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A guide to manufacturing rotary veneer and products from small logs

Editors: William Leggate, Robert McGavin and Henri Bailleres

ACIAR MONOGRAPH 182

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Foreword

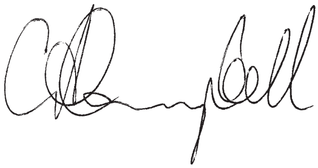
ACIAR has been supporting collaborative forestry research in developing countries for 35 years, with a particular focus on smallholder timber growing as well as the production of value-added products, to enhance the returns from tree growing.

Until recently, there have been limited opportunities to efficiently process small-diameter trees into high-value wood products, because conventional processing methods generally have very low recovery of products from small-diameter trees. As a consequence, large areas of forests including plantations are underutilised and often regarded as low quality.

Production of veneer products has been part of the wood processing sector in many countries, but the capital investment required and the necessary scale of operation was a barrier to adoption, especially for developing countries. Over the past decade, new technologies have emerged that now offer the potential for widespread development of new veneer processing operations that can utilise small-diameter trees grown by farmers. The development of spindleless lathes enables veneer sheet to be produced efficiently from small-diameter logs, down to a core size of 20–50 mm. The capital cost of this processing equipment is generally less than 10% of the cost of traditional veneer lathes, thereby opening up its application more widely in developing countries.

As with the introduction of most new technologies, in order to get the best results research and development is needed along with capacity building. The ACIAR Forestry program has supported a number of research projects in South-East Asia and the Pacific, which have focused on the use of spindleless lathes to produce veneer products from small-diameter plantation trees. Veneer production provides a unique opportunity to add significant value to trees grown by smallholders and in doing so create new industries and employment opportunities in developing countries.

This manual on the production of rotary wood veneer and associated manufacturing of veneer-based products draws on the results from the completed ACIAR projects. It provides extensive information and guidance on the processing of small log resources into veneer, along with the description of manufacturing techniques to convert the veneer into high-value engineered wood products suitable for a range of appearance and structural applications.



Andrew Campbell
Chief Executive Officer, ACIAR

Guest foreword

It is a great privilege to write a foreword for this book on the manufacture of rotary veneer products from small logs. I look back over my involvement with the Australasian veneer, plywood and laminated veneer lumber industry over the past 32 years and see the very great opportunities which modern spindleless veneer peeling technology presents. This technology is truly a game changer and will revolutionise the economics of veneer production and the subsequent production of veneer-based products such as plywood and laminated veneer lumber. This book provides an excellent overview of the veneer and plywood production process and gives an insight to the opportunities it presents.

Traditionally, only the very largest and best logs were suitable for veneer production. The resulting veneer recoveries were relatively low, less than 50%, and the final dried veneer cost, influenced by high log price and recovery, was expensive. We now have new technology with low capital cost (less than 20% of a traditional spindled lathe) capable of producing quality veneer from a low-cost small diameter resource and achieving unheard-of recoveries above 60%. In my opinion, the economics of veneer and plywood production have changed permanently. This opens tremendous opportunities for forest owners and wood processors alike to extract far greater value from low-quality wood resources. Going forward, veneer producers will be seeking small-diameter, fast-rotation plantation logs and small-diameter native forest logs. This type of resource can be supplied in significant volumes and delivered to processors cost-effectively. This will allow veneer processors to continue to compete in an ever more difficult market increasingly dominated by international low-cost structures. To a large extent, the excellent work accomplished by the research team under this ACIAR project will add security and new life to an industry which I have been privileged to have been a part of. Finally, I wish to thank the Queensland Department of Agriculture and Fisheries Forest Product Innovations team at the Salisbury Research Facility for their excellent work.

Simon Dorries

Chief Executive Officer, Australian Forestry Standard

Formerly General Manager of the Engineered Wood Products Association of Australasia

Chairperson Standards Australia Committee TM-011—Engineered Wood Products

Contents

Acknowledgments

Development and production of this book was supported by the Australian Centre for International Agricultural Research (ACIAR) and developed largely from the knowledge achieved through a four-year research project 'Enhancement of production of acacia and eucalypt peeled and sliced veneer products in Vietnam and Australia' (ACIAR project FST/2008/039). The project was co-funded by ACIAR and the Queensland Department of Agriculture and Fisheries (DAF).

Henri Bailleres led the research team, which included Adam Redman, Gary Hopewell, Rob McGavin, Rod Vella, Fred Lane, Joh Fehrmann, Chris Fitzgerald, Eric Littee, Dan Field, Rica Minett and Bill Leggate (Queensland DAF); Barbara Ozarska and Gerry Harris (University of Melbourne); and staff from the Vietnam Academy of Forest Science (VAFS), the Centre for Agricultural Policy (CAP), Vietnam and Vietnam Forestry University (VFU) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

The support provided by Queensland DAF through the provision of the unique facilities located at the Salisbury Research Facility is acknowledged as critical to facilitate the research activities.

The editors acknowledge the material they have drawn on from several publications and web-based resources. These are listed in the 'Further reading' section at the end of each chapter.

Except where otherwise credited, all photographs were provided by Queensland DAF.

The editors also gratefully acknowledge the work undertaken by Simon Dorries, John Huth, Susan House and Ted Stubbersfield in reviewing and commenting on draft versions of this book.

The authors would like to especially acknowledge the significant contributions and critical support by the late Fred Lane during the development and early phases of the project. Fred brought a wealth of commercial veneer processing and product manufacturing experience and skill to the Queensland DAF Forest Product Innovation research team and to the project. His passing midway through the project was a sad loss for his team mates at the Salisbury Research Facility and project partners. His technical knowledge and kind personality along with his friendly face will never be forgotten.

Fred Lane—special thanks.

Preface

William Leggate, Robert McGavin and Henri Bailleres

Many countries have a low-grade hardwood plantation or native forest timber resource destined for low-value products such as woodchip, landscaping or bioenergy. Much of this resource could potentially provide a better return on investment, and improved employment opportunities, if it was processed instead into higher value products such as veneer-based engineered wood products. The purpose of this book is to provide veneer product manufacturers with useful, fundamental knowledge needed to consistently produce material fit for purpose.

In recent years there has been a proliferation of rotary peeling plants worldwide, and particularly in South-East Asia. China and Vietnam are leading the way with this technology and are successfully processing very young plantation hardwoods. To a large extent this is due to the advantages of veneer-based products as outlined below; however, technological advances in peeling equipment also enable the efficient processing of very small and young plantation hardwood logs. Logs with small end diameters less than 15 cm (and from trees less than 5 years of age) are being successfully converted into veneer-based products. In some regions, these operations are so successful that peeling plants compete with pulpwood companies for the same quality log resource.

The advantages of veneer-based products compared to other options such as sawing are multifaceted and are discussed in detail in the first chapter of this book. Improved recovery is foremost, with typical recovery from rotary peeling usually much greater than that achievable by sawmilling similar quality and sized logs. This improved recovery is largely because the peeling process does not produce sawdust or wood chips, unlike log conversion by sawing. This improved yield has a significant effect on the potential return on investment to the processor. Veneer can also be rapidly dried (i.e. pre-shrunk for downstream processes such as gluing and to prevent performance issues in-service) compared to the time required to dry solid wood products, resulting in reduced energy costs and less inventory and storage issues.

Developments in the engineering of veneer-based products during the last century have also resulted in materials that are stable and straight, and can be manufactured in a wide range of sizes to a consistent quality. In sawn timber, the grade quality and therefore piece value is limited by the major defect, whereas the manufacture of veneer-based products allows for randomisation of defects to attain the best grade possible and enable supply of a consistent and homogeneous product. This means that rotary veneer processing provides an opportunity to use low-quality logs that are not suitable for sawing or other process options.

This book describes best practice for manufacturing veneer-based products from small logs such as those harvested from short rotation hardwood plantations or from native forests during silvicultural treatments.

These technical guidelines are mainly based on the R&D portfolio undertaken by the Queensland Department of Agriculture and Fisheries (DAF) that includes the project 'Enhancement of production of acacia and eucalypt peeled and sliced veneer products in Vietnam and Australia' (ACIAR project FST/2008/039). They also draw on and complement training materials of the Engineered Wood Products Association of Australasia (EWPAA).

The book is divided into 12 chapters:

- Chapter 1 provides an introduction to veneer processing and product manufacture;
- Chapter 2 provides a summary of rotary veneer product types and uses, and highlights the advantages of veneer processing compared to solid wood processing;
- Chapters 3, 4 and 5 describe recommended best practice methods for rotary-peeled veneer manufacture from the log grading stage to veneer drying;
- Chapters 6, 7 and 8 summarise veneer grading, quality control and veneer recovery;
- Chapter 9 provides best practice methods for product manufacture;
- Chapter 10 discusses product grading and quality control;
- Chapter 11 explains important concepts in protecting veneers and veneer products from biological degradation; and
- Chapter 12 details the research outcomes resulting from activities undertaken to assess the plantation acacia and eucalypt timber resource in Vietnam for suitability for rotary veneer production.

While this book describes best practice recommendations for rotary-peeled veneer production from plantation and small native forest logs covering a wide range of scenarios, it is impossible to cover all situations. Specific recommendations will ultimately vary depending on equipment type, plant layout, and the level of investment, scale of operation, resource, labour, product, market and economic considerations. For example, optimal lathe settings will be strongly influenced by lathe type and wood species, while gluing procedures will be very different depending on the target product, type of glue, and detailed instructions provided by adhesive manufacturers.

It is also important to highlight that although the book provides general recommendations, veneer product manufacturers and veneer users should also seek specific expert assistance.

Work place health and safety (WHS) aspects are outside the scope of this book. However, strict attention to best practice WHS measures is of paramount importance and readers should seek separate specialist advice on this matter.

This book forms part of a series. Details relevant to veneer processing of coconut palm are to be published in a partner publication 'A guide to the rotary veneer processing of coconut palms'.

Glossary

These definitions are drawn from sources listed in 'Further reading' below.

ADHESIVE	A substance that is used to bond materials to each other through surface attachment
AS/NZS	Australian and New Zealand standards
BACK	The veneer ply on the back side of the panel
BARK POCKET	A zone of bark partly or wholly enclosed in the veneer; not to be confused with the bark associated with an encased knot
BILLET	Alternative name for a log which has been prepared for rotary peeling
BLOW	A localised delamination caused by excessive steam pressure build-up during the hot-pressing operation; the steam may result from high moisture content, excessive glue spread, high press temperatures or inadequate pressure release during the later stages of the hot-pressing cycle
BOND	To glue together, as when veneers are bonded to form a sheet of plywood
BOND DURABILITY	Refers to the ability of an adhesive to withstand various exposure conditions ranging from interior exposure (dry and/or infrequent wetting) to prolonged exposure to severe exterior conditions
CLOSED ASSEMBLY TIME (CAT)	The time from when the panel is removed from the pre-press until it is placed in the hot press

CHECKS	**SEASONING CHECKS** – Small slits running parallel to the grain of wood, caused chiefly by stresses produced during seasoning
	LATHE OR PEELER CHECKS – Fractures on the loose side (usually the underside) of the veneer sheet developed as a result of stresses occurring during peeling
CLIPPER	A machine used to cut the veneer ribbons or sheets into specified widths
COLD PRESS	A non-heated press used to assist the adhesive in bonding the panel plies
CORE	The inner part of a veneered panel or plywood between the face and back veneers
CREEP	Slow and continuous deformation of a material with time and use; creep is typically associated with long-term structural loading and changes in moisture content
CROSS BAND	A veneer within a panel or plywood in which the veneer grain directions are parallel to the shorter panel dimension; also defined as the inner layer with a grain direction that is at right angles to the outermost plies
DEFECT, OPEN	Open checks, splits, joints, knot holes, cracks, loose knots, gaps, voids or other openings interrupting the smooth continuity of the wood surface
DELAMINATION	Separation between plies due to adhesive bond failure; separation in the area immediately over or around a permitted defect does not constitute delamination
DENSITY	The weight per unit volume, in kilograms per cubic metre (kg/m^3)

DISCOLORATION	Stains in wood substances; areas of colour differing from the average colour of the surrounding piece or from the colour normally associated with the piece and occurring in either streaks or patches. Common veneer stains include sap stains, fungal stains, stains produced by chemical action caused by the iron in the cutting knife coming into contact with the tannic acid of the wood, or chemical reactions between extractives in wood and glue or finish discolorations. Discoloration may be naturally occurring or as a result of processing operations and adhesive bleed through
DURABILITY (OF WOOD SPECIES)	The durability rating of a species is based on the natural ability of the heartwood of that species to resist decay and insects; in Australia a four-class system is used: durability class 1 being most durable and durability class 4 being least durable
ENGINEERED WOOD PRODUCT (EWP)	A wood product manufactured by bonding together wood strands, veneers, lumber or other forms of wood fibre to produce a larger and integral composite unit with superior performance characteristics; these high-performance building components achieve predictable and reliable performance with the efficient use of natural resources
EXTERNAL GRADE DEFECT	Refers to an abnormality on the bark surface of the tree or log that is clearly visible; they often indicate interior wood grade, and include bumps, bulges, knots, lesions, sweep and holes
FACE VENEER	A term used to describe better quality veneers that are used on the visible surfaces of a panel
FISHTAILS	Wane ends or otherwise defective areas that preclude the veneer piece from being used full length; the affected veneer can be cut back and full thickness areas recovered to be used as cross banding

FORMWORK PLYWOOD (FORM PLY)	Plywood with a high-density or medium-density overlay (HDO or MDO) of phenolic resin impregnated paper bonded onto it
FUNGAL DECAY	Decomposition of wood by fungi
GLULAM	Glue laminated timber
GLUE LINE	The adhesive joint formed between two materials such as veneers in a plywood panel or between face veneers and core in a composite panel
GLUE SPREADER	A piece of equipment used to apply a uniformly thin layer of adhesive to the veneer
GRADE	Refers to the letter-graded quality of veneers used in plywood manufacture (e.g. A, B, C, D), or for particular panels, e.g. A–A which indicates the veneer grade on the face and back of the manufactured panel
GRADE DEFECT	Refers to those defects that take away from the appearance, mechanical performance or otherwise limit the usefulness of the veneer
GRADING	Classifying veneers according to quality standards
GRAIN	The direction, size, arrangement and appearance of the fibres in timber and veneer: the natural growth pattern in wood. The grain runs lengthwise in the tree and is strongest in that direction. Similarly, grain usually runs the long dimension in the long bands (including the face veneers) in a panel of plywood, making it stronger in that direction
GRAIN SLOPE	Expression of the angle of the grain to the long edges or the length of the veneer
GRAIN TEAR-OUT	Gouges in veneer surface
GREEN VENEER	Veneer that has not been dried and has a high moisture content

GUM (OR KINO)	A natural exudation produced in trees usually as a defence mechanism against fire, mechanical damage, drought or insect attack
GUM POCKET	A cavity that contains gum or kino
GUM VEIN	A deposit of gum or kino between growth rings that may be bridged radially at short intervals by wood tissue
HARDWOOD/ SOFTWOOD	Regardless of weight or hardness, 'hardwoods', e.g. red cedar, are technically defined as those woods having vessels (pores), while 'softwoods', e.g. hoop pine, are defined as those not having vessels
HEARTWOOD	The non-active core of a tree distinguishable from the growing sapwood by its usually darker colour and in some species greater resistance to rot and decay
HIGH DENSITY OVERLAY (HDO)	A resin-impregnated fibre overlay used for plywood to provide extremely smooth, hard surfaces that need no additional finishing and have high resistance to chemicals and abrasion. The overlay material is bonded to one or both sides of the plywood as an integral part of the panel faces. Used for concrete forms, cabinets, highway signs, counter-tops and other punishing applications
HOLE	An opening that extends partially or entirely through the piece and attributable to any cause
HOT PRESS	A piece of equipment that uses heat and pressure to bond the assembled veneers and adhesive into a panel
HOT PRESSING	Veneer panels are hot pressed to apply adequate pressure to the glue line while curing the adhesive; higher temperatures can accelerate the rate of cure
INNER PLIES	All plies of a plywood panel except face and back; also referred to as the core
INSECT ATTACK	Deterioration caused by insects such as borers or termites

INTERNAL GRADE DEFECT	Refers to those defects that are not apparent on the exterior bark surface of a tree but become visible on the end when the tree is felled; common interior grade defects include splits, stain, double pith, brittle heart, insect galleries, fungal defects and eccentricity
JOINT	The seam produced by joining the edges of veneer sheets together
KINO	See **GUM**
KNIFE PITCH ANGLE	The angle between the knife face and a horizontal plane (when the billet is peeled at various diameters); also called slope angle
KNIFE, LATHE	A sharp edged tool used to cut the veneer from the peeler billet as part of the peeling process
KNIFE MARK	A mark on the surface of a veneer usually caused by a chipped blade resulting in a raised strip along the veneer surface
KNOT	A portion of a branch that is enclosed by the natural growth of the tree, with grain usually running at right angles to that of the piece of veneer in which it occurs
	LOOSE KNOT – A knot that is not held firmly in place and that cannot be relied upon to remain in place through the manufacturing process and in the final product
	PIN KNOT– A very small knot
	SOUND KNOT– A knot solid across its face, well connected to and as hard as the surrounding tissue and free from decay
LAYER	In plywood, a layer consists of one or more adjacent plies having the wood grain in the same direction

LAY-UP	Usually defined as the step in wood panel manufacture where veneers or reconstituted wood layers are 'stacked' in complete panel 'press loads' after gluing and before pressing; it is also the term given to constructing a panel
LONG BAND	A veneered sheet or panel in which the veneer grain directions are parallel to the long panel dimension
LOOSE SIDE (OF VENEER)	The side of the sheet that was in contact with the knife while the sheet was being cut; it contains cutting checks (lathe checks) because of the bending of the wood at the knife edge
LAMINATED VENEER LUMBER (LVL)	A composite of wood veneer sheet elements with wood fibres primarily oriented along the length of the member, where the veneer element thicknesses are 6.4 mm or less; LVL is one of several types of EWP
LYCTID SUSCEPTIBILITY	The susceptibility of untreated sapwood (of hardwood species) to attack by the lyctid beetle (*Lyctus brunneus*)
MEDIUM DENSITY OVERLAY PANEL (MDOP)	A paintable surface made of plywood with a weather-resistant resin overlay bonded to the wood by heat and pressure. The overlay, which has at least 27% resin content, resists water, weather, wear and degradation. The overlay provides a smooth surface ideal as a paint base. Recommended for concrete formwork, siding and other outdoor applications, signs and displays, furniture, etc.; may be applied to one or both faces of the panel
MELAMINE FORMALDEHYDE ADHESIVE (MFA)	A type of adhesive used to manufacture EWPs
MELAMINE UREA FORMALDEHYDE ADHESIVE (MUF)	A type of adhesive used to manufacture EWPs
MOISTURE CONTENT	The proportion of moisture in wood, expressed as a percentage of its oven-dry weight
MULTILAMINAR WOOD	Large blocks composed of multiple veneers glued together

NOSE BAR	A bevelled or roller bar mounted parallel with the tip of the lathe knife and designed to compress the veneer billet into the cutting edge of the lathe knife; also known as a pressure bar
OPEN ASSEMBLY TIME (OAT)	The period of time from the first veneer passing through the glue spreader until pressure is applied to the panels in the cold press
PATCHING	Replacing voids in veneer with a wooden or plastic composite patch or plug
PHENOL FORMALDEHYDE ADHESIVE (PF)	A type of adhesive used to manufacture EWPs
PEELER CORE	The central portion of the peeler billet that remains after peeling
PLATEN	A steel plate used in hot or cold pressing of veneer panels
PLYWOOD	A panel product made from peeled veneer layers that are arranged perpendicular to each other and bonded by adhesive
PLY	Layer of veneer or single veneer in a panel
PRE-CONDITIONING	Preparing a peeler billet (using heat and wetting agents) for peeling
PRESERVATIVE	Product that prevents or limits wood deterioration
PRESSURE PRESERVATIVE TREATED	Wood treated by pressure-injecting preservative solutions into the wood cells
PHENOL RESORCINOL FORMALDEYDE ADHESIVE (PRFA)	A type of adhesive used to manufacture EWPs
PRODUCT STANDARD	An industry manufacturing or performance specification
POLYURETHANE ADHESIVE (PUR)	A type of adhesive used to manufacture EWPs

POLYVINYL ACETATE ADHESIVE (PVA)	A type of adhesive used to manufacture EWPs
QUALITY CONTROL	A system of process and product monitoring that aims to ensure procedures and protocols are being followed to produce a consistent product of the required quality
RECOVERY	**GREEN VENEER RECOVERY** provides a useful measure of the maximum recovery, taking into account log geometry (sweep, taper, circularity) and lathe limitations (e.g. peeler core size). Green veneer recovery disregards internal log quality. Green veneer recovery is expressed as a percentage of billet volume
	GROSS VENEER RECOVERY provides a useful measure of the maximum recovery of dried veneer that meets the relevant quality specifications. This recovery includes the losses accounted for in green veneer recovery but also includes additional losses from visual grading (i.e. veneer that failed to meet grade) and the drying process (e.g. veneer shrinkage, splits). Gross veneer recovery is expressed as a percentage of billet volume
	NET VENEER RECOVERY provides a useful measure of process efficiency, as it identifies the saleable product, taking into account the product manufacturing limitations. Net veneer recovery includes the losses accounted for in gross veneer recovery but also includes the additional losses due to the trimming of veneer before, during and after product manufacture. Net veneer recovery is expressed as a percentage of billet volume
	GRADED VENEER RECOVERY for an individual grade can be calculated using the same method as for net veneer recovery but using the veneer volumes that meet the specific grade (e.g. A, B, C or D grades in accordance with AS/NZS 2269.0:2012 'Plywood—Structural—Specifications'). Graded veneer recovery is expressed as a percentage of billet volume

