Listen to what the trees are saying…

Wood quality assessment at the speed of sound!

Selected for the Royal Society's
SUMMER SCIENCE EXHIBITION 07

Exhibitors:

Mr Dave Auty, Professor Barry Gardiner, Ms Elspeth Macdonald, Mr Shaun Mochan and Mr Steve Osborne, *Forest Research Agency, Edinburgh;* **Dr John Moore, Mr Andrew Lyon, Mr Roddy Mackenzie,** *Centre for Timber Engineering, Napier University, Edinburgh;* **Mr Peter Carter and Mr Greg Searles,** *FiberGen, New Zealand;* **Dr Alexis Achim,** *Laval University, Canada;* **Mr Paul Mclean,** *University of Glasgow*

Background

Wood is a versatile, beautiful and sustainable building material which, because of growing environmental awareness, is increasingly being chosen by architects for modern construction projects:

"Scientists at Forest Research and its partner institutions are finding ways to reduce waste and increase efficiency in the UK forest industry. Much of the industry produces wood for the construction of new homes, but not all trees are up to the task. Timber shows a large degree of variation from one tree to another, meaning that some trees are simply not good enough to build your new house".
Professor Barry Gardiner, Forest Research

The problem

Figure 1: *Construction of new houses requires good quality timber, but the quality is often unknown until the trees have been processed*

Wood produced from sustainably managed forests in the United Kingdom is increasingly used by the construction industry for new buildings. Before it can be passed 'fit-for-purpose' for different end-uses, wood must meet strict quality standards for both strength and stiffness. Due to the inherent variability of wood and the fact that trees are normally processed in a sawmill before timber is graded, a proportion of processed timber fails to meet these standards. Because it is already cut, this rejected wood is sold at a lower price for other uses, such as pulp or packaging. Such inefficiency increases the cost of processing (including heat wasted in kiln-drying unsuitable wood) and the cost of unnecessary transportation to inappropriate sawmills. All of which has negative environmental, social and economic consequences for the forest industries, rural communities and society as a whole.

Why this matters

As part of the global sustainability agenda, most governments have policies aimed at reducing greenhouse gas emissions. In Scotland, the forestry sector is committed to achieving annual savings of 1million tonnes of CO2 by 2020. A large part of this will be 'locked up' by the growing forests, but reducing the distances travelled by unprocessed wood ('timber miles' – similar to the more familiar 'food miles') can still make a significant contribution to this target.

A practical solution

The capacity of wood to transmit sound and produce beautiful music has long been appreciated. Now, recently developed technologies can measure wood properties in a non-destructive manner using the speed at which sound travels through logs and trees. Such measurements can be made on trees in the forest or logs at roadside. This means wood can be sent directly to the appropriate sawmill, increasing the efficiency of the timber supply chain and significantly reducing the carbon footprint of this multi-billion pound industry.

Figure 2: *Acoustic tools can help increase efficiency in forest industries by allowing us to segregate poor quality material before processing*

Further information

Forest Research
www.forestresearch.gov.uk

Centre for Timber Engineering/SIRT
http://cte.napier.ac.uk/SIRT/

Fibre-Gen
www.fibre-gen.com/

Laval University
www.ffg.ulaval.ca/

Glasgow University Chemistry Department
www.chem.gla.ac.uk/

Scottish Forestry Strategy
www.forestry.gov.uk/forestry/INFD-6AGGZW

Scottish Executive – Climate Change
www.scotland.gov.uk/Topics/Environment/Climate-Change/16327

