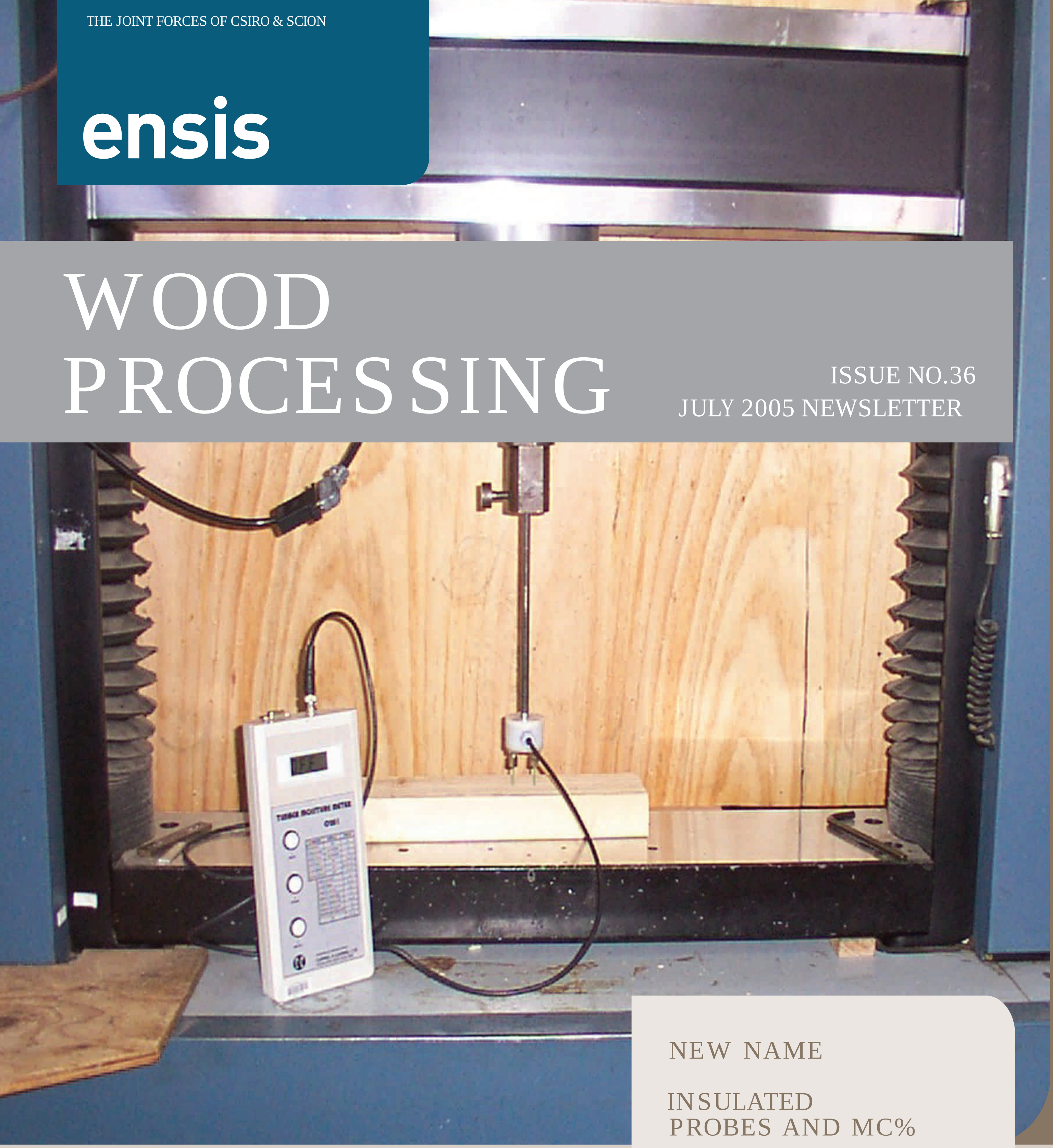
THE JOINT FORCES OF CSIRO & SCION

ensis

WOOD PROCESSING

ISSUE NO.36
JULY 2005 NEWSLETTER



NEW NAME

INSULATED PROBES AND MC%

MICROSCOPY OF COATING PROBLEMS

MORE ON ACETYLATION

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Sawmilling

Issue No. 36 July 2005

NEW COVER —
BUT SAME READABLE WOOD PROCESSING NEWSLETTER

In case you thought you had been dropped from the mailing list, you haven't. The November issue was held back while Forest Research combined forces with CSIRO's Forestry and Forest Products group under a joint venture named Ensis, and Forest Research rebranded itself as Scion (*see below*).

So this July issue represents the missing November 2004 issue (and your April/May issue), and we will have the November 2005 issue combining our expanded Aussie/NewZealand research news-base out on time.

ENSIS BRINGS TOGETHER LEADING FORESTRY R&D PROVIDERS

Ensis is a joint venture between the two leading forestry research agencies in New Zealand and Australia — Scion (formerly Forest Research) and CSIRO Forestry and Forest Products.

For those involved in wood processing and manufacturing, Ensis offers greater research and development capacity to help strengthen business competitiveness in a global market.

The appointment of Larry Little as Chief Executive of Ensis sees the wood-processing sector well represented at management level. Prior to taking on this role, Larry was Chief of CSIRO's Division of Manufacturing and Infrastructure Technology, one of CSIRO's largest Divisions. He has an outstanding background in the building and construction industry, which is a key market for products from the forestry sector.

Larry is ideally suited to lead the trans-Tasman joint venture, holding dual Australian and New Zealand citizenship. He was formerly CEO of BRANZ — the Building Research Association of New Zealand — and has held a range of positions across the construction sector in Canada, New Zealand, and Australia.

This appointment is the latest in a number of changes undertaken recently by the parent companies of Ensis. The most notable of these is the rebranding of Forest Research to the new trading name of Scion. This new name reflects a movement by the organisation to create plant-based biomaterials that can be used as alternatives to synthetic products. The name Scion means the graft of a plant, symbolising the growth of this new strategic direction from the traditional forestry base.

Founded as the New Zealand Forest Research Institute in 1947, Scion has a proud history of helping to develop the concept of plantation forestry as a means of supplying sustainable feedstocks to the wood-processing industries. This legacy of research and development services to the forestry sector continues, with even greater force, through Ensis. As one of the world's largest integrated forestry and forest products research organisations, Ensis now employs 320 researchers, located in eight sites across New Zealand and Australia, offering capabilities that span the entire forestry value chain.

For more information, see www.ensisjv.com or www.scionresearch.com

PRACTICAL TOOLS TO OPTIMISE CUTTING PERFORMANCE, SAWING ACCURACY, AND PERFORMANCE

Louw van Wyk

Over the years Forest Research developed a number of useful tools to help sawmillers improve productivity. Some of these tools were based on ideas obtained from overseas while staff were attending workshops or conferences, while others were developed to solve problems identified by New Zealand sawmillers.

The original tools included the following:

(1) Saw Tooth Inspector.
(2) Band Saw Strain Measuring System.
(3) Log Movement Measuring System.
(4) Data Logging for Size Control (T-Size 2002).
(5) Top Wheel Movement Measuring System.
(6) Glue Line Pressure Sensing System.
(7) Sawblade Temperature Measuring System.
(8) Sawblade Displacement Measuring System.

Technologies changed and some of the tools became obsolete as the data loggers would not work with the new generation of computers, or the manufacturers of the original components went out of business or changed their products so that they were no longer suitable for our use, or products performing similar functions became commercially available. Fortunately we now have new USB-based data acquisition facilities, which means the transducers used with many of the old tools have a new lease of life. These tools housed in "toolboxes" have been loaned to sawmillers, usually for no more than a courier charge and the most popular and well-travelled "toolbox" is the band saw strain gauge which is discussed in this article.

The device made to measure strain on wide bandsaws (Fig 1) is easier to use than traditional strain gauges, which have to be glued on to the sawblade and require special equipment. The system is suitable for use with either mechanical weight strain saws or air strain saws.

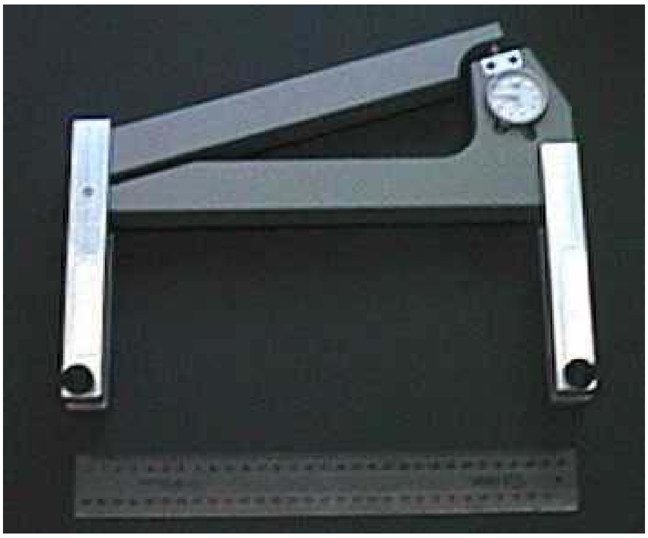
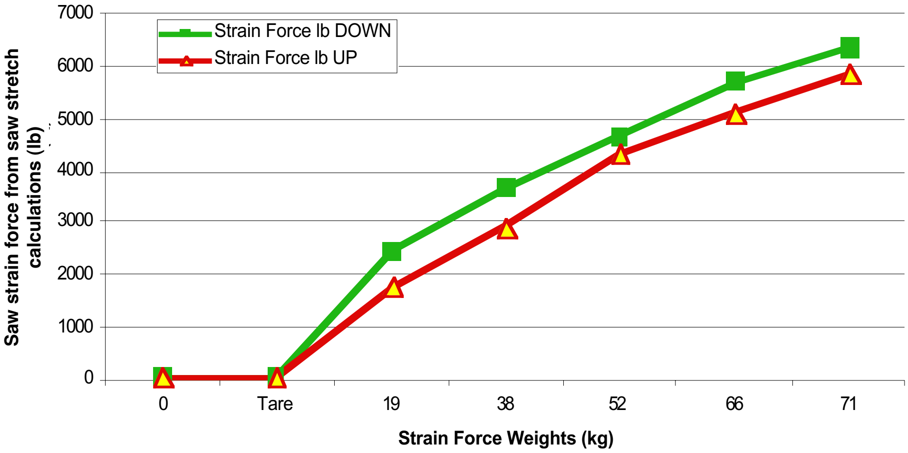


Figure 1. Strain Measuring System

The saw strain gauge readings show the elongation (lengthening) of the sawblade as it is stretched by increasing the strain force. From this the actual stress in the sawblade can be calculated.