REPAIR	Any patch, plug or shim in a veneer. A patch is an insert of sound wood or synthetic material to replace a defect in veneer. 'Boat' patches are oval shaped with sides tapering to points or small rounded ends. 'Router' patches have parallel sides and rounded ends. 'Sled' patches are rectangular with feathered ends. A plug may be a circular or dog-bone shaped wood patch or a synthetic filler of fibre and resin to fill openings and provide a smooth, level, durable surface. A shim is a long narrow wood or synthetic repair not more than 4.8 mm wide. Various other shapes of plug or patch may be encountered
RESIN	A general term for synthetic adhesives. It is also a pale brown exudate produced by many softwoods in response to injury in the cambium
RESORCINOL FORMALDEHYDE ADHESIVE (RF)	A type of adhesive used to manufacture EWPs
ROTARY VENEER	A veneer produced when a billet mounted in a lathe is rotated against a lathe knife; this method of peeling is used to produce veneers for manufacturing products such as plywood, LVL, multilaminar wood and other EWPs
ROUGHNESS	Unevenness of the surface of the veneer or plywood
SAPWOOD	The living wood occurring in the outer portion of a tree immediately under the bark, sometimes referred to as 'sap'; generally it is lighter in colour than the heartwood
SCRATCH	A surface split or gouge that does not penetrate through a veneer sheet
SEASONING (DRYING)	Drying timber to a moisture content range appropriate to the conditions and purposes for which it is to be used
SHRINKAGE	A change in dimensions occurring as the wood dries from a green (wet) to a seasoned (dry) condition; shrinkage can occur in three directions: radial, tangential and longitudinal

SLICED VENEER	Veneer produced by thrusting a log or sawn flitch within a slicing machine that shears off the veneer in sheets
SMOOTH, TIGHT CUT	Veneer carefully cut to minimise peeler or slicer checks
SPINDLED LATHE	A traditional lathe used in rotary veneer production, which uses spindles or 'chucks' to hold the billet in position and to rotate the billet against the knife; this method has proved very reliable and a very effective way to produce high-quality veneer, even at very high production speeds
SPINDLELESS LATHE	A lathe with no spindles; rotary drive is provided through powered backup rollers and often with support from a driven roller nose bar. While spindleless lathes still produce peeler cores, their diameters are often smaller (in the order of 20–50 mm) than those from a spindled lathe. This lathe type is well suited to small-diameter billets
SPLIT	A separation of the fibres in the direction of the grain and extending through the thickness of the veneer
STRENGTH GROUPS	Timbers with similar strength properties are grouped for structural design purposes. Timbers are classified into seven strength groups in Australia (S1 to S7) for unseasoned timber and eight groups (SD1 to SD8) for seasoned timber. Class 1 indicates highest strength in each case. Where complete mechanical data are not available, provisional assessments have been made and are shown in brackets e.g. (S2), (SD2). See Australian and New Zealand standard AS/NZS 2878-2000, 'Timber—Classification into strength groups', for further information
STRESS GRADE	Stress grading is a system for grouping timber in relation to a set of design properties so that design capabilities can be matched with end use. A stress grade has an associated suite of design properties including allowable bending stress and characteristic short duration, average modulus of elasticity parallel to the grain

SWEEP (BEND)	A lengthwise curvature of a log (a trend away from the true cylindrical form), the extent of which may cause a peeler log to be discarded
TACK	The ability of an adhesive to form a partial bond immediately after the adhesive and adherent are brought into contact under low pressure
TIGHT SIDE (OF VENEER)	The side of a veneer sheet that was not in contact with the knife while the sheet was being peeled and contains no lathe checks
UREA–FORMALDEHYDE ADHESIVE (UF)	A type of adhesive used to manufacture EWPs
UNIT SHRINKAGE	The percentage of change in dimensions with each one percent change in moisture content (below about 25% moisture content)
VENEER-BASED PRODUCTS	Products made from peeled or sliced veneers. Examples of veneer-based products produced from peeled veneers include plywood and laminated veneer lumber (LVL)
VENEER	A thin sheet of wood of uniform thickness (usually 1–4 mm for rotary peeled and <1 mm for sliced), created by peeling (peeled veneer) or slicing (sliced veneer) from logs for use in plywood, face decorative veneers, laminated veneer lumber (LVL), veneer multilaminar blocks, etc. Also can be defined as a thin sheet of wood laminated with others under heat and pressure to form plywood, or used for faces of composite panels. Also called ply
VENEER COMPOSING	Veneer composing means to dock and butt join random-width veneers and sections freed from defects and combine them in a full-size sheet for plywood panel production
WAVINESS	Undulations in the veneer surface preventing the veneer from being flat; waves can split and overlap during pressing into veneer-based products

FURTHER READING

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1. Manufacturing rotary veneer and veneer products from small logs: an overview

William Leggate and Robert McGavin

INTRODUCTION

Definition of rotary veneer

For the purpose of this publication, a veneer is a thin layer of wood usually 1–4 mm in thickness, removed from a log using a rotary peeling process. Other forms of veneer such as sliced or sawn veneers are not discussed.

The process of rotary veneer production is to remove a continuous thin ribbon of wood from a peeler billet periphery using a knife that is positioned parallel to the grain. The billet is rotated against the knife using a drive mechanism that varies in design and approach, depending on the technology being used.

Uses of rotary veneer

Rotary-peeled veneers can be used to manufacture products suitable for structural and appearance applications. Common structural applications for products manufactured from rotary-peeled veneers include structural plywood, formwork plywood for concrete construction, packaging, marine ply and laminated veneer lumber. Decorative uses for rotary-peeled veneer include architectural uses, furniture and joinery.

Advantages of veneer-based wood products

Significant advantages of veneer-based products compared to solid wood products include the following.

- Increased yield and value from forest resources. Rotary-peeled veneers provide an opportunity to use lower quality log resources that are not suitable for traditional, sawn products. Additionally, recovery rates are usually higher from a rotary peeling process compared to sawing, especially with small diameter log resources.
- More predictable performance, faster production and a greater range of possible product dimensions. Rotary veneer-based products can be produced in greater lengths, widths and thicknesses compared to products produced by traditional sawing.
- Unlike sawn timber products, veneer-based products allow randomisation of defects. The advantage of this is that defects are not concentrated at one location in the product. The ability to use defective material permits log resources with numerous defects to be converted into veneer-based products that are suitable for structural and appearance applications.
- Versatility and suitability for diverse applications and all building types ranging from detached domestic housing to multi-residential and commercial buildings.
- Greater stability, shear strength and impact resistance. Plywood's cross-laminated construction means that movement within the plane of the panel is minimal. The axial alignment of the grain in one sheet of veneer restrains the tangential movement in adjacent veneers. Unlike solid wood products, shrinkage and strength properties are similar in both planes.
- Greater control over the wood property variability and gradients within the final product compared with sawn products. Veneer-based products can be engineered to suit different structural and appearance applications.
- An ability to span wide supports and good creep resistance. Their ability to withstand large racking forces makes them the preferred building material choice in earthquake-prone regions.

Recent trends in veneer-based products

Young plantation hardwoods are highly suited to veneer-based products. Internationally, there is an increase in rotary veneer processing facilities that are successfully processing very young plantation hardwoods.

In recent years there has been a proliferation of rotary veneer processing plants worldwide, particularly in the Asia region, and especially in China and Vietnam. To a large extent this is due to the advantages of veneer-based products; however, technological advances in peeling techniques are also enabling the efficient processing of very small and young plantation hardwood logs. Logs with small-end diameters less than 15 cm (and from trees less than 5 years of age) are being successfully converted into veneer-based products. In some regions, these operations are now so successful that peeling plants compete with pulpwood companies for the same quality log resource.

GENERAL OVERVIEW OF VENEER-BASED PRODUCT MANUFACTURING

Veneer-based product manufacturing typically involves three main stages: veneer manufacture (billet storage, handling and peeling); veneer clipping, drying and up-grading; and panel lay-up, pressing and finishing (Figure 1.1). Recommended practices for each stage are outlined below.

Stage 1: Veneer manufacture

Grading, sorting and handling logs

- Select logs that meet required specifications—appropriate quality and size.
- Sort logs into batches based on quality, size and species.
- Minimise time between harvesting and processing to avoid degradation.
- Store logs off the ground and protect where necessary from drying and biological attack from insects.
- Cut logs to billets of appropriate length before peeling.

Debarking, pre-conditioning and round-up

- Ensure billets are kept free of stones, dirt and other debris in order to avoid damage to peeler knives and other equipment.

- Debark and consider pre-conditioning (heating) billets prior to peeling. The decision whether to pre-condition or not is a matter of weighing up the advantages and disadvantages for each individual peeling operation. Choose pre-conditioning conditions appropriate for the resource, equipment and target products. As a guide, hardwoods with a density of 500–700 kg/m³ are normally heated to 50–70°C, and wood with a density >700 kg/m³ to 70–90°C. It is important that the desired temperature is reached across the full radius of the billet.
- Round-up to produce cylindrical billets prior to peeling.

Peeling

- Choose lathe technology compatible with log resource characteristics, target products, available supporting infrastructure, labour and other economic factors. Spindleless lathes are proving to be an effective processing method for forest resources such as young fast-grown plantation hardwoods where tree

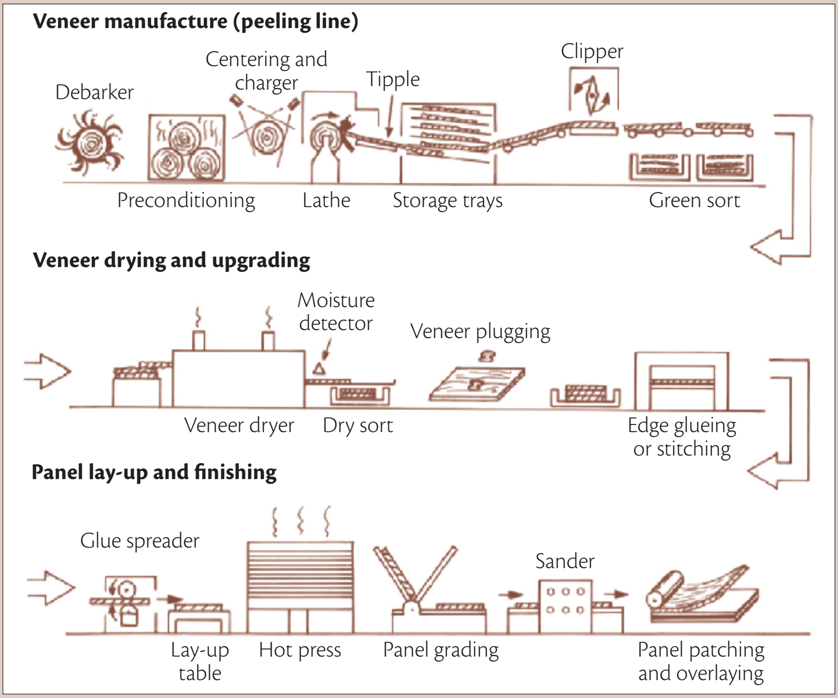

Figure 1.1. The three stages of panel manufacture. Source: Walker (2006), p. 399.

diameters are small (e.g. often <200 mm), billet qualities are comparatively low (at least compared to billets from mature native forests) and billets are prone to end-splitting.

- Adopt manufacturer's specific instructions for lathe set-up appropriate for the resource and target products. Optimal settings are determined by a range of conditions and parameters including the lathe capacity, supporting infrastructure (e.g. billet pre-treatment), species, log size, log quality, speed of production and actual veneer quality requirements (including target thickness and thickness tolerance).
- Position the billet in the lathe in order to maximise the recovery of veneer. In more sophisticated operations using spindled lathes, scanning systems support the optimal positioning.

Stage 2: Veneer clipping, drying and upgrading

Clipping and sorting

- Choose a clipping strategy that recovers the highest amount of accurately sized veneer with acceptable quality.
- Sort the veneers, where appropriate, according to quality, size, cross bands, long bands, fishtails, heartwood and sapwood.

Drying

- Separate the veneers into types that will dry at different rates, e.g. it may be necessary to separate heartwood from sapwood veneers.
- Determine target moisture content according to adhesive, product and market requirements.
- Dry the veneers as soon as possible after peeling to avoid degradation (e.g. by moulds, veneer distortion or buckling).
- Re-dry veneers that do not meet moisture content requirements.

Grading, patching, joining, sorting

- Grade the veneers according to the requirements of relevant standards and/or requirements of customers.
- Consider upgrading veneers through composing and patching veneers. However in some cases, the preference is to patch panels instead.

- Sort the veneers according to type—quality, sizes, mechanical properties (e.g. for modulus of elasticity (MoE) where suitable testing equipment is available and structural products are targeted), cross bands and long bands.

Stage 3: Product lay-up, pressing and finishing

Product manufacture

- Prior to lay-up, ensure that the veneers are of appropriate dimension, quality and moisture content.
- Use an adhesive suitable for intended product end use.
- Prepare and apply adhesive according to adhesive manufacturer's instructions.
- Choose a construction strategy that satisfies the quality requirements of the final product but also efficiently utilises the available veneer qualities that are produced from the forest resource. That is, optimise the placement, use and combination of the lower volume of high aesthetic quality or high mechanical quality veneers and the higher volume of lower qualities veneers. For example, the outer veneers of a panel have the most influence on the mechanical performance of the final product with the inner core veneers having less influence. It is therefore important that veneers with the highest mechanical qualities be favoured for the product outer veneers (in particular face and back veneers) and low mechanical quality veneers be directed towards the inner core veneers.
- Press products according to recommended press schedules.
- Trim, fill and patch products.
- Where necessary sand and finish products.
- Grade and test products according to the requirements of relevant standards and/or requirements of customers.

Storage

- Ideally the storage area should be dry and enclosed thus providing protection from the weather and extreme UV radiation. There should be adequate air circulation.
- Panels should be stored flat and the stacks need to be evenly supported, kept clear of the ground and protected, to avoid machinery damage.
- The surface of stacks should be kept free of contaminants, e.g. dust, oil and adhesives. This can be achieved by wrapping in plastic that can also protect the products from changes in moisture content.

Preservation

- Veneers and veneer-based products may also have to be treated with preservative, depending on the final intended application. Preservative treatment will enhance the durability and service life of veneer-based wood products by preventing or minimising biological degradation.

Quality control

- Adopt a quality control system that includes procedures, protocols and assessments to ensure that the manufactured products adhere to the requirements of relevant standards and/or customer expectations.

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2. Rotary-peeled products: advantages and uses

Gary Hopewell, William Leggate and Robert McGavin

ADVANTAGES OF VENEER-BASED WOOD PRODUCTS

The concept of rotary peeling a log to produce veneer, as an alternative to sawing boards, arose due to the many advantages the process provides. Improved recovery is foremost. This is especially true for many plantation hardwoods where typical recovery from rotary peeling can be twice that achievable by sawmilling similar quality and sized logs. This is largely because the peeling process produces less waste such as sawdust or wood chips. This also increases the potential return on investment to the processor.

Veneer can be rapidly dried—pre-shrunk for downstream processes such as gluing and to prevent performance issues in-service—when compared to the time required to dry solid wood products. This results in faster production, energy cost savings, and less inventory and storage issues.

Developments in the engineering of veneer-based products during the past century have resulted in materials that are stable and straight, and can be manufactured in a wide range of sizes to a consistent quality. In sawn timber, the grade quality and therefore piece value is limited by the major defect, whereas the manufacture of veneer-based products allows for randomisation of defects to attain the best product grade possible. This enables a veneer manufacturer to supply a consistent, homogeneous veneer with good qualities. Thus log resources with numerous defects can be converted into veneer-based products that are suitable for both structural and appearance applications.

Another important and valuable advantage of veneer-based wood products is their stability under cyclical environmental conditions. Plywood is the best known product made from rotary-peeled veneer. It is comprised of layers of veneer known as plies glued together in a cross-laminated construction (i.e. the grain of adjacent plies alternating by 90°). The cross-lamination of plywood means that movement within the plane of the panel is minimal. The axial alignment of the grain in one sheet of veneer restrains the tangential movement in adjacent veneers. In addition to improving stability, cross-lamination greatly improves shear strength and impact resistance, and allows fastenings very close to the sheet edge. Unlike solid wood products, shrinkage and strength properties are similar in both planes.

Other advantages of veneer-based products compared to solid wood products include:

- versatility and suitability for diverse applications and all building types ranging from detached domestic housing to multi-residential and commercial buildings (Figure 2.1);
- greater control over the wood property variability and gradients within the final product compared with sawn products—veneer-based products can be engineered to suit different structural and appearance applications;
- ability to span wide supports—these products have good creep resistance and are able to withstand large racking forces making them the preferred building material choice in earthquake-prone regions;
- improved shear strength and impact resistance.

Figure 2.1. Veneer-based construction products—stable, consistent and strong.

USES OF ROTARY-PEELED VENEERS

Rotary-peeled veneers are most commonly used in structural applications, but they are also used in the manufacture of decorative products (Figure 2.2). Rotary-peeled veneers are usually 1–4 mm thick. Although some products, such as ice-cream sticks and coffee stirrers, are made from single sheets of rotary-peeled veneer, most veneer is glued to form panels or beams (Figures 2.3 and 2.4).

Figure 2.2. Veneer-based decorative products. Photo: Austral Plywoods.

Figure 2.3. Structural beam products manufactured from rotary veneer.

Figure 2.4. A plywood noise barrier..

Plywood panels

Plywood is a major traditional use of rotary-peeled veneer and is comprised of layers of veneer known as plies, glued together with the grain of adjacent plies alternating by 90°. The high-volume uses for plywood panels are:

- structural, for sheathing and bracing;
- form ply for concrete construction;
- flooring, usually covered with carpet, tiles or solid timber overlay;
- noise barriers along roads and railways;
- boat building, truck, trailer and horse float trays and beds;
- shipping container flooring;
- stair treads and risers;
- train, bus and tram floors;
- bridge decks;
- soffits and fascias;
- box beams;
- webs in I-beams and trusses;
- exterior residential cladding;
- temporary hoarding;
- sign boards;
- wall and ceiling lining;
- kitchen and laundry benches;
- walkways;
- aircraft components.

Decorative uses for plywood include:

- architectural fit-outs, e.g. feature walls and ceilings (Figure 2.5);
- furniture;
- decorative flooring.

Figure 2.5. Decorative plywood ceiling. Photo: Austral Plywoods.

Novel hybrids

A range of facings can be used over plywood for special applications in architecture and art projects. For example, aluminium, galvanised iron, copper, stainless steel, fibreglass and carbon fibre have all been used as facing over plywood. Blending, for example, high-strength hardwood veneer faces with low-density softwood core veneers provides the opportunity to maximise the best properties of the different materials and helps gain maximum recovery and value from each resource. Other reconstituted wood-based products can also be combined with rotary-peeled veneer to form a composite panel or beam combining the advantages of both materials, for example medium density fibreboard (MDF) or oriented strand board (OSB) (Figure 2.6). Likewise, sawn wood or other plant materials such as bamboo or coconut palm can be blended with plywood to produce useful panel products (Figure 2.7).

Figure 2.6. Structural beams combining rotary veneer flanges and oriented strand board web.

Figure 2.7. Decorative panel made from coconut palm overlaid on plywood.

Laminated veneer lumber

Laminated veneer lumber (LVL) is a solid wood substitute manufactured from rotary-peeled veneers adhered in parallel layers to form a beam (Figure 2.8). This product has made inroads to many markets as a substitute for sawn timber or steel in load-carrying beam applications such as:

- lintels and headers over windows, doors, verandas and other openings in construction;
- sub-floor framing as joists and bearers;
- internal framing;
- furniture;
- bridge components;
- aircraft parts including propellers.

Figure 2.8. Laminated veneer lumber roof structure. Photo: Engineered Wood Product Association of Australasia.

Multilaminar wood

Multilaminar wood is made of superimposed layers of veneer which are spread with adhesive and then pressed so as to form a block from which sliced veneers or sawn pieces are obtained, mainly for decorative purposes. The construction strategy is similar to that of LVL; however, usually much thicker sections are produced. Various effects, colours, forms and patterns can be achieved by bleaching or dyeing veneers, using different glue types with varying colours, block moulding and also slicing or sawing the blocks at different angles (Figures 2.9 and 2.10).

Figure 2.9. Examples of multilaminar wood applications.

Figure 2.10. Detail of a multilaminar wood block.

Veneer-based mass panels

Mass wood panels are emerging as a popular engineered wood product choice for the construction of medium to tall timber buildings. The most common type of mass wood panel is cross-laminated timber (CLT) and it is used mainly as wall, floor and ceiling panels. CLT is traditionally made using sawn timber feedstock. Veneer-based mass panels provide an alternative to CLT and can be manufactured with panel sizes over 10 m in length, up to 3.6 m in width and typical thickness exceeding 170 mm. They offer many advantages over CLT including superior mechanical properties and more efficient use of forest resources. Veneer-based mass panels have existed in Australia since the 1980s with development mainly focused on bridge decks (Figure 2.11).

Figure 2.11. Bridge deck—an example of a veneer-based mass panel.

Fit for purpose

While a wide range of products can be manufactured from rotary-peeled veneer, not all logs delivered to the mill are suitable for all products. The grade quality of the logs and of the dried veneer will determine the suitability for possible applications and products. The next chapter explains how to grade these logs according to their intended use.

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3. Log specifications, grading and pre-processing

Chris Fitzgerald, Adam Redman, Gary Hopewell, Robert McGavin and William Leggate

A successful veneer operation depends on three main criteria:

- a supply of suitable logs;
- the use of suitable processing and manufacturing techniques;
- an effective sales and marketing program.

In order to sell veneer logs, a transferable and comparative grading system is needed. This gives buyers confidence that the veneer logs meet their manufacturing and quality requirements. The purpose of grading veneer logs is to sort material into groups that match the best utilisation and price/value category. This price/value relationship is set not only by the aesthetics and physical properties of the wood, but also by the demand for particular qualities and species. Most veneer peeling processors buy logs based on log volume, log quality and species.

Factors affecting the veneer quality of peeler logs can be attributed mostly to species, genetics, silviculture, growing conditions and tree health. They include age, growth rate (slow and uniform generally equates to more desirable quality), stem form, knots and limb-related defects (size and location), decay and insect damage. It is important that there is an exchange of information between managers of veneer production facilities and forest managers to provide an understanding of forest management practices that impact on the yield and quality of peeler logs.

The three main criteria used to assign a value to a hardwood peeler log destined for veneer production are species, available volume and grade. Some species are more prized than others due to their rarity, ultimate suitability for a particular end use, or reputation in the market. Available volume considers not only the volume of recoverable veneer from a log but also the scale and long-term supply potential of suitable logs from the forest. Grade refers to a combination of log attributes (beneficial or non-beneficial) that will determine a log's suitability for veneer production.

GRADING A PEELER LOG

Log grading systems vary internationally although the principles are essentially the same. The process aims to:

- identify grade limiting defects;
- measure and/or assess those defects;
- determine other important aspects such as size and species requirements;
- assign a grade to the log.

Grading a log destined for veneer production entails evaluating the log quality and hence the quality of the veneer that can be expected from that log. Log grading is based on a visual assessment of specific log features that are set out for each grade classification. Ideally, the grading rules should be easily understood so they can be applied quickly and accurately. However, it should be noted that different interpretation of the rules can lead to small differences of opinion and sometimes written rules are not adequate to describe all scenarios. Then it is for the experienced grader to use their discretion.

