fig. 5.16 (left): Second last cut of double depth sawing trial.



Fig. 5.17 (right): Face of timber and face of removed board.

The logs were only sawn until the remaining section was heavy enough to keep the piece from moving. In many cases, the section remaining could have produced additional boards if the section was turned over with the flat face on the bearers. The saw would require re-levelling to be parallel with the bearers rather than parallel with the pith. By setting the horizontal cut and raising the saw to produce the final cut at the desired board thickness above the bearers additional boards can be sawn.

5.5.1.1 Blade temperature

Sawing was carried out for this trial in June 2000. The temperature of the wood surface was 7.5°C. An attempt was made to measure the temperature of the blade during the sawing process using an infrared remote thermometer. The blade temperature rose to 24°C during a cut when no water was used. When water was used, the temperature did not increase greater than 7°C. It could be that this rise should not be sufficient to affect the sawing straightness of cut since ambient temperatures far in excess of 24°C could be encountered in mid summer.

5.5.1.2 Blade lubrication

Water is used as a lubricant and to reduce gum build-up on the blade. Although not quantified, after sawing a few boards without water on the blade the amount of force required to pull the blade increased and the cutting speed also reduced i.e. it was harder to pull and slower to cut. Although cutting straightness was not outside the acceptable range it could be assumed that if the build-up continued it is envisaged that the straightness of cut would have been affected. This is consistent with the literature and experience of portable sawmillers (Lucas Mill Pty Ltd, 1999; VTITC, 1999).

5.5.2 Blade tip width and species

The horizontal cuts were not as straight as the vertical cuts in all species and using any blade. This is consistent with the widely held belief on sawdust spillage from the gullet. This causes heating of the blade at the outer edge, which in turn causes the blade to stretch slightly around the outside. The subsequent distortion at the outer edge causes a lack of straightness in the cut. Over 95% of the vertical cuts were within the acceptable tolerance. This shows the greatest problem with cutting straightness is the orientation of the blade rather than the tip width or species.

All blades had the same thickness in the body of the blade but the carbide tip width varied. The narrowest tip width blade (4.5 mm) was the worst performing in the horizontal orientation with the least straight cuts while there was no difference in vertical cut straightness in any of the different tip widths. The narrower tip width might suggest the blade was thinner but this is not correct, as the blades were all the same thickness and the only difference was the distance from the blade face to the timber surface. The narrower tip width blades had less clearance and therefore less volume to accumulate any sawdust spillage.

This could be where the Carbide-tipped tooth and a large gullet produces small sized sawdust that does not stay in the gullet but can get under the sawblade and cause a movement in the blade. Figure 5.11 shows the marks and an irregular surface. This was most likely the result of the blade oscillating or vibrating during the cut. This effect was apparent to some extent in the vertical cuts shown in Fig. 5.13, 5.15 and 5.17 but not to the extent as with the horizontal cuts.

Figure 5.19 shows a vertical cut where the board was cut away after the blade had stalled in a cut. The fine sawdust can be seen building up in the gullet. This may well be the same type of sawdust that would have been spilling from the gullet in a horizontal cut and causing the deviation problems.



Fig. 5.18: Tooth in timber showing removal of sawdust.

There was very little difference in the straightness of cut between the four species except in the horizontal cuts where the Sugar Gum was not as straight as the rest of the species.

The 5.4 mm tip width blade did not perform as well as the 5.0 mm or the 5.7 mm. There is no obvious explanation for this other than it may be a problem with the blade i.e. out of round or a distortion in the blade due to overheating. The results of the earlier trial reported in this chapter showed good results using a 5.4 mm blade in Sugar gum and are not consistent with the later findings. Without greater investigation of the 5.4 mm blade and multiple comparisons using a number of blades, it would not be advisable to discard the 5.4 mm blade as a suitable blade for sawing high-density timbers.

Following the completion of this project some of the blades used were returned to the blade manufacturer for re-tipping as they were damaged on nails buried in logs. Discussions with the saw doctor about the results of this trial led to the revelation that the new blade obtained for this trial did not have tension hammered into the blade. The lack of blade tension will cause the outer edge of the blade to flutter during sawing which may account for the poorer results for the 5.4 mm wide blade.

5.6 Conclusion

These trials suggest that single circular blade sawmills using five-tooth circular sawblades with tip width of 5.0 mm or 5.7 mm are capable of producing straight cuts (within a 1.5 mm tolerance) in the vertical orientation while only half the horizontal cuts would be within 1.5 mm of straight in high density hardwood species.

While the literature claims the use of a multiple depth cut when sawing in the horizontal orientation will increase straightness, this was not found to be the case during these trials. These trials showed there was no difference in the feed-speed using multiple depth cuts (up to 150 mm). There was an effect in the vertical orientation with the double shallower cuts significantly straighter than the single deeper cuts but the setting up of the cuts was very time consuming and would be uneconomical in a production operation. The step that occurred in the cut face with the double depth cuts was greater than the deviation in the single deeper cuts.

Although the results show no difference in the straightness of the double shallow and single deeper horizontal cuts it may be a feature of the logs used rather than a principle to be applied. Operators should keep this in mind if they are having problems when sawing in the horizontal orientation using a single circular blade sawmill.

6 Horizontal Bandsaw – blade configuration

6.1 Introduction

Following the relative success of the initial trials using the Wood-Mizer horizontal bandsaw, further, and more detailed, investigation of the applicability of a horizontal bandsaw for processing dense hard timbers was considered warranted.

Such further investigation required more detailed quantification of parameters that relate to the sawblade itself, such as hook angle, tooth set and blade tension, as well as operational aspects relating more to the mill itself such as feed-speed and engine speed. The former issues are dealt with in this trial whereas the latter are dealt with later.

The issues of tooth set and hook angle are completely transferable from the Wood-Mizer to other horizontal bandsaw mills – these parameters are related to the sawblade and can be altered regardless of the mill on which the blade is used. The main consideration relates to blade tension which is considered sufficiently important to warrant special mention.

Blade tension, or the force that was applied to a bandsaw blade, was considered critical to its performance. Blade manufacturers state an optimum force for the tensioning of bandsaw blades of 172 to 202 MPa (25,000 to 32,000 psi), which is the force applied divided by the area of the cross section of the blade (Thomas, pers. comm.; Wirth, pers. comm.).

Since the Wood-Mizer and Laidlaw ‘Farmill’ have different methods for applying tension to the band it was necessary to find out exactly what tension was applied to the blade when the different screw mechanisms were tightened on one and then apply that to the other mill. The Wood-Mizer uses the compression of a nylon block to indicate blade tightness as described in Chapter 4. On the ‘Farmill’, the only indication of the amount of torque being applied to the tightening nut is from the torque wrench supplied with the mill which is of questionable accuracy and does not have high precision. For this reason, a method had to be devised to accurately quantify sawblade tensions on the Laidlaw ‘Farmill’.

6.2 Aim

The aim of this trial was to compare the effects of varying the hook angle, tooth set and blade tension, while maintaining blade sharpness, on the prescribed standards of cutting accuracy applied in the Section 4.2.2 i.e. 1.5 mm total deviation from the straight cut line.

6.3 Materials and methods

6.3.1 Mills

For this trial, for reasons of availability, a Laidlaw ‘Farmill’ had to be used in place of the Wood-Mizer used earlier. The ‘Farmill’ was set up in similar fashion to the Wood-Mizer as described in Chapter 3.

6.3.2 Logs

This trial used Sugar Gum from the Majorca plantation. The first log (SG06) was the last log from the batch of logs used in the initial trials while the next three logs (SG07, SG08 and SG09) were obtained from a single tree which produced six 2.5 metre logs with a diameters greater than 420 mm. The log marking and handling was the same for each trial as discussed in Chapter 4.

After sawing Log SG06 and 24 cuts of Log SG07, the results showed a significant difference between Logs. For this reason, the results for Log SG06 and the first six cuts of Log SG07 were excluded and the trial continued with three new bandsaw blades and only the logs obtained from the same tree. These three logs provided sufficient additional cuts for all treatments except the 6 cuts with the blade set at 8° hook, 0.5 mm set and 640 kg tension.

6.3.3 Calibration of the blade tension mechanism

Calculation of the force on the blade by calculating the mechanical gain using a screw thread was not feasible:

"...because of the considerable friction forces any theory neglecting them is not even approximately correct." (Martin and Connor, 1970)

As pure mathematical calculations were not possible, an empirical method was needed to obtain a measurement of the tension on a blade. It was decided to use a load cell, which was described in Chapter 3. The load cell was attached to a wire rope which was then placed around the wheels of the bandsaw. The force applied to the wire rope was measured by the load cell and read on the weight indicator.

The low precision of the torque wrench makes repeat applications of the same torque very difficult to achieve. To improve this, the calibration was carried out at each of the major marked positions on the wrench with 10 ft.lb increments, with 10 readings taken at each. The wrench was tightened to each marked position, the load cell reading taken and then the wrench would be eased off until there was no torque, or at least very little torque, applied. It would then be tightened again and the new load cell reading taken. For each torque wrench setting, this gave an average load being applied. Four settings were calibrated – 20, 30, 40 and 50 ft.lb. The 'Farmill' manufacturer specifies tightening to 20 ft.lb, although many operators have found this to be too low and so the higher levels were included.

However, given the problems that friction causes in such a mechanism and the observation that most operators of this type of mill do not keep the mechanism clean it was decided to calibrate the mechanism lubricated and unlubricated. The unlubricated calibration was carried out first for obvious reasons.

For the unlubricated condition, calibration was carried out on the machine after it had been sitting in the open for 2 months. For calibration in the lubricated condition, the sliding metal surfaces, thread and washers were sprayed with WD 40 lubricant and moved to ensure good penetration of the lubricant. Lubricating the moving parts was then repeated after each test (Fig. 6.1 to 6.3).

6.3.4 Sawblade configuration – tension

Once the calibration of the tension mechanism had been carried out, it was possible to set levels of blade tension that could be then applied. For this trial three levels of blade tension were chosen –300 kg, 470 kg and 640 kg. These levels of tension were chosen, in the absence of any solid information, as they seemed to cover the range of tensions suggested by the manufacturers and the users of this type of mill.

To ensure the force on the torque wrench was the same for each reading, weights were hung off the handle (Fig. 6.2). The hook at the top of the weights was placed in the same groove in the torque wrench handle on each occasion (Fig. 6.2). When the torque wrench hung horizontally with the weights attached a light tap was given to the handle of the wrench to ensure that the tension in the blade was as close to balance as possible (Fig. 6.3).

The tensions chosen of 300 kg, 470 kg and 640 kg were transferred to the actual blades by using the weights of 7.5 kg, 9.5 kg and 11.5 kg respectively hung off the torque wrench.



Fig. 6.1 (left): Thread, nut and bearing plates that require lubrication.



Fig. 6.2 (centre): Weights (11.5kg) on the torque wrench.



Fig. 6.3 (right): Method used to tension the blade.

6.3.5 Sawblade configuration – hook and set

Three new blades were manufactured for this trial, by Ballarat Saw Service, from Porta Pro Bi-Metal band.

Before sawing the flitches, all three blades had to be modified slightly for reasons of consistency. The blades came standard with a hook angle of 10°. However, because the hook angle would need to be changed frequently and the available sharpening device did not have a 10° setting (the sharpening machine has settings in 4° increments from 8° up to 24°), the hook angle was changed to 8° while the clearance angle remained unchanged. This required the grinding of the tooth face and gullet while no grinding was required on the back of the tooth. The two other levels of tooth hook angle used were 12° and 16°.

The set of the blades in their original form was increased to 0.6 mm (0.024”) for the first series of cuts. The two other levels of set used were 0.5 mm (0.020”) and 0.4 mm (0.016”).

The grinding and setting procedure was discussed in Chapter 3.

6.3.6 Sawing procedure

The log was set up in the method discussed in Chapter 3. The flitches were sawn from the Sugar Gum logs using a blade not previously used. The balance between engine speed (rpm) and forward feed-speed that had to be applied with the Wood-Mizer, as detailed in Chapter 4, also had to apply in this trial. In this case, the objective was to try to keep engine speed as close as practicable to 3500 rpm – based on the engine manufacturer's specifications.

The first series of cuts was carried out with one of the blades where it was used for six cuts at the first of the three blade tensions. This was repeated with the second blade at a next tension then the third blade at the final tension. This produced a total of 18 cuts at the 8° and 0.6 mm set using the three blades.

After the first 18 cuts, the hook angles were changed, by grinding the three blades, to 12° after which the sawing process using the different tensions was repeated. The final series of cuts, with the 0.6 mm set, were carried out after sharpening and regrounding the hook angles to 16°. This gave a total of 54 cuts at the 0.6 mm set.

After completing the cuts using a 0.6 mm set, the set was reduced to 0.4 mm (0.016") on each of the three blades. The blades were sharpened and the hook remained at 16° and then the three tension combinations were repeated. A further two series of six cuts were carried out with the hook angles changed to 12° and then 8°.

Following the 54 cuts with the set at 0.4 mm the whole process was repeated again with a 0.5 mm (0.020") set.

6.3.7 Analysis

The blade parameter data was analysed using two methods. The first was using all the cuts then testing the total deviation against the factors (tension, set and hook) using an ANOVA on the software package 'Minitab'. The ANOVA technique allows an estimate of the effect of the three independent variables on a dependent variable, to be obtained. For example, the dependant variable is the total amplitude of deviation and the independent variables are hook, set and tension. The effect one independent variable has on another or the interaction effect can also be considered.

The second method was using a proportions parameters test for a binomial sample, on the statistical software package 'S-PLUS'. The test was a pairwise comparison between each of the proportions within each of the factors considered on their own. For example, for hook the number of cuts was considered at the three levels of hook regardless of which tension and set combinations they included. Three pairs of comparisons were possible for each factor so the level of significance for each pairwise comparison had to be reduced accordingly to account for accumulated error. Hence, the significance level becomes $\frac{1}{3}$ of the conventional levels e.g. for 0.05 significance the 'p' value needs to be ≤ 0.0166 . This is considered conservative.

6.4 Results

6.4.1 Calibration of the tension mechanism

There was a considerable effect of lubrication on the tension applied by the torque wrench as can be seen from the calibration curves in Fig. 6.4. In the lubricated condition, the curve is close to linear. However, as can be seen in Fig. 6.4 there is a serious effect of friction on the mechanism in the unlubricated condition at the high torque. The detail of the calibration is shown in Table 6.1.

There was a high level of consistency in readings as indicated by the standard errors in Table 6.1 – especially in the lubricated condition. These were too small to show up as error bars on the chart in Fig. 6.4. For unknown reasons only one reading for the highest torque in the unlubricated condition was taken. However, given the consistency of the other readings this was not considered a serious problem.

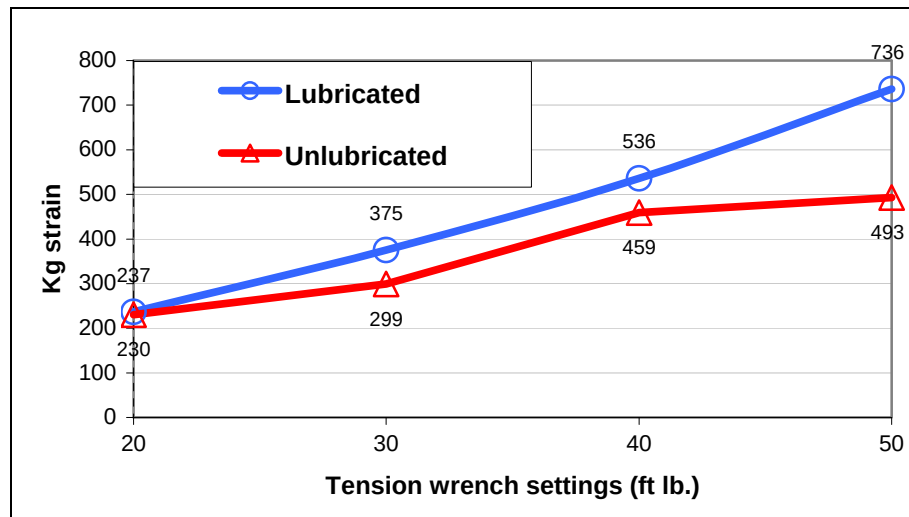


Fig. 6.4: Tension applied to a blade at varying torque in the lubricated and unlubricated conditions.

Table 6.1: Kg weight recorded on the load cell at varying torques in the lubricated and unlubricated conditions.

Torque wrench	Unlubricated			Lubricated		
	Weight (kg)	s.e.	n	Weight (kg)	s.e.	n
20 ft lb.	230	0.97	10	238	0.36	10
30 ft lb.	298	0.81	10	377	0.86	10
40 ft lb.	460	0.96	10	537	1.22	10
50 ft lb.	493	--	1	736	1.55	10

6.4.2 Measurement of board straightness

The amplitude of the profile of deviation from the straight cut line along a log was used as the measure of straightness in this trial. Figures 6.5 – 6.7 show examples of the meaning of

amplitude as it was applied in this trial. In general terms, the amplitude of sawing deviation could occur in any of three ways:

- Where the saw cut strayed both above and below the nominated straight cut line.
- Where the saw cut strayed below the straight cut line for the entire length.
- Where the saw cut rose above the straight cut line for the entire length

Cuts with total amplitude of deviation less than 1.5 mm were rated acceptable. Cuts with deviations greater than 1.5 mm were rated unacceptable. This proved to be a very tight specification when compared to the Australian Standards and could be relaxed in production operations to allow for greater tolerances.

Figure 6.5 shows Cuts10-12 in Log SG08 sawn with a blade having a hook angle of 16°, a set of 0.6 mm and a tension of 300 kg. Amplitude (total deviation) for each cut is within the acceptable range of 1.50 mm.

Figure 6.6 shows Cut7 in Log SG07 sawn with a blade having a hook angle of 8°, a set of 0.6 mm and a tension of 480 kg. The total deviation was in the negative direction (the blade dropped during sawing) and the amplitude was 1.53 mm, which was outside the acceptable range of 1.5 mm.