The following graph shows the saw strain hysteresis for a mechanical strain system. A large difference



Saw strain hysteresis. Mechanical weight strain system

between strain force increasing (up) and decreasing (down) indicates poor knife edges or excessive friction in the system. The system illustrated indicates acceptable knife edge and friction levels.

Theoretical stresses and strains can be calculated based on research by Ed Allen, Ebb Kirbach, Urban Eklund, Bruce Lehmann, and others. The suitability of the formulae has been verified against actual strain measurements using the strain-measuring device.

The actual stresses in a sawblade are complex and vary along the length of the saw, and change over the life of a saw. Detailed documentation describing the stresses in a band saw blade (based on the work of Ed Allen) is provided in the toolbox. Programs for calculating safe working strain levels are included in a disk supplied with the toolbox.

The main benefit of running the correct strain force is reduced sawing variation. Other benefits of using the correct strain and top wheel damping system include a longer safe sawblade life, minimised guide wear, and less wear on mechanical strain components.

This system is easy to use and the calculations are limited to calculating stresses and strains. If weights are used, the fulcrum ratio and strain weights must be known.

Saw strain is important as it affects sawing accuracy, life of the sawblade, and saw maintenance costs. Once a system has been set up correctly, the strain needs to be checked periodically. The strain gauge can detect problems such as worn knife-edges, wrong knife edge angles, and errors in load cell load displays.

CANADIAN FURNITURE PRODUCTION IMPROVED WITH ADOPTION OF QUALITY ASSURANCE SYSTEM

Ian Simpson

As part of a Queen Elizabeth II Technicians Study Award, Ian Simpson visited Canada to study the WOODMARK quality assurance system and determine the potential for adoption of the system in New Zealand. The WOODMARK system discussed in this article should not be confused with the Woodmark quality assurance system used in New Zealand for timber treatment.

The Wood Products Quality Council of Canada developed the WOODMARK system which focuses on the manufacturing aspects of the business from incoming material through to assembly and dispatch. Canadian companies are adopting the system to help them remain competitive in the market place. It has helped improve process management, reduce waste, meet shipment dates, and train staff.

The system focuses on reducing the incidence of non-compliance in the factory, the aim being to assemble a piece of furniture from the individual parts, without problems of incorrectly machined pieces. Assessing the quality of incoming material is another important aspect of the WOODMARK system. Companies often simply accept new supplies of raw material without considering whether the quality is suitable for their process whereas, for example, simple checks of moisture content of packets of timber on arrival could have reduced later problems during manufacture.

Many of the techniques of the WOODMARK systems are simple, and can be easily implemented in any plant. But these simple techniques can have a significant effect on the performance of a business. One company has adopted a simple colour coding system to label the packets of furniture components. The coloured labels indicate the priority assigned to each packet of components, with red labels indicating that highest priority should be assigned. This system has meant that components are ready for assembly and despatch at the planned time.

Check sheets are used in the furniture factories to assist with machine setup. Information about sizing is provided with each packet of components and the operator signs a check sheet after each setup, to confirm that the setup has been compared to the specification of the parts being produced. This simple system of checking has been responsible for reducing the incidence of non-conforming product.

Seven Standards of the WOODMARK System

- ✓ Standard #1 – Management commitment
- ✓ Standard #2 – Quality plan
- ✓ Standard #3 – Inspection of incoming material
- ✓ Standard #4 – Measurement of in-process work
- ✓ Standard #5 – Product traceability
- ✓ Standard #6 - Training
- ✓ Standard #7 – Continuous improvement

Because there are fewer incidences of non-conforming items, the assembly of the furniture from the individual components is more streamlined. Previously, assembly could be interrupted if a part of the furniture was incorrectly manufactured. This often meant that a shipment was delayed while the factory had to give priority to reworking or remanufacturing a replacement part. Staff morale has also improved, as the levels of rework have been reduced.

Dynamic Furniture in Calgary is a large furniture factory with 500 staff and annual sales of C$50 million. The factory manufactures over 3000 pieces of furniture per day and dispatches 60 truck-loads of assembled furniture per week. Dynamic recognised that a quality assurance system could improve the business and decided to adopt the WOODMARK system as it had been developed for a timber processing business.

Dynamic were having 2–3 incidences of non-conforming items per week with most of them resulting from the drilling process. Since the adoption of the WOODMARK system they have been able to reduce the non-conformances, and at the time of the visit they had 57 days without a drilling problem. Kim Moore, Quality Assurance manager at Dynamic, said that the cost of quality has reduced from 2.5% to 1.7% of total sales, representing a saving of C$0.5 million per year.

Firms that have found the system beneficial include Canwood Furniture in Penticton which has been able to maintain high quality production in spite of staff changes as manufacturing processes are now documented and formal training sessions are held. Hilbrecht Fine Furniture in Kewlona has recently adopted the system, and more staff are now involved in reviewing the design of furniture. A mockup of each piece is produced and this has allowed potential manufacturing problems to be identified before the main production run is commenced. Adopting the system for identifying non-compliances has meant that smaller lots of components are inspected during the manufacturing run and the more frequent inspection has reduced non-compliance from 100 parts to 20 parts or less. Standardising the dimensions of the wood joints so that each section matches a standard jig has meant fewer problems during assembly of the furniture.

Although the WOODMARK scheme has been adopted mainly by furniture companies, it is also appropriate in other timber processing businesses such as sawmilling or remanufacturing.

Final inspection of furniture

Marcia Dunnett, Executive Director of the Furniture Association of New Zealand said that New Zealand furniture companies are mainly focused on the local market, although there is increasing focus on export, design, and quality. A number of New Zealand furniture companies have implemented quality systems including ISO and Qbase, but these systems are not designed specifically for furniture.

Further information about the WOODMARK system can be obtained from the author or from the WOODMARK web site at www.wpqc.com/

Wood Quality

Issue No. 36 July 2005

CHARACTERISING THE PLYWOOD-COATING INTERFACE USING LASER CONFOCAL MICROSCOPY

Adya Singh, Bernard Dawson, and Tatjana Smolic

Wood is a versatile natural material, which we use in some form in our everyday life. It is strong and durable, but in outdoor use as a building material it is exposed to factors such as solar radiation and rain, which adversely affect its service life. If unprotected, wood can photodegrade and it can also deteriorate through the action of wood-staining and wood-degrading micro-organisms. Surface coatings such as stains and paints can substantially extend the service life of exposed wooden products. The performance of surface coatings is a function of several factors, including coating type, surface texture of wood, and adhesion of coatings to the wood. Understanding wood-coating interaction, i.e., coating penetration into wood, coating anchorage to wood cells, and coating thickness for film-forming coatings, is important for assessing coating performance, and the use of confocal microscopy in our work is providing valuable information in this regard. Here we provide an example of the application of confocal microscopy in this area of research using a wood-polymer composite consisting of a film-forming semi-transparent stain applied to rough-textured radiata pine plywood.

The wood-polymer composite has been commercially developed as a weather-board product, consisting of an undercoat and two top coats. Rough-textured plywood is a building material of choice for exterior siding because of its aesthetic and economical values. We examined this product by a combination of light and confocal microscopy, with particular attention to the wood-coating interface, in order to assess the influence of the surface texture of the wood on coating distribution. Sliding-microtome cut sections of the sample in the region of wood-coating interface were stained with aqueous toluidine blue and mounted in glycerol for examination with a Zeiss Photomicroscope II. The same sections were then examined and imaged with a Leica TCS/NT confocal laser scanning microscope. Confocal images were acquired using an argon/krypton laser with excitation wavelengths of 488 and 568 and emission wavelengths of 590–660 and 665. A 16x multi-immersion lens with a numerical aperture of 0.5 was used for all images. Occasionally, selected regions were zoomed to about 2x. The surface of the board was viewed by a stereomicroscope.

