Timber Quality Assessment

This Guidance Note is one of a series summarising information presented at a seminar on "Improved Conifer Timber Quality through Plant Selection and Silviculture", held in February 2009 as part of FC Scotland's Timber Development Programme. It reviews the benefits of measuring timber quality, describes methods that are available and discusses the integration of timber quality assessment with forest operations. The presentation itself, which was delivered by Barry Gardiner of Forest Research, is available for download through the seminar web page.

Introduction

There is an increasing requirement for reliable information about the quantity and quality of timber that will be available from forests over time. This type of resource evaluation informs the wood processing industry's strategic investment and marketing decisions, and supports the sustainable management of forests. Measurement of timber quality characteristics can enhance (or at least maintain) value for the seller, whilst minimising risk to the purchaser. To help ensure that timber is allocated to the optimal end-use for its characteristics, the term "precision forestry" has been defined (Ackerman, 2006):

"Precision forestry uses high technology sensing and analytical tools to support site-specific, economic, environmental, and sustainable decision-making for the forestry sector supporting the forestry value chain from bare land to the customer buying a sheet of paper or board."

In this guidance note we describe methods for the assessment of recoverable volume from standing trees and for the measurement of timber mechanical properties in trees and logs. We consider how these techniques can be integrated with forest operations.

Recoverable Volume

Forest mensuration techniques that are used to estimate timber volumes in conifer stands (e.g. Matthews and Mackie, 2006) are based on a sample of measured tree dimensions and an assumed rate of taper. They are not generally able to account for additional factors that affect product recovery such as stem straightness and branch size. Improved estimates of recoverable volume and product mix can be obtained either from direct measurements of these characteristics on a sample of standing trees or through the use of terrestrial or airborne laser scanning technology.

Stem Straightness and Branching Assessment

A stem straightness scoring system, based on a visual assessment of straight log lengths in the lower 6 metres of the stem of standing trees, was developed and tested for use in Sitka spruce (Macdonald *et al.* 2001, 2009a). The straightness scores allocated were shown to be correlated with the out-turn of higher value "green" category sawlogs, identified according to specifications for log dimensions, log straightness, knot size and knot number (Forestry Commission, 1993). Extensive surveys of stem straightness in Sitka spruce growing in Britain were undertaken between 1999 and 2002 (Mochan *et al.* 2001, 2002; Stirling *et al.* 2000), and statistical models developed to allow prediction of stem form from site and stand information.

More recently the use of the stem straightness scoring system has been extended to Scots pine and a measure of branchiness added to improve log grade out-turn predictions. The height of the lowest dead branch is commonly used as an index of Scots pine timber quality in Scandinavia (e.g. Uusitalo, 1997). Trials of this measurement in Scotland showed that a combined assessment of stem straightness score and height of lowest dead branch could be used to estimate the proportion of green sawlog material in an individual tree (Macdonald *et al.*, 2009b).

Terrestrial Laser Scanning

Terrestrial Laser Scanning (TLS) can be used to make stand level assessments of the number of trees, tree diameters, tree heights, crown shape, stem profiles and stem and branch quality related attributes (Keane, 2007). Forest Research has worked with Treemetrics Ltd to evaluate the potential in Britain for deriving stem straightness scores from TLS data and to develop taper functions that will improve stem profile modelling above the height assessed directly by laser scanning (Fonweban *et al* 2008a). The Autostem™ software developed by Treemetrics can be coupled with harvester optimisation software programmes to simulate the cutting of different product mixes from a stand that has been scanned, enabling the forest manager to test alternative strategies and maximise value recovery.

Airborne Laser Scanning (LIDAR)

Airborne LIDAR can provide valuable forest resource information on tree heights, crown width, number of trees, stem diameters, stand volume, and forest biomass (Suarez *et al.*, 2005). Forest Research has recently started to evaluate the potential for using data obtained from LIDAR assessments as inputs to timber quality models predicting stem straightness and wood properties. Preliminary results suggest that this approach offers significant potential as a means of making strategic assessments of timber quality in the standing forest resource (Fonweban *et al*., 2008b).

Mechanical Properties of Timber

The techniques and tools used to assess recoverable timber volumes provide no information about the performance of the final product. For sawn timber that is destined for use in construction, a key market for softwood in Scotland, timber stiffness is the single most important characteristic, generally determining the strength class to which material is allocated (according to BS EN 338:2003). The softwood strength classes range from C14 (weakest) to C50. Timber from conifers grown in the UK can typically attain or exceed C16, the minimum strength class most commonly used for general construction. However, since wood properties vary between and within stands, trees and logs, up to 10% of, for example, sawn spruce timber currently fails to meet the minimum requirements of the C16 strength class. Downgraded timber is sold at a lower price for alternative non-structural uses, increasing operating costs and reducing value recovery.