Figure 6.7 shows the sawing straightness for Cut8 in Log SG08 which had a hook angle of 16 degrees, the set of 0.6 mm and a tension of 300 kg. The total deviation was in both the positive and negative directions which meant the blade rose and then dropped during the sawing. The maximum upwards deviation of 0.28 mm and the maximum downwards deviation of 1.55 mm equal a total deviation of 1.83 mm, which is outside the acceptable range of 1.50 mm.

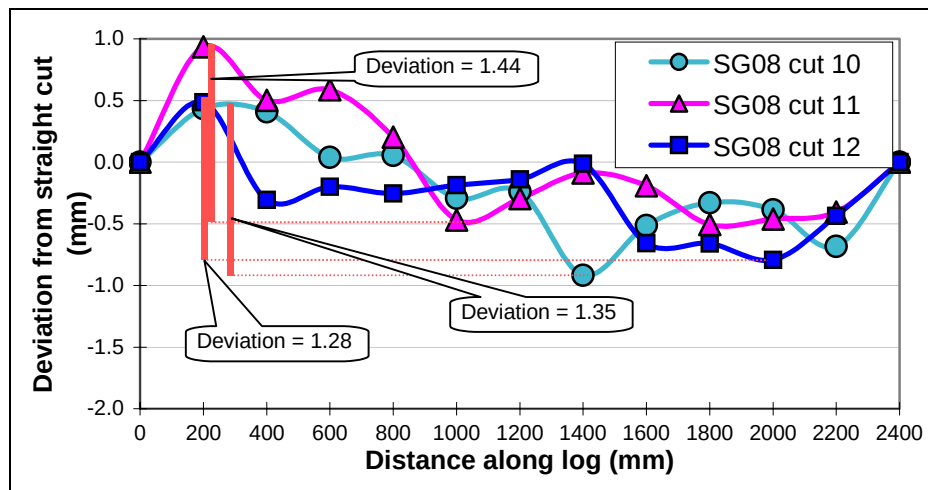


Fig. 6.5: Three cuts where all deviations were within a 1.5 mm amplitude band. The vertical line represents the magnitude or extent of the deviation for each cut.

Of the 156 cuts in Logs SG07, SG08 and SG09 there were 129 cuts that had total deviation of cut along the flitch of less than 1.5 mm. For comparison 28 cuts had total deviations greater than 1.5 mm and of these eight had amplitudes of deviation greater than 2 mm.

6.4.3 Logs

Analysis of variance showed significant differences in board straightness between logs ($p < 0.01$). As discussed earlier, the tests indicated that significantly more cuts from Log

SG06 were outside the tolerance limit than were cuts from Logs SG07, SG08 and SG09, which were collected from a different tree.

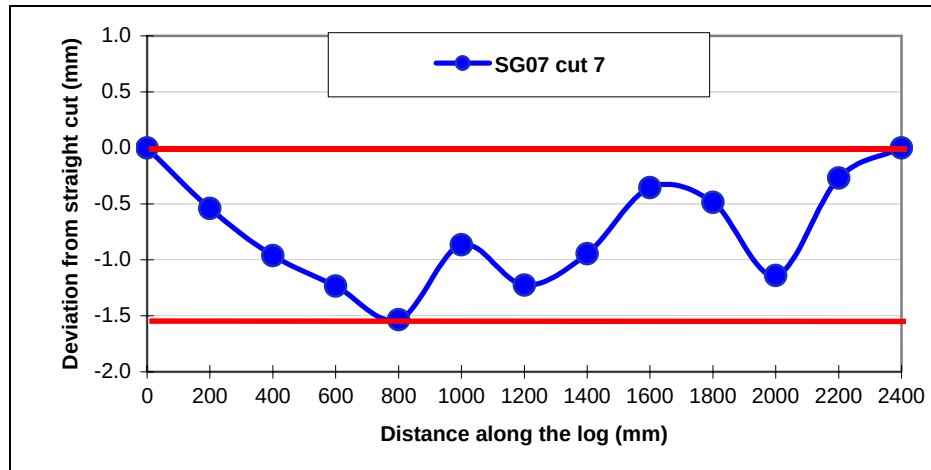


Fig. 6.6: A cut where the deviation strayed outside the 1.5 mm amplitude band (represented by the heavy grid lines). Note that all deviations are below the straight cut line (0.0).

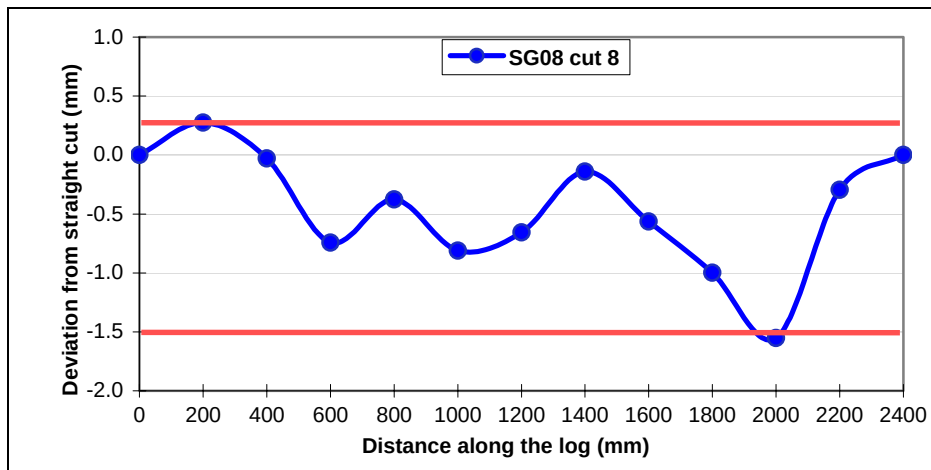


Fig. 6.7: A board where the cut strayed outside the 1.5 mm amplitude band (represented by the heavy lines). This board would be unacceptable according to the criteria. Note that the deviations are caused by rising above (+) and dropping below (-) the straight cut line (0.0).

6.4.4 Effects of blade parameters on straightness of cut

The summary of the numbers of boards falling outside the specified 1.5 mm standard is shown in Table 6.2. Of the 156 cuts, 28 (17.9%) were outside the tolerance and of these eight (5.1%) had an amplitude of deviation greater than 2.0 mm.

Table 6.2: Number of cuts outside the 1.5 mm specifications compared to blade parameters. The number in () is the number in that category.

Tension	300kg	470kg	640kg	Total
Cuts	12 (54)	10 (54)	6 (48)	28 (156)
Hook	8°	12°	16°	
Cuts	9 (48)	5 (54)	14 (54)	28 (156)
Set	0.4mm	0.5 mm	0.6 mm	
Cuts	3 (54)	8 (48)	17 (54)	28 (156)

6.4.4.1 Hook angle

There was no significant difference in the amplitude of deviation of cuts at the three different hook angles ($p = 0.078$) (Fig.6.8). There was also no significant difference in the number of cuts with deviations greater than 1.5 mm at the three different hook angles

Close examination of the raw data shows that of the 28 cuts with a deviation greater than 1.5 mm 50.0% were with blades using a hook angle of 16°, 31.2% were with blades with a hook angle of 8° and 17.8% with a 12° hook angle (Table 6.2).

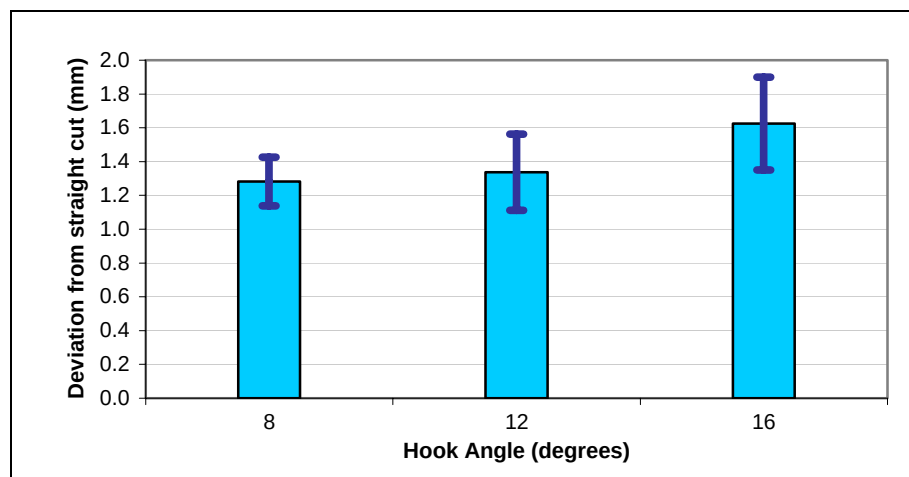


Fig. 6.8: The average deviation of all cuts at the different hook angle (bars = S.E.).

6.4.4.2 Blade Tension

There was no significant effect on the straightness of cut for different blade tensions when the 1.5 mm tolerance was considered ($p = 0.182$) (Fig. 6.9). There was also no significant difference in the number of boards with amplitude of deviations >1.5 mm at the different tensions.

However, with a reduced tolerance there was a significant difference in the straightness of cut and the number of cuts with amplitude of deviations >1 mm at the different tensions. A

tension of 300 kg-wt was 5.75 times more likely to produce a cut with amplitude of deviation >1 mm than either 470 or 640 kg-wt blade tension.

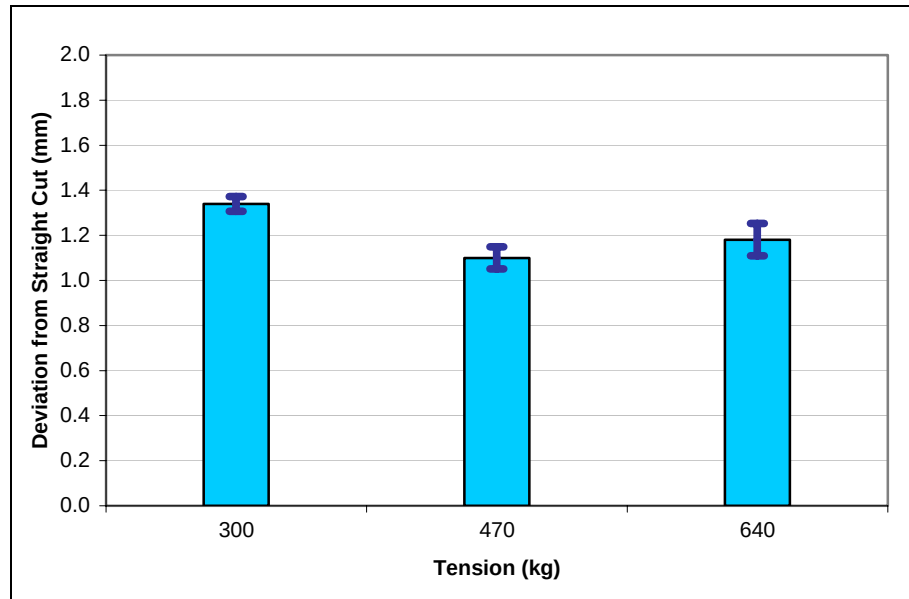


Fig. 6.9: The average deviation of all cuts compared by tension (bars = S.E.).

6.4.4.3 Tooth Set

There was no significant effect of set on the straightness of cut for all the cuts ($p = 0.087$) (Fig. 6.10). However, there was a highly significant ($p < 0.003$) effect in the number of cuts with amplitude of deviation above 1.5 mm. This effect appears to be a higher rejection rate at the highest set of 0.6 mm (refer to Table 6.2).

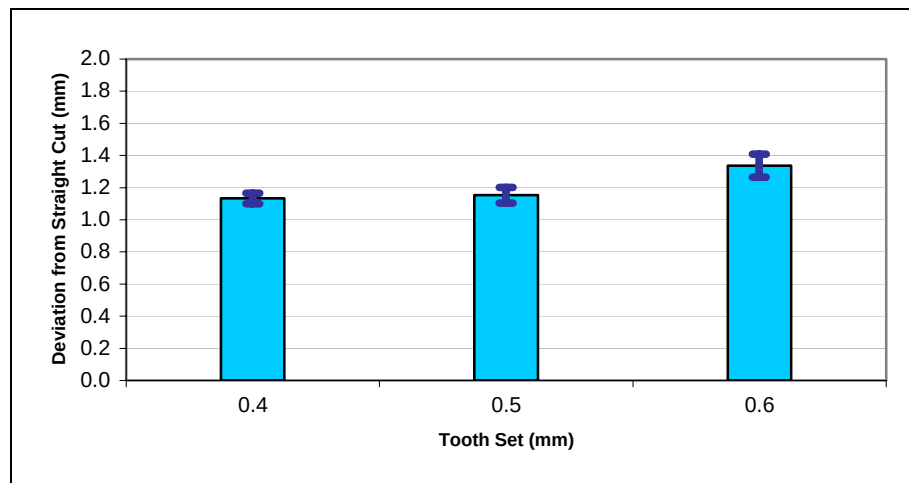


Fig. 6.10: The average deviation of all cuts compared by tooth set (bars = S.E.).

6.4.4.4 Interaction

Further testing on the raw data, which takes into account the actual scale of deviations, was undertaken. Analysis of variance indicated that there was no effect of any of the factors on their own but there were statistically significant interactions involving hook. The interactions between hook and tension ($p = 0.006$) and hook and set ($p < 0.001$) were both highly significant.

The interaction between hook and tension indicates that at the lowest tension (300 kg-wt) and the highest hook angle (16°) there was a large increase in the amount of deviation in the boards.

The interaction between hook and set was more complex – and appears to involve several combinations. At 12° hook and 0.6 mm set there was a decrease in the deviation in boards but if the hook was increased to 16° at the same set there was an increase. However, at 12° hook and a set of 0.5 mm there was a large increase in deviation in boards, but if the hook angle was increased to 16° the deviation decreases. At the lowest set, 0.4 mm, there was a gradual increase in deviation as hook angle increases.

6.5 Discussion

By using the ‘accept or reject’ analysis method, the sample size is reduced and this changes the significance level of the results. Table 6.3 shows the significance level for the deviation using the original hypothesis of 1 mm deviation and the revised standard of 1.5 mm. The significant difference was in the tension at 1 mm deviation while at 1.5 mm the significant difference was in the set.

Table 6.3: Summary of results of comparison of factors for proportions of boards that were unacceptable at the two tolerance levels.

	Greater than 1 mm deviation		Greater than 1.5 mm deviation	
	p-value	Significance	p-value	Significance
Tension	0.011	*	0.412	N.S
Hook	0.110	N.S	0.077	N.S
Set	0.992	N.S	0.002	**

N.S (not significant), * ($p \leq 0.05$) significant, ** ($p \leq 0.01$) highly significant, *** ($p \leq 0.001$) very highly significant,

6.5.1 Calibration of the blade tension mechanism

As previously stated the effect of lubricating the threads and sliding parts on the ‘Farmill’ was clearly demonstrated in the results of the calibration procedure. Given the effect of low blade tension on sawing deviation, it is very important to keep the mechanism clean and lubricated. The fact that most operators do not clean or lubricate the mechanism regularly means that tightening to the manufacturer’s low specifications, of 20 ft-lb, would result in even lower blade tension – although not by much, as the calibration procedure showed (refer to Fig. 6.4). However, this last point means that at 20 ft-lb there must be very little frictional force coming into play – highlighting just how low the blade tension is at that torque.

6.5.2 Effect of hook angle on straightness of cut

The fact that a 12°-hook angle produced less reject cuts than the 8° (44% less) or 16° (64% less) hooks might suggest that it should be better. However, this difference was not statistically significant due to the small percentage of total reject cuts (18%) and the small number of rejected cuts for each hook angle. While considering the total deviation for all cuts there was no statistically significant difference, which implies that the variability in the results is high. This is itself important and is confirmed by the Main Effects plot shown in

Fig. 6.11. This graph shows how the variation is greater for the 16° hook than the 12° or 8°. The 8° hook had the lowest variation in the deviation. If there is considerable variability, in practical terms this means that using an 8° hook might work on some occasions and might not on others but predicting when either will happen is not possible.

It seems improbable, based on practical experience and reports from mill operators, that hook angles are not important to cutting performance. There is the possibility that hook angle is a critical level factor i.e. one which does not give problems until a certain critical value is exceeded. If this is the case, then it is possible that critical level for hook angle was not been exceeded in this trial— apparently by chance.

The reason that only three hook angles were considered was to place a realistic limit on the scope of the trial and it was originally thought that the angles chosen would embrace a suitable range. It is possible this is not the case and a supplementary trial with higher hook angles could be justified. This would be a relatively simple procedure.

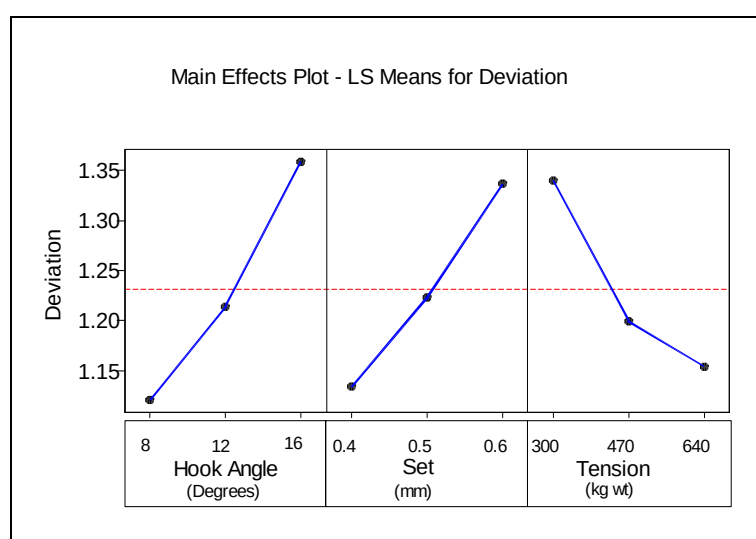


Fig. 6.11: Minitab - Main Effects Plot of the Least Square Difference of the Means of the Deviation.

6.5.3 Effect of blade tension on straightness of cut

The finding that the lowest blade tension results in much higher cut rejection rates tends to concur with practical experience of many operators. This indicates that the ‘Farmill’ manufacturer’s specification for blade tension i.e. tightening the torque wrench to 20 ft-lb, was far too low. In conversation with the manufacturer, it seems that the reason for suggesting such low tension was for fear of breaking the join in the blades. The blade suppliers themselves recommend much higher tensions.

