Acoustic tomography of timber elements

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Abstract Acoustic tomography for the analysis of timber elements is still not widely used, especially for the inspection of structures in service. This is probably due to the fact that data acquisition planning, testing procedure and data interpretation are ticklish tasks, and no standard or guideline are nowadays available to help professionals during tests.
In order to investigate different practical factors affecting tomographic results, an experimental campaign has been carried out, using time-of-flight (TOF) measurement, for imaging internal macroscopic heterogeneities in wood. Different features of the material were investigated, testing softwood specimens with different kinds of both natural and artificial defects.
An instrumented hammer and a piezoelectric transducer were used for emitting signals, in the sonic and ultrasonic frequencies, respectively. In particular, the ultrasonic probe operating frequency is 55 kHz.
The used software optimizes the reconstruction process, comparing results from both iterative inversion algorithms (ART- algebraic reconstruction technique-, SIRT–simultaneous iterative reconstructive technique) and direct inversion techniques (LSQ –least squares- and SVD- singular value decomposition), thus permitting to reduce the influence on results of random errors in the measurement.
The map of velocities is represented by a 256 levels of grey diagram, where the white level corresponds to the maximum velocity, and the black level corresponds to the minimum velocity.
Tomographic images are not always explicit and clearly interpretable. The use of appropriate segmentation techniques permits to highlight and discern the different heterogeneities in the material.
External decay, due to both fungal and insect attacks, is satisfactorily detected by means of acoustic tomography (Fig.1 and Fig.2). It is associated to great signal attenuation, which can hamper the use of ultrasound.
Internal decay and cavities have not been detected, even considering ratios of the hole-to-section area bigger than those reported in literature (Fig.3). The reason of this is maybe due to the anisotropy in the two section directions.
The presence of linear discontinuities, such as cracks and checks, is detected when it is accompanied by decay. Linear backprojection algorithms hardly permit to identify checks in sound wood.
High velocity zones, such as knots, are always satisfactorily detected.
The results highlight some limits of the acoustic tomography, that are related both to the approximations used in the adopted reconstruction method and to the experimental limitations.
Other specific problems, connected to the application on wood, concern the anisotropy of the material and the signal attenuation that could prevent an accurate travel time reading.
Results also suggest some basic methodological instructions for timber structures inspection.
In order to distinguish pathological features of the material from other factors affecting acoustic wave transmission, diverse tomographic techniques, using different type of waves could be coupled.

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In general, it is recommended to couple acoustic tomography with other inspection techniques, for instance with local mechanical tests, for the detection of internal zone of lower densities, and with visual analysis of external features.

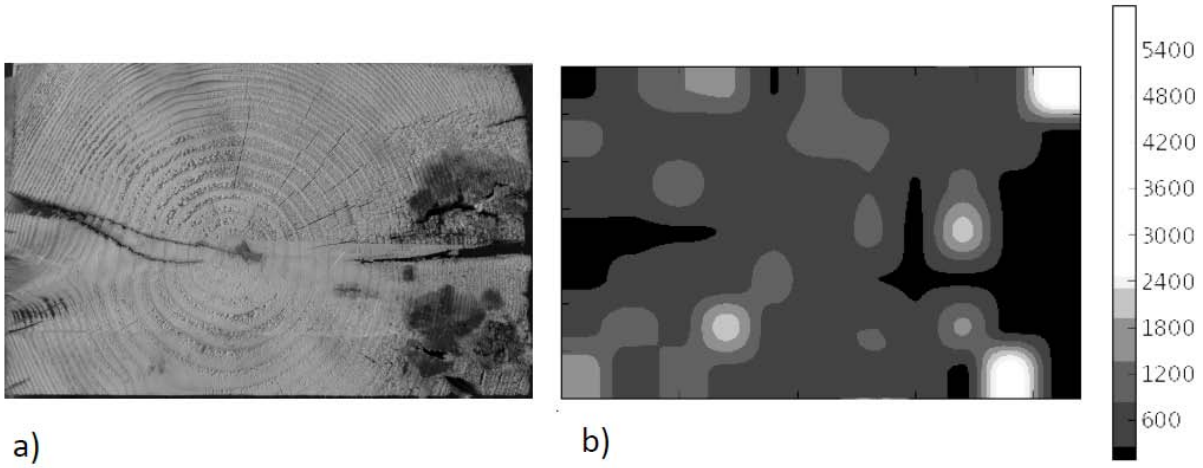

Figure 1 – Fungi decay: a) visible face, b) posterized tomographic image (m/s)

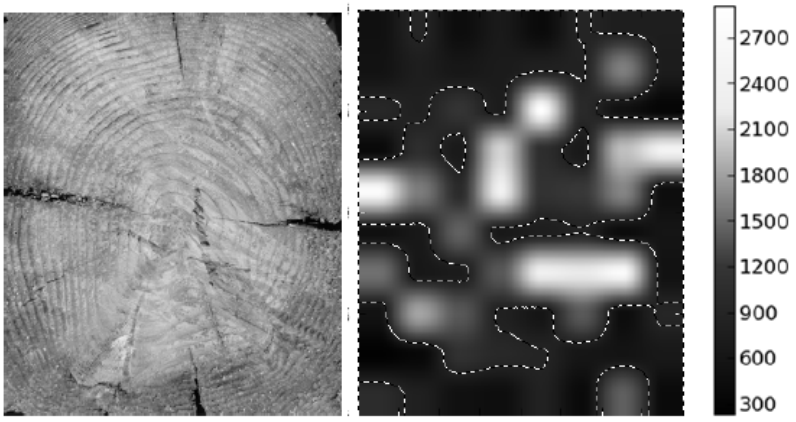

Figure 2 – Insect decay: visible face and tomographic section

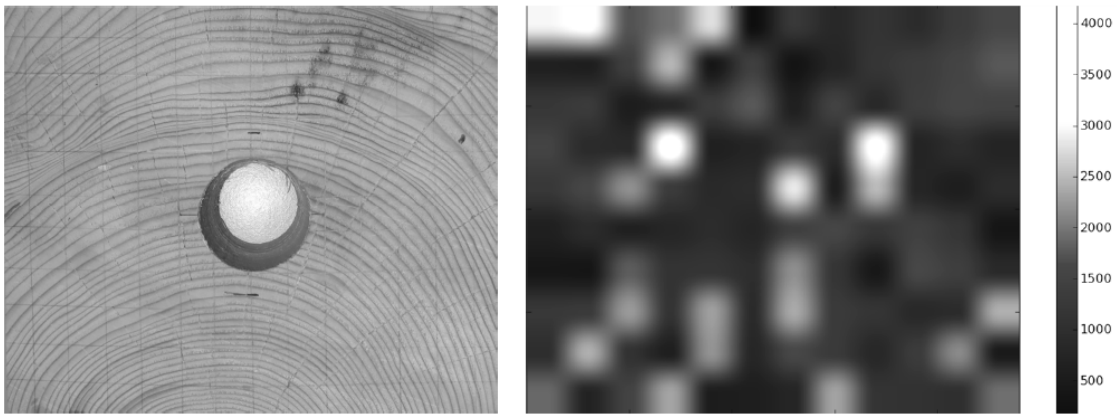

Figure 3 – Simulation of internal decay (ratio of the hole-to-section area equal to 4.9%) picture of the specimen (left), tomogram (right)

Keywords Timber structural members, acoustic tomography, methodology

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