BRE

digest

Timber grading and scanning

Digest 492

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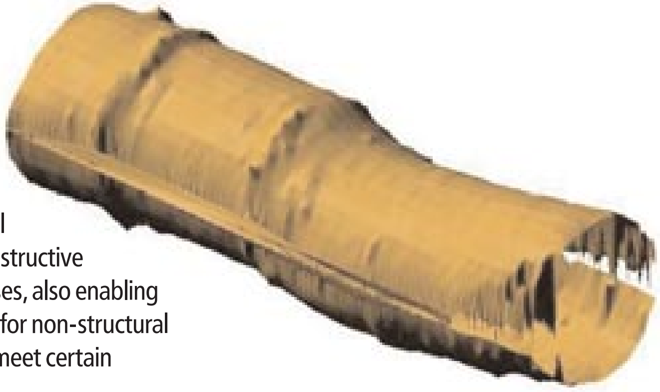
Timber is an immensely useful but naturally variable material. Wood can contain features, such as knots and sloping grain, that may not be suitable for certain end uses. Dimensional defects and distortion can also affect the use of timber.
To use timber reliably for structural purposes, it is important that the strength properties of any member fall within certain limits. Machine grading is a form of non-destructive testing that allows timber to be sorted into strength classes, also enabling timber unsuitable for construction to be rejected. Timber for non-structural uses, such as furniture or flooring, may also be sorted to meet certain appearance grades.

This Digest details advances in grading and scanning technology, for both logs and sawn timber, and changes to structural timber grading due to European harmonisation.



3D log shape data processed as two overlapping surfaces

Since the 1980s there has been remarkable development of advanced timber grading, scanning and sorting technology (Szymani, 1999). This technology ranges from the use of X-rays for internal imaging of logs and boards, to microwaves for detecting sloping grain. Optical board scanners use a variety of methods based on image analysis techniques, including the laser tracheid effect. In some cases these techniques are used in conjunction with machine strength graders, which work by determining stiffness by bending.

Log sorting and processing

To convert logs into sawn lumber efficiently, the shape and size of logs must be known. This information can be used to control log orientation prior to sawing and to optimise cutting patterns, enabling maximum volumetric yield to be obtained while at the same time minimising the number of boards rejected owing to wane. Log shape scanners have developed from relatively simple shadow-type scanners (using alternating arrays of light emitting diodes and photo-receivers) which determine log outline and diameter, to multiple camera-laser scanners which can accurately and quickly determine the precise three-dimensional shape of the log. In the latter type of scanner, images of laser lines projected onto the log surface are processed allowing shape calculation by triangulation (Figure 1 on page 2).

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Figure 1 3D log shape scanner based on laser sheet-of-light triangulation (Image courtesy of Microtec)

The shape of logs can be used to indicate the likely quality of the timber. It is readily possible to record log variables such as sweep (log curvature) and taper, recognise butt logs (those cut from the base of a tree), assess out-of-roundness and other shape features associated with lower quality timber. Abrupt changes in log curvature, for example, indicate disturbed grain which may cause downgrade in sawn timber. Branch swellings may also be correlated to the size of knots. Compression wood in logs may be indicated by their shape and form (Warensjo, 2003). However, compression wood can also form in straight, round trees. Some types of internal defect, including severe cross-grain resulting from stem deviation in early tree life, cannot be readily indicated by log shape.

Laser triangulation can also be used to measure the width and thickness of boards together with profile checking. Stroboscopic directional illumination can detect wane.

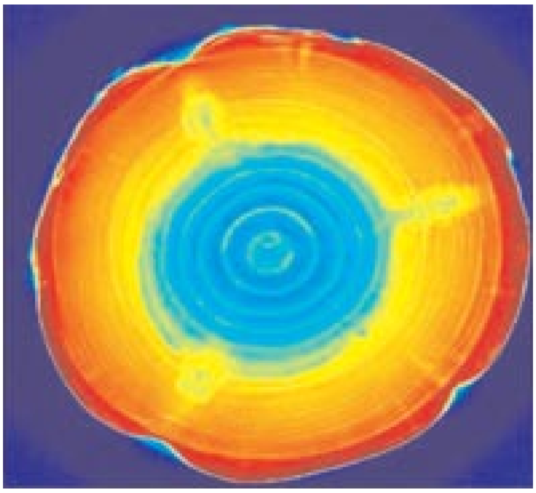


Figure 2 Cross-sectional image of a softwood log produced by X-ray CAT scanner (Image courtesy of Microtec)

Internal imaging of logs

Computed axial tomography (CAT) is the process of imaging parallel to the length axis of an object (Figure 2). Images can be combined to produce a three-dimensional model of the internal structure. CAT methods can be based on the use of microwaves, acoustics, nuclear magnetic resonance and X-rays. X-ray CAT scanners show the greatest potential for internal imaging of logs and have been used both experimentally and in industrial trials (Nystrom and Johansson, 1985). By rotating the X-ray source-and-detector array around the log or rotating the log itself within a fixed detector system, a three-dimensional representation of the internal structure can be obtained.