While considering the deviation for all cuts there was no statistically significant difference due to blade tension, although the variability in the results is high. This is important and is confirmed by the Main Effects plot shown in Fig. 6.11. This graph shows how the variation is greater for the 300 kg tension than the 470 or 640 kg. The 640 kg tension had the lowest variation in the deviation.

Results using a 1 mm tolerance, (not shown) indicate that there was not much difference between the proportion of reject boards, between 470 and 640 kg-wt blade tensions. For practical use it would seem that tensions of 470 kg-wt or higher should be used for cutting to these tolerances. This is equivalent to 35-40 ft-lb on the torque wrench with the tightening mechanism lubricated. However, in order to reduce wear on the drive wheel

bearings, where the tension load is ultimately transferred, operators could choose not to go much above this figure and still expect reasonable cutting performance.

When the tolerance of 1.5 mm was considered the blade tension did not affect cutting performance (refer to Table 6.2). This seems somewhat curious. The fact that at low blade tension there was a large number of boards deviating by greater than 1 mm but not a significantly higher proportion deviating by more than 1.5 mm suggests that most of the blade deviation is occurring up to 1.5 mm. Whether this is likely or not is difficult to say and it could be argued that this has more to do with how much the blade can be made to distort. However, that does not concur with field observations, where quite severe blade distortions have been observed. The finding is possibly an artefact of the data set and there is no sound reason for suggesting to operators that blade tension can be relaxed for such a small change in sawn tolerance.

6.5.4 Effect of tooth set on straightness of cut

The effect of tooth set on the rejection of cuts is not clear. When the low tolerance level of 1 mm is used there is essentially no difference in the proportion of cuts rejected (not shown). However, when the tolerance is increased to the adopted standard of 1.5 mm there are a lot more cuts left outside the range at the highest tooth set of 0.6 mm than for either of the smaller tooth sets of 0.4 mm and 0.5 mm (refer to Table 6.2).

There was no statistically significant difference in the total deviation for all cuts due to set. This implies that the variability in the results is high which is a similar result to the other factors. As with blade tension this is important and is confirmed by the Main Effects plot shown in Fig. 6.11. This graph shows how the variation is greater for the 0.6 mm set than the 0.4 or 0.5 mm. The 0.4 mm set had the lowest variation in the deviation.

This suggests that some levels of blade wandering will occur whatever the tooth set but the amount of blade deviation will be more severe at the highest level of set. This could make sense in high-density timber where the resisting forces acting on the narrow blade will be increased owing to the greater exposure of the leading edge of the blade.

The practical application of this would suggest that operators cutting these high-density timbers should keep tooth set below 0.5 mm.

6.5.5 Interactions involving hook

The largest number of cuts with amplitude of deviation over 1.5 mm was at the lowest tension (300 kg-wt) and the highest hook angle (16°). Although hook was not significant on its own (Table 6.3) the generally held view amongst portable mill operators is that harder woods require lower hook angles on bandsaw blades. If this is the case, then coupled with the fact that low blade tension results in more blade wander then it is quite reasonable to suggest that large hook angles could exacerbate the problem. This has obvious practical implications for bandsaw mill operators.

The complex interactions between hook and set shown in Fig. 6.12 do not make much sense and they are probably of no practical use. The inconsistencies in the direction of changes with changing hook-set combinations could mean that there are extremely complex forces at work in blade movement that cannot be revealed by a study such as this, or it might be a feature of the variability in the data. It could also be that major effects occur above certain threshold values that have inadvertently been excluded in this trial.

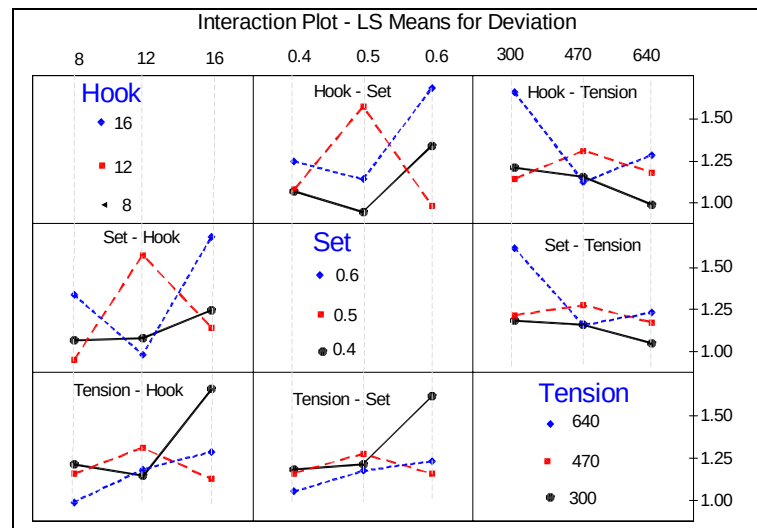


Fig. 6.12: Interaction Plot for the Least Square Differences for the deviation. Derived from Minitab using the graph options in the General Linear Model ANOVA when analysing interaction.

6.5.6 Difference between logs

The differences (considerable increase) in the amount of sawing deviation discovered in Log SG06, compared to the other logs, exposes a potential problem in translating the detailed results from this study to a new set of logs. Why this difference should occur is not clear, but it is interesting to note that this log was from a different tree and the variation between trees could be an important factor in the effective sawing of high-density timbers.

Unfortunately, it is not possible to determine whether the trend discovered in Log SG06 would have occurred in the other logs from the same tree as they had already been used. However, the finding does at least highlight the need to test the various parameters found to give best results in this trial to a range of logs, including different high-density species, in further operational trials.

6.6 Conclusions

6.6.1 General conclusion

These trials have shown that it is possible to cut a high density hardwood (Sugar Gum) with a horizontal bandsaw blade portable sawmill producing a straight cut that is better than or within the Australian standard for green sawn timber.

6.6.2 Blade tension

Low blade tension has a detrimental impact on the accuracy of cutting in Sugar Gum. A blade tension of 470 kg to 640 kg is required on the Laidlaw 'Farmill' horizontal bandsaw to produce straight cuts. These tensions equate to 35 to 45 ft.lb on the torque wrench supplied with the mill when all threads and sliding parts are well lubricated.

6.6.3 Tooth set

A high tooth set (0.06 mm) considerably increases the tendency for a bandsaw blade on the Laidlaw 'Farmill' to produce a greater deviation in the saw cuts.

7 Bandsaw-Effect of blade type on species

7.1 Introduction

Having previously ascertained the importance of blade tension in a horizontal bandsaw, careful measurement of tension is essential. The ability of an operator to reproduce the tensions consistently between blades is limited using the methods discussed and used in earlier chapters.

7.1.1 An alternative method of measuring the tension in a blade

An alternative method of measuring the tension in a blade is to use a strain gauge like the one shown in Fig. 7.1 and 7.2, produced by American Saw and Mfg. Company. This device measures the strain on the blade and is based on the principles of Hooke's Law where stress or applied load is proportional to strain. This device is only accurate if the elasticity of the steel in blades, from all manufactures, is the same. Different steels and different sized blades could have different strain resistances and re-calibration of the device might be required for different blades. However, advice from a local sawblade supplier suggests that differences are unlikely for several reasons. Firstly it is unlikely that each sawblade manufacturer will produce their own steel – in other words it will have to be purchased from a large producer and different sawblade manufacturers could well be buying from the same steel producer. Secondly, the task that the steel is required to perform and the contingent properties required of the steel, in terms of flexibility and strength, are the same for any bandsaw so it is likely that the steel will be very similar in these characteristics.

7.1.2 Comparing Tension between methods

The actual load cell readings and comparative readings from the Lenox measuring gauge are shown in Table 7.1. The calculated blade tension has been derived from the Lenox gauge figure and the cross sectional area of the blade. The figures in bold are within the manufacturer's specifications for the tension of the blades under operating conditions.



Fig.7.1 (left): Large Lenox tension meter being demonstrated by the Regional Sales Manager, Amercia Saw and Mfg Company.



Fig.7.2 (right): Small Lenox tension meter used to monitor blade tension.

Table 7.1: Comparison of different procedures used to determine blade tension.

7.2 Aim

Weight on torque wrench	Torque wrench scale	Load cell reading	Lenox gauge	Calculated blade tension
7.5 kg	25 ft.lb	300 kg	22,500 psi	155.1 MPa
9.5 kg	35 ft.lb	470 kg	28,000 psi	193.0 MPa
11.5 kg	45 ft.lb	640 kg	34,000 psi	234.4 MPa

The aim of these trials was to quantify the sawing performance, in terms of straightness of cut, of a Farmill horizontal bandsaw on four species of high-density hardwoods (Sugar Gum, Yellow Gum, Brown Mallet and Swamp Yate) using blades of two different widths and three different tooth tip constructions.

7.3 Materials and methods

7.3.1 Sawing procedures

The sawing was carried out on the Farmill in the same method as described in Chapter 3 with a target size for boards being 5 mm thick and 150 mm wide. As discussed previously the thickness of boards was not chosen on the basis of any standard commercial size but rather to maximise the number of cuts obtained from each log.

The sawing trials were carried out in a regular process to ensure a high level of consistency. For each set of eight cuts the key issues that were observed were:

- A new blade was used as supplied by the manufacturers
- The moving parts on the blade tensioning mechanism were kept well lubricated with WD40.
- The tension was set using the torque wrench and (11.5kg) weights and the blade tension measured using a Lenox tension meter.
- The throttle was set so that the engine was running at 3600 rpm before commencing the saw cut (manufacturer's specifications).

7.3.2 Blade types

In all, six different blades were used – they were:

- Pacific Saw International 32 mm (1¼") carbon steel blade (32CS).
- Lenox® 32 mm (1¼") Bi-Metal blade (32BM).
- Simonds® 32 mm (1¼") bevelled Carbide-tipped blade (32CT).
- Pacific Saw International 50 mm (2") carbon steel blade (50CS).
- Lenox® 50 mm (2") Bi-Metal blade (50BM).
- Lenox® 50 mm (2") variable pitch Carbide-tipped hogged and bevelled blade (50CT).

Details of the blade manufacture and configuration were shown in Chapter 3.

7.4 Results

All statistical tests in this trial used the one-way ANOVA with a Tukey comparison.

7.4.1 Availability of logs

The availability of Sugar Gum logs was limited in the plantation at Wail. The form and size were not good and only two logs were available for this project. The majority of the Sugar Gum came from a plantation at Majorca in Central Victoria.

This trial used one of the available Sugar Gum logs, which only had a diameter of 320 mm. It was not possible to obtain the eight cuts for each of the six blades i.e. 64 boards due to the shape of the log and smaller diameter. A curve in the log reduced the effective height of the flitch that could be obtained from the log.

As all previous trials were carried out with 32 mm Bi-Metal blades it was decided to randomly select eight cuts from the measurements of the previous trial using the 640 kg tension, 0.50 mm set and 12° hook and 16° hook. This combination best approximated the 32 mm Bi-Metal blade used in this trial. As shown previously the hook angle had no effect on straightness of cut.

The 50 mm Carbide-tipped blade was not replicated in the Sugar Gum due to the small diameter of the log. Using the 50 mm Carbide-tipped blade in the other three species the deviation was greater than with all other blades tested. As there was also little difference between species, it was decided that the use of a second log might add variability that could confound the results while adding little to the overall trial.

7.4.2 Tensions achieved during trial

There was no statistical difference in the tension achieved within the 32 mm wide blade types or within the 50 mm wide blade types but a very highly significant difference ($p < 0.001$) between the tensions achieved with the 32 mm wide blades and 50 mm blades (Fig 7.3).

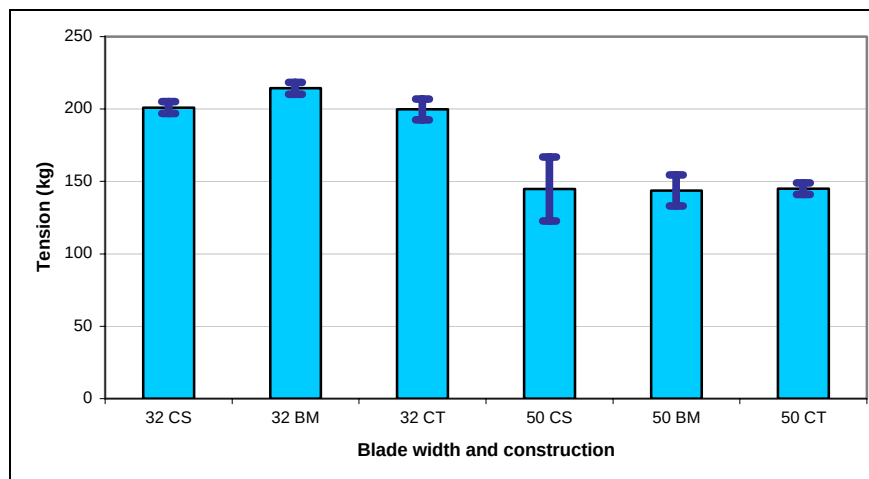


Fig. 7.3: Mean tension applied to the blade as recorded by tension meter with 11.5kg weights on tension wrench. Bars represent the standard error (S.E.).

Table 7.2 shows the tension meter readings for each blade when using the 11.5kg weight on the torque wrench for each of the four species.

There was no difference in the average tension applied to 50 mm blades over the various species but there was a significant difference in the straightness of cut with the 50 mm Bi-Metal blade producing cuts similar to the 32 mm blades.

Table 7.2: Tension meter measurements in MPa (psi) for each blade and species when tension was determined using 11.5kg weight on torque wrench

	32 CS	32 BM	32 CT	50 CS	50 BM	50 CT
Brown Mallet	200 MPa (29000 psi)	207 MPa (30000 psi)	214 MPa (31000 psi)	207 MPa (30000 psi)	131 MPa (19000 psi)	152 MPa (22000 psi)
Sugar Gum	207 MPa (30000 psi)	*	181 MPa (26250 psi)	138 MPa (20000 psi)	172 MPa (25000 psi)	*
Yellow Gum	207 MPa (30000 psi)	215 MPa (31250 psi)	207 MPa (30000 psi)	103 MPa (15000 psi)	124 MPa (18000 psi)	138 MPa (20000 psi)
Swamp Yate	190 MPa (27500 psi)	221 MPa (32000 psi)	197 MPa (28500 psi)	131 MPa (19000 psi)	148 MPa (21500 psi)	145 MPa (21000 psi)

* No tensions measurements were obtained for the Sugar Gum logs that were sawn with the 32 mm Bi-Metal and 50 mm Carbide-tipped blades due to insufficient log availability.

7.4.3 Effect of blade type on straightness of cut

With the cuts for all four species combined there was a very highly significant difference ($p < 0.001$) in the straightness of cut due to blade type. There was no significant difference in the straightness of cut between any of the 32 mm wide blades and the 50 mm wide Bi-Metal blade but a significant difference between both the 50 mm carbon steel and Carbide-tipped blades with the other four blades. While, there was no significant difference ($p = 0.053$) between the 50 mm wide carbon steel and 50 mm wide Carbide-tipped blades (Fig. 7.4).

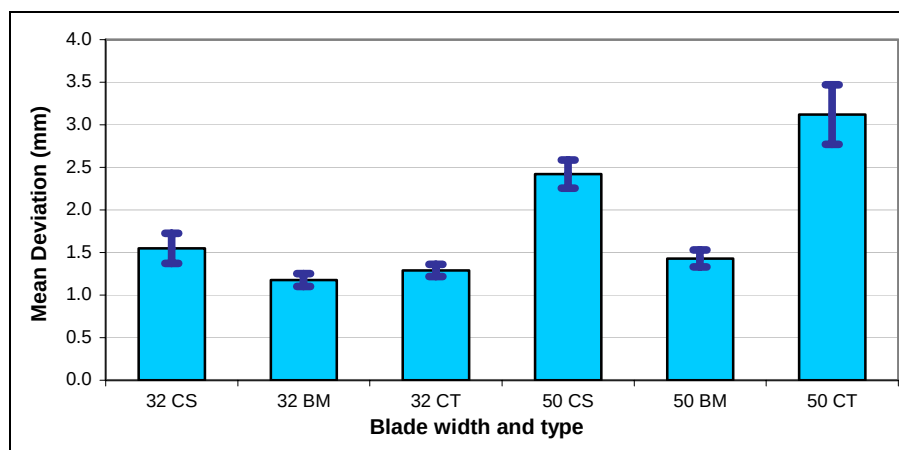


Fig. 7.4: Mean deviation of all species by blade tip width and type (bars = S.E.).

The percentage of cuts with a deviation less than 1 mm, 1.5 mm and 2 mm for each blade tip width and type is shown in Table 7.3. The percentages for the 32 mm Bi-Metal blades include the eight cuts that were randomly selected; as discussed earlier in this chapter.

Table 7.3: The percentage of cuts with a total deviation less than 1 mm, 1.5 mm and 2 mm.

Blade	No. Cuts	Deviation < 1 mm	Deviation < 1.5 mm	Deviation < 2 mm
32 mm CS	32	34%	63%	69%
32 mm BM	32	25%	91%	94%
32 mm CT	32	22%	78%	94%
50 mm CS	32	6%	16%	34%
50 mm BM	32	28%	56%	88%
50 mm CT	24	0%	21%	38%

The mean deviation for all cuts in Brown Mallet was 2.3 mm. The straightness of cut produced by the 50 mm Carbide-tipped blade was very highly significantly worse ($p < 0.001$) than all the other blades. The 32 mm and 50 mm carbon steel blades produced a poorer cut than were obtained with the 32 mm and 50 mm Bi-Metal and 32 mm Carbide-tipped blades (Fig. 7.5).