The stereo-photomicrograph (Fig. 1) reveals the highly irregular nature of the wood-composite surface, with prominent ridges and furrows. The applied coating showed considerable variability in colour,

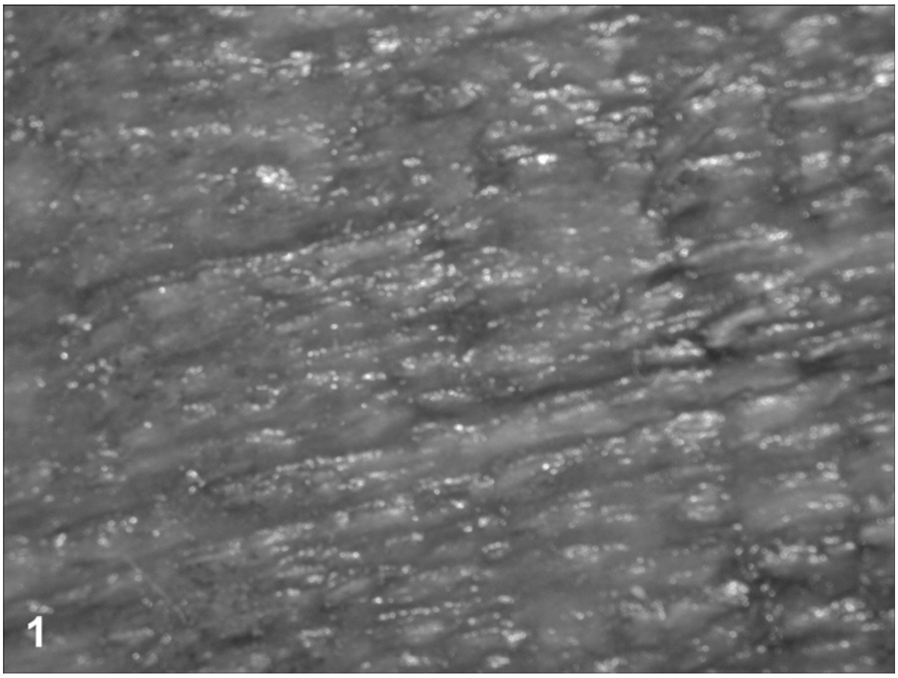


Figure 1. Stereo-photomicrograph revealing the highly irregular contour of the wood-composite surface.

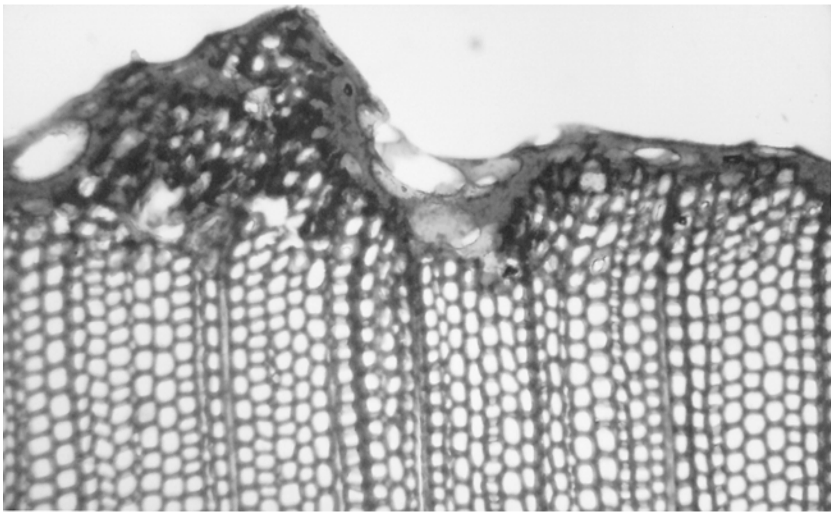


Figure 2. Light micrograph of a transverse section through the wood-coating interface. The thickness of the coating is highly variable.

with the lighter colour corresponding to ridged regions. The sections were first examined at low magnifications of the light microscope, which made it possible to observe relatively large areas, and thus compare ridges, furrows and moderately flat regions often within the same section. Some sections were then examined by both light microscopy and confocal microscopy for a specific area of interest. In Figure 2 (a low-magnification light microscope sectional view) can be seen a ridge consisting of loosely connected irregular masses of wood tissues, reflecting the severity of the damage caused by the bandsaw. The surface tissues associated with the furrow and the flat region are less distorted and appear to be intact. The coating distribution shown in this illustration is extremely irregular as indicated by the marked variability in the thickness of the coating film. The greatest amount appears to have been deposited in the furrow and the least over the apex of the ridge, with distribution being relatively uniform over the flat region of the plywood.

The surface irregularities in the plywood arising from the “ploughing” and “ripping” action of the bandsaw and the pattern of coating distribution over such surfaces were complex. The combined ripping and compression effects of bandsawing often resulted in bending and twisting of tissues in the surface and sub-surface layers of the plywood. Consequently, it was not possible to clearly resolve cellular details of the severely distorted surface tissues by light microscopy. The use of confocal microscopy overcame this problem. Stacking of sequential optical sections helped resolve cellular details of even the most highly distorted surface tissues. This allowed detailed characterisation of the wood-coating interface, and thus an understanding of the pattern of coating distribution in relation to the surface texture as well as the cellular features of the plywood.

Light microscope and confocal images of the same section, which was cut transversely through a coated ridge containing highly distorted tissues, are shown in Figures 3 and 4. In the light micrograph (Fig. 3) cellular features in the ridged part of the veneer surface are not distinguishable. However, in the confocal image (Fig. 4) individual wood cells are clearly resolvable, and even in the most

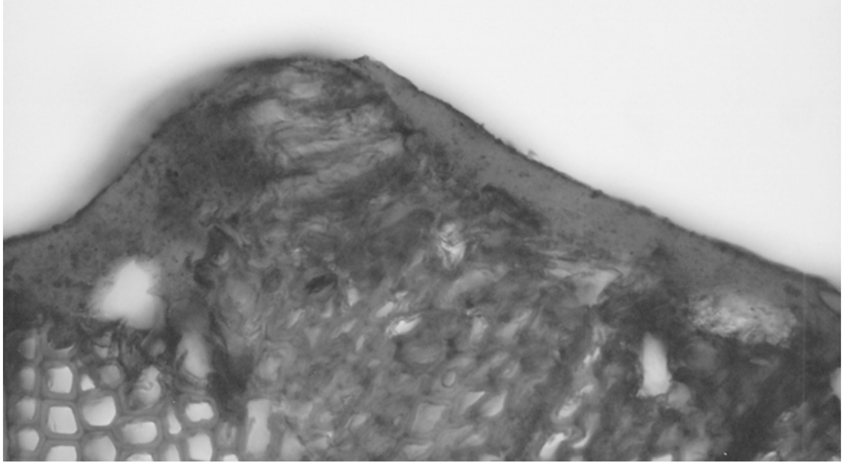


Figure 3. Light micrograph of a transverse section through the wood-coating interface. Wood tissues within the prominent ridge are greatly distorted and appear fuzzy.

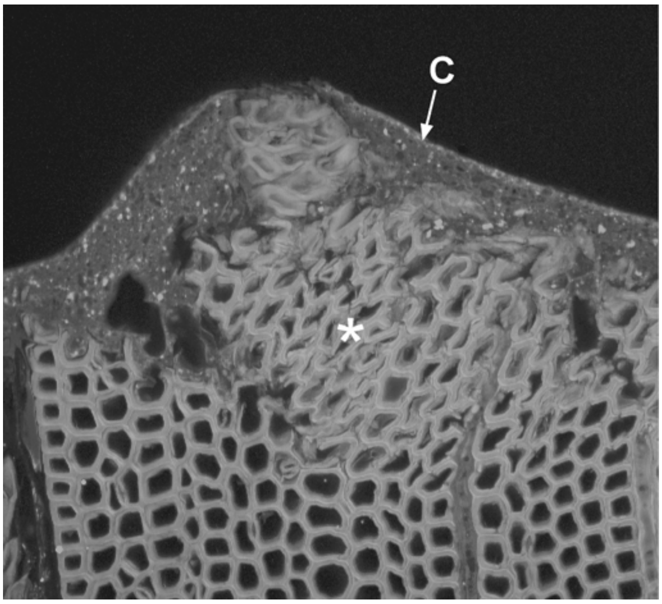


Figure 4. Confocal fluorescence micrograph of the same section as in Figure 3. Wood cells within the ridge are well defined (asterisk). Features such cell collapse, cracks in cell walls, and the pathways of coating penetration are clearly resolvable. C, coating.

highly distorted tissues showing severe cell wall collapse it is possible to distinguish cell walls and the lumen in every cell, and clearly resolve coating distribution and the pathways of coating penetration. As seen in Figure 4, the distribution of coating is highly irregular, corresponding to the complexity of the contour of the ridge and the porosity of its highly distorted tissues. The bulk of coating material is located in the grooves down the slopes of the ridge, and the amount deposited in the apical part of the ridge is very small, resulting is a grossly uneven coating thickness in this region. The coating material has also penetrated into the wood tissues within the ridge. Compression from band-sawing has caused widespread rupturing and delamination of cell walls, in addition to severe cell wall distortion and cell collapse. This explains the presence of the coating material in the cell lumina and also in the openings developed from cracking of cell walls.

As can be seen in Figure 5, another significant feature which could be clearly resolved by confocal microscopy is the protrusion of wood cells and cell walls beyond the outer extremities of the coating. Understandably, this feature was particularly characteristic of the ridged areas of the wood surface, where greatest mechanical damage from band-sawing may have occurred. In addition to being cracked, cell walls in this region appear to be split open and "pulled", particularly in the surface layers. Such wood tissues were either not covered by the coating, or covered only sparingly. Although this feature was also observable by light microscopy, the highly distorted cell walls in the surface layers were clearly resolved only by confocal microscopy because of its ability to bring a relatively large part of a section into the same focal plane, which was not achievable by light microscopy. The exposed cell walls such as those in Figure 5 are likely to become easy targets for colonising micro-organisms in the absence of protection from the coating, which can have a devastating effect on both the appearance and the durability of wood.