The quality of the lumber cut from a log is a function of the number, size and type of internal defects; for example branches or knots. Recent work at BRE has highlighted the particular influence on machine grading stiffness of certain types of knot towards the base of Sitka spruce trees; it has also highlighted the influence of parameters that can only be directly measured by microscopic examination (eg microfibril angle which is quite poorly indicated by variables such as rate of growth and density).

It is possible to rotate a log so that, on conversion into planks, branches form less critical knots; however this procedure would do little to solve the problem of highly disturbed grain which occurs at large whorls. Species such as Sitka spruce tend to have a relatively high number of quite small branches that are both difficult to detect and to avoid. Clearly logs that have unusually large branches or other abnormal growth characteristics are worth diverting away from structural timber production. Other types of internal defect in logs include rot and splits, these being particularly relevant in hardwood processing. Internal imaging of logs is undoubtedly an impressive and rapidly developing technology that will become more commonly used in the future as the need for sorting logs increases and the equipment becomes more affordable.

Strength grading of timber

The process of strength grading is indicative but does not give the actual strength of a piece of timber – this can only be achieved by testing the piece to destruction. The aim of strength grading is to assess the timber against a predetermined set of criteria so that it can be attributed to a strength class or grade stress. This helps to determine values for structural performance that can be used in safe design. Safety is of vital importance for structural applications, but using forest resources efficiently is also important. Grading is therefore a mix of maintaining suitable safety standards while maximising yield.

Strength grading – of whatever type – is based on statistical distributions of not only strength, but also stiffness and density. These data are gathered from exhaustive testing of the available supply for each species that is to be strength graded. In the case of UK-grown Sitka spruce, for example, machine settings are based on samples supplied from all the major growing regions of the UK. It would not be appropriate, therefore, to grade Sitka spruce grown in another country, using UK machine settings, without verifying the validity of these values.

In essence, strength grading of timber breaks down into two distinct types.

- Visual grading of softwoods and hardwoods where the timber is assessed against a set of parameters that describe a visual grade. The visual grade can then be attributed to a strength class or set of grade stresses to facilitate use by engineers.

- Machine strength grading where the timber is graded against settings derived from a settings model and the timber is automatically attributed to a strength class. Machine grading is only carried out on softwoods.

Visual grading

Visual grading is the longest established method of strength grading, going back to 1952 with the introduction of CP 112. CP 112 covered both softwoods and hardwoods as well as the code of practice for structural use, later to become BS 5268-2.

Softwood grading

There is no agreed European visual standard for softwood grading; all visual grading standards are National Documents. However, since 1995, BS EN 518 has been in place. This gives guidance on what a national visual grading standard should include. On harmonisation of the European structural codes, BS EN 518 will be withdrawn and replaced with a new version which will include information contained in prEN 14081.

The current method used in the UK is a knot area ratio (KAR) which is based on test results and has two possible visual grades, GS and SS (BS 4978). GS is the General Structural grade and is the lower of the two grades; SS is Special Structural and the higher grade. KAR grading is based on giving a different weighting to knots that are present in different parts of the cross-section of the timber. The cross-section of the timber is split between two outer margins and the central region, knots in the marginal portions having greater weighting than knots in the central portion.

The parameters relating to these grades apply to all timber species that have been approved for grading. However the same visual grade can be attributed to different strength classes depending on the timber species, reflecting the discrimination and robustness of the grading system.

In terms of structural performance, the results of visual grading are conservative and the stresses attributed to a visual grade are lower than can be achieved by machine grading the same timber. The process is slow compared to machine grading and each practitioner has to be trained, tested and monitored by a third party certification body approved by the UK Timber Grading Committee (UKTGC).

Hardwood grading

Hardwood grading in the UK is carried out under BS 5756 and predominantly covers tropical hardwoods. In recent years oak and sweet chestnut have been added. Unlike softwoods, hardwood visual grading is based on the ratio of the size of a knot compared to the dimensions of the face of the timber it appears on. KAR grading has proved problematic to implement with hardwoods as has machine grading using bending-type machines.