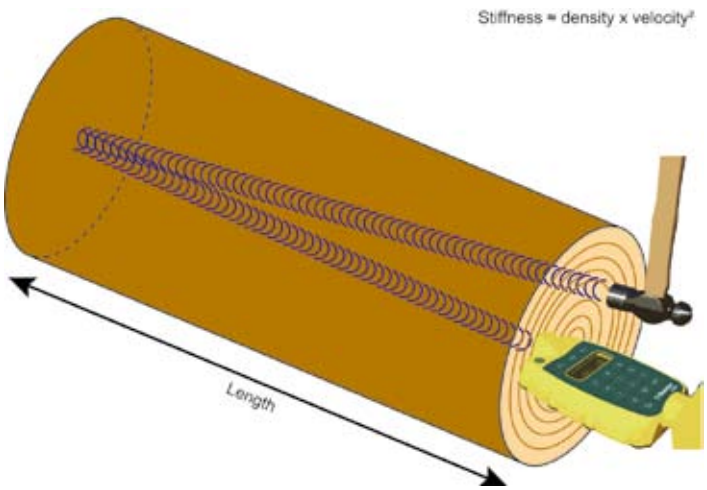

Figure 3: *Resonance method: we deduce the speed of a sound wave by examining its frequency. The speed is directly related to the stiffness of the wood*

The science behind our research

"It is difficult to tell if a tree is suitable for producing construction quality timber simply by looking at it… we have to listen to it as well!"
Dr Alexis Achim, Laval University

So how do we relate the speed at which sound travels through wood to key properties such as stiffness? We rely on a fundamental physical relationship that seems to hold for all materials:

Stiffness = density x velocity^2

Or: MoE = ρV^2

Where MoE is the modulus of elasticity (stiffness) of the tree or log (N m^{-2}), ρ is the wood density (Kg m^{-3}) and V is the speed of sound (m s^{-1}).

Given the density of standing trees and freshly cut logs is fairly constant, we can relate sound velocities directly to stiffness.

There are two main acoustic techniques that we can use to assess wood properties, the resonance method and the time-of-flight method.

For the resonance method we induce a sound wave in a cut log with a hammer tap, which then travels back and forth, resonating strongly at various frequencies. The frequency of this wave corresponds to the number of times it goes back and forth in a second. Because we know the length of the log, we know how far the wave has travelled during that time so we can deduce the speed. Since this method requires a cut surface to reflect the sound wave, it is not suitable for use in standing trees. We can assess these using the time-of-flight method instead, which measures velocity by timing an acoustic wave between two probes set a known distance apart in the outer wood of the tree.

Both methods are being thoroughly evaluated by comparing results with those obtained from destructive techniques such as traditional bending tests. This has shown that acoustic testing is a reliable way to assess timber quality and a valuable tool for forest managers and industry personnel.

Practical implications for the forestry sector

These techniques allow for a non-destructive assessment to be made before the tree is allocated to a particular use, whereas previously it was only possible to determine the stiffness and strength of wood after a tree had been processed. By using acoustics to screen out the poorest quality trees and logs, we can improve the efficiency of the wood supply chain by sending this wood to sawmills dedicated to non-construction grade timber. This has huge potential to have a positive impact on the sale and marketing of timber while minimising the social and environmental impacts of timber transport and processing.

Opportunities for further research

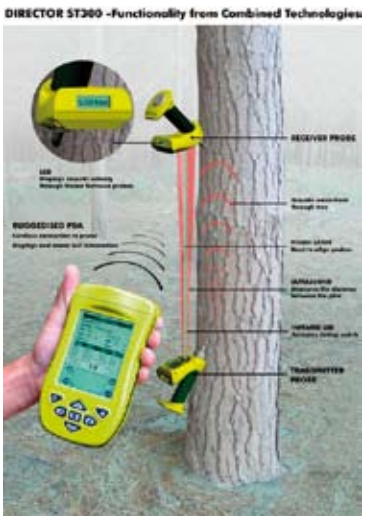

Figure 4: *Time-of-flight method: Here we measure the speed of sound directly in the outer 2-3cm of wood in the standing tree.*

The use of this technology in British forestry is in its infancy, but is growing rapidly. The methods which make the best use of the techniques are currently being tested and implemented by researchers, with guidance from the forest industry. As the acoustic tools develop they will become more accurate, and will eventually be deployed on forest harvester machines so that timber quality can be assessed as the tree is felled, keeping the UK forestry sector at the forefront of sustainable forest management practice.