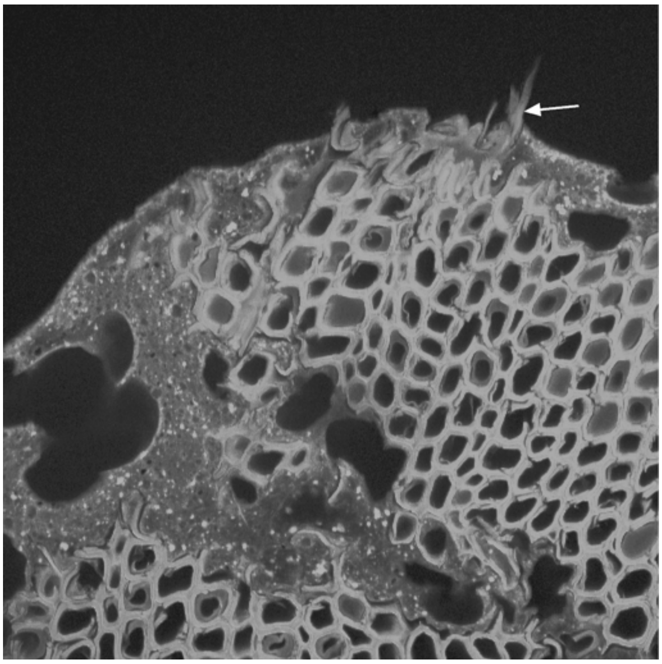


Figure 5. Confocal fluorescence micrograph of a transverse section through the wood-coating interface. The protruded cells (arrow) are in the same focal plane as the wood tissues underneath the coating, and are thus sharply defined.

It may be seen from the examples presented here that confocal microscopy is a valuable tool for assessing the distribution of coating on a rough-textured wood surface. It is apparent from the information obtained that even three coats do not provide adequate coverage of the coating polymer over such a difficult, though attractive, wood surface. Perhaps one or two further coats would be required to ensure that the plywood surface is completely covered by the coating, thus extending the service life of the wood-polymer composite.

Wood Drying

Issue No. 36 July 2005

MEASURING MC PROFILES WITH INSULATED PIN ELECTRODES

Steve Riley, Louw van Wyk

The measurement of wood moisture content with resistance pins is very common and, until the recent arrival of capacitance meters, it was virtually the only means of quickly measuring MC. Even now it is commonly accepted that capacitance meters give only a rough estimate of bulk MC and if you want to measure depth profiles you must use pin electrodes, preferably with insulated pins. Recently a project was carried out to examine what happens when insulated pins are used. The findings indicated that readings must be interpreted very carefully, and that it is almost impossible to get accurate MC gradient information this way.

Problems arise because the physical property being evaluated that relates to MC is electrical resistivity*; however, what is actually being measured by the meter is electrical resistance†. Measured resistance is related to resistivity by the geometry of the measuring system. In the simplest form, measuring the resistance **R,** of a piece of wood whose resistivity is **r**, between two parallel plates is shown in Figure 1.

Thus changing probe geometry (i.e., L or A - distance between pins or their diameter) will change the value of R, even though resistivity r doesn't change. This parallel plate arrangement is not practical for bulk measurement, let alone MC gradient, but is shown to illustrate the simplest example.

Parallel pin measurement has a more complicated relationship between resistivity and resistance

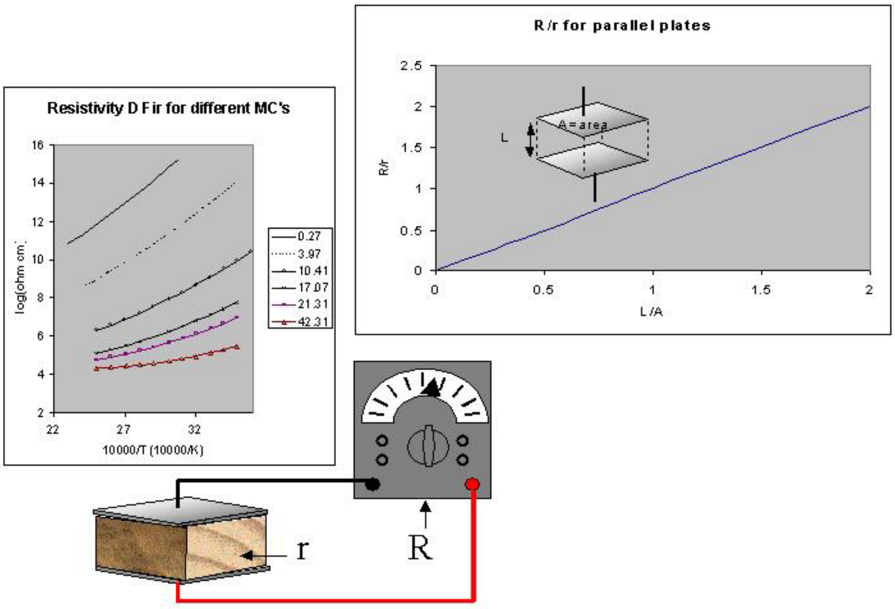


Figure 1. Parallel plate measurement

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* **Electrical resistivity** is an inherent material property which relates the length and cross sectional area of piece of that material to its measured electrical resistance at a given temperature. It can be seen that measured resistance of a piece of uniform material will depend on its size: the resistance will be higher for a longer or narrower section of material. Thus the resistivity of a material defines its resistance properties independent of its size or shape. In the case of wood it decreases with temperature and with moisture content. Its unit of measurement is ohm metres (Ωm)

† **Electrical resistance** of a circuit element is defined as the ratio of voltage across it to the current flowing in it. An element with high resistance needs more voltage to achieve a given current flow than one with low resistance. Its unit of measurement is the ohm (Ω)

(Figure 2). It must be noted that as well as pin separation and thickness, the depth of wood being measured will affect the reading. This is shown in Figure 3, where depth of uninsulated pin insertion greatly affects the resistance.

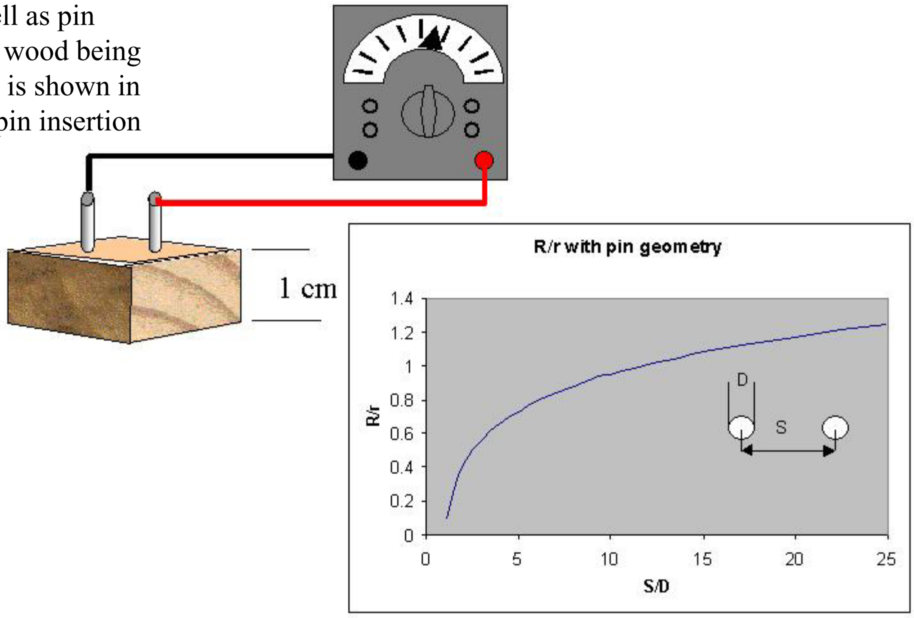


Figure 2. R/r for parallel uninsulated pins in an isotropic medium

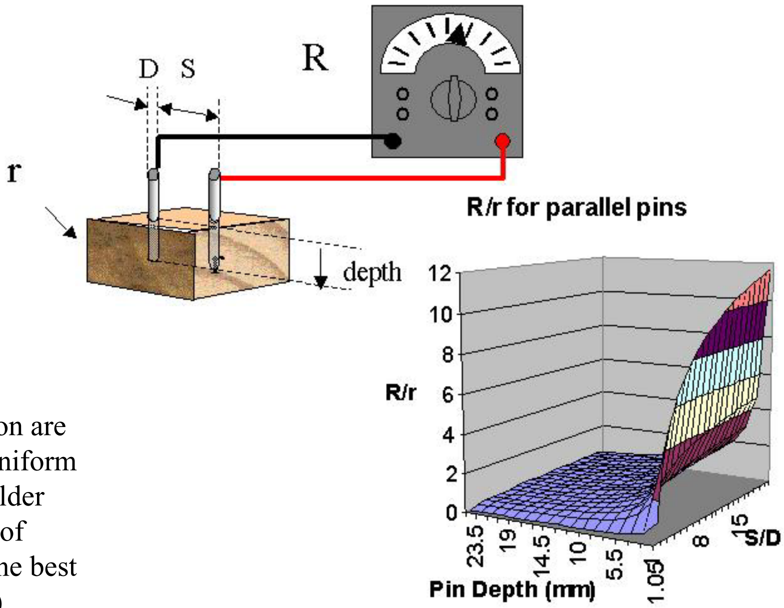


Figure 3. Relationship between pin geometry and measured resistance for a uniform block

Thus far, if pins of a set thickness and separation are used it can be seen that even for measuring a uniform piece of wood, depth is very important. Thus older meters with uninsulated pins specified a depth of insertion. There were even suggestions about the best depth for when gradients are present (Figure 4).