The future for visual grading

Compared to machine grading, visual grading is slow when carried out to the full rigours of the standards. Greater speed and precision are possible using modern scanning techniques; the key to this lies in the development of software capable of determining correctly, from output data, the features present within the timber.

The nature of this development would be a form of machine-enhanced visual grading, working to current grading standards. The burden of proof required for suitability to grade would be to demonstrate that this process grades as well as, or better than, a trained visual grader.

Hardwoods are an obvious starting point due to the mode of grading; that is, the mapping of surface knots and comparing them to the face in which they appear. However, additional hardware would be needed to carry out rate of growth and slope of grain determinations.

Softwood grading using new scanning technologies to BS 4798 would be more complicated as this would require determination of the pith position in order to calculate KAR. Like hardwoods, slope of grain and rate of growth would also need to be assessed.

Rate of growth

Visual grading standards for hardwoods and softwoods have specific requirements for rate of growth determination, although this variable in itself is quite a poor indicator of wood quality. Rate of growth can be determined by an operator or by using image analysis techniques. Recent work at BRE has centred on developing software capable of calculating rate of growth and also determining the position of pith, even where this may lie outside of the piece of timber being assessed (Figure 3). Difficulties can arise, however, where knots appear at the board ends or the growth pattern is irregular. Pith position has been found to be a good indicator of distortion in the form of twist (see ‘Timber distortion’ on page 11).

Figure 3 Screenshot of BRE developed software showing rate of growth and pith prediction. The white dot is the predicted pith position

Machine grading

Operating principles of machine grading are covered in BRE Digest 476. The basis on which machine grading is applied is statistical distributions for strength, stiffness and density. All grading machines adopt this approach (or one similar); for each type of machine there will be a ‘settings model’, which is an algorithm or set of algorithms that, for any given machine setting, provide a set of data that can predict the 5th percentile for strength, and associated mean stiffness and density. All three parameters should meet, or exceed, the requirements of the strength class for a particular size of timber to be acceptable for grading.

Deriving the settings for a single grade (eg strength class C16 and reject) is quite simple, but where grading in combination (eg C16/C24/reject), the process becomes more complicated since the sets of distributions relevant to the two grades can overlap. If the settings are not arranged so that there is separation between the grades, this can lead to inaccuracies. Using statistical distributions also explains why, for a particular strength class, different indicating parameters can be obtained. This is because the higher grade takes the stiffer material leaving the lower grade deficient in stiffness at the C16, 5th percentile level. To achieve adequate stiffness the machine setting is therefore raised so that once again all the requirements of the strength class are met, including stiffness. Putting it another way, the C16 indicating parameter when grading C16/reject can be relatively low, provided that none of the higher material is removed by attempting to grade at C24 level. This may also have implications for log sorting as well as tree selection.

Strength graded timber for general use relies on load sharing: the stronger and stiffer pieces supporting the less strong and less stiff timber. Take away the stronger and stiffer material, and impoverished samples are left. This is why the practice of visual grading to select the better pieces of timber and then machine grading what remains to increase yield is not permitted. Regrading material that has been rejected at more demanding machine grade settings in the expectation that it will pass at lower settings is also not permitted.

Rejects result from determining the characteristic strength; that is, the strength level for which 95% of the sample is in excess of this value. The characteristic strength is determined in order to make the most efficient but safe use of the forest resource. By implication 5% of the timber will fall below the safe use level when the characteristic strength is close to the grade strength of the batch of timber concerned.

Changes to machine grading through European harmonisation

Machine grading is currently controlled by BS EN 519 and implemented under third party certification. However, work is currently underway on the drafting and approval of harmonised structural codes, one of which is prEN 14081-1 to 4, and these will become the main standards for rectangular strength graded timber. Many of the parts of this draft standard are already in the public domain for comment. The drafts make some significant changes to the current standards.

- *Method of determining machine approval criteria*
  The main change in this area is the removal of the requirement to achieve a particular coefficient of determination between the machine indication parameter and measured strength. In BS EN 519 there was a requirement for a coefficient of determination of at least 0.47 between machine indicating parameter and measured strength for each species to be graded. This gave a good indication of the potential for the machine and indicated how well the machine might predict strength. What it did not indicate was how well the model used to derive the machine settings worked. Therefore, it was possible to have a machine that was theoretically capable of giving an accurate prediction of strength yet had a poor model that resulted in inaccurate grading. The new method is to use a statistical approach called the total global matrix. In this approach the whole grading process is evaluated and based on how well the grade criteria are met. This judges the grading model far better than the previous method, so it is possible that a machine with a poor coefficient of determination can be made to grade safely and appropriately to strength classes (though the consequence might well be a very poor yield). This allows the use for certain applications of grading technologies that would have been previously excluded.

