148 In-situ 3D tomography of wood compression

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Abstract. Wood compression exhibits scale-free avalanche like behaviour as well as structure dependent localization of deformation. We have taken 3D x-ray tomographs during compression with constant loading. Using digital volume correlation we can obtain the local strain during the experiment and compare it to global strain and acoustic emission. The wood cells collapse layer by layer throughout the sample starting from the softest springwood. The damage then propagates towards the harder summerwood. Once the collapse of a layer is observed, it propagates through the entire layer. The process is similar to rock fracture where the damage localizes at the largest crack.

Introduction

Based on earlier work [1], wood exhibits scale-free avalanche behaviour as well as structure-dependent localization of deformation. Acoustic emission event energies and waiting times follow power-laws with the exponents reminiscent of brittle porous materials and geophysics. Digital Image Correlation shows damage localization (collapse of softwood layers) when imaged from the side. Here, we have performed 3D tomography simultaneously with compression. This enables us to follow the strain evolution inside the sample.

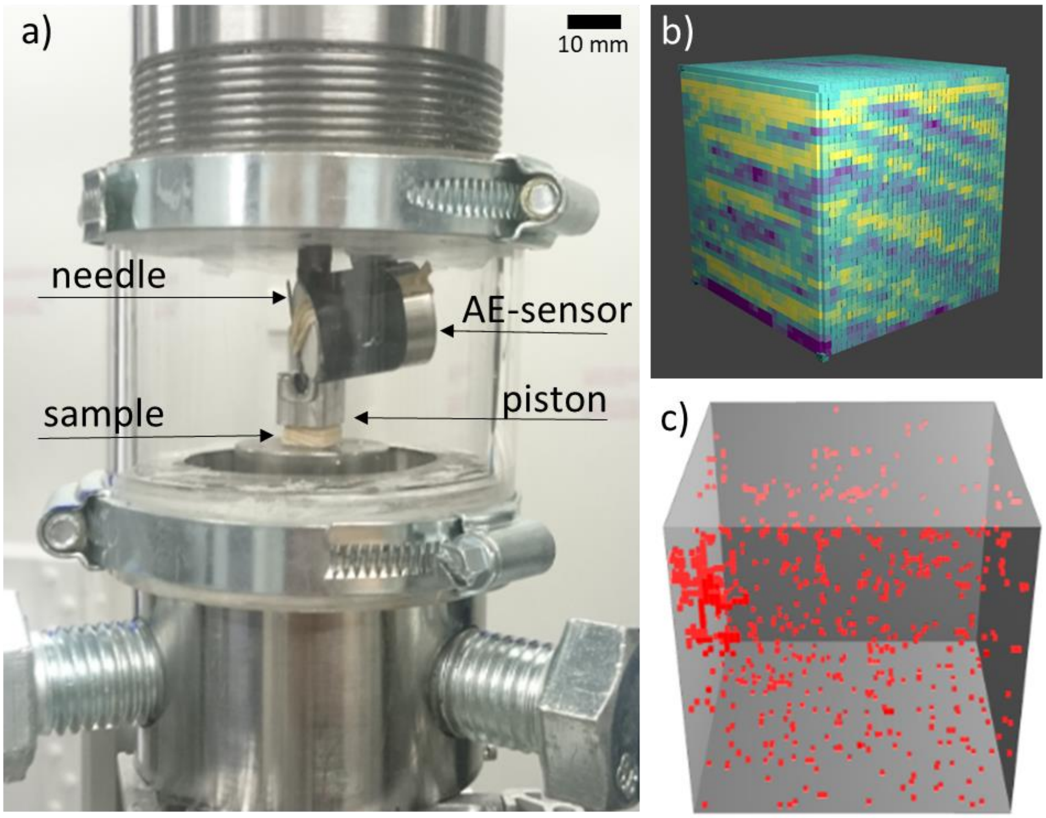

Fig. 1: a) The load string consisting on pneumatic piston that is coupled to the bottom part via plexiglass tubing. The acoustic emission sensor is connected to sample via needle that goes through the piston. The construction allows an unobstructed passage of x-ray beam (left to right) while continously rotating while compressing. b) Snapshot of the 3D strainrate during the experiment shows high strainrates (yellow) at the soft springwood and low strainrates (blue) at the hard summerwood. c) Thresholded strain rate shown as red dots illustrate a high strainrate concentration at the upper left corner. The strain rate starts propagating here thorught the soft wood layer.

Methods

The experiment is performed in European Synchrotron Radiation Facility (ESRF) in the ID15 beamline, where fast tomography (1 Hz) with 0.5 um resolution can be made. The compression is done with a constant force rate simultaneously with the tomography. The samples are 6x6x6 mm dry pine cubes. In addition, we measure global deformation with a laser distance sensor and acoustic emission with a wideband piezo sensor seen in Fig. 1.

Analysis and results

The 3D reconstructions of the sample volumes calculated using standard methods using PyHST2 software developed at ESRF with Paganin phase retrieval. Digital Volume Correlation (DVC) used to calculate local strain (and strain rate) fields seen in Fig. 1b from the 3D reconstruction using TomoWarp2 [2] software. We define a collapse event as high strain rate marked as red dots in Fig. 1c. The time series shown in Fig. 2 shows the evolution of collapsed cells initiating from one end of the soft wood layer, propagating through the sample and further into nearby harder wood areas.

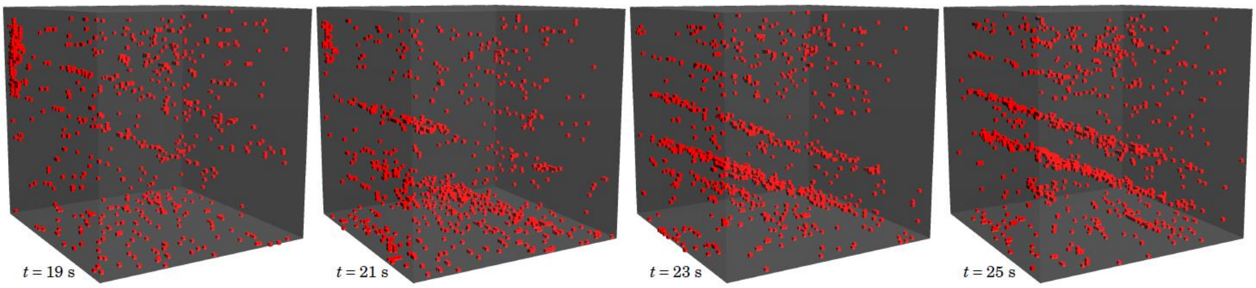

Fig. 2: The local strain rate is thresholded and the areas of high strain rates are plotted in red. In this series of images one can see the evolution of a softwood layer collapse in the lower part of the sample as the band of high strain rates moves upwards (along the compression direction).

Conclusions

We have measured the local strain rate during wood compression with constant load. In-situ tomography for wood works even with this relatively fast compression. One can observe softwood layer (annual ring) collapses through the sample. The Collapses nucleate on the edge of a softwood layer and propagate through the layer. After nucleation the collapse propagates through the softwood layer in the compression direction. The 3D tomography gives us insight how the damage is propagated inside the wood layers. Further work is needed in linking the acoustic emission to the observed collapse events.

References

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[2] E. Tudisco, E. Andò, R. Cailletaud, and S. A. Hall, SoftwareX **6**, 267–270 (2017).