Acoustic Velocity measurements of Oak – Do these assist in detecting shaken stems?

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Summary
A possible means of estimating vessel sizes quickly and accurately in oak trees would be a great asset to tree breeders. Trees with large earlywood vessels could then be removed from breeding programmes as their progeny would be predisposed to a serious defect, shake (especially on traditionally shake-prone sites). This study aimed to determine whether measurements of acoustic velocity might discriminate between trees with large vessels and those with small ones. The results proved to be completely negative.

Introduction
A problem that has always faced oak growers in Britain is that many trees become shaken, meaning that internal splits develop in the stem that are undetectable until the trees are felled, normally at the end of rotations of up to 150 years (see Fig. 1). The timber is consequently degraded and may even fall apart when sawn making it suitable only for low-value purposes such as firewood. It would clearly be a great advantage to be able to identify trees that are liable to be shaken quickly and cheaply. The value of shaken timber can be less than 15% of that of sound timber.

Forest Research (FR) is currently investigating the potential for using acoustic tools to detect for shake in hardwoods (see Fig. 3). These devices measure the speed of a stress wave (or acoustic velocity) between two probes and have been used for some time to estimate stiffness as a desirable timber property in conifers. Preliminary trials have indicated that there may be a correlation between the velocity of longitudinal stress waves and the presence of shake defects in standing oak. It was decided by the Future Trees Trust (FTT) and FR's Tree Improvement Programme organisers to investigate the use of these devices to detect trees with large-diameter earlywood vessels, which are known to predispose trees to shake (Savill, 1986).

Study trees were selected from individuals previously identified for the FTT oak plus tree selection, prior to starting a breeding programme. These trees had already been analysed for vessel diameter, thus enabling a sample including tree with both smaller and larger known vessel diameters to be tested using the acoustic technique. Trees were assessed along the grain (vertically) at each cardinal compass point between probes located at 80 cm and 180 cm above ground level. They were also measured across the grain (horizontally) at 1.3 metres above ground level, taken from north to south. One probe, which acts as a transmitter is tapped with a hammer and the second probe acts as a receiver. Both probes are connected to a timer which measures the delay between tapping and receiving in milliseconds. Time is later converted to velocity by calculation,

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from a known distance between the probes (1 metre for the vertical reading, and from the measured mean diameter at breast height for the horizontal one).