- *Derivation of machine settings (prEN 14081-4)*
  The new approach adopted for deriving machine settings is that they will be set nationally for the timber produced within that country. Traditionally, machine settings have been derived in the UK by BRE and issued to the third party certification bodies by the UKTGC. This applied to all timber that entered the UK regardless of species or country of origin. On harmonisation, each country supplying strength graded timber will have to produce machine settings for that timber. A simplified method of determining the settings required for particular sizes is set out for each country in Part 4 of the code. Therefore, saw mills will be able to determine the setting they need for the timber they are grading based on the country of origin and type of machine. The settings will be BS EN 338 machine settings and not BS 5268 settings.

- *Third party certification*
  Harmonisation of the European standards might end the mandatory requirement for third party certification of the grading process for timber graded in or entering the UK. There are important actions being taken to get this matter rectified and for mandatory third party certification to be maintained within the UK. This is to be resolved by the UKTGC in the near future

Methods of machine grading

Within the UK, structural softwood timber has been machine graded for over 30 years, almost exclusively by what is termed bending-type, or contact, machines. These machines use one of two basic approaches. The first is where the machine has a set deflection for a size of timber and measures the force required to produce the deflection. The second applies a set load for a particular size of timber and measures the deflection produced. In essence both methods measure stiffness and this is related to measured strength. Three bending-type machines are approved for use in the UK: the Computermatic, the Cook-Bolinder and the Raute Timgrader. The benefits of these types of machine for production purposes are that they are robust and show a reasonable degree of accuracy in the prediction of strength.

A large number of species in a wide range of sizes can be graded using bending-type machines. The main drawbacks are limited speed of operation, that they do not grade the full length of the board, and that their operating alignment is out-of-phase with normal mill production. Although bending-type machines do not directly measure the variables that are known to influence strength such as knots or sloping grain, they have the advantage that they directly measure the important criteria of stiffness, albeit the flatwise bending stiffness rather than the edgewise bending stiffness.

Current and potential new technologies

The new technologies that are already in UK and European sawmills are

- stress wave grading
- X-ray grading
- neural network systems.

Other technologies being developed are:

- microwave grading
- combination machines (Figure 4).

Stress wave and dynamic grading

The operating principle of stress wave grading is relatively simple: the measurement of the speed of a stress wave propagating through a timber board. This function is related to stiffness which is finally related to measured strength. The stress wave is typically generated by a small impact hammer as the timber passes through the grading machine. The plank ends are usually trimmed to give a consistent impact target. A microphone at the opposite end of the board picks up the transmitted wave while a laser is used to determine the length of the board. Recording the stress wave by a non-contact laser is also possible. Either the transit time of the stress wave or the fundamental frequency of the induced oscillation is used in the calculation of an indicating parameter. Since the mass of the board is not measured, the indicating