Factors to consider when grading a peeler log are:

- the dimensions of the log (length and diameter);
- the form of the log (the degree to which the log deviates from a true cylinder) including sweep, taper and ovality;
- the presence of defects in the log (external and internal).

Dimension and form

Some definitions relevant to the dimension and form of peeler logs are as follows:

- diameter—the small end diameter with the bark removed;
- length—the nominal length specified plus a trim allowance;
- volume—the calculation of log volume;
- sweep (or bend)—a lengthwise curvature of a log (a trend away from the true cylindrical form), the extent of which may cause a peeler log to be discarded;

- taper—loss of diameter along the length of the log resulting in an elliptically shaped log.

Sweep

Sweep is determined by measuring the maximum distance (a) along the curved side of a log when a line is extended between the log ends (of length L). Log sweep (S) can be calculated in various ways such as the ratio between the two measurements, expressed as a percentage using:

$$S\,(\%) = \frac{a}{L} \times 100$$

Any trend away from a true cylinder is considered a general sweep defect. Sweep for grading purposes can encompass taper as well (Figures 3.1 and 3.2).

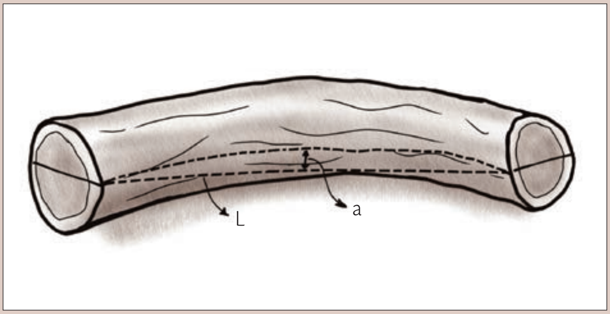

Figure 3.1. Measurement of sweep (bend) in a log.

Figure 3.2. Example of log sweep (bend).

Defects

A defect is defined as any feature of a log that impacts on the quality of the veneer that is recovered from it. The defects discussed below are considered to be the most relevant to grading peeler billets. Some defects may be specific to species or site (including management practices) or related to unforeseen events such as fire, wind throw, hail damage or lightning strike. Others can be man-made such as felling splits, log handling damage and embedded metal.

Some defects are visible in the standing tree while others are only noticed when the tree is felled and the peeler log removed. Defects can include, but are not restricted to, knots, decay, holes, insect damage, splits, ring shake and heart checks (Figure 3.3 and Table 3.1). Peeler log grading rules determine the level of defects, if any, that is permissible within any particular grade. Defects are often considered as a cumulative figure and may incorporate a combination of size, number, position and severity of several defects.

External defects are abnormalities on the bark surface of the tree or log that are clearly visible, such as bumps, bulges, branch stubs, lesions, sweep and holes. Often these exterior defects are associated with interior defects that are only apparent after the tree is felled and the peeler log is cut from the tree. Common interior defects that are noticeable from the end of peeler logs include splits, stain, double heart, brittle heart, insect galleries, fungal defects and pith eccentricity.

Figure 3.3.
Decay and gum veins in the tree centre.

Knots and bark irregularities or distortions occur where the tree has grown over removed branches (Figure 3.4). These are common grade defects and are significant in determining log grade and ultimately veneer grade. Knots and associated defects can be a major issue in eucalypt and acacia peeler logs, especially if they extend into the centre of the log. They appear on the peeled veneer and may limit the final grade of the veneer, depending on end product requirements. However, knots are permissible in peeler logs; the deciding factors are the frequency, quality and diameter of the knots.

Structural veneer can accommodate a greater degree of defect than decorative veneer. For example, face veneers can include characteristics such as small pin knots, insect galleries and slight stain.

The difficulty with visual grading using external log features and form (including those visible on the log end) is that internal defects can often only be estimated, by indicators on the log surface.

Figure 3.4. Knots (old branch stubs) visible on the surface of eucalypt logs (left), and a branch defect that produces an internal knot and hence a veneer defect (right).

Table 3.1. Descriptions (and causes) of the main grade defects.

Defect	Description/cause
Knot	Result of cut or broken-off limbs, green or dead, and can be either protruding, flush or depressed
Split	A longitudinal fissure that can penetrate deep into the log due to the release of internal growth stresses and drying
Hole	Can be due to decayed knots, insect borers, decay or mechanical damage
Bump	A protuberance on the log surface, abrupt with steep surfaces or smoothly undulating, that tapers in all directions
Decay	The decomposition, breakdown and destruction of wood components caused by bacteria and fungi
Mould	A fungus that grows in the form of multicellular filaments or hyphae

Measuring defects

Knots

The maximum diameter of a knot is usually measured in the direction perpendicular to the length of the log and the measurement starts and ends where the knot starts to rise (flare) from the log (Figure 3.5).

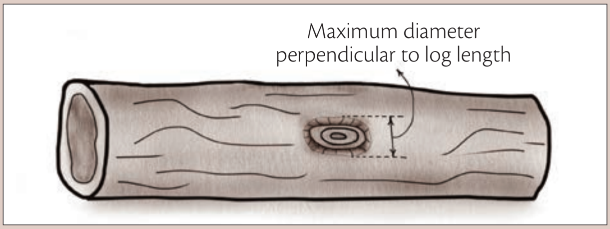

Figure 3.5. Knot measurement for grading purposes.

Splits

Splits, and more generally end-splits, are defined as fissures that reach the log periphery. The maximum external end-split length along the length of the log is measured. End-splits are often measured at both ends of a log, added together and expressed as a percentage of the total log length (Figures 3.6 and 3.7).

Holes

Holes, including insect holes, are usually measured as the maximum diameter of the hole (Figure 3.8). The sizes of holes resulting from insect borer damage can vary (Figure 3.9).

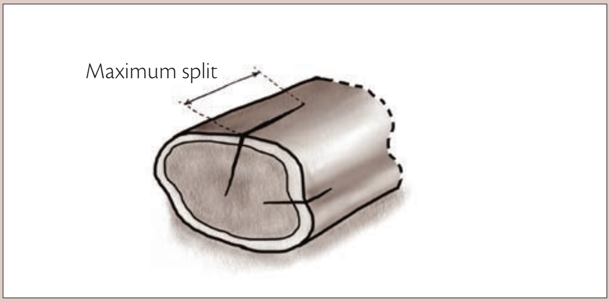

Figure 3.6. End-split measurement for grading purposes.

Figure 3.7. End-splits in eucalypt logs.

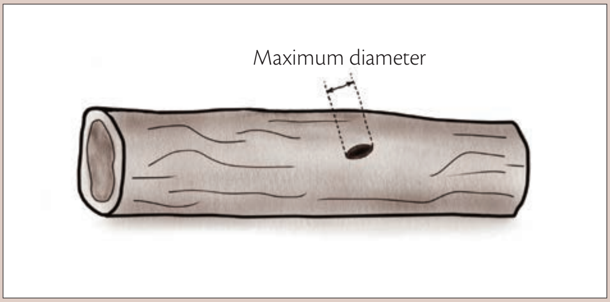

Figure 3.8. Hole measurement for grading purposes.

Figure 3.9. Holes of varying sizes due to insect borer damage.

Bumps

Some grading standards define a significant bump as one that increases the diameter of the peeler log at that point by at least one-quarter of the diameter of the log at the midpoint of the log's length. (Figure 3.10).

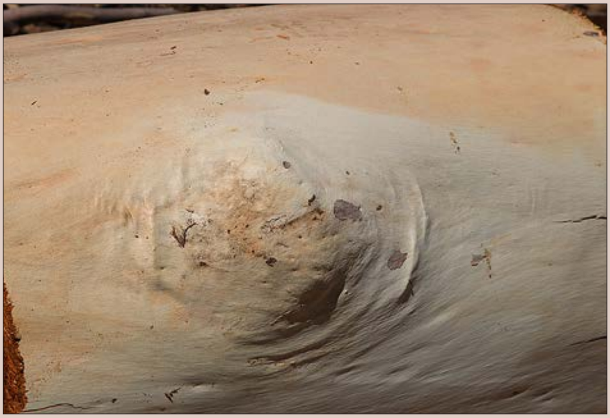

Figure 3.10.
A bump on the surface of a log.

Decay and mould

Decay and mould are recorded as being either present or absent. Decay can negatively impact the peeling process and therefore recovery (Figure 3.11). High infection by mould and blue stain may also render a log unsuitable for peeling, or at least downgrade it.

Figure 3.11.
Significant fungal decay visible on a log end.

Grading a eucalypt peeler log—an Australian example

In Australia each state forest agency has developed specifications for the logs sold within its jurisdiction. Sales between private growers and wood processors either use the same grade definitions or others derived from the specifications developed by the state agencies. Although the general principles are the same throughout Australia, the precise definitions of grades vary. The specifications used by Forestry Tasmania (2015) for grading eucalypt regrowth and plantation peeler logs that are destined for veneer production are given as an example in Table 3.2.

Table 3.2. Peeler log specifications for eucalypt regrowth and eucalypt plantations in Tasmania (2015).

Grade factors	Criteria
General	Logs must be crosscut cleanly at each end perpendicular to their length. All protrusions, limbs and knots are to be trimmed flush with the log surface.
Length	Minimum length is 3.4 m. A minimum length of 2.2 m can be accepted if suitable arrangements can be made for handling and transporting them.
Small end diameter (SED)	Minimum 18 cm.
Large end diameter (LED)	Maximum 70 cm.
Knots and limbs	For logs with an SED < 35 cm, the maximum diameter of any knot or limb is 10 cm. For logs with an SED ≥ 35 cm, the maximum diameter of any knot or limb is 20 cm. There is no limit to the number of knots or limbs allowed as long as they do not exceed the maximum diameters.
Bumps	A log may contain no more than one significant bump in each 1 m of log length. A log may contain any number of bumps that are not significant bumps.
End-splitting	The end of the log may contain minor cracks no more than 5 mm in width.
Scars and evidence of borers	A log may contain scars provided that the log is sound and there is no evidence of any rot beyond the scar itself. A log may contain evidence of borers.
Roundness	Neither end of the log can have a major axis that is more than 20% greater than the minor axis at the end. A log with an irregular or 'fluted' circumference is not allowable.
Sweep	For logs < 5.4 m in length, the maximum permissible sweep is 25% of the SED. For logs ≥ 5.4 m in length, the maximum permissible sweep is 50% of the SED.

LOG STORAGE

Logs should ideally be processed as soon as possible after harvesting, although some time in storage can relieve growth stresses. Timely log processing is especially important in warmer climates. If not processed immediately, logs must be stored correctly until processing.

Logs should be transported to the log holding yard as soon as possible after felling to minimise damage by wood-boring insects that are especially attracted to freshly cut logs. In particular, many of the ambrosia beetles attack logs soon after felling, and can cause severe stain in the sapwood.

Veneer logs can be kept in good condition for some time as long as they are suitably stored (Figure 3.12). With poor storage, logs can deteriorate due to drying and cracking in the log ends (Figure 3.13) and other exposed surfaces; development of blue stain, decay and oxidation stain; attack by insects (green or dry timber); and attack by bacteria causing development of undesirable odours or increased porosity. Deterioration and decay can happen in weeks or months.

Figure 3.12. Eucalypt logs in a storage yard waiting to be processed.

Figure 3.13. Logs can suffer severe end-splitting if they are not either processed quickly or stored correctly.

Much of the risk of log quality degradation is related to the weather to which stored logs are exposed and the impact that this has on log drying rates. Wet weather and low temperatures are more favourable for maintaining log quality than hot, dry temperatures (although some wood fungi thrive in wet conditions). Shrinkage-related defects are minimal during cold, cloudy and wet conditions, and insects and fungi become inactive or die at very low temperatures. Logs stored in dry conditions (while the log itself is still in the green non-seasoned state) are prone to end-checking, blue stain and ambrosia beetle attack. A combination of hot and humid conditions can be ideal for fungal and insect attack.

Best practice for logs waiting to be processed in the log yard includes:

- minimising storage time by moving logs quickly to processing;
- storing logs on bearers off the ground in well drained areas cleared of plant growth, and free from dirt, stones and other contaminants that can cause processing problems;
- sorting and storing logs according to receipt date, size, grade and intended veneer products;
- ensuring sufficient space for loading and unloading logs and that the log storage area remains trafficable in all weather conditions;
- protecting the logs from harsh weather conditions;
- placing S-hooks or nail-plates on the log ends to prevent or minimise end-splitting;
- taking care when handling the logs to prevent mechanical damage;
- making sure workplace health and safety practices are adhered to including log pile stability, and that personal protective equipment is worn.

If logs are to be stored for long periods in warm or hot conditions, then a sprinkler system may be used if one is available (Figure 3.14). This will help to minimise end-splitting and end-checking and will slow the deterioration caused by insects, fungal stain and decay, although it may not completely eliminate them. Log drying and associated problems can also be reduced by:

- end-sealing the logs;
- storing logs close together;
- covering logs with shade cloth or storing in the shade;
- orienting logs to minimise exposure to wind and sun;
- using wind breaks if wind is an issue.

Figure 3.14. Using water sprays in a log storage yard prevents excessive or rapid drying and deters insect and fungal attack.

Logs can be protected from splitting or end-checking by brushing or spraying a coating, such as a wax-based sealer, on the ends of the logs and storing the logs close together (Figure 3.15). This is more effective if used in conjunction with a nail-plate or S-hook (Figures 3.16 and 3.17). The plate should ideally be round and cover most of the end; smaller rectangular plates can be forced out of the end grain through wetting and drying and ultimately have little effect. The logs can also be treated with a registered chemical fungicide and/or insecticide prior to the end-seal to prevent sap stain and insect attack. Logs can be stored with the bark intact to reduce checking and blue stain. Some species, e.g. eucalypt and acacia, deteriorate rapidly when in storage so this should be kept to a minimum for these species. The first logs into storage should be the first out.

Figure 3.15. Log ends coated with a wax-based end-sealer.

Figure 3.16. Nail-plates on eucalypt log ends can minimise end-splitting. Photo: Edgar Stubbersfield.

Figure 3.17. S-hooks on log ends can minimise end-splitting.

DEBARKING

The bark—the protective, outer layer of a tree—prevents the loss of moisture, inhibits insect attack and decay organisms, and is a barrier to fire. Depending on the species and age of the tree at the time of harvest, bark can account for up to 30% of gross log volume. Bark often includes grit and extraneous materials that can damage or blunt veneer lathe knives. The process of removing bark at the time of harvest or in the mill yard is termed debarking or sometimes barking.

When to debark depends on several factors. Debarking in the forest at the time of harvesting has many advantages. It reduces the volume of waste material transported from the forest to the veneer mill. The bark is also much easier to remove immediately after harvesting. Removing the bark may render the billets less susceptible to insect attack, depending on the insect species. Leaving the bark in the forest can also benefit the soil. On the other hand, retaining the bark can partially protect the billet from mechanical damage, and also reduce drying while the billet is transported and stored. Even short delays (>12 hours) in debarking after the tree has been felled can cause the bark to tighten, making it more difficult to remove, especially with manual methods. Debarking is generally easier when trees are harvested in growth periods such as spring and summer seasons. During dry periods it is usually more difficult to remove the bark.

Manual methods

Small mills use simple hand tools for debarking variously known as 'barking bars', 'wrecking bars', 'prybars', 'pinch bars', 'jimmy bars', 'jemmy bars' or small 'crow bars'. They all have a flattened chisel point and often a small bend at one or both ends. The chisel end is jabbed into the bark so that the bar can be used as a lever to lift and peel the bark off the log. Sometimes a starting line is made along the length of the log first, either with a chainsaw or an axe, cut to the depth of the bark thickness. Then the bar is worked along one edge of this cut to separate the bark.

Axes are sometimes used to remove bark. The back of the axe is used to bruise and lift the bark, separating it from the outer surface of the wood. The sharp face of the axe can be used to trim any patches of bark remaining stuck to the surface of the log (Figure 3.18).

Figure 3.18. Removing bark with the cutting face of the axe.

Mill yard machinery can be used for rapid manual debarking, although this method increases the risk of damaging logs. The tynes, blades or buckets of loaders, forklift trucks and graders can be used to slide along logs and remove the bark after which an axe or barking bar is used to finish the task.

Machine debarking

In mills with a high-volume throughput, it is economical to debark logs with a specialised machine. This can be undertaken in the field at the time of harvesting or in the mill yard prior to processing (Figures 3.19 and 3.20). There are several designs and the most suitable one depends on the type of bark. Machine debarking techniques include:

- abrading the bark in a rotating drum (suitable for softwoods and gum-barked hardwoods);
- shear-cutting the bark in a ring debarker (suitable for softwoods);
- removing the bark with a rotating pole shaver (includes 'rosser-head' equipment; suitable for softwoods);
- forcing the bark off with a high-pressure water hose (suitable for softwoods).

The traditional plywood industry generally prefers ring debarkers and rosser-head debarkers because they cause less damage to the log ends. These conventional approaches are suited to traditional forest resources.

Figure 3.19. Mechanised debarking of logs in the forest.

Figure 3.20.
A ring debarker removing bark prior to processing.

Spindleless debarkers and lathes

With the emergence of spindleless lathe technology, it is not uncommon to use these lathes to debark billets immediately before peeling. This approach is particularly attractive to many small veneering operations as it is relatively easy and requires minimal capital investment. However, debarking using a lathe frequently damages the veneer knife (e.g. causing chipping and dulling) and results in reduced veneer quality, machine down-time (due to additional knife replacements) and increased need for knife sharpening.

Many spindleless lathe manufacturers now make dedicated debarkers that are based on the spindleless lathe system. These debarkers are more robust than the lathe, usually with a more basic design, and are well suited to small operations and small-diameter forest resources. Debarking by this method can also incorporate rounding-up, preparing the billet for immediate peeling.

LOG PRE-CONDITIONING

Depending on the peeling equipment, species and the required peeled quality, log pre-conditioning may be carried out. Pre-conditioning normally involves heating by saturated steam or hot water (soaking and/or spraying) to soften (plasticise) the wood and knots (Figures 3.21 and 3.22). These treatments are designed to heat the full radial depth of the log without drying it.

Figure 3.21. Log pre-conditioning using hot water soaking.

Figure 3.22. Log pre-conditioning using saturated steam.

Pre-conditioning is not always necessary and many log peeling enterprises operate successfully without undertaking any pre-conditioning. Whether to pre-condition is an individual business decision based on the following potential advantages and disadvantages.

Potential advantages are:

- reduced energy requirements for the peeling process;
- reduced loading on the veneer lathe (reduced wear and tear, less maintenance);
- improved veneer quality (smoothness, tightness);
- less split sheets and greater full sheet recovery;

- reduced veneer thickness variation;
- reduced knife damage and wear (chipping, blunting);
- the ability for veneer colour modification (which could also be a disadvantage).

Potential disadvantages and risks include:

- over-softening, particularly in the lower density core, resulting in premature peeling failure (e.g. spindle holding failure, billet collapse);
- a need for specialist heating equipment and associated costs;
- hot water, steam and hot billets can be a safety hazard;
- veneer colour modification;
- shrinkage of veneer during drying due to cell collapse during the heating process;
- water-soluble extractives can be leached out of the log reducing the natural durability of the veneer;
- reduction in output—as pre-conditioning is the slowest part of the peeling process it can be logistically difficult to have sufficient pre-conditioned stock ready for peeling to keep pace with the productivity of the lathe;
- an increase in the incidence of splitting;
- environmental management issues with the disposal of waste water.

Approximate wood temperatures aimed for (across the full radius) are as follows:

- softwoods: 50–60°C;
- hardwoods (500–700 kg/m^3 density): 50–70°C;
- hardwoods (>700 kg/m^3 density): 70–90°C.

The time required to pre-condition billets depends on the species, density (higher density wood generally requires longer heating times), billet moisture content (up to approximately 30% moisture content, i.e. fibre saturation point), billet diameter, pre-treatment method (steam versus water), infrastructure capacity, veneer quality requirements, and temperature of the hot water bath or steaming chamber.

LOG ROUND-UP

Ideally, billets presented to the lathe should be cylindrical or as close to cylindrical as possible. Ovality, taper, sweep and bumps affect the peeling process, particularly by lowering productivity and increasing wear on machinery. These defects also have a negative impact on recovery so it is desirable to trim or round up the log (Figures 3.23 and 3.24). Log round-up makes the subsequent peeling more efficient, but the process does not necessarily continue until a perfect cylinder is attained. The operator decides when to stop the round-up phase by estimating when it is worthwhile to recover short lengths and/or widths.

Ideally, to protect the main veneer lathe and increase productivity, the round-up process is performed using a separate machine. This ensures that grit is removed from the billet periphery. This will extend the life of the knife on the main lathe and also provide better quality veneer surfaces. As a rule of thumb, the round-up lathe should peel the log until at least 50% of its surface is dressed.

Figure 3.23. Combining debarking and log round-up in one operation in Vietnam.

Figure 3.24. Cylindrical logs after round-up, and ready for peeling.

LOG POSITIONING

To maximise recovery using spindled lathes, spindles need to be positioned as close as possible to the geometric central axis of the billet. This ensures that the maximum diameter cylinder is provided as the starting point for peeling and the highest recovery is achieved. For this reason positioning tools are also known as optimisers. Methods to find the central axis include:

- operator's visual judgement with or without aids (Figure 3.25);
- manual measurement and marking;
- use of mechanical devices;
- computerised scanning equipment.

High-volume peeling facilities use scanning equipment that collects and sends geometric data to an optimisation computer. The computer determines the spindle x–y positions for both ends of the log and sends these data to the programmable logic controller (PLC) that operates the equipment to implement the centring (spindle locations) and peeling solution (Figure 3.26). Where scanning apparatus is used, dimensions of the log are measured along at least two different planes.

The opportunity to improve veneer recovery through optimised billet positioning is not possible with spindleless technology. Billet positioning using this technology is influenced by the external dimension and shape of the billet.

Figure 3.25. Visual aids such as a light stencil can assist the lathe operator in positioning the lathe spindles.

Figure 3.26. Log scanning ensures logs are positioned in the lathe spindles at the optimal location.

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4. Rotary peeling

Robert McGavin

Rotary veneer production involves using a lathe to remove a continuous thin ribbon of wood from the periphery of a peeler billet. The billet is rotated against the knife using a drive mechanism that varies in design and approach, depending on the lathe technology being used. In close proximity to the knife is a nose bar (or pressure bar) that applies a localised zone of compression just before the point of cutting. This helps improve veneer quality by preventing splits forming ahead of the knife that can cause roughness on the veneer surface (Figure 4.1).