In order to reduce the proportion of timber that fails to meet the requirements of a particular strength grade, a means of identifying the trees and logs which are likely to produce structural timber is required. The earlier in the wood supply chain material can be segregated, the more options there are for directing it towards an appropriate end use – based on its properties and the prevailing market requirements.

Acoustic Tools

A number of portable instruments have been developed to measure the wood stiffness of standing trees, logs and sawn timber using acoustic technology. These instruments measure the speed at which an induced sound (stress) wave travels through a sample of wood, which is proportional to its stiffness. Two acoustic techniques can be used:

1. The time-of-flight method, which is used on standing trees. This measures velocity by timing an acoustic wave between two probes set a known distance apart in the outer wood of a standing tree. A number of hand-held tools that use this method are available and trials of a prototype harvester-mounted acoustic tool for use on standing trees is underway. This latest development would allow cross-cutting decisions to be guided by information about an individual log or tree timber stiffness.

2. The resonance method, which is used on cut logs and sawn timber. The end of a cut log or sawn batten is tapped with a hammer to induce a sound wave which travels back and forth, resonating strongly at various frequencies. The speed of the sound wave is deduced from its frequency and the length of the log or batten. This techniques can be used to assess and sort logs using hand-held tools or using an online system integrated in the log sorting line of a sawmill. Systems for grading sawn timber based on the acoustic resonance method are also available.

Further details about the range of acoustic tools available can be found in Mochan *et al.* (2009).

Recent work by Forest Research and Napier CTE, in collaboration with the UK forest industry, has shown that acoustic technology is a potentially useful method of identifying trees and logs with higher wood stiffness (Auty and Achim, 2008; Lyon *et al.* 2007; Macdonald *et al.*, 2009; Mochan *et al.*, 2007).

Operational Use of Timber Quality Assessment Methods

If the techniques outlined above are to be of value in the sorting and allocation of timber to the optimum end-use, they need to be integrated as far as possible with operational procedures.

Pre-harvest stem straightness and branching assessment carried out as part of a normal volume assessment (e.g. an abbreviated tariff), using the same sampling intensity and plot layout, will provide an indication of potential product breakout in terms of green log yield.

Sorting using acoustic tools offers a means of segregating out trees or logs with inferior stiffness and improving the recovery of higher strength class sawn timber suitable for more demanding structural applications. For example a recent study of three Scots pine stands showed that if all logs with a stress wave velocity of less than 3.1 km s-1 were removed from the population, then the characteristic values of strength and stiffness were sufficient for the timber to meet the requirements for the C22 strength class, compared to the unsorted population which was graded as C20 (Macdonald et al., 2009). Only 20 logs (12.5% of the population) were removed using this criterion. In order to achieve the requirements of the C24 strength class however, the threshold velocity needed to be set at 3.45 km s-1 and approximately 65% of the logs would be rejected. A similar analysis undertaken using acoustic measurements made on the standing trees showed that it was possible to meet the requirement for the C22 strength class by removing those trees with an ST-300 velocity less than 4.5 km s-1 from the population. A total of 30 trees (33% of the population) failed to meet this velocity threshold.

Although screening using the standing tree acoustic assessment was not as efficient as sorting on the basis of log measurements, it does have the advantage of allowing roundwood products to be cut to length in accordance with an intended end-use. This reflects the fact that in general if a measurement is made earlier in the wood-chain, there is more flexibility in the decision making, but a weaker correlation with final product performance.

Over the past 18 months Forest Research has worked with colleagues in Forest Enterprise Scotland and Wales to trial the integration of timber quality assessment methods with operational pre-harvest assessments. Stem straightness was assessed on 150-300 trees prior to felling, and acoustic velocity measured on 350-500 logs at roadside. Results have been mapped and predicted product breakout compared with actual volume recovery measured by the harvester. Initial indications of the cost of integrating these additional measurements are in the region of £0.05/m^3 of harvested timber.

Conclusions

- There is a large variation within and between stands in the stem straightness and branching characteristics of standing trees and in the acoustic properties of timber cut from these trees;
- Estimated green log yield per tree can be predicted from measurements of stem straightness score and, for Scots pine, the height of lowest dead branch on standing trees;
- Innovative laser techniques offer the opportunity for strategic level assessments of timber volumes and quality (using airborne LIDAR) and more detailed stand level pre-harvest assessments (using terrestrial laser scanners);
- Sawn timber stiffness can be predicted from acoustic velocity measurements made on standing trees or on cut logs;
- Trees and logs can be segregated according to acoustic velocity, in order to remove inferior material and improve the recovery of higher strength class sawn timber;
- Future research developments in this area will focus on:
  - Building systems that utilise stem straightness scoring, branching assessment and acoustics to more accurately predict product outturn and product performance.
  - Using tools to determine optimum log cross-cutting, log allocation, tree/log selection, logistic solutions, and optimized wood-chain operations.

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