To overcome this, insulated pins were introduced, with only the points uninsulated. These certainly

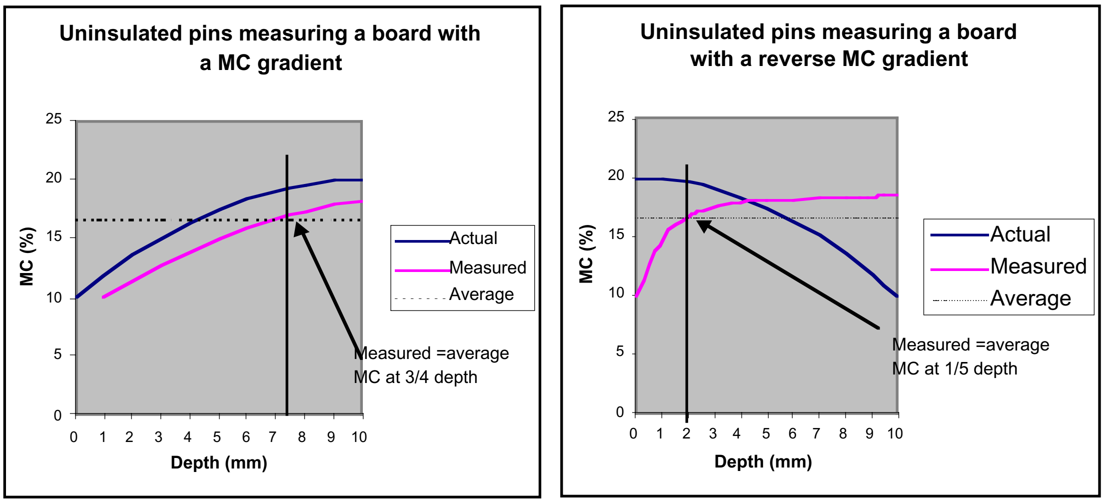


Figure 4. The effect of gradients on uninsulated pins (from C.Skaar (1988) Wood – Water Relations)

reduce the depth of insertion effect and thus by assumption are often used to assess gradients. Since the moisture resistivity relationship is so nonlinear it is assumed that the small area of influence on the uninsulated pin point responds to the wettest region near it and thus will give a reasonable assessment of MC gradient.

Recently with our studies on wood stability and behaviour we re-assessed the means we have for assessing MC gradients and thus examined what is happening with insulated probes. The mathematical relationships demonstrated above were applied to a standard insulated pin (2 mm diameter with 8 mm tapered point). The changing depth and diameter due to the taper were included. Firstly, insulated probes measuring uniform pieces of wood were studied. The results (Figure 5) showed that even with uniform blocks there is an error, and that error increases with MC. To confirm this, blocks of radiata pine were equilibrated for months in an EMC cabinet and immediately measured at different depths with standard insulated pins. Figure 6 tends to confirm the theoretical result, showing that as the tapered section enters the wood a false gradient is measured.

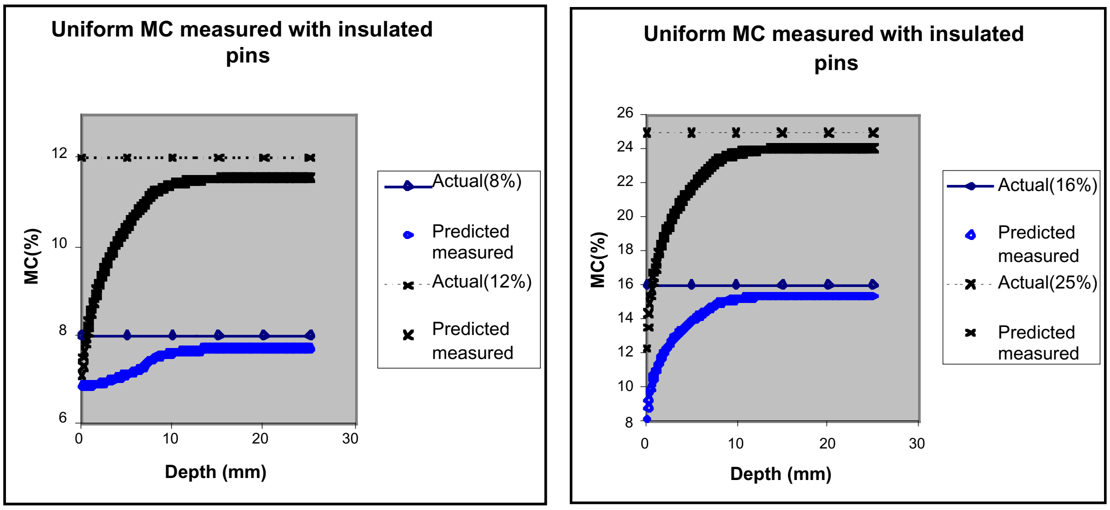


Figure 5. Predicted performance of standard insulated probes in uniform MC samples

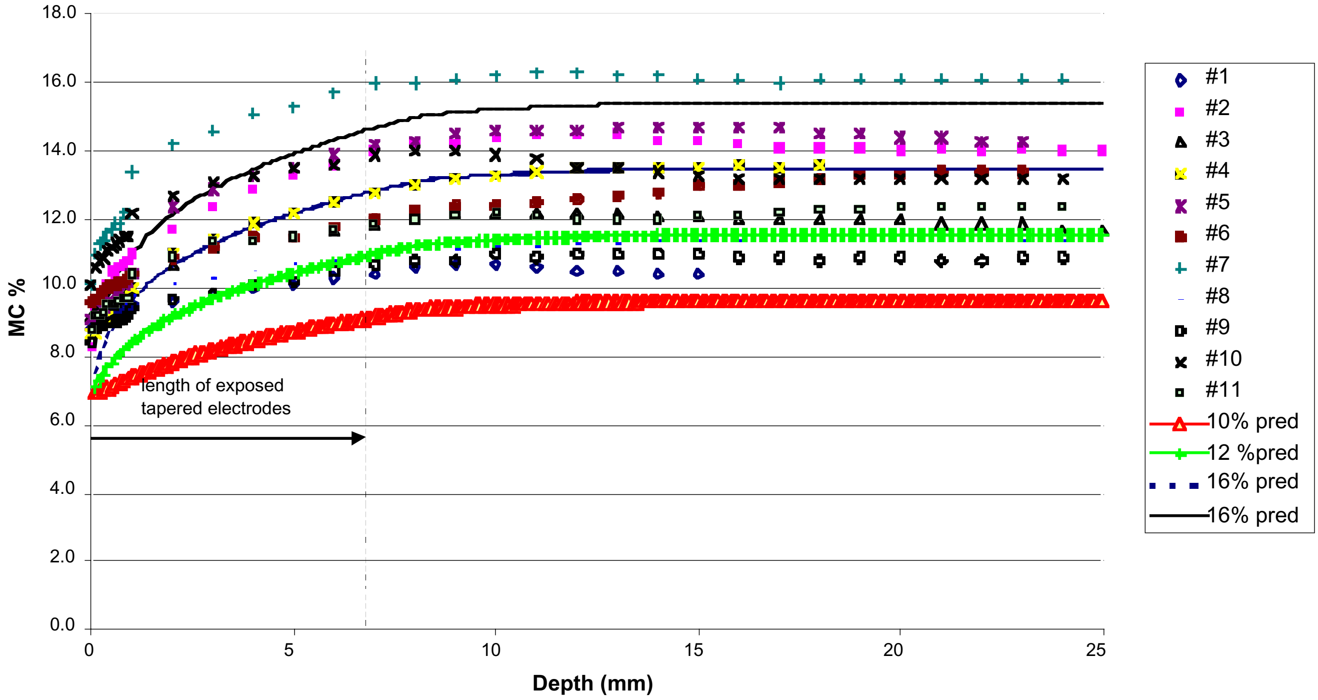


Figure 6. Results of 11 equilibrated samples, with theoretical predictions.

Thus, for example if pins were inserted at 1mm and 25 mm depths, a gradient of 3 % would be registered for a 14% uniform moisture content sample. It would be interesting to see what would be registered if boards with gradients were being measured. For now this can only be done theoretically. Results for different drying gradients are shown in Figure 7.

With linear gradients, measured and actual are not so different, but with non-linear inner gradients, a curve-down gradient will be under-estimated and curve-up gradient over-estimated. With wetting gradients the situation is worse. Figure 8 shows that MC gradient will always be under-estimated

It is not common knowledge that, apart from the uniform gradient example, these results cannot easily be confirmed, because apart from cutting up into thin slices and weighing (with all the uncertainty associated with that process), there really is no simple means for measuring MC distribution in a sample of wood.

