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LOG MERCHANDISING
INCORPORATING 3D X-RAY SCANNING

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EXECUTIVE SUMMARY

The TOMOLOG X-ray scanner, produced by MiCROTEC of Italy, was first commissioned in European wood processing plants in 2001. The long awaited ability to scan logs internally is creating a sea-change improvement in value realisation for the forest industry. X-ray scanning of logs internally has become the catalyst for construction of over 26 forest and sawmill based merchandising yards manufactured by Springer, installed in Europe and South America. These merchandising yards are creating segregations of up to 84 log grades based on external and internal log qualities. Not only is such segregation optimising both appearance and structural log grades, resulting in a better match of log to end product, but the log uniformity created within the log batches is resulting in; increased timber conversion, substantially faster timber processing, and increased sawmill profitability. Annual sawn out-turn of over 800,000 m³ is common place with sawmills associated with many of these merchandising yards, twice that of previous production. The installation of merchandising yards is also being driven by lower costs enabling lower economy of scale, benefits of stems versus traditional harvesting, and transport of 18m long stems on public highways. X-ray evaluation of radiata pine logs has been undertaken with success. Application of X-ray internal log scanning of radiata pine in association with MiCROTEC optical scanners and sonic technologies can have similar value gains as that experienced in Europe and South America when incorporated into a forest or sawmill based merchandising yard. Such log segregation will be based on; branch size, internode length, pruned knotty core size & position, stiffness, density, resin pockets, birds-eye & needle fleck, sinuosity and taper.
X-RAY LOG SCANNER TOMOLOG

Introduction

The TOMOLOG X-ray log scanner was developed by MiCROTEC of Italy and first installed for commercial application in the year 2001. The scanner can be applied as a single, double or treble source, depending on the application required. The X-ray scanner is contained in lead covered housing for required safe operation.

TOMOLOG has been developed for the European log processing industry to produce a realistic transparent 3D image of the log with a longitudinal conveyer speed of up to 200 meters per minute. The result is an image showing the exact position and dimensions of branches, knotty core, and defects. These internal wood characteristics are detected based on the gradient of wood density present. The denser the wood, the lower the X-ray transparency. The data are processed by the optimising computer to produce an exact 3D model of the log.
Layout of the TOMOLOG X-ray system
Two-source X-ray TOMOLOG scanner operating in Hasslacher Drauland Holzindustrie’s merchandising yard, Austria.

Internal wood characteristics are detected based on the gradient of wood density present as shown on this radiata pine X-ray image. Density in this image is shown to range from the early wood associated with the annual rings in the core, of approximately 100 kg/m$^3$ to the high density outer wood up to 500 kg/m$^3$. 
Application of **TOMOLOG** in Europe

The application of **TOMOLOG** in Europe is largely for the purpose of segregating logs in merchandising yards based on the following parameters and accuracy:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>up to 0.8 mm</td>
</tr>
<tr>
<td>Branch size</td>
<td>+ - 5 mm</td>
</tr>
<tr>
<td>Internode length</td>
<td>+ - 5 mm</td>
</tr>
<tr>
<td>Wood density</td>
<td>+ - 1kg/m³</td>
</tr>
<tr>
<td>Foreign objects</td>
<td></td>
</tr>
</tbody>
</table>

In Europe detection of foreign objects in logs (largely shrapnel resulting from wars) is an application of **TOMOLOG**.

A two-source **TOMOLOG** X-ray image (X & Y planes) enables internal log qualities to be identified including branch size, internode length, wood density, heartwood and sapwood.