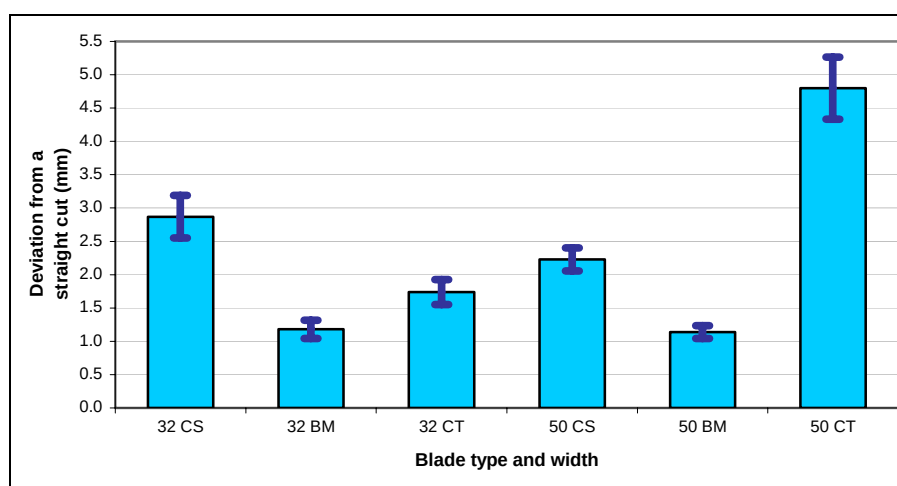


Fig. 7.5: Mean deviation of cuts in Brown Mallet using the different blades (bars = S.E.).

As discussed earlier no result was obtained in Sugar Gum for the 50 mm Carbide-tipped blade and the results for the 32 mm Bi-Metal blade was from a previous trial.

The mean deviation for all cuts in Sugar Gum was 1.7 mm. The straightness of cut produced by the 50 mm carbon steel blade was very highly significantly different ($p < 0.001$) to all the 32 mm blades but not between the 50 mm Bi-Metal. There was no difference between the cut straightness of any of the 32 mm blades (Fig. 7.6).

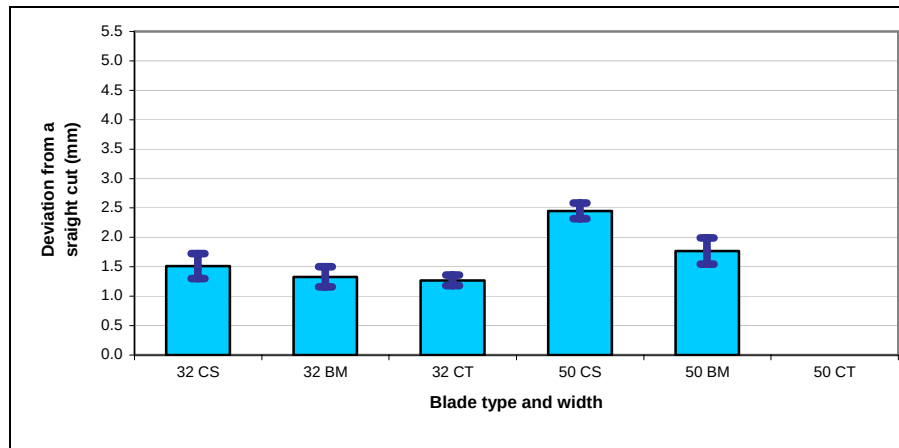


Fig. 7.6: Mean deviation of cuts in Sugar Gum using the different blades (bars = S.E.)

The mean deviation for all cuts in Yellow Gum was 1.2 mm. The straightness of cut produced by all the 32 mm blades was very highly significantly better ($p < 0.001$) than the 50 mm blades (Fig. 7.7).

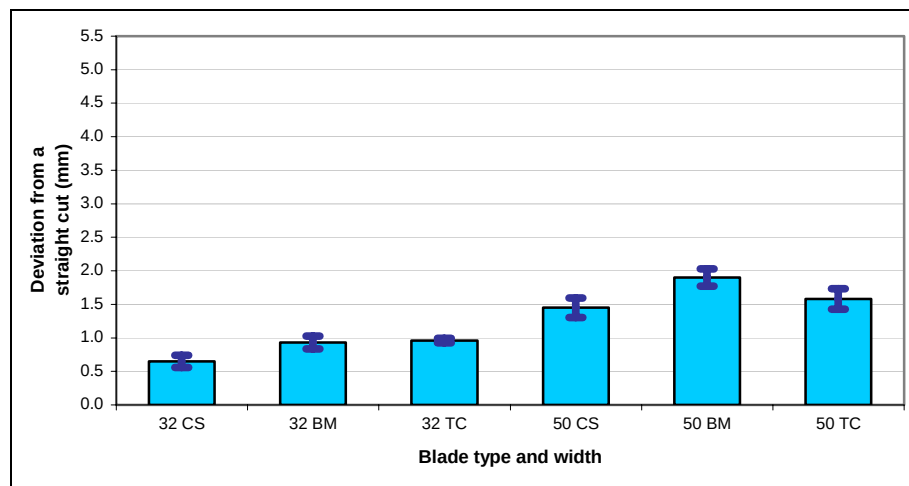


Fig. 7.7: Mean deviation of cuts in Yellow Gum using the different blades (bars = S.E.).

The mean deviation for all cuts in Swamp Yate was 1.8 mm. The straightness of cuts produced by all the 32 mm blades and the 50 mm Bi-Metal were not significantly different. However there was a very highly significantly different ($p < 0.001$) between those four blades and the 50 mm carbon steel and Carbide-tipped blades (Fig. 7.8).

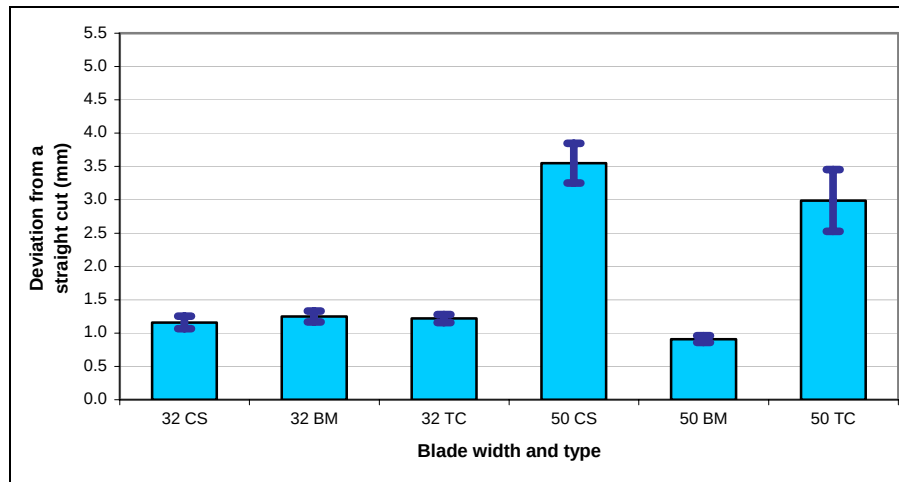


Fig. 7.8: Mean deviation of cuts in Swamp Yate using the different blades (bars = S.E.)

7.4.4 Effect of species on straightness of cut

The results when all blade type and widths were combined showed there was a significant difference ($p < 0.001$) between species in the straightness of cut (results not shown). The Yellow Gum produced the straightest cuts with a mean deviation of 1.2 mm. This was significantly straighter than the Sugar Gum and Swamp Yate but not significantly straighter than the Brown Mallet. The 50 mm Carbide-tipped blades were not used to saw the Sugar Gum and this may have an effect on the accuracy of these comparisons.

There was a significant difference in the straightness of cut between the species using the 32 mm blades ($p < 0.001$). The Brown Mallet was significantly different to the other three species with the greatest deviation in the cuts. The Yellow Gum produced the straightest cuts which were not significantly different to the cuts obtained in the Swamp Yate but were significantly straighter than cuts in the Sugar Gum. There were also no significant differences in the straightness of the Sugar Gum and Swamp Yate cuts (Fig.7.9).

There was a significant difference in the straightness of cut between the species using the 50 mm blades ($p = 0.020$). The Yellow Gum was significantly straighter than the Brown Mallet. There were no significant differences in the cut straightness between the Brown Mallet, Sugar Gum and Swamp Yate or between the Yellow Gum, Sugar Gum and Swamp Yate (Fig.7.10).

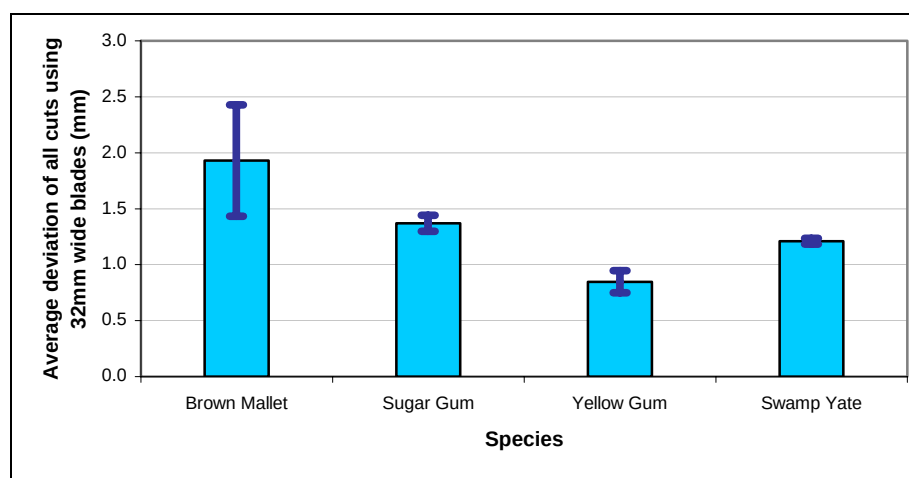


Fig. 7.9: Mean deviation (mm) of 32 mm blades by species (bars = S.E.).

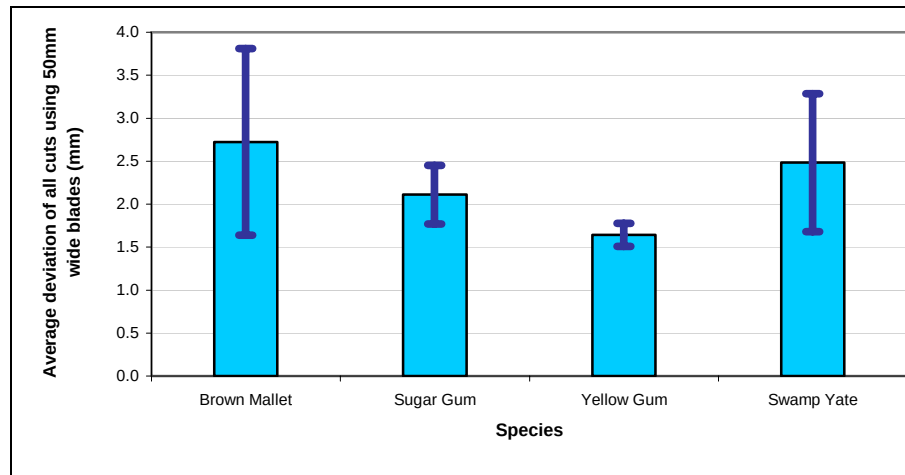


Fig. 7.10: Mean deviation (mm) of 50 mm blades by species (bars = S.E.).

7.5 Discussion

7.5.1 Blade tension

In the previous chapters, blade tension was shown to be more important in the straightness of cut than hook angle or tooth set. When using blades from different manufacturers it is useful to consider the theory that is behind the bandsaw blade and why tension is important.

Blade tension is based on Hooke's law and Young's Modulus.

Definition of Hooke's law:

'The deformation of an elastic body is directly proportional to the magnitude of the applied force, provided the elastic limit is not exceeded.' (Shortley and Williams, 1971)

Definition of Young's Modulus:

'Young's Modulus is the ratio of longitudinal stress to longitudinal strain in the case of a rod or wire under tension or compression.' (Shortley and Williams, 1971)

Thus, a bandsaw blade is tensioned with the applied force proportional to the elongation of the blade.

The tension or more correctly the tension strain, as recorded with the tension meter, assumes blades to have the same elastic modulus (Young's Modulus). Generally, steel has a Young's Modulus of 29×10^6 psi (Shortley and Williams, 1971). This is correct for blades made with the same chemical composition but may not be true for blades from different manufacturers or where the quality of supply of the raw steel band supplied to the blade manufacturers cannot be maintained by the steel foundries.

The use of the tension meter is the best method to measure tension in the blade as this eliminates the effect of friction of the screw threads and bearing plates in the determination of tension. When using blades from the same manufacturer and of the same type it could be assumed they are of the same steel composition and therefore will respond with the same Young's Modulus.

There was very high variability in the tension produced using the torque wrench method employed in this trial. For example, the tension in the 32 mm Carbide-tipped blade ranged from 181 MPa to 214 MPa (26250 psi to 31000 psi). This variation was due to friction in the tightening mechanism on the mill as the variation occurred even though the same blade type was used and the same weight was applied to the torque wrench.

There is a problem in achieving consistency in blade tension on portable mills because most horizontal bandsaw mills employ a screw thread device for tightening the blade. As discussed previously, there are problems with a screw type device due to high and unpredictable friction loss. For this reason the tension meter seems to be the most reliable method of ensuring consistency of blade tension in this type of mill. Some re-calibration of a tension meter might be required if it is used on different types of blade from the same manufacturer or blades from different manufacturers due to possible differences in the properties of the steel, as discussed elsewhere.

The results showed very high variability in the tension achieved with the tension wrench method. With the 32 mm Carbide-tipped blade ranging from this variation was due to the friction on the tensioning as the same blade type and weight on the torque wrench was used.

The failure of the 50 mm wide blades to consistently produce a straight cut may well be a problem with blade tension, which in turn relates to the portable mill used in this trial. As discussed previously the forces required to tension a blade are related to the cross-sectional area of the blade. With the Laidlaw Farmill, forces greater than those used on the 32 mm blades, which would be needed to tighten a 50 mm blade to the same tension, caused a locking block and bolt to break. This highlights the limitation of this particular machine. However, as most horizontal bandsaw mills in this general category have similar capacity, it is likely that this will be a problem across several different makes and models of these types of mills. It would seem that the mill needs to be engineered in the first instance to withstand the forces needed to produce the required tension in a 50 mm blade and if blades could be tightened to the manufacturers recommendations, the 50 mm blade may well perform to an acceptable tolerance.

7.5.2 Effects in different species

The Brown Mallet produced the poorest cuts with the mean deviation from straight, greater than the agreed tolerance for both the 32 and 50 mm blades.

The Yellow Gum log produced the straightest cuts with both the 32 and 50 mm blades although the 50 mm cuts were still above the acceptable tolerance of 1.5 mm deviation from straight.

The Sugar Gum results for the 50 mm blades must be disregarded, as the availability of logs did not allow for the sawing with the 50 mm Carbide-tipped blade.

The 32 mm blades, sawing the Sugar Gum and Swamp Yate both produced an average of cuts within the acceptable tolerance while the Swamp Yate was slightly straighter than the Sugar Gum.

An unexplainable result was the straightness obtained with the 50 mm Bi-Metal blade. In the Swamp Yate and Brown Mallet species the 50 mm Bi-Metal blade produced the straightest cuts of all blades while in the Yellow Gum, which had the straightest cuts overall, this blade was the worst performer with all cuts having a deviation greater than 1.5 mm.

This poorer than expected result for Yellow Gum sawn with the 50 mm Bi-Metal blade may be due to inaccurate tensioning of the blade or some factor relating to the blade as each species was milled with a different blade and used in the factory supplied condition.

7.5.3 Wide blades

Both the 50 mm wide carbon steel and Carbide-tipped blades produced cut where the straightness was unsatisfactory for the standards selected with only 16% and 21% of cut less than 1.5 mm total deviation from straight.

The 50 mm Carbide-tipped blade could not be used in the same way as the other blades. The cutting was very easy with little effort required to push the saw-head along the log. Maintaining a constant 3500 rpm was difficult, as the engine speed would drop below 3500 rpm very quickly. With the other blades, the drop in engine revs was slower and less extreme than with this blade. When the forward pushing speed was slowed, the engine speed did not recover, as with the other blades. It was observed that when the engine speed dropped quickly the blade had dived in to the log. The cutting feed-speed was then slowed but the blade did not recover from the dive and return to the straight cutting position as with the other blades. It was found that the saw-head had to be reversed 50 to 100 mm and the cut recommenced. Fig. 7.11 shows the extent of the dives in Log BM01.



Fig. 7.11: Brown Mallet log sawn with the 50 mm Carbide-tipped blade showing positions along the log where the blade dived and the sawing head was reversed to recover cutting line.

7.5.4 Quality of finish

The quality of cut obtainable using any type of saw is not only the straightness of cut and size tolerances but also the surface finish of the cut.

Fig. 7.11 shows the Brown Mallet log after cutting with 50 mm CT blade # 2. There are no teeth marks on this log and the finish between the two dive points shown in this photo is very smooth. If this blade had not dived then the surface finish of the board would be excellent.

Boards with rough surfaces produce more difficulties with handling and although they may be technically acceptable, their appearance makes them look less acceptable than a smoother finished board.

The Australian Standard for 'Types of Timber Surfaces' AS1728-1975 has been withdrawn and relevant information is now included in the performance standard 'Timber – Hardwood – Sawn and Milled Products' AS2796-1999. This standard no longer gives definitions for finishes of sawn products but relies on a fit for purpose principle. As long as the finish is acceptable to both supplier and consumer then it is acceptable.

Figure 7.12 shows the surfaces of two Swamp Yate boards EO01/23 and EO01/24. Both boards show teeth marks across their faces. These teeth marks are generally produced by

one or more teeth that are out of alignment along the band and are often at the point where the band has been joined.



Fig. 7.12 (left): Tooth marks on boards cut with Carbide-tipped blades in Swamp Yate. Top board cut with 32 mm blades and bottom board cut with 50 mm blade.

The upper board EO01/23 was the last board cut with the 32 mm CT blade # 3 while the lower board was the first cut with the 50 mm CT blade # 1.

The different spacing of the teeth relate to the number of teeth out of alignment and the feed-speed of the blade along the log.

7.6 Conclusion

This trial was to examine blades with different tooth-tip construction and of differing widths and how these blades performed in the sawing of four high-density timbers.