Traditionally, the rotary veneer industry received premium quality logs that were large in diameter and high in quality. To match the resource, rotary veneer lathes and other processing equipment were designed and built to be large and robust. To accommodate the changes in available resource and to improve efficiency, technology has evolved in several key areas. While initial development was focused towards improving efficiencies through increasing production speeds,

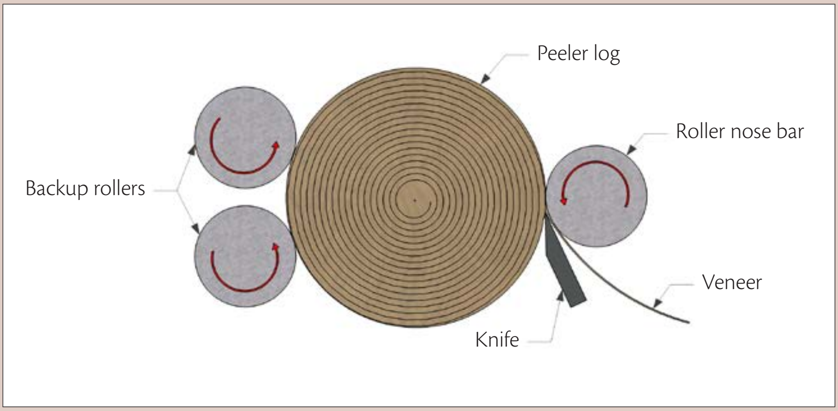

Figure 4.1. Illustration of rotary peeling using a spindleless lathe.

in recent decades much focus has been on improvements in resource recovery through minimising waste, and systems that better accommodate smaller diameter and sub-optimum quality billets. The three major types of lathes are presented below—spindled, hybrid and spindleless.

SPINDLED LATHES

The traditional method of rotary veneer production uses a spindled lathe (Figures 4.2–4.5). This type of lathe uses spindles or 'chucks' to hold the log in position and to rotate the billet against the knife. This method has proved very reliable and a very effective way to produce high quality veneer, even at very high production speeds. With spindled lathes, the billet is reduced in diameter during peeling to a size that is just larger than the spindles. Stopping at this point is necessary to prevent damage resulting from the knife coming into contact with the spindles. Historically, spindle size was large to allow the transfer of the torque forces necessary to hold and turn very large diameter billets. Peeler core diameters above 200 mm were not uncommon in early commercial lathes. This meant that there was a large volume of the billet, in the form of a peeler core, from which no veneer could be recovered.

The loss of veneer recovery with large peeler cores becomes much more important as the billet starting diameter reduces (e.g. with the transition from mature native forest to fast-grown plantations). Efforts were made to reduce the spindle size to improve the recovery of veneer. However, sufficient size is necessary to provide adequate billet holding capacity, especially during the early stages of peeling when the billet diameter is largest. Failure to provide sufficient holding capacity leads to 'spin outs' where the spindles lose grip on the billet and the billet cannot be peeled further. To minimise spin outs, spindle pressure can be increased; however, this results in billet end-splitting, especially in hardwoods.

Staged or semi-retractable spindles provide a good improvement, allowing large diameter billets to be driven by large spindles, and as the billet diameter is reduced, the outer part of the spindle retracts from the billet reducing the spindle diameter and therefore allowing the peeling process to continue and more veneer to be recovered from the billet. But even with this approach, spindle diameters less than 100 mm are rarely achieved and peeler core diameters of 110 mm and above are common. For forest resources such as young fast-grown plantation hardwoods where tree diameters are small (often less than 200 mm), billet qualities are comparatively low (compared to billets from mature native forests) and billets are prone to end-splitting, traditional spindled lathes rarely perform efficiently, resulting in low veneer recoveries.

Figure 4.2.
An example of a spindled lathe.

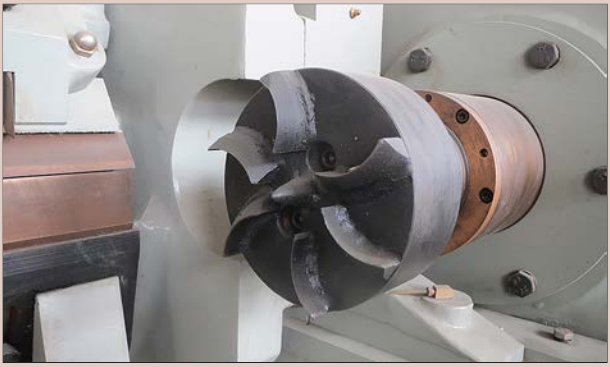

Figure 4.3.
'Chucks' or 'spindles' on a spindled lathe.

Figure 4.4.
End-splitting during peeling with a spindled lathe.

Figure 4.5.
End-splitting made worse by the spindles on a spindled lathe.

HYBRID SYSTEMS

An alternative to the spindled lathe has been developed by Meinan, a Japanese company. Spindles are used to position the billet and provide rotary drive, however the spindles are completely retracted once the billet diameter is close to the spindle diameter. Additional drive is provided through a sectional nose bar that contains a series of spiked gang roll segments. Two in-feed brace rolls (similar to backup rolls) are used. These combine with the gang roll to allow the peeling process to continue after the spindles have retracted. This allows further processing until the peeler core is released at diameters below 75 mm. These lathes are well suited to large-scale, high-throughput operations.

SPINDLELESS LATHES

Spindleless lathes were originally designed and developed for further processing of peeler cores produced from conventional spindled lathes. Spindleless lathes are also referred to as 'chuckless lathes' or 'centreless lathes'. While the approach has existed for decades, the commercial adoption remained very low due to their reputation for producing poor quality veneer, mainly due to variation in veneer thickness.

In the last decade or so spindleless lathe technology has developed quickly, with wide adoption in some countries, prompted by the rapidly growing availability of small-diameter forest resources, particularly from young fast-grown hardwood plantations. While spindleless lathes were originally developed to process the already pre-rounded peeler cores, many of the spindleless lathe operations today successfully use the lathes to directly process small-diameter unrounded billets (Figures 4.6 and 4.7).

Figure 4.6. An example of a spindleless lathe.

Figure 4.7. A log being peeled with a spindleless lathe.

Spindleless lathes, as the name suggests, have no spindles. Rotary drive is provided through powered backup rollers and often with support from a driven roller nose bar. While spindleless lathes still produce peeler cores, their diameters are usually in the order of 20–50 mm. Figure 4.8 illustrates a peeler core produced from a standard rotary veneer spindled lathe and a peeler core produced from a spindleless veneer lathe.

Without the reliance on spindles to hold the billet in position, and the damage to billets from the stresses created within a relatively concentrated zone, spindleless lathes are proving to be very successful in processing logs of quality below that previously accepted. Species more prone to end-splitting can be peeled with a reduced risk of the splits becoming worse during peeling. In fact, unlike spindles that force the splits further apart, the drive mechanism on a spindleless lathe effectively presses the splits together during peeling. The small peeler core size also means that billets with smaller starting diameters can be peeled. For these reasons, spindleless lathes have been adopted mostly where there is a large supply of small diameter and sub-optimum quality billets (i.e. from young, fast-grown hardwood plantations).

Figure 4.8.
A 45 mm peeler core (left) produced from a spindleless veneer lathe, compared with a 130 mm peeler core produced from a standard, commercial spindled lathe.

OPTIMAL LATHE SETTINGS

The quality of the veneer is heavily influenced by the lathe settings. Optimal settings are determined by a range of conditions and parameters including the lathe capacity, supporting infrastructure (e.g. capacity of equipment used for billet pre-treatment), species, log size, log quality, wood density, grain structure, speed of production and actual veneer quality requirements (including target thickness and acceptable thickness tolerance). Some of the common variables for lathe settings include knife angle, knife grind angle, knife height, pitch angle, nose bar position (horizontal and vertical), nose bar design and feed rate.

For spindled lathes, there is widely available documentation supported by many decades of research that provides lathe settings specific to species and target veneer qualities. The vast majority of published settings and approaches to improve veneer qualities are transferable between spindled lathe manufacturers and models. For hybrid lathes, such as Meinan, documented settings are usually provided by the supplier and are very specific to the individual operation.

While a very large number of spindleless lathes now exist, there are few examples of documented lathe settings. In addition, the vast majority of spindleless lathe designs have targeted simple, lean designs with minimal capacity to change settings. This means the opportunity to optimise settings to suit a particular operation is limited. There are also several variations to lathe design and operational methods that result in major differences in lathe settings between manufacturers and models. For example, while nose bar designs on spindled lathes are relatively similar, a much larger range of designs exists for spindleless lathes. They are almost always a roller style, but diameters range from 30 to 150 mm, and they can be power driven or free spinning, segmented or full width, smooth or grooved. The design of the nose bar, along with other design features, has a large influence on optimum position of the knife.

The feed rate is also very different on a spindleless lathe compared to a spindled lathe. With the latter, the knife carriage is moved towards the spindle at a uniform rate relative to the billet rotation. The rate of advance influences the veneer thickness per log revolution. With a spindleless lathe, there are two common approaches, both of which move the billet towards the knife. The first approach uses hydraulic pressure against the driven feed roller to move the billet towards the knife. The other approach uses a mechanical system to move the feed rollers towards the knife. Later mechanical versions use screw drives (similar to the mechanism that moves the knife carriage on a spindled lathe). While the latter probably has better control, all approaches can lead to veneer thickness variation, especially if a wide variation in wood properties exists within the billets being peeled. On-going developments are however quickly overcoming these limitations.

Another major difference between spindled and spindleless lathes is the control of the knife pitch angle relative to the billet surface. On spindled lathes, the knife carriage changes the knife pitch angle during peeling as the billet diameter is decreased to maintain an optimal angle. With the exception of a couple of very recent spindleless lathe models, the knife pitch angle is set and then remains constant during the peeling operation. This means that the optimum settings are potentially compromised for a significant part of the billet peeling.

The large range of spindleless lathe designs and the capacity to influence settings explains why optimum lathe settings are not published. Although some basic lathe operation principles apply, optimum lathe settings are specific to lathe model, the resource being processed and the target end product.

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5. Veneer clipping and drying

Robert McGavin

CLIPPING

Veneer clipping is usually done as part of the peeling operation. As the veneer ribbon leaves the lathe, it is transported along a conveyor to a clipper that clips (cuts) the veneer, parallel to the grain, into smaller, more manageable veneer sheet widths. Alternatively, the veneer ribbon is coiled or reeled immediately after the lathe and is moved to a separate clipping station. Regardless of approach, any clipping strategy should aim to recover the highest amount of veneer of a dimension and quality that aligns to the target end products (Figures 5.1–5.3).

The simplest clipping systems are manual operations that utilise hand- or foot-operated guillotines. These are relatively slow and rarely adopted given the availability of relatively cheap, more automated systems.

The next level of technology utilises a mechanical clipper system, normally activated on a time interval. This means that the sheet width is determined by the speed that the veneer ribbon is travelling through the clipper and the time interval between the clipper knife being activated. Often with these operations, the clipper knife is fixed to a rotating shaft meaning that the knife blade clips the veneer at each revolution. This is a simple, low capital cost approach that is much more efficient than hand-operated guillotines; however, it provides little opportunity to maximise the recovery of specific grade qualities. This is because the clipping strategy does not consider veneer quality (e.g. defects such as knots, splits etc.) and focuses on veneer width only. This approach can result in a low-grade recovery as unacceptable defects remain in the veneer sheets. While these defects can be removed during follow-up processes, this can lead to less than desirable and variable veneer sheets widths, and added costs.

Advanced systems incorporate veneer scanning technology that can be programmed to detect and measure defects within the veneer as it travels

Figure 5.1.
Veneer sheets being clipped manually by guillotine in Vietnam.

Figure 5.2.
Veneer ribbon being coiled in preparation for a separate clipping operation.

Figure 5.3.
Veneer ribbon ready for clipping.

between the lathe and clipper. Using this information, unacceptable defects (e.g. large knots) can be limited to narrow strips of veneer that can be clipped out and rejected. The remaining veneer ribbon is clipped to sheet widths that best suit the final end product. This approach maximises the recovery of veneer with acceptable qualities, operates at speeds that equal the lathe operating speeds, and also produces more accurately sized veneer sheets.

DRYING

The main reason for drying veneer is to remove excessive moisture so that the veneers are prepared for adhesive application and product manufacture. Drying soon after clipping is preferred, to prevent mould, veneer distortion (e.g. buckling) and other degradation. Practical objectives are to dry at low cost, with short drying time, and to achieve appropriate quality.

Veneer drying approaches have evolved over time. The simplest and lowest cost approach is to air-dry veneers (Figure 5.4), however this gives little control over drying time and quality. There are various types of mechanical drying systems, with the most common in larger commercial operations being the jet-box conveyer-type dryer (Figure 5.5). With this system, veneers are fed along a conveyor system into the dryer and passed through a series of chambers where hot air is blasted across the veneers. Temperature and conveyor speeds are adjusted to ensure the veneer exits the dryer with the appropriate moisture content and suitable quality. A number of moisture monitoring systems are commercially available that identify under-dried (wet) veneers at the dryer exit, allowing these veneers to be separated and re-dried.

The most important and common form of avoidable degradation during veneer drying is out-of-range and uneven moisture contents. The target moisture content and acceptable range both between veneers and within a veneer depend mainly on the adhesive to be used to manufacture the final product, but the species and the manufacturing process also have an influence. A common target moisture content is 6% with a range of 3–10%.

Drying-induced defects include buckling, splitting and surface modification. All these defects affect the veneer recovery, and the aesthetics and mechanical qualities of the final product. These defects are generally more common if excessively high temperatures are used or if the veneer has been over- or under-dried.

The variables that effect drying time are veneer thickness, wood species, the mix of heartwood and sapwood, initial moisture content, drying temperature, air velocity and relative humidity. Air-drying may take several days or weeks whereas a jet-box dryer can dry veneer within minutes. Better utilisation of the dryer is achieved by batching veneer to take account of large variations in initial moisture content. Moist sapwood, drier heartwood and veneer already partially dried require progressively milder drying schedules.

Figure 5.4.
Air-drying veneer sheets in Vietnam.

Figure 5.5.
Jet-box conveyor-type veneer dryer.

6. Veneer grading and upgrading

Joh Fehrmann, Robert McGavin and William Leggate

Veneer sheets are graded so that they can be segregated into categories that reflect their best use and price/value. This price/value relationship is set by the aesthetics and mechanical properties of the wood in addition to the demand for the species. A transferable and comparative grading system gives buyers confidence and reassurance that the veneers will meet their manufacturing and quality requirements.

The standards or rules for grading veneer may be set by the industry or by individual companies based on sound knowledge and understanding of market and consumer requirements. Veneer can be graded for different uses such as for face veneer, substrate veneer, plywood, laminated veneer lumber (LVL) and form ply. The grading system applies a set of rules (grade criteria) to classify material into different grade classes. Grade criteria can include natural wood features or defects and/or process-induced defects caused when peeling or handling the veneer. Grade classes are usually assigned either a letter (A, B, C etc.) or number (1, 2, 3 etc.), where the best grade class is 'A' or '1' and subsequent grades reflect lower quality veneers.

Veneer can be graded visually by an experienced grader, or using automated grading equipment. When done visually, the grader assesses the sheet against the grade criteria and the predominant defect/feature determines the grade class that is assigned. The grader may use tools such as steel rulers, measurement tapes or other equipment to determine the size and severity of defects/features. In large-scale production lines, automated grading processes are often used based on cameras and scanners, and linked with optimised clipping and sorting systems to segregate veneer into grade classes.

Apart from visual defect grading, veneer may also be segregated into grade classes based on mechanical properties where structural products are targeted.

Mechanical grading is an automated process based on the veneer dynamic modulus of elasticity. Ultrasonic grading is the most frequent method and is widely used in large-scale plywood manufacturing mills.

DEFINITIONS OF GRADE DEFECTS

The following are definitions of common defects affecting veneer grade. Additional defect definitions are provided in references such as Standards Australia (1997).

Sound knot (inter-grown knot)

A sound knot is solid across its face, as hard as the surrounding tissue, and free from decay (Figure 6.1).

Figure 6.1.
Sound knots.

Loose knot

A loose knot is one that is not held firmly in place by wood fibre, and cannot be relied upon to remain in place in the piece (Figure 6.2).

Figure 6.2.
A loose knot.

Pin knot

A pin knot is a very small knot (Figure 6.3).

Figure 6.3. Pin knots.

Hole

A hole can be attributable to any cause and can extend partially or entirely through the piece (Figure 6.4).

Figure 6.4. Hole: two examples.

Split

A split is a separation of the fibres in the direction of the grain and extending through the thickness of the veneer (Figure 6.5).

Figure 6.5.
Splits.

Gum pocket

A gum pocket is a cavity that contains gum (or kino). Gum is a natural exudation produced in trees, usually as a defence mechanism against fire, mechanical damage, drought or insect attack (Figure 6.6).

Figure 6.6.
Gum pocket.

Gum vein

A gum vein is a deposit of gum (or kino) between growth rings and may be bridged radially at short intervals by wood tissue (Figure 6.7).

Figure 6.7.
Gum vein.

Insect attack

Insect attack is deterioration caused by borers or termites (Figure 6.8).

Figure 6.8.
Insect attack.

Discoloration

Discoloration is an area of colour that is different from the average colour of the piece, or different from the colour normally associated with the piece and occurring in either streaks or patches (Figure 6.9).

Figure 6.9.
Discoloration.

Grain tear-out

Grain tear-outs are gouges in the veneer surface (Figure 6.10).

Figure 6.10.
Grain tear-out.

Knife mark

Knife marks are caused by a damaged blade, resulting in a raised strip along the veneer surface (Figure 6.11).

Figure 6.11.
Knife mark.

Fungal decay

Fungal decay is the decomposition of wood by fungi (Figure 6.12).

Figure 6.12.
A decay zone (stained) also with insect attack.

Waviness

Waviness is an undulation in the veneer that can cause problems in production. For example, during pressing the waves could split and overlap, affecting product quality (Figures 6.13 and 6.14).

Figure 6.13. Waviness.

Figure 6.14. Waviness causing an overlapping split when flattened.

Cumulative defect

A cumulative defect occurs when defects are in such close proximity that they are measured in combination (Figure 6.15). Australian and New Zealand standard AS/NZS 2269.0:2012 stipulates that in any 300 mm line drawn across the grain anywhere on the veneer sheet, the aggregate dimension of defects such as knots, gaps in edge joints, splits, holes, patches, bark and unsound resin pockets and gum veins shall not exceed 45 mm, 75 mm or 120 mm depending on the veneer grade class and whether the veneers are hardwood or softwood.

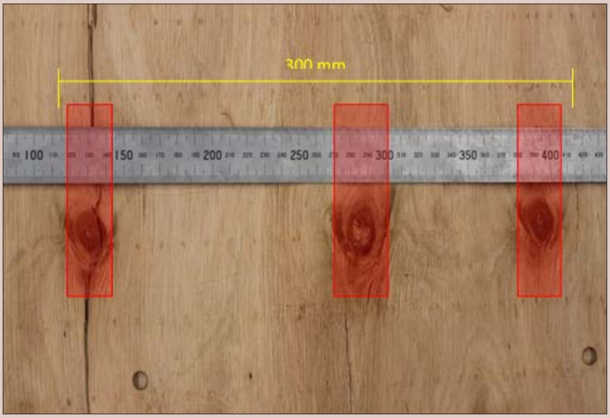

Figure 6.15. Cumulative defect measurement.

Roughness

Roughness is unevenness in the surface of the veneer or plywood.

Scratch

A scratch is a surface split or gouge that does not penetrate from one side to another on a veneer sheet.

Joint

A joint is the seam produced by jointing the edges of veneer sheets together.

Bark pocket

A bark pocket is a zone of bark enclosed in the veneer. It should not be confused with the bark surrounding a knot (encased knot).

VENEER GRADES ACCORDING TO AUSTRALIAN AND NEW ZEALAND STANDARD AS/NZS 2269.0:2012

This standard provides minimum performance requirements and specifications for manufacturing structural plywood that are acceptable to users, specifiers, manufacturers and building authorities in Australia and New Zealand. The standard is applicable to both hardwood and softwood resources.

There are five veneer grades specified, A, S, B, C and D, with F a reject grade.

- A-grade veneer is a high-quality appearance grade veneer suitable for clear finishing. This grade should be specified for the face veneer in plywood where surface decorative appearance is a primary consideration (Figure 6.16).
- S-grade veneer is a similar specification to A-grade veneer, but some characteristics (not permissible for grade A) are allowed when specified as decorative features. These include knots, holes, discoloration, hobnails, and other characteristics as agreed between manufacturer and customer.
- B-grade veneer is an appearance grade veneer suitable for high-quality paint finishing. This face veneer quality should be specified for applications requiring a high-quality paint finish (Figure 6.17).
- C-grade veneer is defined as a non-appearance grade veneer with a solid surface. All open defects such as knot holes or splits are filled. Plywood with a C-grade face is intended for applications requiring a solid non-decorative surface. An example is plywood flooring that will be overlaid with a decorative surface (Figure 6.18).
- D-grade veneer is defined as a non-appearance grade veneer with permitted open imperfections and is the lowest veneer grade. It is intended for structural applications where decorative appearance is not a requirement, e.g. structural plywood bracing (Figure 6.19).
- F-grade veneer is defined as reject grade, i.e. sheets not meeting the minimum requirements of the above grades (Figure 6.20).

Figure 6.16.
A-grade veneer.

Figure 6.17.
B-grade veneer.

Figure 6.18.
C-grade veneer.

Figure 6.19.
D-grade veneer.

Figure 6.20.
F-grade veneer.

COMPARING INTERNATIONAL GRADES

A comparison of veneer grades under different international standards is provided in Table 6.1.

Table 6.1 Comparison of veneer grades under different international grading standards.

	Australia/ New Zealand	USA	Europe	Russia	Canada	China	Vietnam
Standard	2269.0:2012	PS 1-95	EN 635.2&3	GOST 99-96.1&2	0151-09	LYT-1519	TCVN 10316
Grade	S & A	N & A	E & I	E & I	B	I	I
	B	B	II	II	C f/b	II	II
	C	C	III	III	C	III	III
	D	D	IV	IV	–	IV	IV
	–	–	–	–	–	V	V

UPGRADING

Veneer grade can be improved or upgraded if the defects which are limiting higher quality grades are removed from the veneer. Upgrading can be achieved through veneer patching and veneer composing. In patching, a machine is used to remove defects in a veneer sheet and a patch of clear wood or plastic of the same size is used to fill the void. Veneer composing takes narrow random width veneer pieces and joins them into a full-size sheet. This practice can be undertaken manually using a veneer splicer (Figure 6.21) or automated using a veneer composer machine (Figure 6.22), which combines the steps of piece preparation (i.e. clipping square straight edges), jointing and docking joined sheets to the required final width into one process, enabling greater production speed and efficiency.