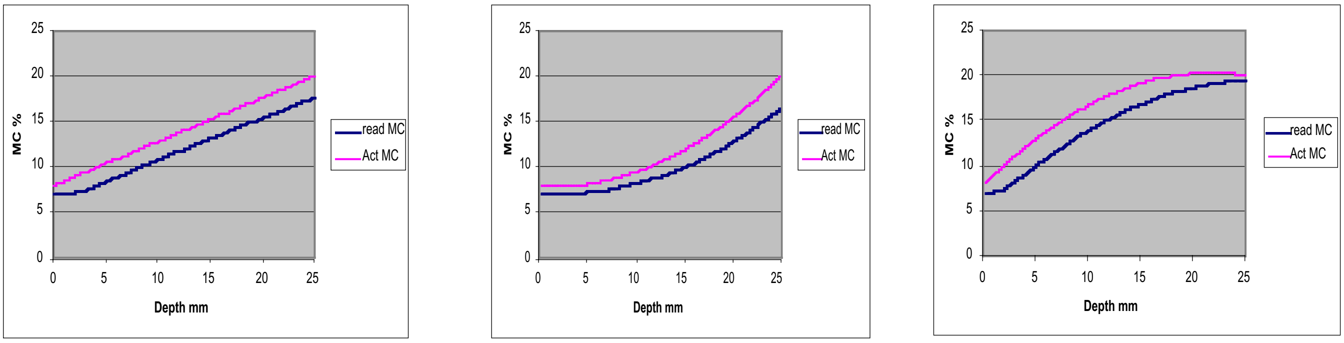


Figure 7. Insulated pins measuring drying gradients

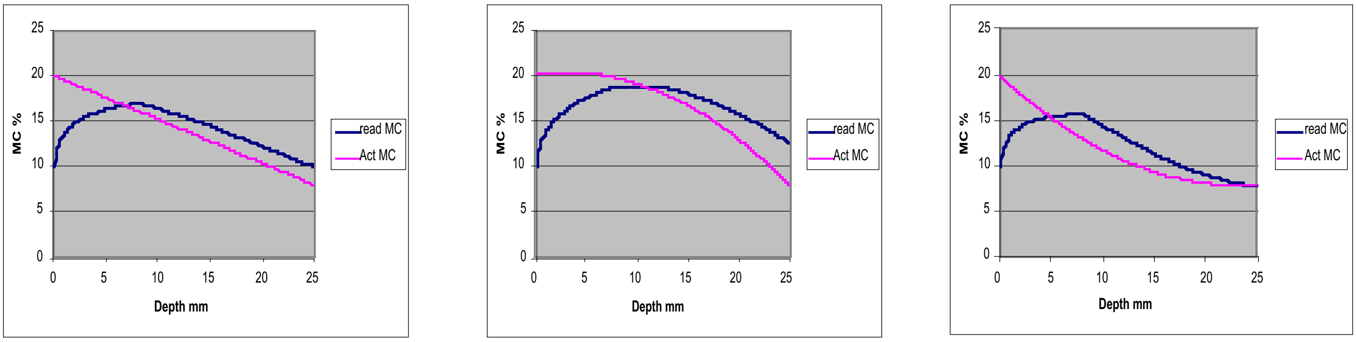


Figure 8. Insulated pins measuring a wetting gradient

What this initial study has shown is:

- Resistance type moisture meters with pin type probes are still a versatile standard means of measuring MC; however, readings must be interpreted very carefully.
- With un-insulated pins a consistent depth must be used, and gradients should not be assessed.
- With insulated pins —
  - a nonexistent drying gradient can be measured on a uniform sample. The size of this “gradient” depends on the MC.
  - drying gradients can be roughly assessed but could be confused with uniform MC unless sufficient readings are taken.
  - wetting gradients will be under-emphasised.
  - with irregular MC distributions, no interpretation is possible with regard to true distribution.
- Further work is required to design a means of measuring MC distribution in wood

WOOD QUALITY ASSESSMENT FOR STRESS MODELLING PROJECT

Hamish Pearson and Rob Evans

One of the barriers to understanding wood behaviour is a good knowledge of stress development during processing and in use. This is a very challenging topic, and a project is now well under way to model stress development in wood during kiln drying. A better understanding of stress development could help improve kiln schedules and reduce wood degrade associated with the drying of lumber. Unfortunately, stress cannot be measured directly. The best approach is to simulate kiln-drying conditions in a controlled environment and measure strain (changes in wood dimension) as a function of stress. Then, a stress model can be created as a function of kiln drying temperature, time, and wood moisture content. This article outlines the wood sampling approach that was used to obtain test specimens for the stress project, and also reports on some aspects of wood quality.

Sampling Method

Previous international work on stress modelling has shown that both experimental equipment and wood variability play a critical role. The equipment required to carry out this project is complex and requires excellent process control, accuracy, and the ability to perform under extreme conditions of high temperature and pressure. Additionally, experimental designs must be carefully considered so that sample size can be kept to a minimum whilst still delivering valid correlations to yield meaningful data for modelling. In this way any relationships between factors such as stress, time, temperature, and moisture content can be documented and modelled with accuracy.

There are two main methods for collecting suitable wood samples to obtain data for modelling interdependencies between factors. The first method is to use a large number of randomly chosen samples to ensure that statistical variability is relatively low and that true factor effects can be easily distinguished. The second method is to choose a small, highly defined sample set so that more wood quality information is known for each sample, and factor effects can be statistically evaluated. For the stress modelling project, initial focus has been on the design, construction, and calibration of highly specialised equipment, and the development of modelling equations. For this reason, wood samples have been taken from a single, well-documented radiata pine stem. This helps to ensure validity of the data required for modelling and minimises sampling costs. Future work can then be expanded to a larger sample after the equipment and initial models have been established.

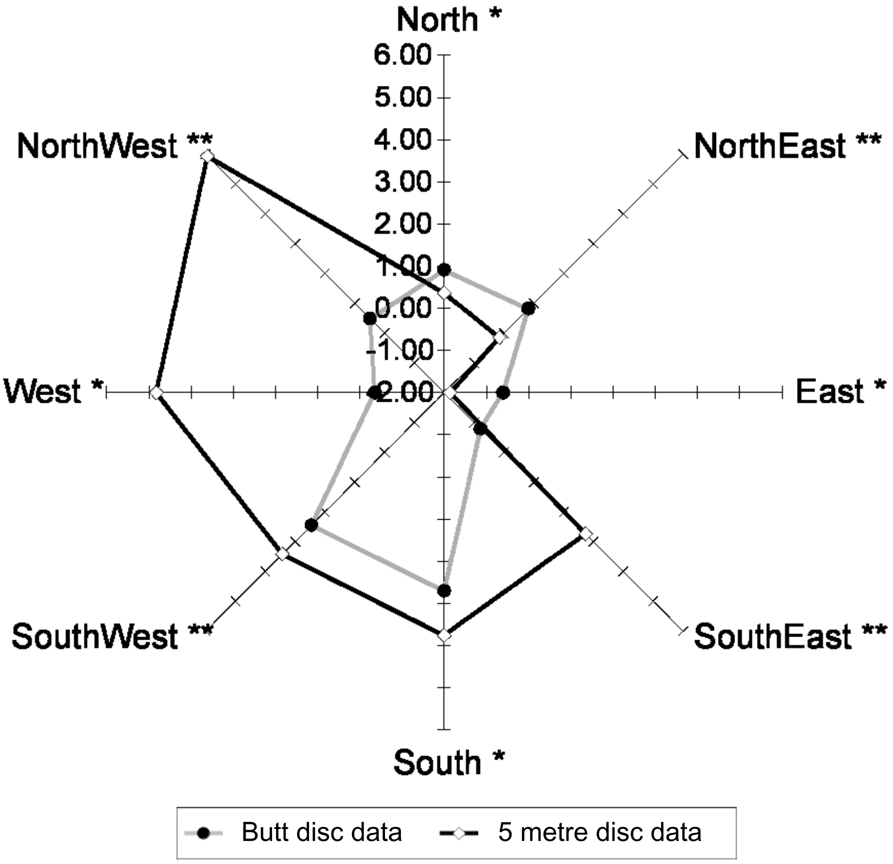
One 32-year-old radiata pine tree from Whakarewarewa Forest was harvested and the 5-m-long butt log was taper sawn to ensure matched tangential grain samples for identified growth rings. Disc samples from either end of the log were used for conventional wood property assessment at Forest Research and additionally pith-to-bark samples from the four cardinal directions were analysed for spiral grain, density, microfibril angle, and stiffness using SilviScan at CSIRO. Initial wood quality results were as follows.

Spiral Grain

Spiral grain data were obtained from two discs taken from each end of the 5-m-long butt log. The relative compass direction associated with each disc before the tree was harvested was recorded, and results at each growth ring boundary for eight compass directions (N, NE, E, SE, S, SW, W, and NW) were averaged over the full pith-to-bark length. Measurements were made using the scribe method for pith-to-bark compass directions NE, SE, SW, and NW whilst measurements were made at CSIRO Australia using SilviScan for compass directions N, E, S, and W; hence the interleaving of the two data sets shown in Figure 1. In line with Cown's work (*Forest Research Bulletin 216*, 1999), mean spiral grain was generally lower at the base of the log than at 5 m, and was higher in juvenile wood than in mature wood. However, all spiral grain angles were relatively small, with low standard deviations. It is therefore estimated that tensile test results using wood samples taken between the wood quality discs are not likely to be affected by spiral grain.

Stiffness

Predicted stiffness from SilviScan (Figure 2) was not a function of tree height or compass direction (radial growth ring direction) but of tree age at both heights. Compression wood was not noticeable in the outer growth rings and overall stiffness results were similar to established mean wood quality results for radiata pine (*FRI Bulletin No. 216*). It is therefore estimated that tensile stiffness results using samples taken between the wood quality discs are not likely to be affected by radial compass direction or the



NOTE:

* *Where north, east, south, west samples were measured by SilviScan at CSIRO*

** *Where northeast, southeast, southwest, northwest samples were measured by Scribe at Forest Research*

Figure 1. Mean pith to bark spiral grain (degrees) as a function of compass direction