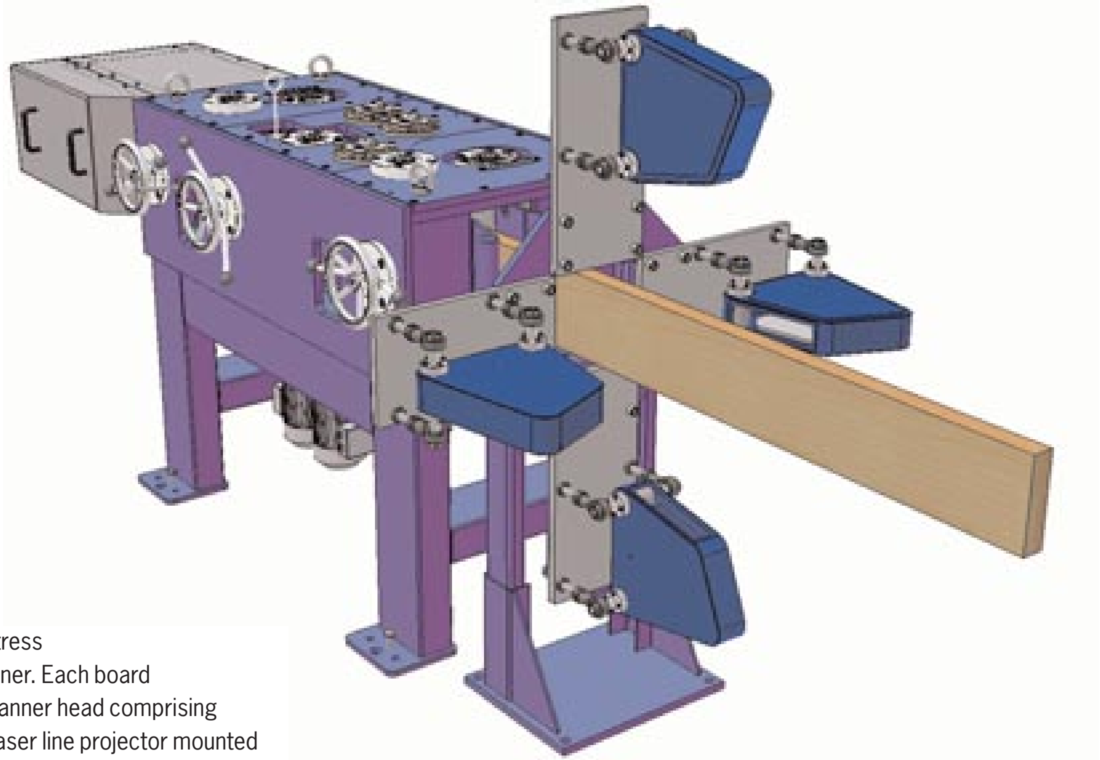


Figure 4 Combined stress grader and timber scanner. Each board face is scanned by a scanner head comprising a single camera and a laser line projector mounted in a protective box
(Image courtesy of Ersson)

parameter is an indirect measure of the stiffness of the board. The main benefit of these machines is that they are arranged in line with the normal sawmill function saving space and conveyor equipment. One drawback in the technique is that it is sensitive to moisture content. A second drawback is that the machine indicating parameter is not related directly to strength but to stiffness, which is then related to strength.

X-ray grading

X-ray graders assess the density of the timber, recording knot sizes and positions together with clear wood density. The source of the X-rays is either a high voltage tube or radioactive isotope, with detection being performed by a scintillator array. An algorithm is used to relate the received data to a machine indicating parameter which, in turn, is related to measured strength. In the laboratory, X-ray graders have proved highly effective at strength grading but in the sawmills experience has shown that they tend to produce slightly lower yields than bending machines.

Before their full potential came to be recognised, initial work was carried out with X-ray graders as devices that could be added to the front end of conventional bending-type machines. As non-contact machines they can grade at speeds up to 350 m/min, thus increasing productivity. The whole length of the board is graded and there is no need for visual over-rides. It is these advantages that make X-ray machines attractive to sawmillers who may be prepared to suffer a small drop in yield to get greater productivity.

The main drawback of these machines is that they are moisture content sensitive as moisture reduces the transmittance of the X-rays, hence making the material appear denser than it is. For this reason a moisture content meter may be placed in line with the X-ray grader. Compression wood, which tends to be denser than normal wood but actually less stiff (Reynolds and Moore, 2004), may also adversely affect such equipment. The formation of severe compression wood is also associated with stem deviation in trees, and, therefore, sloping grain.

X-ray type machines have been approved to strength grade European redwood/whitewood, and UK-grown Sitka spruce.

Neural network systems

An artificial neural network (ANN) is a computer-based information processing system. In the case of an ANN designed to grade timber, the system acquires information from the boards being assessed (the precise form of this data is not critical) and relates this to the ultimate performance. The key element is the novel structure of the information processing system – composed of a large number of highly interconnected processing elements – which effectively learns by example. ANNs can grade either to an identified strength for each piece of timber, as current machines do, or by pattern matching and attributing the timber to a strength class based on the knot distribution and other features. These machines can grade with great speed, depending on the means of capturing the data.

At least one neural network machine has been approved for grading of European redwood/whitewood for the glulam industry in Austria.

Microwave grading

Like X-rays, microwaves were first investigated as an additional method for enhancing the accuracy of bending-type machines. The principle of the use microwaves is to determine the slope of grain and to indicate the presence of knots by their influence on the attenuation and phase of polarised signals. Measuring slope of grain alone is unlikely to provide sufficient data to be able to predict the strength grade of timber with sufficient accuracy, and the most likely use is in combination with other machines. However, combination machines have drawbacks as well as benefits, and these are discussed in the next section. Microwave machines, like X-ray machines, are sensitive to the moisture content of the timber.