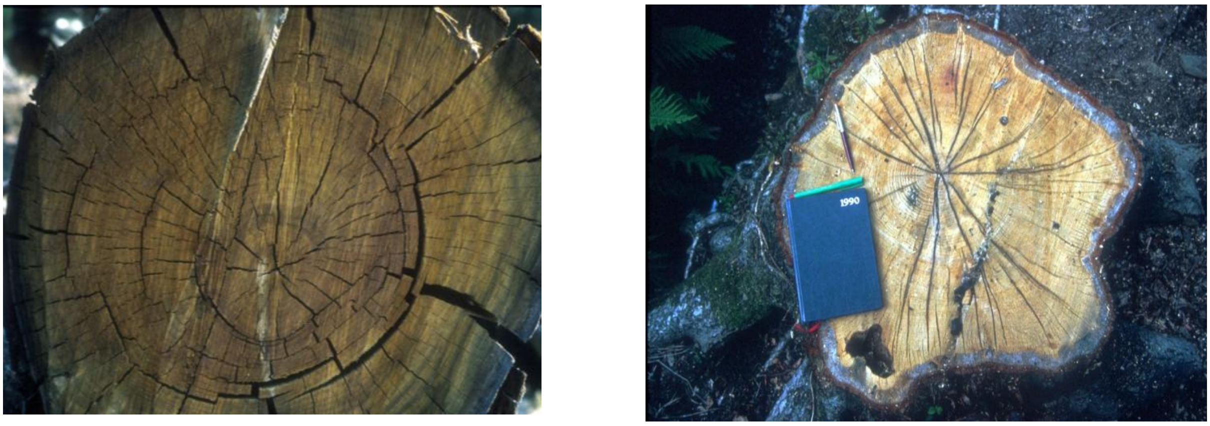

Figure 1. Shaken logs of oak. Left, ring shake, right star shake

Oak has very large early wood vessels that can be seen with the naked eye. Some reach 300 µm in diameter, or about one third of a millimetre (Figure 2). Savill (1986) found that earlywood vessels with greater diameters than average (say >160 µm) predispose wood to shake, in a similar way to bones with large pores being more prone to fracture. The same phenomenon has been found in both corals and concrete, where pieces with larger pores in them are more susceptible to breaking. Vessel size has subsequently been found to be a highly heritable characteristic of oak trees (Kanowski *et al.*, 1991), so that it is possible to select and breed trees with small vessels to reduce its incidence. This is currently being done by the Future Trees Trust. Large vessels alone will not cause a tree to be shaken. They are, as mentioned above, the predisposing factor. A trigger also has to operate to cause the shake. This could be drought: shake is much more common on drought-prone soils. Wind sway is also thought to be an important factor.

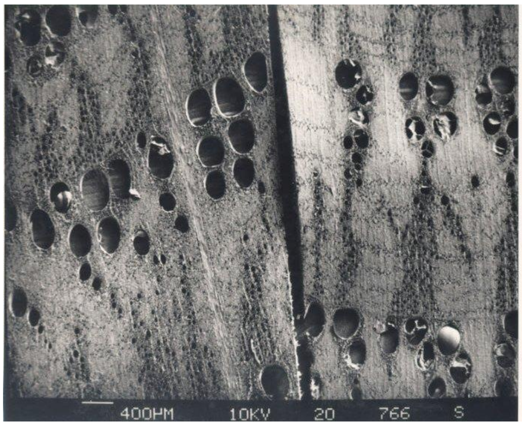

Figure 2. Horizontal sections of oak timber showing a tree with very large early wood vessels (left) and smaller vessels (right)

It is a lengthy and expensive task to determine vessel sizes in trees, involving collecting wood cores from the trees, preparing them for microscopic examination, and then carrying out detailed measurements of the vessels. A quick means of estimating vessel sizes would be a great asset to tree breeders. This study aimed to determine whether measurements of acoustic velocity might discriminate between trees with large vessels and those with small ones.

Figure 3. Acoustic tool in use. The picture shows the probes only: the meter that measures the time is out-of-shot.

Methods

Twenty four out of some 200 of FTT's plus trees were selected, 13 with mean vessel diameters less than 160µm and 11 greater than 160µm. 160µm is the approximate boundary between trees not liable to shake on the basis of vessel diameter, and those predisposed to it. Measurements of vessel diameter were made on cores of wood collected during the 1990s by Jason Hubert when selecting plus trees for the breeding programme. The plus trees selected for testing in this exercise were mostly located in the counties of Herefordshire, Gloucestershire and Worcestershire to minimise travelling times. Of the 24 trees, 18 were identified with complete certainty and six were identified with reasonable certainty – the plus trees actually measured could possibly have been one of their neighbours, though this was very unlikely (the original paint markings have faded in many cases).

The operating procedure is:

- Identify breast-height and fix a level tape at this point
- Knock the probes in at 50cm above and below breast-height, each at approximately 45 degrees to the vertical, so that the penetration points are 100cm apart (see Fig. 3). There are sliding weights on each probe to drive them in - generally a hammer or mallet is used. The spiked probes penetrate to a depth of approximately 4.5cm.
- Knock the top probe with a tapping hammer three times.
- The meter measures the time (in microseconds) it takes for a pressure / sound wave to travel between the top ('start') probe and the bottom ('end') probe.
- Record the four measurements and take a mean reading (the readings are usually identical or very close, *so long as* the probes are driven in sufficiently to stop them moving in further and in particular that even taps

are used with the hammer - a glancing blow will often give a slightly slower reading)

- Repeat - measurements are taken at the four cardinal compass points around the trunk.
- Repeat the procedure across the main stem between probes located at 1.3 metres in height, orientated from North (transmitter) to South (receiver).
- Acoustic velocity (normally expressed in km/s) is determined later, by calculation to incorporate a correction function unique to each individual device (Forest Research has two).