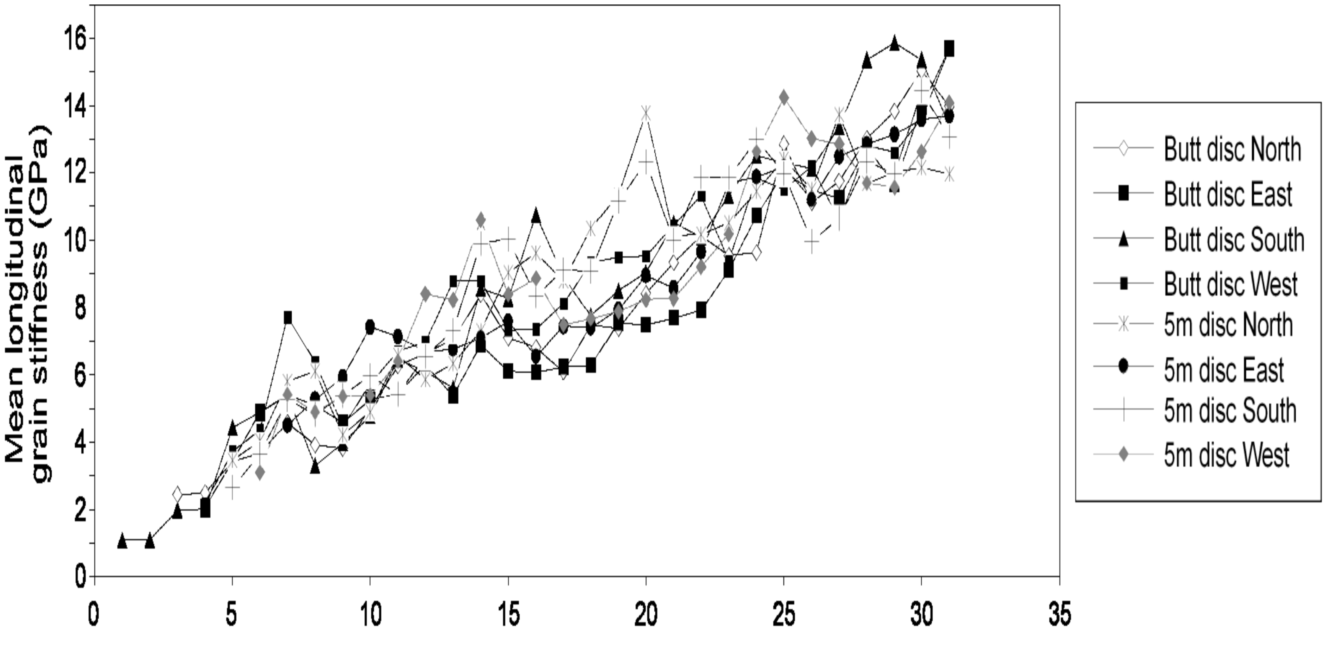


Figure 2. Mean pith to bark spiral grain (degrees) as a function of sample direction

longitudinal position along the butt log from which samples were removed. However, matched samples will be taken from the outer growth rings (thus eliminating compression wood) and from growth rings of the same age (hence the butt log was taper cut).

Preliminary 3-Dimensional Spatial Modelling

The final stress model will involve solving complex differential equations that relate wood material properties with stress and strain. The best current method for solving the equations is to use finite element analysis and this in turn is best achieved through the use of a 3-dimensional computer-aided design (CAD) spatial model of all samples taken from the sample log. By knowing where each sample existed in the original tree, along with measurements and estimates of its wood quality, accurate spatial stress-strain distortion modelling is possible

A full 3-dimensional log model was thus formulated in CAD by mapping all growth rings from the two wood quality discs into a co-ordinate data system. This was achieved using specialised ring-mapping software (Figure 3). The data were then imported into CAD to create a 3-dimensional model (Figure 4) of the sample log, which will be used for later finite element analysis. (In Figure 4 the relative log position is shown with respect to the growth rings of one end disc but in reality all growth rings are included in the full model and exist as concentric cones.)

Initial tests will involve tension stress modelling of tangential sapwood samples, but future work will be expanded to other wood types such as heartwood and grain types such as radial or longitudinal.

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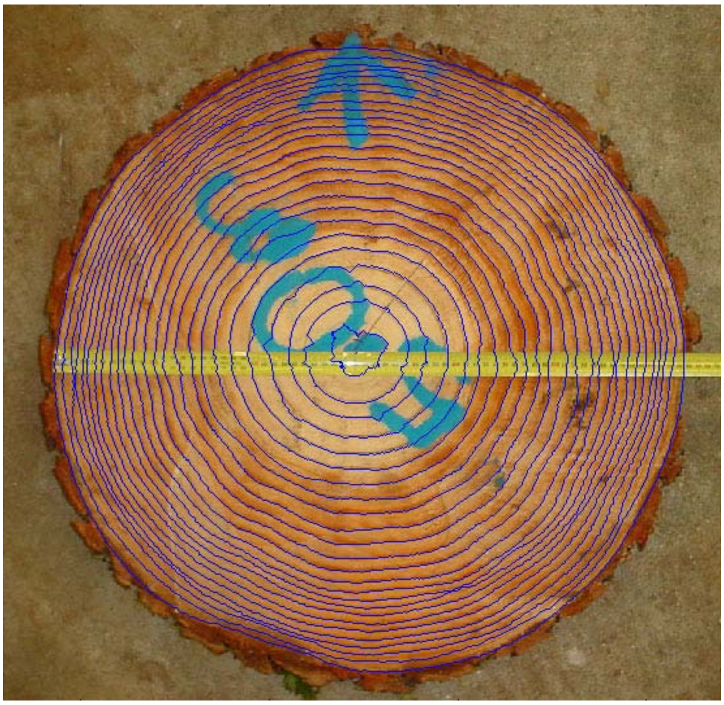


Figure 3. Ring mapped end disc.

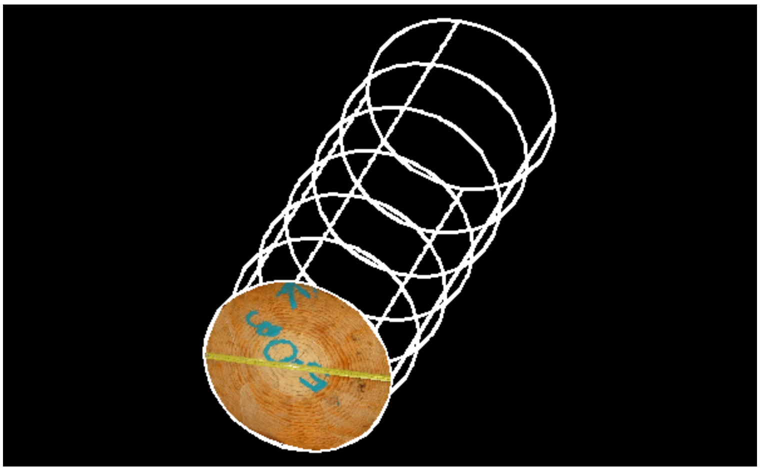


Figure 4. Digitised tree model as three-dimensional CAD object.

Wood Preservation

Issue No. 36 July 2005

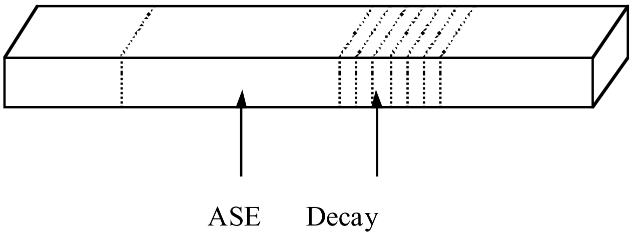
STABILITY AND DECAY RESISTANCE OF ACETYLATED WOOD

K. Nasheri, G Durbin, A. Singh, and D. O'Callahan,

In the last issue (No.35 May 2004) we brought you an article on Forest Research's development of an improved process for acetylation of radiata pine and how it can improve stability. This issue reports further on the effect of acetylation on stabilisation and improvements to durability.

A number of acetylated samples with different weight gains were tested for their anti-fungal efficacy. Decay resistance to three brown-rot fungi tested was directly related to increased weight gain due to acetylation, which also increased dimensional stability. Microscopic observations provided further evidence for the resistance of acetylated wood to brown rot.

Radiata pine sapwood measuring 300×73×45 mm was used for dimensional change ASE (Anti Shrink Efficiency) measurement and "sutter block" decay testing. Sutter decay test sections (7 mm long) were prepared from the mid section of each 300-mm sample.



All wood samples were oven-dried prior to treatments except two samples which were 9% moisture content before treatment.

ASE (Anti Shrink Efficiency) was calculated by comparing oven dried and water saturated volume change of acetylated samples with untreated controls.

Decay test methodology

Replicate blocks for each treatment were labelled and then conditioned to constant weight at 12% equilibrium moisture content (emc). After conditioning, the blocks were weighed, packaged, and sterilised by exposure to ethylene oxide gas. Using standard Forest Research "Sutter Test" procedures, the blocks were then placed aseptically into pure culture of *Coniophora puteana, Tyromyces palustris,* and Auckland Brown Rot "sutter" containers. Incubation was for 6 weeks at 25°C for *C. puteana* and Auckland BR, and 8 weeks for *T. palustris*.

After incubation the blocks were cleaned, air dried, reconditioned to constant weight at 12% emc, and re-weighed. Percentage weight loss for each block was calculated and means were determined for each treatment.

Microscopy

The acetylated wood was harder to section with a sliding microtome than unacetylated (control) wood, and therefore wood blocks were sectioned by hand using a single-edge razor blade to avoid any compression-induced distortion to wood tissue. The sections obtained from selected treatments (No. 4 *Coniophora puteana* and control in Table 1) were observed without staining with a light microscope in the conventional as well as polarisation modes.

Decay resistance of radiata pine sapwood and its stability were improved significantly by increase in weight gain (wpg) due to acetylation. Table 1 shows the weight gain of selected treatments by acetylation, and improvement in their decay resistance and stability.

Table 1 shows that decay resistance to all three brown rot fungi is directly related to weight gains due to acetylation.