Splicing and composing, while adding labour cost and extra handling, result in improved grade recovery, increased veneer quality and can improve final panel quality.

Figure 6.21.
Veneer splicing.

Figure 6.22.
Veneer composer.

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7. Veneer quality control

Joh Fehrmann, Robert McGavin and William Leggate

Quality control is a system of process and product monitoring that aims to ensure procedures and protocols are being followed to produce a consistent product of the required quality. Such systems help to identify issues quickly and correct the manufacturing process if necessary. Optimised quality control systems also help to reduce manufacturing costs by reducing rejects and downgraded products, reducing repair and reprocessing costs, increasing recovery and reducing waste, and increasing productivity.

The objectives of quality veneer production are to:

- maximise veneer recovery;
- produce long and straight veneer ribbons;
- minimise buckling and waviness;
- minimise veneer breakage/splitting;
- ensure a smooth surface;
- produce uniform thickness.

While there are a number of steps involved in the production of veneer that affect veneer quality (e.g. pre-conditioning, peeling and drying), peeling has the most influence on the quality. For this reason many quality control checks are necessary immediately after the lathe, so that any set-up issues are identified and rectified quickly (Figure 7.1).

Figure 7.1. Assessing veneer quality.

QUALITY ISSUES RELATED TO PEELING

Ribbon mis-tracking

The ribbon should leave the lathe in a straight line onto the conveyer belt producing a consistent cylindrical peeler core (Figure 7.2). A straight-tracking ribbon will produce a peeler core with the same diameters at each end and at its centre. Mis-tracking occurs if the ribbon tracks in an arc to either the left or the right side of the conveyer, depending on which end of the knife leads into the cut (Figure 7.3). The effect of mis-tracking becomes accentuated as the diameter of the peeler core becomes smaller and might only be noticeable when peeling large diameter billets.

Figure 7.2. Examples of straight tracking.

Figure 7.3. Examples of mis-tracking.

The conveyer belt is designed to take the ribbon away from the lathe in a straight line and mis-tracking can cause splits along the concave edge of the ribbon and waviness (see below), especially if the veneer ribbon is straightened. The ribbon can break or split into unfavourably sized sections, thus reducing the overall veneer recovery. Mis-tracking veneer can also cause the clipper to jam.

Mis-tracking indicates the need to realign the lathe settings (e.g. knife, nose bar, rollers). Multiple adjustments and fine tuning might be necessary to achieve straight tracking.

Waviness

A veneer ribbon is considered flat if the ribbon sits even and parallel with the conveyer belt and exhibits minimal gaps between the veneer and the belt's surface. The presence of waviness in a freshly peeled veneer ribbon indicates an issue with the lathe settings. Waviness within the ribbon may be linked to barrelling or cotton-reeling which is generally accompanied by thickness variation.

Barrelling and cotton-reeling

Barrelling occurs when the veneer ribbon exhibits buckles and wrinkles in the centre and its edges are tight and stretched. On a spindled lathe, barrelling is caused by insufficient back-roll pressure and/or when the horizontal opening between the knife and pressure bar of a lathe is narrower at the centre of the log than near the ends. Consequently, the peeler core develops the shape of a barrel, with the central section fatter than the ends (Figure 7.4).

Cotton-reeling is caused by the opposite effects of barrelling, leading to a veneer ribbon that is stretched and tight in the centre and buckled and wrinkled at the edges, and a peeler core that has the shape of a cotton reel (Figure 7.5). On a spindle lathe, cotton-reeling is caused if the back-roll pressure is too high or uneven, and/or the horizontal opening is wider towards the centre of the log than near the ends.

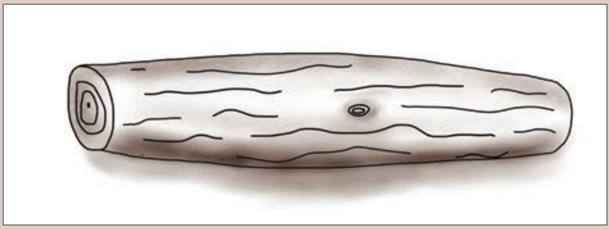

Figure 7.4. An illustration of barrelling in the peeler core.

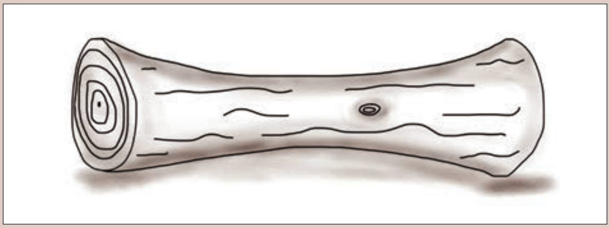

Figure 7.5. An illustration of cotton-reeling in the peeler core.

The drying process can exacerbate barrelling and cotton-reeling. Upon entering the dryer, the buckles of barrelled veneer are flattened, causing further stress on already-stretched edges and ultimately creating open splits at intervals along the edges (Figure 7.6). Cotton-reeled veneer on the other hand can develop open splits along its already stretched centre in response to buckles on the edges flattening as the veneer enters the dryer. Where certain areas of veneer dry at different rates, differential shrinkage and differential tension occurs. These tensions are the primary cause of buckling and splitting in dried veneer.

Figure 7.6. Buckling and splitting on opposite edges of the veneer ribbon.

Thickness variation

If all peeling parameters are optimised (e.g. billet pre-treatment and lathe settings) the green veneer thickness should have minimal variation. Uniformity in thickness (within and between veneer sheets) directly affects the manufacturing process, and ultimately, the quality of the final product. In order to achieve efficiency in gluing and finishing, minimal variation in the panel thickness is required. Excessive thickness variation can cause the following problems:

- variation in the amount of adhesive spread on veneers resulting in poor bond quality of the finished product—for instance, thinner veneers will tend to have more glue spread on their surface than thicker veneers with the same machine set-up;
- variation in platen pressure in the press during product manufacture;
- undesired variation in the product thickness causing the product to be outside specifications;
- low pressure areas which cause poor localised bonding and can increase the blow rate.

Variation in thickness for green veneer can be monitored by using a hand-held dial thickness gauge (Figure 7.7). To minimise measurement error, it is important for the operator to calibrate the gauge and use the same method for each assessment. Thickness measurements should be taken along both edges of the ribbon at opposite points. The system and frequency of measurement will vary depending on standards, production and product requirements; however, good practice would be to select a random sub-sample of veneer sheets and measure at 300 mm intervals on both sides along the veneer sheet edge (parallel to the grain) with measurements taken on areas free of knots, pronounced grain deviations, decay and other major defects (Figure 7.8).

Thickness tolerances

Various standards provide thickness tolerances for peeled veneer for plywood production. For example, the American standard PS 1-95 (APA–The Engineered Wood Association 1996) states a thickness tolerance of 5% of the nominal dried veneer thickness. Other standards, e.g. Vietnamese standard TCVN 10316:2014 (Standards Vietnam 2014) and Chinese standard LYT 1599:2011 (Standards China 2011), provide a list of thickness tolerances depending on the nominal thickness of the veneer (Table 7.1).

Figure 7.7. A hand-held dial gauge used to measure veneer thickness.

Figure 7.8. Routine checking for veneer thickness variation.

Table 7.1. Thickness tolerances in accordance with the Vietnamese standard (TCVN 10316:2014) and Chinese standard (LYT 1599:2011).

Nominal thickness range (mm)	Thickness tolerance (mm)
0.55–0.65	± 0.03
0.66–1.00	± 0.04
1.01–1.60	± 0.06
1.61–2.00	± 0.08
2.01–3.20	± 0.10

Tightness and looseness

Veneer is characterised by the presence of small checks or fissures roughly parallel to the grain commonly referred to as lathe or peeler checks. These checks form on the underside of the veneer that is in direct contact with the knife as the veneer passes between the knife and the nose bar as it is being cut from the billet and flattened out (Figure 7.9). The underside of the veneer containing the lathe checks is referred to as the loose side and the upper side is referred to as the tight side. Veneer that has many deep lathe checks is termed 'loose-cut' veneer while veneer having shallow infrequent checks is termed 'tight-cut'. Lathe checks will affect the veneer quality significantly; and a balance is required between tightness and looseness.

Veneer with optimal tightness has only small and fine peeler checks, and has little tendency to curl, buckle or split during drying. Fewer peeler checks mean greater strength across the grain and tight-cut veneers are less likely to rip or split during manual handling. Tight veneers are associated with superior weathering properties and exhibit less finishing faults. However, veneer that is too tight can cause pressing problems if the veneer has not dried flat. Deep peeler checks and rough surfaces significantly increase the surface area of the veneer (up to three times), leading to excessive absorption of adhesive and/or surface coatings and distorted reflection of light (relevant for appearance grade).

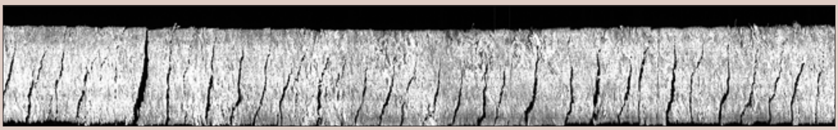

Figure 7.9. Peeler checks on the underside or loose side of veneer.

Surface roughness

Surface roughness results from factors such as excessive peeler checks, splits and grain tear-out. Roughness originates from splitting ahead of the knife edge during the peeling process due to cleavage action of the knife. The direction of splitting in relation to the cutting path determines the degree of severity of roughness. The development of roughness in the peeler billet is also dependent on and intensified by inherent lines of weakness within the timber (fibre direction, wood rays and/or growth ring slope), pith eccentricity and cross-grain.

The two main disadvantages of surface roughness are the reduction in veneer grade class and manufacturing complications (e.g. increased adhesive usage because of the increased surface area and reduced bond quality.

Optimal lathe settings, combined with appropriate pre-treatment of the billet, are effective methods to minimise surface roughness.

QUALITY ISSUES RELATED TO VENEER MOISTURE CONTENT

Veneer moisture content has an important influence on product quality. The veneer must be at the right moisture content for the following reasons:

- so that it can be glued successfully;
- to avoid biological degradation including fungal (stains and decay) and insect damage;
- to ensure that the veneers are pre-shrunk prior to product manufacture;
- to ensure product dimensional stability and therefore prevent veneer and panel distortion, e.g. waviness and warpage;
- to avoid splits and checking; and
- so that it is compatible with manufacturing processes such as the pressing closed and open assembly times.

The target moisture content of the veneer is dependent on the adhesive and manufacturing protocols, however a common target moisture content is 6% with a range of 3–10% (e.g. for most phenol formaldehyde resins). Urea formaldehyde resins are often more tolerant of higher moisture content and wider variation.

The two most common methods of measuring moisture in veneer are with a resistance meter or a capacitance meter.

Resistance meter (pin-type meter)

A resistance moisture meter uses two or more pins that penetrate the veneer at a desired depth (Figure 7.10). Direct current travels between the pins through the wood and the resistance is measured. Dry wood allows only little current to pass whereas wood with higher moisture content permits more. The meter reads how much resistance there is to the current and correlates the resistance to wood moisture content. This type of meter becomes less accurate as the moisture content increases. Pin-type meters are more accurate and effective in determining the moisture gradient within wood (the difference between shell and core moisture content) than other types of meter as the operator can control the pin depth.

Capacitance meter (electromagnetic field meter)

A capacitance meter measures the moisture content of wood without penetrating the wood (Figure 7.11). A sensor emits electrical waves that create an electromagnetic field. This field behaves differently depending on how much moisture is in the wood and the wood density. Capacitance meters measure the capacity of the wood to store energy (capacitance), the amount of power the wood absorbs from the field (power loss) or the wood's resistance to the field (impedance). This pinless meter type is less effective in measuring the moisture gradient within wood compared to a resistance meter. Also, readings provided by a capacitance meter are influenced more by surface moisture, so that readings for material beneath the surface veneer are generally less accurate. They are also affected by surface roughness. However, they are easy to use and do not damage the veneer surface.

Table 7.2 compares the two types of moisture meters and the influence of physical factors and various features.

Hand-held resistance moisture meters provide quick access to moisture content information and are relatively easy to use in small-scale operations and are especially useful to determine the moisture content of sheets outside the production line. Commercial plants producing veneer on a large scale often install 'in-line moisture measurement systems' as part of their production line (Figure 7.12). These systems usually use the capacitance method. They are often combined with automatic grading systems and form an essential part of a highly automated process.

Table 7.2. Factors affecting the use of each type of moisture meter.

Factor	Capacitance meter	Resistance meter
Temperature	No	Yes
Chemicals	No	Yes
Grain orientation	No	Yes
Moisture gradient	Yes, in some models (but less effective than resistance meters)	Yes
Wood species	Yes*	Yes*
Wood density	Yes*	No
Surface texture	Yes	No

* Both require species correction which is broadly related to density. Resistance meters also require temperature conversion.

Figure 7.10. A hand-held resistance moisture meter.

Figure 7.11. A hand-held capacitance moisture meter.

Figure 7.12. In-line veneer moisture measurement.

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8. Veneer recovery

Robert McGavin

The calculation of veneer recovery is important to provide guidance on the efficiency of the veneering operation, to compare and evaluate forest resources, and to establish fundamental economic information. There are different methods to calculate veneer recovery, and it can be very valuable to calculate recovery in several different ways to obtain valuable information such as where losses are occurring within the process. However, it can be confusing to compare between reported recovery values unless details of the methods used are known.

Four recovery calculation methods are provided below: green veneer recovery, gross veneer recovery, net veneer recovery, and graded veneer recovery.

Green veneer recovery (GNR) provides a measure of the maximum recovery, taking into account log geometry (sweep, taper, circularity) and lathe limitations (e.g. peeler core size). GNR disregards internal log quality. GNR (%) for a batch of veneer billets can be calculated as follows:

$$\mathrm{GNR} = \frac{\mathrm{L} \times \sum_{\mathrm{veneer}} (\mathrm{GT}_{\mathrm{mean}} \times \mathrm{GW})}{\sum_{\mathrm{billet}} \mathrm{V}} \times 100$$

where GT_{mean} is the average green veneer thickness (m), GW is the green veneer width (m) perpendicular to the grain (as measured prior to clipping and excluding any major defects, e.g. wane or undersize thickness, that are present at the beginning or end of the veneer ribbon), L is the veneer length (m) parallel to the grain, and V is the billet volume (m^3).

Gross veneer recovery (GSR) provides a measure of the maximum recovery of dried veneer that meets the relevant quality specifications (e.g. AS/NZS 2269.0:2012). This recovery includes the losses accounted for in GNR but also includes additional losses from visual grading (i.e. veneer that failed to meet grade) and the drying process (e.g. veneer shrinkage, splits, etc.). GSR (%) is calculated as follows:

$$GSR = \frac{L \times \sum_{veneer}(DT_{mean} \times GRW)}{\sum_{billet} V} \times 100$$

where DT_{mean} is the mean dry veneer thickness (m), GRW is the width (m) perpendicular to the grain of dried veneer that meets the grade requirements (e.g. A, B, C, and D grades in accordance with AS/NZS 2269.0:2012), L is the veneer length (m) parallel to the grain, and V is the billet volume (m^3).

Net veneer recovery (NR) provides a measure of process efficiency, as it identifies the saleable product, taking into account the product manufacturing limitations. NR includes the losses accounted for in GSR but also includes the additional losses due to the trimming of veneer before, during and after product manufacture. The loss incurred when veneer sheets are reduced in width to the final product size is known as a trimming factor. While this varies between operations, an example is provided of a trimming factor of 0.96. This corresponds to reducing the veneer sheet width perpendicular to the grain from 1,250 to 1,200 mm. In the following example, the veneer sheets are also reduced in length (parallel to the grain) from 1,300 to 1,200 mm. For this example, that relates to the manufacture of 1,200 × 1,200 mm final product, the NR (%) can be calculated as follows:

$$NR = GSR \times 0.96 \times \frac{1{,}200}{1{,}300}$$

$$\text{thus } NR = GSR \times 0.88615$$

Graded veneer recovery for an individual grade can be calculated using the same method as for NR but using the veneer volumes that meet the specific grade (e.g. A, B, C or D grades in accordance with AS/NZS2269.0:2012).

FURTHER READING

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9. Product manufacture

Rod Vella, Robert McGavin and William Leggate

This chapter describes the various components of veneer-based product manufacture, focusing on panel products such as plywood. During this process, veneers are glued and pressed together, and then trimmed, repaired, sanded, finished and machined further. The recommendations in this chapter are general and their suitability will depend on many factors including individual plant equipment, scale and layout; specific raw material (resource), products and market factors; and available finances, labour and other economic considerations.

Given the importance of bond performance to the integrity of the final product, we start the chapter with a section on adhesive types and applications, before describing the stages in the manufacturing process.

ADHESIVES

All veneer-based products involve the use of adhesives during manufacture. For example, plywood is manufactured from sheets of cross-laminated veneers or plies, arranged in layers and bonded with an adhesive. Adhesive systems and gluing protocols are therefore critical components in veneer-based product manufacture.

A variety of adhesives can be used for bonding veneers during product manufacture. Australian and New Zealand standard AS/NZS 2754.1:2016 provides information relating to the suitability of adhesives for the manufacture of plywood and laminated veneer lumber (LVL). Factors that influence adhesive selection include cost, compatibility with the assembly process, glue line strength and durability requirements and intended end use for the product. Bond durability is related to the expected conditions the glue line will be exposed to.

Many adhesive systems used to manufacture veneer-based products are composed of resin, fillers and extenders. The resin content is the amount of resin solid in the glue mix and it is the resin that interacts with the substrate to form the adhesive bond. This should not be confused with the general term 'resin' that is often used to describe the overall adhesive mix. Fillers and extenders are added to some adhesive systems and can assist adhesion and reduce costs. Common fillers include nutshell flour (e.g. macadamia nut), wood flour (e.g. alder bark) and mineral flours, while common extenders include wheat flour, maize flour and starches. These are inert materials added in small quantities to improve adhesive working properties such as viscosity, tack, transfer and cohesive strength. Correct viscosity is important to prevent the adhesive from being over- or under-absorbed into the timber face. Water is often added to adhesives to assist with viscosity control. Specific viscosities may be required to suit the type of equipment used to apply the adhesive and the overall manufacturing protocols.

There are two main categories of wood adhesive: thermosetting and thermoplastic. Thermosetting adhesives provide a rigid glue line that, once cured, will not re-plasticise if heated. Examples include the formaldehyde-based adhesives. It is generally accepted that these will not creep when subjected to long-term stress. Thermoplastic adhesives will re-plasticise when reheated. Examples include polyvinyl acetate (PVA) adhesives. It is generally accepted that thermoplastic adhesives will creep under long-term stress and for that reason they are not acceptable for any structural plywoods.

The properties and applications of the different commonly used adhesives are described below and summarised in Table 9.1.

Urea–formaldehyde adhesives

Urea–formaldehyde (UF) resins are commonly used adhesives in the veneer industry for non-structural, interior applications. UF adhesives have several advantages:

- they are relatively inexpensive;
- they can be cured at ambient temperature or heated to an elevated temperature to accelerate the curing process;
- they are light in colour and produce light-coloured glue lines that do not discolour high-quality face veneers.

Disadvantages of UF adhesives are:

- their use is restricted to indoor applications only—the bonds lack long-term temperature and moisture resistance meaning products manufactured with this adhesive type should not be used in applications where exposure to the weather or increased temperature are expected;
- they can emit formaldehyde over time although modern systems use low-emission formulations.

Melamine–formaldehyde and melamine–urea–formaldehyde adhesives

Melamine–formaldehyde (MF) and melamine–urea–formaldehyde (MUF) adhesives have increased water resistance compared to UF adhesives and therefore are commonly used for the manufacture of semi-weather exposed and some fully weather exposed products. They are also commonly used for impregnating the paper sheets that make up the backing in plastic laminates. However, the high cost of melamine limits the use of MF adhesives. MUF adhesives provide a lower cost alternative, but with lower bond durability. MUF adhesives are more expensive than UF adhesives but with improved bond durability.

Phenol–formaldehyde adhesives

Phenol–formaldehyde (PF) adhesives are widely used in the veneer industry. They have outstanding bond durability due to good waterproof properties and therefore are favoured for the manufacture of structural products, especially where weather exposure is possible.

Advantages of PF adhesives include:

- high bond durability;
- low cost;
- good tacking properties which provides some advantages during the manufacturing process.

Disadvantages of PF adhesives include:

- the emission of formaldehyde over time although modern systems use low-emission formulations;
- the use of a high curing temperature (~ 145°C) and/or a longer press time compared to UF adhesives;

- they are dark in colour and therefore produce dark-coloured glue lines;
- a requirement for low veneer moisture content within a narrow range;
- the pH is high (usually >10) making these adhesives corrosive to equipment and they can present a workplace safety hazard;
- the high pH can mobilise extractives in certain species during pressing causing bonding difficulties.

Polyurethane adhesives

Polyurethane (PUR) adhesives are isocyanate-based systems. While these adhesives are not traditionally used in the manufacture of veneer products they have been adapted for some applications, particularly in Europe, and are gaining popularity.

Advantages of PUR adhesives are:

- most are thermosetting polymers and do not soften when heated (at least in normal service conditions);
- they can be effective for bonding a variety of materials including wood, metals, rubbers, cured epoxy, leather, tile and glass, many plastics, concrete and brick;
- they do not emit formaldehyde;
- they work effectively within a higher range of veneer moisture content;
- they are used mainly as cold-setting adhesives which makes them suitable for production facilities where heated presses are not available or for products where heat transfer is challenging due to product dimension (such as glulam, multilaminar wood and finger-jointed products);
- they are suitable for products used in weather exposed applications as they have good UV resistance and are durable;
- a wide range of systems are available offering varying curing times providing flexibility in production applications;
- they produce clear or white glue lines.

Disadvantages of PUR adhesives are:

- they can have a limited shelf life, especially once opened and exposed to the atmosphere;
- they require the use of solvents (e.g. acetone, thinners) for cleaning application equipment and cleaning must take place while the adhesive is still uncured;

- curing times can vary considerably due to their sensitivity to humidity and veneer moisture content;
- performance may be compromised in extreme temperatures;
- they can be unsuitable for high density (>750 kg/m^3) hardwoods in external structural applications.