7.6.1 Blade type – in terms of width

The 32 mm blades generally produced straighter cuts than did the 50 mm blades. The exception to this was the 50 mm Bi-Metal blade which produced the straightest cuts in the Brown Mallet and Swamp Yate.

7.6.2 Blade type – in terms of tooth-tip construction

The Bi-Metal blades, as a whole, produced straighter cuts than the Carbide-tipped or carbon steel.

The 32 mm Bi-Metal blades were the best performing with 91% of cuts having a total deviation less than 1.5 mm. Next best performer was 32 mm Carbide-tipped with 78% of cuts having a total deviation less than 1.5 mm. Both these blades produced cuts of equal straightness (94%) when the tolerance was increased to 2 mm.

The 50 mm carbon steel blades were the poorest performing blades with 65% of cuts having deviations greater than 2 mm. The 50 mm Carbide-tipped blades were only slightly straighter than the carbon steel with 62% of cuts having a total deviation less than 2 mm.

The 50 mm Bi-Metal blades were by far the best of the 50 mm wide blades and better than the 32 mm carbon steel. If a wider blade is required, the 50 mm Bi-Metal blades should be considered as the best possibility.

7.6.3 Species

The straightest cuts were produced in the Yellow Gum with an average deviation of 1.2 mm. The Brown Mallet was the most difficult to produce straight cuts with an average deviation of 2.3 mm. The other species, Sugar Gum and Swamp Yate, were similar in straightness of cuts with average deviations of 1.7 mm and 1.8 mm respectively.

7.6.4 Tension

Blade tension still appears to be a major factor in the straightness of cut using a horizontal bandsaw. The lack of adequate tension in the wide blades may be the reason for the poorer performance.

8 Operational factors

8.1 Introduction

Operational factors as discussed by Stewart and Hanson (1998) of break-even volumes, handling equipment, log and timber prices are specific to each operator and not part of this project. The major operational factor pertaining to portable sawmills that is important to this project is the feed or feed-speed. This is because the time taken to produce a cut in a log is a cost to the operator of the mill. If sawing rates are slow then the production rates will be down and financial returns low.

All previous trials were based around the mills operating with 'engine speed' near to constantly and kept at 3500 rpm. This method did not allow for any faster sawing of boards therefore it was decided to use fixed speeds and examine their effects on straightness of cut.

Another operational issue that required examination was blade longevity. If a blade blunts quickly then sharpening will be required which reduces production time and reduces the blade life expectancy thus increasing operational cost.

The speed of cut appears more relevant to the horizontal bandsaw than to the single circular sawmill. As discussed in Chapter 4, the horizontal bandsaw appears to have a critical speed at which the straightness of cut cannot be maintained while the single circular sawmill was seldom limited by the feed-speed and therefore no feed-speed controlling attachment was used with the single circular sawmill.

The horizontal bandsaw appears to have difficulty cutting at times and increased force is required to push the saw carriage along the flitch. While this appeared not to show as a problem in the cutting straightness no quantifiable analysis had been carried out. Installation of measuring equipment allowed the measuring of the pulling force on the carriage during the sawing operation.

8.2 Aims

The aims of this trial were to:

- Investigate the effect of the derived feed-speed in relation to the blade orientation, blade tip width and species with the single circular sawmill.
- Investigate the effect of the derived feed-speed (as discussed in Chapters 6 and 7) with the variables tested on bandsaw blades (tension, hook, set and type of blade) on straightness of cut. In this respect, feed-speed is treated more as an effect rather than a controlled variable.
- Conduct specifically designed trials to control feed-speed and test the effect of this on straightness of cut over a range of feed-speeds.
- Investigate the force required to pull the sawing head through logs of different species at different speeds
- Investigate the effects of sawing procedures on engine speed, as an indication of engine power
- Investigate the longevity, or duration, of saw-blade sharpness

8.3 Materials and methods

While feed-speed was not a controlled variable in previous trials, the time taken to complete each cut was recorded for each board. This enabled a comparison to be made on the effects of the controllable variables on feed-speed. This data was used for the analysis using the single circular sawmill and for the first part of the analysis relating to the horizontal bandsaw.

For the second part of the analysis, equipment was designed and installed to actually control the rate at which the sawing head was fed along each cut while other factors relating to each blade were varied.

8.3.1 Single circular sawmill

Feed-speed was obtained from the timed duration of each cut and the length of the flitch for all cuts in the trial reported in Chapter 5. During those trials it was attempted to contain the engine speed to the range around 3500-rpm while sawing the four species.

The speed was obtained from six cuts with the blade sawing in each of the vertical and horizontal orientations. The trial used four blade tip-widths of 4.5, 5.0, 5.4 and 5.7 mm in each of the 4 high-density species (Brown Mallet, Sugar Gum, Yellow Gum, and Swamp Yate).

8.3.2 Horizontal bandsaw

8.3.2.1 *Controlled engine speed with tension, hook and set varied*

Feed-speed was obtained from the timed duration of each cut and the length of the flitch for all cuts in the trial reported in Chapter 6. During that trials it was attempted to contain the engine speed to the range of 3500- 3600-rpm while sawing Sugar Gum.

The speed was obtained from eight cuts using a 32 mm Bi-Metal blade with the following factors varied:

- Three tooth sets (0.4mm, 0.5 mm and 0.6 mm)
- Three hook angles (8°, 12° and 16°)
- Three blade tensions (300kg, 470kg and 640kg) as measured by the system of blade tensioning reported in that trial

8.3.2.2 *Controlled Engine Speed with blade type and width varied.*

Feed-speed was obtained from the timed duration of each cut and the length of the flitch for all cuts in the trial reported in Chapter 7. During that trial it was attempted to contain the engine speed to the range of 3500- 3600-rpm while sawing the four species selected – Brown Mallet, Sugar Gum, Yellow Gum and Swamp Yate.

The speed was obtained from eight cuts using the different types of blades as described in detail in Chapter 3. The blade types were:

- 32 mm wide Carbon Steel (32CS)
- 32 mm wide Bi-Metal (32BM)
- 32 mm wide Carbide-tipped (32CT)

- 50 mm wide Carbon Steel (50CS)
- 50 mm wide Bi-Metal (50BM)
- 50 mm wide Carbide-tipped (50CT)

8.3.2.3 Controlled Feed-speed

As in the previous bandsaw trials, the Laidlaw Farmmill was used for this trial. The basic mill set up and measuring procedures were used as described in Chapter 3, but some modifications were made to the mill to enable a constant travel speed of the power-head along the log.

The power head of the mill was attached to a 240-volt electric motor with reduction gearbox that was attached to a winch-drum through a dog clutch (Fig. 8.1). The electric motor was controlled by an adjustable frequency drive controller, which enabled the motor speed to be varied while maintaining full torque (Fig. 8.2). The motor and winch arrangements were bolted to a timber plank, which straddled the carriage tracks, while the controller was used on a worktable adjacent to the mill.

The winch was attached to the sawing power head by a 2 mm steel cable but as the height of the power head would vary with each saw cut the cable had to be kept level with the sawing head to ensure the same horizontal pulling force was maintained. To achieve this, the cable was run through a pulley, attached to a vertical steel pipe placed at the end of the saw bed as a post, which could be adjusted in height to line up with the power-head (Fig. 8.3).



Fig. 8.1: (left) Electric motor reduction gearbox and winch

Fig. 8.2: (right) Variable frequency drive controller.

In order to measure the actual pulling force applied during the cut the steel cable was attached to the power head through a load cell and weight indicator (Fig. 8.4). The prepared flitch was marked on the side at 400 mm intervals with the first mark at 200 mm from the start of the flitch. As the power-head moved along the flitch during the cut an assistant would indicate that the blade was over the mark and a recording of the force in kilograms, from the weight indicator, and the engine speed, from the tachometer, were recorded.

In this trial, six cuts were taken for each feed-speed and in each of the four species. The lowest feed-speed used was 2 m·min⁻¹ as the adjustable frequency drive controller, winch drum diameter and electric motor would not allow a lower speed to be achieved. It was decided that the speed would be increased in 1 m·min⁻¹ intervals. The first species trailed was Sugar Gum then Swamp Yate. The very limited supply of logs for the other two

species did not allow for each speed increment to be trailed and it was decided to use a starting feed-speed of $5 \text{ m} \cdot \text{min}^{-1}$ for both the Brown Mallet and Yellow Gum. When these cuts produced poor results then slower speed were used while if the cuts were straight the higher speed were tested.



Fig. 8.3 (left): Power head and carriage attached to the constant feed-speed cable.

Fig. 8.4 (right): Load cell and weight indicator set up on the Farmill to record force during the cutting operation.

8.4 Results

In all comparisons, data was analysed using one-way ANOVA with a Tukey's comparison to test the effect of each factor on its own.

8.4.1 Single circular sawmill – controlled engine speed with blade tip width and species varied

In all the cuts over the four species the feed-speed varied from $1.39 \text{ m} \cdot \text{min}^{-1}$ to $8.95 \text{ m} \cdot \text{min}^{-1}$ with a mean of $4.03 \text{ m} \cdot \text{min}^{-1}$.

8.4.1.1 Blade sawing orientation

For all cuts in the vertical blade-orientation, as compared with the horizontal orientation, there was no significant difference in cutting speeds ($p = 0.115$) with means of $3.91 \text{ m} \cdot \text{min}^{-1}$ for the horizontal and $4.16 \text{ m} \cdot \text{min}^{-1}$ for the vertical cuts.

Examining each blade-tip width against blade orientation, for all species combined, revealed no differences between the feed-speeds using the 4.5, 5.0 or 5.4 mm blades but when using the 5.7 mm blade the vertical cuts were significantly faster ($p = 0.005$) than the horizontal cuts.

Also when examining the various species against blade orientation there was no differences in feed-speeds for Swamp Yate and Yellow Gum but for Sugar Gum the horizontal cuts were significantly faster ($p < 0.047$) than the vertical cuts while in the Brown Mallet the vertical cuts were faster ($p < 0.001$) than the horizontal cuts.

8.4.1.2 Species

For all blade tip widths and in both sawing orientations there was a highly significant difference ($p = 0.002$) between the species. Swamp Yate and Sugar Gum were sawn at a

significantly faster rate than Brown Mallet while the Yellow Gum showed no significant difference in the feed-speed to any species (Fig.8.5).

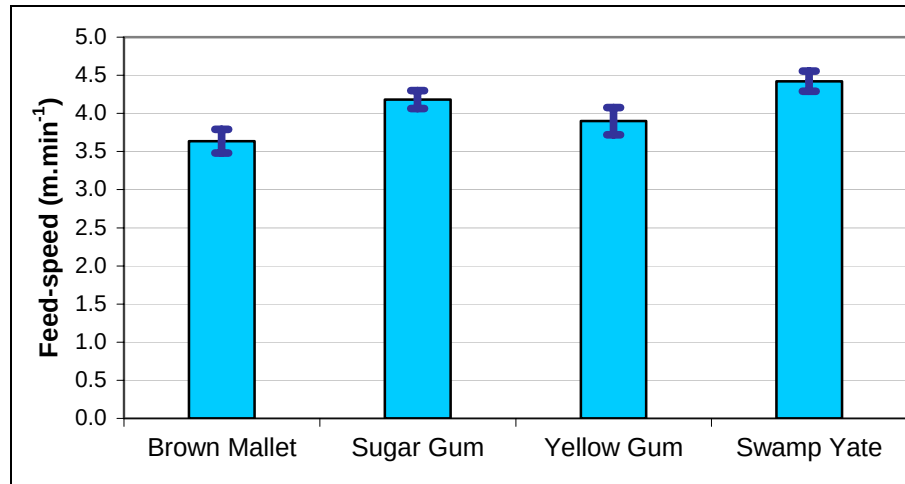


Fig. 8.5: Feed-speed comparing species (bars = S.E.).

Examination of the feed-speed for cuts in each species by blade-tip width showed significant differences but these were not consistent across the species. The results are summarized in Table 8.1, and the significance level for the species against individual blade-tip width is shown in the right-hand column of the table.

Table 8.1: Summary of relative feed-speeds for species and blade-tip widths with significance levels.

	4.5 mm	5.0 mm	5.4 mm	5.7 mm	Significance level for species
Brown Mallet	slower	faster	slower	slower	$p < 0.001$
Sugar Gum	faster	faster	slower	slower	$p < 0.001$
Yellow Gum	slower	faster	slower	slower	$p < 0.001$
Swamp Yate	faster	slower	slower	slower	$p < 0.001$
Significance level for blade-tip width	$p < 0.001$	$p = 0.038$	$p = 0.021$	$p = 0.002$	

8.4.1.3 Blade-tip width

For all species and in both sawing orientations combined there was a highly significant difference ($p < 0.001$) between the species. The two narrower tipped blades (4.5 and 5.0 mm) sawed at significantly faster rates to the wider tipped blades (5.4 and 5.7 mm) (Fig.8.6).

Examination of the feed-speed for cuts in each blade-tip width by species showed significant differences but these were not consistent across the blade-tip widths. The results are summarized in Table 8.1. The significance level for the blade-tip width against each species is shown across the bottom row of the table.

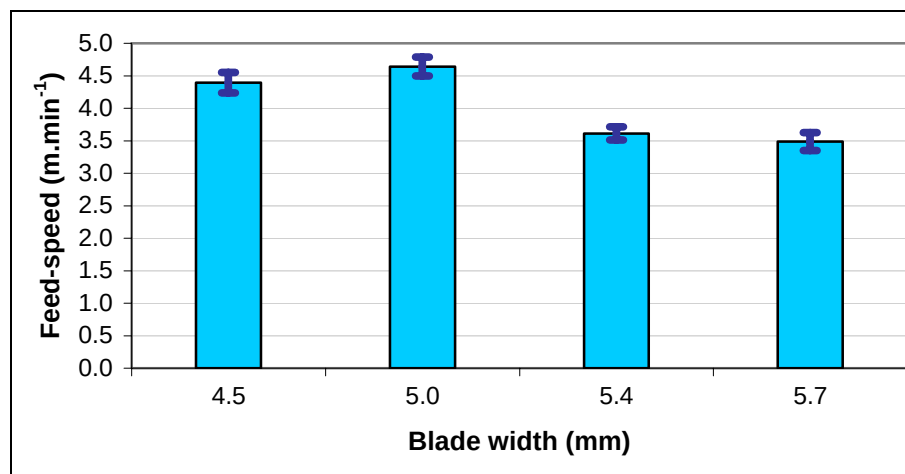


Fig. 8.6: Feed-speed comparing blade-tip widths (bars = S.E.).

8.4.2 Horizontal bandsaw - Controlled engine speed with tension, hook and set varied

In the Sugar Gum feed-speed varied across all cuts from 0.99 m·min⁻¹ to 6.76 m·min⁻¹ with an average of 2.46 m·min⁻¹.

8.4.2.1 Blade tension

For blade tension (Fig. 8.7), feed-speed was significantly slower ($p < 0.001$) for the lowest blade tension but there was no difference between the higher tensions.

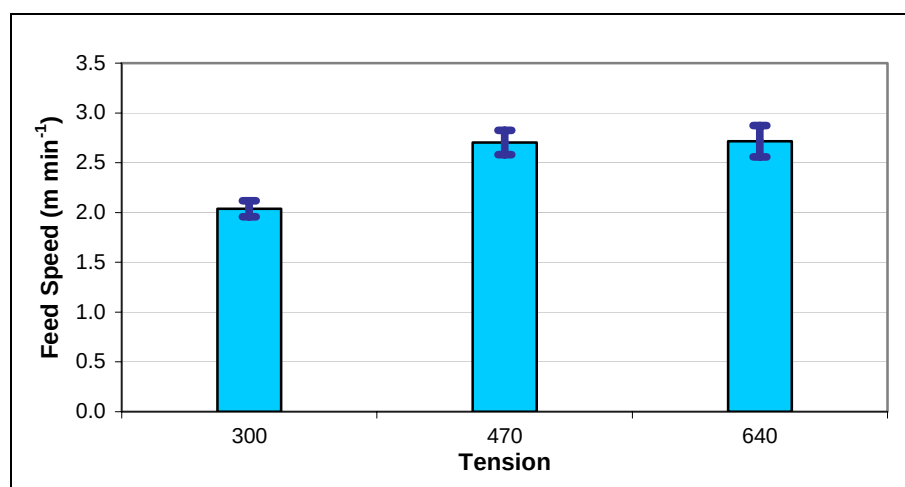


Fig. 8.7: Feed-speed compared to blade tension (bars = S.E.).

8.4.2.2 Blade tooth set

Feed-speed was significantly different for tooth set ($p < 0.001$) with the feed-speed for the widest set faster than the other two sets (Fig. 8.8).

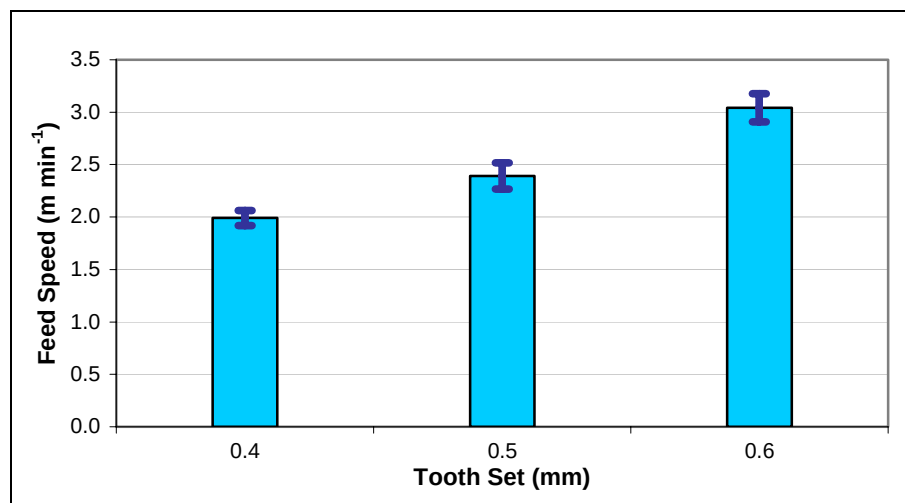


Fig. 8.8: Feed-speed compared to tooth set (bars = S.E.).