Figure 1 shows the relationship between acetylation wpg and percentage weight loss after 6 weeks' exposure to *Coniophora puteana*

Figure 2 shows the relationship between acetylation wpg and percentage weight loss after 8 weeks' exposure to *Tyromyces palustris*

Figure 3 shows the relationship between acetylation wpg and percentage weight loss after 6 weeks' exposure to Auckland isolate

Table 1. Percentage weight loss after 6 (Cp & Ak) and 8 weeks' (Tp) exposure to wood-decay fungi

Treatment number	Acetylation (% wpg)*	ASE (%)	Fungi		
			Coniophora puteana	*Tyromyces palustris*	Auckland isolate
1	23	75.4	0	3.66	0
2	13.9	62.4	12.86	19.95	6.01
3	19.6	69.4	0	7.45	0
4	21.7	74.7	0	1.47	0
5	25.5	80.4	0	na	0
Control	na	na	31.57	22.23	32.1
6†	5.3	26.4	28.18	34.29	32.49
7	9.7	40.7	23.24	19.98	20.26
8	16	63.5	9.26	14.22	5.16
9	19.3	70.9	0	9.14	0
10	22.4	70.1	0	1.24	0
11	18.1	68.5	0	3.01	0
12*	8.1	39.3	26.53	20.79	28.13

* Percentage weight gain due to acetylation
† Samples at 9% mc

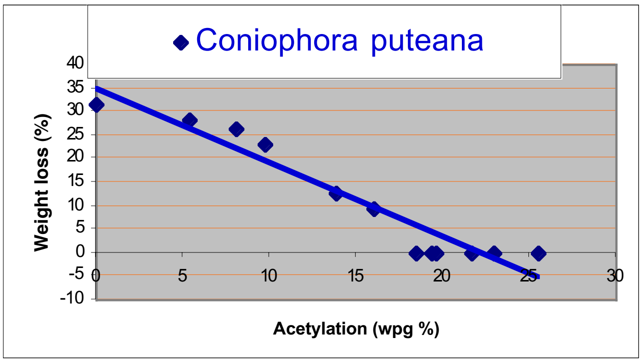


Figure 1.

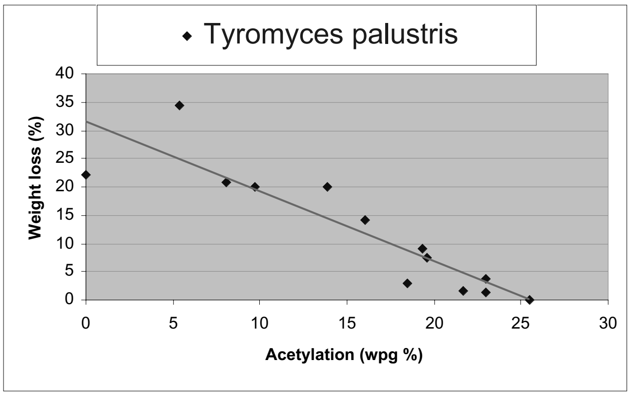


Figure 2.

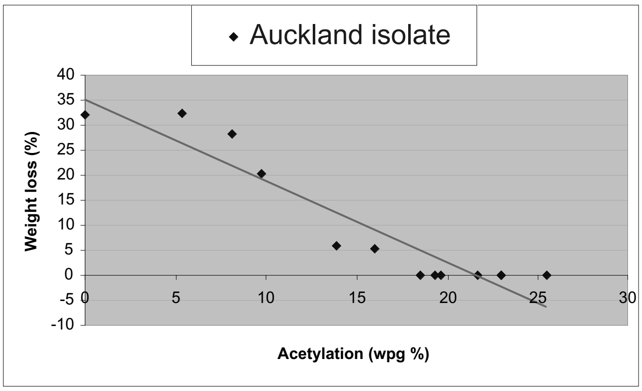


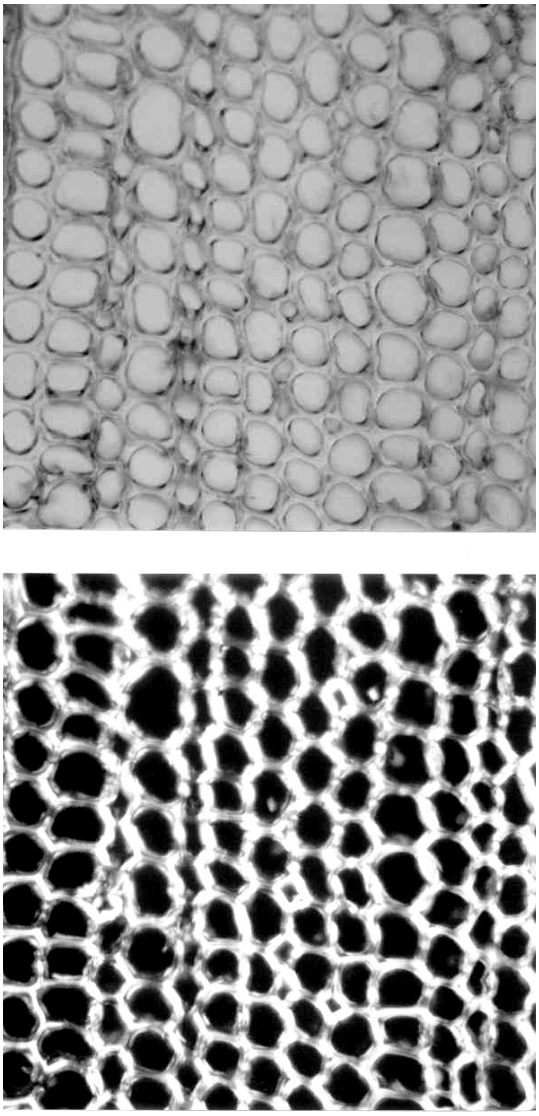
Figure 3.

Weight loss due to brown-rot fungi attack at lower weight gains of 5% to 8% was very close to that of untreated control samples. This could be the fungicide threshold effect of acetylation, or another possibility is the effect of extractive wash-off from the treated wood. In other words, the effect of lack of extractives supersedes the low weight gain by acetylation. Generally wood extractives improve durability, but during acetylation some wood extractives will dissolve in acetic acid and un-reacted acetic anhydride and will eventually wash away from the wood.

To identify the effect of extractives on weight loss of sutter blocks a series of treatments was conducted, injecting wood extractives into the wood. Further tests on the decay resistance of these treatments are in progress.

Light microscopy is a useful tool for assessing the severity of brown-rot decay. An early indication is depolimerisation of cellulose, which can be monitored by polarising light microscopy as cellulose shows a strong birefringence (glow) under polarised light. Thus, the loss in the birefringence of cell walls is an indication of a loss in cellulose.

The paired micrographs in Figures 4 and 5 were prepared from the images of the same section of acetylated wood taken under conventional (Fig. 4) and polarisation (Fig. 5) modes of the light microscope. Wood cells appear bulked and the cell walls are strongly birefringent (glowing), an indication that they are not degraded. In comparison, in the paired micrographs in Figures 6 and 7, which were prepared in the same way from unacetylated (control) wood, pockets of tissues show prominent cell collapse (arrow in Fig. 6) and a significant loss in the



Figures 4 and 5

The volumetric swelling coefficient was calculated according to the following formulae:

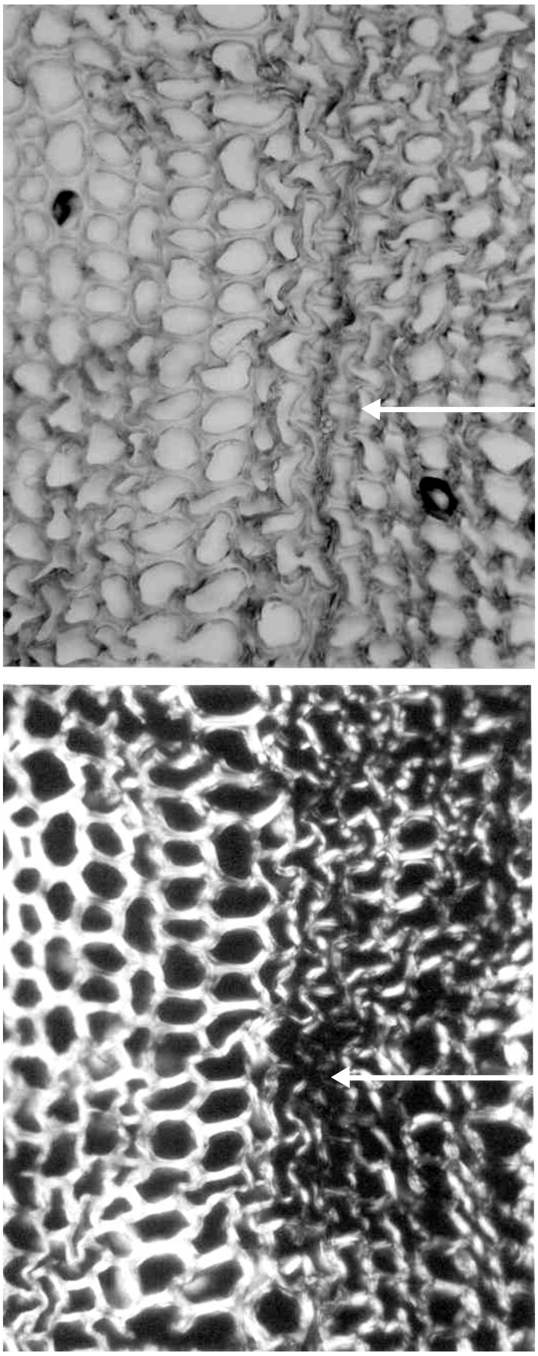
$$S = \frac{V_2 - V_1}{V_1} \times 100$$

where S = volumetric swelling coefficient
V_2 = wood volume at water saturation
V_1 = oven-dried wood volume before saturation

Anti Shrink Efficiency is then calculated as follows:

$$ASE = \frac{S_C - S_M}{S_C} \times 100$$

where S_C is volumetric swelling coefficient of the control and S_M is volumetric swelling coefficient of the modified wood sample.



Figures 6 and 7

birefringence of their walls (arrow in Fig. 7). These features suggest that cell wall degradation is well under way.

In conclusion, the work presented provides evidence that the extent of acetylation achieved using the process developed at Forest Research was very effective in protecting radiata pine wood from brown rot decay.

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Remanufacturing	Jeremy Warnes / John Turner (NZ)
Wood Quality	Dave Cown (NZ) Jugo Ilic (Aust)
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