Table 9.1. Summary of adhesive properties and applications.

Adhesive	Properties	Application
Urea–formaldehyde (UF)	Hot and cold setting Low cost Low bond durability Light colour glue line Water clean-up	Internal use only such as furniture and interior plywood panels
Melamine–urea–formaldehyde (MUF)	Hot and cold setting More expensive than UF Better bond durability than UF Light colour glue line Water clean-up	Interior use or applications with limited exterior exposure
Melamine–formaldehyde (MF)	Hot setting Good bond durability Light colour glue line Expensive Water clean-up	Interior and exterior applications
Phenol–formaldehyde (PF)	Hot setting High durability, strength and stability Superior bond durability Dark colour glue line Narrow veneer moisture content range required Water clean-up Low cost	Interior and exterior applications
Polyurethanes (PUR)	Cold setting Requires higher veneer moisture content Flexible curing times Clear or white glue line Superior bond durability Adheres to most materials Solvent clean-up	Interior and exterior applications
Polyvinyl acetate and derivatives (PVA and PVAc)	Cold setting and thermoplastic Light colour glue line Low to medium bond durability Low cost Non-structural	Interior use or applications with limited exterior exposure

Polyvinyl acetate and derivatives

Polyvinyl acetate (PVA) and derivatives are the most common thermoplastic adhesives used in woodworking. They lose moisture and solidify to form a tight bond between two wood surfaces and they provide some water resistance.

THE STAGES OF PRODUCT MANUFACTURE

Lay-up

After veneer production, drying, grading and sorting, lay-up is the next stage in manufacturing veneer-based products. Lay-up is where veneers or reconstituted wood layers are 'stacked' in complete panel 'press loads' after gluing and before pressing; it is also the term given to constructing a panel. This involves a number of steps for producing properly constructed engineered panels and other veneer-based products. Large-scale operations have automated lay-up processes; however, in many plants, lay-up is undertaken manually and can be very labour intensive. The following focuses on manual lay-up processes.

The placement of veneers (in a given position within the final product) is determined by the quality and performance requirements of the final product. These are usually aesthetic or mechanical qualities (see Chapter 6). Selecting for appearance-focused products will place an emphasis on veneers with good aesthetic qualities for either one side of the product (e.g. face veneer of a plywood panel) or for both back and face veneer, depending on the use of the panel.

Selecting veneers for structural products gives greater priority to mechanical, rather than aesthetic, properties. Veneer mechanical properties are determined using various methods. The positioning of veneers with particular mechanical properties within a product has significant impact on the mechanical properties of the final product. Structural products may also have aesthetic requirements, and in this case veneers will need to be sorted and selected for both appearance and mechanical qualities.

The most efficient construction strategy is one that satisfies the quality requirements of the final product but also maximises the use of the qualities available from the forest resource. For example, the outer veneers of a panel have the most influence on the mechanical performance of the final product while the inner core veneers have less influence. Therefore veneers with the highest mechanical qualities should be used for the outer veneers (in particular face and back veneers) and veneers with lower mechanical quality can be used for the inner core veneers. In this way the mechanical requirements of the product can be achieved with the mix of veneer qualities. Similarly, for many appearance products, the concealed veneers (core veneers) can be veneers with lower aesthetic qualities and the face and back of the product should be the higher quality veneers.

Each veneer will have a tight side (without lathe checks) and a loose side (with lathe checks). When laying-up the veneer sheets into a panel, the tight side should be positioned towards the exposed panel surface and the loose side towards the concealed panel surface. This lay-up is called 'tight side out and loose side in'.

A final consideration is panel thickness, which depends on the number of veneers used, the original veneer thickness and the veneer density. Manufacturing veneer-based products involves pressing panels at high pressure for prolonged periods which compresses the individual veneers. Density is important to consider when determining the number of veneers and required veneer thickness for a particular thickness of panel, as high density veneers will compress less than lower density veneers.

Different lay-up designs for different products are described below.

Lay-up for plywood

For plywood, the veneer sheets need to be orientated so that the grain direction of each veneer sheet is perpendicular to that of the veneer sheets above and below it. The majority of plywood is made from an odd number of veneers with the face and back veneers having a grain orientation parallel to the length of the panel. Plywood is available in various lengths, widths and thicknesses. Standard dimensions for length are 1,800 mm, 2,400 mm and 2,700 mm while width is generally 1,200 mm. Sizing can be imperial or metric. A wide range of plywood thicknesses are available and are generally between 3 mm and 28 mm depending on product and intended end uses.

To make plywood, the adhesive is usually applied to both faces of the cross band (and every second veneer). During lay-up, veneers that will have adhesive applied are separated from those that will not and they are stacked separately.

Lay-up for formwork plywood

Formwork plywood or form ply is plywood with a high-density or medium-density overlay (HDO or MDO) of phenolic resin impregnated paper bonded onto it. Formwork plywood is specially designed for use in concrete formwork applications and is intended to provide a high-quality off-form concrete surface finish meeting the Australian standard AS 3610 'Formwork for concrete'. Australian standard AS 3610 specifies five classes of surface finishes from Class 1 (highest) to Class 5 (lowest). Formwork plywood is typically produced to meet surface finish Classes 2 and 3 of AS 3610. Australian standard AS 6669 'Plywood—Formwork' lists the manufacturing requirements for plywood to meet surface Classes 2 to 5. Plywood is not suitable for meeting Class 1 surface finishes as defined in AS 3610. Around 40% of all plywood sold in Australia is used in the formwork industry.

Formwork plywood has the same lay-up as plywood and is commonly available in stress grades from F11 to F27 (Table 10.3) and usually manufactured with a PF or MUF adhesive. The lower stress grades are often manufactured with a softwood core such as radiata pine and a thin (0.9–1.5 mm) hardwood veneer on the two faces. The hardwood faces provide mechanical benefits but are mostly used to give a long-wearing smooth surface finish and to improve the panel's impact resistance. Thin face veneers are also less prone to swelling when exposed to moisture, producing panels which are more stable when exposed to moisture. The higher stress grades are generally comprised of either all hardwood veneers or a mix of hardwood and high-quality softwood. The overlay helps to protect the hardwood face veneer, inhibits moisture penetration, reduces the potential for extractive staining and provides a sound surface for the concrete. Softwood faces can also be used in form ply although a very high quality is necessary and they are usually less resistant to impacts.

Lay-up for LVL

Laminated veneer lumber (LVL) is manufactured by bonding together multiple rotary-peeled veneers under heat and pressure with all veneers usually having the same grain orientation. LVL sizes vary between manufacturers. Manufactured sheets are usually 1,200 mm and 2,400 mm wide and in standard thicknesses of 35, 36, 39, 45 and 63 mm. LVL is usually bonded using a PF adhesive that provides a waterproof bond that is able to withstand exposure to the weather for a long period without deterioration.

LVL is generally manufactured in a continuous press and as such requires no manual lay-up, with all veneers having the same grain orientation, i.e. the grain is orientated to be parallel with the length of the piece. Adhesive is usually applied to one face of every veneer, except for the face veneer, to which no adhesive is applied. However, LVL can also be constructed in a similar way to plywood, where the adhesive is applied to every second veneer. This requires separating the face veneers from the remaining veneers.

Gluing

The steps for achieving an acceptable bond quality include:

- mixing the adhesive;
- applying the adhesive;
- open assembly;
- pre-press;
- closed assembly (if necessary depending on adhesive and product type);
- hot press (if necessary depending on adhesive and product type); and
- cooling and storing.

Adhesive mixing

The adhesive is mixed following the manufacturer's instructions. The example below is for a PF adhesive that has resin (liquid or powder), fillers, extenders and water as components.

For a standard PF mixing procedure:

1. Add resin to mixer. If the resin is powdered, add the specified amount of water first and thoroughly mix.
2. Slowly add fillers and extenders while mixing and continue until thoroughly mixed.
3. Add water. Check viscosity to ensure it is within the manufacturer's specifications. It is better to start with a slightly thicker mix and slowly add water to bring it within range than to begin with an adhesive that is not thick enough and then trying to correct by adding resin, fillers and extenders.

Adhesive application

The adhesive can be applied mechanically to veneers using several different methods:

- double-roll spreaders—applies adhesive to both faces of the veneers by means of rollers, which are often corrugated to control the spread of the adhesive (Figure 9.1);
- extruders—applies beads of adhesive to one face of the veneer which then spreads to coat the whole surface upon pressing (Figure 9.2);
- curtain coaters—applies adhesive in a thin film or curtain on one side of the veneer only as it passes through the coater (Figure 9.3);
- spray coaters—the adhesive is atomised and applied as a thin film to one surface of the veneer.

Each adhesive has a technical data sheet (TDS) that specifies the spread rates, press pressures and timings. The spread rate is the amount of adhesive recommended by the manufacturer to be applied and is usually given in grams per square metre (gsm). The spread will also be specified as either double glue line (DGL) or single glue line (SGL). DGL is the amount of adhesive as measured when applied to each contact veneer face within the glue line, and SGL is the amount of adhesive as measured when applied to a single veneer face within the glue line.

The adhesive applicator should be set up to deliver the correct amount of adhesive onto the veneer sheets before manufacturing the panels. This is normally done using sacrificial veneers to determine the correct configuration.

Usually, at least two operators are required to operate the glue spreader (Figure 9.4). One person feeds the segregated veneers on the in-feed side of the glue spreader and the other receives the veneers on the out-feed side and lays them up as required for the type of panel being manufactured.

Figure 9.1. A double-roll glue spreader.

Figure 9.2.
Applying adhesive with an extruder.
Source: Schneider Holz Germany.

Figure 9.3.
A curtain coater.
Source: Wesbeam Pty Ltd, Australia.

Figure 9.4.
Glue spreading.

Pressing

Open assembly

Open assembly time (OAT) is the period of time from the first veneer passing through the glue spreader until pressure is applied to the panels in the cold press (also known as a pre-press). This time period allows the adhesive to start penetrating into the face of the veneer and the start of a chemical reaction causes the adhesive to begin to 'tack'. OAT will be specified in the TDS, but it also depends on the ambient conditions, so it is necessary to adjust the procedures with changes in operating conditions (e.g. temperature and humidity fluctuations). Because of these fluctuations, panels are usually produced in batches, the size of which will be constrained by the press capacity.

Pre-press

Pre-pressing (also called cold pressing; Figure 9.5) is important because it prevents the glue line from drying out too much, facilitates adhesive transfer between veneers and forces adhesive to penetrate into the wood structure, and removes air from the glue line. Pre-pressing takes place in an unheated press for a specified time at a specified pressure (given in the TDS). This pressure must be calculated to suit the type of press being used.

Figure 9.5.
Panels in pre-press.

Closed assembly

Some adhesives, such as UF, MUF and PF, require heat and pressure to be applied to accelerate or complete the curing process. Closed assembly time (CAT) is the time from when the panel is removed from the pre-press until it is placed in the hot press. The CAT allows the adhesive to penetrate the veneers before curing and reduces the amount of water in the glue line as it is absorbed into the veneers. If the CAT is too short, there will be too much moisture and the bond may fail or 'blow' after hot pressing (Figure 9.6). If the CAT is too long, the adhesive will dry out causing a poor bond and weak glue line prone to delamination.

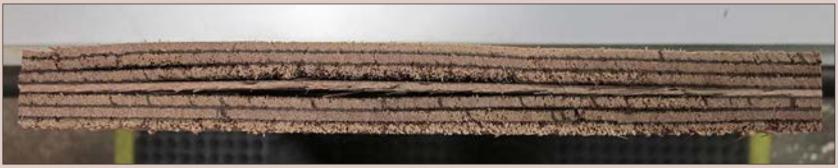

Figure 9.6. Panel blow.

Hot pressing

Panels are hot pressed to apply adequate pressure and temperature to the glue line while curing the adhesive (Figure 9.7). Higher temperatures accelerate the rate of cure. The three ruling factors are temperature, pressure and time. Both temperature and pressure are stipulated in the TDS. The time depends on the number and thickness of veneers in the panel and the time required for the middle glue line to reach cure temperature (generally around 100°C for PF adhesives).

Figure 9.7. A hot press.

The hot press loading time should be minimised to prevent the outer glue line of the panels loaded first starting to cure prior to pressure being applied which will result in a very poor bond. Panels removed from the hot press can be sprayed immediately with a light film of water which assists in equalising the moisture in the outer sheets and reduces warping in the panels.

TRIMMING, SANDING AND FINISHING

After manufacture, panels are usually trimmed to the precise size required, normally by passing through two sets of parallel, gauged circular saws (Figure 9.8). At this stage, patching or filling can also be carried out if necessary. Patching involves filling the voids with shims or wood patches. The shims are used to fill splits by sawing out and then inserting the shim. Larger defects are routed out and a patch is used to fill the void. Filling, by means of a synthetic filler or putty, is used to repair minor imperfections such as splits, knots, knot holes and resin pockets in the face and back veneers. Care has to be taken to ensure that the putty closely matches the colour of the veneer. Time should be allowed for the putty to harden prior to sanding.

Figure 9.8. Panel edge-trimming in Vietnam.

A wide-belt sander can be used to achieve a smooth, even finish of the surface veneers. These machines are available in a variety of configurations (e.g. single or multiple belts) with feed speeds of up to about 30 m per minute. Wide-belt sanders can be used to reduce thickness variation in veneers prior to product manufacture (Figure 9.9) or within the finished panels (Figure 9.10).

Figure 9.9. Sanding veneers to reduce thickness variation.

Figure 9.10. Automated plywood sanding line.

PANEL STORAGE

It is important to store panels correctly to allow them to acclimatise and to prevent the absorption of excess moisture. Panels should be stacked neatly and stored flat on a minimum of three raised runners or bearers of equal thickness placed at both ends and in the middle to prevent buckling and permitting the passage of air. Ideally, panels should be stored under a roof to reduce exposure to the elements. In addition, panels are usually wrapped in plastic to prevent them from being contaminated by dust, oil, adhesive or other contaminants.

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10. Product grading and quality

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Chapters 6 and 7 discussed grading and quality control aspects relevant to veneers. This chapter discusses these issues as applicable to the manufactured product. The following topics are discussed:

- bond quality and issues related to bond failure;
- grade classes for structural plywood;
- tolerances for structural plywood.

BOND QUALITY

Bond classes

Requirements for adhesive bond quality are described in relevant standards and/or agreed specifications between suppliers and customers. In Australia and New Zealand, four different adhesive bond classes for plywood are specified in the Australian and New Zealand standard AS/NZS 2754.1(int.):2016 'Adhesives for timber and timber products—Adhesives for the manufacture of plywood and laminated veneer lumber (LVL)'. Test methods to demonstrate bond performance are specified in AS/NZS 2098.2:2012 'Methods of test for veneer and plywood'. The following section describes 'Method 2: Bond quality of plywood (chisel test)' as per AS/NZS 2098.2:2012.

These bond classes are based on product exposure and end use and are as outlined in the aforementioned Australian and New Zealand standard. It should be noted that different countries will have different standards that connect required bond classes with intended end use and exposure. It is important that the requirements of the relevant standard be followed for the country where the product and adhesive is going to be used. A summary of the different bond classes, where they are required and how they are evaluated is shown in Table 10.1.

Table 10.1. Summary of different bond classes.

Bond class	Example	Application	Chisel methodology
A	Phenol–formaldehyde resin or resorcinol–formaldehyde adhesives	Extreme, long-term exposure to weather or damp/wet conditions Long-term structural performance without glue line breakdown or creep, e.g. structural plywood flooring, exterior cladding, marine ply and scaffolding planks	Chisel test after immersion in 100°C water for 72 + 1 hour or 6 hours at 200 kPa steam pressure (autoclave). Keep moist and complete the test within 24 hours
B	Melamine–urea–formaldehyde adhesives	Short-term (not more than 2 years) extreme exposure to weather or damp/wet conditions as well as structural performance without glue line breakdown or creep, e.g. concrete formwork Long-term exposure to a protected exterior environment, or non-structural applications, e.g. exterior door skins	Chisel test after immersion in 100°C water for 6 hours +5 mins, –0 mins. Keep moist and complete the test within 24 hours
C	Urea–formaldehyde, polyvinyl acetate, isocyanate, polyurethane adhesives	Interior, non-structural, and involving full protection from the weather, wet or damp conditions Can be used in long-term exposure to generally high humidity or short-term exposure to extremely high humidity, e.g. interior panelling in bathrooms	Chisel test after immersion in water at 70 ± 1°C for a period of 3 hours +5 mins, –0 mins
D	Urea–formaldehyde, polyvinyl acetate, isocyanate, polyurethane adhesives	Non-structural, fully protected from the weather, wet or damp conditions Interior applications with exposure to long-term medium humidity with occasional exposure to high humidity, e.g. furniture, interior wall panelling	Chisel test after immersion in water at 15–20°C for a period of 16–24 hours

Chisel test

The evaluation of bond quality for veneer-based products is usually conducted using a chisel test. The Australian and New Zealand standard AS/NZS 2098.2.2012 outlines this procedure ('Methods of test for veneer and plywood, Method 2: Bond quality of plywood—chisel test'). The test forcibly separates veneers along the glue line, allowing the percentage of wood fibre on the exposed surfaces to be estimated and the glue line to be evaluated. A quality glue line will demonstrate substantial wood fibre failure on the separated veneers, while a poor bond will have little or no wood fibre remaining indicating the adhesive has failed.

The test procedure uses a pneumatic chisel to force the glue line apart in a direction perpendicular to the veneer grain (Figure 10.1). Individual veneers from each glue line are then assessed to estimate the percentage area covered by wood fibres (Figure 10.2) and a bond quality value from 0 to 10 (where 10 is the best) is assigned to each glue line (Table 10.2). Under normal circumstances, a sample pass or fail would be determined in accordance with the specification outlined in the relevant standard for the product (e.g. AS 6669:2016 'Plywood—Formwork'; AS/NZS 2269.0:2012 'Plywood—Structural—Determination of structural properties—Evaluation methods'; AS/NZS 2271:2004 'Plywood and blockboard for exterior use'; AS/NZS 4357.0:2005 'Structural laminated veneer lumber—Specifications'). Each of these standards requires a sample to have an average bond quality score of not less than 5, with any individual glue line not less than a bond quality score of 2.

Figure 10.1. A pneumatic chisel is used to separate veneers in the chisel test method.

Figure 10.2. Veneers are separated to assess wood fibre failure.

Table 10.2. Estimated wood failure and equivalent bond quality values.

Estimated wood failure (%)	Bond quality value
0–5	0
6–15	1
16–25	2
26–35	3
36–45	4
46–55	5
56–65	6
66–75	7
76–85	8
86–95	9
96–100	10

Glue line failures

Effective quality control is essential to ensure that the product bonds meet the requirements of the relevant standard and that the product will adequately perform during its intended use.

The most common causes of inadequate bonds are:

- over-penetration of adhesive;
- adhesive dry-out;

- veneer thickness variation leading to variation in press pressure;
- adhesive pre-cure;
- adhesive under-cure;
- veneer case hardening or surface inactivation.

Over-penetration of adhesive

The common causes of over-penetration are:

- high initial veneer moisture content;
- high glue spread;
- press open assembly time too short;
- high press temperatures causing increased adhesive flow;
- low adhesive viscosity.

This problem is identified by:

- good adhesive transfer between veneers;
- limited glue solids remain in the glue line; however, fillers remain;
- blown panel.

Remediation measures include:

- check veneer moisture content prior to panel production;
- check the adhesive viscosity;
- check adhesive spread rates;
- check recommended press open assembly time parameters remembering that this is temperature sensitive;
- after pre-pressing, check that the adhesive has transferred between veneers and that the veneers have 'tacked'.

Adhesive dry-out

Common causes of adhesive dry-out are:

- low initial moisture content in the veneer;
- low adhesive spread rate;
- veneer temperature elevated due to insufficient cooling and equalisation time following drying;
- press open assembly time too long;
- high adhesive viscosity.

This problem is identified by:

- little or no adhesive transfer between veneers;
- little wetting of the un-spread veneer;
- no adhesive penetration;
- adhesive spreader roller marks are still visible on the veneer;
- excessive adhesive remains present on spread veneer.

Remediation measures include:

- check veneer moisture content prior to panel production;
- check adhesive spread rates;
- check the adhesive viscosity;
- check press open assembly time procedures, remembering that this is temperature sensitive;
- after pre-pressing, check to see that veneers have 'tacked';
- check the veneer temperature especially if there is minimal delay between drying and adhesive application.

Veneer thickness variation

Variation in the thickness of veneers can be due to a number of causes. It can occur when spliced or jointed veneer has a thickness change between adjacent veneers. It can also occur during the peeling process due to incorrect settings or equipment limitations; this can be localised variation (within a veneer sheet) or a gradual change in thickness during the peel resulting in variation between veneer sheets. The acceptable variation in veneer thickness is usually up to 5% of the nominal thickness.

This problem is identified by:

- no adhesive transfer in failed zone;
- no wetting in failed zone;
- no penetration of adhesive into the veneer in failed zone;
- a distinct demarcation between a good/bad bond zone;
- spreader roller marks are still visible on spread veneer in the failed zone.

Remediation measures include:

- check for thickness variations along the width of veneers to be pressed;
- check for thickness variation at spliced zones;
- check the lathe settings;

- check for mechanical issues with the lathe such as worn bearings on the rollers;
- segregate and sort veneers based on thickness to reduce thickness variation during product manufacture.

Adhesive pre-cure

Adhesive pre-cure occurs when the adhesive cures before sufficient press pressure is applied. This results in the adhesive not flowing correctly and too little wetting occurs to form an adequate bond. This can occur if a panel sits too long before being pre-pressed, or the panel remains on a hot platen of the hot press for too long before pressure is applied.

In un-prepressed plywood this problem is identified by:

- limited adhesive transfer;
- limited adhesive wetting;
- no adhesive flow (e.g. spreader marks still visible);
- no adhesive penetration.

In pre-pressed plywood this problem is identified by:

- adequate adhesive transfer;
- poor adhesive penetration;
- adequate quantity of adhesive on both surfaces;
- adhesive in the glue line has cured and is difficult to scrape off.

Remediation measures include:

- check press protocols to ensure sufficient and even pressure;
- check the hot press loading protocols to ensure panels are not left too long in the hot press before pressure is applied or loading time is excessive.

Adhesive under-cure

Adhesive under-cure is caused by insufficient pressing time or by insufficient temperature.