Analysis

Various analyses were performed on the data, including correlation, regression and analysis of variance. They were performed using Minitab on both the complete data set and also on a reduced set, omitting the six trees which had an element of doubt associated with them. The results did not differ in any substantial way between the two sets, so only those for the complete set are given below.

Results

Correlation and regression analyses

In a correlation analysis (results not shown), vessel diameter showed no relationship at all with any of the five Acoustic Values recorded. This is illustrated in the regression plots in Figures 4 and 5, where the correlation coefficients (r^2) are 0.0% 1.8%, and the regression lines almost flat

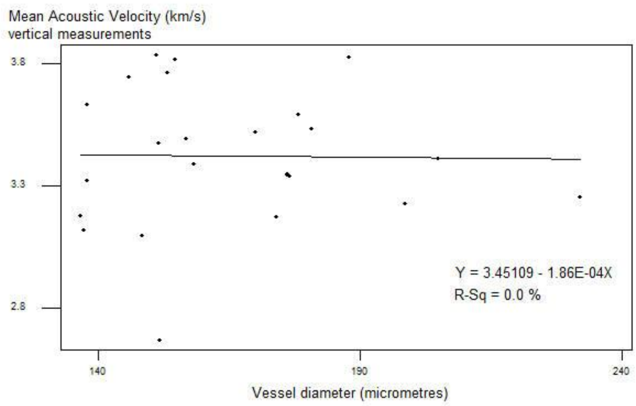

Figure 4. Regression of vessel diameter and mean Acoustic Value for N, E, W and S measurements

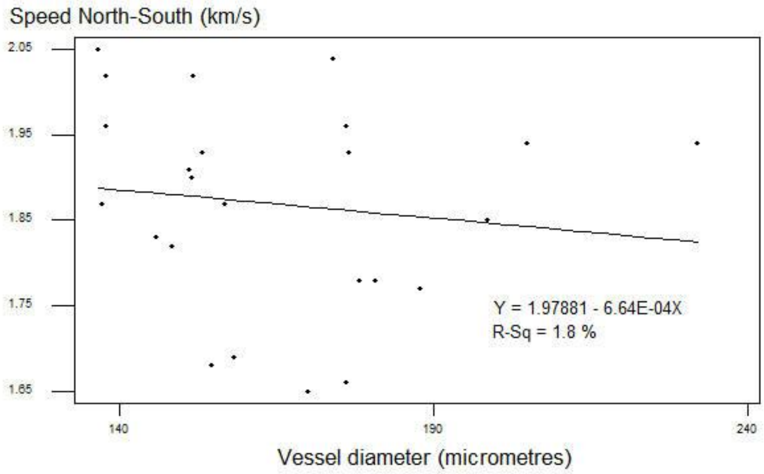

Figure 5. Regression of vessel diameter and speed N-S

The only variable that is rather weakly, but nevertheless consistently correlated with Acoustic Value is dbh, though this is of no help at all in determining vessel size.

Analysis of Variance
Analyses of variance revealed that none of the four vertically measured sets of data (collected at each of the cardinal compass points), or the horizontally measured N-S set approached anything like significance.

Conclusion
On the basis of this evidence we must conclude that acoustic values are of no practical value determining the vessel sizes, and hence predisposition to shake in oaks. The only reliable method that remains available at present is to use flushing time in the spring. Both Lechowicz, (1984) and Savill and Mather (1990) found that trees that flush latest within a population tend to have the biggest vessels. Hence, within a population trees that are predisposed to shake can be identified at that time.

References
Kanowski, P.J., Mather, R.A. and Savill, P.S. (1991). Short note: Genetic control of oak shake; some preliminary results. *Silvae Genetica 40*, 3/4, 166-168.
Lechowicz, M.J. (1984). Why do temperate deciduous trees leaf out at different times? Adaptation and ecology of forest communities. *The American Naturalist 124* (6), 821-842.
Savill, P.S. (1986). Anatomical characters in the wood of oak which predispose trees to shake. *Commonwealth Forestry Review 62*, 109-116.
Savill, P.S. and Mather, R.A. (1990). A possible indicator of shake in oak: relationship between flushing dates and vessel sizes. *Forestry 63*, 355-362.