The primary timber species being processed in countries such as Austria where **TOMOLOG** is in use, is spruce, commonly around 150 years of age. While some log diameters range up to 85cm, the average log diameter of approximately 30 cm SED is similar to Chilean radiata pine but obviously smaller than most New Zealand radiata pine. This smaller log size means that most of the European log resource can easily be scanned by the current 500 mm diameter limit of **TOMOLOG** based. However recent improvements in X-ray scanning technology developed by MiCROTEC is likely to result in large logs being successfully scanned.
The primary application of TOMOLOG is to segregate logs based on internal quality along with true shape scanning and surface based digital imagery called SCREENLOG. European merchandising yards commonly segregate up to 84 sorts or log batches based on external and internal quality characteristics. Each batch is homogeneous and the difference between batches including log size is small. Such segregation enables greatly accelerated volume through-put with sawing speeds of up to 140m/minute. Uniform log sizes with homogeneous internal qualities are feed end-to-end into profilers and saws applying the same sawing pattern. Because the difference between the log batches is small, change over time for re-setting saws is a maximum of 10 minutes. Log conversion to sawn lumber is commonly required to meet a minimum of 60%. Such sawmills commonly have daily log throughput of 5,500 m³ resulting in 1.25 million m³ of log throughput or over 800,000 m³ of timber out-turn annually. Segregation and sawing of logs based on both external and internal characteristics also enables better matching of log quality to customer and end product requirements.

150 year-old spruce logs ready for X-ray scanning and segregating in a sawmill-based merchandising yard.

European merchandising yards are commonly used to segregate logs up to 84 batches.
The benefits of stems versus traditional harvesting along with transportation of 18m long stems on public highways throughout much of the forestry world are two of the factors influencing investment in Log Merchandising Yards.
Log batches produced using X-ray scanning contain uniform internal and external characteristics.
European log batches containing homogenous exterior and interior characteristics enables accelerated sawn timber out-turn of over 800,000 m$^3$ annually.
European log batches containing homogenous exterior and interior characteristics also enables a better match to customer and end product demands.
FIRST VALIDATION OF TOMOLOG X-RAY SCANNING FOR RADIATA PINE

In 2004 the first validation of the TOMOLOG X-ray scanner based on radiata pine was carried out by Forestal Mininco S.A., Chile. Fifteen pruned logs with a maximum SED of 420 mm were flown to an Austrian sawmill where they were X-ray scanned. Scanned images were compared with the actual size and position of the knotty core based on destructive sampling methodology.

Results showed that TOMOLOG was able to adequately scan the knotty core and the software was able to interpret it.

Radiata pine pruned log X-ray scanned image at 120m/min showing pruned knotty core.
Chilean pruned radiata pine logs being destructively sampled to quantify the size and position of the knotty core following X-ray scanning.

Software was able to be applied to the scanned image for the purpose of defining the size and position of the knotty core, and applying the optimum sawing solution.
The X-ray image of pruned logs is interpreted by the software to apply a precise quality description for each pruned log relating to exterior shape, size and position of the defect core.
APPLICATION OF TOMOLOG X-RAY SCANNER IN A RADIATA PINE MERCHANDISING YARD

A key application of the TOMOLOG X-ray scanner is in a merchandising yard, processing full or partial length stems. The advantages of such technology are:

   a) By combining stem shape, surface based imagery and internal stem quality, optimum log-grade out-turn can be achieved using bucking algorithms.

   b) By combining stem shape with the internal log characteristics, quality of each pruned and unpruned log can be precisely quantified based on; knotty core size and position, branch size, internode lengths, and strength & stiffness, ensuring that logs are precisely matched to sawmill and end product requirements.

   c) Scanned pruned logs can be segregated based on true shape and internal characteristics enabling high speed batch sawing as practiced in Europe, if desired.

   d) Use of a benign ID tag inserted into pruned logs can also act as reference point for the scanned image, and automated wood processing.

   e) Pruned and unpruned logs with known internal qualities will remove processing risk and enable ease of pricing, on an individual log basis if desired.

   f) Merchandising yards may become forest warehouses where growers are paid on log quality delivered and wood processors purchase logs of precise quality.
A primary use of the TOMOLOG X-ray scanner is in merchandising yards to optimise both appearance and structural log grade out-turn.