This problem is identified by:

- adequate adhesive transfer;
- adequate adhesive quantity on both veneer faces;
- outer glue lines are satisfactory but the inner glue lines show poor adhesion.

Remediation measures include:

- check the hot press platens with a thermocouple to ensure adequate temperature has been achieved;
- check that the press time is adequate—measuring the temperature of the middle glue line in the panel during hot pressing can assist in calibrating the press protocols.

Veneer surface inactivation or case hardening

Inactivated veneer surfaces are indicated when the wood resists wetting. This problem is usually caused by drying veneer at excessive temperatures or by over-drying.

The components that make up wood are held together by strong molecular forces. When wood is machined, the molecular bonds are broken. The newly created open bonding sites are unstable and have strong attractive forces, and the higher the number of available bonding sites the greater the total attractive force. It is this attraction that gives freshly machined wood its wettability. Water, gases, microscopic dust and dirt particles, extractives in the wood and, of course, adhesives are all likely candidates to bind with open bonding sites. The longer freshly machined wood is exposed to the atmosphere, the more of these bonding sites will be taken by gases and pollutants and the fewer will be available for the adhesive. This is why wood loses its wettability over time and the wood surface becomes inactivated. When the wood is heated, the chance of an inactivated surface increases because heat increases the movement of extractive (non-soluble) compounds, potentially moving to the surface and attaching to open bonding sites. Extreme heat can alter the molecular chemistry, destroying available bonding sites.

This problem is identified by:

- veneer has discoloured after drying;
- poor adhesive transfer or wetting;
- no adhesive penetration into the spread veneer;
- the failed area resembles a dried-out bond;
- the glue line has an imprint of the opposite surface (often appearing as a wood grain pattern) and an occasional loose fibre imbedded in the glue.

Remediation measures include:

- check that the dryer temperature is not excessive;
- check the veneer moisture content at the completion of drying to determine suitability of drying time;
- reduce the veneer storage period.

GRADES OF STRUCTURAL PLYWOOD

Grades for structural plywood vary depending on the country and specific customer requirements. This section describes the key specifications of the Australian and New Zealand standard AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications'.

In accordance with this standard, all the veneers in a finished sheet of structural plywood should comply with the following requirements:

1. Veneers shall be free from decay and active insect attack.
2. In any 300 mm line drawn across the grain anywhere on the plywood sheet, the aggregate dimension of knots, gaps in edge joints, splits, holes, patches, bark and unsound resin pockets, gum veins and areas of inactive decay shall not exceed the following:
   - for Quality A and B hardwood veneers—45 mm;
   - for Quality S, C and D hardwood veneers—75 mm;
   - for Quality A and B softwood veneers—75 mm;
   - for Quality S, C and D softwood veneers—120 mm.
3. Veneers shall be cut smoothly and tightly to a uniform thickness.
4. Veneers may be in more than one piece.

The veneer qualities apply to veneers on the lower limit of grade. Each pack of structural plywood shall include a reasonable distribution of panels having face veneer of quality above the lower limit.

Plywood panels manufactured to AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications' are deemed suitable for permanent structures and in addition to the determination of a specific surface grade (A, S, B, C, D) are required to be categorised into stress grades (also referred to as F-grades). In order to be used appropriately as a structural element, panels must meet the minimal structural performance criteria for a given stress grade. Table 10.3 gives the characteristic properties of structural plywood that are required for each specific stress grade category.

Table 10.3. Characteristic properties for F-grades (source: AS/NZS 2269.0:2012).

Stress grade	Characteristic strength (MPa)				Short duration average modulus of elasticity, (MPa) (*E*)	Short duration average modulus of rigidity (MPa) (*G*)
	Bending (f'_b)	Tension (f'_t)	Panel shear (f'_s)	Compression in the plane of the sheet (f'_c)		
F34	90	54	6.0	68	21,500	1,075
F27	70	45	6.0	55	18,500	925
F22	60	36	5.5	45	16,000	800
F17	45	27	5.1	36	14,000	700
F14	36	22	4.8	27	12,000	625
F11	31	18	4.5	22	10,500	525
F8	25	15	4.2	20	9,100	455
F7	20	12	3.9	15	7,900	395
F5	14	9.6	3.7	12	6,900	345
F4	12	7.7	3.4	9.6	6,100	305

The values for short duration average modulus of rigidity are derived values using the equation $G = E/20$.

Australian and New Zealand standard AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications' describes two methods for determining the F-grade of plywood: mechanical F-grading and in-grade testing. The F-grading system assigns known and reliable values for a range of key structural properties such as bending stiffness, bending strength, shear strength, compression strength and tension strength.

Mechanical F-grading

Mechanical stress grading is carried out at an ambient temperature range of 5–35°C and with moisture content of the panels in the range 8–15%.

Each finished plywood panel, manufactured to AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications', and to which an F-grade is to be assigned using this method, is supported over a predetermined test span and loaded at mid-span. F-grades are assigned to the mechanically graded panels, based on the calculated modulus of elasticity (E) determined for each sheet by measuring the load-deflection response (Δ/P) and calculating E using the following equation:

$$E = \frac{L_3}{48\, I\, (\Delta/P)} \qquad (1)$$

where E = modulus of elasticity (MPa), Δ = deflection (mm), P = applied force (N), L = span of the test sheet (distance between supports) (mm), and I = sum of the second moments of area (moments of inertia) of all plies in the panel (as calculated by the method described in Appendix B in the standard AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications') (mm^4).

An F-grade is assigned to each panel such that the modulus of elasticity as determined from Equation 1 meets the short duration average modulus of elasticity given in Table 10.3. F-grades determined by this method are applicable to the direction in which each panel has passed through the mechanical testing machine. This is usually the longer dimension of the panel which, in most cases, is parallel to the grain. Where the F-grade or structural properties are required in the alternative direction (usually the shorter panel dimension and across the face grain), the in-grade testing method should be used.

Validation of mechanically F-graded structural plywood sheets

At the beginning of production, the F-grade should be validated through an initial testing of bending strength and shear or tension strength based on a random sample of 30 panels for each characteristic property listed in Table 10.3. The F-grade is validated only if the properties meet the requirements given for the assigned F-grade. The F-grades or stress grades assigned to structural plywood through machine stress grading should be continuously validated by ongoing testing from production of one stiffness and one strength property, usually modulus of elasticity and bending strength. The validation test is deemed valid only if the characteristic stiffness or strength property is not less than the value for the relevant property given in Table 10.3.

Samples should be selected from current production at a frequency of 1 in 500 structural panels and all panels should be in the finished form as supplied to the market. The testing configuration for validation of mechanically F-graded plywood sheets is the same as the configuration for in-grade testing.

In-grade testing

Stress grades or characteristic properties may be assigned to structural plywood through testing and evaluating a sample of actual 'in-grade' product. The random sample should consist of a minimum of 30 in-grade plywood panels. Where F-grades are assigned, the characteristic strength and stiffness values obtained from in-grade testing should meet each of the characteristic values for the F-grade, as specified in Table 10.3. The F-grade or characteristic strength and stiffness properties assigned to structural plywood through in-grade testing should be continuously validated by ongoing testing from production of one stiffness and one strength property, usually modulus of elasticity and bending strength.

Mechanical properties determined using in-grade testing remain valid only while the controlling process variables remain within the limits defined in the manufacturing specification; therefore, it is strongly recommended that manufacturing be carried out under a third-party-audited, process-based, quality control program. The commercially produced plywood to which mechanical properties are assigned, based on the in-grade testing method, should be manufactured from veneers that are representative of the wood resource, arranged in the same manner as the plywood used in the in-grade testing and evaluation.

PERMISSIBLE TOLERANCES OF FINISHED PLYWOOD (AS/NZS 2269.0:2012)

The Australian and New Zealand standard AS/NZS 2269.0:2012 'Plywood—Structural. Part 0: Specifications' also sets out the permissible tolerances for dimension, shape and moisture content for structural plywood. These are detailed in Tables 10.4, 10.5 and 10.6.

Dimensions

When measured in accordance with AS/NZS 2098.4 'Method 4: Measurement of dimensions and shape for sheets of veneer and plywood', unless otherwise agreed by contract, the actual dimensions of structural plywood should not differ from the ordered dimension by more than the tolerances given in Table 10.4.

Table 10.4. Permissable tolerances for thickness, length and width of finished plywood (AS/NZS 2269.0:2012).

Sanded/un-sanded	Average panel thickness*	Tolerance
Sanded	Up to and including 7.5 mm	±7%
Sanded	Over 7.5 mm up to and including 17.5 mm	±4%
Sanded	Over 17.5 mm up to and including 25 mm	±3%
Sanded**	Over 25 mm	Not specified
Un-sanded	An additional thickness tolerance of +0.3 mm per sheet	

Average panel length and width tolerance = ±1.5 mm.
* Thickness dimensions apply to sheets without overlays or other coatings.
**For sanded sheets over 25 mm thick the tolerance on thickness should be agreed between the manufacturer and purchaser.

Shape

Table 10.5. Permissable tolerance for shape of finished plywood (AS/NZS 2269.0:2012).

Condition	Tolerance
Squareness	The difference in length of the two diagonals of the sheet shall not exceed 0.2% of the length of the longer diagonal
Straightness of edges	Any edge of a sheet shall not deviate from a straight line by more than 0.05% of the length of that edge
Flatness*	For an unloaded sheet, the maximum distance between the underside of the sheet and a flat horizontal surface shall not exceed the following: • for sheets not exceeding 7.5 mm thickness—50 mm • for sheets exceeding 7.5 mm thickness—30 mm When the sheet is loaded as specified in the following, the sheet shall touch the flat horizontal surface vertically below the loaded area: • for sheets not exceeding 7.5 mm thickness—10 kg • for sheets exceeding 7.5 mm thickness—15 kg

* Flatness to be determined prior to installation or use. At the time of test, panels should be in accordance with the moisture content requirements.

Moisture content

Table 10.6. Permissable tolerance for moisture content of finished plywood (AS/NZS 2269.0:2012).

Thickness	Tolerance
Sheets not exceeding 7.5 mm	Not less than 10% and not more than 15%
Sheets exceeding 7.5 mm thickness	Not less than 8% and not more than 15%

Moisture content is measured anywhere in the sheet at the time of dispatch.
Preservative-treated plywood may be treated after branding and may be supplied at a higher moisture content. This may be appropriate for the application.

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11. Protecting veneers and veneer-based products

William Leggate

Veneers can be subject to degradation caused by many factors, including:

- insects such as termites and borers (e.g. lyctid beetle) (Figures 11.1 and 11.2);
- fungi that cause staining and decay (Figure 11.3);
- marine borers;
- bacteria;
- fire;
- chemicals;
- mechanical causes.

These degradation agents can result in large-scale damage that is unsightly, very difficult and costly to repair, and more importantly, can cause buildings to be unsafe and health hazards. This chapter provides a brief description of the protection of veneers and veneer-based products against degradation caused by biological agents.

There are several options for protecting veneers from biological degradation. These include:

- choosing wood species with appropriate natural durability for the intended application and 'exposure' environment;
- using chemical preservatives;
- using other non-traditional preservation options such as wood modification by heat treatment, chemical reactions (e.g. acetylation), polymerisation and impregnation (e.g. furfurylation);
- adopting correct design, construction and utilisation practices to maximise the service life of the wood.

Figure 11.1. Termite damage to wood.

Figure 11.2. Lyctid beetle damage to wood including larvae and frass. Photos: Ted Stubbersfield (left); Doug Howick (right).

Figure 11.3. Fungal decay in wood.

WOOD SPECIES WITH NATURAL DURABILITY

Durability is one of the key performance factors used to assess the suitability of a timber species for a specific application. The durability rating of a species is based on the natural ability of the heartwood of that species to resist decay and insects. The sapwood of all species is considered to be non-durable and is categorised as the lowest class of durability. The heartwood of many species exhibits some degree of durability due mainly to the presence of toxic extractives and also low moisture permeability.

Most countries have standards that describe the durability ratings of commercial species. Australian standards AS 5604 'Timber—Natural durability ratings' and AS 1604 ' Specification for preservative treatment' provide guidance on durability requirements for a range of in-ground and above-ground applications (Table 11.1). Those species with higher durability ratings will be expected to last longer in-service. There is some evidence to suggest that the high temperature drying and pressing processes used in the manufacture of plywood and LVL have the potential to affect the natural durability of the wood species and the probable life expectancies listed in Table 11.1 may not always be achieved.

Table 11.1. Durability classes and life expectancy (from AS 5604).

Durability class	Probable in-ground life expectancy (in years)	Probable above-ground life expectancy (in years)
1	Greater than 25	Greater than 40
2	15–25	15–40
3	5–15	7–15
4	0–5	0–7

Young plantation hardwoods

The natural durability of mature wood of most commercially used timber species is reasonably well understood and documented. However, the durability of young plantation-grown hardwood timber species is less well known and the wood may not perform as well as mature wood of the same species. Despite the species having a historical usage, young plantation hardwoods may not be suitable for certain applications, especially where the natural heartwood durability is relied upon.

Depending on species and intended product end use, exposure and service requirements, veneers containing sapwood may need to be treated. Young plantation hardwoods will normally contain greater proportions of sapwood compared to older plantations or mature native forest. Some species have sapwood that is susceptible to attack by lyctid beetles. This would potentially result in larger volumes of wood from plantations requiring preservative treatment.

CHEMICAL PRESERVATIVES

The durability of timber can be greatly augmented by the use of chemical preservatives that protect the wood from biological attack by organisms such as insects and fungi. There are numerous types of wood preservatives that vary in chemical composition, intended application or exposure environment, required chemical loading in wood, performance, treatment method, cost, ease of use, safety and toxicity. These usually contain insecticides and/or fungicides depending on the intended wood product applications. Common preservatives include: boron, copper azole (CA), alkaline copper quaternary (ACQ), permethyrin, chromated copper arsenate (CCA) and light organic solvent (LOSP) based formulations. Wood preservatives can be applied using various methods such as vacuum-pressure impregnation (Figure 11.4), diffusion, dipping, spraying, brush or roller. The chosen preservative and application method will depend on costs and available equipment as well as the wood product end-use hazard rating and requirements of standards and customers.

Preservative treatment of wood is primarily concerned with the treatment of sapwood because the heartwood of many species is difficult to treat successfully with conventional methods. However, veneers containing heartwood are usually easier to treat compared to sawn wood with heartwood because of the smaller dimensions plus the presence of peeler checks that aid preservative penetration. If the heartwood is to be included in the product, it is necessary to select species with suitable heartwood natural durability for the intended use.

In Australia, there are six main levels of treatment (hazard levels) and a number of sub-levels which relate to the durability or biological hazard to which the end product is going to be exposed. Preservative treatment level is specified using the hazard level scale (Table 11.2).

Table 11.2. Levels of treatment (hazard levels) for all wood products. Source: the Australian Timber Database (www.timber.net.au).

Hazard level	Exposure	Specific service conditions	Biological hazard	Typical uses
H1	Weather protected, above ground	Completely protected from the weather and well ventilated and protected from termites	Lyctid borer	Framing, flooring, furniture, interior joinery
H2	Weather protected, above ground	Protected from wetting, nil leaching	Borers and termites	Framing, flooring etc. used in dry situations
H2F	Weather protected, above ground	Protected from wetting, nil leaching	Borers and termites	Framing (envelope treatment) used in dry situations south of the Tropic of Capricorn only
H2S	Weather protected, above ground	Protected from wetting, nil leaching	Borers and termites	LVL/plywood (glue line treatment) used in dry situations south of the Tropic of Capricorn only
H3	Weather exposed, above ground	Subject to periodic moderate wetting and leaching	Moderate decay, borers and termites	Weatherboard, fascia, pergola posts (above ground), window joinery, framing and decking
H3A	Weather exposed, above ground	Products predominantly in vertical exposed situations and intended to have supplementary paint coat system that is regularly maintained	Moderate decay, borers and termites	Fascia, bargeboards, exterior cladding, window joinery, door joinery and non-laminated verandah posts
H4	Weather exposed, in-ground contact	Subject to severe wetting and leaching	Severe decay, borers and termites	Fence posts, greenhouses, pergola posts (in-ground) and landscaping timbers
H5	Weather exposed, in-ground contact, contact with or in fresh water	Subject to extreme wetting and leaching and/or where the critical use requires a higher degree of protection	Very severe decay, borers and termites	Retaining walls, piling, house stumps, building poles, cooling tower fill
H6	Marine water	Subject to prolonged immersion in sea water	Marine wood borers and decay	Boat hulls, marine piles, jetty cross bracing

Figure 11.4. A semi-industrial scale vacuum-pressure impregnation plant.

Most veneers and veneer-based products can be treated by conventional wood preservative processes that are used for solid wood products such as sawn timber (Figure 11.5). These processes may involve pressure treatments such as vacuum-pressure impregnation, or non-pressure treatments such as diffusion, brushing, roller application, dipping and spraying. It is possible to treat the veneers (before gluing) or the panels (after gluing) and even to incorporate preservative into the glue lines. However, the preference is usually to treat the veneers before panel assembly or to incorporate wood preservatives into the glue line. This is because in full panel treatment, the glue lines tend to obstruct the penetration of preservatives and waterborne preservatives can cause premature glue line failure. Not all wood preservatives are compatible with all adhesives and therefore care needs to be taken to ensure that any wood preservation process does not impede successful panel manufacture or product service life. It is difficult to bond some preservation-treated plywood, particularly with phenolic or resorcinol adhesives.

In certain cases such as for envelope treated panels, if the panel is cut or machined after treatment then a localised remedial application of preservative (e.g. by brush or roller) is necessary for the cut or machined areas. This is because in envelope treatments the preservative will not have penetrated throughout the panel.

Treating plywood or LVL after manufacture or surface treating with 'brush on' preservatives should be done, if possible, only after machining, sawing and boring of the plywood or LVL has been completed. Glue line treatments are only currently available for certain exposure situations (e.g. H2 in Australia) although work is underway for glue line treatments suitable for outdoor above-ground applications (e.g. H3 in Australia). Only H1 and H2 glue line treatments are currently approved in Australia. Often when glue line treatments are used it is in combination with panel surface treatments.

Most countries have standards that specify treatments intended to protect veneer-based products in service from decay organisms and insect pests. Treatment specifications vary depending on the type of wood (hardwood, softwood), its natural durability and its exposure and service requirements. For example, in Australia detailed requirements are provided in the Australian timber preservation standards (AS1604 series). Producers of veneers and veneer-based products should treat in accordance with these standards and/or specific requirements of customers.

Figure 11.5. Preservative-treated plywood used for noise barrier construction.

NOVEL PRESERVATION METHODS

Novel or non-traditional preservation methods include wood modification by heat treatment, chemical reactions (e.g. acetylation), polymerisation and impregnation (e.g. furfurylation). These methods are much less commonly used compared with traditional chemical preservative options and are normally more expensive; however, recent technological advances are resulting in their increased uptake. Motivated by health and environmental concerns, the general strategy is to increase the durability of wood without the use of toxic compounds. Most of these methods rely on modification to the wood structure and/or chemistry, so that water movement into the wood is limited, and also the wood becomes less attractive to degrading organisms.

MAXIMISING THE SERVICE LIFE OF WOOD

The service life of wood products is increased by the adoption of sound structure design, construction, and maintenance and utilisation practices. These strategies normally revolve around limiting the ingress of water into the wood and avoiding situations that lead to increased biological attack by organisms such as insects and fungi.

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12. Case study—Characterisation of plantation acacias and eucalypts for veneer production in Vietnam

Adam Redman, Henri Bailleres, Gary Hopewell and William Leggate

BACKGROUND

This case study is an examination of plantation acacia and eucalyptus grown in Vietnam and describes key characteristics of the resource that influence veneer production. The information in this chapter was derived from research undertaken in the ACIAR project 'Enhancement of veneer products from acacia and eucalypt plantations in Vietnam and Australia' (FST/2008/039). This was a co-funded project and included contributions from ACIAR, Queensland Department of Agriculture and Fisheries (DAF), University of Melbourne (UoM), GFA Consultancy Group, Vietnamese Academy of Forest Sciences (VAFS), Vietnamese Forestry University (VFU) and Vietnam Centre for Agricultural Policy (CAP).

Vietnam has over 3 million hectares of plantation forests comprised of acacias (the most significant plantation species with a cover of approximately 43%, mainly *Acacia mangium* (Figure 12.1)*, Acacia auriculiformis* and *Acacia* hybrids (*Acacia mangium* × *A. auriculiformis*)), eucalypts (mainly *Eucalyptus urophylla*), rubberwood (*Hevea brasiliensis*), pine (*Pinus* spp.) and several fast-growing natives. The majority of these plantations were established to provide wood chip for the pulp and paper industry. However, in recent years there has been an emerging interest in conversion of the plantations into higher value export products such as sawn wood and veneer-based products for furniture components, structural plywood, laminated veneer lumber (LVL), form ply and packaging.

Veneer processing is a large established industry in Vietnam. In 2010 it was estimated that there were 6,224 enterprises and households participating in veneer processing and/or veneer-based products manufacture. A Vietnamese standard for grading veneers—TCVN 10316:2014—has been established. This is a replica of the Chinese standard LYT 1599.2011; however, there is no widely used grading system for determining veneer log qualities. The implementation of a log grading standard, or widely adopted non-standardised system, will help align log quality with processing and product requirements, potentially producing better quality end products. A log grading system also allows for the implementation of a log purchasing cost structure.

The objectives of this case study were to characterise the current *A. mangium*, *Acacia* hybrid *(A. mangium* × *A. auriculiformis)* and *E. urophylla* resource and to determine the log and peeled veneer quality. The study also facilitated feedback to the growers to improve current silvicultural and genetics work being undertaken in association with ACIAR projects in Vietnam. Finally, the study provided data to define log grading standards for veneer logs in Vietnam, which will assist in optimising veneer processing methods and product development.

Figure 12.1. An acacia plantation in Vietnam.

TREE, LOG AND PEELED VENEER ASSESSMENTS

Three plantation species were chosen based on the current and projected high volume of material for commercial use. These were *E. urophylla*, *A. mangium* and an *Acacia* hybrid (*A. mangium* × *A. auriculiformis*). Nine sites (three sites for each species) were selected for the study. At each site the trees were either of a different age or were grown under a different thinning regime. All trees were of the appropriate age/size class representative of material currently in use for veneer production in Vietnam. Details of each trial site—species, age, location, stocking rate, thinning history, soil type, elevation—are in Table 12.1. All sites were considered to be flat.

Table 12.1. Trial site details.