Combination machines

A number of grading machines combine direct or indirect stiffness measurement of boards (by actual bending or by dynamic methods) together with knot detection using X-rays or sloping grain detection using microwaves. Other variants are also possible, including using optical knot detection on the surface of boards combined with stiffness or density measurement. The basic principle is that the greater the number of grading technologies measuring different parameters of strength that can be brought together into a single grading operation, the more accurate the prediction of strength will be. This is fundamentally true, but there are drawbacks. Increasing the number of technologies in a single grading operation can result in diminishing returns while costs increase markedly. That is to say, the best prediction of strength (as established by the coefficient of determination) may be achieved by the first method of grading – any additional method results in only a marginal improvement to the coefficient of determination and the increase in improvement is progressively less with each additional method. Therefore, for combination grading to be effective, careful selection of the grading technologies is needed. However, by increasing the accuracy of a grading machine the device may be made more reliable. A grading machine which is poor at predicting strength because it is not measuring certain types of defect or misinterpreting variables has to operate in an over-conservative manner. Therefore, by increasing accuracy, both yield and reliability can be increased. Adding optical detectors to bending type machines which do not measure stiffness over the entire length of the board can obviate the need for an operator to be present to perform visual over-rides.

Machine control and output control

Most grading operations are machine controlled where the machine is the only effective measure of determining strength and there is a system in place to regulate that grading process. This process works well where there is a need for flexibility, for grading several different sizes within one shift, or for regularly changing the species being graded.

Where there are long production runs of a single dimension and of single species, output control has advantages. This method is favoured in the USA. The basic principle is to grade the timber against a machine setting or indicating parameter but to check the output of the grading process periodically throughout the course of a production run by proof loading a number of pieces of graded timber. If the timber is found to be safe with regard to the proof load then the process is ‘in control’, but should the results of the proof test indicate the grading is unsafe then corrections based on statistical parameters must be applied.

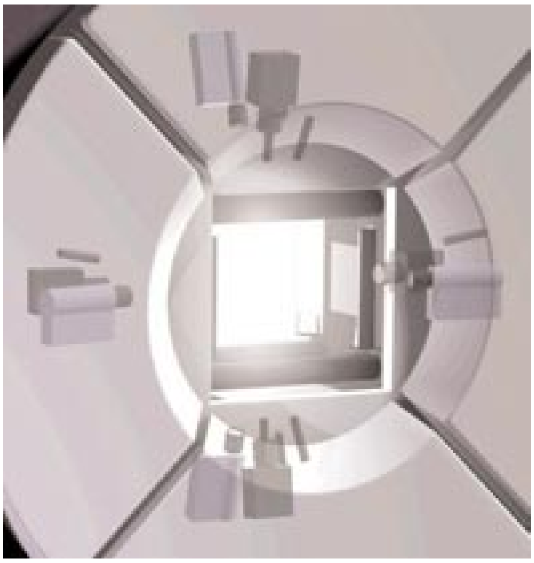
Optical board scanners

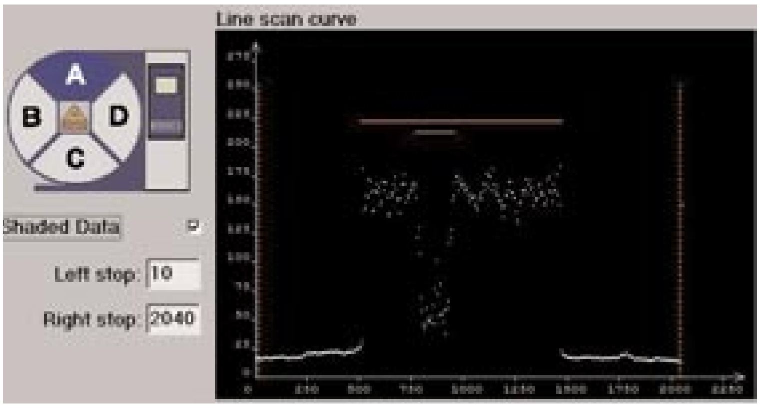
Optical board scanners use a variety of camera types and optical detectors, together with infrared laser dot and laser line illumination (Figure 5). In most cases the boards are fed through the scanner longitudinally on a conveyor. Basic scanners can use an array of photo-detectors to detect dark features such as knots. Modern advanced scanners use several interacting measurements to detect defects such as knots, splits and resin pockets – on all four faces of the board simultaneously – as well as dimensional defects.

High-resolution line cameras are used to detect defects that are darker than the surrounding wood – such as black knots – and for dimensional checking. Line cameras capture the light reflected from the board in a one-dimensional array, as opposed to a two-dimensional grid such as a television image or bitmap (Figure 6). A two-dimensional image suitable for further analysis of variables (eg knot size) is obtained by processing the camera output having calibrated the system for the board size. The board length is obtained by relating the data acquired from the cameras to the speed of the conveyor. The light source is fluorescent tubes (ie visible light). Colour cameras are also used for detecting differences in colour, facilitating the sorting of timber for appearance.