The potential value gains of knowing the individual log internal defect recognition for pruned logs.
The benefits of scanning for internal defect recognition are clearly significant. While the absolute log values in the Table above, may not be precise, the relative potential gains based on internal defect recognition of pruned logs are shown to be large.

The specific advantage of TOMOLOG X-ray scanner in a pruned log sawmill will be its application to precisely identify the edge of the knotty core and apply a sawing pattern to maximise clearwood recovery (as shown below). A detailed explanation of the current methodology to describe pruned log quality and potential for further value gains associated with individual internal log description using TOMOLOG is presented in Appendix I.

APPLICATION OF TOMOLOG X-RAY SCANNER FOR SEGREATION OF INTERNODAL LOGS

The TOMOLOG X-ray scanner is commonly used in merchandising yards for the segregation of internodal logs. Spruce, unlike radiata pine, does not have distinctive branch whorls as shown in the single source X-ray image below. However internodes are identified which contain only very small branches. Such internodes are used for window and door etc components or recovery of blanks for finger jointing.

Application of X-ray scanning to segregate internodal logs of radiata pine is anticipated. While TOMOLOG may be constrained by the very large diameter logs, the expectation is that recognition of the outer wood only will be sufficient to enable identification of the whorls and subsequent segregation.
TOMOLOG X-ray scanner is commonly used for segregation of internodal logs.
The X-ray image of unpruned logs is interpreted by the software to apply a precise description of branch size, whorl depth and internode length.
APPLICATION OF TRUE SHAPE AND SCREEN-LOG OPTICAL SCANNER FOR SEGREGATION OF LOGS CONTAINING RESINOUS CHARACTERISTICS, BIRDS-EYE & NEEDLE FLECK

While the TOMOLOG X-ray scanner is ideal for segregation based on branch characteristics, at high throughput speeds its ability for recognition of resinous characteristics, and birds-eye & needle fleck is unlikely. Identification and segregation for logs containing these defects in appearance grade end-use will be obtained using the following MiCROTEC technologies.

Detailed true shape scanning is achieved using an optical scanner containing 8 cams as shown above.
The result of true shape scanning is a detailed image as that shown above displaying the exact shape and texture of the log.
The digital log product produced by MiCROTEC called SCREENLOG is based on high resolution colour imagery taken at a speed of up to 240 m/min. This 360 degree 3D image is then rapped around the detailed true shape image as shown above. The representation is photo realistic and corresponds with the original log down to the smallest detail as shown in the images above. Furthermore, the 360 degree image can be unzipped as shown below.

The digital image together with the corresponding log data (including X-ray) permits precise screening and log segregation. SCREENLOG is installed in all the merchandising yards established by Springer and Microtec to date.

The combination of precise DiSHAPE and SCREENLOG precision images of stems and logs enables subsequent application of bucking and sorting solutions.

The SCREENLOG technology also has application for identification of logs containing resin pockets and birds-eye & needle fleck based on their respective
under-bark characteristics clearly displayed on the stem surface of radiata pine as shown below.
The use of SCREENLOG as a means of recognising and segregating of logs containing pitting (see above) associated with Type 2 & 3 resin pockets will result in considerable gains for appearance grade processing.

Furthermore the use of SCREENLOG as a means of recognising and segregation of logs containing birds-eye and needle fleck (see symmetrical pattern originating from
stem needles contained on the segregated stems above) will also result in considerable gains for appearance grade processing of radiata pine.
Microtec’s product called ViSCAN for measuring timber stiffness is based on optical vibration measurement from the devise shown below and density determined by X-ray. The stand alone ViSCAN unit is incorporated into merchandising yards for the assessment and segregation of logs for stiffness.

ViSCAN uses a hammer and the precision of a laser to assess log stiffness for segregation of structural logs.

Oscilloscope trace of the vibration signal
Fourier analysis of the vibration signal showing resonant frequencies.

