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MICROFRACTURE AND DAMAGE IN WOOD: A LATTICE SIMULATION AND ACOUSTIC EMISSION MEASUREMENT

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ABSTRACT

Wood fracture poses some interesting challenges due to the myriad of relevant microstructural energy dissipation mechanisms. As such, modelling fracture of wood is difficult, as each relevant toughening mechanism must somehow be represented within the framework of the numerical scheme. For the work presented here, we chose a lattice-based modelling approach. With it we are able to explicitly represent a relatively wide range of microstructural features including anisotropic cellular structure, earlywood-latewood boundaries, local grain deviations, and other heterogenieties. In the lattice model, the material is represented by a network of spring elements, each having appropriately assigned stiffness and strength properties. These properties follow statistical distributions such that simulated bulk properties also achieve appropriate statistical distributions. The goal of such a representation is to produce a model that so closely resembles the structure of the material, that observable behaviour such as size effects, strain softening, and brittle-ductile transitions occur naturally.

In previous work, we established a 2D morphological lattice model [1] we could use to capture a wide range of damage and failure mechanisms, including microcracking and crack bridging. In the work described here, our goal was to further investigate the physics of wood fracture using acoustic emission (AE) techniques to quantify microcracking in laboratory specimens. The hypothesis is simply that the temporal distribution of broken lattice elements in a specimen under monotonic loading should parallel the distribution of measured AE energy measured in a comparably loaded specimen.

The experiments were conducted as follows. Specimens consisted of notched dogbone specimens with a 5 mm by 5 mm cross section. Notches were 1 mm deep, cut into the specimen on all four sides. The loading was performed under closed-loop control using a 10 mm gage length extensometer attached to the specimen over the notch as feedback. This experimental configuration was intended to provide us with stable crack growth, however it was only moderately successful.

Two broad-banded AE sensors were mounted to the specimen just outside the range of

the extensometer. A full waveform acquisition system was used to record AE activity. The energy of the AE waveform was determined by integrating the square of the recorded voltage signal over the full length of the waveform.

Simulations were conducted as follows. Two dimensional versions of the laboratory specimens were created with a network of lattice elements. Element properties, including earlywood-latewood distinctions, geometry, and statistical variations were previously established for spruce [1] using an optimisation procedure described in [2]. Boundary elements were restrained vertically, but free horizontally to allow for poisson effects. Loading was accomplished by applying small displacement increments to one boundary edge. Equilibrium forces were then calculated for the lattice network, and the forces in each element were checked against the pre-established strength for that element. If the element force exceeded its strength, it was removed from the lattice and the elastic energy released by the broken element was calculated.

Illustrations of simulated and real specimens are shown in Figure 1. This figure shows a common failure mode: a mixture of tensile and shear cracking. Nearly all of the damage is confined to the notch region in the simulated specimen, and this was confirmed by the AE source location data. Regarding energy release, we compared the cumulative energy of broken lattice elements with the cumulative AE energy released. This comparison could not be direct as the AE energy is not directly transferable to fracture energy, however, qualitatively the patterns were quite similar. Both show a slow energy release up to just prior to peak load, when both show a rapid increase. Post peak comparison was difficult to compare due to mixed success with closed-loop experimental control.

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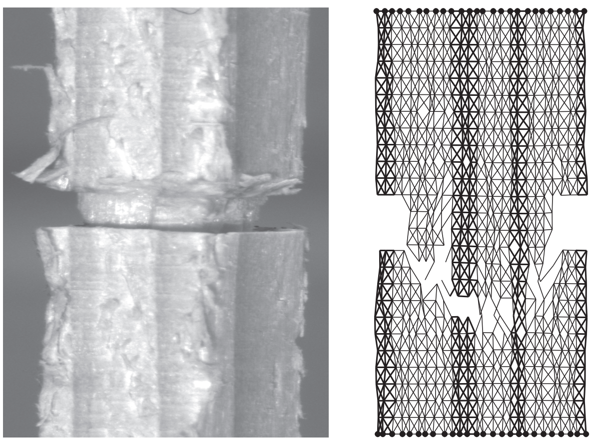

Figure 1. Illustrations of both actual and simulated test specimens.