8.4.2.3 Tooth hook angle

There was no significant effect of hook angle on feed-speed (Fig. 8.9) with average feed-speeds of 2.5 m·min⁻¹.

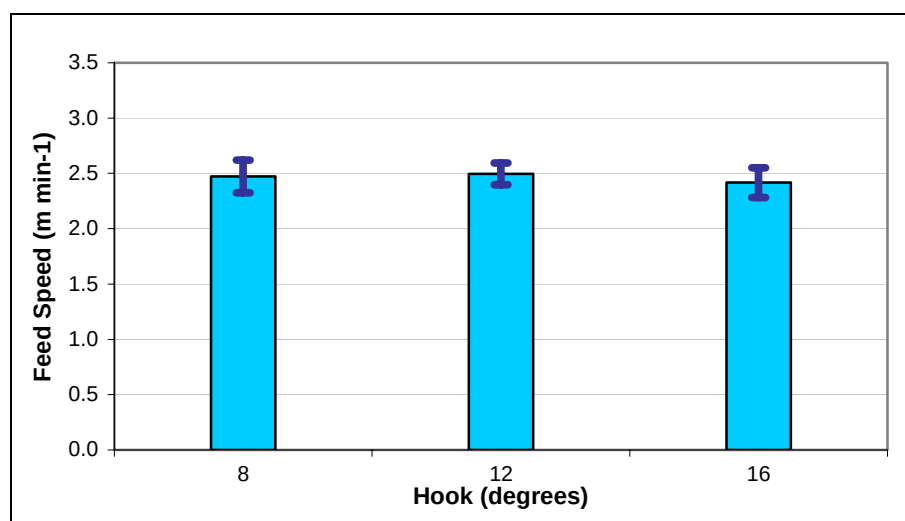


Fig. 8.9: Feed-speed compared to hook angle (bars = S.E.).

8.4.3 Horizontal bandsaw - Controlled engine speed compared to species and blade type

For operational reasons, it was not possible to achieve the same number of replicates of each species x speed combination. The summary of the results is shown in Tables 8.2 and 8.3.

Table 8.2: The mean and coefficient of variation of the measured deviation (mm) from a straight cut for species at each tested speed.

	Sugar Gum		Swamp Yate		Brown Mallet		Yellow Gum	
Speed	Mean	cv	Mean	cv	Mean	cv	Mean	cv
2 m min ⁻¹	1.08	15 %	1.04	14 %				

3 m min ⁻¹	1.34	17 %	0.99	17 %		
4 m min ⁻¹	1.36	14 %	1.08	23 %		
5 m min ⁻¹	1.76	11 %	0.88	25 %	0.73	11 %
6 m min ⁻¹	1.80	24 %	1.00	18 %	1.01	39 %
7 m min ⁻¹	2.95	39 %	1.43	11 %	0.84	16 %
8 m min ⁻¹					1.35	28%

Table 8.3: Mean, Maximum and Minimum of the measured deviation from a straight cut for each speed and species

	Sugar Gum			Swamp Yate			Brown Mallet			Yellow Gum		
Speed	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min	Mean	Max	Min
2 m min ⁻¹	1.08	0.70	-0.38	1.04	0.89	-0.15						
3 m min ⁻¹	1.34	0.93	-0.41	0.99	0.87	-0.11						
4 m min ⁻¹	1.36	0.49	-0.88	1.08	0.93	-0.15						
5 m min ⁻¹	1.76	0.94	-0.82	0.88	0.84	-0.04	0.73	0.62	-0.12	1.22	-0.19	1.02
6 m min ⁻¹	1.80	0.54	-1.26	1.00	0.96	-0.04	1.01	0.43	-0.58			
7 m min ⁻¹	2.95	1.39	-1.56	1.43	0.94	-0.49	0.84	0.28	-0.84	1.66	-0.40	1.26
8 m min ⁻¹							1.35	0.28	-1.07			

8.4.3.1 Species

Feed-speed varied across all boards from 0.22 m.min⁻¹ to 7.48 m.min⁻¹ with an average of 2.46 m.min⁻¹.

Swamp Yate was significantly faster to saw than was the Sugar Gum ($p < 0.01$). There was no significant difference in the speed of sawing between Brown Mallet and Yellow Gum (Fig. 8.10).

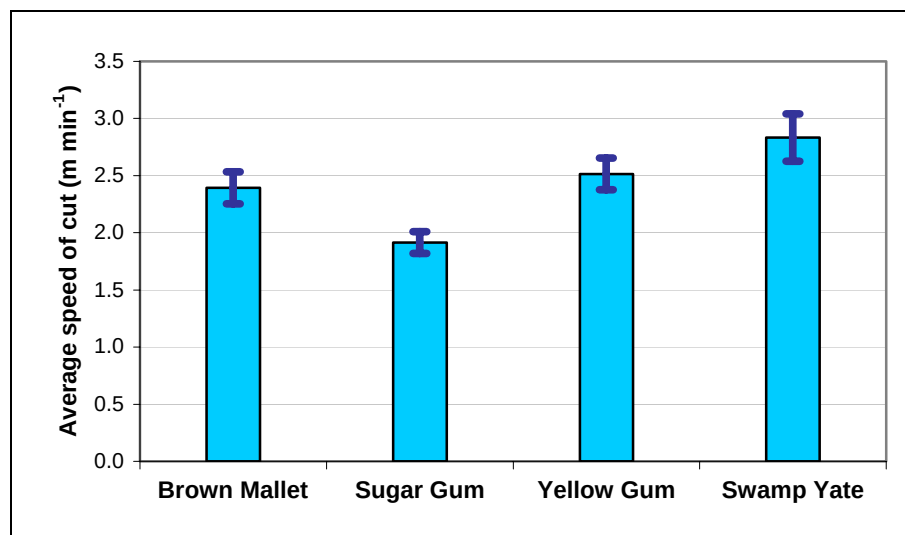


Fig. 8.10: The average feed-speed for all cuts by species (bars = S.E.).

8.4.3.2 Controlled engine speed with variable blade type

The average feed-speed for the different blades fell into two distinct groups, which were significantly different to each other ($p < 0.001$) while there was no difference within the groups (Fig. 8.11). The faster group contained both 32 mm and 50 mm Bi-Metal blades plus the 32 mm Carbide-tipped blade. The slower group comprised both the carbon steel blades (32 mm and 50 mm) and the 50 mm Carbide-tipped blade.

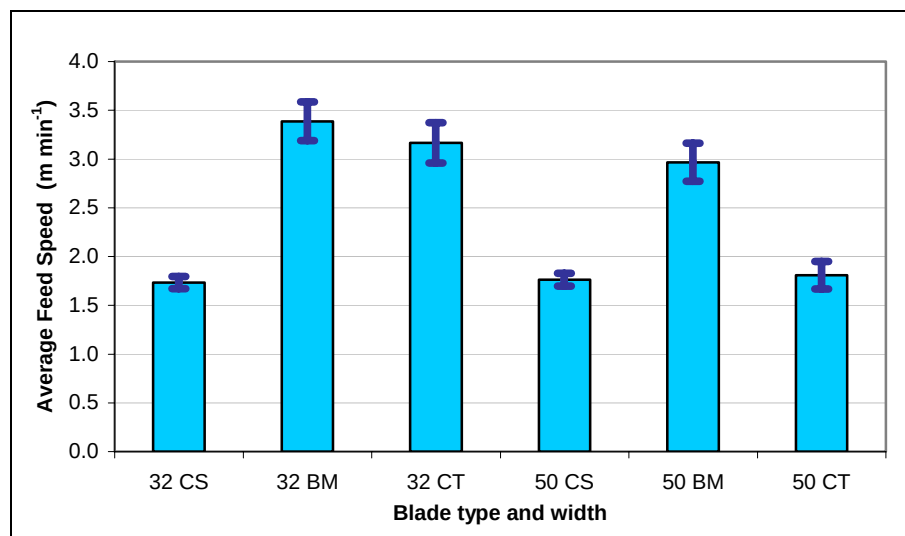


Fig. 8.11: Average feed-speed for different blades (bars = S.E.). Blade codes are as described earlier.

8.4.4 Horizontal bandsaw - Controlled Feed-speed Sawing

During the controlled feed-speed trials, while the feed-speed of the sawing head was kept constant, the variables measured were the deviation of the cut, engine speed and the force applied to pull the sawing head through the log.

8.4.4.1 Calculated v nominal feed-speed

The actual feed-speed was calculated by timing the duration of each cut. This was compared to the nominated feed-speed in order to ascertain the reliability of using the nominated speed as a controlled variable.

The nominal, or controlled speed, was found to be very close to the actual, or calculated speed, with the variation between cuts very small (the standard error bars are almost not visible in Fig. 8.12). The largest variation was at the 5 m·min⁻¹ level where the actual speed was 3.2% below the nominal speed.

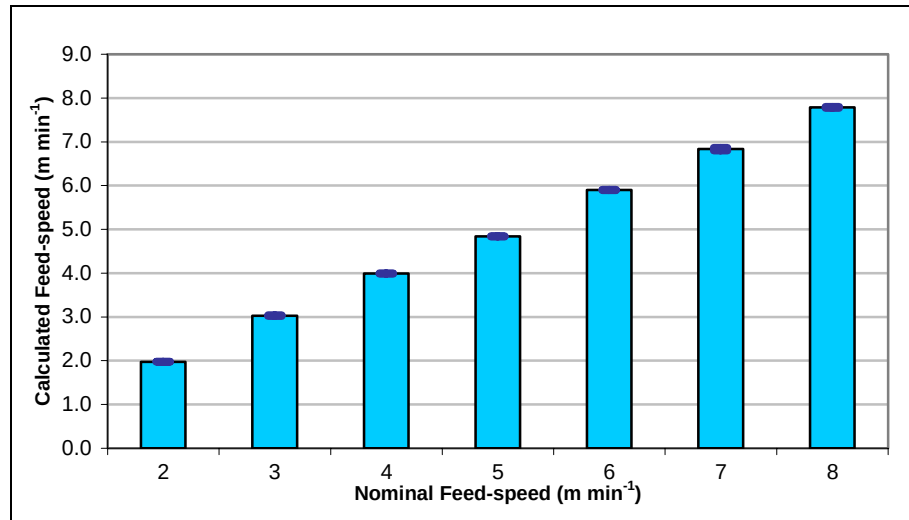


Fig. 8.12: Calculated feed-speeds for all cuts as compared with nominal feed-speeds (bars = S.E.).

8.4.4.2 Force and Engine speed

The force required to pull the carriage while sawing through the flitch averaged 13 kg-wt with a maximum of 17 kg-wt. There was no significant difference in force when compared with feed-speed using an ANOVA.

The engine speed dropped from the start of the cut through to the end of the cut when constant feed-speeds were applied. There was a significant difference in the reduction in engine speed from the slowest feed-speed to the fastest feed-speeds although there was no difference between adjacent speeds except for a feed-speed of 8 m·min⁻¹ which was faster than the 7 m·min⁻¹ (Fig.8.13). In other words, while there was a significant difference in the reduction in engine speed as feed-speed increased, this was comprised mostly of a gradual reduction as feed-speed increased.

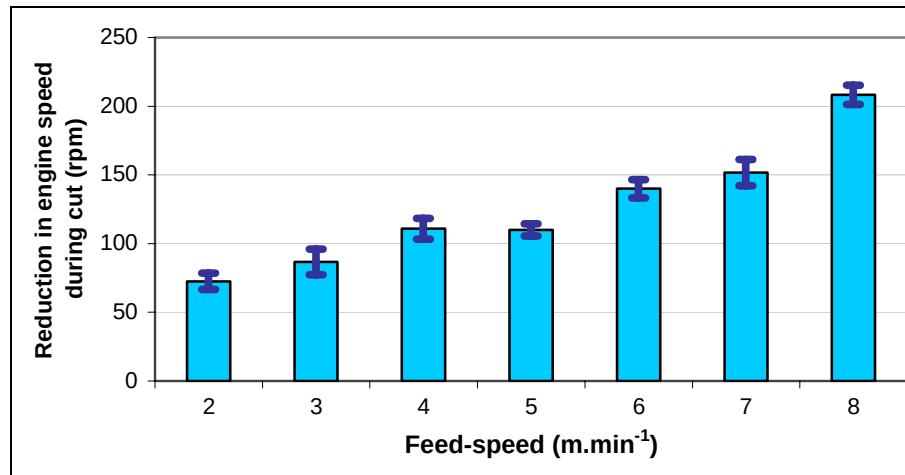


Fig. 8.13: Reduction in engine speed at the various feed-speeds.

8.4.4.3 Deviation compared to species

Across all species taken together, the deviation for each board varied from 0.58 mm to 4.49 mm with an average of 1.38 mm.

The deviation along the cut for all species combined (Fig. 8.14) showed the deviation for the 7 m·min⁻¹ feed-speed was significantly greater than all the slower speeds ($p < 0.01$). There were no significant differences in the deviations between the 2, 3, 4, 5, 6 and 8 m·min⁻¹ feed-speeds or between the 7 and 8 m·min⁻¹ feed-speeds.

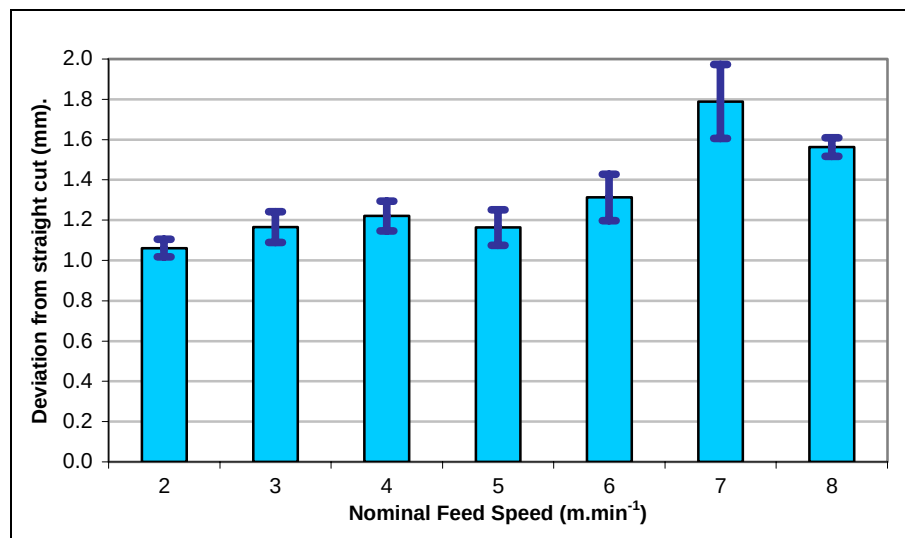


Fig. 8.14 Deviation along the cut for all species by feed-speed in m·min⁻¹ (bars = s.e.)

The average deviation along the cut of each speed class in Brown Mallet reveals the greatest variation at the fastest speed of 8 m·min⁻¹. The average of the deviations of all speeds was within the acceptable range of 1.5 mm. At 6 m·min⁻¹ feed-speed, the deviation of only one cut was outside the acceptable range of 1.5 mm (1.74 mm). While at the 8 m·min⁻¹ speed three cuts were outside the acceptable range of 1.5 mm (1.63, 1.69 and 2.14 mm) while all cuts at the 5 and 7 m·min⁻¹ were within the acceptable range (Fig. 8.15 and 8.16).

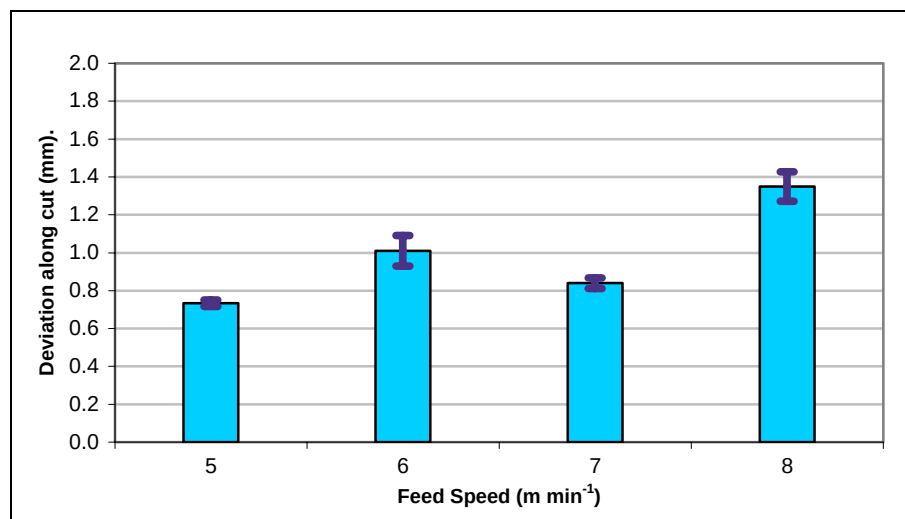


Fig. 8.15: Means of the deviation along the cut for six cuts at each feed-speed in Brown Mallet (bars = s.e.).

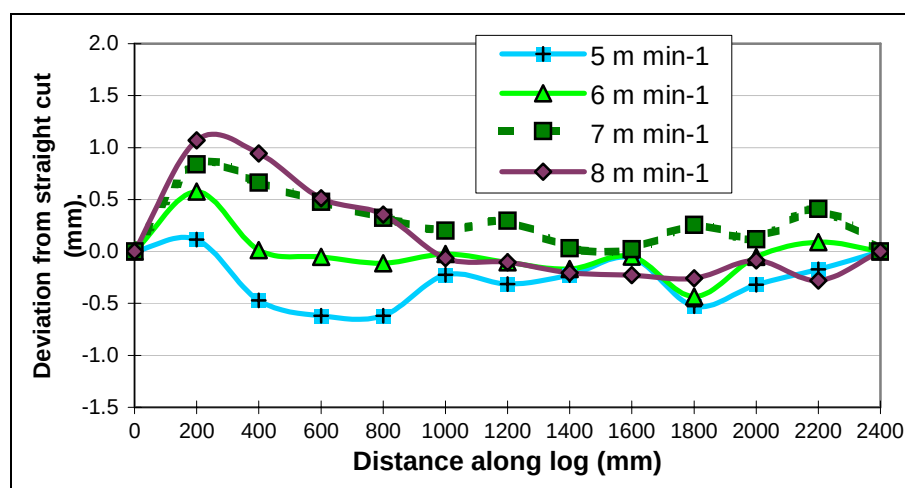


Fig. 8.16: Profile of deviation for cuts along the flitch in Brown Mallet.