MERCHANDISING YARDS

Over 26 merchandising yards have been constructed by SPRINGER throughout Europe and South America (see reference list below). Each merchandising yard commonly incorporates the following technologies; true-shape scanner, SCREENLOG, TOMOLOG X-ray scanner, and ViSCAN for segregating logs for strength and stiffness. Each merchandising yard incorporates log sorting bins ranging in number from 22 to 84, with annual through-put ranging from 50,000 to 1,200,000 m³.

A typical merchandising yard layout is shown below.

The following is a Reference list of merchandising yards manufactured and installed by SPRINGER, incorporating Microtec’s TOMOLOG X-Ray scanner and other technologies.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Website</th>
<th>Through-Put</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ante</td>
<td>Germany</td>
<td><a href="http://www.ante.de">www.ante.de</a></td>
<td>400,000 m³</td>
</tr>
<tr>
<td>Binder Holzindustrie</td>
<td>Austria</td>
<td><a href="http://www.binderholz.at">www.binderholz.at</a></td>
<td>800,000 m³</td>
</tr>
<tr>
<td>Binder Kösching</td>
<td>Germany</td>
<td></td>
<td>1,000,000 m³</td>
</tr>
<tr>
<td>Egger</td>
<td>Austria</td>
<td></td>
<td>50,000 m³</td>
</tr>
<tr>
<td>Hasslacher</td>
<td>Austria</td>
<td><a href="http://www.hasslacher.at">www.hasslacher.at</a></td>
<td>700,000 m³</td>
</tr>
<tr>
<td>Heggenstaller</td>
<td>Germany</td>
<td><a href="http://www.heggenstaller.de">www.heggenstaller.de</a></td>
<td>600,000 m³</td>
</tr>
<tr>
<td>Hoeve Forest</td>
<td>United Kingdom</td>
<td></td>
<td>350,000 m³</td>
</tr>
<tr>
<td>Karl &amp; Huber</td>
<td>Austria</td>
<td><a href="http://www.k-h.at">www.k-h.at</a></td>
<td></td>
</tr>
<tr>
<td>KFT</td>
<td>Germany</td>
<td><a href="http://www.kft.de">www.kft.de</a></td>
<td>1,200,000 m³</td>
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<td>KNT</td>
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<td><a href="http://www.knt.de">www.knt.de</a></td>
<td>1,300,000 m³</td>
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<td>KHS</td>
<td>Germany</td>
<td></td>
<td>1,000,000 m³</td>
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<td>Klenk</td>
<td>Germany</td>
<td><a href="http://www.klenk.de">www.klenk.de</a></td>
<td>1,500,000 m³</td>
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<tr>
<td>Kogler</td>
<td>Austria</td>
<td><a href="http://www.kogler.at">www.kogler.at</a></td>
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<td>Mayr Melnhof</td>
<td>Austria</td>
<td><a href="http://www.mrm-holz.at">www.mrm-holz.at</a></td>
<td>1,100,000 m³</td>
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<tr>
<td>Offner Holzindustrie</td>
<td>Austria</td>
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<tr>
<td>Samonig</td>
<td>Austria</td>
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<td>Stora Enso Timber</td>
<td>Brand / Austria</td>
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<td>Stora Enso Timber</td>
<td>Planca / Tschechien</td>
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<td>Austria</td>
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<td>Steyremühl</td>
<td>Austria</td>
<td><a href="http://www.steyremuehl.at">www.steyremuehl.at</a></td>
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<tr>
<td>Schwörer Haus</td>
<td>Germany</td>
<td><a href="http://www.schwoerer.de">www.schwoerer.de</a></td>
<td></td>
</tr>
<tr>
<td>Schweighofer</td>
<td>Sebes / Romania</td>
<td><a href="http://www.schweighofer.de">www.schweighofer.de</a></td>
<td>1,100,000 m³</td>
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<tr>
<td>Terranova Group</td>
<td>Chile</td>
<td><a href="http://www.terranova.cl">www.terranova.cl</a></td>
<td>250,000 m³</td>
</tr>
</tbody>
</table>
SAMONIG
AUSTRIA