Data from all the various sensing devices is used to build up a false-colour image of the board (Figure 7) on which defect zones can be identified.

Figure 5 Sophisticated board scanner with multiple camera and laser arrays (Image courtesy of Innovativ Vision)





Left stop: 10

Right stop: 2040

Figure 6 Line camera output. The width of the board is indicated by the received light response (red line); knots on the board face are indicated by the drop in received light (yellow line)

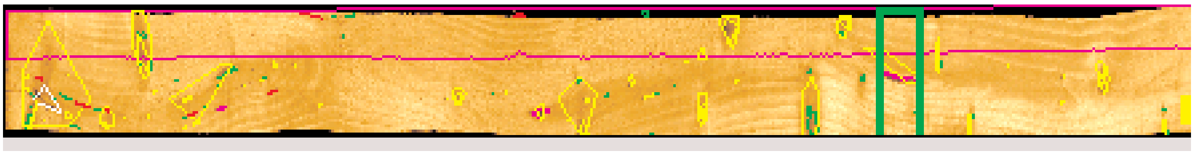


Figure 7 False-colour image of board showing knot zones

Tracheid effect

When a laser beam is projected onto timber the light is scattered along the grain – this phenomenon being termed the tracheid effect. The angle of the observed halo around the projected laser dot corresponds to the grain angle on the board (Figure 8). This information can be used to detect disturbed grain around sound knots that might otherwise be difficult to detect. Arrays of laser dots projected across the whole width of the surface of the board can be analysed to obtain information on the size of the knots.

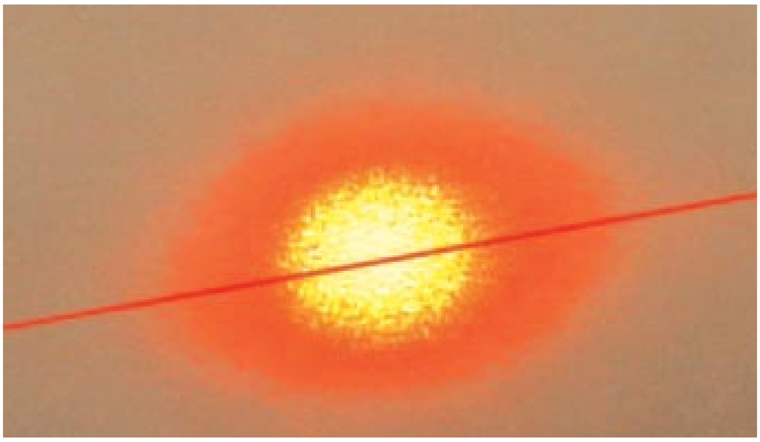


Figure 8 Tracheid effect. The laser halo indicates the timber grain angle

Another method based on the laser tracheid effect is to capture data from cameras viewing a laser line projected across the width of the board. Again, this form of illumination highlights light coloured, sound knots. The laser light is usually infrared, detected by infrared sensitive cameras. Sophisticated board scanners can also use the ratio of the laser dot width to length to indicate the presence of other types of defect such as compression wood.

Optical board scanners may be used in a wide variety of applications such as in the flooring and furniture industries, and in the fabrication of glulam and finger-jointed timber. Scanners can control cross-cutting equipment to remove defects, and also sorting equipment that can turn or orientate pieces of timber so that in final products (eg furniture or cladding) defects are hidden. The exposed edges of products such as window frames can be made so that they are free of knots, as can fixing points for screws or nails. By scanning boards prior to grading, they can be trimmed or cross-cut so that features likely to cause downgrade are removed or their effect minimised.

Timber distortion

Forms of distortion are bow, spring and twist (Figure 9).

Distortion in the form of twist is known to be caused by spiral grain (Stevens, 1961; Brazier, 1965). Although the magnitude of spiral grain in UK-grown Sitka spruce, for example, varies (typically from around 3–6°), the position of the piece of timber with respect to the pith or centre of the log is of equal influence. Pieces cut from the centre of the log tend to twist more (Johansson, 2002). Sorting timber purely on the basis of slope of grain may therefore not be the entire solution. Methods of automatic laser measurement of slope of grain have been examined by Nystrom (2002), and equipment using these techniques is currently undergoing industrial trials in Sweden for sorting at log, canted log and sawn timber stages. A relatively simple algorithm is used to determine grain angle from images of laser halos; but complications arise in boards that have high numbers of knots and a wandering pith. Cooper and Maun (2004) describe a method of re-engineering boards to reduce twist.