For Sugar Gum (Fig. 8.17 and 8.18), there was a significantly greater ($p < 0.001$) total deviation between the 7 m·min⁻¹ feed-speed and the slower speeds, between which there were no significant differences.

The average deviation along the cut of each speed class in Sugar Gum reveals the greatest variation at the fastest speed of 7 m·min⁻¹, with the total deviation of the 5, 6 and 7 m·min⁻¹ appearing outside the acceptable range of 1.5 mm. As the lowest speed of 2 m min⁻¹ the mean deviation was the lowest. With trials using faster feed speeds the deviations although acceptable increased with increasing speeds (Fig. 8.17 and 8.18).

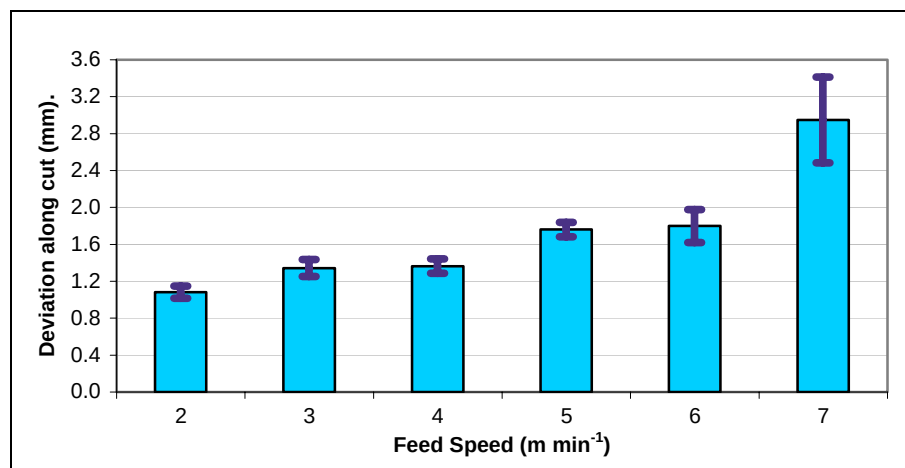


Fig. 8.17: Means of deviation along the cut at each feed-speed in Sugar Gum (bars = s.e.).

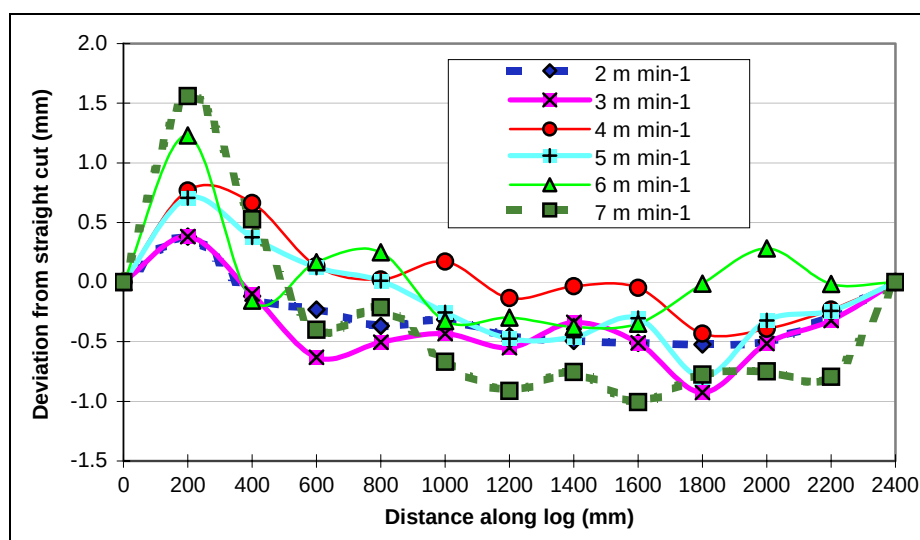


Fig. 8.18: Profile of deviation of cuts along the flitch in Sugar Gum.

For Yellow Gum (Fig. 8.19), there was a significant difference in the deviation from a straight cut between the feed-speed at 7 m·min⁻¹ and the slower speed of 5 m·min⁻¹.

The average deviation along the cut of each feed-speed class in Yellow Gum was significantly greater ($p < 0.001$) at the fastest speed of 7 m·min⁻¹ than at 5 m·min⁻¹. The total deviations of all cuts at a speed of 5 m·min⁻¹ were within the acceptable range of 1.5 mm while at the 7 m·min⁻¹ speed, the deviations of five cuts were outside the acceptable range of 1.5 mm (1.59, 1.69, 1.69, 1.73 and 1.89 mm) (Fig. 8.19 and 8.20).

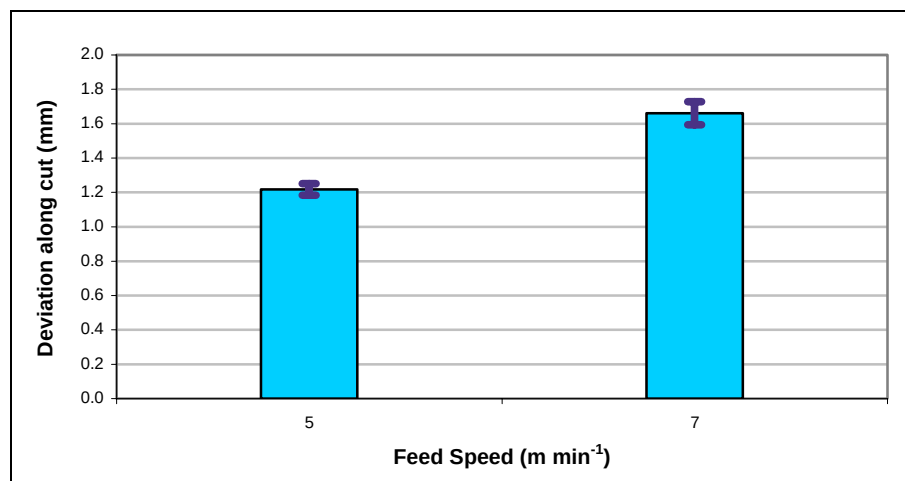


Fig. 8.19: Means of deviation along the cut at each feed-speed in Yellow Gum (bars = s.e.).

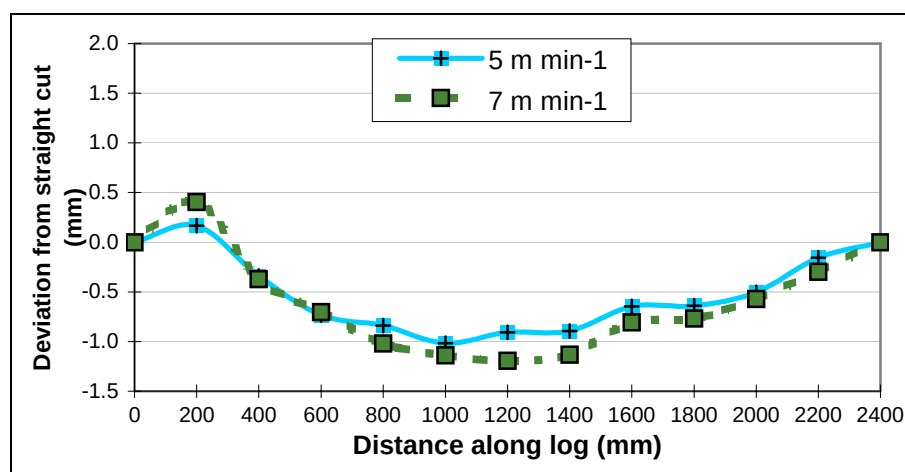


Fig. 8.20: Profile of mean deviation of cuts along the flitch for each feed-speed in Yellow Gum.

The average deviation along the cut of each feed-speed class in Swamp Yate showed the deviation was significantly greater ($p < 0.001$) at the fastest speed of $7 \text{ m} \cdot \text{min}^{-1}$ than at all other feed-speeds except for the $4 \text{ m} \cdot \text{min}^{-1}$ feed-speed. There was no significant difference in deviations for the feed-speeds 2 to $6 \text{ m} \cdot \text{min}^{-1}$. The average of the total deviations at all speeds was within the acceptable range of 1.5 mm. At the $7 \text{ m} \cdot \text{min}^{-1}$ speed, the deviation of only 2 cuts was outside the acceptable range of 1.5 mm (1.57 and 1.75 mm) and all other cuts were within the acceptable range (Fig. 8.21 and 8.22).

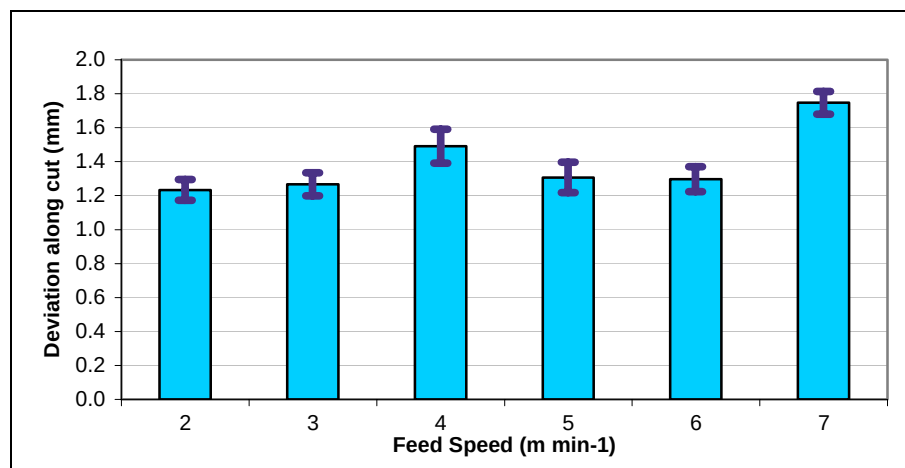


Fig. 8.21: Means of the total deviation along the cut for six cuts at each feed-speed in Swamp Yate (bars = s.e.).

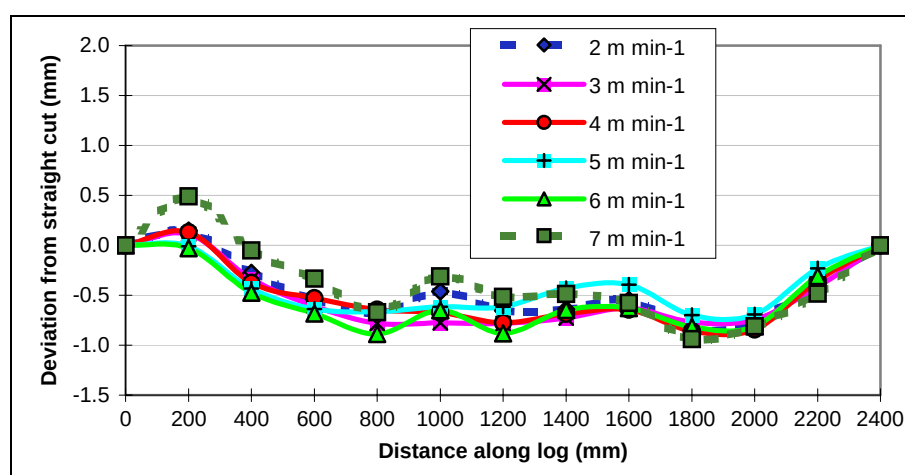


Fig. 8.22: Profile of deviation for cuts along the flitch from feed-speeds of 2, 3, 4, 5, 6 and 7 m·min⁻¹ in Swamp Yate.

8.4.5 Horizontal bandsaw - Blade longevity

By the continuous use of a blade without sharpening, the effect of blade dulling on the change in deviation could be measured. There was no significant difference between the deviations at 8 m·min⁻¹ ($p = 0.127$) of any of the groups of cuts containing six boards.

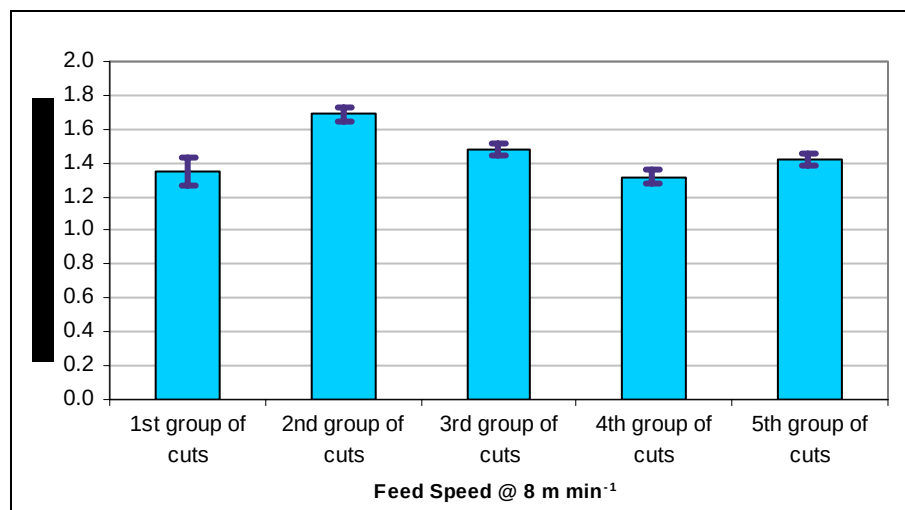


Fig. 8.23: Means of deviations along 30 cuts (five groups of six cuts) at feed-speed of 8 m·min⁻¹ in Brown Mallet without changing or sharpening the blade (bars = S.E.).

8.5 Discussion

8.5.1 Single circular sawmill – controlled engine speed with blade tip width and species varied

As shown in Chapter 5 the orientation of the cut significantly affects the straightness of cut but these results show that the speed of cut is not affected by orientation.

In all the species, it was either of the narrower tipped blades (4.5 and 5.0 mm) that sawed at the fastest feed-speed. This would appear to be logical as there was less timber being removed in the saw kerf. The available power from the motor was controlled to maintain engine speed at 3500 rpm and this would favour a blade which required less power to remove wood from the saw-cut.

The 5.0 mm blade proved to produce the fastest feed-speed in Sugar Gum, Yellow Gum, and Brown Mallet while in Swamp Yate the fastest feed-speed was obtained when using the 4.5 mm blade. This would suggest that when considering feed-speeds, a blade with a 5.0 mm wide tip should produce the fastest feed-speed in the majority when sawing the high-density species trialled. The 4.5 mm wide blade would be a second option as this blade obtained fast feed-speeds in half the species.

8.5.2 Horizontal bandsaw - controlled engine speed with tension, hook and set varied

As mentioned earlier, the speed of cutting is actually a derived quantity that results from the way this trial was conducted, i.e. the saw-blade was pushed in such a way as to maintain engine speed (and by implication engine power). However, the findings are useful.

The average feed-speed for each log used is shown in Fig 8.24. Log SG06 was the last log available from the initial logs procured. Logs SG07, SG08 and SG09 were part of a second batch of six logs obtained from the same tree. After cutting Log SG06 and SG07, it was realized there were highly significant differences in both speed and sawing deviation between logs. It was decided to repeat the cuts with the same combination of variables as used in Log SG06 in the next three logs. This degree of difference between logs was expected, as the variation between different trees is considerable but by using logs cut from

within the same tree, it was hoped to reduce differences between trees and test the variables of tension, hook and set. There was a significant difference between the feed-speed of the logs, with Log SG07 cutting faster than Logs SG08 and SG09.

The significantly slower feed-speed at the lowest blade tension (Fig. 8.7) is probably due to increased drag caused by increased wandering of the blade. This has obvious implications for productivity as well as cutting accuracy.

The significantly faster feed-speed associated with the highest set (Fig. 8.8) and the fact that there was an increasing trend in feed-speed from the lowest set, although the difference between 0.4 and 0.5 mm set was not significant, suggests that the wider bite of the blade is allowing the sawblade to move through the wood faster. This makes sense and while it will have important implications for operational trials, it does provide a conflict with the possible lower cutting accuracy associated with the highest set. However, there may be another explanation. All the cuts made with the wider sets (0.6 mm) were in Log SG07, which cut significantly faster than the logs (SG08 and SG09) which were sawn with the narrower sets. This could need more study and the effect of log differences that were outside the scope of this project need greater investigation.

The fact that there was no effect of tooth angle on feed-speed is a little surprising, as it might have been expected that a higher tooth angle would increase the bite into the wood. It is possible that other factors are dominating the effect of hook angle in the data. The relatively small changes in hook angle (8° , 12° and 16°) may be a factor as no aggressive hook angles were selected for this trial. The industry suggests a low (less aggressive) hook angle for hardwoods while softwoods will allow a larger (more aggressive) hook angle. However, the terms more and less aggressive are very subjective or qualitative and it is possible that in an attempt to quantify the effects of hook angle the range chosen has inadvertently been within tolerable limits for what is considered less aggressive.

The speed of cut was again a derived quantity, which may give an idea of the operational characteristics of the blade. Although there was a statistical difference in the average speed of cut between the species (Fig. 8.10) with the Swamp Yate (2.8 m min^{-1}) cutting faster than the Sugar Gum (1.9 m min^{-1}) the actual speeds are not greatly different. The Sugar Gum cuts did not include any samples with the 32 mm Bi-Metal or the 50 mm Carbide-tipped blades, as there were not enough logs available. As the two blades not included in the Sugar Gum sawing were the fastest and almost slowest this would average out and the chart in Fig. 8.11 would show the true indication of the feed-speed.