Annual capacity 800,000 cubic meter logs
Log lengths 3.0 – 14.0 meters
78 sorting bins
1 crosscut saw, 1 butt end reducer
1 debarker
APPENDIX I

Quality index for pruned logs:

A Pruned Log Index (PLI) for sawlogs and Clear Veneer Potential (CVP) index for peeler logs was developed by Jim Park in 1989 and 1999 respectively. Both indices are based on log size, log shape and size of defect core using different mathematic expressions for calculation as shown below. PLI uses a scale of 1 to 10, whereas CVP uses a scale of 10 to 70.

\[
\text{PLI} = \left(\frac{D_{1.3} - DC}{10}\right)^{0.5} \times \left(\frac{D_{1.3}}{DC}\right) \times \left(\frac{C_{\text{vol}}}{L_{\text{vol}}}\right)^{1.6}
\]

\[
\text{CVP} = \left(\frac{R_{\text{vol}} - P_{D\text{Cvol}}}{L_{\text{vol}}}\right) \times 100
\]

Where

- \(D_{1.3}\) = diameter (mm) under bark 1.3 m from the butt end
- \(DC\) = defect core diameter (mm)
- \(C_{\text{vol}}\) = volume of common wood (m\(^3\))
- \(L_{\text{vol}}\) = under bark log volume (m\(^3\))
- \(R_{\text{vol}}\) = perfect cylinder volume based on the minimum radius from the log central axis (m\(^3\))
- \(P_{D\text{Cvol}}\) = vol of peeler defect core volume based on the radius of the longest pruned branch stub and associated occlusion (m\(^3\)).

Input variables to calculate PLI are obtained via cross sectional destructive sampling or by sawing assessment at the time of pre-harvest.

Both indices are well correlated with clearwood recovery based on board grades and veneer grades respectively. Furthermore PLI and CVP have a strong relationship with net log value regarding production costs and market prices.
Relationship between PLI and net log value and PLI and clear lumber recovery.

Most pruned logs have a strong and direct relationship between PLI & CVP, except for those logs with displaced defect cores.
**Fig.** Relationship between PLI and CVP

Relationship between PLI and net log value for peeler & sawlogs.

\[ y = 8.8539x - 4.5473 \]

\[ R^2 = 0.8049 \]
3.1.2 Quality index for unpruned logs.

Meneses M. & Guzman S. (2002) developed an index for unpruned logs based on Internode Index, called Largo de Internudo Base (LIB). This index is defined as “50% of the log length contains internodes of a length equal or greater than LIB”.

\[
\text{LIB} = \left( \frac{\sum (\text{IL} => b)}{\text{LL}} \right) \times 100
\]

Where

- IL = Internode length
- LL = Log length
- B = 0.2m to 1.6m

Low LIB means shorter internodes for finger joint lumber recovery to maximise production of blanks. High LIB means longer internodes with high potential for shop lumber recovery to maximise door and windows clear cutting components. Several mathematic models have been fitted by Meneses & Guzman (2002, 2006). Stand input data is obtained by measuring the internode lengths of either standing or felled trees.

![Graph showing the relationship between LIB and recovery of Shop2 & better.](image)

Fig. Relationship between LIB and recovery of Shop2 & better.

While stands can be assessed to determine an average PLI, or segregated into PLI grades, the relationship with clearwood recovery is only moderately high. But without the detailed knowledge of the size and position of the defect core on an individual log basis, application of a sawing pattern to achieve the best clearwood recovery will continue to be a guesstimate.
\[ y = 0.1309x - 0.0349 \]
\[ R^2 = 0.2797 \]

\[ y = 5.8852x - 9.6572 \]
\[ R^2 = 0.6914 \]