Species	Age (years)	Location	Original stocking rate (spha)	Thinning history	Soil	Elevation (m)
Acacia hybrid	7	Ba Vi, Ha Noi (21°05.572'N, 105°20.191'E)	2,000	Unthinned	Basalt	70
	11 (i)	Cau Hai, Phu Tho (21°32.768'N, 105°13.12'E)	1,100	To 800 spha at 8 years	Ferralite	200
	11 (ii)	Ba Vi, Ha Noi (21°06.952'N, 105°19.973'E)	1,500	Unthinned	Laterite	70
A. mangium	6	Ba Vi, Ha Noi (21°05.572'N, 105°20.191'E)	2,000	Unthinned	Basalt	70
	9	Cau Hai, Phu Tho (21°32.848'N, 105°11.273'E)	2,000	To 1,650 spha at 6 years	Ferralite	200
	14	Ba Vi, Ha Noi (21°07.902'N, 105°22.679'E)	1,500	Unthinned	Laterite	70
E. urophylla	11	Cau Hai, Phu Tho (21°32.462'N, 105°12.193'E)	1,100	To 800 spha at 8 years	Ferralite	200
	14	Ba Vi, Ha Noi (21°10.575'N, 105°22.028'E)	Not provided	Unthinned	Laterite	70
	19	Ba Vi, Ha Noi (21°09.437'N, 105°20.602'E)	1,700	To 570 spha at 2 years	Ferralite	70

Note: As there are two 11-year-old *Acacia* hybrid sites, they are labelled 11(i) and 11(ii).

The location of each trial plot was primarily based on ease of access. At each location a plot of 15 m radius was established. Within each plot approximately 30 trees were randomly selected and the diameter at breast height (1.3 m from the ground) over bark (DBHOB) was measured using a diameter tape. Within the same plot a smaller subset of trees—enough to provide approximately 20 peeler logs—was randomly selected (using a random number generator) for harvesting and merchandising (Figure 12.2).

Figure 12.2. Merchandised *Acacia mangium* logs.

Peeler logs were transported to the Tien Dong Company's processing plant for peeling. The plant is located approximately 50 km north of Hanoi.

Prior to peeling, log properties that can affect the potential volume, grade quality and value of peeled veneer were measured. These were: log form (sweep, taper and ovality), the frequency and size of visible knots, heartwood proportion and sapwood width, and log stiffness. Log form, knots, heartwood proportion and sapwood width were measured using measuring tapes. Log stiffness was measured acoustically using the CIRAD Forêt Bing device as described by Brancheriau and Baillères (2002). The Bing device determines the dynamic modulus of elasticity (MoE) by analysing the natural vibration spectrum. To measure MoE, one end of the log is struck with a hammer and the dynamic aural signal is recorded using a microphone positioned at the other end of the log (Figure 12.3).

Log volume was calculated from dimensional measurements, allowing subsequent peeled veneer green recoveries to be calculated.

Logs were trimmed to a length of 1.3 m, rounded and peeled using a Chinese brand spindleless lathe (Figure 12.4). The target veneer sheet dimensions were 2.8 mm thick × 1.3 m (same as log length) × 0.95 m (Figure 12.5). The dimensions of each sheet were recorded to determine veneer recovery.

Veneer sheets were air-dried for 2 to 3 days (Figure 12.6) to a moisture content of approximately 25% before final drying in a steam-heated 30-daylight press dryer at 100°C for 30 minutes to a final moisture content target of 10% (Figure 12.7). Dried veneer stiffness was measured using the acoustic Bing tool. Dried veneer dimensions were measured to calculate veneer gross and net recoveries.

Figure 12.3. Log stiffness assessment using the Bing acoustic method.

Figure 12.4. Veneer peeling.

Figure 12.5.
Veneer sheets after peeling.

Figure 12.6.
Veneer air drying.

Figure 12.7.
Veneer press drying.

Veneer quality was assessed by visual grading in accordance with AS/NZS 2269.0:2012 (Standards Australia 2012). This standard separates structural veneer into four main veneer surface qualities according to absence or severity of imperfections and defects (Table 12.2). The grade-limiting defects assessed included: loose knots, sound knots, holes, gum veins, kino, insect tracks, splits, discoloration, bark pockets, compression, roughness, grain breakout, cumulative defects and wane.

Table 12.2. Veneer quality grade descriptions.

Veneer grade	Description
A	A high-quality appearance grade veneer suitable for clear finishing. This appearance grade quality should be specified for the face veneer in plywood where surface decorative appearance is a primary consideration.
B	An appearance grade suitable for high-quality paint finishing. This face veneer quality should be specified for applications requiring a high-quality paint finish.
C	Defined as a non-appearance grade with a solid surface. All open defects such as knot holes or splits are filled. Plywood with a quality C face is designed specifically for applications requiring a solid non-decorative surface such as plywood flooring which is to be overlaid with a decorative flooring surface.
D	Defined as a non-appearance grade with permitted open imperfections. Plywood manufactured with face veneer quality D is the lowest appearance grade of plywood. It is designed specifically for structural applications where decorative appearance is not a requirement, e.g. structural plywood bracing.

Tree diameter

The diameter at breast height is an indicator of tree vigour and suitability for a peeler log. Larger tree diameters are generally able to produce higher volumes of veneer with better grade quality, depending on the log form. Average DBHOB, standard deviation and the number of trees assessed for each species and size class are provided in Table 12.3.

The average diameter of 11-year-old *Acacia* hybrid was approximately 35% higher than that of *E. urophylla* of the same age. Logs of similar average diameter were recorded for both 14-year-old *A. mangium* and *E. urophylla*. For average diameter there was no difference between 14- and 19-year-old *E. urophylla*. The variations that exist between sites may be attributed to a number of factors including age, quality of site and silvicultural regime. Unfortunately, the silvicultural regime for the 14-year-old *E. urophylla* plantation is unknown.

Table 12.3. Average diameters of the three tree species aged 6–19 years.

Species	Age (years)	Average DBHOB* (cm)
Acacia hybrid	7	14.2 (2.5)
	11 (i)	21.7 (3.1)
	11 (ii)	22.3 (2.6)
A. mangium	6	13.6 (2.2)
	9	20.6 (3.8)
	14	25.5 (6.2)
E. urophylla	11	16.2 (2.6)
	14	25.7 (4.2)
	19	24.3 (4.3)

* Standard deviation in parentheses.

Log form (sweep, taper and ovality)

High values of sweep and taper, and a ovality value less than 1, all contribute to more material being lost during the rounding-up process, resulting in lower log recovery. Minimal differences in average sweep were recorded between species and age groups, except for 19-year-old *E. urophylla* where sweep was zero for all logs tested (Table 12.4). Little difference in average taper was measured for each species and age group and the taper values are considered to be low. All logs peeled were relatively round logs (ovality > 0.9) except for the nine-year-old *A. mangium* logs that had the lowest average ovality ratio of 0.83. Ovality may be caused by site conditions such as elevation, slope, wind etc. The cause of the low ovality score for logs from this plantation is unknown and would require further investigation.

Table 12.4. Values for sweep, taper and ovality for the three tree species aged 6–19 years.

Species	Age (years)	Sweep* (%)	Taper* (%)	Ovality*
Acacia hybrid	7	0.59 (0.46)	0.34 (0.22)	0.94 (0.03)
	11 (i)	0.52 (0.41)	0.48 (0.33)	0.92 (0.04)
	11 (ii)	0.39 (0.33)	0.52 (0.35)	0.93 (0.05)
A. mangium	6	0.34 (0.35)	0.57 (0.31)	0.94 (0.04)
	9	0.65 (0.33)	0.40 (0.29)	0.83 (0.04)
	14	0.38 (0.36)	0.60 (0.36)	0.94 (0.04)
E. urophylla	11	0.51 (0.47)	0.36 (0.19)	0.94 (0.04)
	14	0.48 (0.38)	0.56 (0.49)	0.89 (0.03)
	19	0.00 (0.00)	0.42 (0.31)	0.97 (0.02)

* Standard deviation in parentheses.
Note: ovality ratio of 1 is a perfect circle.

Knots

Veneer grading standards include limitations on the frequency and size of knots. More frequent, larger knots result in lower grade veneer with reduced quality and value. The number of knots and the number of knots with a diameter larger than 3 cm, per log, were measured in this study (assessed on the exposed surface of the log). The characterisation of log knot properties was useful in the development of a proposed plantation veneer log standard discussed later in this chapter.

The average number of knots, and the number of knots with a diameter greater than 3 cm, for each species and age class are provided in Table 12.5. The *Acacia* hybrid logs exhibit up to 85% more knots compared to the other species at similar ages. By age 19 years, *E. urophylla* suffered less from knot downgrade, which was probably due to the natural self-pruning habit of eucalypts, unlike acacias that naturally retain branches and form knots for the full radius of the tree.

Table 12.5. Total knots and number of knots > 3 cm diameter in the three tree species aged 6–19 years.

Species	Age (years)	Number of knots*	Number of knots > 3 cm*
Acacia hybrid	7	19 (5)	1 (1)
	11 (i)	22 (6)	8 (4)
	11 (ii)	28 (7)	16 (5)
A. mangium	6	16 (5)	1 (1)
	9	10 (4)	5 (3)
	14	15 (6)	11 (6)
E. urophylla	11	15 (3)	6 (2)
	14	18 (10)	4 (4)
	19	4 (4)	2 (2)

* Standard deviation in parentheses.

Heartwood proportion and sapwood width

The proportion of heartwood in the cross-sectional area and the sapwood radial width within a log can have utilisation and processing implications, particularly where durability (resistance to fungal and insect attack) and appearance properties are required. A smaller sapwood band is desirable as it means less timber is wasted if the sapwood is required to be removed, or less chemical preservatives are needed if the sapwood is to be treated.

Average heartwood proportion, average sapwood width and their standard deviations are provided in Table 12.6. The comparatively high heartwood proportion and low sapwood width displayed by *A. mangium* at 14 years old demonstrates a clear advantage over the other species for appearance products where natural heartwood colour is advantageous. Additionally, for this species, both attributes improve with age (i.e. increasing heartwood proportion and decreasing sapwood width).

In contrast, *E. urophylla* recorded the lowest average heartwood proportion and highest sapwood width, as well as displaying greater variability (standard deviation) in these properties than the acacias. While this characteristic has minimal effect on mechanical properties, any sapwood contained in products manufactured from these species may require preservative treatment depending on the end use. Large volumes of sapwood increase the cost of treatment as more preservative chemical is required.

Table 12.6. Average heartwood and sapwood proportion in the three tree species aged 6–19 years.

Species	Age (years)	Average heartwood proportion* (%)	Average sapwood width* (cm)
Acacia hybrid	7	64.2 (6.0)	5.1 (0.5)
	11 (i)	71.7 (4.3)	5.0 (0.3)
	11 (ii)	69.4 (5.9)	5.1 (0.5)
A. mangium	6	60.9 (6.9)	5.8 (0.5)
	9	75.1 (4.6)	4.6 (0.7)
	14	82.5 (5.8)	3.8 (0.9)
E. urophylla	11	64.7 (5.8)	4.9 (0.4)
	14	58.8 (12.0)	6.9 (1.4)
	19	68.3 (9.7)	6.1 (1.3)

* Standard deviation in parentheses.

Log modulus of elasticity

For each species tested, the average green log MoE increased with age until stabilising at around 14 years old, presumably the post-juvenile phase (Table 12.7). Based on the results, the species can be ranked from high to low log stiffness as follows: *E. urophylla, Acacia* hybrid and *A. mangium*. The highest average stiffness was in 14-year-old *E. urophylla*. This was approximately 40% more than that for *A. mangium* at the same age.

Table 12.7. Average modulus of elasticity (MoE) in logs for the three tree species aged 6–19 years.

Species	Age (years)	MoE* (MPa)
Acacia hybrid	7	11,700 (825)
	11 (i)	13,432 (882)
	11 (ii)	14,393 (789)
A. mangium	6	9,677 (501)
	9	12,463 (912)
	14	12,769 (1446)
E. urophylla	11	13,897 (1303)
	14	17,925 (2640)
	19	17,011 (1553)

* Standard deviation in parentheses.

Veneer modulus of elasticity

Stiffer veneer has better structural properties than low stiffness veneer, and structural veneer-based products are usually ranked and sold on their average stiffness properties, with stiffer structural products being generally more profitable.

Average veneer stiffness tended to increase with increasing age for each species before plateauing around age 14 years (Table 12.8). This trend is indicative only as limited sites were investigated. Similar to the log stiffness results, *E. urophylla* is considerably stiffer than the *Acacia* species but also produces veneer with a wider stiffness variation. Larger variation in minimum and maximum veneer stiffness is expected for older plantations as older trees contain a higher proportion of stiffer outer wood as well as lower stiffness internal wood.

Table 12.8. Modulus of elasticity (MoE) in veneer produced from the three tree species aged 6–19 years.

Species	Age (years)	MoE* (MPa)
Acacia hybrid	7	9,822 (1,664)
	11 (i)	11,568 (2,244)
	11 (ii)	13,039 (1,951)
A. mangium	6	8,664 (1,481)
	9	10,871 (1,615)
	14	10,933 (1,972)
E. urophylla	11	9,789 (2,919)
	14	14,880 (3,874)
	19	13,836 (2,822)

* Standard deviation in parentheses.

Recovery

Green recovery

Green veneer recovery provides a useful measure of the maximum recovery possible taking into account log geometry (sweep, taper, ovality) and lathe limitations (e.g. peeler core size). Green veneer recovery disregards internal log quality. Green veneer recovery, for each species and age class, expressed as a percentage of billet volume, is presented in Table 12.9.

Green recoveries were similar across species and age groups, varying between 68% and 78% which is about twice the comparable recovery (green-off-saw, GOS) achieved when processing similar plantation resources using traditional sawing techniques.

Table 12.9. Green recovery for the three tree species aged 6–19 years.

Species	Age (years)	Green recovery (%)
Acacia hybrid	7	72
	11 (i)	76
	11 (ii)	72
A. mangium	6	74
	9	67
	14	73
E. urophylla	11	72
	14	68
	19	78

Gross and net recovery

Gross veneer recovery provides a useful measure of the maximum recovery of dried, graded veneer that meets the relevant quality specifications, for example AS/NZS 2269.0:2012 (A-grade to D-grade). Net veneer recovery provides a useful measure of process efficiency, as it identifies the saleable product, taking into account the product manufacturing limitations. Net veneer recovery includes the losses accounted for in gross recovery but also includes the additional losses due to the trimming of veneer before, during and after product manufacture.

Table 12.10 presents the gross and net recovery values for each species and age group. Recovery values are consistent between species and age groups. The green, gross and net veneer recoveries are all in the same order of magnitude as those presented by McGavin et al. (2014) for a range of Australian plantation eucalypt species also peeled using spindleless lathe technology.

Table 12.10. Gross and net recovery in veneer produced from the three tree species aged 6–19 years.

Species	Age (years)	Gross recovery (%)	Net recovery (%)
Acacia hybrid	7	60	50
	11 (i)	64	54
	11 (ii)	60	50
A. mangium	6	62	52
	9	59	49
	14	59	50
E. urophylla	11	61	51
	14	64	54
	19	65	55

Grade quality

Grading veneer for quality provides forest growers and processors with important information to characterise the resource and potentially improve its quality. Forest growers are able to use the grading natural feature information to improve forest practices and silviculture, and veneer processors can use the process-related defect data to improve processing practices. Additionally, grading provides processors with a means to estimate the economic value of the resource and optimal product utilisation.

Table 12.11 shows the veneer grading results for each species and age group, presented as the percentage of log volume. Across all species, loose knots have the most influence in restricting veneers from attaining a grade higher than D-grade (according to AS/NZS 2269.0:2012). Other defects common across all species and contributing to preventing veneers from attaining higher grades than D-grade are sound knots, cumulative defects, holes, grain breakout and roughness. The latter two are potentially influenced by the manufacturing process and therefore there is great opportunity to further optimise the process through the introduction of log pre-conditioning and lathe setup to reduce the defects.

Sound knots are a common defect, given the trees are relatively young and small in diameter. In general these knots are very small and are scattered in distribution rather than concentrated. Small and scattered knots will have the least impact on structural properties (i.e. strength). Increased proportions of B-grade and C-grade veneer with increasing age were most evident for 19-year-old *E. urophylla*. These results are expected as the proportion of knot-affected wood in the lower part of the tree decreases with age, due to natural and/or mechanical pruning of lower tree branches and subsequent occlusion of branch stubs with sound wood over time.

Table 12.11. Graded veneer (as a percentage of log volume) produced from the three tree species aged 6–19 years.

Species	Age (years)	A-grade (%)	B-grade (%)	C-grade (%)	D-grade (%)
Acacia hybrid	7	0	0	2	48
	11 (i)	0	<1	<1	52
	11 (ii)	0	1	1	48
A. mangium	6	0	0	3	47
	9	0	2	6	41
	14	0	1	4	45
E. urophylla	11	0	0	0	51
	14	1	11	14	28
	19	0	20	6	29

A PEELER LOG GRADE CLASSIFICATION FOR VIETNAM

Vietnam currently does not have a widely used, standardised veneer log grading system for peeler logs. Within the ACIAR project a review was conducted by researchers from project partner organisations of the veneer log grading rules in typical Vietnamese companies. On the basis of this review, and the resource assessment described above, a grading system relevant to processing small acacia and eucalypt plantation veneer logs is proposed for Vietnam (Table 12.12). The proposed grading system has two grades, grade A and grade B, where grade A is of higher quality. For a log to meet grade A classification, all grade criteria must be satisfied. For instance, if one criterion meets class B then the log is classed as a grade B log. If a log displays a criterion outside either the grade A or grade B classification, it is considered a reject log, i.e. not fit for peeling. However, special consideration may be given to accepting reject logs, depending on the company and client specifications.

Table 12.12. Proposed grading system for peeler logs in Vietnam.

Criterion	Grade A	Grade B
Knot	Maximum diameter ≤ 10 cm	Unlimited
Bend	Maximum 3%—no multiple bends	Maximum 4%—no multiple bends
Total end-split	Total split ≤ 10% log length	Total split ≤ 20% log length
Holes/insect holes	Maximum diameter ≤ 5 mm	Maximum diameter ≤ 20 mm
Decay	Not permitted	Permitted
Mould	Not permitted	Permitted
Metal objects	Not permitted	Not permitted

The metal object criterion is included to prevent peeling logs that have imbedded metal objects such as nails, fencing wire etc., which can cause severe damage to the lathe and injury to machine operators. There is no minimum diameter or log length proposed in the log grading specifications because this is subject to the limitations of machinery and should be specified separately by the independent processor or log buyer. Log specifications will vary depending on whether the lathe is spindled, spindleless or a hybrid type.

Generally, Vietnamese companies are using spindleless lathes to peel their veneer. Spindleless lathes are favoured because they are capable of processing small diameter logs. Some companies in Vietnam are using eucalypt logs less than

8 years old with diameters as small as 10 cm. The Forestry Tasmania log grading specifications only allow for peeler log small end diameters as low as 18 cm but up to a maximum of 70 cm. To accommodate the larger diameter logs in Tasmania, a hybrid lathe is used.

Ideally, logs should be processed as soon as possible after harvesting to avoid degradation, although sometimes longer storage can help by relieving growth stresses. Timely log processing is especially important in warmer climates, such as Vietnam, where log splitting and cracking can be a serious problem.

STUDY SUMMARY

The objective of this research was to characterise and analyse plantation trees and logs for peeled veneer production in Vietnam. More specifically, the aim was to characterise the *Acacia mangium*, *Acacia* hybrid (*A. mangium* × *A. auriculiformis*) and *E. urophylla* resource, assess the log and peeled veneer quality, and provide feedback to improve current thinning and genetics work being undertaken in association with ACIAR projects in Vietnam. In addition, the study provided guidelines to define log grading standards for veneer logs, to assist in optimising veneer processing methods and product development.

The study carried out wood and veneer processing trials from a total of nine plantation sites, three per species, where each site had a different thinning or age regime and had trees of the appropriate age/size class to meet the requirements for veneer production. Results indicate that some species perform better than others in terms of certain tree, log and peeled veneer properties dependent on the final utilisation of the veneer or veneer-based product. *A. mangium* demonstrated a clear advantage over the other species in terms of having a high heartwood proportion (increasing steadily with age), a trait particularly useful for products where natural heartwood colour is advantageous. *E. urophylla*, which produces veneer with higher stiffness and a higher proportion of stiffer material than the other species at a similar age, may be more suitable for structural products than the other species.

Minimal differences in average sweep and taper were recorded between species and age groups except for the 9-year-old *A. mangium* that displayed a lower ovality ratio (0.83) implying a higher degree of ovality. This may be caused by site conditions such as elevation, slope, wind etc. Additional investigation as to why trees on this site have oval shaped stems should be done by forest growers. Ovality of logs negatively impacts on veneer recovery.

Acacia hybrid logs appear to have the highest frequency of knots, and on average the largest knots, compared with the other species of similar age. The 19-year-old *E. urophylla* logs recorded the lowest frequency of knots, probably due to their older age.

Net recovery, which indicates the saleable volume, varied between 49% and 55%, approximately double that reported for solid wood processing (sawmilling) of similar diameter and plantation species.

A very high proportion of the recovered veneer met the D grade requirements of AS/NZS2269.0:2012 with a small proportion meeting the requirements of higher grade qualities. These results suggest the hardwood veneer could be used in mainly non-appearance structural plywood products and/or core veneers. Options to improve the visual grade quality include defect docking, veneer jointing or multilaminar veneer production for furniture manufacture.

The 14- and 19-year-old *E. urophylla* veneer achieved much higher proportions of the better B- and C-grade veneers with 35% B grade (face veneer) attained for the 19-year-old plantation.

Loose and sound knots were the main reasons preventing veneers achieving a grade quality higher than D grade. Other defects common across all species and contributing to preventing veneers from attaining grades higher than D grade were cumulative defects, resource holes, grain breakout and roughness. The latter two—grain breakout and roughness—are considered a manufacturing defect and therefore there is great opportunity to further optimise the process through the introduction of billet conditioning (steaming or boiling) and lathe setup to reduce these defects.

While the study has demonstrated that high-quality veneer can be processed from young, fast-grown plantation hardwood and a range of veneer-based composite products can be manufactured with desirable structural qualities, certain species have qualities better suited to certain products. The inclusion of site information for each species and age class can be used by forestry researchers to further investigate the potential to improve site and clonal selection for longer term breeding programs based on some of the tree, log and veneer grade quality and property trends presented in this report. Additional research is necessary to establish economic profitability parameters around veneer quality, rotation age and manufactured products.

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