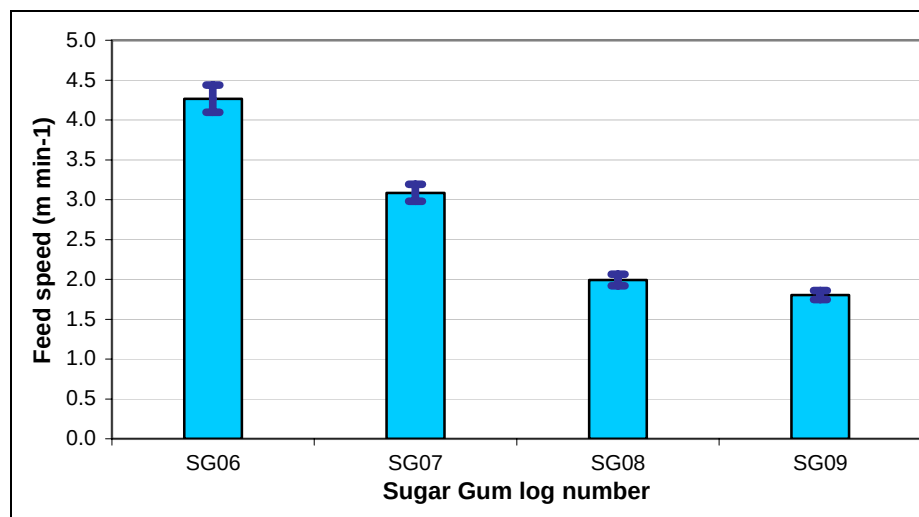


Fig. 8.24: Average speed of cut for each log in the controlled speed, tension, hook and set trials.

8.5.3 Horizontal bandsaw - Controlled Feed-speed Sawing

There were some surprising results from this trial. This showed that driving the sawing head through at a near constant speed produced less sawing problems than pushing the carriage along the flitch by hand.

Feed-speeds of $8 \text{ m} \cdot \text{min}^{-1}$ were not expected when setting up this trial. The earlier results indicating that there is a critical feed-speed have been proved incorrect and that the more or less constant force exerted on the blade as it saws into the flitch, produces a superior cut with less deviation at a faster feed-speed. This could have implications for operators wishing to speed up sawing while maintaining an acceptable quality of cut.

However, excessive speed does cause problems with sawing. Fig. 8.25 shows a cut, where, due to an error in selecting the correct sawing speed with the adjustable frequency drive controller, the speed was set at twice the desired feed rate. This caused the blade to dive when it was about 600 mm along the cut, the engine speed dropped very quickly and the force increased. The motor was stopped and the cut had to be wedged open to allow the blade to be withdrawn. The implication is that there is a critical feed-speed but with a controlled driving mechanism this might be greater than pushing by hand. The cost of installing such a mechanism has to be considered on its merits by individual operators.

This should not be a common practice but shows what can happen when excessive feed-speeds are employed. Time is lost, material wasted and blades can be destroyed.

The profile of deviations shows the blade generally rose as it entered the cut then fell before more or less leveling out at the end. The reason for this rise and then fall is not obvious and may be a factor of the tension of mill design but the deviations in most cases were minimal.

The forces applied to pull the sawing head through during sawing varied considerably. The force was not consistent during a given cut and the readings would change constantly. The recorded results were the readings when the blade was above the specified marks but the force could be 2 or 3 kg-wt different in another position.



Fig. 8.25: Diving cut in Sugar Gum due to incorrect speed setting.

The average force required was 13 kg-wt with the maximum only 17 kg-wt. This appeared lower than was anticipated as the carriage and motor had to be pulled by this force. Some cuts, in earlier trials where the carriage was pushed by hand, seemed to require more effort than this. These forces did not show any particular pattern that could be useful in any way either along the cuts or in relation to feed-speed. It was expected that force may increase with feed-speed but this was not proven or even indicated. This would seem to suggest that if all parameters are correctly set (engine speed, blade tension, hook angle and set) the effort required to saw through a hard dense timber such as Sugar Gum with a bandsaw is relatively low. The low power requirement is precisely one of the advantages espoused for bandsaw mills.

The optimum feed-speed varied for each species. Brown Mallet produced straight cuts at $8 \text{ m} \cdot \text{min}^{-1}$ and due to difficulties in measuring, faster speeds were not investigated. However, Sugar Gum failed to produce straight cuts at speeds above $4 \text{ m} \cdot \text{min}^{-1}$. Swamp Yate also produced straight cuts at $7 \text{ m} \cdot \text{min}^{-1}$ but the lack of logs prevented any faster speeds being investigated. Only two speeds were tried in Yellow Gum which showed $5 \text{ m} \cdot \text{min}^{-1}$ was acceptable while at $7 \text{ m} \cdot \text{min}^{-1}$ the average deviation was above 1.5 mm.

The optimum feed-speeds for different species was shown to vary. This is an issue that each operator will need to assess on its merits depending on their particular mill, the width of cut and the species being sawn. From these trials a maximum feed-speed of $4 \text{ m} \cdot \text{min}^{-1}$ would achieve the straightest cuts in all species but operationally the Brown Mallet can be sawn at twice that feed-speed with a similar straightness.

8.5.4 Horizontal bandsaw - Blade longevity

Sawing of the Brown Mallet with the 32 mm Bi-Metal blade produced 30 cuts without any difference in the straightness. The need to produce a quantity of boards before changing blades is obvious as changing and sharpening blades is time-consuming and loss of production occurs. The cost of replacing blades after they have worn out is also important. However, the investigations by Stewart and Hanson (1998) showed that the economics of portable milling are not greatly affected by productivity or maintenance and running costs. The most important factor was the price received for the timber and this highlights the greater need for careful sawing in wood that has potentially a very high value.

The performance of the 32 mm Bi-Metal blade showed that it was a good production blade for all circumstances.

8.6 Conclusion

The speed of sawing using the controlled engine speed was almost twice as fast with the single circular saw than with the horizontal bandsaw.

8.6.1 Single circular sawmill – controlled engine speed with blade tip width and species varied

The 5.0 mm blade milled at the fastest feed-speed for the majority of species and was equal in producing the straightest cuts in the difficult horizontal orientation. The 5.0 mm blade appears to be the best overall-performing blade for use on a single circular sawmill with high density species.

8.6.2 Horizontal bandsaw - controlled engine speed with tension, hook and set varied

The feed-speed of the horizontal bandsaw increased with wider tooth set but the speed decreased if the blade tension was too low. However, sawing with a blade using the highest set of 0.6 mm results in a greater deviation in the straightness of cut.

8.6.3 Horizontal bandsaw - Controlled engine speed compared to species and blade type

The 32 mm Bi-Metal blade produced the straightest cuts at the highest feed-speed and may be marginally better than the 32 mm Carbide-tipped blade.

8.6.4 Horizontal bandsaw - Controlled Feed-speed Sawing

The use of an adjustable frequency drive controller and motor to produce a constant feed-speed of the carriage along the log gave faster cutting rates with no reduction in straightness. These results showed that although the force required to pull the sawing head through the cut was not constant and varied along the log, the speed tended to stay around 3450 rpm and cutting straightness was maintained in all species if the feed-speed was below $5\text{ m}\cdot\text{min}^{-1}$.

This trial revealed that on a horizontal bandsaw a power driven sawing-carriage feed system gives superior cutting performance with faster feed-speeds and without reducing straightness than can be achieved by manually pushing the power head along the flitch.

The Sugar Gum was the hardest to saw and achieve a straight cut. For Sugar Gum, feed-speeds must not be above $4\text{ m}\cdot\text{min}^{-1}$ to obtain satisfactory results. For Brown Mallet feed-speeds of $8\text{ m}\cdot\text{min}^{-1}$ are acceptable. Yellow Gum were milled at around $5\text{ m}\cdot\text{min}^{-1}$ while in Swamp Yate feed-speeds over $6\text{ m}\cdot\text{min}^{-1}$ started to reduce straightness in the cuts.

It was obvious that feed-speeds vary with species, and operators will need to look at each species and determine their own optimum cutting rates.

8.6.5 Horizontal bandsaw - Blade longevity

No conclusions can be drawn from the trials into blade longevity as only one blade was investigated.

9 Conclusion

The objective of this study was to investigate the use of two basic types of portable sawmill in the processing of some farm or plantation grown trees from the semi arid regions of Australia. An investigation by Blakemore *et al.* (2001) revealed there were a limited number of plantations with sufficient quantity of suitable saw logs within the low rainfall regions of south-eastern Australia for sawing trials. The only plantations that had sufficient sawlogs were of high-density eucalypt species. The four species selected were Brown Mallet (*Eucalyptus astringens*), Sugar Gum (*Eucalyptus cladocalyx*), Yellow Gum (*Eucalyptus leucoxylon*) and Swamp Yate (*Eucalyptus occidentalis*).

Due to the limited quantity of logs that will be available from the low rainfall regions of south-eastern Australia, the establishment of a large infrastructure would not be warranted. This would suit the use of portable sawmills which can be used on-site and operate at a financially viable level with lower volumes of timber if they are producing high value timber.

There is a perception by some within the sawmilling industry that portable sawmills cannot produce the sawing quality in high-density timbers that is required by the furniture industry. The results from this project showed the selected species produced dimensionally consistent boards that have the potential to be used in the manufacture of furniture.

Timber that is used in furniture has traditionally been at the high value end of the market and this indicates that milling these high-density species with a portable sawmill can be profitable, if further research shows the species have the desired wood properties required for quality furniture manufacturing.

This project only investigated the milling of the four trial species mentioned above, with two different portable sawmills. The blade characteristics were examined and compared to establish any limiting factors with the sawing of high-density timber.

9.1 Different types of portable mill

The mills used in the sawing trials were a single circular blade type sawmill, which was represented by a 'LucasMill TM Model 8' and a horizontal bandsaw type sawmill, which was represented by a 'Laidlaw ®Farmill'. These mills were at the lower end of automation available on portable sawmills with both mills requiring an operator to push and pull the power head along the log to produce sawn boards.

The investigation of sawing with both types of portable mill was the straightness of cut as the measure of sawing accuracy with total deviation or waviness in the cut of less than 1.5 mm being considered acceptable.

Both portable mills were shown to produce straight saw cuts, given the right conditions in the blade configuration and feed-speed for the species selected.

Both mill types have specific issues and limitations in relation to performance and operators will be required to select the mill which best suits their needs related to species availability and desired final product.

It was not the purpose or scope of this study to recommend a particular type of portable sawmill in preference to another. Both the circular and band sawmills produced acceptably straight cuts. The differences in mill type concerns issues such as size of cut, log and flitch handling, productivity and recovery as covered in detail in Stewart and Hanson (1998).

9.2 Operational performance of different mills

Operationally little could be changed on the single circular blade sawmill with the width of blade tip the only variable that could be altered. The examination of four blade-tip widths showed a blade with a 5 mm wide tip produced the straightest cuts and at the fastest feed-speeds.

The horizontal bandsaw allowed more blade variables to be examined such as hook angle, tooth set and blade tension. These results indicated the set affected the feed-speed of the cut while low tension reduced the straightness of cuts. The hook angle did not affect the straightness of cut but this may be a factor of the fact that only lower hook angles were selected for examination. The interaction between variables was not conclusive and could not be explained satisfactorily from the results.

The introduction of a power feed unit to the horizontal bandsaw significantly increased cutting feed-speeds without any reduction in the straightness of cut. This may be an option for operators wanting to increase production rates.

9.3 Comparison of different blade types

A range of blade types from different manufactures are available for use on horizontal bandsaws and with each manufacturer recommending their blades, it was decided to examine three blades manufactured with different tip construction and at two different blade widths. This revealed that the narrower Bi-Metal blade would saw straighter than the wider blade or blades manufactured with the different tip construction but this may be due to limitations on the tension that could be applied to the wide blades with the horizontal bandsaw used in these trials.

There is no mill or no blade, that will mill all species, in any condition, every time but operators will need to examine their particular circumstance to determine the best combination of variables to produce the result they require. To this end, this report has attempted to examine some of the variables in sawing high-density timber species. This is not intended as a prescription but as some suggestions that may assist operators, if they are having difficulties with their portable sawmill.

9.4 Recommendations

The following recommendations are made;

- The examination of the silvicultural practices such as thinning and pruning to increase the availability of quality sawlogs from high-density timber species.
- The commercialisation of high-density timber species and their suitability for use in the manufacture of furniture.
- The wood and engineering properties of the high-density timber species for use in engineered products as very little is known about the properties of many of these species. Some of these engineering property are durability, modulus of elasticity, modulus of rupture, glueability, nail holding capabilities.
- The development of suitable adhesives to glue some of the difficult high-density timber species as Oszaka and Ashley (1999) are suggesting problems with gluing, e.g. Sugar Gum.

Glossary

Backsawn: sawn so that the wide face of the piece is a tangential plane of the growth rings. Trade practice in Australia is to class timber as quarter sawn when the average inclination of its growth rings to its wide face is less than 45 degrees (Fig. 10.1).

Board: a piece of timber sawn on all four sides with greater width than thickness.

Cant: a flitch with at least two sawn surfaces.

Clearance or back angle (γ): Is the angle between the back of the tooth and a line that joins the tooth tips (Fig. 10.2). Clearance angles of 10 degrees are suitable for many timbers. Small clearance angles give stronger tooth and greater wear but require greater feed forces (Frankson, 1977).

Face angle: (Fig 10.2) is the angle of the tooth face in relation to the body of the blade. The angle should remain at 90 degrees for all teeth to pull sawdust forward out of the kerf (Wood-Mizer, 1988).

Flitch: a large piece of sawn log intended for further cutting.

Growth rings: a ring sometimes visible on the cross section of a trunk or branch marking a cycle of growth.

Growth Stresses: the tension and compression forces within a log that, when released, can cause distortion in a board.

Gullet depth: is the distance from a line joining the tooth tips to the deepest point of the gullet (Fig. 10.2).

Hook or rake angle (α): is the angle included between a line from the tooth tip and perpendicular with the back of a bandsaw blade, and a line following the cutting face of the tooth. For a circular saw, the angle is between a line from the center of the saw to the tooth tip and a line following the cutting face of the tooth (Fig. 10.2).

Kerf: is the width of timber removed by a sawblade during a cut. This is addition of the blade thickness plus the clearance on each side of the blade produced by the set, swage or tip.

Pitch or tooth spacing: is the distance between teeth (Fig. 10.2). This can be expressed as teeth per inch (tpi) or teeth per foot (tpf) for imperial measurements. Generally, for metric units pitch is a millimeter distance tooth tip to adjacent tooth tip.

Quarter sawn: sawn so that the wide face of the piece is a radial plane of the log. Trade practice in Australia is to class timber as quarter sawn when the average inclination of its growth rings to its wide face is greater than 45degrees (Fig. 2.2).

Radial: is the direction at right angles (90°) to the growth rings (Fig. 10.1- from pith to bark direction).

Sawing Deviation: a deviation of a saw cut from the intended line or contour (SAA, 1975).

Set: is the distance a tooth is bent or deflected from the line of the body of the blade, to give clearance for the body of the blade to pass through the wood during sawing. A tooth with no set is called a raker tooth (Fig 10.3).

Slab: a piece of timber that has been dimensioned to thickness but not width.

Tangential: in the same general direction as the growth rings (Fig. 10.1).

Tooth or sharpness angle (β): can be also be called the tooth-point angle or included angle. It is the angle from the cutting face to the back of the tooth (Fig. 10.3). This angle should be as large as possible to ensure sufficient strength in the tooth and reduced wear (Frankson, 1977).

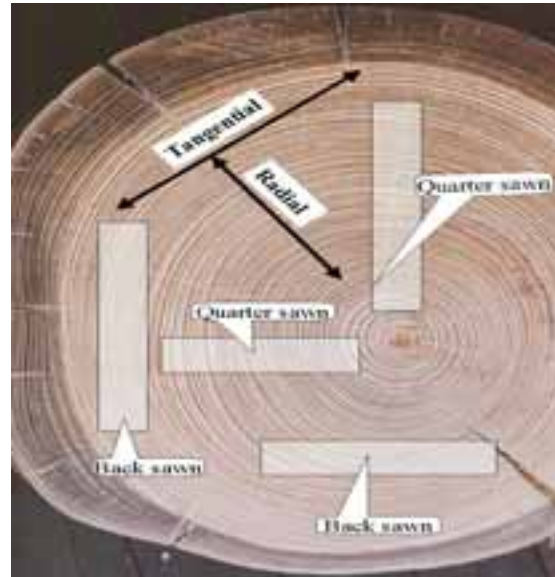


Fig. 10.1: Examples of back sawn and quarter sawn boards in a log. The arrows indicate the tangential and radial direction relative to the growth rings

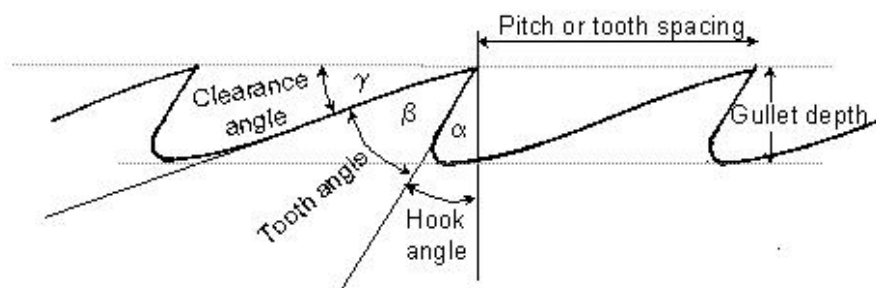


Fig. 10.2: Side view of typical bandsaw blade showing tooth shape and spacing. This is a representative drawing from the explanation of the terms used in describing a blade and not meant to be the profile for all blades.

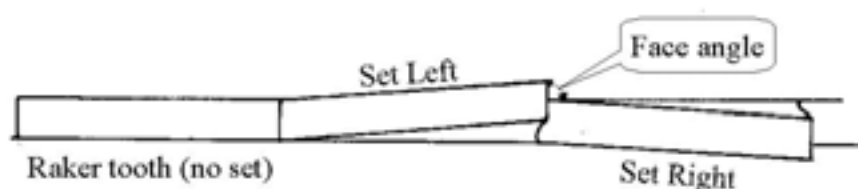


Fig. 10.3: Top view for blade showing left and right set, face angle and raker tooth.

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