Bow and spring in boards is caused by unbalanced longitudinal shrinkage. Both juvenile wood (Thornqvist, 1993) and compression wood differ from normal or mature wood because of the significant longitudinal shrinkage. An imbalance of juvenile wood or compression wood from one side or face of a board to another can therefore cause distortion. Timber which is fast grown tends to have a high proportion of juvenile wood. Compression wood is a type of reaction wood that affects conifers that have been partially blown over, trees on the windward side of exposed plantations, the lower parts of trees growing on slopes, and wood below heavy branches (Desch and Dinwoodie, 1996; see also www.forestry.gov.uk/compressionwood). Both compression wood and slope of grain can be indicated by the laser tracheid effect (Figures 8 and 10).

Determining the amount of compression wood within a board, and its propensity to distort, based purely on surface imaging is problematic. It is not possible to determine the extent of compression wood within a board without knowledge of the growth ring structure. Some forms of scanner may be capable, by viewing the board ends, of determining both the proportion and position of juvenile wood in a board together with the compression wood content on each of the faces. However, it may be more appropriate to adopt a timber drying and handling process that provides maximum restraint, therefore limiting distortion rather than adopting a sorting strategy. For some types of glue laminated products or re-engineered timber, sorting using the above scanning techniques will be particularly useful.

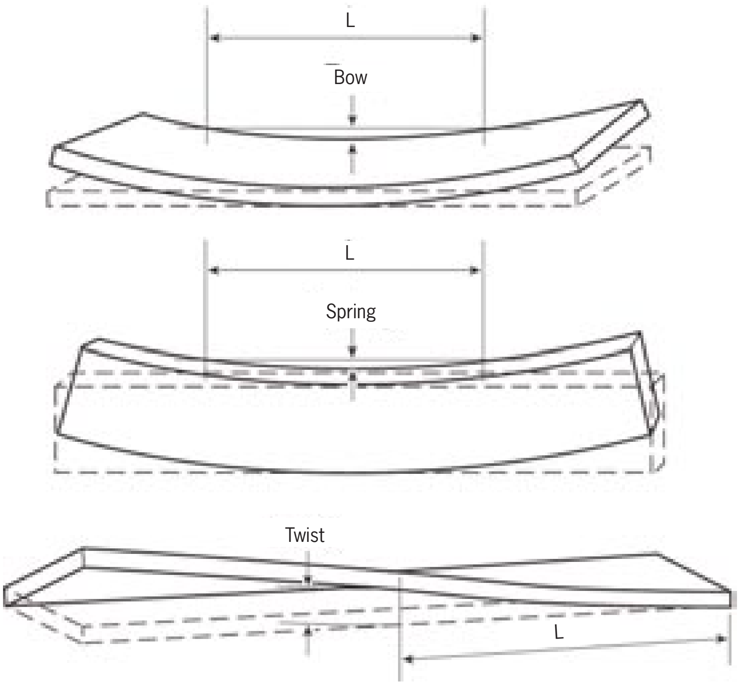


Figure 9 Types of timber distortion

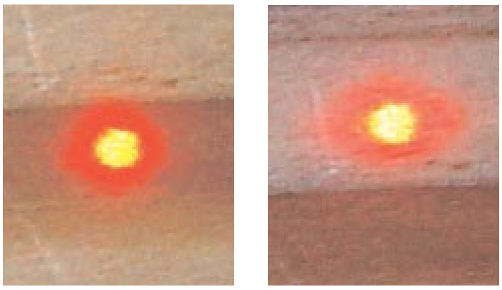


Figure 10 Laser halo in compression wood (left) and normal wood (right)

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British Standards

BS 4978:1996 Specification for visual strength grading of softwood
BS 5268-2:2002 Structural use of timber. Code of practice for permissible stress design, materials and workmanship
BS 5756:1997 Specification for visual strength grading of hardwood
BS EN 338:2003 Structural timber. Strength classes
BS EN 518:1995 Structural timber. Grading. Requirements for visual strength grading standards
BS EN 519:1995 Structural timber. Grading. Requirements for machine strength graded timber and grading machines

Draft European Standards

prEN 14081-1 Timber structures. Strength graded structural timber with rectangular cross section. Part 1: General requirements
prEN 14081-2 Timber structures. Strength graded structural timber with rectangular cross section. Part 2: Machine grading. Additional requirements for initial type testing
prEN 14081-3 Timber structures. Strength graded structural timber with rectangular cross section. Part 3: Machine grading. Additional requirements for factory production control
prEN 14081-4 Timber structures. Strength graded structural timber with rectangular cross section. Part 4: Machine grading. Grading machine settings for machine controlled systems

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